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FINAL REPORT ON ENVIRONMENTAL MONITORING NSB KINGS BAY GA
9/16/1985
ALVAREZ, LEHMAN AND ASSOCIATES

FINAL REPORT ON ENVIRONMENTAL MONITORING NAVAL SUBMARINE BASE KINGS BAY, GEORGIA OCTOBER 1983 TO SEPTEMBER 1984

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Presented To:

DEPARTMENT OF THE NAVY
OFFICER IN CHARGE OF CONSTRUCTION
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EXECUTIVE SUMMARY

Environmental monitoring of construction of Naval Submarine Base, Kings Bay, Georgia (SUBASE) has been conducted by the U.S. Navy since 1978. A-1 phase development is overlapping with T-1 phase operations maximizing the potential for environmental impact and impact mitigation.

Selection of Kings Bay as a Naval Submarine Base included extensive environmental studies to document conditions prior to development. Comprehensive environmental monitoring is in keeping with the Navy's policy of continually assessing the effects of Naval activities on the environment to minimize impacts within all practical limits.

Data collected during the 1983-1984 monitoring program updates environmental conditions at SUBASE, provides additional baseline information about the site, and documents the effectiveness of environmental policies and controls during the past fiscal year.

Routine environmental monitoring during the 1983-1984 monitoring year included:

* Surface Runoff Water Quality Monitoring
* Storm Event Runoff Monitoring
* Ground Water Quality Monitoring
* Wastewater Land Application Monitoring

* Estuarine Water Quality Monitoring
* Sediment Quality Monitoring
* Dredge and Dredge Disposal Monitoring
* Estuarine Benthic Invertebrate Surveys
* Estuarine Fisheries Surveys
* Oyster Bioaccumulation Surveys
* Hardwood Swamp Vegetation Surveys
* Saltmarsh Vegetation Studies
* Non-Routine Tasks Performed in Response to Unexpected Environmental Problems

Monitoring was performed on behalf of OICC, TRIDENT by Alvarez, Lehman & Associates, Inc., of Gainesville, Florida.

SUBASE construction activities during 1983-1984 were characterized by extensive earthwork and dredging operations including road, drainage and site preparation in the Family Housing, Personnel Support, Industrial Support, Strategic Weapons Facility and Waterfront areas; creation of several borrow areas for fill material resulting in establishment of Stimson and Monroe chains of lakes and the expansion of stormwater lake D into an 80-acre freshwater lake; dike construction and dredge material disposal at Mainside, Disposal Area No. 2, and Crab Island disposal areas; and dredging of turning basins and channels from upper Kings Bay to a point near Drum Point Island in Cumberland Sound.

Results of the 1983-1984 monitoring program are:

1. Surface runoff from SUBASE in February 1984 was highly turbid and was a likely source of high turbidities in the North River. Reference turbidity standards were exceeded.

2. Storm event monitoring detected higher turbidity and lower dissolved oxygen levels in stormwater runoff from developed watersheds when compared to an undeveloped watershed. No relevant standards were violated for parameters measured.

3. Groundwater monitoring confirmed contamination of groundwaters east of Personnel Support Area stormwater lake Y.

4. No significant impacts to surface waters due to wastewater sprayfield operations were found for the parameters measured.

5. Nutrient and metals concentrations in wastewater sprayfield wells were often considerably higher than concentrations in wells located elsewhere on SUBASE.

6. Estuarine water quality surveys continue to show Kings Bay remains unstratified despite channel expansion and deepening. Although elevated metals levels were documented occasionally, no chronic metals contamination exists in Kings Bay. A subsurface turbidity

plume and occasional high turbidity levels were recorded for Kings Bay.

8. Evidence of oil and grease contamination was found in sediments from surface water drainage stations on SUBASE. Lead and zinc levels were slightly elevated at a surface water station draining one of the most developed areas of SUBASE.

9. Sediments in Kings Bay have higher metals levels than sediments from undredged channels in Crooked River and Cumberland Sound.

10. Turbidity in effluents discharged from Mainside Disposal Area exceeded ambient Kings Bay turbidities during two of six months monitored. The differential measured between ambient and effluent turbidities would be prohibited in the State of Florida.

11. Bottom disruption by construction dredging was the probable cause of low benthic invertebrate diversities in Kings Bay compared to Cumberland Sound and adjacent areas. Fluctuations in benthic community densities were also attributed to dredging, as were low macroinvertebrate catches in Kings Bay.

12. Low fish abundance and diversity within Kings Bay were attributed to year-round dredging.

13. Copper levels in oysters from upper Kings Bay were slightly higher than those measured outside the bay. Other parameters provided no evidence of impacts associated with SUBASE development.

14. Vegetation surveys in SUBASE hardwood swamps showed vegetative species were healthy and reproducing in all swamps. Missing size classes of certain species in some swamps may have resulted from alteration of natural hydroperiods by perimeter and interceptor ditches.

15. Saltmarsh vegetative surveys showed marsh productivities comparable to other marshes in the southeast.

Several recommendations are made with respect to minimizing noted impacts and improving the monitoring program to allow better cause-effect interpretation of the environmental data.

1.0 INTRODUCTION

1.1 Monitoring Objectives

The U.S. Navy is developing Naval Submarine Base (SUBASE) at Kings Bay, Georgia (Figure 1-1) under the direction of the Officer in Charge of Construction, TRIDENT (OICC, TRIDENT). Environmental monitoring has been conducted by the Navy since 1978 to document SUBASE related impacts on upland and estuarine habitats. The monitoring program reflects the Navy's commitment to mitigation of environmental impacts and fulfills obligations made in the T-1 Environmental Impact Statement (EIS) and A-1 Supplement (SEIS) to document impacts during the period of base construction (Environmental Science and Engineering, Inc., 1977, 1980a, b). A list of environmental studies in the Kings Bay area is presented in Appendix A to illustrate the Navy's efforts devoted to impact identification and mitigation.

A-1 phase SUBASE development is currently overlapping with T-1 phase operations. This period of intensive construction of ashore-based submarine refit capability coupled with ongoing tender-based operations was projected in the SEIS to be the decade of critical concern in terms of mitigation of environmental impacts. The objectives of the monitoring program are to provide OICC, TRIDENT with ongoing reviews of SUBASE-related impact incidence and extent, and to provide the technical data necessary for sound environmental planning for impact mitigation.

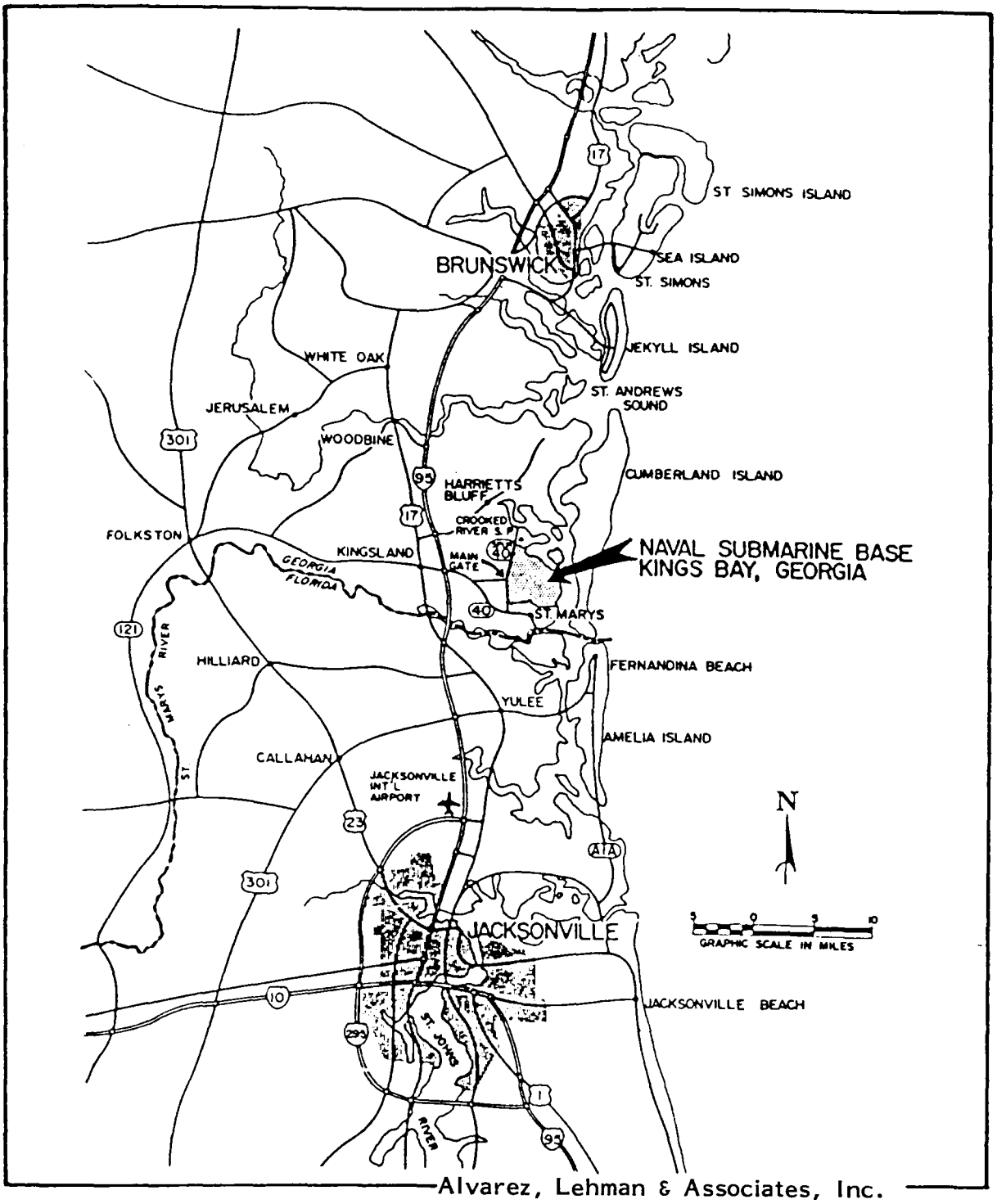

FIGURE 1-1. Location of Naval Submarine Base, Kings Bay, Georgia

1.2 Overview of Environmental Monitoring

Environmental monitoring of SUBASE has included water quality and biological assessments of upland and estuarine habitats. Water quality surveillance provides an instantaneous look at environmental conditions at the moment of sampling. Comparison of SUBASE water quality against standards mandated by state and federal agencies provides one measure of impact. Biological monitoring provides evaluation of time-integrated SUBASE effects on the environment. It addresses biological significance of environmental degredation indicated by violations of water quality standards. A comprehensive monitoring program of both water quality and biological assessment is required to address short and long term effects of SUBASE development.

The environmental monitoring program included the following components during the 1983-1984 monitoring year:

* Surface Runoff Water Quality Monitoring
* Storm Event Runoff Monitoring
* Groundwater Quality Monitoring
* Wastewater Land Application Monitoring
* Estuarine Water Quality Monitoring
* Sediment Quality Monitoring
* Dredge Monitoring

* Estuarine Benthic Invertebrate Surveys
* Estuarine Fisheries Surveys
* Oyster Bioaccumulation Surveys
* Hardwood Swamp Vegetation Surveys
* Saltmarsh Vegetation Studies
* Non-Routine Tasks

This report presents the results of environmental monitoring conducted by Alvarez, Lehman & Associates, Inc. on behalf of OICC, TRIDENT between October 1983 and September 1984.

1.3 SUBASE Development and Operations: 1983-1984

Extensive earthwork and dredging operations occurred during 1983-1984 (Figure 1-2). Upland earthwork included borrow and fill for construction of Vallejo Drive, the Missile Haul Road, and the Strategic Weapons Facility/Limited Area. Borrow sites were incorporated into the SUBASE drainage system as Stimson and Monroe chains of stormwater lakes and Lake D. Upland development also included construction of additional housing facilities, electrical distribution systems, and thermal distribution lines, all of which required excavation, filling, or grading.

Construction during 1983-1984 exposed extensive upland acreage as bare soil for extended periods. These unstabilized soils are highly susceptible to erosional processes. Suspended solids (and associated contaminants) may

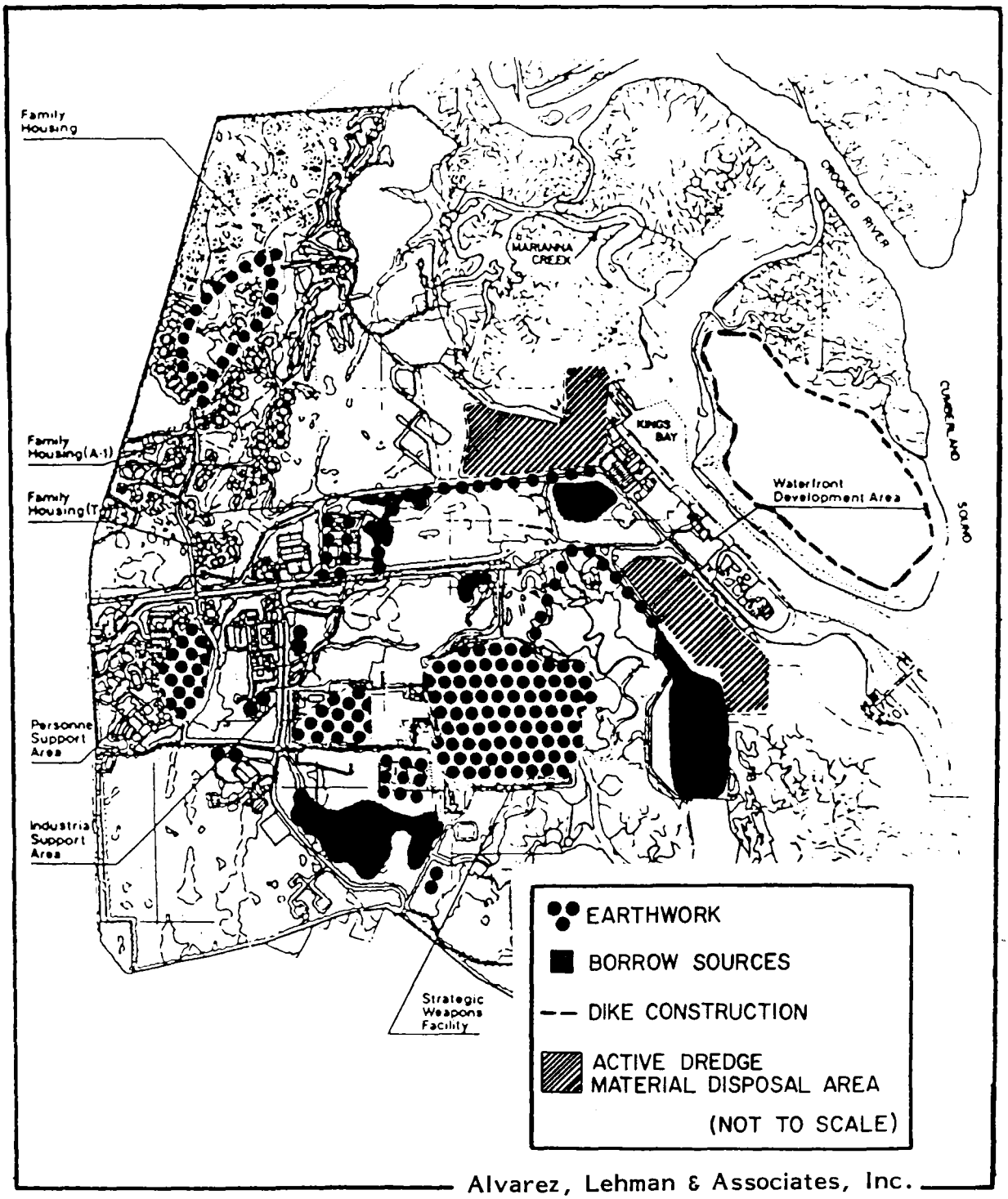

FIGURE 1-2. Major Construction Areas on Naval Submarine Base, Kings Bay, Georgia, 1983-1984

wash through base drainage systems, and deposit in receiving waters and fringing wetlands impacting upland, wetland, and aquatic habitats. Wetland habitats, and surface and groundwaters were routinely monitored for such impacts.

Monitoring of vegetation and water table levels in hardwood swamps was initiated during this period to address SUBASE drainage system impacts on these wetlands. Stormwater runoff constituents were monitored through storm event sampling of base drainage systems.

Bottom sediments were dredged from Cumberland Sound near Drum Point Island up to the upper turning basin in Kings Bay between November 1982 and December 1984 (Figure 1-3). Phase I construction dredging (upper turning basin and Kings Bay) started in November 1982 and continued through the 1983-1984 monitoring period. Phase II construction dredging (Cumberland Sound approach channel) initiated in March 1984 also continued through this monitoring period. These dredging operations were monitored closely for potential impacts to estuarine resources in Kings Bay and Cumberland Sound. Biannual surveys of benthic invertebrates, fish and macroinvertebrates, and oysters were performed to assess dredging effects on these resources.

Operations-related monitoring was included during 1983-1984. This monitoring included quarterly surveillance of surface water, groundwater, and soil conditions within the wastewater land application (sprayfield) area.

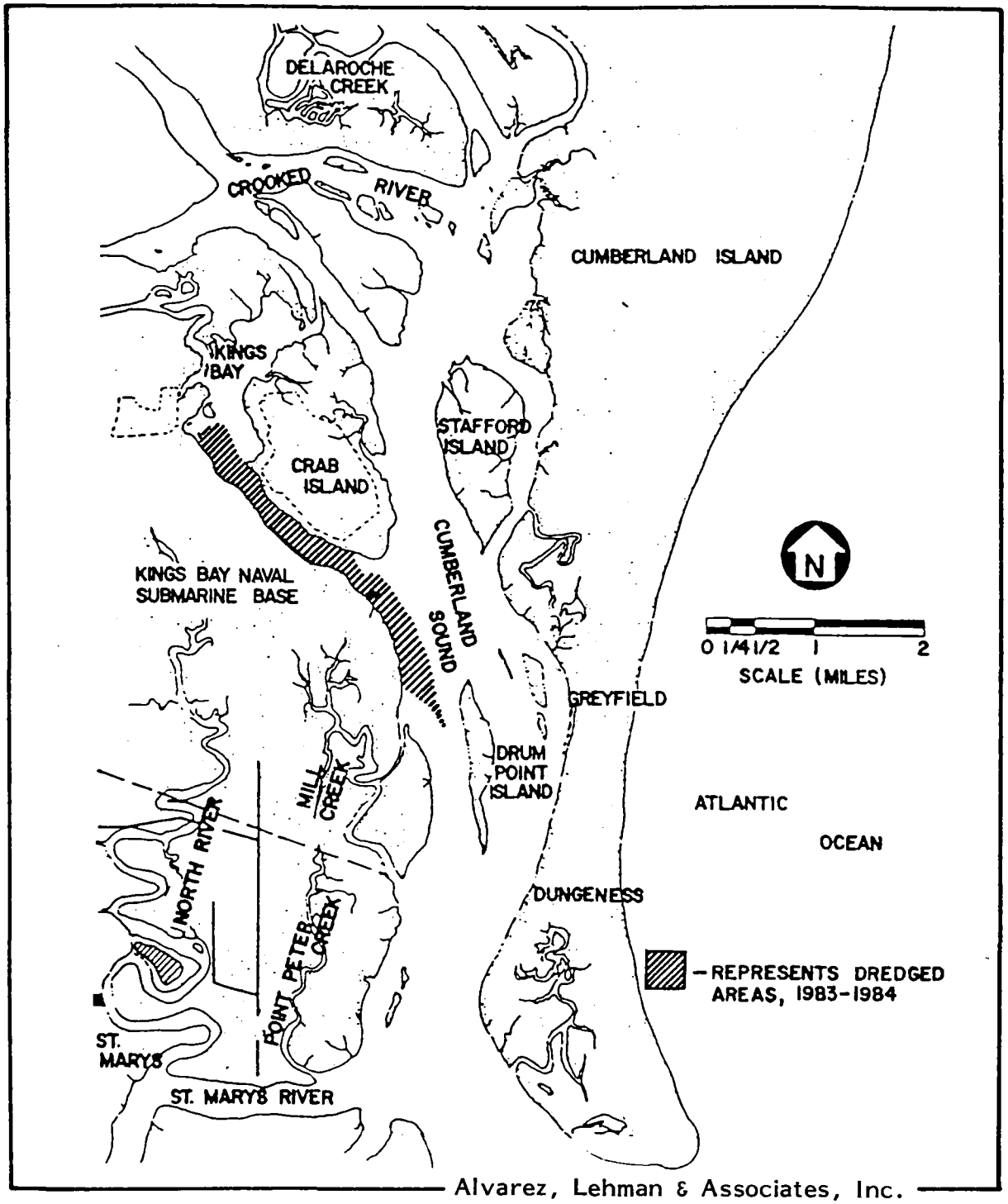

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FIGURE 1-3. Approximate Area Dredged in Kings Bay and Cumberland Sound, Georgia, 1983-1984

2.0 METHODS

Methods used are described by subprogram in the following sections. Analytical methods, methods of preservation, and holding times for each parameter are listed in Table 2-1. A list of instruments and equipment used to perform field sampling is provided in Table 2-2.

2.1 Surface Runoff Water Quality

Surface water quality was monitored at five stations (Table 2-3, Figure 2-1) on a quarterly basis. Stations NR-5, NR-8 and NR-9 have been monitored since 1978. Station SD-1 was added to the program in 1983 and Station MC-1 was added in 1984. Station MC-1 is located approximately 200 meters north of the Etowah Park recreation facility on U.S.S. John Calhoun Road. Sampling was performed on the west side of a culvert which drains a tributary to Marianna Creek. This site receives runoff through the north drain from SUBASE family housing.

Stations NR-5, NR-8, and SD-1 are located downstream of active SUBASE construction sites. They potentially provide information on construction-related runoff water quality. Station NR-5 was moved from its original site to a new drainage swale just south of U.S.S. Henry L. Stimson Drive during the fourth quarter (August 1984). Grab samples were composited from the east ends of the four corrugated metal pipes (inside diameters = 5 feet) beneath U.S.S. Woodrow Wilson Avenue. Depth and

TABLE 2-1. Water Quality Parameters and Methods of Preservation and Analysis, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Parameter	Preservation*	Analytical Method	Maximum* Holding Time	Reference
Depth	in situ	Calibrated Leadline	NA	-
Water Temp.	in situ	Thermister	NA	1
Conductivity	in situ	Electrode	18	2
Salinity	in situ	Electrode	NA	1
pH	in situ	Electrode	NA	1
Dissolved Oxygen	in situ	Membrane Electrode	NA	1
Current Velocity	in situ	Flow meter	NA	3
Turbidity	Chill, 4°C	Nephelometry	48 hr	2
Total Dissolved Solids	Chill, 4°C	Gravimetry	7 days	2
Total Suspended Solids	Chill, 4°C	Gravimetry	7 days	2
Alkalinity	Chill, 4°C	Titration (pH 4.5)	14 days	2
Sulfate	Chill, 4°C	Colorimetry	28 days	2
Chloride	none req.	Colorimetry	28 days	2
Ammonia Nitrogen	Chill, 4°C			
	H_2SO_4, pH <2	Automated Phenate Procedure	28 days	2
Total Kjeldahl Nitrogen	Chill, 4°C			
	H_2SO_4, pH <2	Automated Phenate Procedure	28 days	2
Nitrate + Nitrite Nitrogen	Chill, 4°C			
	H_2SO_4, pH <2	Cadmium Reduction	28 days	2
Total Phosphorus	Chill, 4°C			
	H_2SO_4, pH <2	Ascorbic Acid Procedure	28 days	2
Total Organic Carbon	Chill, 4°C			
	H_2SO_4, pH <2	TOC/TC Carbon Analyzer	28 days	2
Cation Exchange Capacity	Chill, 4°C	Agitation/Filtration	NA	2
Oil and Grease	Chill, 4°C			
	H_2SO_4, pH <2	Infrared Spectroscopy	28 days	2
Biochemical Oxygen Demand 5-day	Chill, 4°C	Incubation/Membrane Electrode	48 hrs	2
Magnesium, total	HNO_3, pH <2	Atomic Adsorption Spectroscopy	6 mos	2
Calcium, total	HNO_3, pH <2	Atomic Adsorption Spectroscopy	6 mos	2
Potassium, total	HNO_3, pH <2	Atomic Adsorption Spectroscopy	6 mos	2
Cadmiun, total	HNO_3, pH <2	Atomic Adsorption Spectroscopy	6 mos	2
Chromium, total	HNO_3, pH <2	Atomic Adsorption Spectroscopy	24 hrs	2
Copper, total	HNO_3, pH <2	Atomic Adsorption Spectroscopy	6 mos	2
Lead, total	HNO_3, pH <2	Atomic Adsorption Spectroscopy	6 mos	2

---------- Continued ----------

TABLE 2-1. Continued

Parameter	Preservation*	Analytical Method	Maximum* Holding Time	Reference
Mercury, total	HNO_3, pH <2	Atomic Adsorption Spectroscopy	28 days	2
Zinc, total	HNO^3, pH <2	Atomic Adsorption Spectroscopy	6 mos	2
Fecal Coliform Bacteria	Chill, 4°C	Multiple Tube Technique/MPN	6 hrs	1
Fecal Streptococci Bacteria	Chill, 4°C	Multiple Tube Technique/MPN	6 hrs	1

* USEPA 1982
NA = Not Applicable, analyzed immediately
1. APHA, 1980
2. USEPA, 1979
3. Hershey, R.W. (ed) 1978

Source: Alvarez, Lehman and Associates, Inc., 1985

TABLE 2-2. Field Instruments and Equipment Used for Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Parameter	Instrument Type	Manufacturer	Model
Dissolved Oxygen	DO Meter	Yellow Springs Instruments	57, 58
Temperature, Water	SCT Meter	Yellow Springs Instruments	33
	Thermometer	American Scientific Products	Glass, armored
Temperature, Air	Thermometer	American Scientific Products	Glass
Conductivity	SCT Meter	Yellow Springs Instruments	33
Salinity	SCT Meter	Yellow Springs Instruments	33
pH	pH/Millivolt Meter	Orion	407 A/F
Turbidity	Turbidimeter	Hach Chemical Company	16800
Weight (mass)	Electronic Balance	Ohaus	3000 m
Current Velocity	Pigmy Current Meter	Gurley	642
	Electronic Current meter	Montedoro-Whitney	PVM-2, PVM-2A
Wind Velocity	Hand Held Meter	Dwyer	-
Sediment Cores	Petite Ponar/Hand Corer	Wildco	Petite Size
Benthic Invertebrates	Ponar	Wildco	Full size
Necton	Trawl	Marinovich Trawl Company	5 Meter, Otter
Depth	Sounding Line	Wildco	-
	Meter Rule	Various	-
Water Sampling	Kemmerer	Wildco	Beta plus, 1930-G60
Soil Sampling	Shovel	-	-
Transparency, water	Secchi Disc.	Wildco	Oceanographic
Light Penetration, water	Light Meter	Licor	LI-185A
Well Sampling,	Peristaltic Pump	Masterflex	7570-10
	Pump Head	Masterflex	7015-20
Filtering, ground water	Pressure/Vacuum Filter	Geotech Geofilter	102 mm

Source: Alvarez, Lehman and Associates, Inc., 1985

TABLE 2-3. Surface Water Quality Station Designations and Descriptions, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Station Designation	Description
MC-1	Mid-channel, tributary of Marianna Creek at USS John Calhoun Road, North of Etowah Park
NR-5	Mid-channel, tributary to North River at Flemming Road crossing.
NR-8	Mid-channel, North River at USS Henry L. Stemson Drive crossing.
NR-9	Mid-channel, North River at New Point Peter Road crossing.
SD-1	Mid-channel, Lake D drainage outfall upstream from confluence with marsh.

Source: Alvarez, Lehman and Associates, Inc., 1985

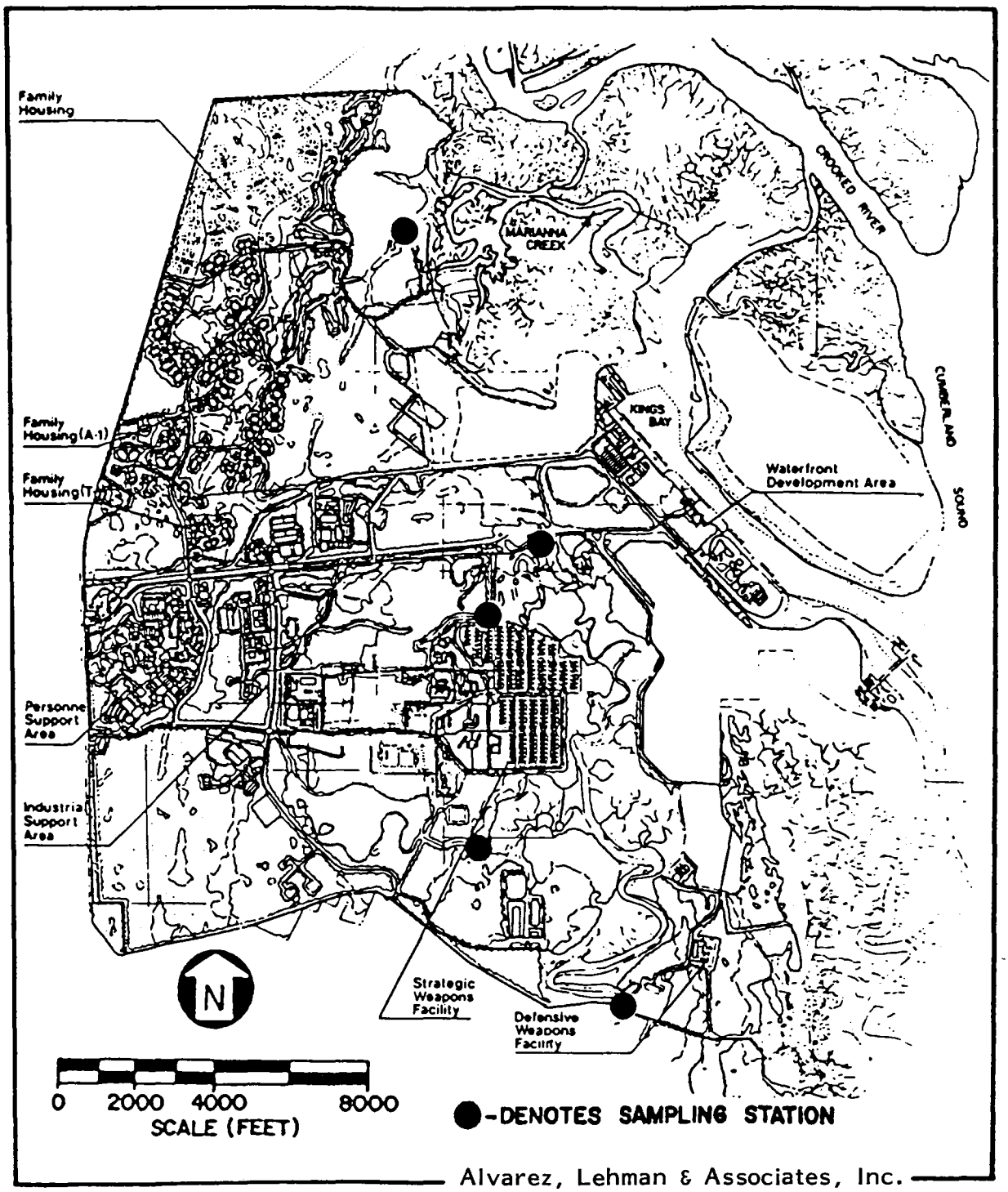

FIGURE 2-1. Surface Water Sampling Stations, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

current velocity were obtained in each culvert.

Parameters listed in Table 2-4 were measured at each station during November 1983, February 1984, May 1984 and August 1984. General weather conditions were also noted on the field data sheets. Samples were obtained from surface grabs and placed in sample containers made of either plastic or glass. Sample bottles were prepared prior to sampling by the analytical laboratory and contained the appropriate preservatives for each analytical fraction. Samples were placed on ice immediately following collection and during shipment to the laboratory.

2.2 Storm Event Runoff

Three storm event sampling sites (Table 2-5, Figure 2-2) were monitored during the 1983-1984 contract period. Each site is located within a separate watershed on SUBASE. Sites SS-1 and SS-2 are located in developed areas and Site SS-3 is located just north of the SUBASE perimeter in an undeveloped area.

Parameters measured during storm event monitoring are listed in Table 2-6. Attempts were made to monitor summer (thermal convection) and winter (frontal) storm events at each station. Sampling was performed at approximate 15 minute intervals for all parameters from the beginning of rainfall through peak flow and into the declining stage of the runoff hydrograph during each storm event.

TABLE 2-4. Water Quality Parameters for Surface Freshwater Monitoring, Naval Submarine Base, Kings Bay, Georgia 1983-1984

Parameters
<u>In Situ</u>
Depth
Water Temperature
Conductivity
Salinity
pH
Dissolved Oxygen
Current Velocity
<u>Laboratory</u>
Turbidity
Total Suspended Solids
Ammonia Nitrogen
Total Kjeldahl Nitrogen
Total Phosphorus
Total Organic Carbon
Biochemical Oxygen Demand, 5-day
Oil and Grease
Cadmium, total
Chromium, total
Copper, total
Lead, total
Mercury, total
Fecal Coliform Bacteria

Source: Alvarez, Lehman and Associates, Inc., 1985

TABLE 2-5. Storm Event Runoff Monitoring Stations Designations and Descriptions, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Station Designation	Site Designation	Watershed Status
SS-1	East swale along USS James Madison Road near UEPH housing, downstream of lakes X and Y.	Developed
SS-2	South swale along USS Benjamin Franklin Drive 100 meters west of culvert under USS Danial Webster Road.	Developed
SS-3	Cherry Point Road at unnamed creek approximately 0.8 kilometers east of Georgia SR 40 Spur North.	Undeveloped

UEPH = unaccompanied enlisted personnel housing

Source: Alvarez, Lehman and Associates, Inc., 1985

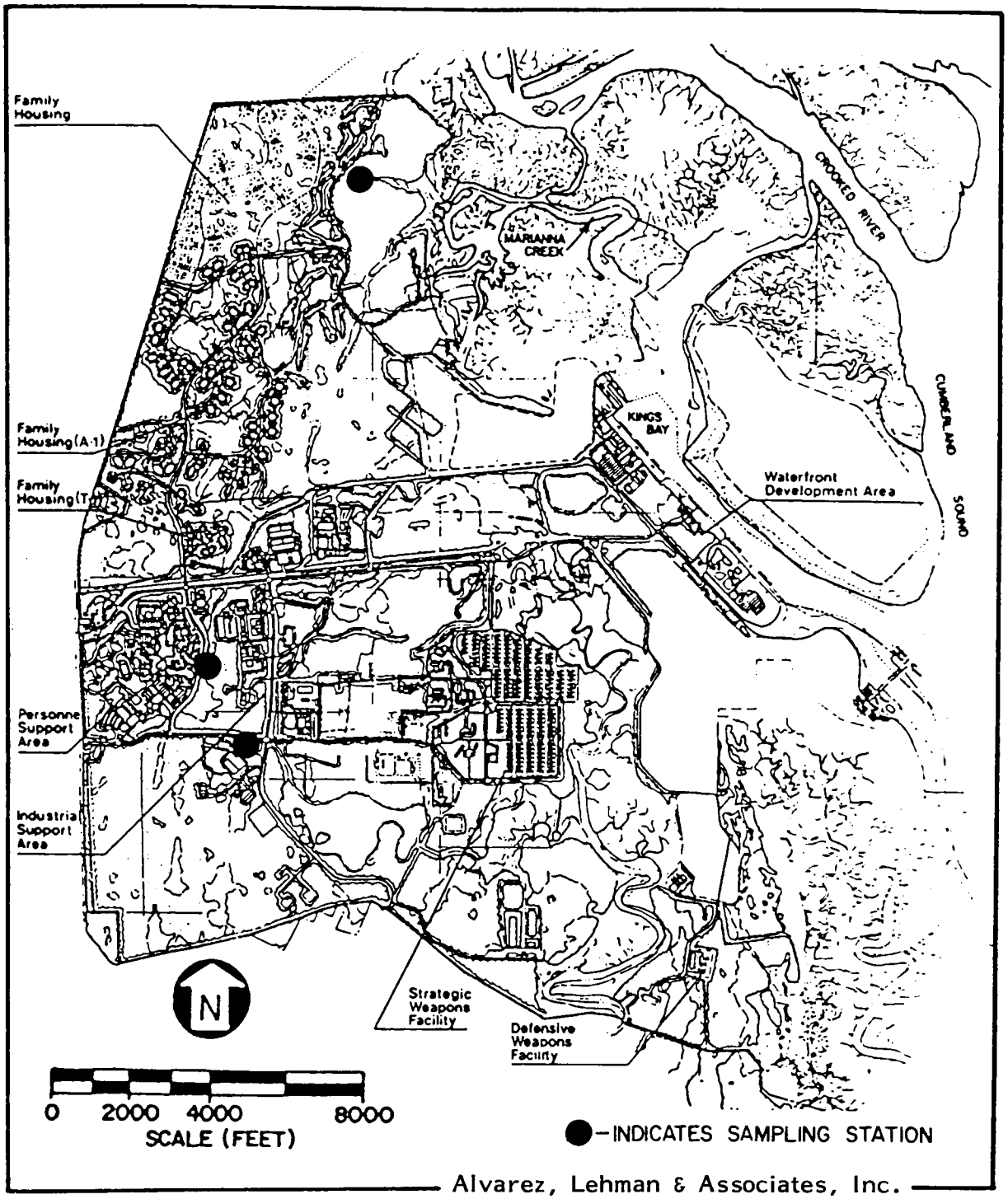

FIGURE 2-2. Locations of Storm Event Monitoring Sites, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

TABLE 2-6. Water Quality Parameters for Storm Event Monitoring, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Parameter
<u>In Situ</u>
Depth
Water Temperature
Conductivity
pH
Dissolved Oxygen
Rainfall
Wind Velocity and Direction
Air Temperature
Current Velocity
Turbidity

Source: Alvarez, Lehman and Associates, Inc., 1985

2.3 Groundwater Quality

Groundwater quality was monitored at seven shallow aquifer wells (Table 2-7, Figure 2-3). Well IF-1N (N = new) was constructed to replace Well IF-1 which was destroyed during Industrial Refit Facility site preparation. Other new wells installed were PD-1 and PS-1A. Wells PS-1, PW-1, PW-2 and IF-2 have been monitored since 1982. Well A has been monitored since 1978.

During monitoring year 1983-1984, Wells A, PS-1, PW-1, PW-2 and IF-2 were monitored in November 1983. Wells PS-1A, IF-1N, and PD-1 were constructed and hydraulically developed in December 1983. Well PS-1A was installed in December 1983 to confirm groundwater contamination documented at Well PS-1 during 1982-1983 monitoring. The new wells were first sampled in February 1984. All wells were monitored in May 1984 except Well PW-2 which was destroyed by construction sometime after the February sampling.

Each well was purged of between two and five well volumes prior to obtaining water samples to insure that water quality was representative of local groundwater conditions. Conductivity was monitored during purging to determine when water quality had stabilized. Water was purged from each well using a peristaltic pump system. After purging the wells, samples were obtained and analyzed for the parameters listed in Table 2-8. *In situ* parameters were measured from a sample collected in a bucket. Samples

TABLE 2-7. Groundwater Well Designations and Locations at Naval Submarine Base, Kings Bay, Georgia 1983-1984

Well Designation	Site Designation	Diameter Inches/Construction
A	Adjacent to Fire Tower east of Main Gate south of USS Henry L. Stimson Drive.	3/PVC
PS-1	East of ditch conveyancy from pond YB control structure. Approximately 100 feet north of bend in ditch.	2/PVC
PS-1A	Approximately 20 meters north of Well PS-1.	2/PVC
PW-1	At northwest corner of Public Works fenced vehicle parking area.	2/PVC
PW-2	East of USS Danial Webster Road, 200 feet south of USS Pulaski Drive and approximately 20 feet east of treeline.	2/PVC
IF-IN	West side of remnants of York Road, approximately 50 feet west of field.	2/PVC
IF-2	East side of Yenah (Towee) trail at sharp bend to north.	2/PVC
PD-1	Approximately 75 feet Southeast of DPDO stormwater pond berm.	2/PVC

DPDO = defense property disposal office

Source: Alvarez, Lehman and Associates, Inc., 1985

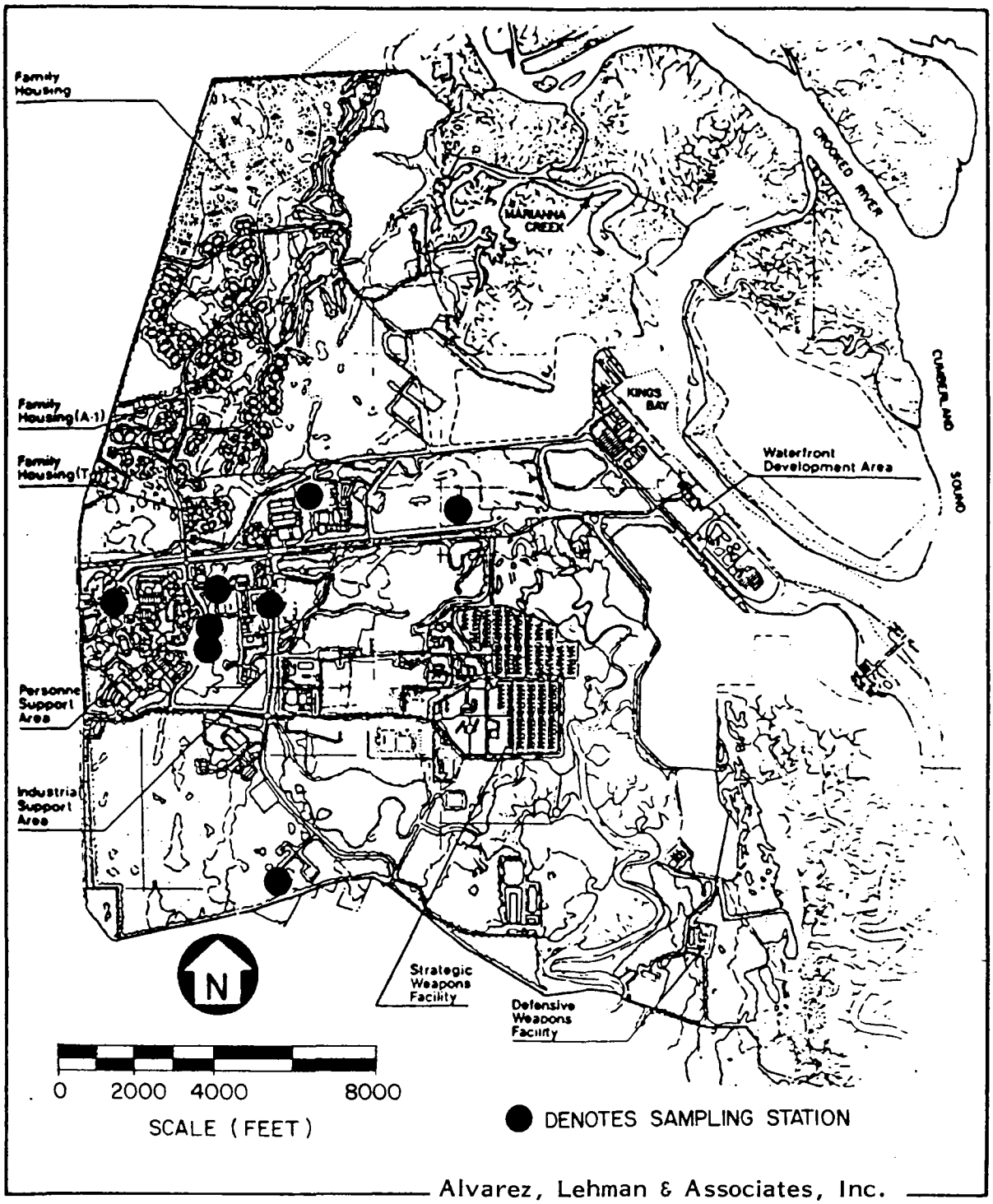

FIGURE 2-3. Groundwater Observation Well Locations, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, 1983-1984

TABLE 2-8. Water Quality Parameters for Routine Groundwater Monitoring at Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Parameter
<u>In Situ</u>
Well depth
Depth to water table
Water temperature
Conductivity
pH
<u>Laboratory</u>
Total dissolved solids
Alkalinity
Sulfate
Choloride
Total Kjehldahl Nitrogen
Nitrate + Nitrite Nitrogen
Total Phosphorus
Calcium, total
Cadmium, total
Chromium, total
Copper, total
Lead, total
Mercury, total
Zinc, total
Fecal coliform bacteria

Source: Alvarez, Lehman and Associates, Inc., 1985

for chemical analysis were pumped directly into bottles containing the appropriate types and quantities of preservative. Samples were transported chilled to the laboratory for analysis.

2.4 Sprayfield Monitoring

Wastewater Land Application Area (sprayfield) monitoring was incorporated into the routine environmental monitoring program during the 1983-1984 monitoring year. This monitoring included surface water, groundwater and soil samples.

2.4.1 Surface Water

Sprayfield perimeter ditches were monitored at six sites (Table 2-9, Figure 2-4). Sites were chosen to monitor runoff and groundwater exfiltration from different application zones each quarter.

Twenty-four hour composite samples obtained in three fractions from each station were collected. *In situ* measurements were obtained at the same time each fraction was collected. Sample containers were filled to one-third capacity, sealed and stored on ice during the compositing period. Upon collection of the third grab sample, a separate sample for bacteriological analysis was collected. Samples were chilled during transport to the laboratory for analysis (Table 2-10).

TABLE 2-9. Wastewater Land Application Surface Water Quality Station Designations and Descriptions, Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia 1983-1984

Station Designation	Site Designation
G-1	East side of Satilla Trail, just south of Suwanee Trail. North side of culvert.
G-2	East side of Satilla Trail approximately 100 meters south of Sautee Trail.
G-3	North side of USS Mariano G. Vallejo Avenue at 1st interceptor ditch from sprayfield.
G-4	West side of King Road approximately 50 meters North of USS Mariano G. Vallejo Avenue.
G-5	At corner of King Road's sharp bend to right, below confluence of interceptor ditches.
G-6	West side of Robison Road just north west of junction with King Road.

Source: Alvarez, Lehman and Associates, Inc., 1985

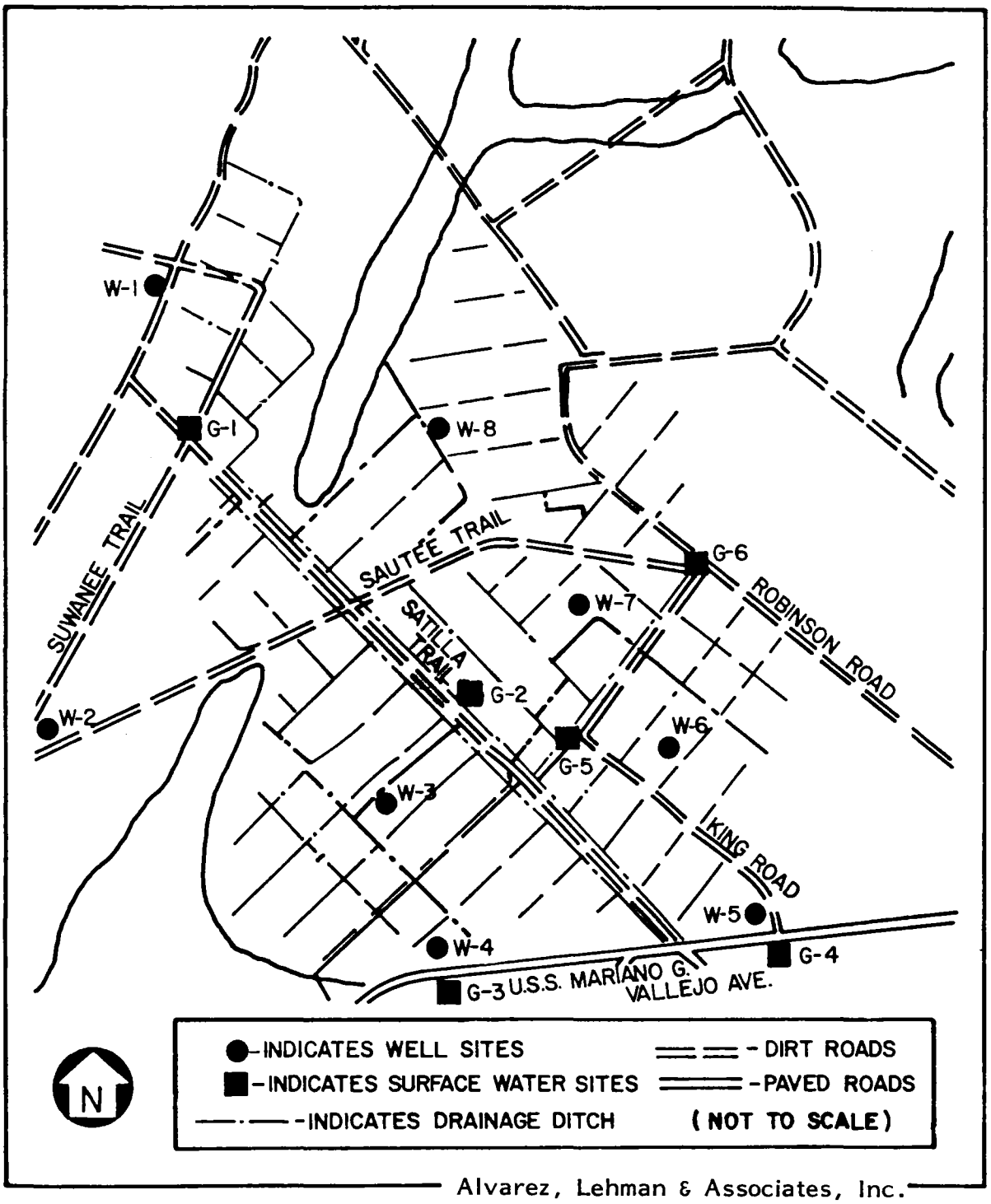

FIGURE 2-4. Locations of Wastewater Land Application Surface Water, Groundwater and Soils Stations, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

TABLE 2-10. Water Quality Parameters for Wastewater Land Application Surface Water Monitoring, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Parameters
<u>In Situ</u>
Water Temperature
Conductivity
pH
Dissolved Oxygen
Water Depth
General Weather Conditions
General Flow Conditions
<u>Laboratory</u>
Total Kjeldahl Nitrogen
Nitrate + Nitrite Nitrogen
Total Phosphorus
Total Copper
Total Lead
Total Mercury
Total Cadmium
Total Chromium
Fecal Coliform Bacteria
Fecal Streptococci Bacteria

Source: Alvarez, Lehman and Associates, Inc., 1985

2.4.2 Groundwater

Sprayfield groundwater monitoring wells were installed in 1980 prior to the start-up of the wastewater treatment plant (WWTP) to monitor the surficial aquifer below the sprayfield (Table 2-11, Figure 2-4).

Well W-2 was not found prior to first quarter sampling because it was destroyed by roadway construction. A new Well W-2 was installed February 17, 1984 and was sampled during subsequent quarters. The new well was constructed of 2-inch PVC pipe with five feet of 0.010-inch slotted screen on the bottom portion. Installation depth was approximately ten feet below grade. Original wells were constructed of 3-inch PVC casing equipped with an inner 1.5-inch PVC pipe with a foot valve as an air lift sampling device for each well. Insufficient volumes of water apparently rendered the air lift devices useless and they were removed from the wells shortly after construction. No records of hydraulic development were found for the original wells and similar problems in extracting suitable water volumes during the 1983-1984 monitoring were encountered. The wells appeared to be too shallow. An attempt was made during the first quarter to purge each well prior to sampling. Due to extremely slow recharge of the wells, this practice was abandoned for subsequent quarters. Samples were comprised of the water existing in the well at the time of sampling.

During 1983-1984, wells were sampled by pumping with a peristaltic pumping system. November 1983 and February 1984 samples contained large

TABLE 2-11. Wastewater Land Application Groundwater Monitoring Well Designations and Locations, Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Well Designation	Site Designation	Diameter Inches /Construction
W-1	At the southwest corner of Suwannee Trail and on unnamed trail outside the sprayfield boundry.	2/PVC
W-2	Approximately 25 meters northeast of the junction of Sautee and Suwannee trails, outside the sprayfield boundry.	2/PVC
W-3	Near the northwest corner of application zone 2.	3/PVC
W-4	Near the southeast corner of application zone 1.	3/PVC
W-5	Near the southeast corner of application zone 3.	3/PVC
W-6	Near the center of application zone 3.	3/PVC
W-7	Near the northern-most tip of application zone 3 in application zone 4.	3/PVC
W-8	Near the borders of application zones 5, 6 and 8 in application zone 5.	3/PVC

Source: Alvarez, Lehman and Associates, Inc., 1985

amounts of silts and sand particles. May and August 1984 samples were field-filtered through a 102 mm glass fiber filter to remove these particles. Samples were placed in appropriately preserved sample containers, chilled and transported to the laboratory for analysis (Table 2-12). In situ measurements were obtained from a bucket sample pumped from the well prior to analytical fraction collection.

2.4.3 Soils

A soil sample was obtained from a randomly chosen application zone within the sprayfield during each quarter. Samples were obtained by digging approximately two feet deep with a shovel. Total depth was determined by the uniformity of the soil horizons at each sample site. Digging was stopped at the point where the deepest horizon became uniform in appearance with increased depth. General lithology of the soils was recorded and samples were submitted to the laboratory for analysis of parameters listed in Table 2-13.

2.5 Estuarine Water Quality

Estuarine water quality was monitored at six stations (Table 2-14, Figure 2-5) located in Kings Bay and the Cumberland Sound estuarine complex on a quarterly basis. Stations TD, TE and DD2 have been sampled since 1980. Station W1 was added in 1982 to monitor water quality near the wharf area upstream of the Tender, U.S.S. Simon Lake. Station CR1 was added as a

TABLE 2-12. Water Quality Parameters for Wastewater Land Application Groundwater Monitoring, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Parameter
<u>In Situ</u>
Water Temperature
Conductivity
pH
Depth to Apparent Water Table
<u>Laboratory</u>
Total Dissolved Solids
Alkalinity
Chloride
Sulfate
Total Kjeldahl Nitrogen
Nitrate + Nitrite Nitrogen
Total Phosphorus
Total Calcium
Total Cadmium
Total Chromium
Total Copper
Total Lead
Total Mercury
Total Zinc
Fecal Coliform Bacteria
Fecal Streptococci Bacteria

Source: Alvarez, Lehman and Associates, Inc., 1985

TABLE 2-13. Analytical Parameters for Soils Samples from the Wastewater Land Application Area at Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Parameter
Cation Exchange Capacity
ph
Magnesium
Calcium
Potassium
Total Kjeldahl Nitrogen
Total Phosphorus

Source: Alvarez, Lehman and Associates, Inc., 1985

TABLE 2-14. Estuarine Water Quality Station Designations and Descriptions, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Station Designation	Station Description
TD	Upper turning basin. 100 meters south of drydock site.
W1	Central Kings Bay, east of wharf area, 100 meters north of Tender.
TE	Mid-channel at navigational aid no. 45 (FL G 2.5 sec).
DD2	Approach to USS Oak Ridge (ARDM), 100 meters south of vessel.
TF	Mid-channel approximately 100 meters west of Cumberland Island near the Dungeness Wharf.
CR1	Mid-channel at constriction in marsh tributary of the Crooked River.

Source: Alvarez, Lehman and Associates, Inc., 1985

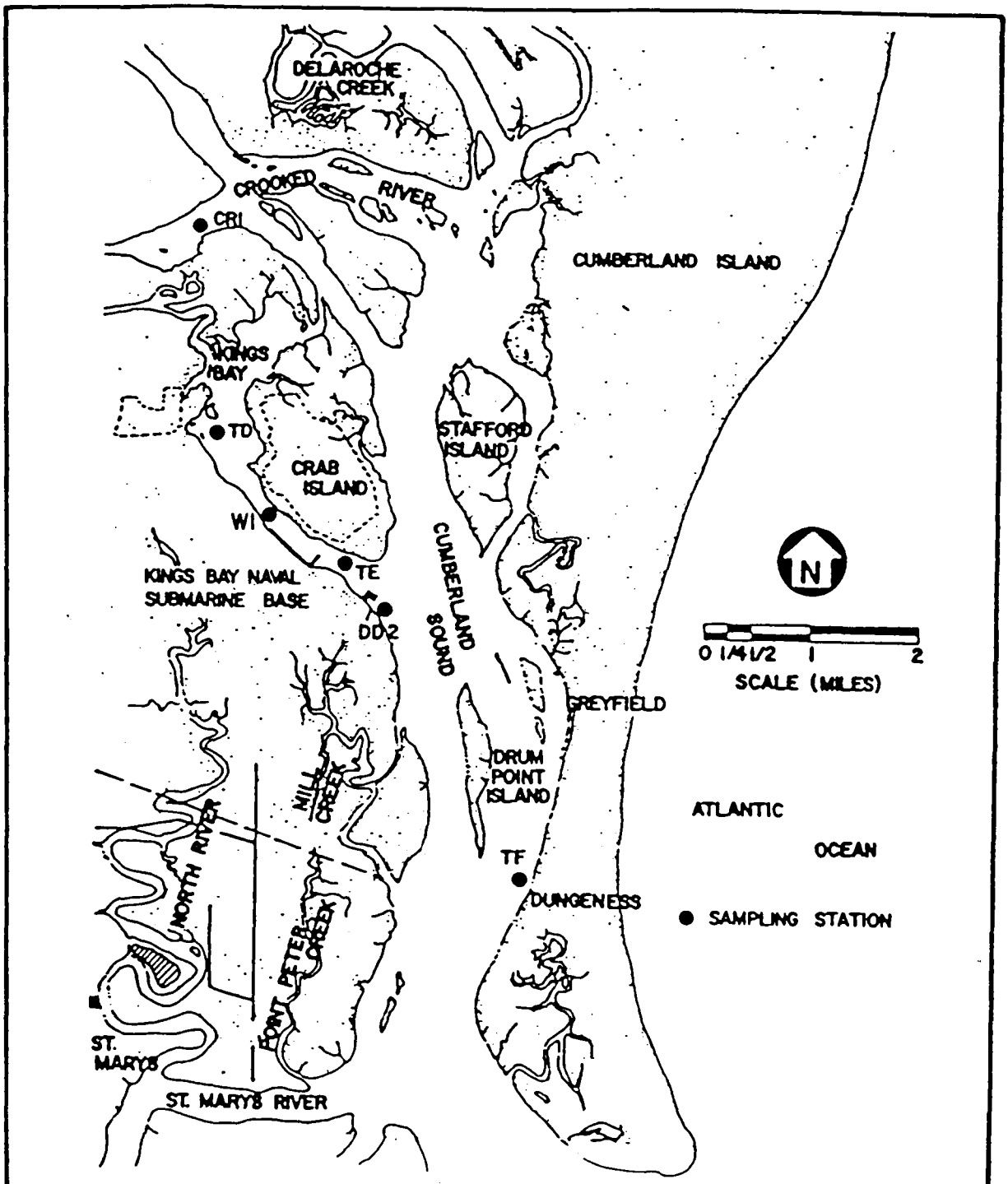

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FIGURE 2-5. Estuarine Water and Sediment Quality Stations, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

control site in 1982, but was referred to as station CRB (Crooked River Branch). Station TF was moved in 1982 from its original site near the northern tip of Drum Point Island to midway between Stafford Island and Greyfield Inn near the west side of Cumberland Island. In 1983, it was moved again to its present location near the Dungeness Wharf. This station represents an area within the Cumberland Sound that is removed from naval operations within Kings Bay.

Water column profiles for dissolved oxygen, temperature, conductivity, and salinity were obtained at one meter intervals at each station. General weather conditions and approximate tidal stage were noted. Samples for laboratory analysis were obtained approximately one meter from the bottom using a non-metalic water sampling bottle. Oil and grease samples were obtained from the surface. All samples were transferred to laboratory-prepared sample containers and transported chilled to the laboratory for analysis (Table 2-15).

2.6 Sediment Quality

Sediment samples were collected from each surface runoff and estuarine water quality station during August 1984.

Three petite ponar grabs (15 cm x 15 cm) at each station were obtained. A 250-cubic centimeter subsample from the center of each grab was placed into a glass container and sealed. The samples were transported

TABLE 2-15. Parameters for Estuarine Water Quality Monitoring, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Parameter
<u>In Situ</u>
Water Temperature
Conductivity
Salinity
Dissolved Oxygen
pH
Depth
<u>Laboratory</u>
Turbidity
Total Suspended Solids
Ammonia Nitrogen
Total Kjeldahl Nitrogen
Total Phosphorous
Total Organic Carbon
Total Copper
Total Chromium
Total Lead
Total Cadmium
Total Mercury
Fecal Coliform Bacteria
Oil and Grease

Source: Alvarez, Lehman and Associates, Inc., 1985

chilled to the laboratory for analysis (Table 2-16).

Extracts of each sediment sample were made for metals analysis by adding 100 grams of the composite sediment sample to one liter of 0.1 N hydrochloric acid. This mixture was shaken for one hour, centrifuged and filtered through a 0.45 u membrane filter. The resulting filtrate was then analyzed by atomic adsorption spectroscopy for the listed metals.

A separate fraction for oil and grease analysis was acidified to pH 2. Magnesium sulfate was added and mixed to dry the sediments. The sample was extracted for 4 hours using freon-113 (1,1,2-trichloro-1,2,2-trifluoroethane) in a Soxholet extraction apparatus. The resulting extract was analyzed spectrophotometrically using the referenced method (Table 2-1).

2.7 Dredge Monitoring

During 1984, OICC, TRIDENT initiated a daily monitoring program to compare the quality of Mainside Disposal Area (Mainside) effluents with ambient Kings Bay waters (Ambient). In situ parameters were monitored daily and samples for laboratory analysis were collected on alternate days at the disposal area outfall and at a station located in the lower turning basin within Kings Bay. Methods followed during daily dredge monitoring are described in "Report on Daily Monitoring of Kings Bay Water Quality in Comparison with Return Flow Water Quality From Mainside Disposal Area, NSB,

chilled to the laboratory for analysis (Table 2-16).

Extracts of each sediment sample were made for metals analysis by adding 100 grams of the composite sediment sample to one liter of 0.1 N hydrochloric acid. This mixture was shaken for one-hour, centrifuged and filtered through a 0.45 u membrane filter. The resulting filtrate was then analyzed by atomic adsorption spectroscopy for the listed metals.

A separate fraction for oil and grease analysis was acidified to pH 2. Magnesium sulfate was added and mixed to dry the sediments. The sample was extracted for 4-hours using freon-113 (1,1,2-trichloro-1,2,2-trifluoroethane) in a Soxholet extraction apparatus. The resulting extract was analyzed spectrophotometrically using the referenced method (Table 2-1).

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TABLE 2-16. Sediment Quality Analytical Parameters, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Parameter
Mercury
Lead
Zinc
Cadmium
Chromium
Oil and Grease

Source: Alvarez, Lehman and Associates, Inc., 1985

Kings Bay, Georgia" (Alvarez, Lehman & Associates, Inc., 1985f).

2.8 Biological Monitoring

2.8.1 Benthic Invertebrates

Benthic invertebrates were surveyed in February and August 1984. Eight sites were monitored each season (Table 2-17, Figure 2-6). Three full-size ponar grab samples (23 cm x 23 cm) were collected at each site. Each replicate sampled 0.053 square meter of substrate surface. Replicates were processed separately.

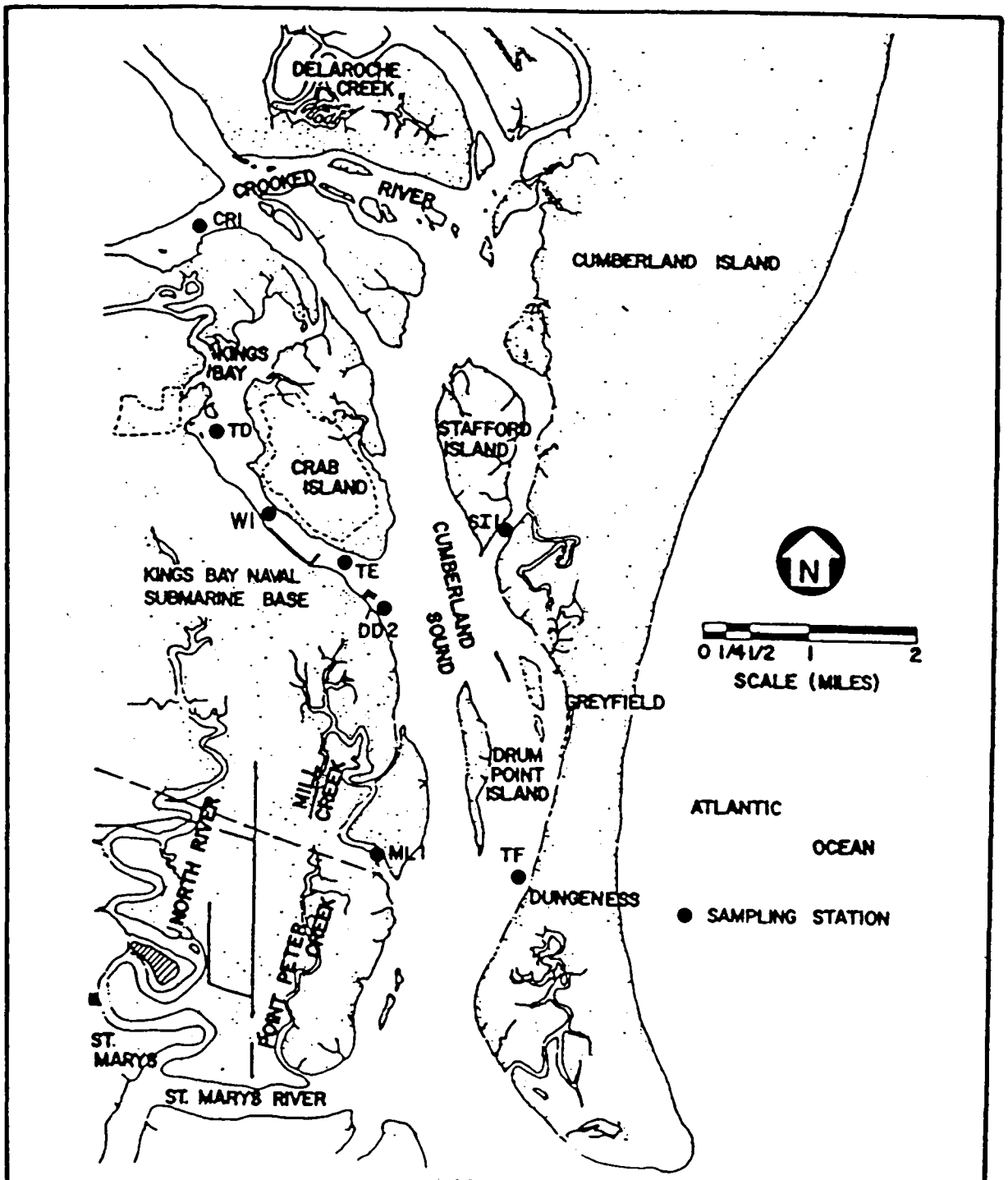
Each grab was field-sieved through 500 u Nitex screen. The residue was transferred to prelabelled plastic bags and fixed with 10 percent buffered Formalin. Rose bengal stain was added to the preservative. This stain concentrates in the tissues of organisms alive at the time of collection. Staining expedites subsequent coarse sorting of organisms from the sample residues remaining after sieving. All organisms were represerved pending identification.

Species identifications and counts were performed under a binocular dissecting microscope. Whole organisms and fragments with heads were counted for each species. Taxonomic references consulted include Pettibone (1963), Smith (1964), Williams (1965), Menzies and Frankenberg (1966), Abbott (1968; 1974), Brattegard (1969; 1970), Watling and Maurer (1973),

TABLE 2-17. A Summary of Benthic Sampling Locations Monitored During Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Station Designation	Site Designation
TD	Sampled since 1978 as Station D-West on Transect D. Roughly 100 meters east of the future drydock location in upper Kings Bay. Positioned on the upstream margin of the upper turning basin.
W1	Located roughly 100 meters out from the north end of the existing wharf in the lower turning basin of Kings Bay.
TE	Sampled since 1978 as Station E-West on Transect E. Roughly 100 meters out from the western shore of Kings Bay and 100 meters downstream of the Tender U.S.S. Simon Lake
DD2	Located roughly 100 meters downstream of the floating drydock (ARDM) pier and in line with the ARDM mid-line.
CR1	Located in the channel of Crooked River Branch, a meander off of the river's main axis. Natural channel control site. Formerly referred to as Station CRB.
TF	New site, located at Dungeness Wharf in Cumberland Sound. Natural channel control site.
SI1	Located in Stafford Island Channel between Stafford and Cumberland Islands. Natural channel control site.
ML1	New site, located midstream in the mouth of Mill Creek. Natural channel control site.

Source: Alvarez, Lehman and Associates, Inc., 1985



Alvarez, Lehman & Associates, Inc.

FIGURE 2-6. Sampling Stations for Benthic Invertebrate and Trawl Surveys, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Bousfield (1973), Gardiner (1975), Andrews (1977), Fauchald (1977), and McKinney (1977).

2.8.2 Macroinvertebrates

Macroinvertebrates living on or near the bottom (demersal macroinvertebrates) were surveyed by otter trawl in March and August 1984 (Table 2-18, Figure 2-6).

During each survey, trawls were pulled against an ebbing tide during daylight conditions. Trawling generally was limited to the first half of an ebbing tide. Two 15-minute trawls were pulled against the current at each site. Engine speed was maintained as uniformly as possible to standardize the distance trawled at each location.

The trawl used was a 5-meter, semi-balloon otter trawl with a body made of 2.8-cm, stretch-mesh nylon netting. An inner bag of 1.3-cm, stretch-mesh nylon net lined the cod end to maximize retention of juvenile forms. Each wooden door measured 76.0 cm x 38.0 cm x 1.9 cm and was fitted with iron boots. Door design caused the trawl to fish at the bottom surface. This gear type is selective of bottom-associated organisms.

Whenever possible, trawl catch was field-sorted to allow for the release of organisms surviving following gear retrieval. Large macroinvertebrates were released following measurement and enumeration.

TABLE 2-18. A Summary of Sites Trawled During Environmental Monitoring Surveys at Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Station Designation	Site Designation
TD	Area sampled since 1978 as Station D-West (Transect D). Trawl path roughly covered an area including benthic site TD (upper turning basin) in Kings Bay. Silty mud substrate at approximately 40 feet.
W1	Area sampled since 1982 as Station W1. Trawl path extended from the bow of the Tender U.S.S. Simon Lake to the north end of the existing wharf (the lower turning basin) and included benthic site W1. Silty mud substrate at about 40 feet.
TE	Area sampled since 1978 as Station E-West (Transect E) located in lower Kings Bay. Trawl path extended from just upstream of the drydock (ARDM) pier to just downstream of the Tender U.S.S. Simon Lake, and included benthic site TE. Silty mud substrate at about 40 feet.
DD2	Area sampled since 1978 as Station F-West (Transect F) located along the western shore of Cumberland Sound south of Kings Bay. Trawl path extended from the southern margin of an old dredge spoil disposal area dike system to just downstream of the ARDM pier. Muddy sand substrate at about 30 feet.
CR1	Area sampled since 1982 as Station CRB. Trawl path followed the channel of Crooked River Branch from its junction with the river proper into the meander (toward Cherry Point). Sandy mud substrate at roughly 20 to 25 feet.
SI1	Area sampled since 1982 as Station SI1. Trawl path followed the channel into the pass between Stafford and Cumberland Islands to where the mouth of Oldhouse Creek enters the channel. Sandy mud substrate at roughly 20 to 25 feet.

----------Continued----------

TABLE 2-18. Continued

Station Designation	Site Designation
TF	New location. Cumberland Sound along Cumberland Island near Dungeness Wharf. Sandy mud substrate at approximately 25 feet.
ML1	New location. Mouth of Mill Creek to the first meander west. Sandy mud substrate at approximately 20 feet.

Source: Alvarez, Lehman and Associates, Inc., 1985

Otherwise, the trawl catch was chilled on ice or preserved with 10 percent, buffered Formalin for transport to the laboratory. Where catch volume precluded retention of the entire sample, all large organisms were picked out and retained with a subsample (volume basis) of the more uniformly sized small organism fraction. Subsample counts were multiplied by the number of splits in order to estimate the total catch number per taxon.

In the laboratory, organisms were sorted to species and enumerated. Up to 20 individuals of each species were measured from each trawl. Maximal carapace width was recorded for crabs. For mantis shrimp and commercial shrimp, total length from the rostrum to the telson was measured. Mantle length was measured on squid.

2.8.3 Demersal Fish

Fish recovered in trawl surveys described in Section 2.8.2 were handled in the manner described for macroinvertebrates. Large specimens were counted, measured, and released as soon as possible after trawl retrieval. Samples chilled on ice during transport to the laboratory were processed within 24 hours, or fixed with 10 percent, buffered Formalin pending analysis.

Size measurement of stingrays was maximum wing width. For all other fish, total length (snout tip to the most distal point of the tail) was recorded. Up to 20 representative individuals of each species were

measured from each trawl replicate to estimate mean total lengths.

2.8.4 Oyster Tissue

Oysters (*Crassostrea virginica*) were collected in February and August 1984 from five stations (Table 2-19, Figure 2-7). Oyster tissues were shucked from their shells and split into two subsamples. Each subsample was frozen and transported to the designated laboratories for analysis.

One tissue subsample was transported to the analytical laboratory for metals, pesticides and PCB analysis (Table 2-20) while the other was submitted to Dr. Richard Lee (Skidaway Institute of Oceangraphy) for petroleum hydrocarbon residue analysis. Metals were analyzed by atomic adsorption spectroscopy. Pesticides and PCB's were analyzed by Gas-Liquid Chromatography (GLC) using packed column techniques. Petroleum hydrocarbons were analyzed by high performance liquid chromatography (HPLC). Of primary concern during the hydrocarbon analyses was the polycyclic aromatic hydrocarbon (PAH) fraction; the aliphatic hydrocarbon fraction was not analyzed.

2.8.5 Swamp Vegetation/Wells

Permanent sampling stations were established in May 1984 within six hardwood swamps at SUBASE (Figure 2-8). Each station was comprised of one

TABLE 2-19. Oyster Station Designations and Descriptions, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Station Designation	Site Designation
0-1	Upper Kings Bay at mouth of Marianna Creek.
0-2	Northern tip of Stafford Island.
0-3	West bank of Cumberland Sound approximately midpoint between ARDM and the mouth of Mill Creek.
0-4	West bank of Cumberland Sound adjacent to the ARDM site.
0-5	East bank of Cumberland Sound just south of Dungeness Wharf.

Source: Alvarez, Lehman and Associates, Inc., 1985

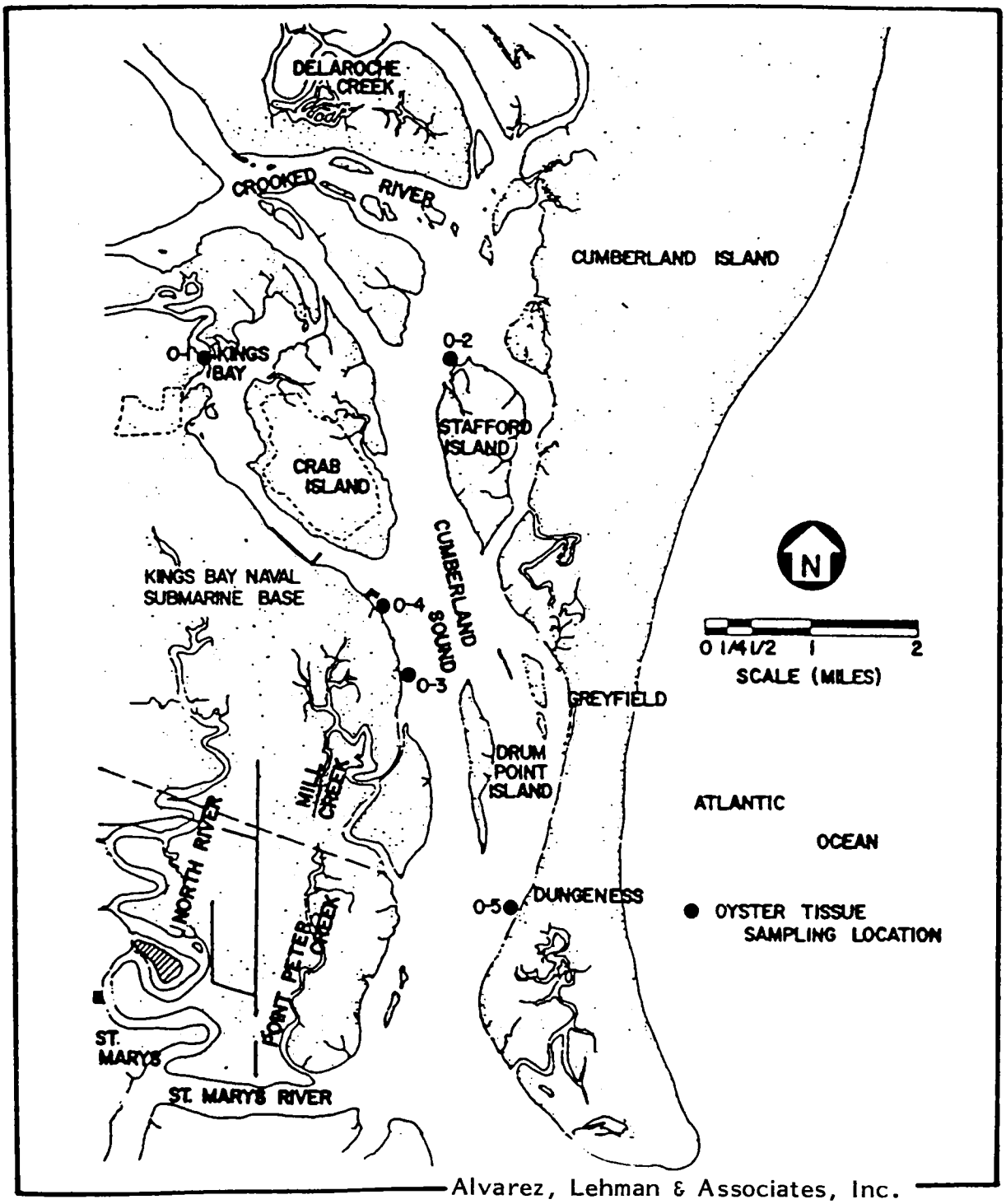


FIGURE 2-7. Locations of Oyster Tissue Collection Sites, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

TABLE 2-20. Parameters for Oyster Tissue Analysis, Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Parameter
Chlorinated Hydrocarbon Pesticides
Aldrin
Dieldrin
p, p-DDT
o, p-DDT
Heptachlor
Mirex
x-BHC
Chlordan
Endrin
Lindane
Toxaphene
Heptachlor epoxide
Polychlorinated Biphenyls (PCB's)
Polycyclic Aromatic Hydrocarbons (PAH's)
Metals
Mercury
Lead
Cadmium
Chromium
Copper
Percent Moisture

Source: Alvarez, Lehman and Associates, Inc., 1985

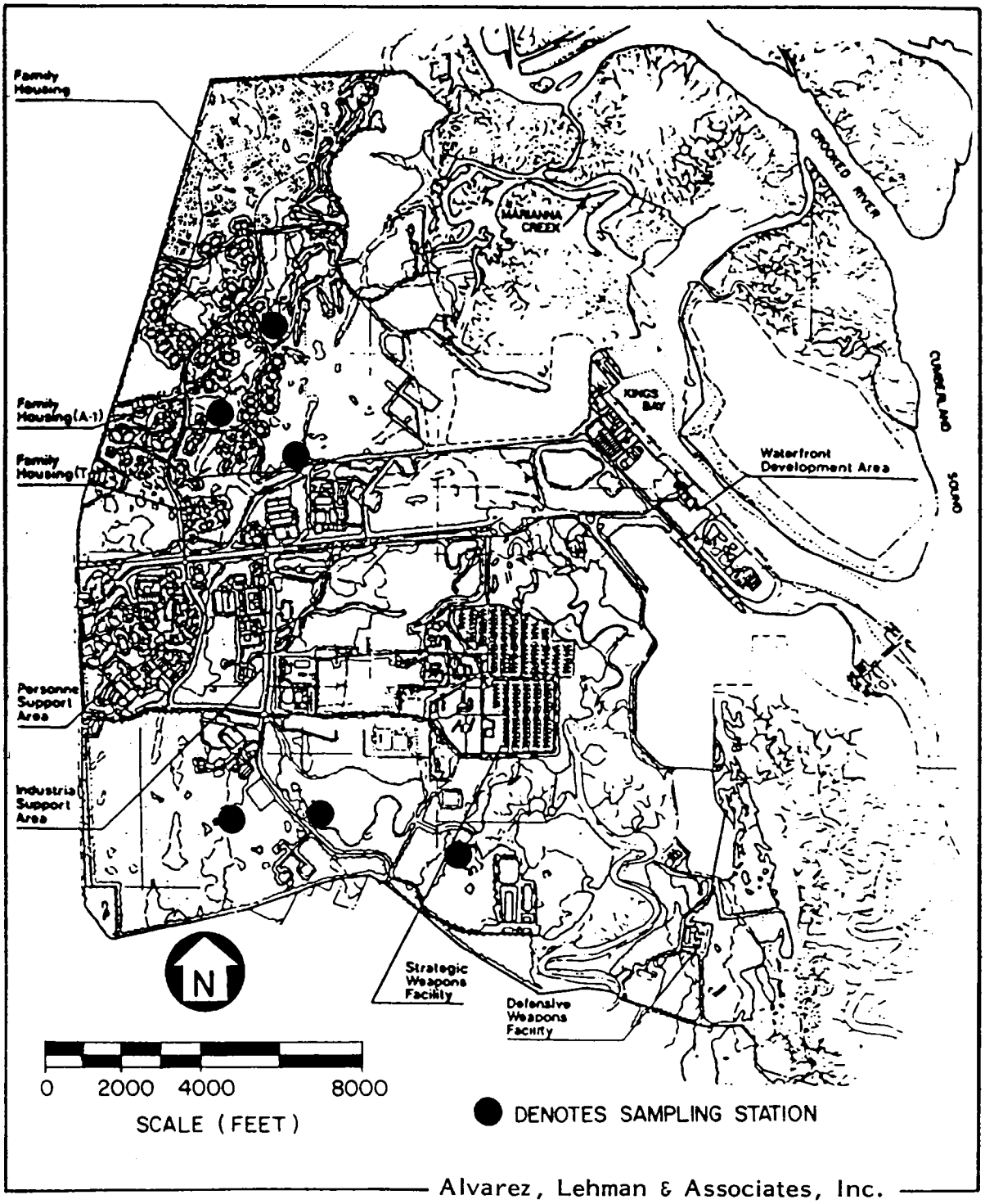


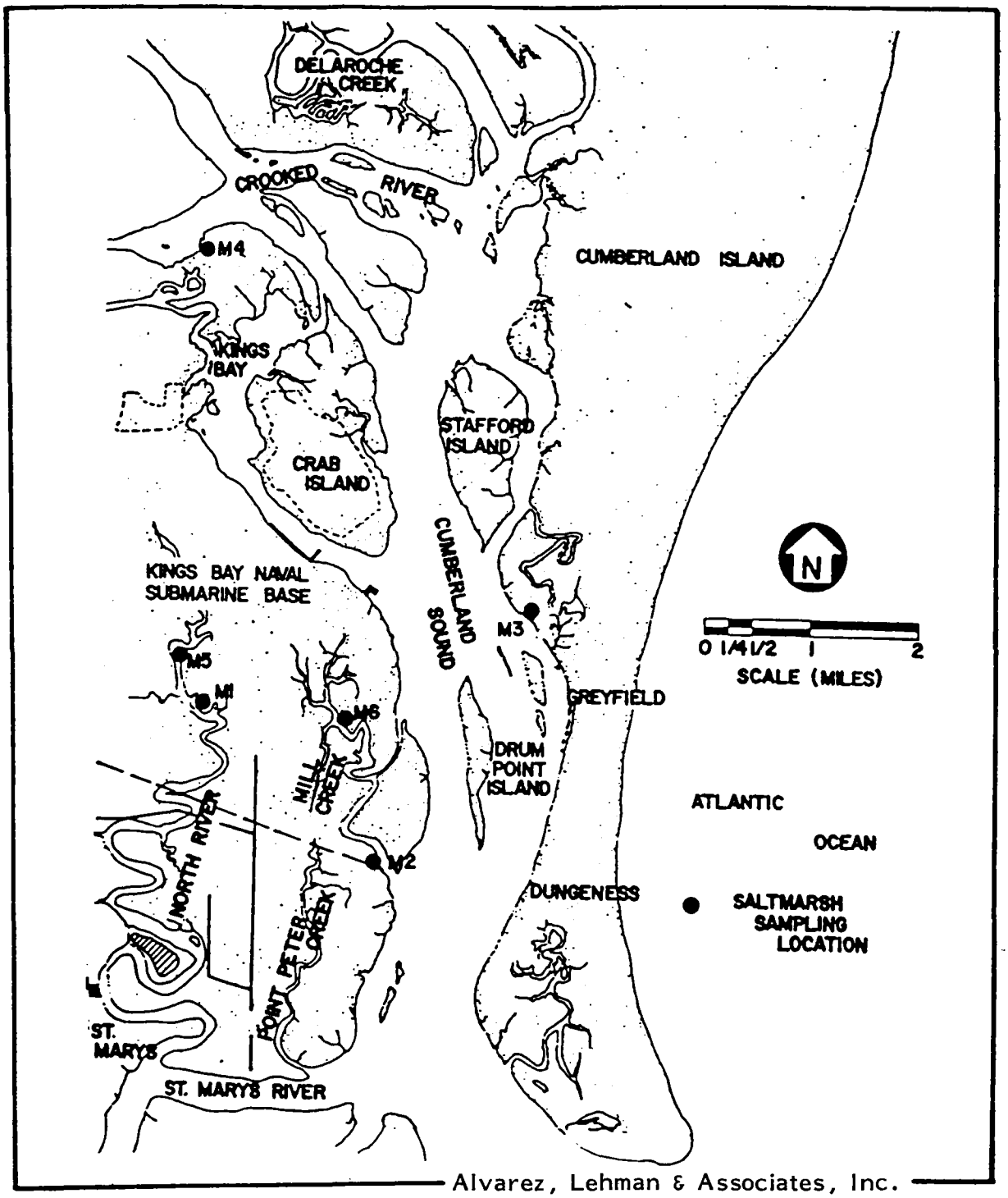
FIGURE 2-8. Locations of Swamp Vegetation Monitoring Sites, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

20 meter x 50 meter quadrat, with twenty-five one meter square subquadrats along the centerline of the larger quadrat. In the 20 meter x 50 meter (m) quadrat, the diameter at breast height (dbh) of all plants taller than 1.5 m was measured.

Vegetation counts were made according to diameter categories: 0-1 cm, 1-3 cm, 3-5 cm, 5-10 cm, 10-15 cm, up to 64 cm. Vegetation data were generally divided into overstory ($\geq$ 25 cm dbh), understory (12.7 to 25 cm dbh) and shrub layers ($\leq$ 12.7 cm dbh) for reporting purposes. Density and relative density were determined for each of these strata. Percent relative density was calculated by dividing the total number of a given species by the total number of all plants from all species within each layer and multiplying by 100. In each subquadrat, all vegetation below breast height (ground cover) was surveyed. Percent cover for each species as well as area cover by ground litter was estimated in each subquadrat. Frequency was determined by the total number of subquadrats with a given species divided by the total number of subquadrats for each swamp station.

2.8.6 Saltmarsh Vegetation

Smooth cordgrass (*Spartina alterniflora*) was sampled monthly from February through August 1984 at six stations (Figure 2-9). A 50 m transect line calibrated in one meter intervals was stretched perpendicular to the marsh shoreline toward the marsh interior at each station. A random numbers table was used to select reference points along the transect for



Alvarez, Lehman & Associates, Inc.

FIGURE 2-9. Locations of Salt Marsh Monitoring Stations, Naval Submarine Base, Kings Bay, Georgia, February Through August 1984

quadrat positioning. Three 0.5 meter square quadrats were harvested of all vegetation at each station each month. Smooth cordgrass stalks from each replicate were field sorted into live and dead fractions and stored in pre-labeled plastic bags pending laboratory processing.

One 10 cm deep core (PVC tube, inside diameter = 10 cm) of the substrate was recovered from each quadrat each month. Cores were stored in labeled plastic bags pending laboratory analysis for below-ground (root) biomass.

In the laboratory, average plant height in centimeters (cm) was estimated by measuring a representative stalk from each replicate. Wet weights were recorded to the nearest gram for the live and dead-stalk fractions. Samples were dried to constant weight; dry weights were recorded to the nearest gram.

Substrate cores were washed to separate sediments and shell fragments from the below-ground smooth cordgrass root mass. Wet-weight and dry-weight analyses were performed. All biomass data were standardized to grams per square meter of saltmarsh.

2.9 Non-Routine Monitoring

Paragraph 2.2 of the Scope of Work for Environmental Monitoring (FY84) dated September 9, 1983 provided a procedure for OICC, TRIDENT to initiate

non-routine sampling on SUBASE according to need. The non-routine monitoring aspects of the overall program were defined as the program progressed.

Tasks were assigned alpha-numeric identification numbers at the time of intitiation. For example, the second task was identified by the task number B011284-5. This alphanumeric code identified that the second task (B) was initiated on January 12, 1984 (011284) and involved collection of five (5) environmental samples.

Four non-routine tasks were intiated by the OICC, TRIDENT Project Manager during 1983-1984. These were:

Task Number	Description
A120983-5	Fuel-saturated Soils Assessment (Alvarez, Lehman & Associates, Inc., 1984a)
B011284-5	Monroe Roadside Ditch Water Quality Study (Alvarez, Lehman & Associates, Inc., 1984b)
C053084-14	Fly Ash Analysis (Alvarez, Lehman & Associates, Inc., 1984d)
	Disposal Area No. 2 Seepage Study (Alvarez, Lehman & Associates, Inc., 1984e)
D062884-16	Disposal Area No. 2 Turbidity Plume Study (Alvarez, Lehman & Associates, Inc., 1985c)

Detailed descriptions of methods employed during sampling and analysis for each of these tasks are presented in the reports cited.

3.0 RESULTS AND DISCUSSION

3.1 Surface Runoff Water Quality

The Draft Supplement to the Environmental Impact Statement (DSEIS) projected increased potential for stormwater drainage impacts to surface water systems of SUBASE with continued A-1 development (Environmental Science and Engineering, Inc., 1980a). Impacts were anticipated from all SUBASE drainage basins. Development of family housing in the Marianna Creek Basin was expected to impact the north drain to Marianna Creek by increasing oil and grease, lead, and bacteriological contamination, and by decreasing ambient oxygen levels due to discharge of drainage having high biochemical oxygen demand. Increased nutrient levels were also anticipated due to runoff from fertilized lawns and other landscaped areas. Station MC-1 was added to the 1983-1984 monitoring program to monitor drainage from this basin.

Stormwater drainage to North River was expected to increase over T-1 levels due to extensive construction associated with the Strategic Weapons Facility, additional personnel support and administrative complexes, utility lines, and industrial refit areas. These developments will increase SUBASE impervious areas resulting in increased rates and volumes of surface runoff. Increased loading of biochemical oxygen demand, oil and grease, lead, and other chemical constituents was predicted (Environmental Science and Engineering, Inc., 1980b). Stations SD1, NR5, and NR8 were

monitored to detect any increased contaminant loading to North River. Station NR-9 at the New Point Peter Road bridge was sampled to monitor water quality conditions in North River at a point downstream of all Navy-related discharges.

In general, water quality data recorded for the 1983-1984 monitoring year (Tables 3-1 through 3-4) were within the range of values reported for surface waters in this area from 1978-1983 (Jones, Edmunds & Associates, Inc., 1984). High biochemical oxygen demand (BOD), nutrients, metals, and oil and grease levels predicted by the DSEIS were not consistently documented.

Dissolved oxygen at Station NR-9 (North River) was below the Georgia Department of Natural Resources (GDNR) water quality standard for industrial waters (3.0 milligrams per liter) during all quarters except February. This data is consistent with historical records for this station (Jones, Edmunds & Associates, Inc., 1984) and may be partially due to high BOD wastewater from Gilman Paper Company effluent discharge to the lower reach of the North River. All other surface runoff sites were above the 4.0 mg/l minimum required for most Georgia surface waters (Georgia Department of Natural Resources, 1980).

Conductivity levels indicated that sampling was accomplished under varying tidal conditions. Sampling in February and August was conducted at low tide; water quality accurately represented SUBASE drainage. Analytical

TABLE 3-1. Summary of Surface Water Quality Data, Naval Submarine Base, Kings Bay, Georgia, November 29, 1983

Parameter*	Station				
	MC-1	NR-5	NR-8	NR-9	SD-1
In Situ					
Depth (m)	0.7	1.1	1.3	8.3	0.1
Temperature (°C)	18.5	16.7	16.7	17.2	19.3
Conductivity (umhos/cm)	28,800	8,100	9,600	ND	148
Salinity (ppt)	19	5.5	6.0	11.2	0
pH (S.U.)	7.8	7.6	7.6	7.2	7.1
Dissolved Oxygen	7.5	6.0	5.7	2.6	9.5
Current Velocity (m/sec)	NM	NM	NM	0.16	0.26
Laboratory					
Turbidity (NTU)	7.7	27	23	4.6	18
Total Suspended Solids	27	17	23	27	6.0
Ammonia Nitrogen	0.15	0.18	0.15	0.62	0.05
Total Kjeldahl Nitrogen	0.15	0.67	0.50	1.1	0.58
Total Phosphorus	0.08	0.34	0.36	0.59	0.67
Total Organic Carbon	11	23	31	37	19
BOD_5	1.2	2.8	2.3	6.9	1.5
Oil and Grease	<0.10	0.35	<0.10	0.37	0.27
Cadmium	0.012	<0.002	0.002	<0.002	<0.002
Chromium	<0.005	<0.005	<0.005	<0.005	<0.005
Copper	<0.005	<0.005	<0.005	<0.005	<0.005
Lead	0.07	<0.01	0.10	<0.01	<0.01
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Fecal Coliform (MPN/100 ml)	0.51	0.92	0.22	1.6	1.6

* all values reported are milligrams per liter unless otherwise noted
m = meters
°C = degrees Centigrade
ND = no data
NM = not measurable
umhos/cm = micromhos per centimeter
ppt = parts per thousand or g/kg
S.U. = standard units
m/sec = meters per second
NTU = nephelometric turbidity units
BOD_5 = 5-day Biochemical Oxygen Demand
MPN/100 ml = most probable number per 100 milliliters

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-2. Summary of Surface Water Quality Data, Naval Submarine Base, Kings Bay, Georgia, February 28, 1984

Parameter*	Station				
	MC-1	NR-5	NR-8	NR-9	SD-1
In Situ					
Depth (m)	0.20	0.36	0.40	4.90	0.12
Temperature (°C)	13.2	15.0	14.8	15.0	16.1
Conductivity (umhos/cm)	300	234	900	4,800	150
Salinity (ppt)	0	0	<1	3.5	0
pH (S.U.)	6.8	6.9	7.1	7.3	7.2
Dissolved Oxygen	9.8	8.8	11.4	8.0	12.4
Current Velocity (m/sec)	0.41	0.66	0.14	0.01	0.26
Laboratory					
Turbidity (NTU)	53	470	57	75	14
Total Suspended Solids	27	484	34	109	6.6
Ammonia Nitrogen	0.04	0.08	0.12	0.13	<0.04
Total Kjeldahl Nitrogen	0.64	3.1	0.61	1.3	0.52
Total Phosphorus	0.22	2.3	0.32	0.62	0.11
Total Organic Carbon	32	100	25	42	25
BOD_5	1.0	2.5	3.0	2.2	0.9
Oil and Grease	0.31	1.1	0.24	0.70	1.7
Cadmium	<0.002	0.004	<0.002	<0.002	<0.002
Chromium	<0.005	0.015	<0.005	<0.005	<0.005
Copper	<0.005	<0.005	<0.005	<0.005	<0.005
Lead	<0.01	0.02	<0.01	<0.01	<0.01
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Fecal Coliform (MPN/100 ml)	240	240	460	240	93

* all values reported are milligrams per liter unless otherwise noted
m = meters
°C = degrees centigrade
umhos/cm = micromhos per centimeter
ppt = parts per thousand or g/kg
S.U. = standard units
m/sec = meters per second
NTU = nephelometric turbidity units
BOD_5 = 5-day Biochemical Oxygen Demand
MPN/100 ml = most probable number per 100 milliliters

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-3. Summary of Surface Water Quality Data, Naval Submarine Base, Kings Bay, Georgia, May 13, 1984

Parameter*	Station				
	MC-1	NR-5	NR-8	NR-9	SD-1
In Situ					
Depth (m)	0.28	0.07	0.30	6.40	0.08
Temperature (°C)	26.0	26.5	29.0	26.0	30.0
Conductivity (umhos/cm)	7,000	2,800	6,000	13,000	180
Salinity (ppt)	4.2	2.0	3.5	7.8	0
pH (S.U.)	7.5	7.5	7.6	7.5	7.2
Dissolved Oxygen	6.5	6.5	7.0	2.4	9.1
Current Velocity (m/sec)	0.13	0.52	0.04	0..45	0.02
Laboratory					
Turbidity (NTU)	12	13	34	5.9	1.0
Total Suspended Solids	12	21	37	12	2.6
Ammonia Nitrogen	0.13	0.33	1.0	0.47	<0.04
Total Kjeldahl Nitrogen	0.37	0.98	1.4	1.2	0.11
Total Phosphorus	0.12	0.31	0.05	0.22	0.05
Total Organic Carbon	31	51	27	111	10
BOD_5	<1	7.2	5.7	4.8	1.2
Oil and Grease	0.29	0.26	0.68	0.52	0.27
Cadmium	0.004	<0.002	<0.002	<0.002	<0.002
Chromium	<0.005	0.005	<0.005	<0.005	<0.005
Copper	0.006	<0.005	<0.005	<0.005	<0.005
Lead	0.21	<0.01	0.01	<0.01	0.04
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Fecal Coliform (MPN/100 ml)	150	<2,400	460	23	14

* all values reported are milligrams per liter unless otherwise noted
m = meters
°C = degrees Centigrade
umhos/cm = micromhos per centimeter
ppt = parts per thousand or g/kg
S.U. = standard units
m/sec = meters per second
NTU = nephelometric turbidity units
MPN/100 ml = most probable number per 100 milliliters
BOD_5 = 5-day Biochemical Oxygen Demand

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-4. Summary of Surface Water Quality Data, Naval Submarine Base, Kings Bay, Georgia, August 2, 1984

Parameter*	Station				
	MC-1	NR-5	NR-8	NR-9	SD-1
In Situ					
Depth (m)	0.26	0.15	0.46	5.83	0.18
Temperature (°C)	26.0	28.0	28.0	28.0	29.5
Conductivity (umhos/cm)	2,700	310	3,150	1,250	210
Salinity (ppt)	2	0	2	7	0.5
pH (S.U.)	7.0	7.3	7.2	7.2	7.3
Dissolved Oxygen	5.9	7.3	6.0	2.8	7.6
Current Velocity (m/sec)	0.09	0.36	0.62	0.09	0.45
Laboratory					
Turbidity (NTU)	12	120	17	6.1	96
Total Suspended Solids	13	99	19	16	42
Ammonia Nitrogen	0.06	<0.04	0.60	0.21	<0.04
Total Kjeldahl Nitrogen	0.25	0.61	1.10	0.83	0.81
Total Phosphorus	0.11	0.31	0.15	0.15	0.40
Total Organic Carbon	15	28	14	29	18
BOD_5	1.3	2.9	1.8	2.5	2.3
Oil and Grease	0.25	0.64	0.35	1.1	0.43
Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002
Chromium	<0.005	0.006	<0.005	0.012	<0.005
Copper	0.005	0.006	0.005	0.008	0.005
Lead	0.01	<0.01	<0.01	0.05	0.01
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Fecal Coliform (MPN/100 ml)	>2,400	>2,400	1,100	460	93

* all values reported are milligrams per liter unless otherwise noted
Station NR-5 was moved; depth and current velocity are averages of four culverts; discharge is total for all culverts

m = meters
°C = degrees Centigrade
umhos/cm = micromhos per centimeter
ppt = parts per thousand or g/kg
S.U. = standard units
m/sec = meters per second
BOD_5 = 5-day Biochemical Oxygen Demand
MPN/100 ml = most probable number per 100 milliliters
NTU = nephelometric turbidity units

Source: Alvarez, Lehman & Associates, Inc., 1985

records for November and May were influenced by presence of estuarine waters due to higher tide stage at the time of field collections.

No water quality criteria for turbidity or total suspended solids (TSS) exist for Georgia's surface waters. Comparatively the State of Florida prohibits activities which cause localized turbidities to exceed those of ambient waters by more than 29 nephelometric turbidity units (NTU) (Florida Department of Environmental Regulation, 1983). High levels of turbidity or TSS often correspond to elevated levels of trace metals, nutrients, and biochemical oxygen demand.

SUBASE drainage exceeded the Florida turbidity standard during February and August (Figure 3-1). In February, waters draining to both Marianna Creek (Station MC-1) and North River (Stations NR-5 and NR-8) were highly turbid. Using the lowest turbidity value for the quarter as an estimate of ambient turbidity, base runoff through all three of these SUBASE drains exceeded the Florida reference standard.

Base-wide elevated turbidity during February reflects the wetter than normal winter of 1984 causing increased runoff erosion of construction sites. High turbidity and TSS levels at Station NR-5 probably reflect runoff from cleared areas associated with construction of the Stimson chain of stormwater retention ponds, drainage swale extension to the limited area, and site preparation for the Strategic Weapons Facility. Drainage from SUBASE was a likely source of highly turbid water in the North River

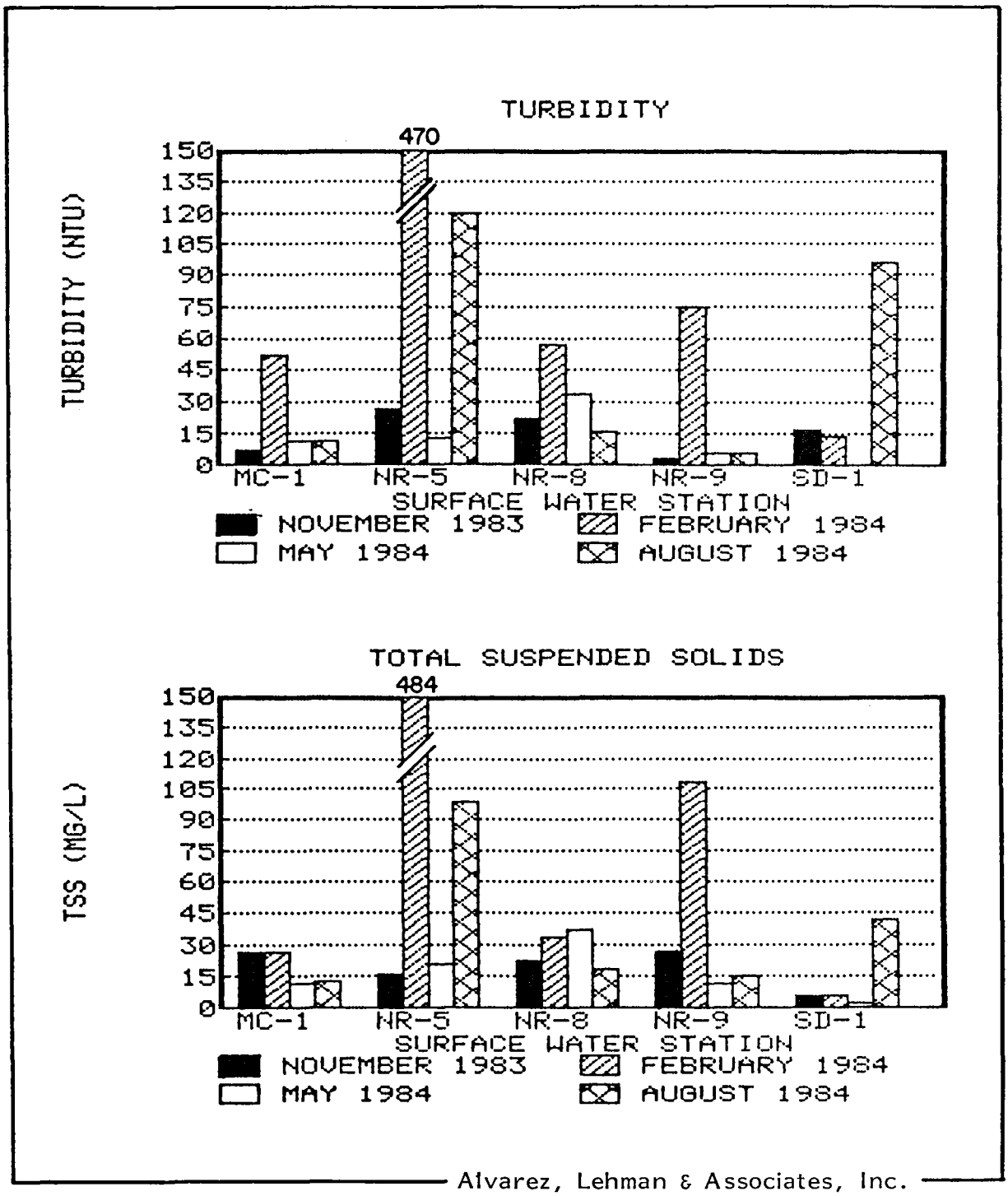


FIGURE 3-1. Turbidity and Total Suspended Solids in Surface Water Runoff, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

during this month. Levels of nutrients were high as a result of organic nitrogen and phosphates associated with elevated solids concentrations (Figure 3-2).

In August, SUBASE runoff to North River through Stations NR-5 and SD-1 exceeded the Florida turbidity standard. High levels of turbidity and total suspended solids observed at Station SD-1 reflected dewatering of Lake D in preparation of expansion of this retention lake. Turbid discharge from the swale (Station NR-5) draining the Stimson chain of lakes to the North River, reflected ongoing construction of the area's drainage swales, bridges and culverts.

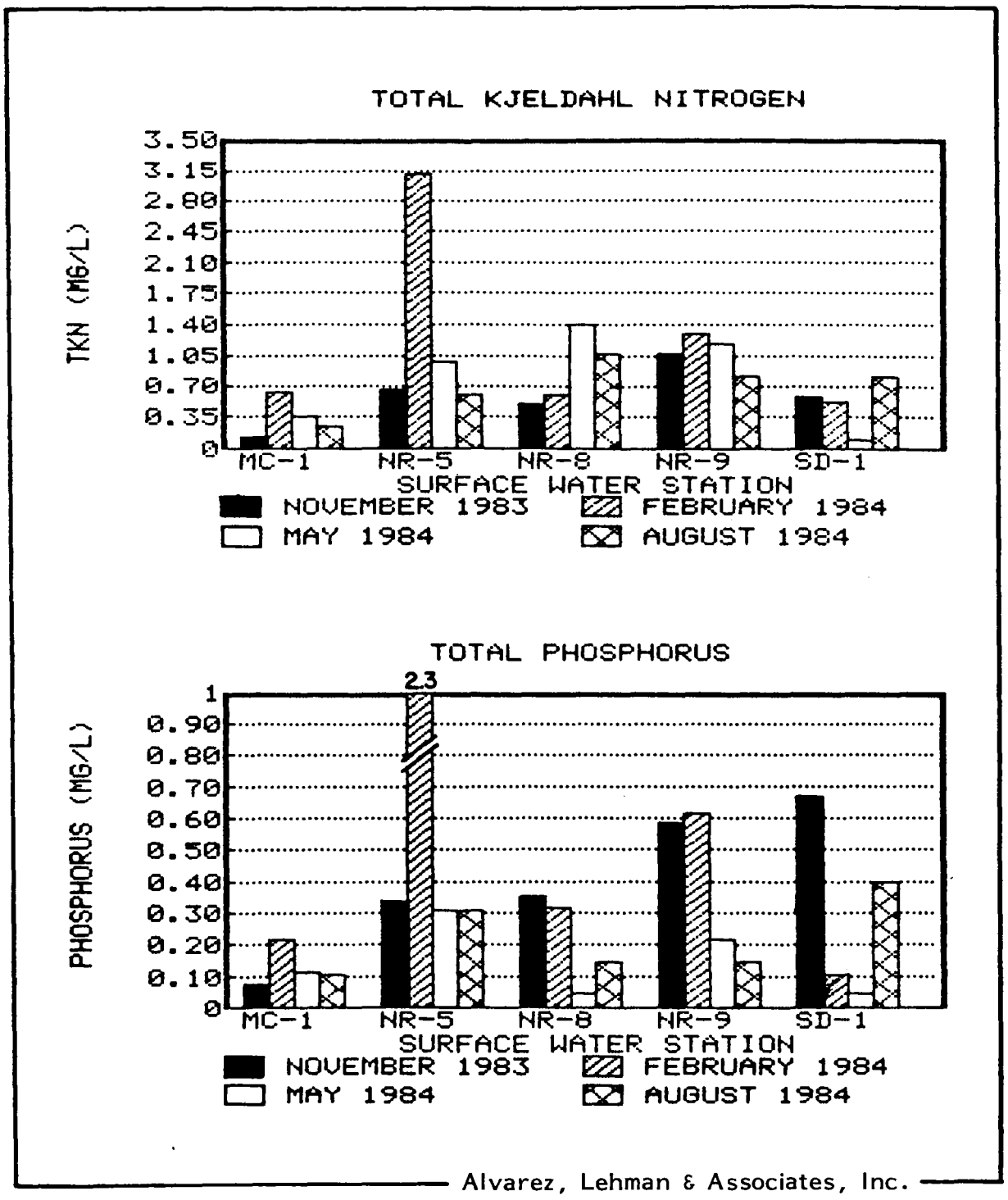


FIGURE 3-2. Total Kjeldahl Nitrogen and Total Phosphorus in Surface Water Runoff, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

3.2 Storm Event Runoff

The DSEIS projected both construction and operational impacts on stormwater drainage systems on SUBASE. Upland site preparation and construction were expected to increase the potential for stormwater erosion resulting in increased loads of suspended solids and related chemical constituents.

Operational impacts were anticipated in the form of higher quantities and peak rates of surface water runoff due to increased areas of impervious surfaces (e.g. roads, parking lots, building complexes) and drainage improvements installed to prevent flooding under 100-year storm conditions. Drainage network design incorporated swales, retention ponds, and natural hardwood swamps in a system designed to mimic the net rate of release of stormwater runoff in an undeveloped watershed. This system was to allow natural treatment of stormwaters through settlement of suspended materials before discharge to downstream reaches. It was projected that silt transport to receiving waters could be minimized by use of catchment basins, use of careful grading techniques, and prompt seeding of exposed bare earth (Environmental Science and Engineering, Inc., 1980a).

Monitoring during 1983-1984 included storm event runoff sampling to evaluate these DSEIS predictions. Storm event sampling was attempted at three sites on SUBASE. Site SS-1, located in a swale receiving overflow from stormwater retention pond Y, was monitored to evaluate runoff from the

northern part of the Personnel Support Area (PSA), including active construction areas for Unaccompanied Enlisted Personnel Housing (UEPH) and support facilities. Site SS-2 located in a swale along U.S.S. Benjamin Franklin Road receives overflow from a hardwood swamp along the east side of U.S.S. James Madison Road. This swamp serves as a temporary storage site for surface drainage from the southern parts of PSA, including the TRIDENT Training Facility (TRITRAFAC) construction site. The control station, Site SS-3, was located in an undeveloped watershed on Cherry Point along a small tributary stream leading to Marianna Creek.

The storm event monitoring objective was to compare runoff and storm water quality from developed and undeveloped sites under the two types of rainfall events which occur in the area. Frontal storms were successfully monitored at all three sites. Thermal convection storms were successfully monitored at only one site, SS-1. The frontal storm cumulative rainfall depths are graphically compared in Figure 3-3.

The four monitored storms included a small storm (0.37 inches), a medium storm (0.63 inches) and two large storms (1.89 inches). The large storms occurred in April when typically the water table is close to the surface. The runoff from both sites SS-1 and SS-3 was large in volume (Table 3-5).

Catchment response to rainfall is illustrated in the hydrographs in Figures 3-4 and 3-5. The hydrographs at SS-1 are well defined and typical

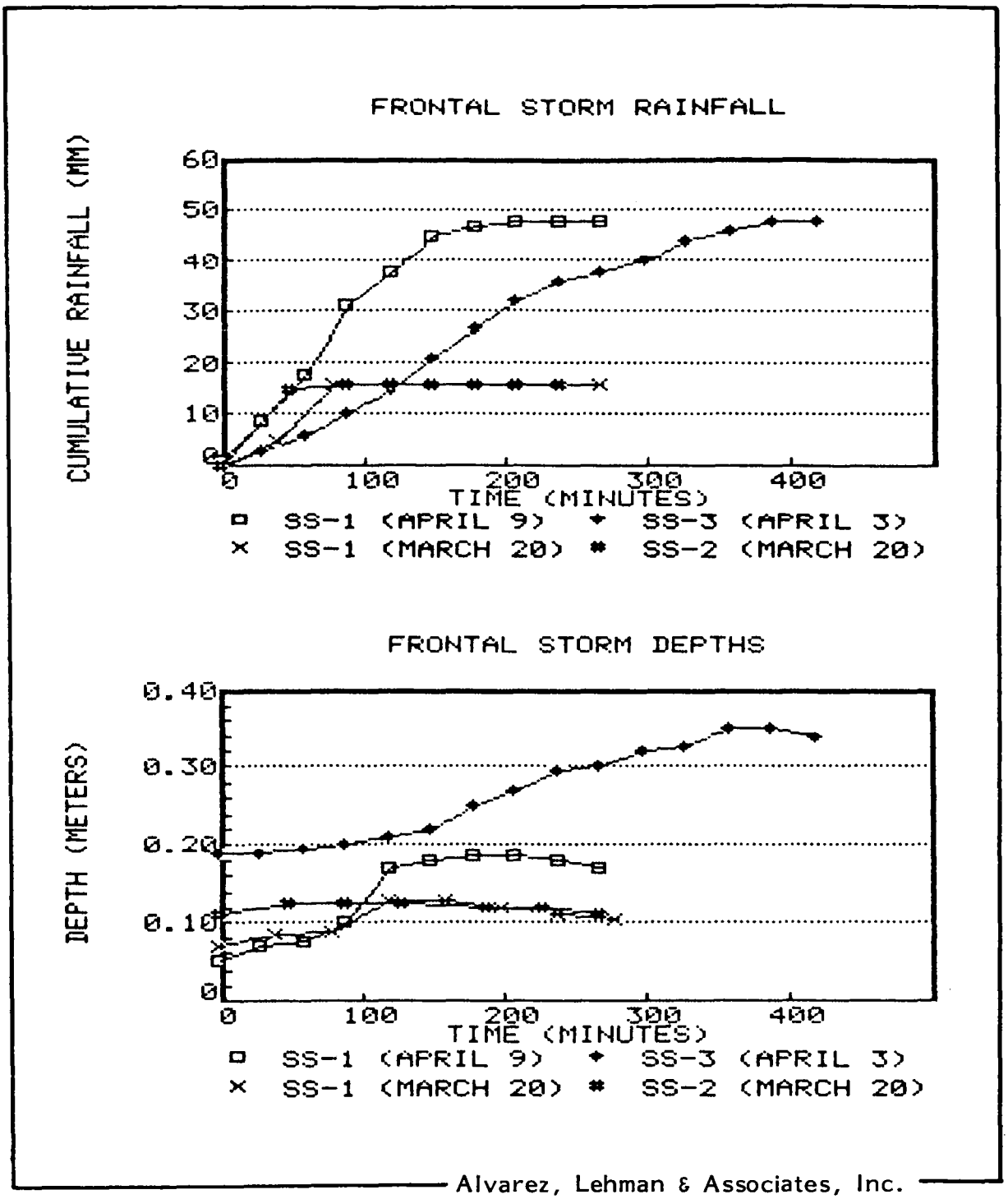


FIGURE 3-3. Cumulative Rainfall and Depth During Frontal Storm Event Monitoring, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

TABLE 3-5. Storm Event Rainfall and Flow Volumes from Three Sites at Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Station	Date	Rainfall (Inches)	Flow Volume (CF)
SS-1	3/20/84	0.63	4548
SS-1	4/9/84	1.89	24721
SS-1	9/4/84	0.37	472
SS-2	3/20/84	0.63	296
SS-3	4/3/84	1.89	68652*

CF = cubic feet
*Base flow = 27216 CF
Storm flow = 41436 CF
Flow volume = total flow volume through cross section during storm event

Source: Alvarez, Lehman & Associates, Inc., 1985

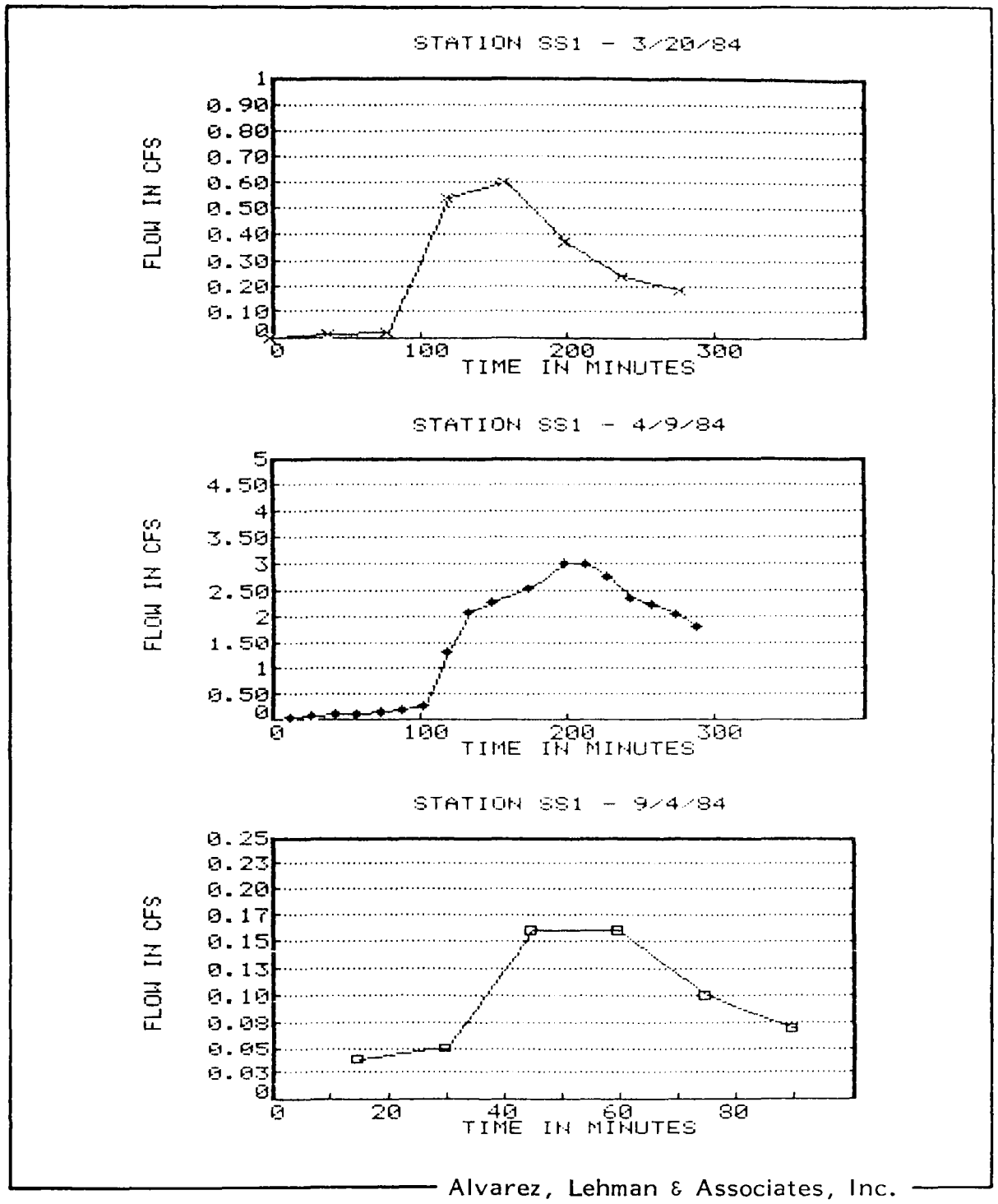


FIGURE 3-4 Storm Hydrographs for Site SS-1 for Three Storms, Naval Submarine Base, Kings Bay, Georgia, March, April and September 1984

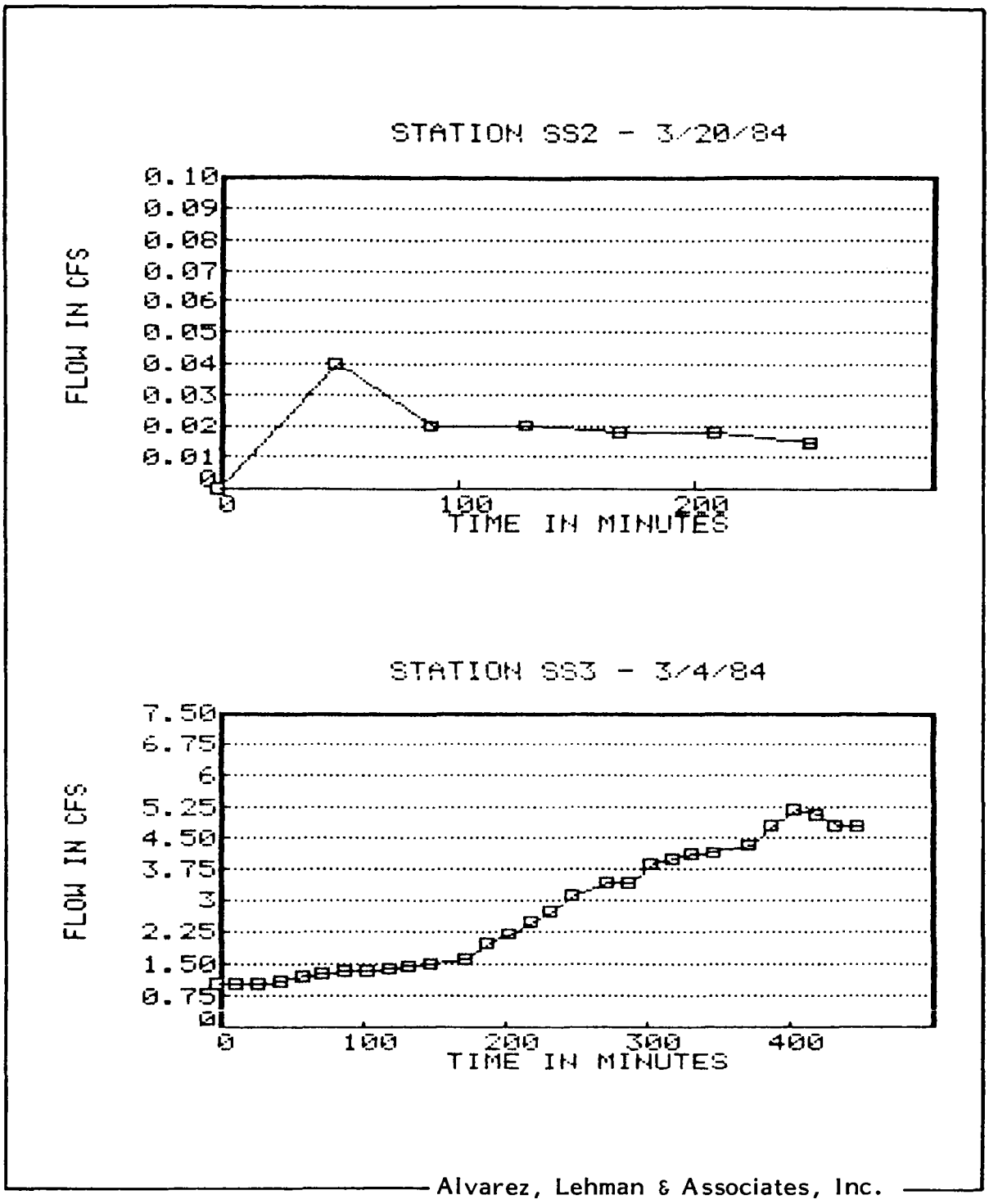


FIGURE 3-5. Storm Hydrographs for Sites SS-2 and SS-3 for Two Storms, Naval Submarine Base, Kings Bay, Georgia, March 1984

of developed basins. The flow volume from site SS-2 was small with a small peak flow which illustrates slow rainfall-runoff response (perhaps due to the buffering effect of the hardwood swamp along U.S.S. James Madison Road). Catchment response to rainfall at the Cherry Point site (SS-3) was the slowest of those observed, which is typical of undeveloped catchments when compared with developed ones. The flow volume was much higher, however, due to the high water table in the Cherry Point area. The peak flows were also greater than the peak flows from site SS-1. These differences may be due to a larger catchment area for site SS-3. Measurements of turbidity for the two large storms for sites SS-1 and SS-3 (Figure 3-6) show that the turbidity at SS-1 is higher than at SS-3. This result is expected based on the base development in the catchment of site SS-1.

Rainfall for the Kings Bay region during March 1984 was 8.26 inches, which exceeded the average level of precipitation in the study area by over 4.5 inches (OICC, TRIDENT, 1984). Above average rainfall may have resulted in more runoff having high levels of particulate and dissolved solids resulting in atypically high conductivities. The higher conductivity at SS-1 during the March storm event may reflect construction site drainage to this swale via Pond Y and the higher than average rainfall runoff in March. Conductivity levels at Site SS-2 were comparable to SS-1 during the March storm (Figure 3-7).

Dissolved oxygen (DO) levels at the undeveloped site (SS-3) remained

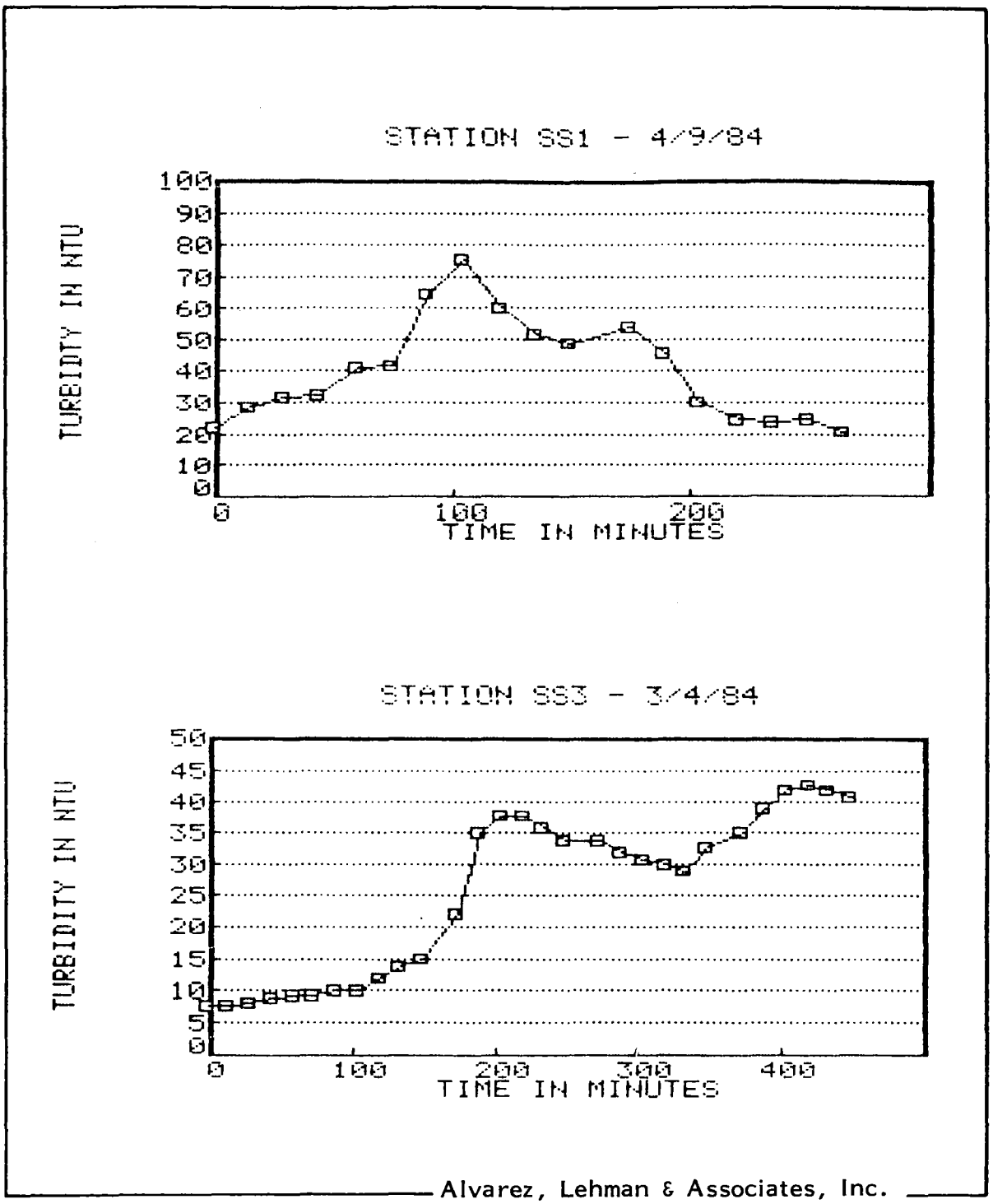


FIGURE 3-6. Storm Pollutographs for Turbidity for Sites SS-1 and SS-3 During 48mm Rainstorms, Naval Submarine Base, Kings Bay, Georgia, March and April 1984

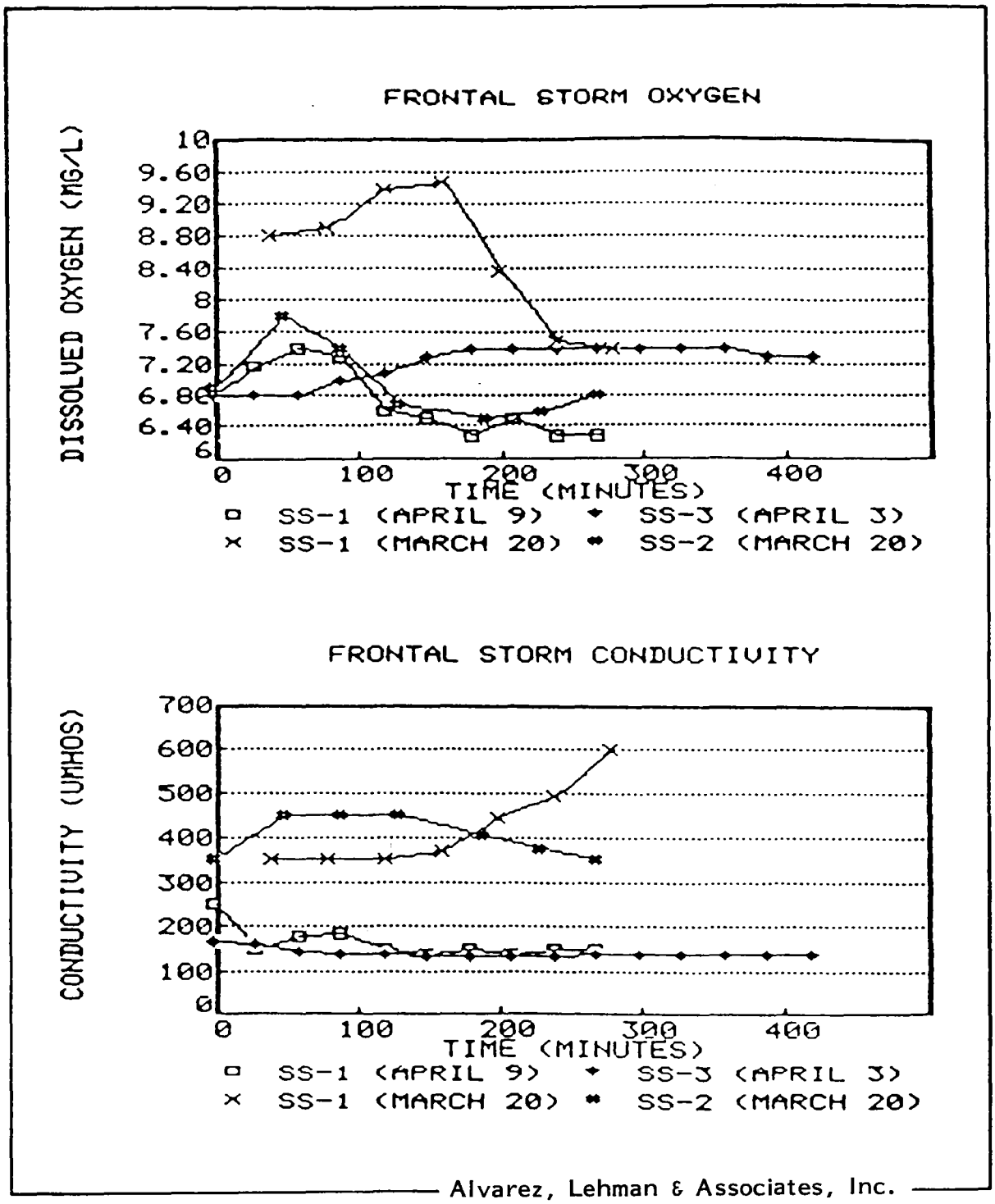


FIGURE 3-7. Dissolved Oxygen and Conductivity During Frontal Storm Event Monitoring, Naval Submarine Base, Kings Bay, Georgia, March and April 1984

relatively constant throughout the storm event monitored with a slight increase that could be equated to increased reaeration due to higher flow velocites during the storm. In contrast, wide fluctuation in DO occurred at the developed sites. All three frontal storm events monitored at Sites SS-1 and SS-2 demonstrated initial increases in DO due to higher flow velocites followed by dramatic drops suggesting the effects of stormwater-related oxygen demanding substances offsetting the reaeration effects of higher flow (Figure 3-7). DO levels remained above the 4.0 mg/l minimum required by the State of Georgia for surface water systems (Georgia Department of Natural Resources, 1980) throughout all storm events monitored.

Thermal convection storms were localized, difficult to predict and consequently, hard to monitor. Thundershowers are frequent in the Kings Bay area during the summer and early fall months. They are typically of short duration and produce variable amounts of rain ranging up to several inches per storm. No storms of this magnitude were successfully monitored.

On September 4, a thunderstorm lasting approximately 30 minutes was monitored at Site SS-1 (U.S.S. James Madison Road). Most of the rainfall occurred within the initial 15 minutes of the storm, and the resulting rise in depth at the sampling site was small and brief in duration. Turbidity and DO showed inverse changes over time with DO declining as turbidity levels rose. The DO standard for Georgia surface waters was not violated and the observed DO decline was less than one milligram per liter.

Thunderstorm monitoring at Site SS-3 at Cherry Point did not detect changes in stream depth or flow. Field observations suggested that a large amount of rainfall is necessary before measurable runoff at Cherry Point occurs. Water table depths are much deeper in October creating a large depression storage in the fall months. Consequently only large rainstorms will produce runoff from this undeveloped site.

3.3 Groundwater Quality

Water quality within the surficial aquifer at SUBASE could potentially be impacted by construction and operation activities but specific impacts on groundwater quality were not predicted in the DEIS. Infiltration from drainage swales and stormwater retention ponds could introduce anthropogenic contaminants into shallow groundwaters. Monitoring was conducted to document unforseen long-term changes that may occur.

Physical characteristics of groundwater wells monitored during 1983-1984 are presented in Table 3-6. Well A was one of the original groundwater observation wells installed during EIS-related studies of the site. All other wells monitored during 1983-1984 were installed after January 1983.

Depth to water (from grade) was considered indicative of water table levels below ground surface and was similar in November 1983 and May 1984

TABLE 3-6. Summary of Groundwater Well Physical Characteristics, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Well	Well Diameter (cm)	Casing Type	Screen Length (m)	Screen Size (cm)	Well Depth (from grade, m)
A	7.62	PVC	0.86	ND	4.36
PS-1	4.90	PVC	1.52	0.025	6.13
PS-1A	4.90	PVC	1.52	0.025	2.71
PW-1	4.90	PVC	1.52	0.025	5.88
PW-2	4.90	PVC	1.52	0.025	ND
IF-1N	4.90	PVC	1.52	0.025	4.85
IF-2	4.90	PVC	1.52	0.025	5.64
PD-1	4.90	PVC	1.52	0.025	4.36

cm = centimeters
m = meters
ND = No Data
PVC = Polyvinyl chloride

Source: Alvarez, Lehman & Associates, Inc., 1985

(Table 3-7). Storms prior to February's survey caused areawide rises in groundwater levels.

Results of groundwater monitoring for 1983-1984 (Tables 3-8 through 3-10) were generally comparable to historical groundwater data obtained from these wells (Jones, Edmunds & Associates, 1984). Monitoring wells showed similar groundwater quality between one another and between sampling periods.

Two new wells were constructed and sampled during the 1983-1984 monitoring year. Well IF-1N was constructed in replacement of Well IF-1 which was destroyed by construction. Well PD-1 was constructed to monitor groundwater quality near DPDO. Figure 3-8 summarizes the conductivity and total dissolved solids levels measured during November or February and May for all wells except Wells PS-1 and PS-1A. Conductivity levels in the new wells (excluding PS-1 and PS-1A) were generally comparable to those in the older wells. Dissolved solids concentrations were more variable; levels for the new wells were similar to those of at least one of the older wells on all occasions.

Well PS-1 is located east of the Personnel Support Area near stormwater retention pond Y. Waters pumped from this well have consistantly been high in conductivity, total dissolved solids, alkalinity, and chlorides. An oily residue has persisted at this well (Jones, Edmunds & Associates, Inc., 1984). To confirm that the residue and high

TABLE 3-7. Summary of Groundwater Levels*, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Well	November 29, 1983	February 23, 1984	May 22,1984
A	1.03	NS	1.18
PS-1	1.18	1.01	1.45
PS-1A	NS(1)	0.82	1.34
PW-1	1.25	NS	1.48
PW-2	1.17	NS	NS
IF-1N	NS(2)	0.64	0.87
IF-2	1.51	NS	1.74
PD-1	NS(3)	0.18	0.98

* depth to water, in meters, from grade
NS = not sampled
(1) Constructed December 1983; confirmation well for PS-1
(2) Constructed December 1983; replacement well for IF-1
(3) Constructed December 1983; new well

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-8. Summary of Groundwater Quality Data, Naval Submarine Base, Kings Bay, Georgia, November 29, 1983

Parameter*	Well							
	A	PS-1	PS-1A	PW-1	PW-2	IF-1	IF-2	PD-1
In Situ								
Depth to water (m)	1.44	1.43	NC	1.45	1.37	WD	1.87	NC
Water Temp. (°C)	22.1	20.8	NC	22.2	20.0	WD	21.0	NC
Conductivity (umhos/cm)	95	998	NC	119	92	WD	120	NC
pH (S.U.)	4.4	6.7	NC	4.6	5.1	WD	5.2	NC
Laboratory								
Total Dissolved Solids	<2	738	NC	18	16	WD	52	NC
Alkalinity	2.3	331	NC	5.1	15	WD	27	NC
Sulfate	5.4	3.9	NC	5.4	6.8	WD	12	NC
Chloride	20	158	NC	25	18	WD	13	NC
Total Kjeldahl Nitrogen	0.13	0.66	NC	0.20	0.06	WD	0.24	NC
Nitrate+Nitrite Nitrogen	<0.02	<0.02	NC	<0.02	0.06	WD	<0.02	NC
Total Phosphorus	0.20	1.5	NC	0.15	0.17	WD	0.45	NC
Total Calcium	4.3	160	NC	1.2	3.9	WD	3.8	NC
Total Cadmium	<0.002	<0.002	NC	<0.002	<0.002	WD	0.002	NC
Total Chromium	<0.005	<0.005	NC	<0.005	<0.005	WD	<0.005	NC
Total Copper	<0.005	<0.005	NC	<0.005	<0.005	WD	<0.005	NC
Total Lead	0.02	0.02	NC	0.03	0.01	WD	0.03	NC
Total Mercury	<0.0002	<0.0002	NC	<0.0002	<0.0002	WD	<0.0002	NC
Total Zinc	0.057	<0.005	NC	0.007	0.017	WD	0.052	NC
Fecal Coliform (MPN/100 ml)	<0.22	<0.22	NC	<0.22	0.51	WD	0.22	NC

* all values reported are milligrams per liter unless otherwise noted
WD = well destroyed by construction
NC = well not constructed
m = meters
°C = degrees centigrade
umhos/cm = micromhos per centimeter
S.U. = standard units
MPN/100 ml = most probable number per 100 milliliters

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-9. Summary of Groundwater Quality Data, Naval Submarine Base, Kings Bay, Georgia, February 23, 1984

Parameter*	Well			
	PS-1	PS-1A	IF-1N	PD-1
In Situ				
Depth to water (m)	1.01	0.82	0.64	0.18
Water Temp. (°C)	18.0	16.5	18.0	16.5
Conductivity (umhos/cm)	900	1,100	55	98
pH (S.U.)	6.8	6.4	4.7	6.3
Laboratory				
Total Dissolved Solids	660	1,154	8.0	95
Alkalinity	327	305	<0.5	12
Sulfate	6.3	179	5.3	9.1
Chloride	144	135	11	17
Total Kjeldahl Nitrogen	1.8	3.7	1.7	3.2
Nitrate+Nitrite Nitrogen	<0.02	<0.02	<0.02	<0.02
Total Phosphorus	1.5	0.73	0.11	0.19
Total Calcium	150	127	1.4	5.4
Total Cadmium	<0.002	<0.002	<0.002	<0.002
Total Chromium	<0.005	0.012	<0.005	<0.005
Total Copper	<0.005	<0.005	<0.005	<0.005
Total Lead	<0.01	<0.01	<0.01	<0.01
Total Mercury	<0.0002	<0.0002	<0.0002	<0.0002
Total Zinc	0.022	0.029	0.031	0.049
Fecal Coliform (MPN/100 ml)	4	4	<3	<3

* all values reported are milligrams per liter unless otherwise noted
m = meters
°C = degrees centigrade
umhos/cm = micromhos per centimeter
S.U. = standard units
MPN/100 ml = most probable number per 100 milliliters

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-10. Summary of Groundwater Quality Data, Naval Submarine Base, Kings Bay, Georgia, May 22, 1984

Parameter*	Well							
	A	PS-1	PS-1A	PW-1	PW-2	IF-1N	IF-2	PD-1
In Situ								
Depth to water (m)	1.18	1.45	1.34	1.48	WD	0.87	1.74	0.98
Water Temp. (°C)	21.5	22.0	22.0	23.0	WD	21.5	22.0	23.5
Conductivity (umhos/cm)	150	1,150	860	150	WD	80	111	110
pH (s.u.)	4.2	6.5	6.2	5.6	WD	4.1	5.7	5.8
Laboratory								
Total Dissolved Solids	76	754	780	94	WD	36	32	90
Alkalinity	0.44	338	201	3.5	WD	1.2	12	8.1
Sulfate	14	4.9	77	13	WD	5.8	12	13
Chloride	21	159	75	44	WD	8.7	15	13
Total Kjeldahl Nitrogen	0.10	0.58	1.9	0.15	WD	0.27	0.19	0.07
Nitrate+Nitrite Nitrogen	0.27	<0.02	0.04	0.02	WD	<0.02	0.02	<0.02
Total Phosphorus	0.03	1.0	0.10	0.09	WD	0.04	0.05	0.06
Total Calcium	3.0	150	82	0.47	WD	0.99	3.7	1.7
Total Cadmium	0.002	0.003	0.004	<0.002	WD	<0.002	0.004	<0.002
Total Chromium	<0.005	<0.005	0.005	<0.005	WD	<0.005	<0.005	<0.005
Total Copper	<0.005	<0.005	<0.005	<0.005	WD	<0.005	<0.005	<0.005
Total Lead	<0.01	0.02	0.02	<0.01	WD	<0.01	<0.01	<0.01
Total Mercury	<0.0002	<0.0002	<0.0002	<0.0002	WD	<0.0002	<0.0002	<0.0002
Total Zinc	0.062	0.022	0.046	0.024	WD	0.039	0.087	0.016
Fecal Coliform (MPN/100 ml)	<0.22	<0.22	<0.22	<0.22	WD	<0.22	<0.22	<0.22

* all values reported are milligrams per liter unless otherwise noted
WD = well destroyed by construction
m = meters
°C = degrees centigrade
umhos/cm = micromhos per centimeter
S.U. = standard units
MPN/100 ml = most probable number per 100 milliliters

Source: Alvarez, Lehman & Associates, Inc., 1985

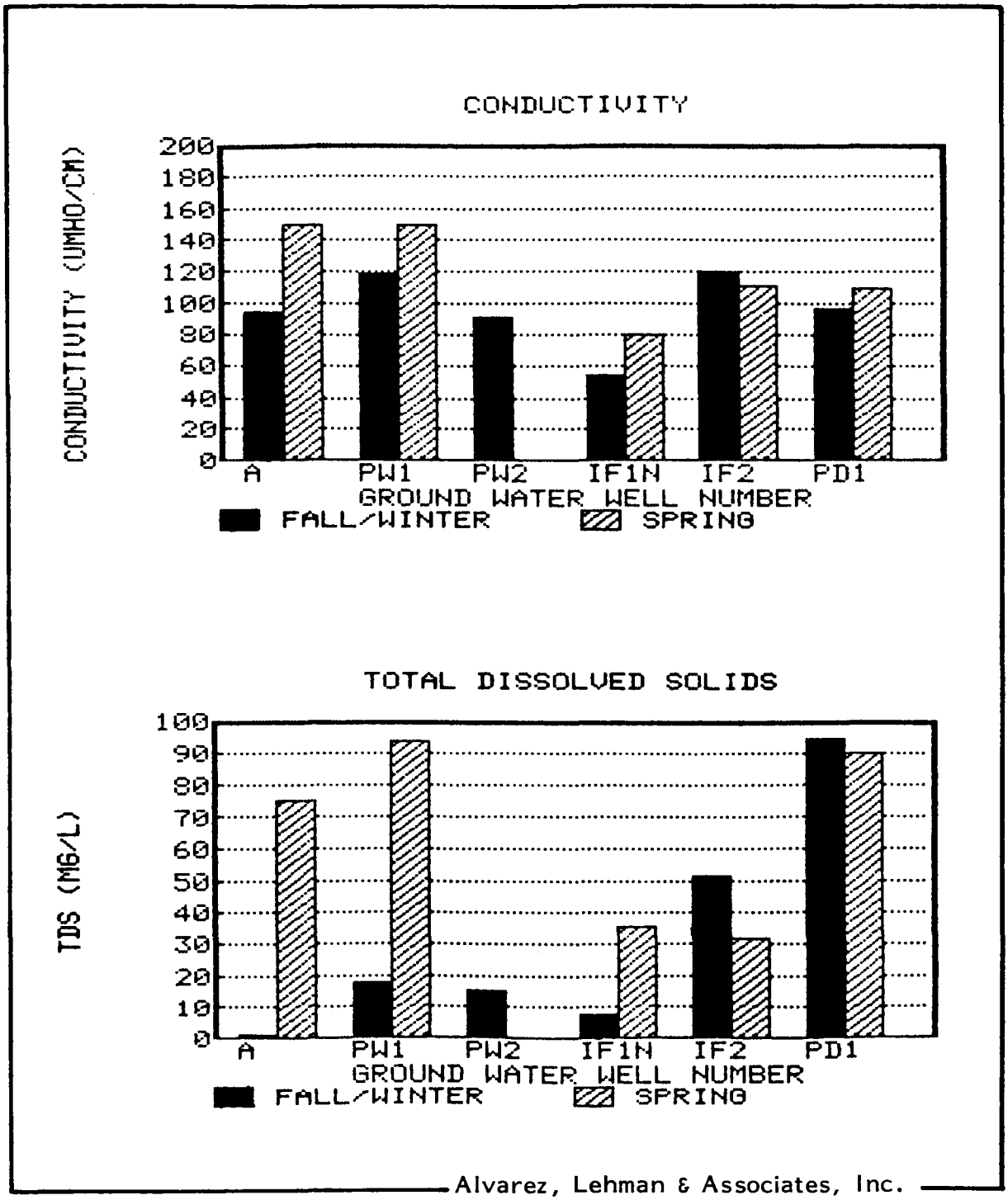


FIGURE 3-8. Conductivity and Total Dissolved Solids in Groundwater, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

concentrations were not a result of contamination during well installation, a new well (Well PS-1A) was constructed approximately 20 meters north of Well PS-1. Comparison of Well PS-1 and PS-1A water quality (Figure 3-9) showed the poor water quality documented at Well PS-1 is also present at Well PS-1A.

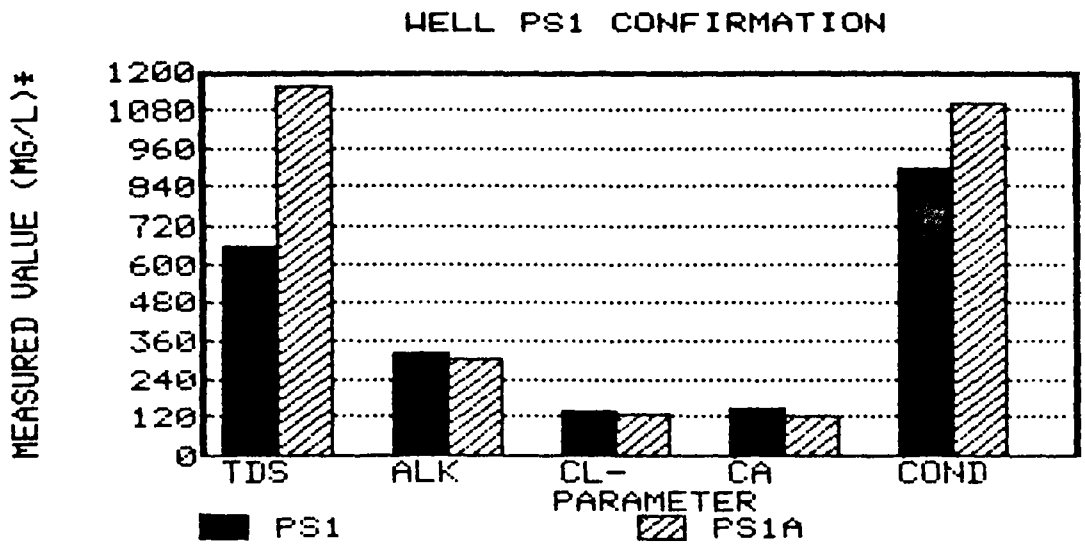
Although oil and grease have not been analyzed for in groundwater samples, it was noted that Well PS-1A also yielded an oily residue upon purging. No known source of oil in this area exists and the origin of this contamination is not known. High conductivities, alkalinity, and chloride concentrations may be associated with nearby wetland seepage.

3.4 Sprayfield Monitoring

Surface water quality, groundwater quality and soils from the SUBASE sprayfield were monitored on a quarterly basis during the 1983-1984 monitoring year.

3.4.1 Surface Water

During SUBASE sprayfield development, a system of drainage ditches was constructed. The drainage ditches lower the groundwater table and increase the aerobic zone available for wastewater percolation. Application rates for wastewater are approximately 0.25 inches per week (Metcalf and Eddy, 1984). These rates were determined low enough to provide adequate nutrient



Alvarez, Lehman & Associates, Inc.

FIGURE 3-9. Comparison of Selected Parameters in Groundwaters from Monitoring Wells PS-1 and PS-1A, Naval Submarine Base, Kings Bay, Georgia, February 1984

removal before wastewater enters the shallow aquifer. Surface waters from the sprayfield ditches were monitored to determine if wastewater contaminants were present in shallow groundwaters collected by the drainage system. Monitoring results are presented in Tables 3-11 through 3-14.

Water samples obtained from the sprayfield ditches during 1983-1984 contained one-tenth of the average applied total phosphorus concentration anticipated based on wastewater treatment plant effluent analysis conducted by Metcalf and Eddy (1984). Less than 10 percent of the applied total Kjeldahl nitrogen and nitrates were found in sprayfield surface waters. Combined nitrate/nitrite concentrations were well below the 10 mg/l level stipulated in the SEIS (Environmental Science and Engineering, 1980).

Sprayfield surface drainage contained considerably lower levels of total Kjeldahl nitrogen and total phosphorus than surface runoff from other areas on base (Figures 3-10 and 3-11). No surface water quality impacts associated with sprayfield operations were found.

3.4.2 Groundwater

Shallow groundwaters were monitored at existing sprayfield observation wells. These wells were installed prior to placing the sprayfield in service and have been monitored for chlorides, nitrate, and conductivity on a monthly basis since 1981 (SUBASE Public Works, Personal Communication, 1985). Collection of samples from existing wells has been difficult since

TABLE 3-11. Summary of Wastewater Land Application Surface Water Quality Data, Naval Submarine Base, Kings Bay, Georgia, November 28-29, 1983

	Station Designation					
Parameter*	G-1	G-2	G-3	G-4	G-5	G-6
In Situ						
Water Temperature (°C)	17.4	17.3	18.3	17.2	17.9	17.4
Conductivity (umhos/cm)	97	178	121	197	187	176
pH (S.U.)	4.9	7.2	5.5	6.3	6.0	6.5
Dissolved Oxygen	5.2	7.3	7.7	8.6	8.8	8.0
Water Depth (m)	0.59	0.16	0.33	0.19	0.20	0.26
Flow Conditions ** (m/sec)	MF	NF	LF	LF	MF	NF
Laboratory						
Total Kjeldahl Nitrogen	0.18	0.09	0.80	0.16	0.06	0.14
Nitrate+Nitrite Nitrogen	0.02	0.03	0.32	0.02	<0.02	0.03
Total Phosphorus	0.42	0.09	0.91	0.22	0.21	0.06
Total Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Total Chromium	0.008	0.008	0.016	0.005	<0.005	0.011
Total Copper	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Total Lead	<0.01	0.02	0.03	<0.01	<0.01	<0.01
Total Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Fecal Coliform (MPN/100 ml)	21	93	2,400	93	>2,400	210
Fecal Strep (MPN/100 ml)	1,100	>2,400	21	43	93	460

* all values are 24-hour averages reported as milligrams per liter unless otherwise noted
** NF = no flow, MF = moderate flow, LF = low flow
m = meters
°C = degrees centigrade
umhos/cm = micromhos per centimeter
S.U. = standard units
MPN/100 ml = most probable number per 100 milliliters

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-12. Summary of Wastewater Land Application Surface Water Quality Data, Naval Submarine Base, Kings Bay, Georgia, February 28, 1984

	Station Designation					
Parameter*	G-1	G-2	G-3	G-4	G-5	G-6
In Situ						
Water Temperature (°C)	9.6	9.6	9.1	9.3	9.5	9.3
Conductivity (umhos/cm)	78	181	99	168	169	114
pH (S.U.)	5.3	6.9	5.3	6.5	6.2	6.1
Dissolved Oxygen	8.6	9.6	9.4	9.2	9.2	9.8
Water Depth (m)	0.45	0.13	0.25	0.14	0.18	0.22
Flow Conditions ** (m/sec)	NF	LF(0.02)	LF(>0.01)	MF(0.21)	MF(0.32)	LF(>0.01)
Laboratory						
Total Kjeldahl Nitrogen	0.42	0.38	1.0	0.26	0.20	0.43
Nitrate+Nitrite Nitrogen	0.32	<0.02	<0.02	<0.02	0.03	0.06
Total Phosphorus	0.36	0.17	0.09	0.10	0.22	0.19
Total Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Total Chromium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Total Copper	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Total Lead	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Total Mercury	<0.0002	0.0003	0.0003	0.0004	0.0004	0.0006
Fecal Coliform (MPN/100 ml)	9	28	<3	23	23	23
Fecal Strep (MPN/100 ml)	43	43	<3	43	21	23

* all values are 24-hour averages reported as milligrams per liter unless otherwise noted
** NF = no flow, MF = moderate flow, LF = low flow
m = meters; m/sec = meters per second
°C = degrees centigrade
umhos/cm = micromhos per centimeter
S.U. = standard units
MPN/100 ml = most probable number per 100 milliliters

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-13. Summary of Wastewater Land Application Surface Water Quality Data, Naval Submarine Base, Kings Bay, Georgia, May 7, 1984

Parameter*	Station Designation					
	G-1	G-2	G-3	G-4	G-5	G-6
In Situ						
Water Temperature (°C)	28.0	27.3	30.3	28.6	28.3	28.6
Conductivity (umhos/cm)	118	220	300	285	260	170
pH (S.U.)	5.4	6.9	7.2	6.9	7.2	7.0
Dissolved Oxygen	8.1	6.8	7.5	7.6	7.7	7.7
Water Depth (m)	0.31	0.21	0.24	0.08	0.20	0.17
Flow Conditions ** (m/sec)	NF	NF	NF	MF(0.27)	LF(0.10)	NF
Laboratory						
Total Kjeldahl Nitrogen	0.35	0.50	0.49	0.15	0.18	0.28
Nitrate+Nitrite Nitrogen	0.04	<0.02	<0.02	<0.02	0.03	<0.02
Total Phosphorus	0.10	0.06	0.03	0.08	0.05	0.07
Total Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Total Chromium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Total Copper	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Total Lead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Mercury	<0.0002	0.0004	0.0005	<0.0002	0.0002	<0.0002
Fecal Coliform (MPN/100 ml)	<3	<3	<3	<3	23	<3
Fecal Strep (MPN/100 ml)	240	43	9	1,100	93	150

* all values are 24-hour averages reported as milligrams per liter unless otherwise noted
** NF = no flow, MF = moderate flow, LF = low flow
m = meters; m/sec = meters per second
°C = degrees centigrade
umhos/cm = micromhos per centimeter
S.U. = standard units
MPN/100 ml = most probable number per 100 milliliters

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-14. Summary of Wastewater Land Application Surface Water Quality Data, Naval Submarine Base, Kings Bay, Georgia, August 7, 1984

Parameter*	Station Designation					
	G-1	G-2	G-3	G-4	G-5	G-6
In Situ						
Water Temperature (°C)	27.7	27.0	29.2	28.3	27.3	27.7
Conductivity (umhos/cm)	187	237	150	340	291	203
pH (S.U.)	6.1	6.4	6.7	6.5	6.1	6.2
Dissolved Oxygen	4.5	3.2	7.1	3.8	6.2	4.3
Water Depth (m)	0.30	0.23	0.06	0.47	0.40	0.42
Flow Conditions ** (m/sec)	NF	NF	LF(0.09)	MF(0.16)	MF(0.18)	NF
Laboratory						
Total Kjeldahl Nitrogen	0.10	0.94	0.09	0.32	0.11	0.54
Nitrate+Nitrite Nitrogen	0.02	0.12	0.13	0.02	<0.02	0.04
Total Phosphorus	0.02	0.04	<0.02	0.02	<0.02	0.06
Total Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Total Chromium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Total Copper	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Total Lead	0.07	0.04	0.02	0.04	0.03	0.03
Total Mercury	<0.0002	0.0010	<0.0002	<0.0002	<0.0002	<0.0002
Fecal Coliform (MPN/100 ml)	<3	28	<3	<3	<3	<3
Fecal Strep (MPN/100 ml)	>2,400	>2,400	>240	2,400	>2,400	>2,400

* all values are 24-hour averages reported as milligrams per liter unless otherwise noted
** NF = no flow, MF = moderate flow, LF = low flow
m = meters; m/sec = meters per second
°C = degrees centigrade
umhos/cm = micromhos per centimeter
S.U. = standard units
MPN/100 ml = most probable number per 100 milliliters

Source: Alvarez, Lehman & Associates, Inc., 1985

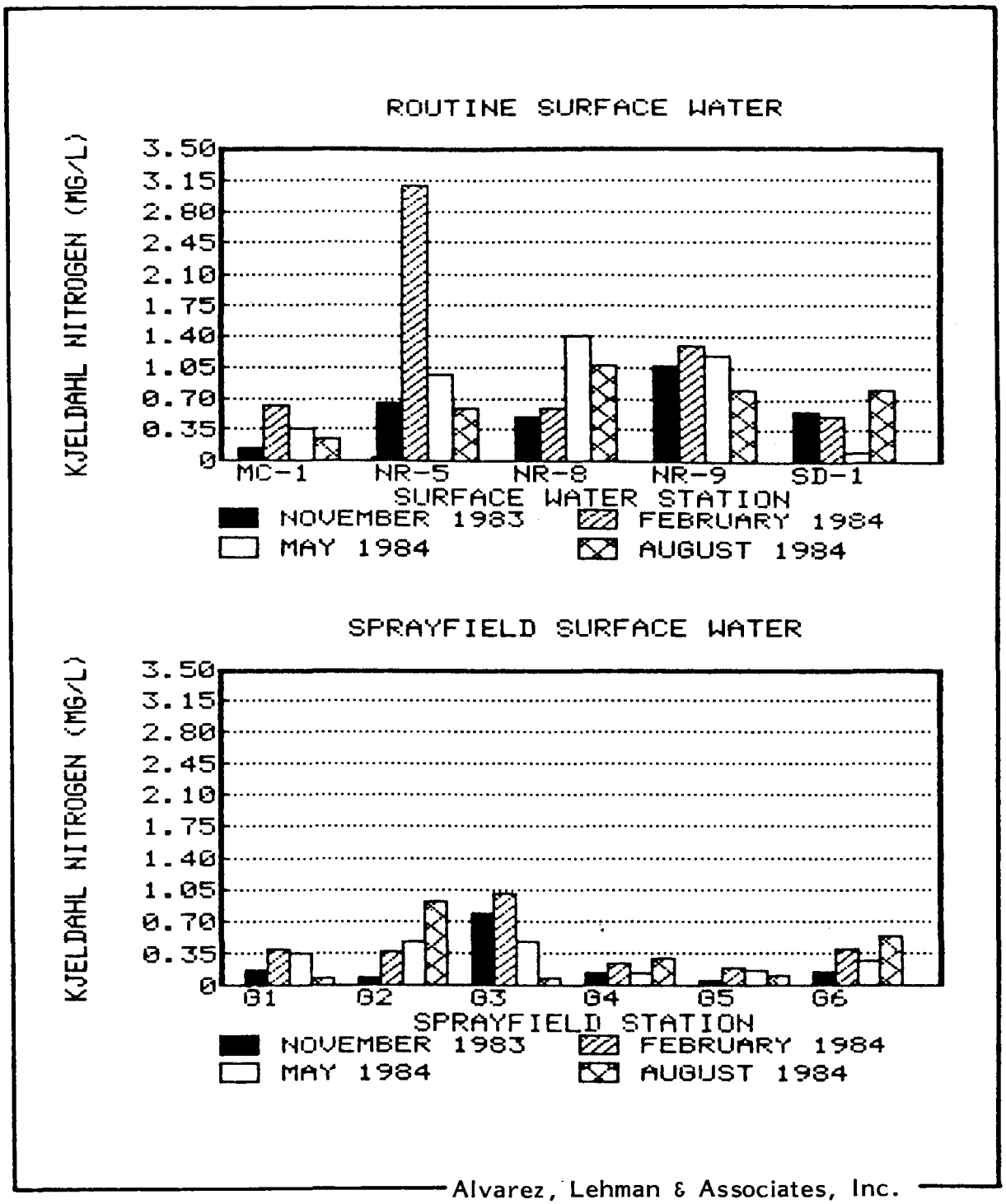


FIGURE 3-10. Total Kjeldahl Nitrogen Concentrations in Sprayfield and Reference Surface Waters, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

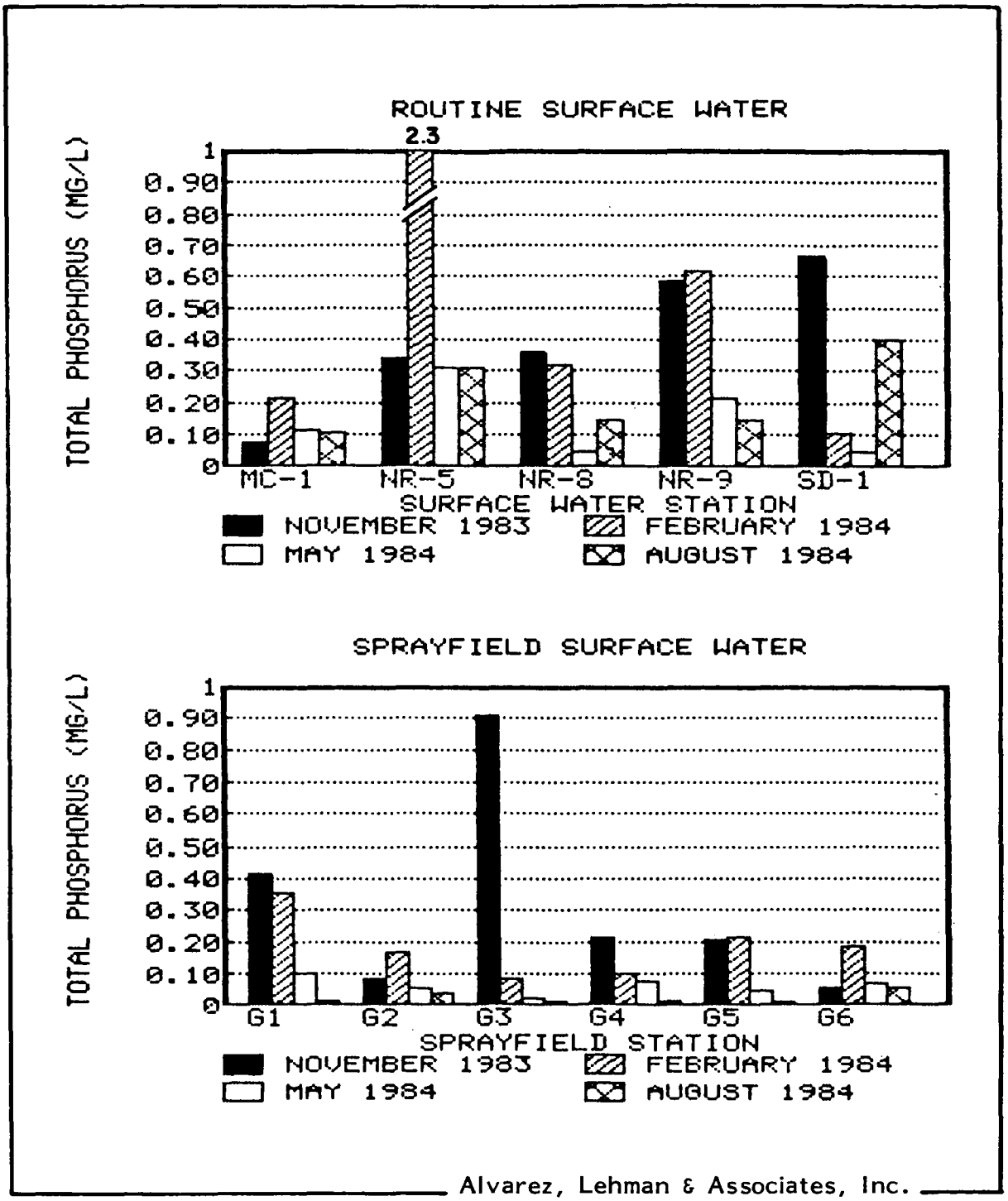


FIGURE 3-11. Total Phosphorus Concentrations in Sprayfield and Reference Surface Waters, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

well installation. The wells have produced very low yields and the contents have been very silty. Attempts by others to sample these wells have yielded less than 10 liters of groundwater and usually require 24 to 48-hours for recharge (SUBASE Public Works, Personnel Communication, 1985; Jones, Edmunds & Assocates, Inc., 1984). Low volume yields suggest that these wells are not deep enough to allow proper sampling of groundwaters in the sprayfield.

An attempt to purge the wells prior to sampling was made in November 1983. The wells did not recharge immediately following pumpdown making sample collection difficult. Subsequent samples collected in May and August without purging were filtered through a coarse, glass-fiber filter to remove silts. Well samples collected without well purging may not be representative of groundwater quality since conditions within a well casing are different from surrounding groundwater conditions.

Results of quarterly surveys of sprayfield wells (Tables 3-15 through 3-18) showed Well W-4 contained the highest levels of trace metals, sulfate, and phosphorus during several quarters. Wells W-3, W-6, and W-7 contained the highest levels of nitrate plus nitrite nitrogen during several quarters. These wells also demonstrated high Kjeldahl nitrogen. Groundwater quality data fluctuated with few consistent patterns evident from quarter to quarter.

Concentrations of lead in Wells W-3 through W-8 were above the Interim

TABLE 3-15. Summary of Wastewater Land Application Groundwater Quality Data, Naval Submarine Base, Kings Bay, Georgia, November 27-29, 1983

Parameter*	Well							
	W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8
In Situ								
Depth to water (m)	1.96	ND	1.58	2.20	2.10	1.75	2.50	1.50
Water Temp. (°C)	21.8	ND	18.8	23.5	22.0	20.5	21.0	21.0
Conductivity (umhos/cm)	270	ND	190	125	159	209	250	228
pH (S.U.)	5.8	ND	5.9	4.6	4.5	5.8	5.7	5.6
Laboratory								
Total Dissolved Solids	96	ND	118	120	116	150	96	102
Alkalinity	4.6	ND	35	6.3	<0.6	46	28	26
Sulfate	9.0	ND	9.1	19	15	9.0	2.5	16
Chloride	58	ND	36	18	33	22	21	38
Total Kjeldahl Nitrogen	0.42	ND	0.41	0.26	1.2	0.46	0.36	0.06
Nitrate+Nitrite Nitrogen	0.03	ND	0.37	0.06	0.15	0.67	0.19	0.29
Total Phosphorus	0.52	ND	0.59	13	2.2	0.16	5.0	0.45
Calcium	13	ND	11	3.0	1.6	22	1.3	5.9
Cadmium	0.004	ND	<0.002	0.004	<0.002	0.007	0.003	0.005
Chromium	0.008	ND	<0.005	0.036	0.027	0.19	0.051	0.081
Copper	0.015	ND	0.12	1.2	0.005	0.26	0.10	0.33
Lead	0.05	ND	0.69	1.9	0.35	4.2	0.17	3.5
Mercury	<0.0002	ND	<0.0002	<0.0002	<0.0002	0.0005	<0.0002	<0.0002
Zinc	6.2	ND	0.17	0.61	0.11	1.6	0.17	0.67
Fecal Coliform (MPN/100 ml)	4	ND	<3	1,100	<3	93	<3	<3
Fecal Strep (MPN/100 ml)	7	ND	43	>2,400	4	240	<3	<3

* all values reported are milligrams per liter unless otherwise noted
ND = no data, well destroyed by construction
m = meters
°C = degrees centigrade
umhos/cm = micromhos per centimeter
S.U. = standard units
MPN/100 ml = most probable number per 100 milliliters

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-16. Summary of Wastewater Land Application Groundwater Quality Data, Naval Submarine Base, Kings Bay, Georgia, February 22, 1984

Parameter*	Well							
	W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8
In Situ								
Depth to water (m)	0.08	ND	1.17	1.61	2.03	1.78	1.68	1.38
Water Temp. (°C)	16.5	16.5	16.5	18.0	18.0	15.0	16.8	17.0
Conductivity (umhos/cm)	105	185	120	90	122	80	112	98
pH (S.U)	4.7	4.6	5.4	5.6	5.6	5.7	6.0	5.2
Laboratory								
Total Dissolved Solids	92	122	88	86	104	116	54	86
Alkalinity	<0.5	<0.5	14	13	7.6	14	23	6.5
Sulfate	31	14	11	77	38	13	8.0	13
Chloride	28	63	37	20	32	18	20	29
Total Kjeldahl Nitrogen	0.58	0.28	0.07	4.0	2.5	1.9	0.19	2.9
Nitrate+Nitrite Nitrogen	<0.02	0.03	0.02	0.02	<0.02	<0.02	0.06	0.02
Total Phosphorus	2.2	0.04	0.12	5.0	1.7	1.0	0.21	0.65
Calcium	3.2	3.3	3.9	4.6	3.5	3.6	5.0	2.9
Cadmium	0.003	0.002	<0.002	0.002	<0.002	<0.002	<0.002	<0.002
Chromium	0.013	<0.005	<0.005	0.033	0.025	0.010	0.007	0.013
Copper	<0.005	0.010	0.028	1.3	0.013	0.011	0.059	0.025
Lead	<0.01	<0.10	0.05	1.7	0.46	0.11	0.01	0.15
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0002
Zinc	0.056	1.4	0.11	0.56	0.082	0.059	0.067	0.13
Fecal Coliform (MPN/100 ml)	<3	0.22	0.92	<3	<3	<3	0.22	0.22
Fecal Strep (MPN/100 ml)	28	0.22	<0.22	<3	7	<3	0.51	0.51

* all values reported are milligrams per liter unless otherwise noted
m = meters
°C = degrees centigrade
umhos/cm = micromhos per centimeter
S.U. = standard units
MPN/100 ml = most probable number per 100 milliliters

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-17. Summary of Wastewater Land Application Groundwater Quality Data, Naval Submarine Base, Kings Bay, Georgia, May 15-16, 1984

Parameter*	Well							
	W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8
In Situ								
Depth to water (m)	1.53	0.66	1.40	1.87	2.12	2.11	1.98	1.45
Water Temp. (°C)	23.0	21.0	19.5	26.0	22.0	23.0	22.0	21.0
Conductivity (umhos/cm)	260	115	250	190	145	115	105	135
pH (S.U.)	5.3	4.4	3.7	5.4	5.3	5.8	6.3	5.5
Laboratory								
Total Dissolved Solids	126	86	122	102	128	132	106	76
Alkalinity	3.1	1.3	10	9.6	4.4	7.6	11	8.7
Sulfate	11	8.3	10	7.7	12	17	10	10
Chloride	80	19	26	17	29	13	16	29
Total Kjeldahl Nitrogen	0.13	0.22	0.23	2.7	0.05	0.24	0.13	0.24
Nitrate+Nitrite Nitrogen	0.06	<0.02	0.12	0.08	0.09	0.06	0.11	0.02
Total Phosphorus	0.11	0.05	0.06	0.78	0.03	0.11	0.04	0.03
Calcium	2.0	0.95	3.7	2.9	4.0	5.7	5.3	3.1
Cadmium	0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Chromium	<0.005	<0.005	<0.005	0.012	<0.005	<0.005	<0.005	<0.005
Copper	0.006	<0.005	0.017	0.14	<0.005	0.006	0.009	<0.005
Lead	0.01	<0.01	0.03	0.23	<0.01	0.04	<0.01	<0.01
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Zinc	1.2	0.11	0.10	0.20	0.20	0.13	0.05	0.10
Fecal Coliform (MPN/100 ml)	<3	<3	<3	<3	<3	<3	<3	<3
Fecal Strep (MPN/100 ml)	<3	<3	<3	<3	<3	<3	<3	<3

* all values reported are milligrams per unless otherwise noted
m = meters
°C = degrees centigrade
umhos/cm = micromhos per centimeter
S.U. = standard units
MPN/100 ml = most probable number per 100 milliliters

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-18. Summary of Wastewater Land Application Groundwater Quality Data, Naval Submarine Base, Kings Bay, Georgia, August 8-9, 1984

Parameter*	Well							
	W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8
In Situ								
Depth to water (m)	1.52	0.50	1.20	1.70	1.63	1.87	1.95	1.33
Water Temp. (°C)	25.0	27.0	25.0	28.0	27.0	24.5	25.0	23.0
Conductivity (umhos/cm)	210	550	200	120	150	150	170	160
pH (S.U.)	6.0	5.2	6.1	6.0	5.8	6.1	6.3	6.1
Laboratory								
Total Dissolved Solids	174	100	160	100	120	180	110	100
Alkalinity	6.1	3.3	7.1	15	9.4	2.4	17	6.6
Sulfate	19	11	4.9	2.5	4.9	14	4.9	6.0
Chloride	42	32	34	7.3	22	14	20	24
Total Kjeldahl Nitrogen	0.04	<0.04	0.04	1.7	0.42	14	1.0	<0.04
Nitrate+Nitrite Nitrogen	<0.02	0.14	<0.02	0.04	0.05	0.30	0.23	0.07
Total Phosphorus	0.03	<0.02	<0.02	0.13	<0.02	0.57	0.02	<0.02
Calcium	1.3	1.1	2.9	3.9	3.4	5.5	5.0	2.8
Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002	<0.002
Chromium	<0.005	<0.005	0.007	<0.005	<0.005	<0.005	<0.005	<0.005
Copper	<0.005	<0.005	0.009	0.038	0.005	0.007	0.018	<0.005
Lead	<0.01	<0.01	<0.01	0.06	<0.01	0.03	<0.01	<0.01
Mercury	0.0002	0.0014	<0.0002	<0.0002	<0.0002	<0.0002	0.0015	0.0015
Zinc	0.10	0.05	0.06	0.08	0.032	0.09	0.08	0.05
Fecal Coliform (MPN/100 ml)	11	<3	7	<3	<3	11	<3	43
Fecal Strep (MPN/100 ml)	7	<3	<3	4	<3	21	<3	7

* all values reported are milligrams per liter unless otherwise noted
m = meters
°C = degrees centigrade
umhos/cm = micromhos per centimeter
S.U. = standard units
MPN/100 ml = most probable number per 100 milliliters

Source: Alvarez, Lehman & Associates, Inc., 1985

Federal Drinking water standard (U.S. Environmental Protection Agency, 1975) of 0.05 milligrams per liter in November, and most were also above the standard in February. However, samples from all wells except W-4 were below the lead standard in May and August. The apparent reduction of lead levels may have been due to sample filtration procedures used in May and August. Filtration removes silts which absorb metals. Silts in water samples will bias analytical results.

Copper and zinc were also present at high concentrations in several wells during 1983-1984 monitoring. Concentrations exceeded Florida's secondary drinking water standards (Florida Department of Environmental Regulation, 1984) of five mg/l for zinc and one mg/l for copper during at least one quarter of the monitoring year. The shallow-water aquifer is not suitable for use as a potable water supply; these water quality standard violations are provided only as a relative measure of environmental conditions of groundwaters below the SUBASE sprayfield since the State of Georgia does not have standards for these metals.

Groundwater quality within the sprayfield was compared with groundwater quality elsewhere on SUBASE for 1983-1984. Total dissolved solids (TDS) at sprayfield wells generally exceeded levels documented in observation wells located primarily in the western portion of SUBASE (Figure 3-12). Total phosphorus and Kjeldahl nitrogen levels in sprayfield wells frequently exceeded background levels in other SUBASE monitoring wells (Figures 3-13 and 3-14). Similar although less consistent

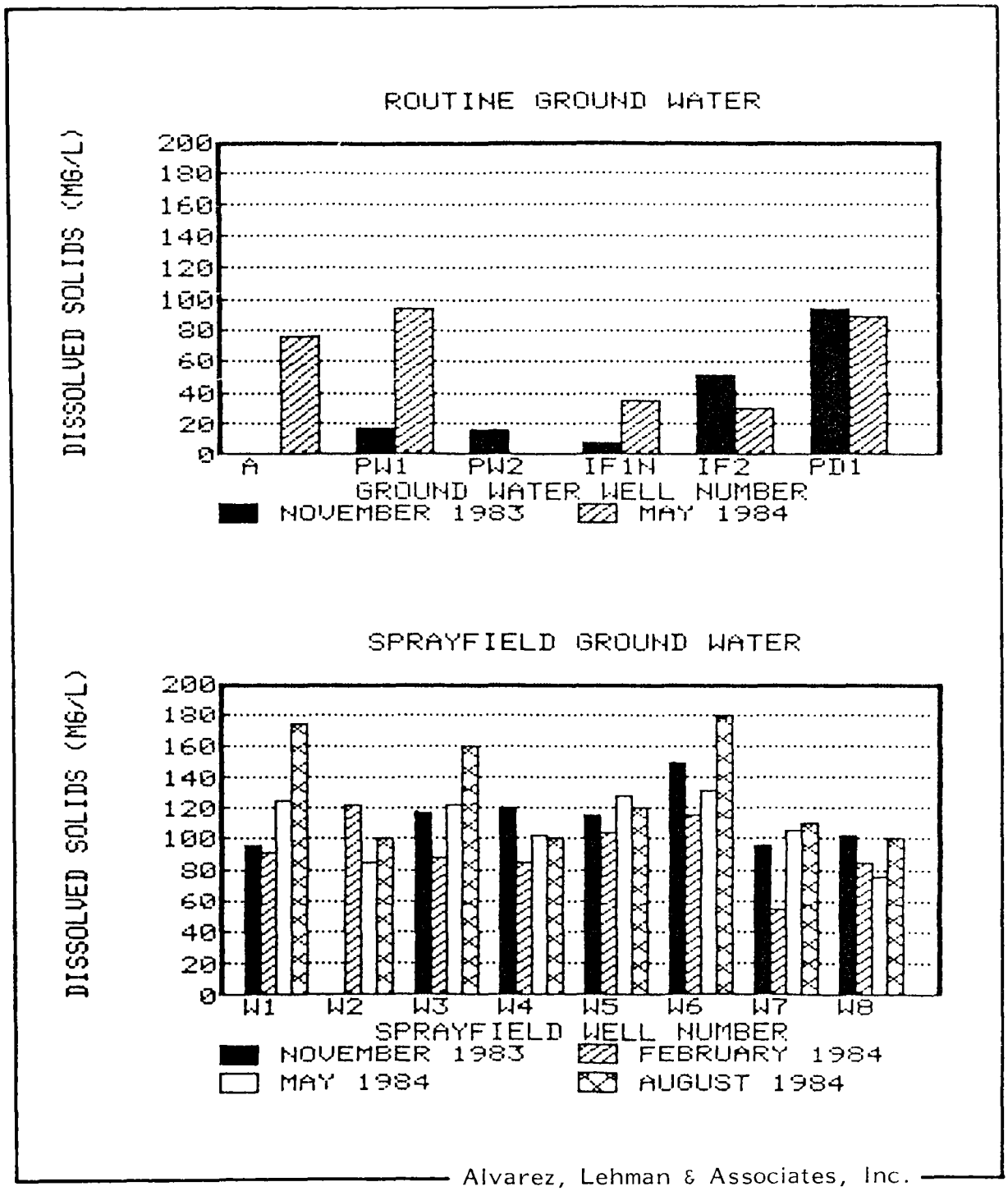


FIGURE 3-12. Total Dissolved Solids Concentrations in Sprayfield and Reference Ground Waters, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

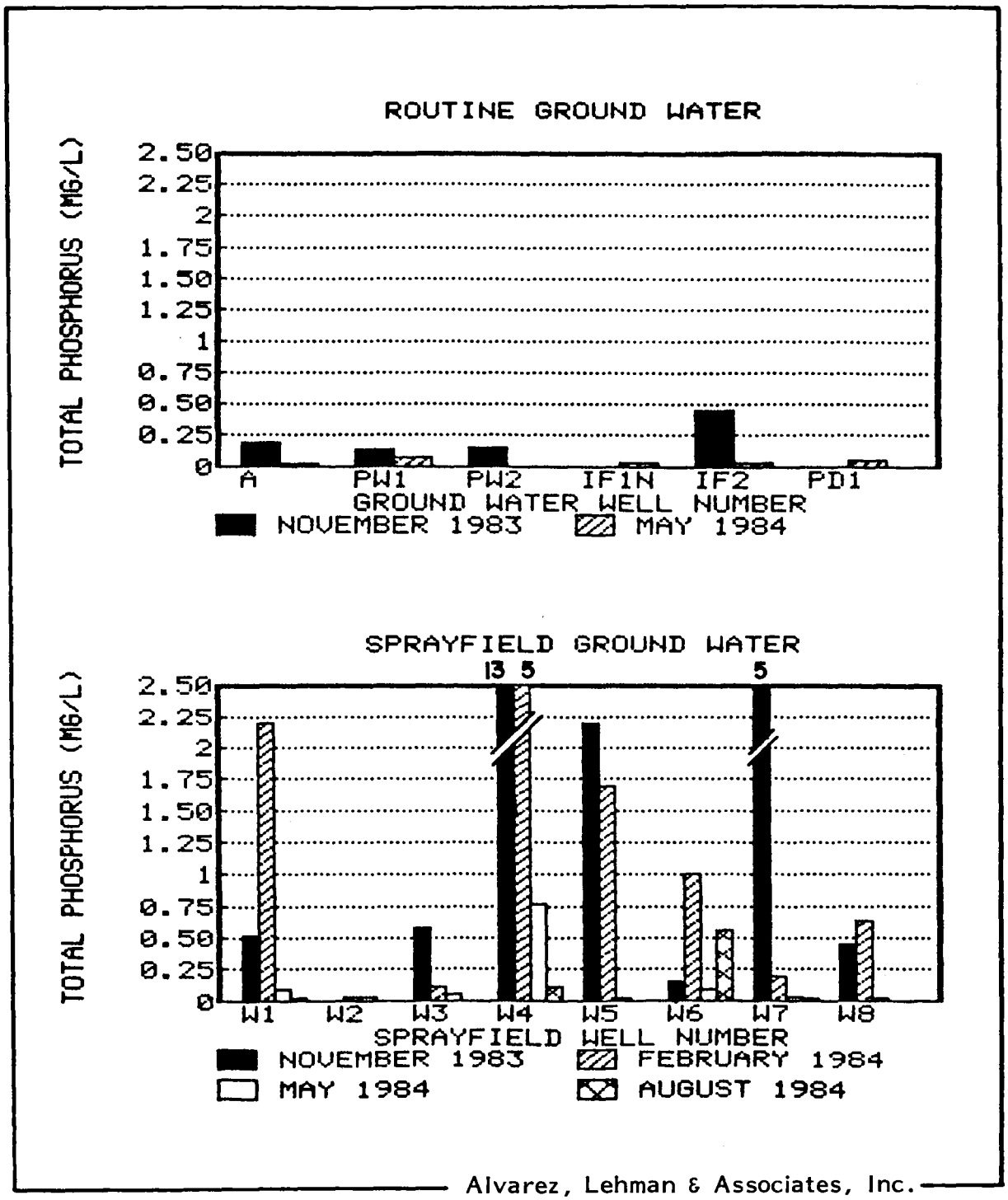


FIGURE 3-13. Total Phosphorus Concentrations in Sprayfield and Reference Ground Waters, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

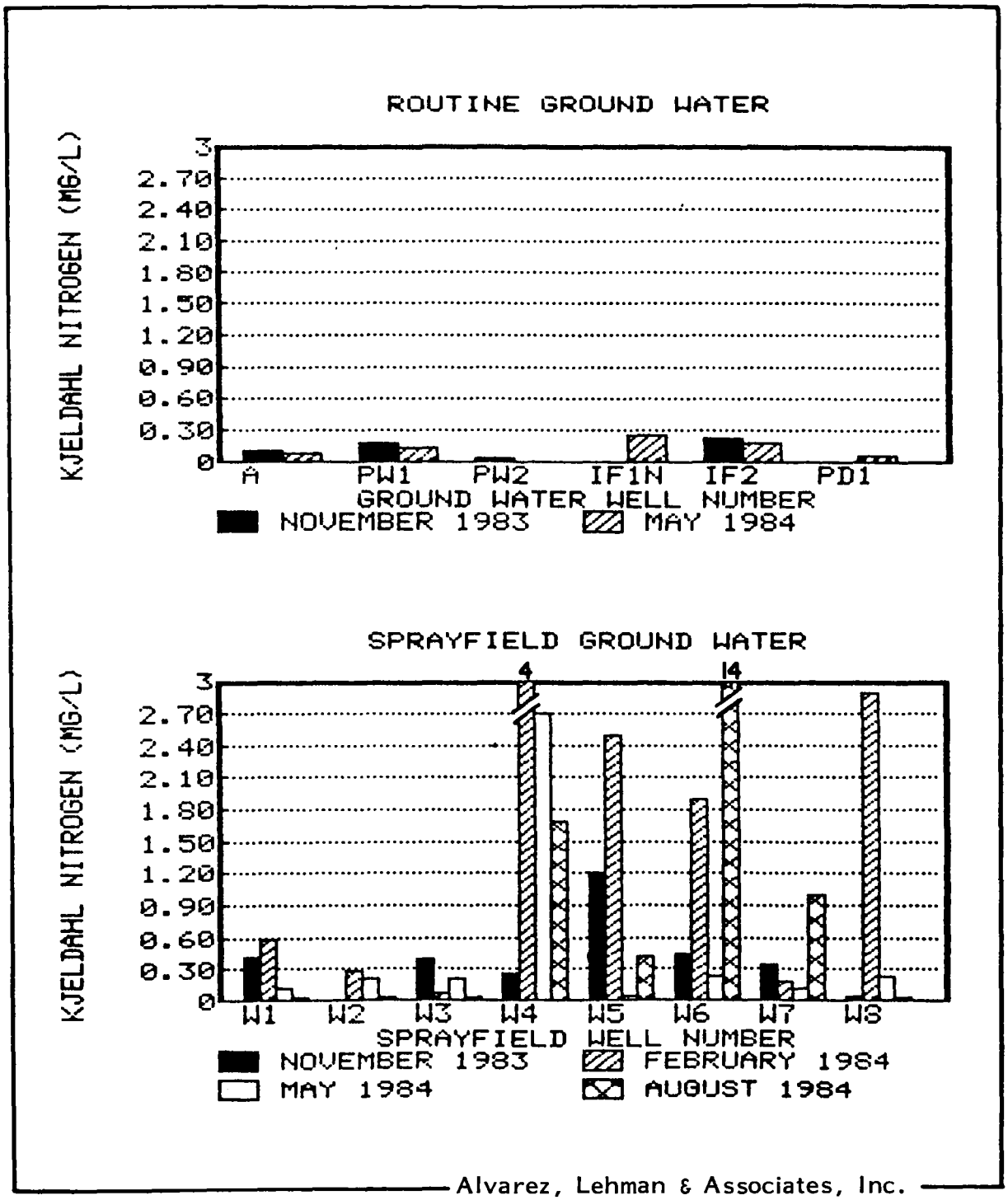


FIGURE 3-14. Total Kjeldahl Nitrogen Concentrations in Sprayfield and Reference Ground Waters, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

differences were evident for selected metals. These observations suggest that operation of the sprayfield has resulted in some effluent-related pollutant buildup in sprayfield groundwater. Direction of groundwater flow and pollutant transport can not be determined from the data presently available.

3.4.3 Soils

A review of soils types in the wastewater sprayfield was performed by Metcalf and Eddy (1984). Most soils were classified as Mandarin fine sand with small patches of Rutledge fine sand. Both series are characterized by very deep, poorly-drained fine sands. Mandarin soils generally have a weakly cemented, highly organic, hardpan at a depth of approximately 0.5 meters, with very little organic material in the sand above the hardpan. Rutledge soils have a high organic material content but no discernible hardpan layer. Both soils are classified as highly acidic in the surface layers. Water tables in undisturbed Mandarin soils generally are found between 0.5 to 1.0 meters below grade during the summer and fall wet periods.

Soil samples were obtained from randomly chosen wastewater land application zones during each quarter of the 1983-1984 monitoring year. The first quarter sample was obtained from Zone 7. Zone 5 was sampled during the second quarter. The third quarter sample was from Zone 3 and the fourth quarter sample was from application Zone 7.

Soils data (Tables 3-19 and 3-20) generally agree with US Soil Conservation Service (USSCS) descriptions for the area. Soil pH ranged from 4.1 to 4.5. Nutrients, total Kjeldahl nitrogen and total phosphorus were found to be one to two orders of magnitude greater than those measured in the groundwater below the sprayfield. These high nutrient levels probably reflect the large amount of organic material present in the first few centimeters of the soil (first horizon) which made up one-third of the composite sample. The relatively high cation exchange capacity is also likely due to the amount of organic material present in the samples.

3.5 Estuarine Water Quality

Environmental impacts on estuarine systems adjacent to SUBASE were anticipated in the SEIS due to stormwater discharges, dredging-related activities, submarine refit operations, waterfront wastewater treatment plant effluent discharge and submarine and support vessel operations. Primary concern for estuarine water quality impact centers around dredge-related activities, sediment resuspension during submarine and support vessel operations, and long-term chronic accumulation of metals or other contaminants from SUBASE operations.

Quarterly estuarine water quality surveys performed in 1983-1984 continued long-term monitoring efforts intended to detect chronic contaminant release associated with SUBASE operations. Short-term water

TABLE 3-19. Wastewater Land Application Zone Soils Description, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Land Application Zone	Depth (cm)	Soils Description
7	0-12	Sand, grey/white with organic debris
	12-18	Sand, grey/white very little organics
	18-61	Sand, fine, brown/tan reddish tint
5	0-20	Sand, grey/black, highly organic, moist
	20-44	Sand, grey, very little organics, moist
	44-?	Clay/sand, black, very moist
3	0-21	Sand, black to grey white, highly organic
	21-55	Sand, grey/white, very little organics, moist
	55-?	Sand, fine, black, very moist
7	0-29	Sand, black to grey white, organic, moist
	29-82	Sand, fine, grey, very little organics, moist
	82-?	Sand, fine, grey/black, very moist

All samples were obtained by shovel
cm = centimeters

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-20. Summary of Wastewater Land Application Zone Soil Sample Data, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

	Land Application Zone Soil Sample Designation			
Parameter*	Zone 7 11/28/84	Zone 5 3/1/84	Zone 3 5/31/84	Zone 7 8/16/84
pH (S.U.)	4.5	4.5	4.4	4.1
Cation Exchange Capacity, (mg/100g)	56	105	47	33.5
Magnesium	22	34	28	2.6
Calcium	54	129	93	25.0
Total Kjeldahl Nitrogen	232	550	500	167
Total Phosphorus	29	200	50	2.0
Potassium	16	12	30	33

* all values reported are milligrams per kilogram unless otherwise noted
S.U. = standard units
g = grams
mg = milligrams

Source: Alvarez, Lehman & Associates, Inc., 1985

quality impacts associated with construction and maintenance dredging and dredged material disposal area dewatering were measured as a separate component of this monitoring program and results were reported separately (Alvarez, Lehman & Associates, Inc., 1985f).

Water column profiles performed in the study area confirmed the continued lack of significant water column stratification at any of the six sites monitored. This estuarine system is well mixed despite recent channel and turning basin deepening and widening. Poor circulation, reduced flushing, and increased stratification due to creation of a deep harbor in Kings Bay may yet occur. However, such development effects have not been demonstrated.

Results of quarterly estuarine water quality analyses are presented in Tables 3-21 through 3-24. Mean water column dissolved oxygen in Kings Bay and Cumberland Sound was found to be above the required 4 mg/l standard (Georgia Department of Natural Resources, 1980) during all sampling periods at all stations. Highest oxygen values (water column means) were recorded in February when temperatures were low (Figure 3-15). Oxygen concentrations were lowest in August.

Turbidity and total suspended solids levels were very high at Station W-1 in November 1983 (Table 3-21, Figure 3-16). These high solids levels were probably a result of dredge activity in the Kings Bay area near the small boat facility construction site. Secchi depth records on this date

TABLE 3-21. Summary of Estuarine Water Quality Data, Naval Submarine Base, Kings Bay, Georgia, November 27, 1983

Parameter*	Station Designation					
	TD	W1	TE	DD2	CR1	TF
In Situ						
Water Temperature (°C)†	18.0	17.8	17.9	18.5	18.0	18.8
Conductivity (umhos/cm)†	35,050	34,100	34,800	36,190	33,000	35,600
Salinity (ppt)†	25.8	25.0	25.4	25.9	24.2	25.8
Dissolved Oxygen†	7.7	7.3	7.5	7.2	7.8	7.2
pH (S.U.)	7.9	7.85	7.95	8.0	7.9	8.0
Total Depth (m)	6.6	14.8	16.4	14.8	5.9	14.8
Secchi Depth (m)	1.3	1.5	1.7	1.5	1.3	1.3
Laboratory						
Turbidity (NTU)	6.6	90	4.1	12	6.9	9.1
Total Suspended Solids	27	304	25	46	30	36
Ammonia Nitrogen	0.12	0.05	<0.04	<0.04	<0.04	<0.04
Total Kjeldahl Nitrogen	0.12	0.05	0.10	0.21	0.10	<0.04
Total Phosphorus	0.09	0.10	0.05	0.10	0.07	0.08
Total Organic Carbon	19	20	11	22	15	11
Oil and Grease**	0.35	0.40	0.02	0.28	0.16	0.26
Total Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Total Chromium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Total Copper	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Total Lead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Fecal Coliform (MPN/100 ml)	1.6	>1.6	<0.22	0.92	0.51	<0.22

* all values reported in milligrams per liter unless otherwise noted
† water column average
** oil and grease and pH samples taken at surface; all others from one meter above bottom unless otherwise noted
°C = degrees Centigrade
m = meters
umhos/cm = micromhos per centimeter
ppt = parts per thousand
S.U. = standard units
NTU = nephelometric turbidity units
MPN/100 ml = most probable number per 100 milliliters

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-22. Summary of Estuarine Water Quality Data, Naval Submarine Base, Kings Bay, Georgia, February 29, 1984

Parameter*	Station Designation					
	TD	W1	TE	DD2	CR1	TF
In Situ						
Water Temperature (°C)†	11.9	13.2	13.3	13.1	11.6	12.8
Conductivity (umhos/cm)†	26,000	27,640	28,093	27,526	24,900	26,590
Salinity (ppt)†	21.5	22.5	22.7	22.4	20.4	22.3
Dissolved Oxygen†	8.6	8.9	8.8	8.0	4.8	8.2
pH (S.U.)	7.7	7.8	7.9	7.8	7.8	7.9
Total Depth (m)	4.3	11.5	13.1	14.1	4.4	8.8
Secchi Depth (m)	0.85	1.1	1.2	0.8	0.9	0.8
Laboratory						
Turbidity (NTU)	12	7.1	8.3	25	20	11
Total Suspended Solids	32	22	28	70	71	39
Ammonia Nitrogen	0.12	0.08	0.09	0.06	0.08	0.06
Total Kjeldahl Nitrogen	0.40	0.55	1.1	0.60	0.35	1.0
Total Phosphorus	0.18	0.11	0.15	0.80	0.15	0.14
Total Organic Carbon	16	17	16	16	18	14
Oil and Grease**	0.45	0.35	0.52	0.73	0.43	0.44
Total Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Total Chromium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Total Copper	<0.005	<0.005	0.079	<0.005	<0.005	<0.005
Total Lead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Fecal Coliform (MPN/100 ml)	<0.22	<0.22	<0.22	<1.6	<0.22	<0.22

* all values reported in milligrams per liter unless otherwise noted
† water column average
** oil and grease and pH samples taken at surface; all others from one meter above bottom unless otherwise noted
°C = degrees Centigrade
m = meters
umhos/cm = micromhos per centimeter
ppt = parts per thousand
S.U.= standard units
NTU = nephelometric turbidity units
MPN/100 ml = most probable number per 100 milliliters

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-23. Summary of Estuarine Water Quality Data, Naval Submarine Base, Kings Bay, Georgia, May 5, 1984

Parameter*	Station Designation					
	TD	W1	TE	DD2	CR1	TF
In Situ						
Water Temperature (°C)†	24.4	24.2	23.8	24.1	25.0	24.7
Conductivity (umhos/cm)†	41,312	40,682	41,442	41,300	38,900	41,277
Salinity (ppt)†	26.6	26.2	27.2	27.1	25.0	ND
Dissolved Oxygen†	5.3	5.3	5.4	5.8	5.4	5.5
pH (S.U.)	7.6	7.6	7.6	7.6	7.8	7.7
Total Depth (m)	15.7	11.2	13.1	14.8	3.9	8.5
Secchi Depth (m)	0.9	1.2	1.2	1.2	0.9	0.8
Laboratory						
Turbidity (NTU)	8.6	9.2	8.0	8.5	12	14
Total Suspended Solids	21	39	34	32	37	47
Ammonia Nitrogen	0.09	0.08	0.07	0.08	0.04	0.06
Total Kjeldahl Nitrogen	0.20	0.34	0.42	0.33	0.29	0.39
Total Phosphorus	0.08	0.08	0.08	0.08	0.09	0.13
Total Organic Carbon	8.5	9.5	7.0	7.0	10	14
Oil and Grease**	0.38	0.71	0.13	0.32	0.73	0.43
Total Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Total Chromium	<0.005	<0.005	0.011	<0.005	<0.005	<0.005
Total Copper	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Total Lead	0.05	<0.01	0.02	0.04	<0.01	0.02
Total Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Fecal Coliform (MPN/100 ml)	0.92	>1.6	0.22	0.51	>1.6	0.92

* all values reported in milligrams per liter unless otherwise noted
† water column average
** oil and grease and pH samples taken at surface; all others from one meter above bottom unless otherwise noted
°C = degrees Centigrade
m = meters
umhos/cm = micromhos per centimeter
ppt = parts per thousand
S.U. = standard units
NTU = nephelometric turbidity units
MPN/100 ml = most probable number per 100 milliliters
ND = no data

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-24. Summary of Estuarine Water Quality Data, Naval Submarine Base, Kings Bay, Georgia, August 1, 1984

Parameter*	Station Designation					
	TD	W1	TE	DD2	CR1	TF
In Situ						
Water Temperature (°C)†	29.6	28.2	23.2	27.8	29.5	27.6
Conductivity (umhos/cm)†	45,389	44,036	41,750	47,688	46,917	49,111
Salinity (ppt)†	28.1	27.7	26.1	30.1	28.9	31.3
Dissolved Oxygen†	5.2	4.7	4.4	4.6	6.2	5.4
pH (S.U.)	7.9	7.8	7.8	7.8	7.5	8.3
Total Depth (m)	8.5	13.1	12.5	15.1	5.2	9.2
Secchi Depth (m)	0.67	1.6	1.6	1.6	1.3	1.6
Laboratory						
Turbidity (NTU)	5.5	17	10	8.0	13	7.8
Total Suspended Solids	25	58	39	40	45	39
Ammonia Nitrogen	0.07	0.10	0.08	0.08	0.14	<0.04
Total Kjeldahl Nitrogen	0.59	0.54	0.45	0.38	0.43	0.17
Total Phosphorus	0.09	0.10	0.15	0.08	0.11	0.08
Total Organic Carbon	12	12	8.8	9.4	13	7.2
Oil and Grease**	<0.10	0.97	0.46	<0.10	0.21	0.76
Total Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Total Chromium	<0.005	<0.005	<0.005	<0.005	0.006	<0.005
Total Copper	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Total Lead	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
Total Mercury	0.0005	0.0005	<0.0002	0.0007	<0.0002	0.0004
Fecal Coliform (MPN/100 ml)	0.51	>1.6	0.51	1.6	0.92	0.51

* all values reported in milligrams per liter unless otherwise noted
† water column average
** oil and grease samples taken at surface; pH all others from one meter above bottom unless otherwise noted
°C = degrees Centigrade
m = meters
umhos/cm = micromhos per centimeter
ppt = parts per thousand
S.U = standard units
NTU = nephelometric turbidity units
MPN/100 ml = most probable number per 100 milliliters

Source: Alvarez, Lehman & Associates, Inc., 1985

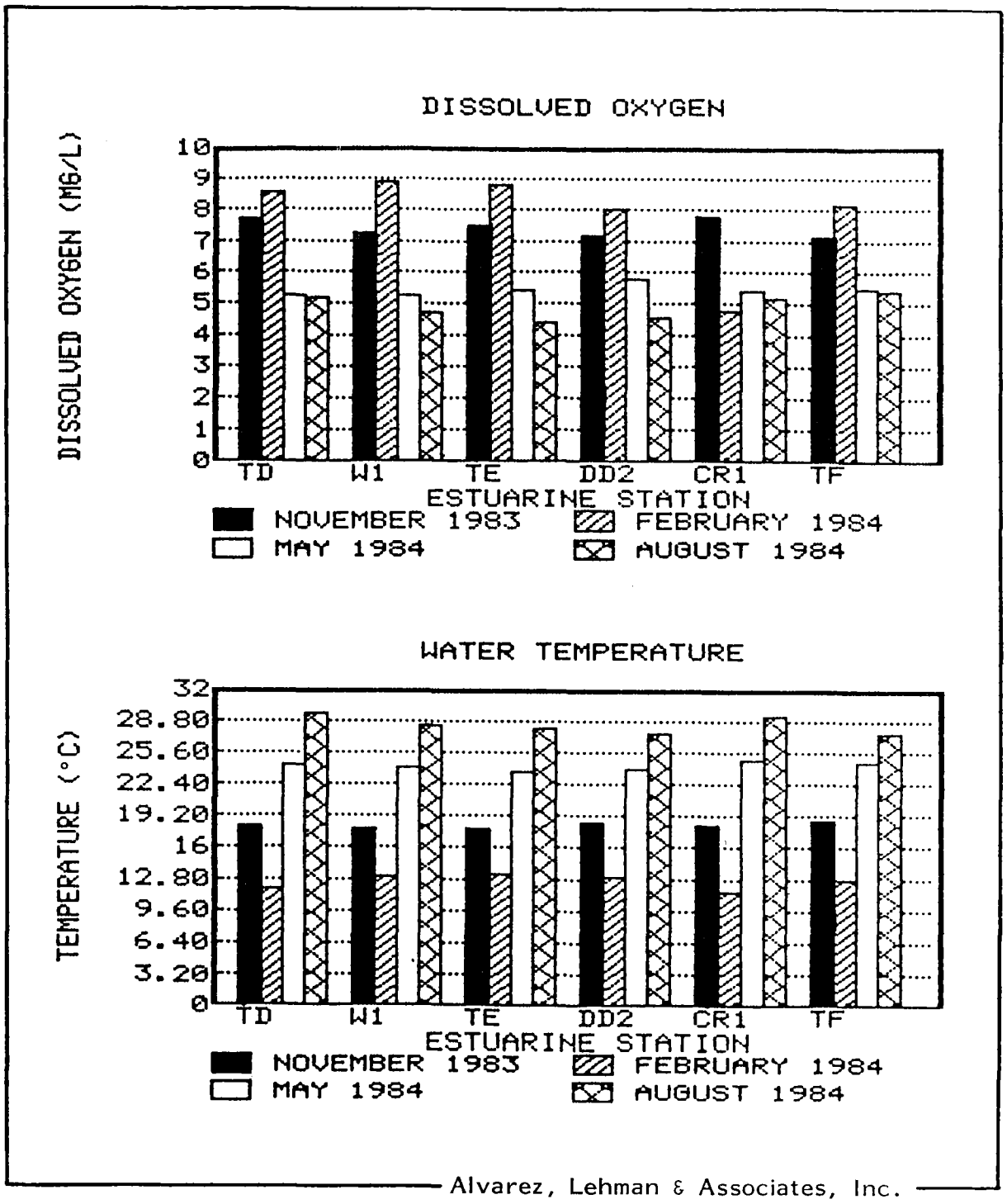


FIGURE 3-15. Dissolved Oxygen Concentrations and Temperatures in Estuarine Waters, Kings Bay and Cumberland Sound, Georgia, 1983-1984

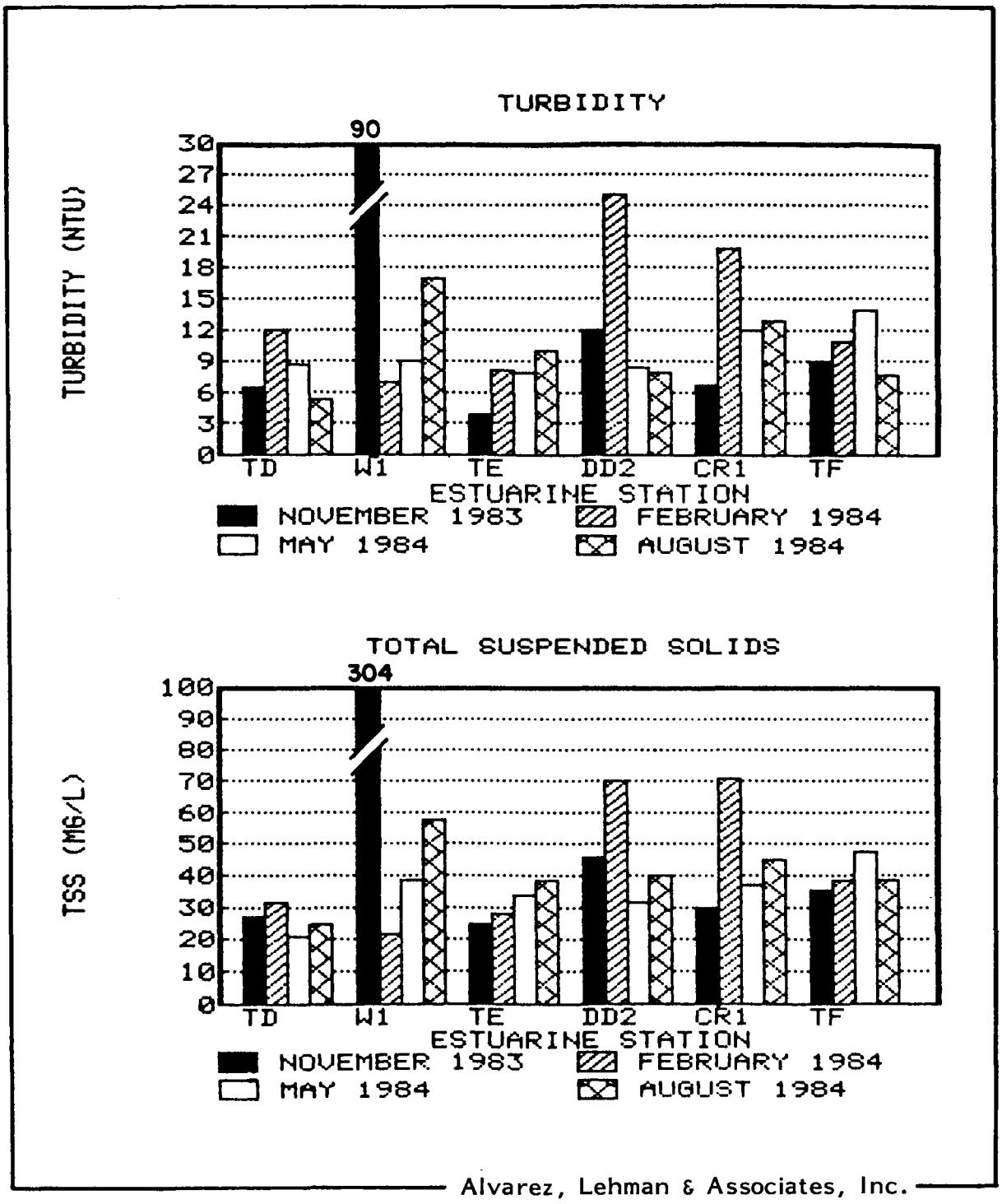


FIGURE 3-16. Turbidity and Total Suspended Solids in Estuarine Waters, Kings Bay and Cumberland Sound, Georgia, 1983-1984

gave no indication of surface plume presence. This sample documents the presence of a subsurface turbidity plume in the lower turning basin of Kings Bay. Waters from this station exceeded the reference standard for turbidity in Florida waters which mandates that turbidity shall not be raised by more than 29 NTU above background levels (Florida Department of Environmental Regulation, 1983). However, no other parameters were elevated in this sample.

Nutrient concentrations in Kings Bay and Cumberland Sound were similar to concentrations previously reported for the area (Jones, Edmunds & Associates, Inc., 1984). Total Kjeldahl nitrogen and total phosphorus data (Figure 3-17) gave no indication of nutrient enrichment due to SUBASE waterfront WWTP effluent discharge or dredging activities.

A copper concentration of 0.079 mg/l was measured at Station TE in February. This value exceeded the federal criterion for copper in surface waters (0.023 mg/l) (U.S. Environmental Protection Agency, 1980). Lead concentrations were slightly above detection limits at Stations TD, TE, DD2 and TF in May, and Stations TD and DD2 exceeded the Florida lead standard of 0.03 mg/l. Chromium was detected at Station TE in May at a level of 0.011 mg/l. Other trace metal concentrations were generally at or below the analytical detection limit. Chronic metals contamination was not documented.

Oil and grease concentrations documented by routine estuarine surveys

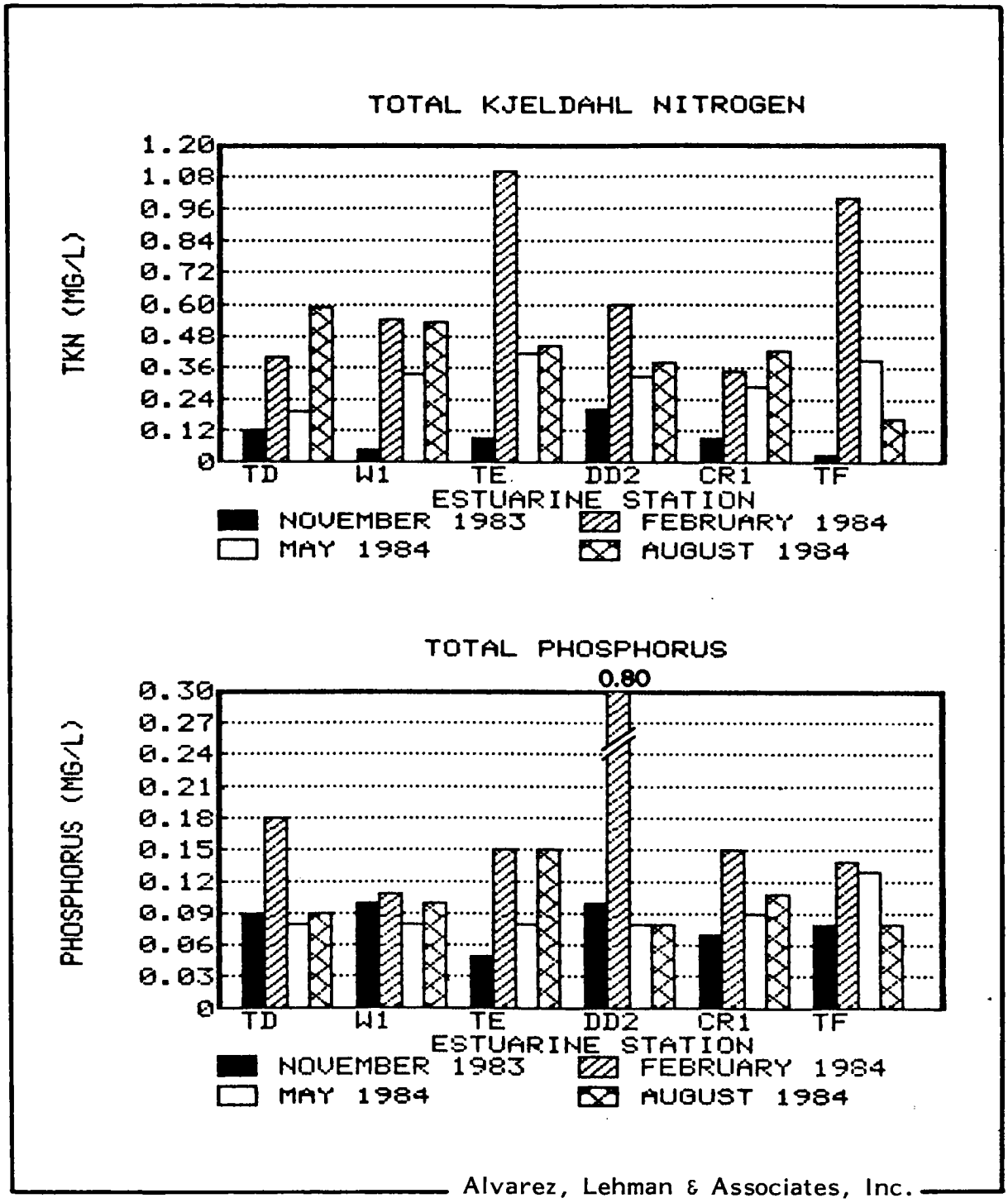


FIGURE 3-17. Total Kjeldahl Nitrogen and Total Phosphorus in Estuarine Waters of Kings Bay and Cumberland Sound, Georgia, 1983-1984

were uniformly low. All values from the Kings Bay area during 1983-1984 monitoring were below one mg/l. The State of Florida prohibits oil and grease residues greater than five mg/l in its surface waters (Florida Department of Environmental Regulation, 1983). The State of Georgia has no oil and grease standard for surface waters.

Levels of fecal coliform bacteria in the Cumberland Sound estuarine system were consistently below the standard of 1000 cells per 100 ml required by the Georgia Department of Public Health for shellfish harvesting.

3.6 Sediment Quality

In the Draft Supplement to the Environmental Impact Statement, the Navy predicted that stormwater drainage from SUBASE would have long-term effects on concentrations of oil and grease, lead, and other contaminant levels in aquatic sediments of Kings Bay and other receiving waters (Environmental Science and Engineering, Inc., 1980a). Additionally, decreased flushing and increased sedimentation were anticipated in Kings Bay due to alteration of bay configuration by dredging. The sedimentation rate within the Kings Bay area was projected at nearly 500,000 cubic yards per year. Since suspended solids scavenge chemical constituents from the water column as they settle, high potential exists for contaminant concentration in surficial sediments in the bay.

Contaminants bound in sediments are typically converted to chemical forms having little ecological impact. However, sediment resuspension may remobilize such concentrated constituents, and conversion to toxic forms can occur. Sediment resuspension only occurs to a limited degree during hydraulic dredge operations (Jones, Edmunds & Associates, Inc., 1983), but dredged material disposal area effluent discharge can contain elevated levels of metals, nutrients, and other constituents. Dragline dredging has been shown to cause high levels of silt resuspension (Jones, Edmunds & Associates, Inc., 1983; Alvarez, Lehman & Associates, Inc., 1984f).

The Navy also predicted that bottom sediments in Kings Bay and Cumberland Sound would periodically be resuspended by submarine passage or support vessel operations. Monitoring of trace metals and oil and grease concentrations in bottom sediments of the estuarine areas and in surficial sediments at the major surface runoff drains from SUBASE was performed to determine if the predictions made in the DSEIS were occurring to a detectable level.

3.6.1 Estuarine Sites

Surficial sediments collected in August 1984 from the six estuarine water quality sampling locations were comprised primarily of fine-grained materials, particularly within Kings Bay. Sand and shell were present in higher concentrations in sediments from Crooked River, the Stafford Island Channel, Mill Creek, and Cumberland Sound at Dungeness Wharf.

Although no grain-size analyses were performed, field observations showed sediments within Kings Bay were physically unlike those found in undredged areas in this estuarine complex. Sediments recovered from within Kings Bay were comprised almost exclusively of fine silts whereas higher sand content at the other sites resulted in more consolidated samples. Smaller-grained sediments in Kings Bay represent the accumulation of suspended solids from the water column and bank erosion and slumping. Disparity in sediment character has been consistently demonstrated between Kings Bay and other areas in Cumberland Sound since 1976 (Environmental Science and Engineering, Inc., 1977; Jones, Edmunds & Associates, Inc., 1981, 1982, 1984).

Station DD2 down-estuary from the ARDM, and the control station in Crooked River (CR1), had lower levels of copper, chromium, lead, and zinc than the other sites (Table 3-25). Oil and grease concentrations at these sites were the two lowest values found.

Dredging operations initiated within Kings Bay in November 1982 continued throughout most of the 1983-1984 monitoring year. Although different phases and levels of construction and maintenance dredging of bottom sediments occurred, metals and oil and grease levels from sites within Kings Bay remained relatively high. Oil and grease levels ranged from 3 to 10 times higher than the base value found at the Crooked River control site (CR1). However, the oil and grease level at control Station

TABLE 3-25. Summary of Estuarine Sediment Quality Data, Naval Submarine Base, Kings Bay, Georgia, August 1984

Parameter *	Station Designation					
	TD	W1	TE	DD2	CR1	TF
Moisture (Percent)	68.0	73.8	77.7	40.6	33.1	69.1
Oil and Grease	1730	5060	3500	1100	480	2200
Mercury	0.056	0.038	0.045	0.034	0.036	0.049
Lead	5.9	11	13	2.5	2.4	7.4
Zinc	33	49	53	13	9.3	38
Cadmium	< 0.28	< 0.34	< 0.40	< 0.20	< 0.10	0.81
Chromium	29	36	39	8.9	5.4	29
Copper	8.1	6.5	7.0	1.4	0.76	4.3

* All values in milligrams per kilogram, dry-weight basis unless otherwise noted

Source: Alvarez, Lehman & Associates, Inc., 1985

TF was also higher than the reference value from Station CR1 by a factor of almost 5. Similarly, concentrations of copper, chromium, lead, and zinc in Kings Bay were considerably higher than the reference value at Station CR1 but comparable to the levels found at Station TF.

The observed differences appear attributable to the physical disimilarity of Crooked River sediments from those at the other sites as demonstrated by the moisture content of each sediment sample (Table 3-25). Higher sand content at Station CR1 was clearly illustrated by lower moisture content. This station reflects the type of natural bottom substrate which has been removed from Kings Bay by Army and Navy dredging. Higher metals levels in Kings Bay sediments are related to the physical characteristics of sediments of dredged areas, and therefore are a result of bay bottom development. They do not necessarily reflect recent metals inputs to this system.

Sediment metals levels documented during monitoring in this study area from 1980 to 1983 were reported to be considerably lower than values presented in the Environmental Impact Statement (Jones, Edmunds & Associates, Inc., 1984). This interpretation appears to have been due to differences in units used in reporting the data. Conversion of all values reported between 1980 and 1983 to milligrams of metal per kilogram of dry sediment allowed comparison of results from August 1984 with all previous monitoring results. 1984 means for each metal from sites within Kings Bay and Cumberland Sound (control stations) were compared to historical means

for these regions (Table 3-26). The metals levels for 1984 were comparable to or lower than the historical values. These data do not indicate any accumulation of metals at these monitoring locations.

3.6.2 Surface Runoff Sites

Most SUBASE stormwaters drain to either Marianna Creek or North River. Design of the SUBASE drainage system included stormwater retention ponds to slow down surface runoff and allow sedimentation of suspended solids and associated chemical constituents.

Major chains of stormwater retention ponds (Monroe and Stimson) were under construction during 1983 and 1984, and drainage modifications are ongoing to date. Without ponds to entrap suspended solids and bedload, high potential for solids transport to receiving areas existed during this study period. Since various contaminants typically are absorbed on suspended particulates, subsequent sedimentation could cause localized buildup of sediment contaminants in receiving areas where suspended load deposition occurs. These conditions were anticipated in the DSEIS in the prediction of stormwater-related metals and oil and grease concentration in aquatic sediments (Environmental Science and Engineering, Inc., 1977).

Sediment samples collected from surface runoff monitoring stations in August 1984 were analyzed for oil and grease and selected trace metals (Table 3-27). Oil and grease concentrations were uniformly high at all

TABLE 3-26. Average Concentrations of Selected Metals in Sediments from Kings Bay and Cumberland Sound Near Naval Submarine Base, Kings Bay, Georgia Between 1976 and 1984

Parameter *	1976-1977	November 1980	November 1981	August 1983	August 1984
KINGS BAY					
% Moisture	54.3	64.2	62.9	75.3	65.0
Cadmium	< 0.5	14.0	5.4	4.1	< 0.4
Copper	5.7	25.1	5.4	8.1	5.8
Chromium	34.3	55.9	53.9	12.2	28.2
Lead	11.0	165.0	29.7	8.1	8.1
Mercury	0.09	0.56	8.36	0.08	0.04
Zinc	30.0	313.0	75.5	109.0	37.0
CUMBERLAND SOUND					
% Moisture	19.6	27.4	23.2	51.0	51.1
Cadmium	< 0.5	6.9	2.6	4.1	0.5
Copper	< 0.1	5.5	3.9	2.0	2.5
Chromium	1.7	8.3	11.7	10.2	17.2
Lead	< 5	15.2	14.3	4.1	4.9
Mercury	0.06	0.14	3.50	0.04	0.04
Zinc	2.1	13.8	27.3	65.3	23.7

* All metals concentrations in milligrams of metal per kilogram of dry sediment

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-27. Summary of Sediment Quality Data from Surface Water Stations, Naval Submarine Base, Kings Bay, Georgia, August 1984

Parameter *	Station Designation				
	MC1	SD1	NR5	NR8	NR9
Moisture (Percent)	39.4	27.2	28.9	37.8	38.7
Oil and Grease	20000	17000	20000	20000	20000
Mercury	0.026	0.019	0.034	0.039	0.039
Lead	< 0.5	1.0	5.5	3.2	2.6
Zinc	10	1.1	46	14	10
Cadmium	< 0.15	< 0.12	< 0.13	< 0.13	0.41
Chromium	5.3	1.5	3.0	5.3	10
Copper	1.9	0.34	1.9	< 0.31	1.5

* All values in milligrams per kilogram, dry-weight basis unless otherwise noted

Source: Alvarez, Lehman & Associates, Inc., 1985

sites monitored. Indications of chronic oil and grease contamination were found at all of the monitored sites.

Lead was the primary metal projected by the DSEIS as likely to occur in aquatic soils receiving base drainage. Although use of lead-free fuels has been encouraged on SUBASE, potential for exhaust-related lead release remains. Sediments from Station NR5 relocated in the new swale draining the Stimson chain of stormwater lakes showed the highest lead levels for this period. This site was positioned just downstream from M.C. Anderson's laydown area and a haul road (U.S.S. Woodrow Wilson Avenue) heavily used by earthmoving equipment. Lead levels at this station suggest chronic contamination. Slightly elevated lead levels were also noted at Stations NR8 and NR9; both sites are located at bridges where roadside drainage may have contributed low-level inputs of this metal.

Of the other metals analyzed, only zinc showed a distributional pattern similar to that of lead. Highest concentrations occurred at Station NR5, with slightly elevated levels noted at Stations NR8, NR9, and MC1, in that order. This sequence of stations parallels the relative intensity of vehicular traffic and the areal extent of impermeable surfaces within SUBASE drainage basins during this monitoring period.

While these observations imply that SUBASE drainage may have been responsible for low-level metals inputs to receiving area sediments, metals concentrations found in August 1984 were generally lower than those of August 1983 (Table 3-28). No buildup of metals concentrations has been indicated by sediment monitoring at these stations over the past two years.

TABLE 3-28. Average Concentrations of Selected Metals in Sediments from Surface Water Drains from Naval Submarine Base, Kings Bay, Georgia Between 1976 and 1984

Parameter *	1976-1977	November 1980	November 1981	August 1983	August 1984
Station NR5					
% Moisture	NS	NS	NS	30.0	28.9
Cadmium	NS	NS	NS	9.2	< 0.13
Copper	NS	NS	NS	0.9	1.9
Chromium	NS	NS	NS	2.9	3.0
Lead	NS	NS	NS	8.6	5.5
Mercury	NS	NS	NS	< 0.029	0.034
Zinc	NS	NS	NS	51.5	46.0
Station NR8					
% Moisture	NS	NS	NS	76.0	37.8
Cadmium	NS	NS	NS	183.5	< 0.13
Copper	NS	NS	NS	4.6	< 0.31
Chromium	NS	NS	NS	< 2	5.3
Lead	NS	NS	NS	20.9	3.2
Mercury	NS	NS	NS	< 0.083	0.039
Zinc	NS	NS	NS	321.1	14.0
Station NR9					
% Moisture	NS	NS	NS	61.0	38.7
Cadmium	NS	NS	NS	< 0.5	0.4
Copper	NS	NS	NS	2.6	1.5
Chromium	NS	NS	NS	33.3	10.0
Lead	NS	NS	NS	12.8	2.6
Mercury	NS	NS	NS	< 0.051	0.039
Zinc	NS	NS	NS	281.6	10.0
Station SD1					
% Moisture	NS	NS	NS	32.0	27.2
Cadmium	NS	NS	NS	1.5	< 0.12
Copper	NS	NS	NS	2.7	0.3
Chromium	NS	NS	NS	2.4	1.5
Lead	NS	NS	NS	8.8	1.0
Mercury	NS	NS	NS	< 0.029	0.019
Zinc	NS	NS	NS	26.5	1.1
Station MC1					
% Moisture	NS	NS	NS	NS	39.4
Cadmium	NS	NS	NS	NS	< 0.15
Copper	NS	NS	NS	NS	1.9
Chromium	NS	NS	NS	NS	5.3
Lead	NS	NS	NS	NS	< 0.5
Mercury	NS	NS	NS	NS	0.026
Zinc	NS	NS	NS	NS	10.0

* All metals concentrations in milligrams of metal per kilogram of dry sediment
NS = Not sampled

Source: Alvarez, Lehman & Associates, Inc., 1985

3.7 Dredge Monitoring

Daily dredge monitoring was conducted from March to September 1984 at the Mainside Disposal Area outfall and an Ambient (Kings Bay) station as part of the 1983-1984 environmental monitoring program. The objective was to compare Mainside Disposal Area effluent quality with Kings Bay ambient water quality. Particular emphasis was placed on determining if any state or federal water quality criteria were violated by these effluent discharges.

The scope of the dredge monitoring program was restricted to data acquisition and presentation in tabular format. An interim report summarizing the results of daily dredge monitoring between March and July 1984 was submitted to OICC, TRIDENT in October 1984 (Alvarez, Lehman & Associates, Inc., 19841). A final report summarizing the results based upon the full data set for March through September 1984 was submitted to OICC, TRIDENT in February 1985 (Alvarez, Lehman & Associates, Inc., 1985f).

Although no detailed analyses were conducted, several patterns in the data were evident in monthly mean values (Tables 3-29 and 3-30). Effluent quality was relatively good during March, April, and May, but was poor in June and July. Effluent quality was improved in August but was again poor in September.

TABLE 3-29. Monthly and Overall Means of Water Quality Parameters at the Kings Bay Ambient Station Dredge Monitoring at Naval Submarine Base, Kings Bay, Georgia, March to September 1984

PARAMETER *	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	MEAN	ST. DEV.	ST. ERR
IN SITU										
Air Temperature, C	20.6	23.7	27.5	29.6	30.8	30.2	27.2	27.1	3.7	1.4
Water Temperature, C	16.7	19.5	25.0	28.0	28.5	28.7	26.0	24.6	4.7	1.8
Conductivity, umhos/cm	26306	21525	40356	45748	44533	42577	40369	37345	9487	3586
Salinity, ppt	19.6	15.2	26.2	28.3	27.0	26.0	25.9	24.0	4.8	1.8
Dissolved Oxygen	7.2	6.5	5.5	4.9	5.0	4.7	5.8	5.7	0.9	0.3
pH, S.U.	7.7	7.7	7.6	7.6	7.7	7.8	7.9	7.7	0.1	0.0
Total Depth, feet	36	37	37	38	39	38	37	37	1	0
Secchi Depth, feet	3.1	3.0	3.6	3.5	3.9	3.5	3.3	3.4	0.3	0.1
Current, feet/second	0.79	0.95	0.76	0.39	0.36	0.67	0.38	0.61	0.24	0.09
ANALYTICAL										
Turbidity, NTU	6.1	8.2	7.2	7.6	8.3	7.4	7.6	7.5	0.7	0.3
Suspended Solids	26	27	33	37	39	30	35	32	5	2
Ammonia	0.08	0.09	0.06	0.07	0.10	0.10	0.12	0.09	0.02	0.01
Kjeldahl Nitrogen	0.42	0.53	0.37	0.35	0.49	0.72	0.40	0.47	0.13	0.05
Nitrate/Nitrite	0.03	0.03	0.05	0.03	0.10	0.03	0.10	0.05	0.03	0.01
Orthophosphate	0.05	0.04	0.06	0.06	0.03	0.07	0.07	0.05	0.02	0.01
Total Organic Carbon	12	15	13	12	9	11	14	12	2	1
5-day BOD	2.3	1.2	1.4	1.3	1.8	1.6	1.9	1.6	0.4	0.1
Total Cadmium, ug/l	2	2	2	2	2	2	2	2	0	0
Total Chromium, ug/l	5	5	5	7	6	6	6	6	1	0
Total Copper, ug/l	21	7	6	5	5	5	6	8	6	2
Total Lead, ug/l	10	13	31	13	15	11	23	17	8	3
Total Iron, ug/l	350	350	314	355	447	496	464	397	71	27
Total Mercury, ug/l	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.2	0.0	0.0

* All values in milligrams per liter unless otherwise noted
C = degrees Centigrade
ppt = parts per thousand
cm = centimeters
S.U. = standard units
NTU = nephelometric turbidity units
ug/l = micrograms per liter

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-30. Monthly and Overall Means of Water Quality Parameters at the Mainside Disposal Area Outfall, Dredge Monitoring at Naval Submarine Base, Kings Bay, Georgia, March to September 1984

PARAMETER *	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	MEAN	ST. DEV.	ST. ERR.
IN SITU										
Air Temperature, °C	23.3	25.0	29.5	30.6	32.9	30.6	28.5	28.6	3.4	1.3
Water Temperature, °C	20.4	22.6	26.7	30.1	29.7	28.8	27.8	26.6	3.7	1.4
Conductivity, umhos/cm	27563	24200	42861	47791	44655	43921	42536	39075	9226	3487
Salinity, ppt	19.6	16.1	27.2	27.9	26.8	26.7	26.3	24.4	4.6	1.7
Dissolved Oxygen	8.7	8.5	7.0	6.5	6.9	7.1	7.6	7.5	0.8	0.3
pH, S.U.	8.4	8.3	8.2	8.0	8.3	8.5	8.4	8.3	1.6	0.6
Ponding Depth, cm	45	43	85	26	67	109	111	69	33	13
Total Discharge, cfs	18.7	15.7	20.3	14.0	14.5	17.2	10.2	15.8	3.4	1.3
ANALYTICAL										
Turbidity, NTU	8.3	9.0	8.7	39.9	34.5	14.1	50.4	23.6	17.6	6.7
Suspended Solids	26	29	30	905	125	63	1860	434	705	266
Ammonia	0.12	0.06	0.05	0.45	0.94	0.29	11.50	1.92	4.24	1.60
Kjeldahl Nitrogen	0.77	0.69	0.56	0.94	1.77	1.31	20.70	3.82	7.45	2.82
Nitrate/Nitrite	0.14	0.02	0.02	0.03	0.02	0.04	0.03	0.04	0.04	0.02
Orthophosphate	0.09	0.05	0.06	0.09	0.09	0.09	2.25	0.39	0.82	0.31
Total Organic Carbon	16	15	18	32	12	17	34	21	9	3
5-day BOD	4.6	3.0	4.2	3.2	5.1	4.8	19.1	6.3	5.7	2.2
Total Cadmium, ug/l	2	2	2	2	2	2	2	2	0	0
Total Chromium, ug/l	5	6	12	46	9	7	42	18	18	7
Total Copper, ug/l	5	5	5	9	6	5	14	7	3	1
Total Lead, ug/l	10	11	18	17	10	13	30	16	7	3
Total Iron, ug/l	206	262	143	7147	1681	941	8361	2677	3527	1333
Total Mercury, ug/l	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.0

* All values in milligrams per liter unless otherwise noted
°C = degrees Centigrade
ppt = parts per thousand
cm = centimeters
cfs = cubic feet per second
S.U. = standard units
NTU = nephelometric turbidity units
ug/l = micrograms per liter

Source: Alvarez, Lehman & Associates, Inc., 1985

The final environmental impact statement (FEIS) (Environmental Science and Engineering, Inc., 1977) predicted high BOD loadings and increased levels of ammonia and nutrients in disposal area return flows. Parameters which were significantly higher in Mainside effluents when compared to ambient water quality included turbidity, total suspended solids, total organic carbon, ammonia and total Kjeldahl nitrogen, orthophosphate, biochemical oxygen demand, chromium, and iron (Alvarez, Lehman & Associates, Inc., 1985d). Poor effluent quality frequently was documented when ponding depths of less than two feet occurred. Prolonged storm conditions may also have influenced effluent quality through resuspension of silts within the disposal area.

Violations of water quality standards were documented for several parameters in disposal area effluents. Violations corresponded with turbid effluent discharge from Mainside; elimination of turbid effluent discharges through better weir management practices could eliminate most water quality standards violations. It was recommended (Alvarez, Lehman & Associates, Inc., 1985d) that OICC, TRIDENT authorize an appropriate level of data analysis directed toward correlation of water quality parameters with environmental and disposal area operational practices. Data analysis and interpretation should be directed toward development of site-specific disposal area management criteria to be used by SUBASE during future dredging operations.

3.8 Biological Monitoring

3.8.1 Benthic Invertebrates

The Environmental Impact Statement and its supplements projected that SUBASE-related dredging of Kings Bay and Cumberland Sound would have significant impacts on benthic invertebrate communities in the study area (Environmental Science and Engineering, Inc., 1977, 1980). Reduction in benthic invertebrate abundance was expected to follow dredging operations, and high frequency of physical habitat disruption was expected to inhibit benthic community stabilization.

Routine monitoring in February 1983 documented the anticipated absence of benthic invertebrates in Kings Bay sediments immediately following the initial round of A-1 phase dredging. However, invertebrate density and diversity at most sites within Kings Bay in August 1983 were comparable to control sites distributed throughout Cumberland Sound indicating rapid recovery from construction impacts (Jones, Edmunds & Associates, Inc., 1984). Monitoring was conducted in February and August 1984 to determine if ongoing A-1 phase dredging had any long-term impacts on several community characteristics, including density, diversity, and overall species composition.

Benthic invertebrate abundance and diversity records produced by the February and August 1984 monitoring surveys are presented by replicate in

Appendix B. Triplicate bottom grabs were collected and analyzed separately from each of eight stations during each survey. Analyses presented in Appendix B show that replicates generally recovered comparable numbers of organisms and numbers of taxa. Many of the rare species, however, did not occur in all three replicates at a given station resulting in considerable error in assessment of density and diversity if stations means were used in data set analysis. Total station data (sum of the replicate records) were used for all analyses in this report to avoid underestimation of invertebrate density and diversity. All data produced by previous monitoring surveys (Jones, Edmunds & Associates, 1979a, 1979b, 1980, 1981b, 1982a, 1984) were analyzed in this same manner.

An overview of results of February and August 1984 surveys is presented in Table 3-31. As typical for benthic communities in the southeast, benthic invertebrate densities in February (winter) greatly exceeded those in August (summer). This seasonality in invertebrate populations is a natural phenomenon. Contributing factors might include natural life history cycles of individual species, range in seasonal predation pressure from demersal fish and macroinvertebrates, and natural range in ambient water quality conditions (turbidity, salinity, dissolved oxygen, temperature). Segregation of natural seasonal variation in benthic communities from changes possibly induced by SUBASE construction dredging or other activities is extremely difficult. Environmental monitoring analyses emphasized between-station faunal differences within each quarter rather than between-season differences.

TABLE 3-31. Summary of Benthic Invertebrate Survey Results for Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, February and August 1984

		FEBRUARY				AUGUST			
LOCATION	STATION	DENSITY (IND/M2)	# OF TAXA	DIVERSITY (BASE 2)	EVENNESS (J)	DENSITY (IND/M2)	# OF TAXA	DIVERSITY (BASE 2)	EVENNESS (J)
KINGS BAY									
UPPER KINGS BAY	TD	5677	24	2.27	0.23	706	10	1.28	0.19
MIDDLE KINGS BAY	W1	19849	42	1.37	0.12	1374	12	1.50	0.19
LOWER KINGS BAY	TE	46704	36	0.93	0.07	1764	12	1.84	0.23
ARDM	DD2	12445	55	3.60	0.33	2854	31	3.14	0.36
KINGS BAY	MEAN	21169	39	2.04	0.19	1675	16	1.94	0.24
KINGS BAY	ST. DEV.	17980	13	1.18	0.12	900	10	0.83	0.08
KINGS BAY	ST. ERR.	8990	6	0.59	0.06	450	5	0.42	0.04
CONTROLS									
CROOKED RIVER BRANCH	CR1	10302	45	3.11	0.29	2962	22	1.63	0.18
STAFFORD ISLAND CHANNEL	SI1	1865	35	3.84	0.47	422	11	2.62	0.43
DUNGENNESS	TF	9824	48	3.43	0.32	1342	11	1.42	0.18
MILL CREEK	ML1	2161	32	3.39	0.40	2382	16	2.68	0.38
CONTROL	MEAN	6038	40	3.44	0.37	1777	15	2.09	0.29
CONTROL	ST. DEV.	4653	8	0.30	0.08	1125	5	0.66	0.13
CONTROL	ST. ERR.	2327	4	0.15	0.04	562	3	0.33	0.07

IND/M2 = Individuals per meter square
ST. DEV. = Standard devia
ST. ERR. = Standard error

Source: Alvarez, Lehman & Associates, Inc., 1985

In February, mean station density within Kings Bay (21,169 individuals per square meter) greatly exceeded the control station mean (6,038 individuals per square meter). Extremely high total invertebrate densities were documented at Stations W1 and TE in middle and lower Kings Bay, and corresponding Shannon-Weaver diversity and evenness values were very low reflecting the strong predominance of the community by selected species (Figure 3-18). Control station diversity and evenness values were much higher than those demonstrated in Kings Bay. Divergence of the Kings Bay station group from the control group is a strong indication of faunal response to recent and ongoing dredging operations in the bay.

The key species which appeared to have responded to naval dredge operations within Kings Bay was the dwarf surf clam, *Mulinia lateralis*. This species accounted for over 78 percent of the total number of individuals found at Stations W1 and TE. No comparable populations were detected at any of the control stations.

Mulinia lateralis is an opportunistic species with life history characteristics which favor its rapid establishment following environmental perturbations. Among these characteristics is the tendency for rapid population explosions (after perturbation creates unoccupied substrates) and equally abrupt crashes. Unstable population levels contribute to extreme variation in benthic oxygen demand on overlying waters; living populations as well as dead and decaying organisms drain oxygen and release

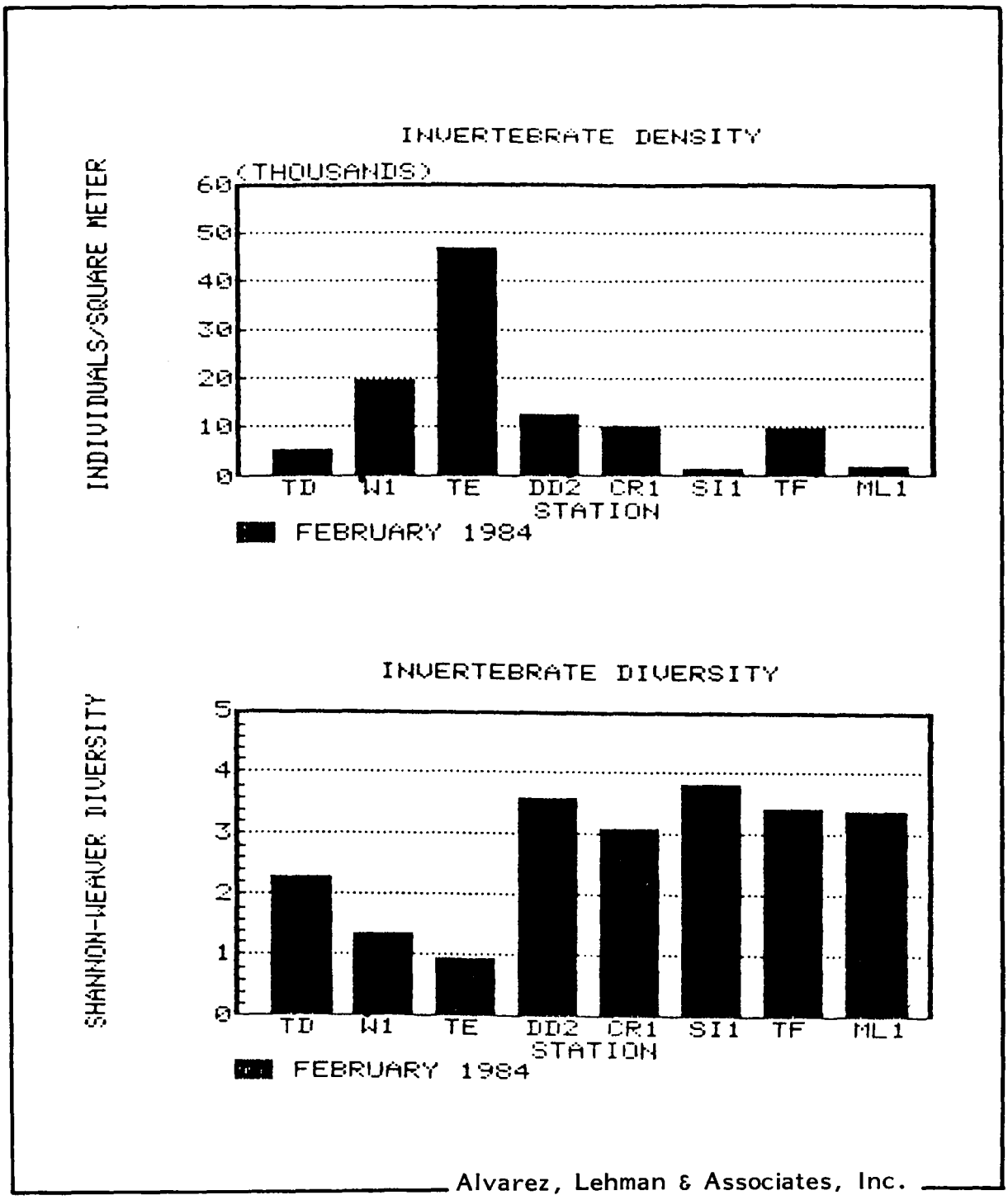


FIGURE 3-18. Benthic Invertebrate Density and Diversity, Naval Submarine Base, Kings Bay, Georgia, February 1984

nutrients from the sediments to the overlying water. Population level instability in predominant taxa leads to instability of the community. Such instability is an undesired side effect of coastal zone development.

In contrast to the winter survey results, the August 1984 density and diversity estimates did not clearly demonstrate divergence of Kings Bay benthic communities from those of several control stations (Figure 3-19). Sites within Kings Bay (TD, W1, and TE) exhibited lower densities and diversities than several of the control stations. However, some control stations also exhibited low invertebrate densities. The summer records do not clearly indicate any relation between SUBASE development and gross invertebrate community characteristics.

Numerically dominant taxa from the control areas were compared with those from within Kings Bay by calculation of Biological Index (BI) values according to the method described by Sanders (1960). Taxa within each station were ranked according to numerical abundance. Point values were assigned to the ten top ranked taxa (ten points to the most abundant down to one point for the tenth most abundant). BI values for each numerically dominant species were calculated by summing the point values from each station. Numerical dominance is objectively assessed through this system since high BI values are only achieved through both high numerical abundance and high frequency of abundance at all stations. For comparative purposes, all BI values were expressed as the percent of the maximum value possible.

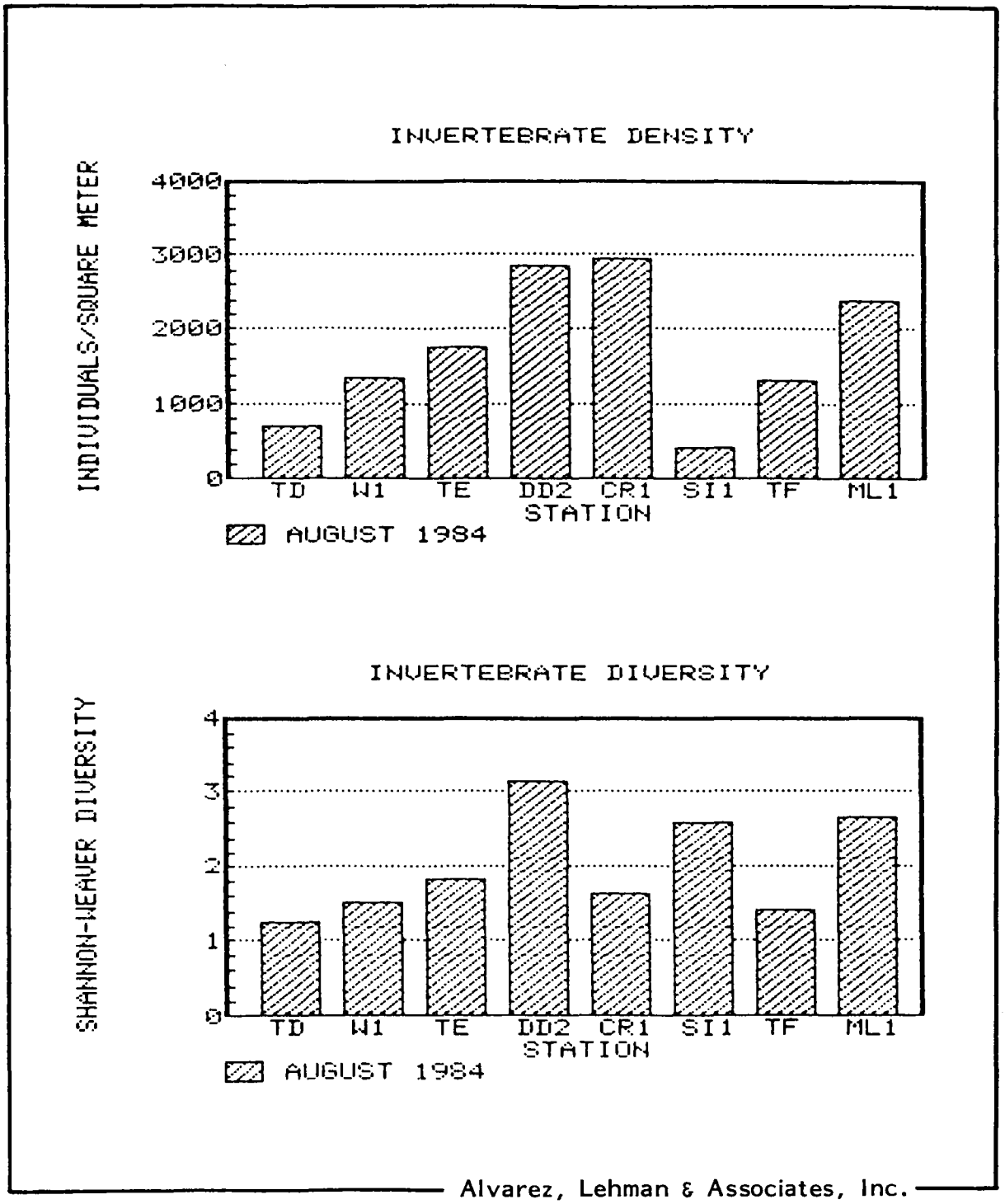


FIGURE 3-19. Benthic Invertebrate Density and Diversity, Naval Submarine Base, Kings Bay, Georgia, August 1984

Numerically dominant taxa within the immediate vicinity of Kings Bay were not consistently dominant at many of the control sites during February (Table 3-32). As noted previously, Mulinia lateralis was only abundant in lower Kings Bay in areas that had been disrupted by construction and maintenance dredging over the preceding year. The spionid polychaete Paraprionospio pinnata was the most dominant taxon due to consistent high ranking at all four sites in this part of the study area. Neither of these species is typically this dominant during the winter in this study area. While P. pinnata was also dominant at several of the control sites, it was not nearly as prevalent outside of Kings Bay (Figures 3-20 through 3-23).

Numerically dominant taxa found at the control sites more closely resembled the species assemblage expected during the winter months based on surveys in this study area since 1978. Dominant taxa included the polychaetes, Streblospio benedicti , Heteromastus filiformis , and P. pinnata . Lower levels of consistent dominance are suggested by the lower BI values. This is consistent with the high Shannon-Weaver and evenness values observed at the control sites when compared with locations within Kings Bay (see Table 3-31).

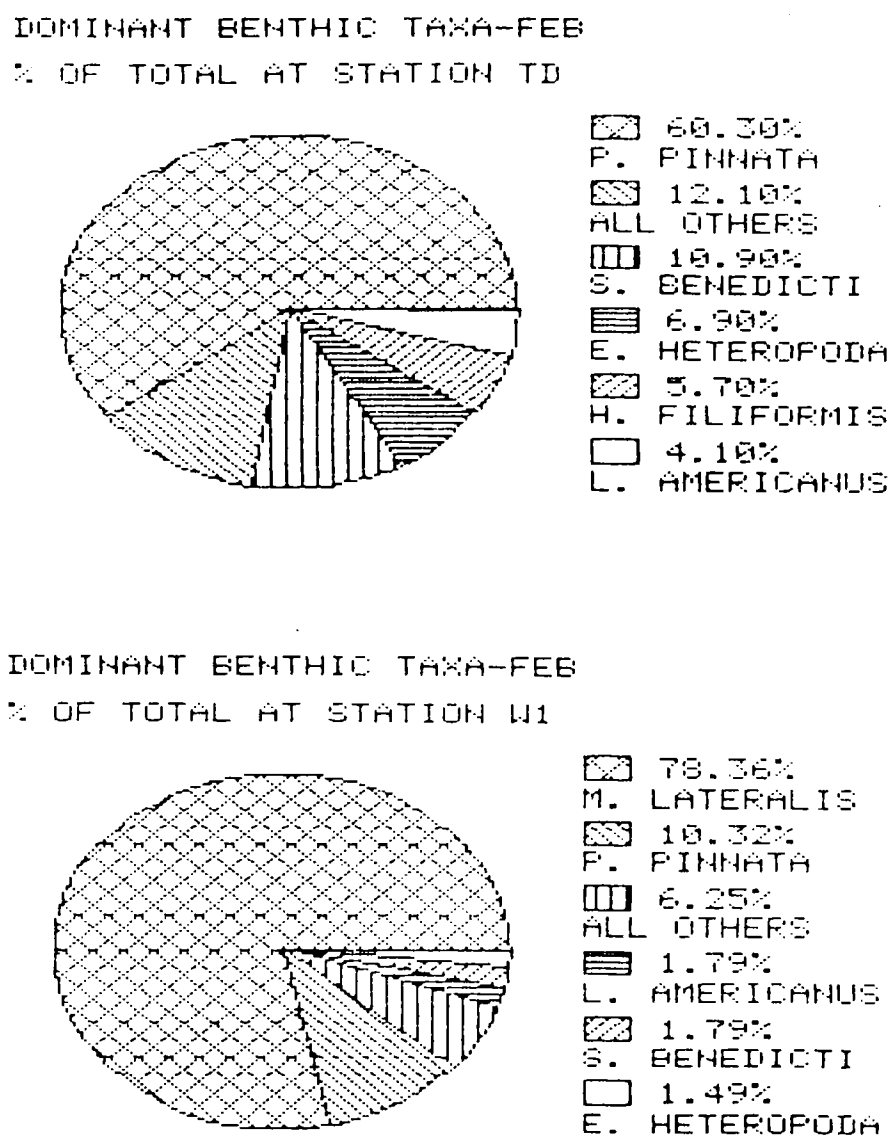
In August, faunal assemblages within Kings Bay were comparable to those at the control sites indicating a convergence of the faunas. Taxa numerically dominant within the Kings Bay area were essentially the same as

TABLE 3-32. Numerically Dominant Benthic Invertebrate Taxa Collected from Kings Bay and Control Stations, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, February 1984

Kings Bay Stations (TD, W1, TE, DD2)		Control Stations (CR1, SI1, TF, ML1)	
% of Max* BI	Taxon	% of Max BI	Taxon
85	Paraprionospio pinnata	84	Streblospio benedicti
83	Mulinia lateralis	65	Heteromastus filiformis
80	Streblospio benedicti	58	Paraprionospio pinnata
58	Heteromastus filiformis	56	Scoloplos fragilis
50	Eteone heteropoda	43	Ampelisca spp.
43	Leucon americanus	35	Oligochaeta
40	Oligochaeta	30	Eteone heteropoda
18	Tellina sp.	23	Leucon americanus
13	Rhynchocoela	20	Unid. ophiuroid
13	Exogone dispar	15	Oxyurostylis sp.
13	Unid. gastropods	15	Sabellaria vulgaris
11	Platyhelminthes	14	Rhynchocoela
10	Haploscoloplos fragilis	13	Monoculodes sp.
10	Odostomia sp.	13	Eudorella sp.
		10	Cerapus sp.

*max = maximum biological index value = 40
BI = Biological Index

Source: Alvarez, Lehman & Associates, Inc., 1985



Alvarez, Lehman & Associates, Inc.

FIGURE 3-20. Numerically Dominant Benthic Invertebrate Taxa at Stations TD and W1, Naval Submarine Base, Kings Bay, Georgia, February 1984

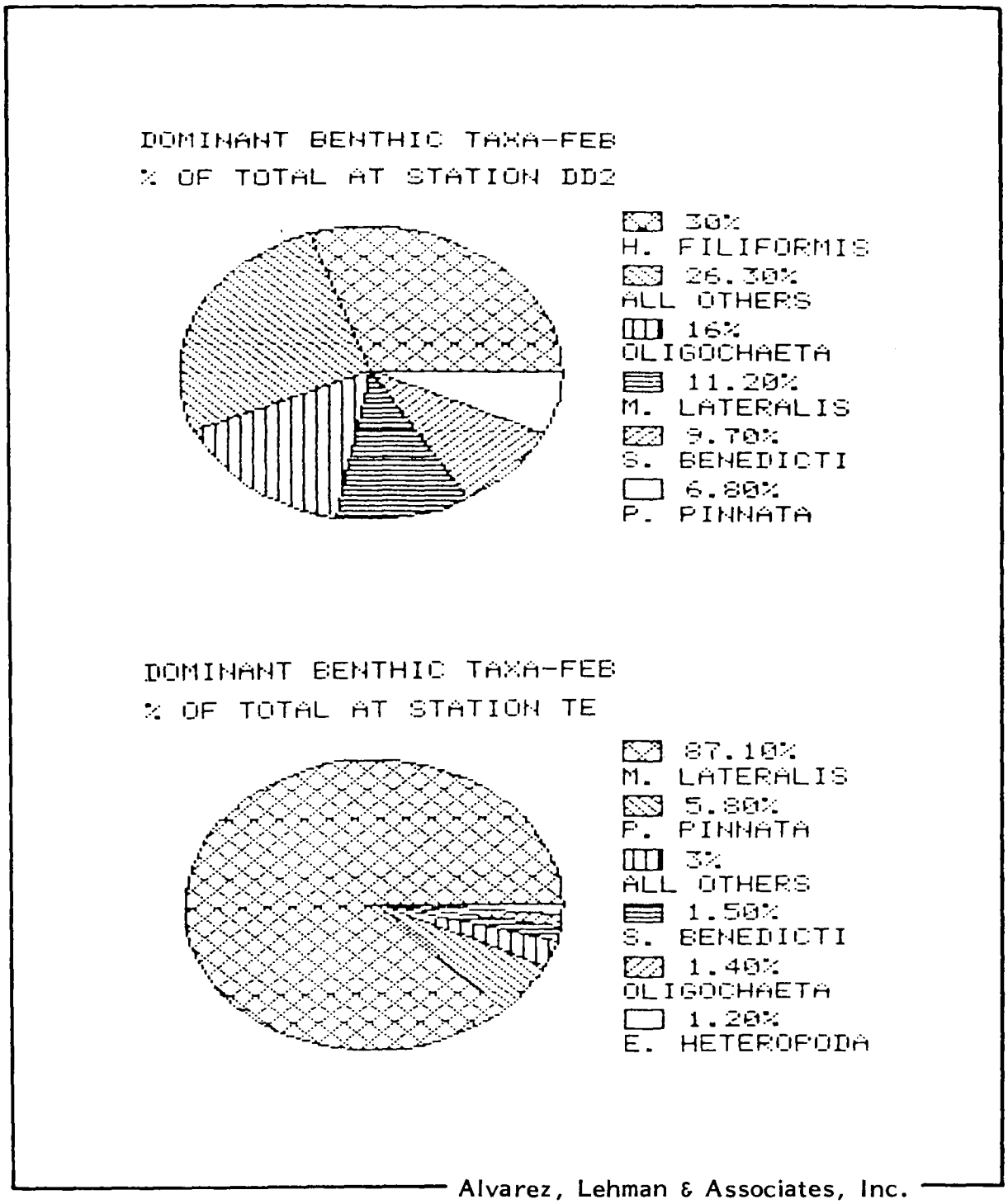


FIGURE 3-21. Numerically Dominant Benthic Invertebrate Taxa at Stations DD2 and TE, Naval Submarine Base, Kings Bay, Georgia, February 1984

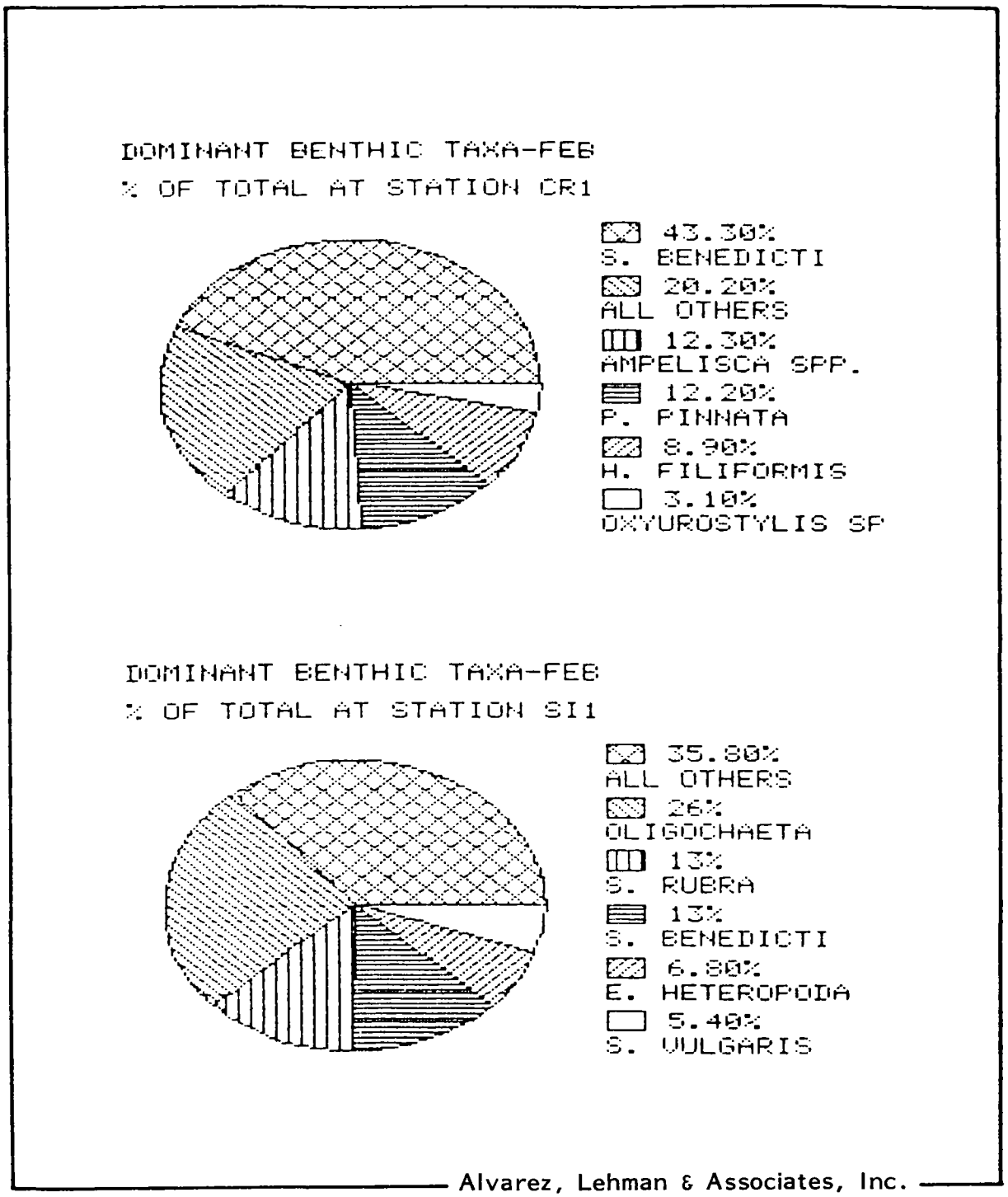


FIGURE 3-22. Numerically Dominant Benthic Invertebrate Taxa at Stations CR1 and SI1, Naval Submarine Base, Kings Bay, Georgia, February 1984

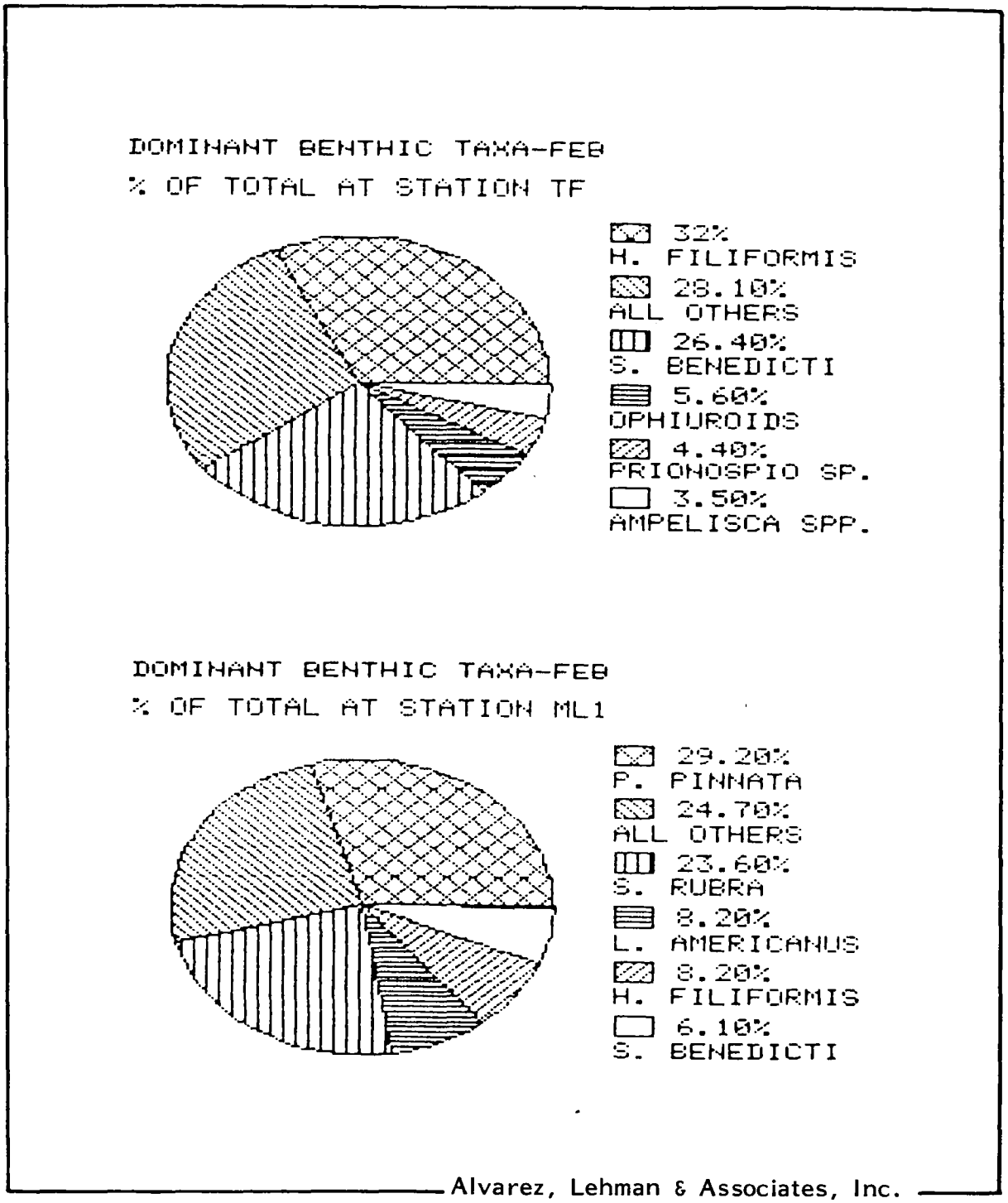


FIGURE 3-23. Numerically Dominant Benthic Invertebrate Taxa at Stations TF and ML1, Naval Submarine Base, Kings Bay, Georgia, February 1984

those in undredged areas of this estuarine system (Table 3-33). All eight stations were predominated by Paraprionospio pinnata (Figures 3-24 through 3-27). This species has frequently been among the summer season dominant taxa; its dominance is consistent with its pattern of being most abundant during and following periods of dredging in Kings Bay.

Alteration of benthic communities within Kings Bay has been indicated by recent surveys of benthic invertebrates in the study area. Gradual conversion of the bay bottom from sand-dominated to silt/clay-dominated substrates has resulted in benthic faunas strongly predominated by a few selected taxa. These taxa have demonstrated widely fluctuating populations which indicate pulsed population success and failure. Community instability is an undesired side effect of harbor development in Kings Bay which may ultimately reduce the value of localized benthic resources as a food resource for demersal feeding fishes.

3.8.2 Macroinvertebrates

Trawl surveys were conducted in Kings Bay, Cumberland Sound, and adjacent areas in February and August 1984. During February, very few macroinvertebrates were found in Kings Bay (Table 3-34). Similarly low densities were documented in the Crooked River control site. Higher numbers of invertebrates having commercial value (shrimp and blue crabs) were encountered at the Stafford Island Channel and Cumberland Sound control sites (SI1 and TF).

TABLE 3-33. Numerically Dominant Benthic Invertebrate Taxa Collected from Kings Bay and Control Stations, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, August 1984

Kings Bay Stations (TD, W1, TE, DD2)		Control Stations (CR1, SI1, TF, ML1)	
% of Max* BI	Taxon	% of Max BI	Taxon
100	Paraprionospio pinnata	100	Paraprionospio pinnata
80	Leucon americanus	63	Leucon americanus
78	Heteromastus filiformis	60	Scoloplos rubra
48	Oligochaeta	36	Oligochaeta
40	Tharyx setigera	35	Sigambra tentaculata
28	Streblospio benedicti	31	Heteromastus filiformis
26	Edotea montosa	26	Edotea montosa
26	Neomysis americana	23	Lepidonotus sublevis
25	Glycinde sp.	20	Glycinde sp.
15	Sigambra tentaculata	20	Tharyx setigera
15	Unid. ophiuroid	19	Streblospio benedicti
13	Haploscoloplos fragilis	18	Neomysis americana
10	Rhynchocoela	15	Prionospio sp.
		11	Sabella microphthalma
		11	Ampelisca spp.
		11	Cerapus sp.
		10	Rhynchocoela
		10	Unid. mysid

*max = maximum biological index value = 40
BI = Biological Index

Source: Alvarez, Lehman & Associates, Inc., 1985

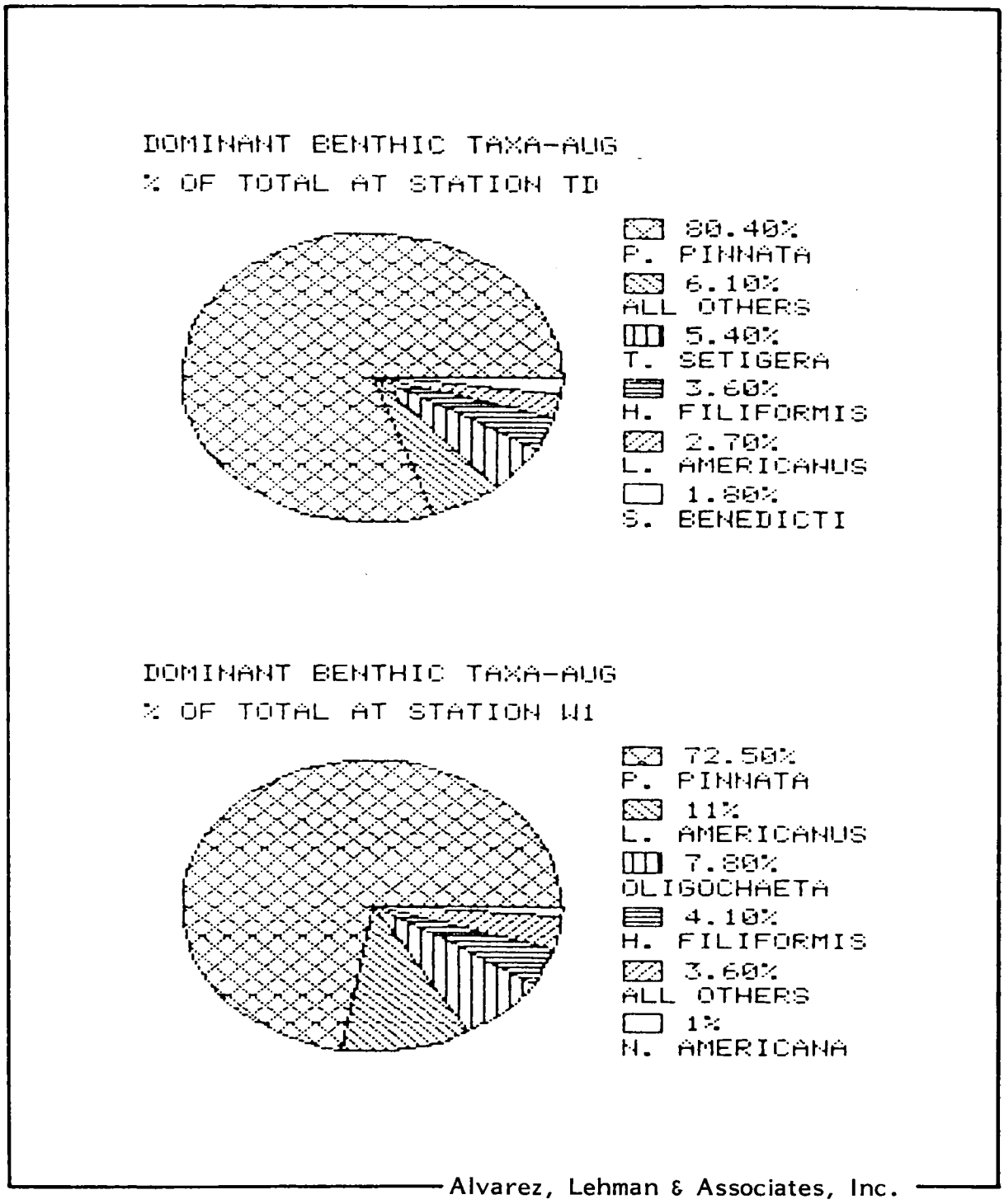


FIGURE 3-24. Numerically Dominant Benthic Invertebrate Taxa at Stations TD and W1, Naval Submarine Base, Kings Bay, Georgia, August 1984

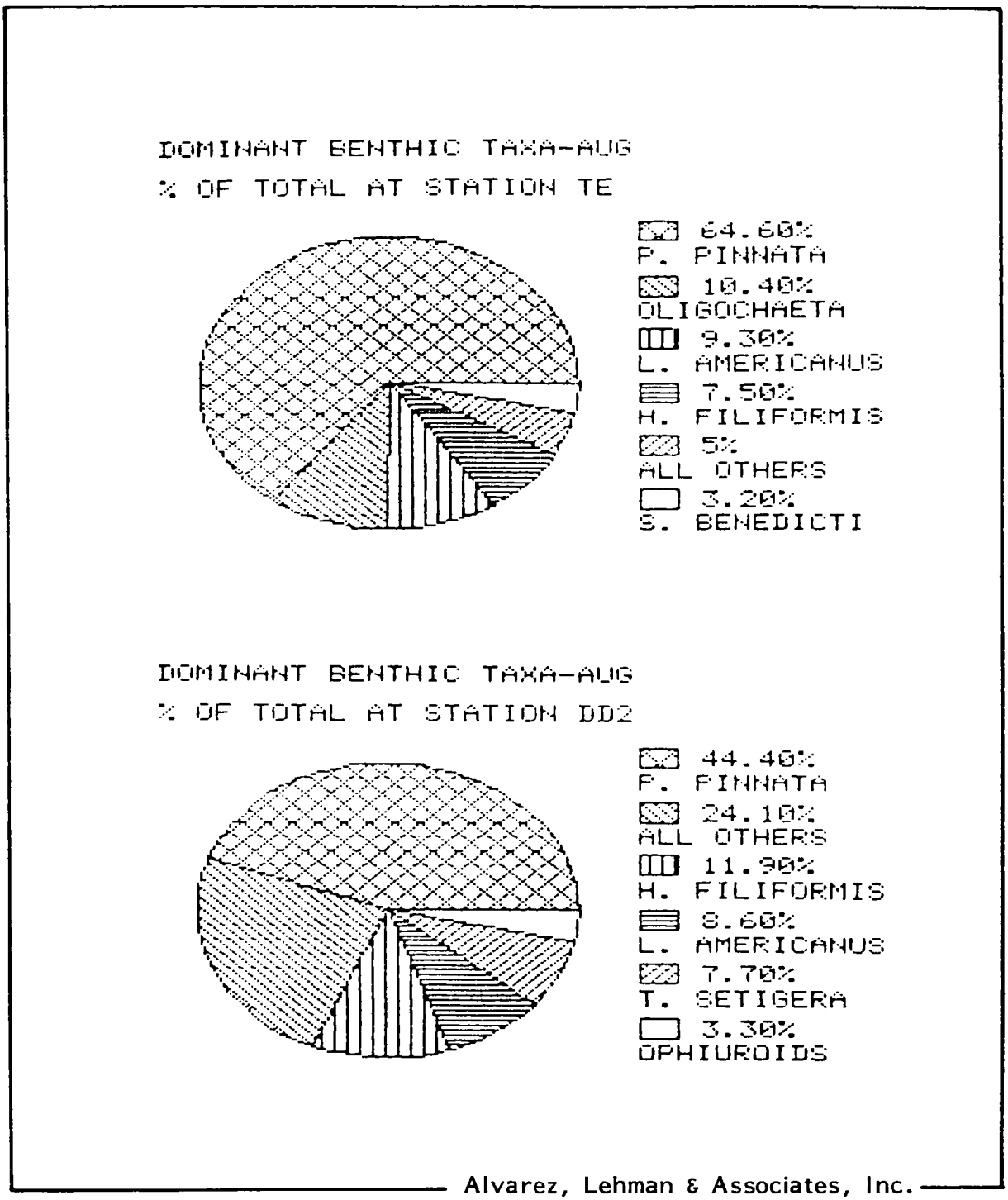


FIGURE 3-25. Numerically Dominant Benthic Invertebrate Taxa at Stations TE and DD1, Naval Submarine Base, Kings Bay, Georgia, August 1984

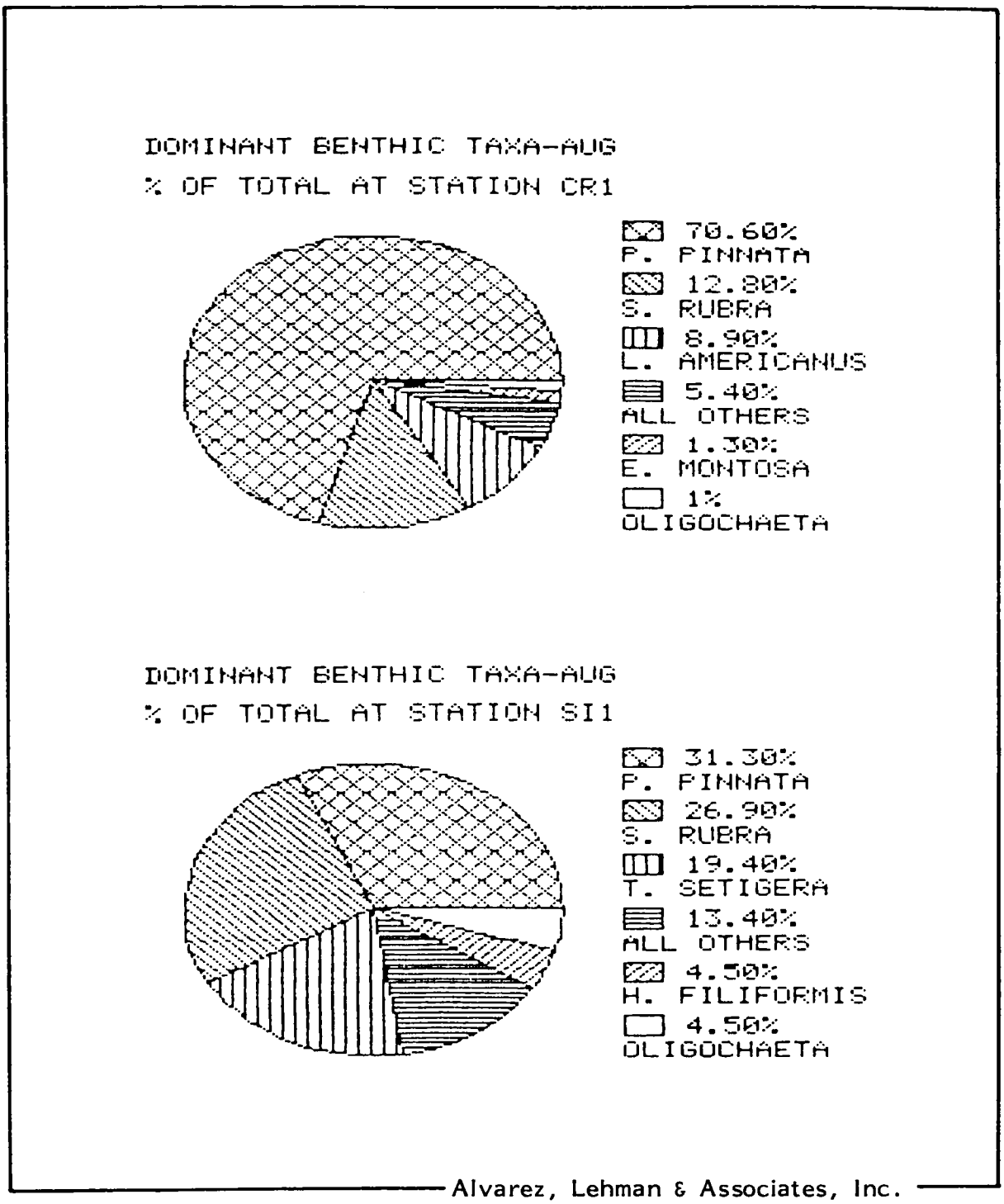


FIGURE 3-26. Numerically Dominant Benthic Invertebrate Taxa at Stations CR1 and SI1, Naval Submarine Base, Kings Bay, Georgia, August 1984

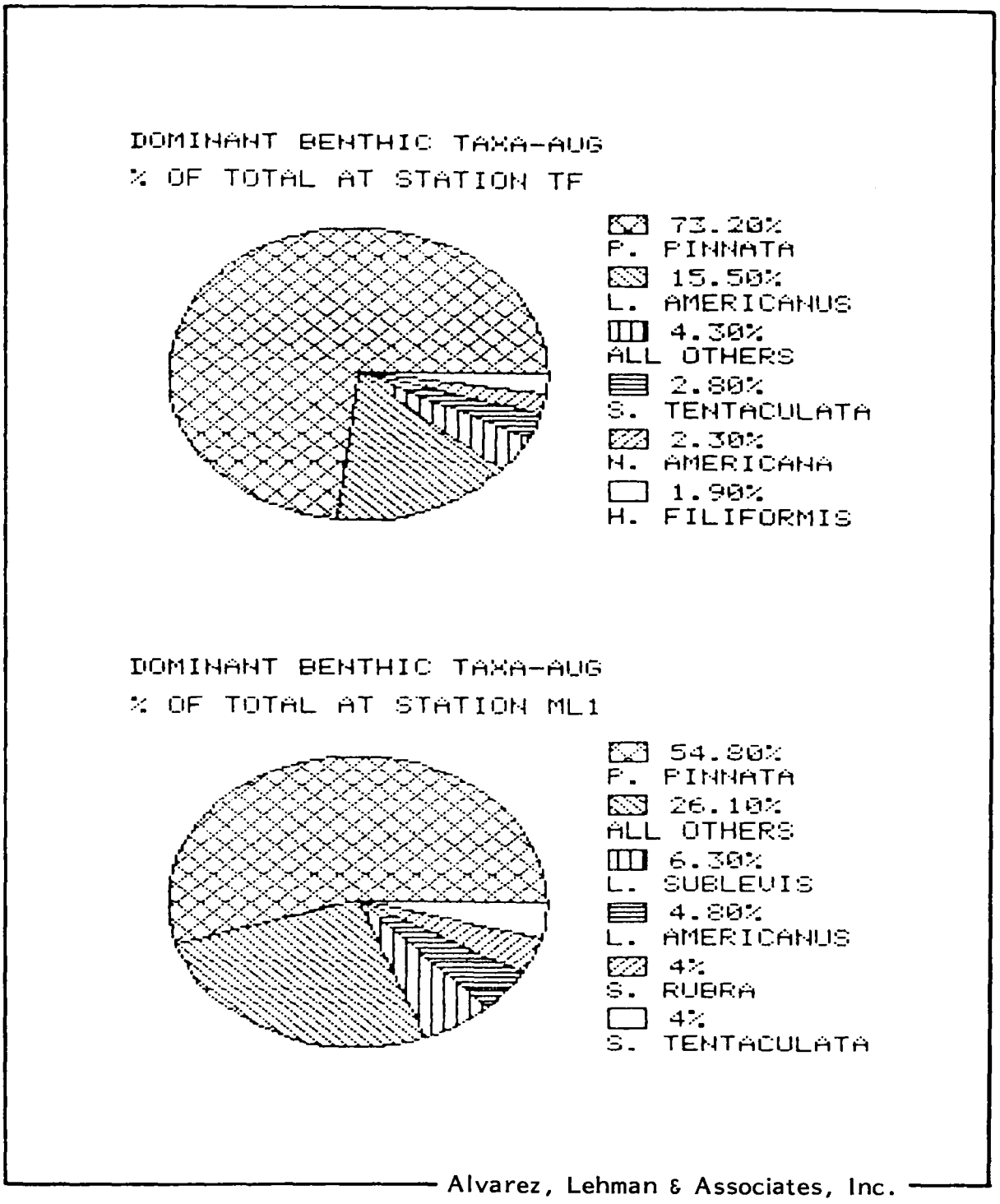


FIGURE 3-27. Numerically Dominant Benthic Invertebrate Taxa at Stations TF and ML1, Naval Submarine Base, Kings Bay, Georgia, August 1984

TABLE 3-34. Macroinvertebrate Species Abundance* and Diversity at Stations Trawled During Environmental Monitoring Surveys at Naval Submarine Base, Kings Bay, Georgia in March and August 1984

	STATION				KINGS BAY		STATION				CONTROL	
TAXON	TD	W1	TE	DD2	TOTAL	MEAN	CR1	SI1	TF	ML1	TOTAL	MEAN
March 1984												
Mollusca												
Lolliguncula brevis	1		2		3	1	1	3			4	1
Mulinia lateralis		40			40	10					0	0
Crustacea												
Penaeus aztecus				1	1	0	1	2	1		4	1
Penaeus setiferus	2		2		4	1		15	43		58	19
Callinectes sapidus	2	1		2	5	1	2	3	35		40	13
Unid. xanthid crabs					0	0	1	1			2	1
Total Taxa	3	2	2	2	5	4	4	5	3	0	4	4
Total Individuals	5	41	4	3	53	13	5	24	79	0	108	36
August 1984												
Mollusca												
Lolliguncula brevis		3	2	6	11	3	68	8	16	23	115	29
Busycon spiratum					0	0		1			1	0
Crustacea												
Squilla empusa					0	0		1	1		2	1
Pagurus longicarpus				2	2	1				1	1	0
Penaeus aztecus					0	0	1	1		1	3	1
Penaeus setiferus	1		2		3	1			2	2	4	1
Portunus gibbesi				1	1	0	2	4		3	9	3
Callinectes sapidus	1				1	0					0	0
Callinectes ornatus					0	0		1			1	0
Libinia sp.					0	0		3	1		4	1
Echinodermata												
Unid. starfish					0	0				1	1	0
Total Taxa	2	1	2	3	5	2	3	7	4	6	10	5
Total Individuals	2	3	4	9	18	5	71	19	20	31	141	35

* Abundance as individuals per 30-minute trawl effort

Source: Alvarez, Lehman & Associates, Inc., 1985

Similar results are documented for August 1984 (Table 3-34). Kings Bay sites had lower densities (organisms per 30 minutes of trawling) than control locations sampled in Crooked River, Mill Creek, and Cumberland Sound. Additionally, sites near Kings Bay had lower diversities (numbers of taxa).

Catch records for February and August 1984 contrasted sharply with those of 1983 when more dense invertebrate aggregations were encountered throughout the study area. The dramatic contrast between the two years may in part reflect a faunal response to dredging operations in this area throughout both 1983 and 1984. However, low abundance of macroinvertebrates at the control sites as well as within Kings Bay suggests that an areawide decline in this community has occurred. It is highly feasible that the severe freeze of December 1983 had a serious impact on macroinvertebrates overwintering within estuarine and nearshore habitats. Cold weather impacts on commercial fishing interests all along the Georgia and Florida Atlantic coasts were described by many as the worst of the century. When viewed from this overall perspective, the differences between macroinvertebrate catches in Kings Bay and the control sites during 1983-1984 monitoring were insignificant.

3.8.3 Demersal Fish

Development of harbor facilities within Kings Bay has altered its

physical character over time. Port development has deepened and widened this embayment beyond conditions occurring in natural estuarine systems along the Georgia coast. The net effect of changes in the configuration of Kings Bay on its suitability as a habitat for estuarine fishes remains unknown, and is the primary motivation for continued studies on fish communities near SUBASE.

Trawl catch records for the surveys performed in March and August 1984 are presented by replicate in Appendix C. Replicates were generally similar in species totals but varied considerably in total catch according to variation of fish schools. Since total catch better represented the fauna present at each station, replicate data was summed and all fish analyses were performed on total catch per 30 minutes of trawling at each station.

Despite the severe freeze that occurred at the end of December 1983, fish were abundant at Control Stations CR1, SI1, and TF in March 1984 (Tables 3-35 and 3-36, Figure 3-28). In accordance with the scope of work, Station ML1 was not trawled in March. This site was added to the program in August. Fish abundance within Kings Bay was very low compared to the control stations. This pattern was repeated in August.

Numerically dominant fish species present at the Kings Bay and control stations were generally the same (Table 3-37). However, the difference between the areas in terms of relative abundance of each species is

TABLE 3-35. Fish Community Species Composition and Abundance at Stations Trawled During Environmental Monitoring Surveys at Naval Submarine Base, Kings Bay, Georgia in March 1984 (Catch/two 15-minute tows)

	STATION				KINGS BAY		STATION				CONTROL	
TAXON	TD	W1	TE	DD2	TOTAL	MEAN	CR1	SI1	TF	ML1	TOTAL	MEAN
CLUPEIFORMES												
Anchoa mitchilli	12	6	84	10	112	28	1,075	899	282		2,256	752
Brevoortia tyrannus	9				9	2	23		1		24	8
GADIFORMES												
Urophysis floridanus			1	11	12	3	13	11	23		47	16
Urophysis regius	1		29	2	32	8	5	7	144		156	52
ATHERINIFORMES												
Menidia menidia					0	0	1				1	0
GASTEROSTEIFORMES												
Syngnathus fuscus					0	0	2				2	1
PERCIFORMES												
Hypsoblennius hentzi					0	0			1		1	0
Peprilus alepidotus		1			1	0		1	5		6	2
Peprilus triacanthus		1	1		2	1	5				5	2
Bairdiella chrysura	1		2		3	1		98	60		158	53
Cynoscion regalis				3	3	1		1	7		8	3
Leiostomus xanthurus	1			2	3	1		2			2	1
Menticirrhus americanus			1		1	0					0	0
Menticirrhus littoralis					0	0		1			1	0
Micropogon undulatus		2		2	4	1	18		160		178	59
Stellifer lanceolatus		1	5		6	2			1,077		1,077	359
Lagodon rhomboides				3	3	1					0	0
Trichiurus lepturus					0	0			1		1	0
Prionotus scitulus			1		1	0					0	0
PLEURONECTIFORMES												
Ancylopsetta quadrocellata			1		1	0		1			1	0
Symphurus plagiusa					0	0			64		64	21
Number of Taxa	5	5	9	7	15	7	8	9	12	NS	18	10
Number of Individuals	24	11	125	33	193	48	1,142	1,021	1,825	NS	3,988	1,329
Catch/Minute	1	0	4	1	6	2	38	34	61	NS	133	44
Shannon-Weaver Diversity	1.60	1.87	1.43	2.42	2.21	1.83	0.46	0.66	1.95	NS	1.83	1.02
Evenness	0.35	0.54	0.21	0.48	0.29	0.40	0.05	0.07	0.18	NS	0.15	0.10

NS = Station not sampled this quarter

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-36. Fish Community Species Composition and Abundance at Stations Trawled During Environmental Monitoring Surveys at Naval Submarine Base, Kings Bay, Georgia in August 1984 (Catch/two 15-minute tows)

	STATION				KINGS BAY		STATION				CONTROL	
TAXON	TD	W1	TE	DD2	TOTAL	MEAN	CR1	SI1	TF	ML1	TOTAL	MEAN
SQUALIFORMES												
Sphyrna tiburo					0	0	1				1	0
CLUPEIFORMES												
Anchoa hepsetus					0	0	8			3	11	4
Anchoa mitchilli	3	38	34	7	82	21	1674	42	255	214	2185	728
Brevoortia tyrannus	1				1	0					0	0
Opisthonema oglinum					0	0	1				1	0
SILURIFORMES												
Arius felis	2				2	1	5	10	3	1	19	6
Bagre marinus					0	0	462	13	10	4	489	163
BATRACHOIDIFORMES												
Opsanus tau					0	0	1				1	0
GASTEROSTEIFORMES												
Syngnathus louisianae					0	0	1				1	0
PERCIFORMES												
Chloroscombrus chrysurus		2	3	4	9	2	146		10	30	186	62
Selene vomer				1	1	0	4	1		1	6	2
Trachinotus carolinus					0	0			1		1	0
Chaetodipterus faber	3			2	5	1	10	12	6	9	37	12
Eucinostomus gula					0	0	1			10	11	4
Gobiosoma bosci					0	0				1	1	0
Peprilus alepidotus			1	1	2	1					0	0
Bairdiella chrysura					0	0	3	7	3	4	17	6
Cynoscion regalis	2	2	1		5	1	2		7	10	19	6
Leiostomus xanthurus	1				1	0	2			1	3	1
Menticirrhus americanus		1			1	0	1		8	1	10	3
Micropogon undulatus	1				1	0	2		13	10	25	8
Stellifer lanceolatus		3	47	8	58	15		1	247		248	83
Centropristis ocyurus	1				1	0					0	0
Larimus fasciatus					0	0			1		1	0
Sphyraena barracuda					0	0				3	3	1
Trichiurus lepturus				2	2	1			7		7	2
PLEURONECTIFORMES												
Etropus crossotus					0	0			1		1	0
Symphurus plagiusa			1		1	0		1	1	1	3	1
Trinectes maculatus					0	0		1	2		3	1
TETRAODONTIFORMES												
Chilomycterus schoepfi					0	0	2	1			3	1
Number of Taxa	8	5	6	7	15	7	18	10	16	16	27	15
Number of Individuals	14	46	87	25	172	43	2326	89	575	303	3293	823
Catch/Minute	0	2	3	1	6	1	78	3	19	10	110	27
Shannon-Weaver Diversity	2.84	1.00	1.40	2.42	2.08	1.92	1.23	2.31	1.85	1.78	1.76	1.79
Evenness	0.75	0.18	0.22	0.52	0.28	0.42	0.11	0.36	0.20	0.22	0.15	0.22

Source: Alvarez, Lehman & Associates, Inc., 1985

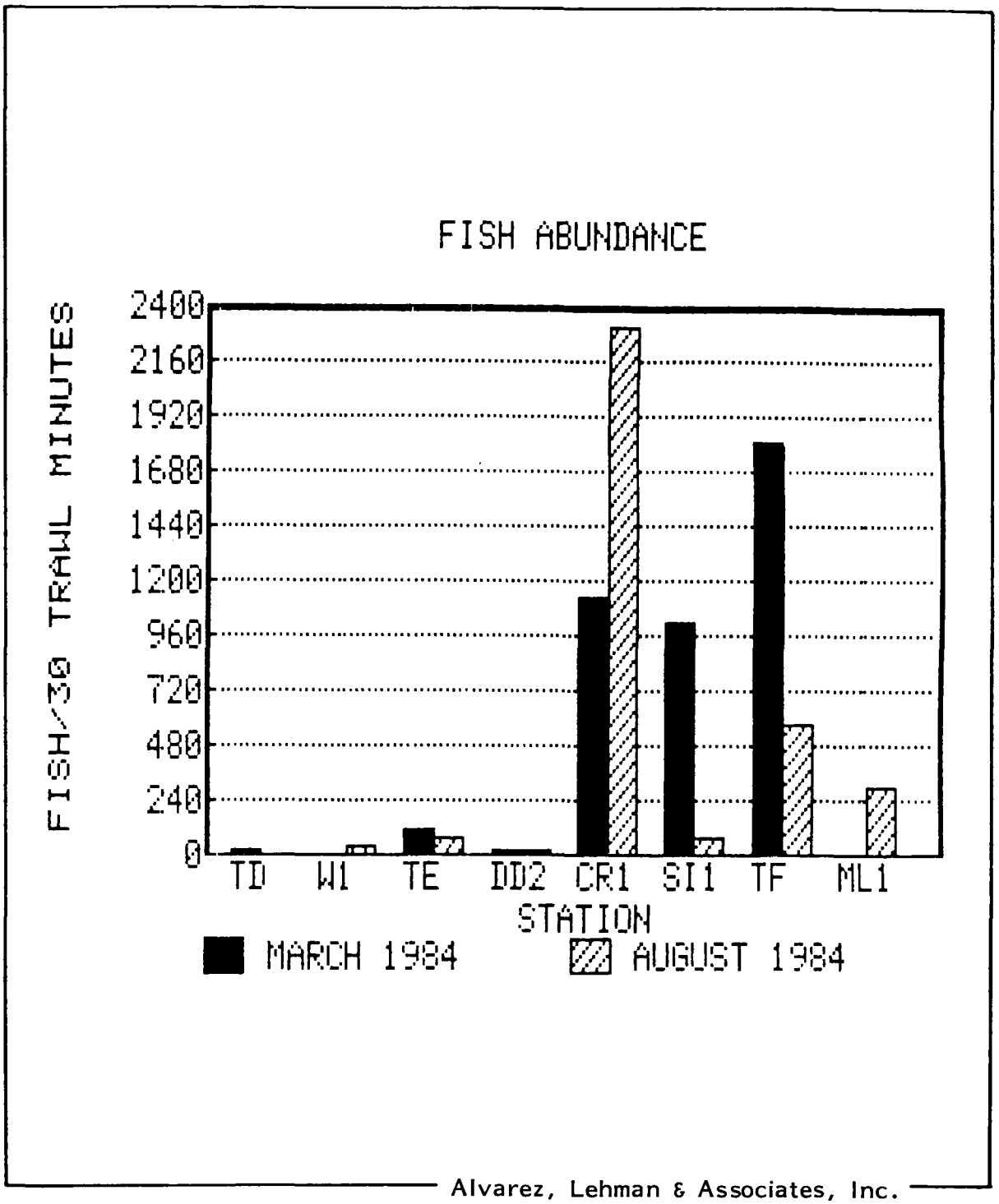


FIGURE 3-28. Total Fish Abundance at Trawl Stations, Naval Submarine Base, Kings Bay, Georgia, March and August 1984

TABLE 3-37. Numerically Dominant Fish Species from Kings Bay and Control Stations, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, March and August 1984

	Kings Bay Locations (TD, W1, TE, DD2)		Control Locations (CR1, SI1, TF, ML1)	
Month	No. of Fish	Species	No. of Fish	Species
March	112	Anchoa mitchilli	2,256	Anchoa mitchilli
	32	Urophysis regius	1,077	Stellifer lanceolatus
	12	Urophysis floridanus	178	Micropogon undulatus
	9	Brevoortia tyrannus	158	Bairdiella chrysura
	6	Stellifer lanceolatus	156	Urophysis regius
August	82	Anchoa mitchilli	2,185	Anchoa mitchilli
	58	Stellifer lanceolatus	489	Bagre marinus
	9	Chloroscombrus faber	248	Stellifer lanceolatus
	5	Chaetodipterus faber	186	Chloroscombrus chrysurus
	5	Cynoscion regalis	37	Chaetodipterus faber

* Total number of fish caught at all stations

Source: Alvarez, Lehman & Associates, Inc., 1985

striking.

Two measures of fish diversity were evaluated. Shannon-Weaver diversity indices calculated from station catch records (Figure 3-29) showed that diversity within Kings Bay was comparable to that at the control stations during both March and August despite lower numbers of taxa and numbers of individuals. More even distribution among the species present resulted in relative equity in Shannon-Weaver diversity values.

In contrast, the total number of fish species present at each station (Figure 3-29) clearly indicated that the control sites were more diverse. In March, 15 species were recovered from the four sites in and near Kings Bay as opposed to 18 species from the control site. The mean number of species per station in Kings Bay (7) was slightly lower than the control station mean (10). This measure of diversity indicated an even greater difference between station groups in August. The total and mean numbers of fish species at the control sites (27 and 15) were approximately twice as high as the corresponding values at the Kings Bay sites (15 and 7).

Consistent disparity between station groups in total fish abundance and total number of species was found during 1983-1984 monitoring. Year-round SUBASE construction dredging was the probable cause of reduced fish abundance and diversity in Kings Bay during both March and August 1984.

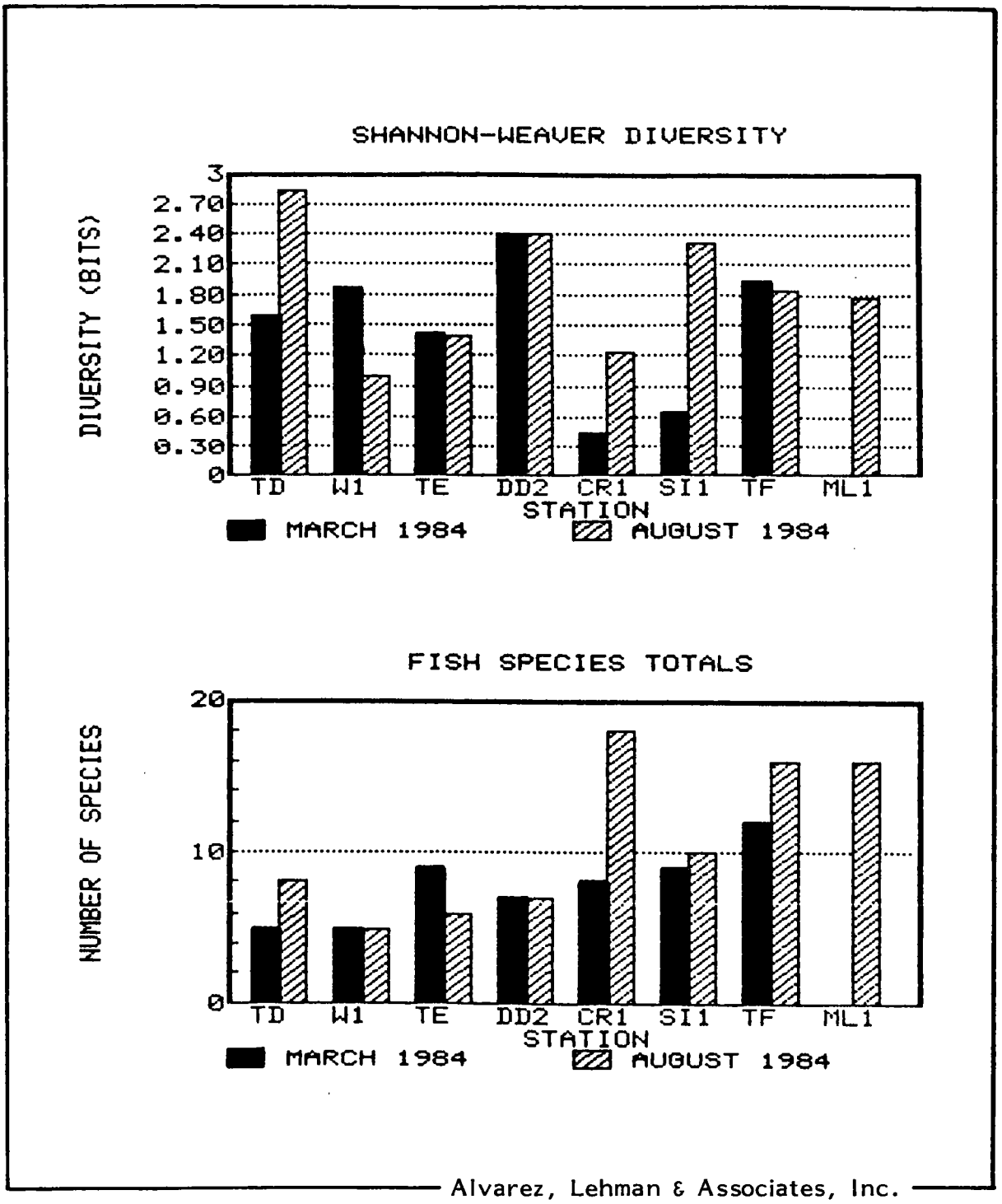


FIGURE 3-29. Fish Diversity Estimates at Trawl Stations, Naval Submarine Base, Kings Bay, Georgia, 1983-1984

Mean total lengths for six members of the drum family (Sciaenidae) and the bay anchovy (Anchoa mitchilli) were evaluated to determine if any size segregation between stations was evident (Table 3-38). In August, smaller sized bay anchovies, star drum (Stellifer lanceolatus), and sea trout (Cynoscion regalis) predominated at Stations W1, TE, and DD2 in lower Kings Bay. This pattern was also evident in preceding years suggesting that this deep-water habitat was used as a nursery area by very small fish despite ongoing construction in the study area. No other patterns in size records were found.

Trawl studies of fish communities have been conducted in Kings Bay, Cumberland Sound, and adjacent areas since spring 1976. Due to changes in the program over the past eight years, complete records only exist for 4 stations (C, D, E, and F). Stations D, E, and F correspond to sites designated TD, TE, and DD2 during the 1983-1984 monitoring year. Total fish abundance records (fish per 30 minute trawl effort) and Shannon-Weaver diversity values were compiled for all quarterly trawl surveys at each of the 4 stations sampled most continuously since 1976 (Tables 3-39 and 3-40).

Annual means for total fish abundance were calculated for each station based upon available quarterly records. Comparison of annual mean estimates demonstrated significant differences between years (Figure 3-30). Fish abundance at several stations was particularly high in 1982 and 1983. During baseline EIS studies, trawl catch in lower Kings Bay (Station E) averaged just below 1,400 fish per 30 minutes of trawling. All other

TABLE 3-38. Mean Total Lengths (millimeters) of Selected Fish Species Trawled from Kings Bay and Cumberland Sound, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, March and August 1984

Station	Month	Anchoa mitchilli	Bairdiella chrysura	Cynoscion regalis	Leiostomus xanthurus	Menticirrhus americanus	Micropogon undulatus	Stellifer lanceolatus
TD	MARCH	52	126	*	107	*	*	*
	AUGUST	56	*	215	105	*	102	*
W1	MARCH	58	*	*	*	*	31	66
	AUGUST	32	*	30	*	148	*	20
TE	MARCH	60	*	*	*	144	*	73
	AUGUST	53	*	29	*	*	*	37
DD2	MARCH	65	125	153	186	*	184	*
	AUGUST	29	*	*	*	*	*	62
CR1	MARCH	46	*	*	*	*	22	*
	AUGUST	45	109	194	126	130	149	*
SI1	MARCH	46	122	160	118	*	*	*
	AUGUST	40	155	*	*	*	*	120
TF	MARCH	65	120	110	110	*	87	83
	AUGUST	50	123	128	*	98	129	71
ML1	MARCH **							
	AUGUST	48	93	101	142	65	158	*

* None caught at this station this month
** Station not sampled

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-39. Total Fish Abundance* at Stations Trawled in Kings Bay and Cumberland Sound Since 1976, Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia

		STATION			
YEAR	MONTH/QTR	C	D	E	F
76-77	SUMMER	231	302	556	362
	FALL	582	1057	4895	698
	WINTER	24	20	59	100
	SPRING	198	124	86	107
1978	MAY	131	828	122	160
	AUG	275	238	271	87
	NOV	11	26	343	22
1979	FEB	40	104	177	42
	JUNE	52	43	75	71
	SEPT	44	16	360	185
	DEC	318	412	120	178
1980	FEB	16	28	89	38
	MAY	22	328	894	18
	AUG	200	100	465	9
	NOV	10	2	14	505
1981	FEB	0	7	123	19
	MAY	17	52	89	160
	AUG	67	18	44	246
	NOV	155	103	1250	92
1982	FEB	619	96	38	2083
	MAY	353	683	21	155
	AUG	171	2553	5507	2196
	NOV	NS	NS	NS	NS
1983	FEB	286	302	864	1179
	MAY	NS	NS	NS	NS
	AUG	272	134	32382	918
	NOV	NS	NS	NS	NS
1984	MAR	NS	24	125	33
	MAY	NS	NS	NS	NS
	AUG	NS	14	87	25
	NOV	NS	NS	NS	NS
	MEAN	171	293	1887	373
	SD	174	535	6370	597
	SE	36	105	1249	117
	N	24	26	26	26

* Total number of fish per 30 minutes of trawling
NS = no sampling scheduled

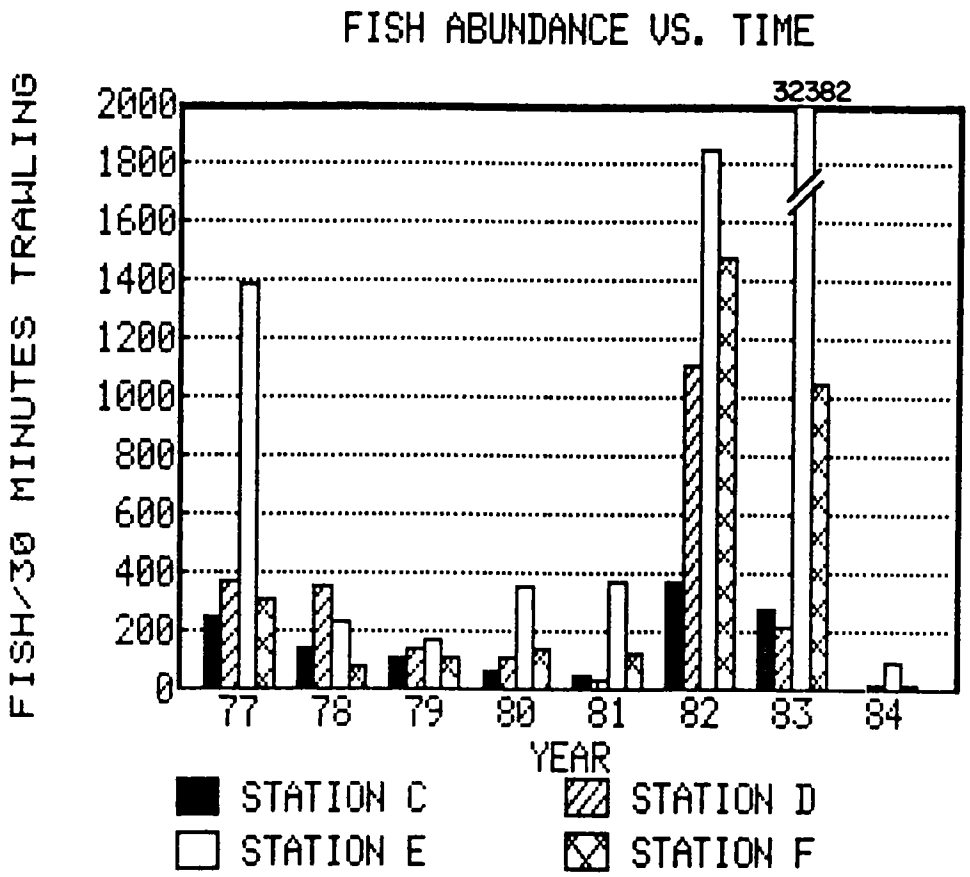
Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-40. Shannon-Weaver Diversity* at Stations Trawled in Kings Bay and Cumberland Sound Since 1976, Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia

		STATION			
YEAR	MONTH/QTR	C	D	E	F
76-77	SUMMER	1.80	2.90	2.40	2.00
	FALL	2.80	2.20	2.00	3.20
	WINTER	2.20	2.00	0.30	1.40
	SPRING	0.50	1.40	2.50	2.30
1978	MAY	2.60	2.40	2.80	2.20
	AUG	2.80	2.20	1.10	3.10
	NOV	1.80	2.40	1.40	3.00
1979	FEB	1.20	0.60	0.20	3.10
	JUNE	1.90	1.60	2.00	3.50
	SEPT	1.10	1.50	0.40	0.90
	DEC	0.44	0.55	1.77	1.12
1980	FEB	0.34	2.13	2.05	1.54
	MAY	2.22	0.38	0.45	1.34
	AUG	0.89	0.40	0.71	2.64
	NOV	1.39	1.00	2.07	0.10
1981	FEB	0.00	0.00	0.07	0.00
	MAY	1.71	0.98	2.67	0.06
	AUG	0.11	2.20	2.73	0.50
	NOV	0.00	0.35	0.09	0.00
1982	FEB	0.80	1.31	0.18	0.29
	MAY	0.05	0.63	2.13	0.76
	AUG	1.57	0.66	0.47	0.56
	NOV	NS	NS	NS	NS
1983	FEB	0.46	2.93	1.48	1.84
	MAY	NS	NS	NS	NS
	AUG	0.38	2.38	0.06	0.92
	NOV	NS	NS	NS	NS
1984	MAR	NS	1.60	1.43	2.41
	MAY	NS	NS	NS	NS
	AUG	NS	2.84	1.40	2.42
	NOV	NS	NS	NS	NS
	MEAN	1.21	1.52	1.34	1.58
	SD	0.92	0.90	0.95	1.13
	SE	0.19	0.18	0.19	0.22
	N	24	26	26	26

*Shannon-Weaver Diversity (d), Log Base 2.
NS = no sampling scheduled

Source: Alvarez, Lehman & Associates, Inc., 1985



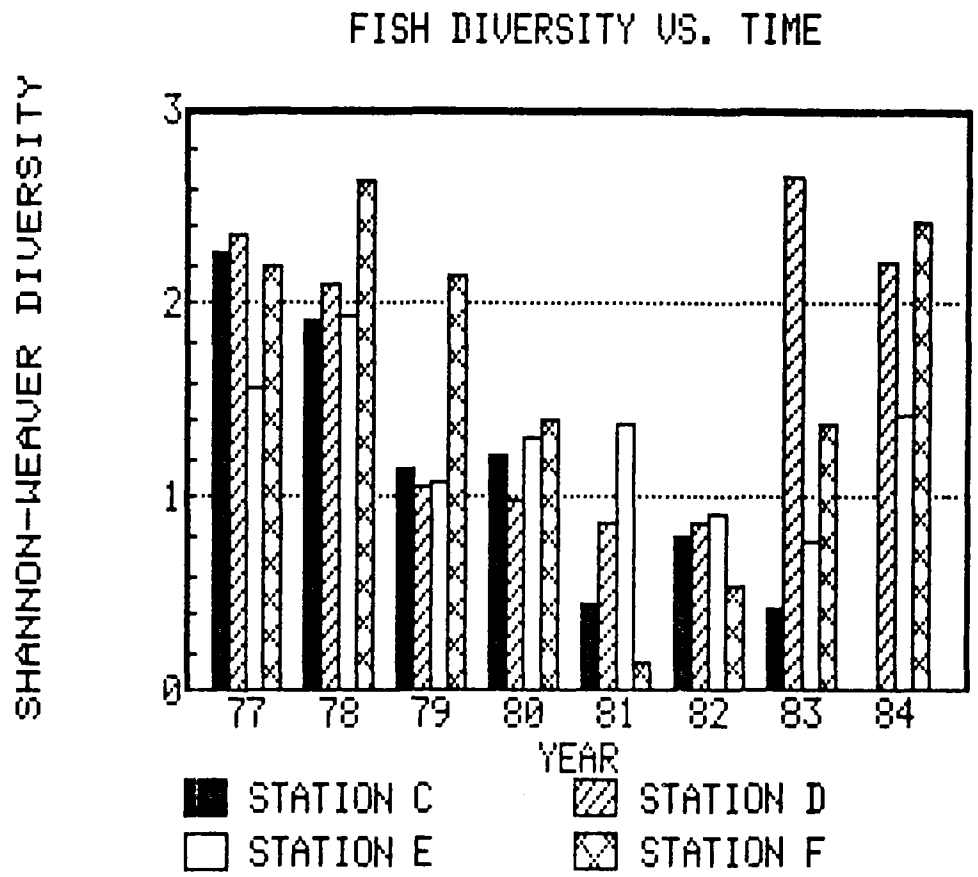
Alvarez, Lehman & Associates, Inc.

FIGURE 3-30. Annual Mean Total Fish Abundance at Stations C, D, E, and F, Naval Submarine Base, Kings Bay, Georgia, 1976-1984

station catch totals averaged below 400 fish. Fish abundance at Station E was also much higher than at the other sites in 1980, 1981, 1982, and 1983. This pattern was not strongly evident during the 1983-1984 monitoring surveys. No long-term trends in total catch records were suggested by this graph.

Of these four sites, Stations D and F have generally demonstrated the highest diversity values during each year (Figure 3-31). No long-term trends are apparent for Stations D, E, or F. A significant correlation (r-square = 0.47) was found between diversity and time at Station C (Figure 3-32); diversity decreased over time. However, no significance is placed on this trend since comparable decrease in diversity was not documented at the Kings Bay sites within the areas most intensively developed by the Navy since 1978.

Preliminary analysis showed that total catch records were not normally distributed. Natural log transformation was performed prior to further analyses. Station means were calculated for the eight-year period and compared using a variance plot (Figure 3-33). Variance plots graphically compare the significance of differences between parameter means. Means are denoted by the X mark, thick and thin vertical bars indicate $\pm$ 1 and $\pm$ 2 standard deviation ranges, and horizontal hash marks represent $\pm$ 1 and $\pm$ 2 standard errors (SE) from the mean. By convention for small sample sizes, means overlapping by $\pm$ 2 SE are not considered significantly different. Long-term means for total fish abundance at these four stations



Alvarez, Lehman & Associates, Inc.

FIGURE 3-31. Annual Mean Shannon-Weaver Diversity Values for Stations C, D, E, and F, Fish Trawl Studies, Naval Submarine Base, Kings Bay, Georgia, 1976-1984

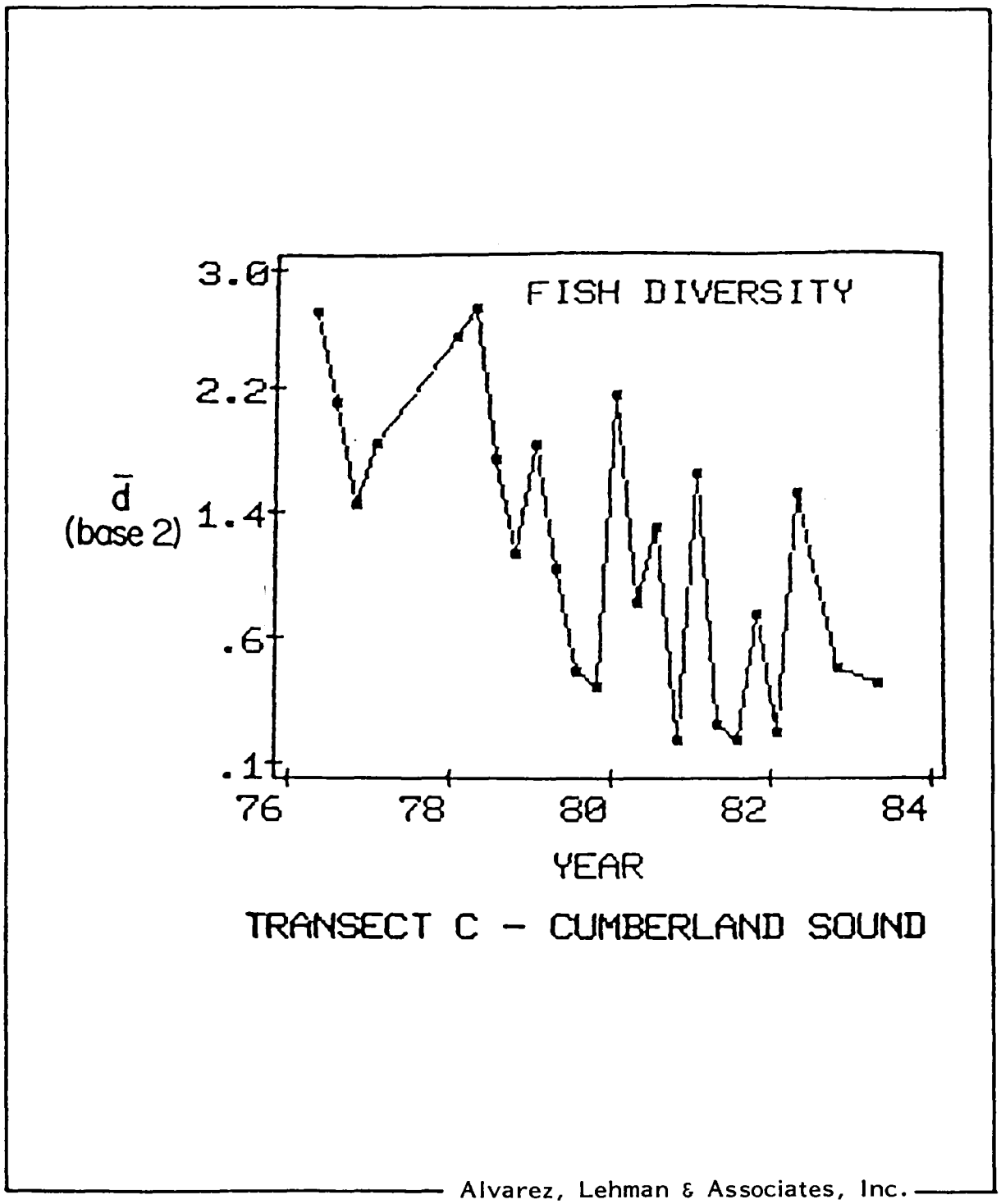
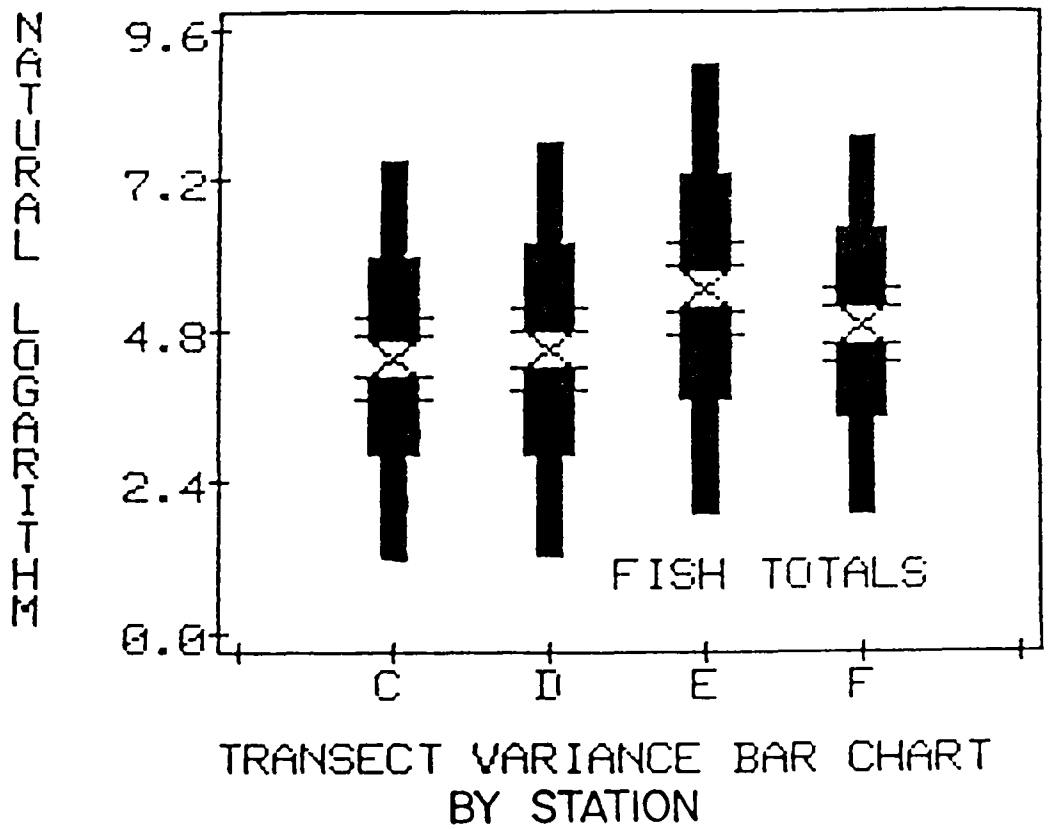


FIGURE 3-32. Shannon-Weaver Diversity at Station C, Fish Trawl Studies, Naval Submarine Base, Kings Bay, Georgia, 1976-1984



Alvarez, Lehman & Associates, Inc.

FIGURE 3-33. Comparison of Mean Total Fish Abundance During Long-Term Trawl Studies, Naval Submarine Base, Kings Bay, Georgia, 1976-1984

were not significantly different.

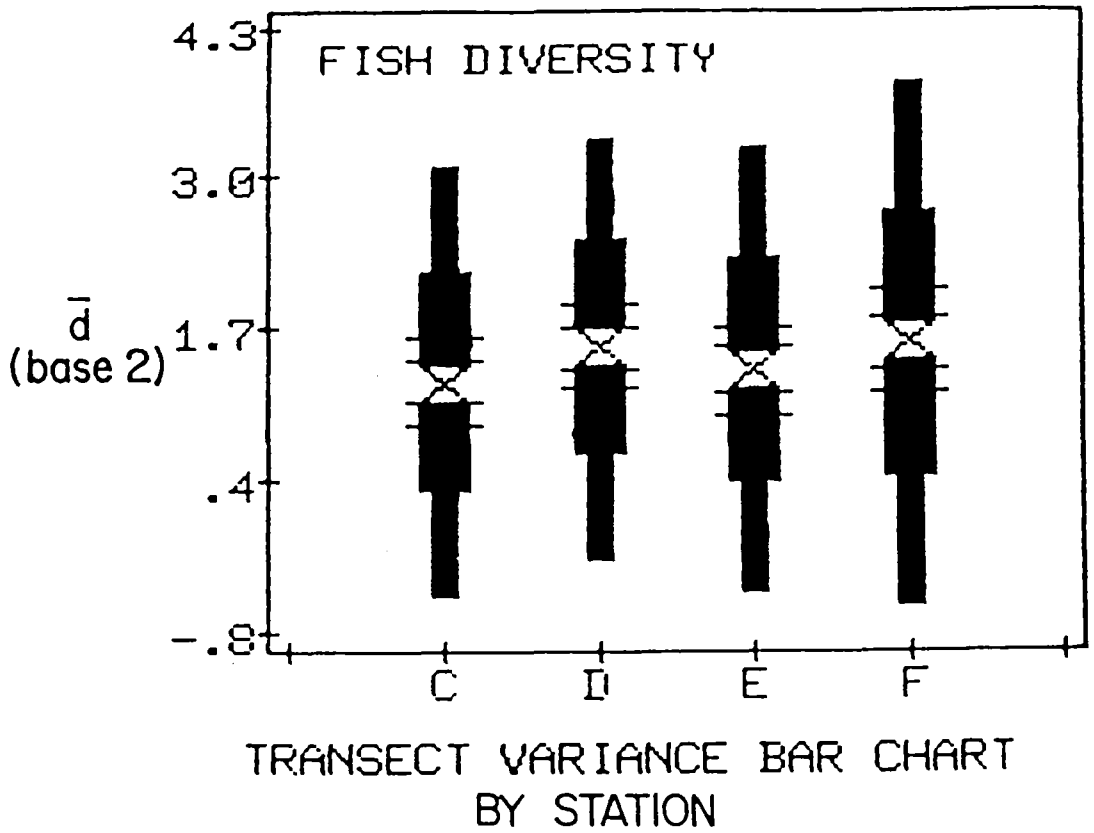
Means for Shannon-Weaver diversity at each station based on all routine trawl records generated between 1976 and 1984 were also compared using a variance plot (Figure 3-34). No significant differences between station means for this parameter were indicated.

Hence, 1983-1984 trawl studies demonstrated reduced fish abundance and diversity in Kings Bay when compared to control sites in Cumberland Sound and other adjacent areas. These impacts are presumed to be short-term in nature. Impact severity and longevity will be assessed by ongoing monitoring. Statistically significant long-term impacts have not been demonstrated.

3.8.4 Oyster Tissue

Bivalves are one of the best indicators of pollution in estuarine waters due to their ability to accumulate certain trace metals and organic compounds (Goldberg *et al.*, 1978) and their sessile nature. Trace metals, polycyclic aromatic hydrocarbons (PAH's), chlorinated hydrocarbon pesticides and polychlorinated biphenyls (PCB's) in oyster tissue from within Kings Bay and the Cumberland Sound estuarine complex have been monitored since 1978.

Over these years, station coverage and the list of analytical



Alvarez, Lehman & Associates, Inc.

FIGURE 3-34. Comparison of Mean Shannon-Weaver Diversity During Long-Term Trawl Studies, Naval Submarine Base, Kings Bay, Georgia, 1976-1984

parameters has varied. Four of the original oyster bars were monitored during 1983-1984 and three of these have retained their original station numbers (0-1, 0-2 and 0-3). Station 0-5 was referred to as Station 4 during previous years and Station 0-4 was added during this monitoring year. During 1983-1984, trace metal analyses were for mercury, lead, cadmium, chromium and copper.

Oyster tissue trace metal concentrations found during 1983-1984 (Tables 3-41 and 3-42) were within the range of values reported between 1978 and 1982.

Since 1976, oyster reefs along the western shore of Kings Bay have been removed by dredging and other Navy related construction activities (Alvarez, Lehman & Associates, Inc., 1985h). One of the remaining oyster bars (Station 0-1) located in upper Kings Bay has consistently shown higher tissue concentrations for copper than any other oyster reef in the study area. Copper levels again exceeded those of sites elsewhere in the study area in August 1984 (Figure 3-35). Chromium levels were also higher at this site.

Although it has been postulated that higher than average tissue burdens of copper may be related to SUBASE activities, analysis of estuarine water and sediment samples collected from upper Kings Bay area have not shown levels of copper which were significantly higher than other sites in Kings Bay or Cumberland Sound. Potential copper sources in Kings

TABLE 3-41. Summary of Oyster Tissue Contamination Data, Naval Submarine Base, Kings Bay, Georgia, February 1984

Parameter	Station Designation				
	O-1	O-2	O-3	O-4	O-5
Date Sampled	2/25/84	2/25/84	2/25/84	2/25/84	2/25/84
Percent Moisture	87.77	86.18	87.47	87.12	88.19
Metals*					
Mercury	0.1	0.055	0.075	<0.008	<0.008
Lead	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium	0.20	0.27	0.25	0.23	0.24
Chromium	0.24	0.56	0.22	0.36	0.28
Copper	13	11	11	11	8.6
Polycylclic Aromatic Hydrocarbons (PAH's)*					
Acenaphthene	22	20	3	6	5
Phenanthrene	6	3	5	12	11
Methylphenanthrene	BD	4	4	6	3
Fluoranthene	0.8	1.5	1.3	1.0	2.5
Benzofluorene	0.03	0.02	0.04	0.04	0.05
Benzo(b)fluoranthene	0.8	0.2	0.6	0.3	0.2
Benzo(a)pyrene	BD	BD	0.04	BD	BD
Chlorinated Hydrocarbon Pesticides & PCB's	BD	BD	BD	BD	BD

* all values are reported as milligrams per kilogram, wet weight except PAH's which are expressed as nanograms per gram, wet weight
BD = Below Detection

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-42. Summary of Oyster Tissue Contamination Data, Naval Submarine Base, Kings Bay, Georgia, August 1984

Parameter	Station Designation				
	0-1	0-2	0-3	0-4	0-5
Date Sampled	8/25/84	8/24/84	8/22/84	8/22/84	2/24/84
Percent Moisture	86.62	90.03	88.85	88.07	90.28
Metals*					
Mercury	<0.0031	<0.0028	<0.0024	<0.0023	<0.0039
Lead	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium	0.22	0.05	0.04	0.04	0.08
Chromium	0.68	0.32	0.34	0.35	0.61
Copper	19	4.4	8.3	13	7.2
Polycylclic Aromatic Hydrocarbons (PAH's)*					
Acenaphthene	1	2	3	3	2
Phenanthrene	2	1	3	2	4
Methylphenanthrene	1	1	2	1	3
Fluoranthene	2.7	6.5	0.5	1.9	10
Benzofluorene	BD	BD	BD	BD	
Benzo(b)fluoranthene	1.4	1.8	0.8	1.4	2.7
Benzo(a)pyrene	BD	BD	0.01	0.2	0.8
Chlorinated Hydrocarbon Pesticides & PCB's	BD	BD	BD	BD	BD

* all values are reported as milligrams per kilogram, wet weight except PAH's which are expressed as nanograms per gram, wet weight
BD = Below Detection

Source: Alvarez, Lehman & Associates, Inc., 1985

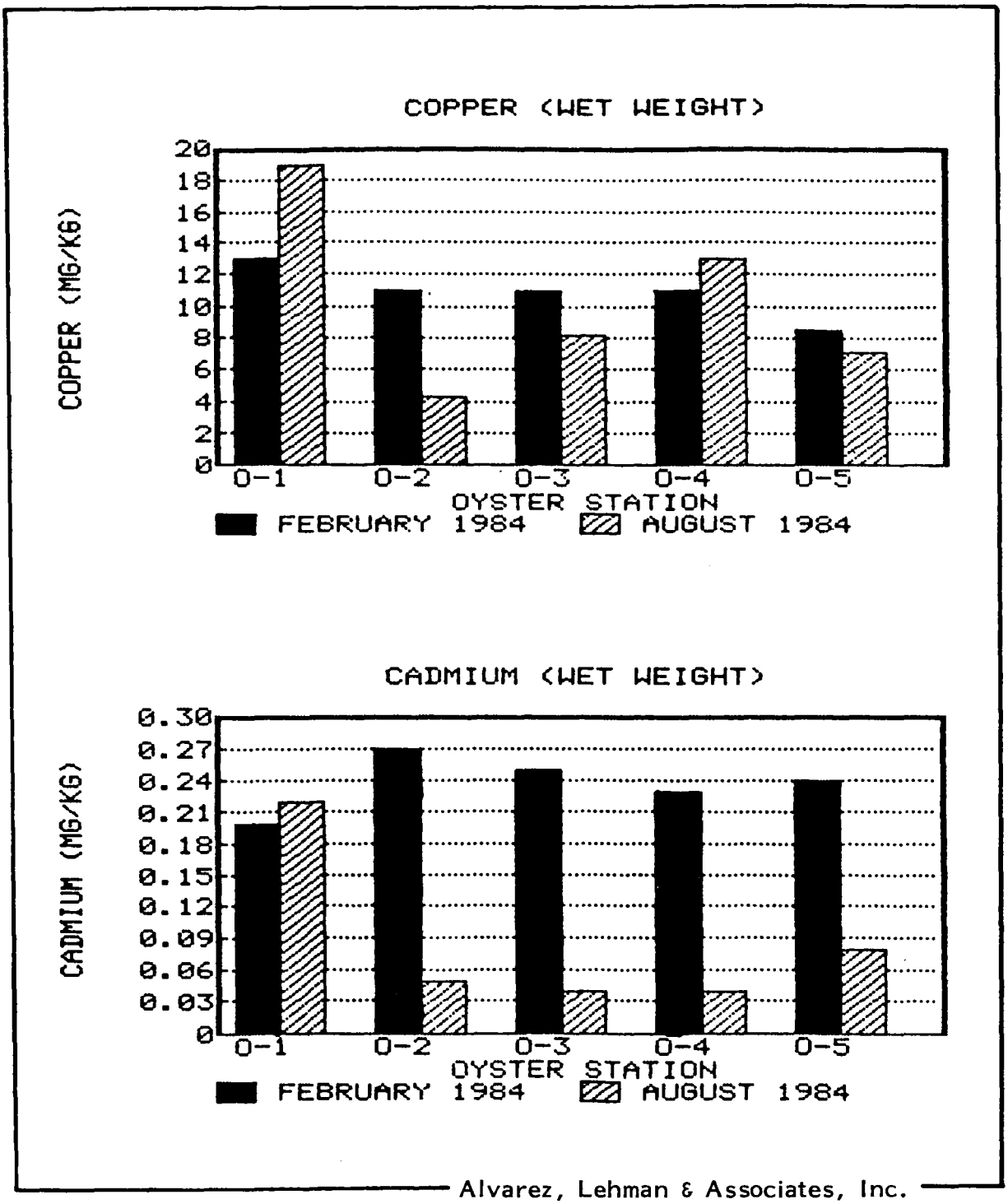


FIGURE 3-35. Total Copper and Cadmium Concentrations in Eastern Oysters from Kings Bay and Cumberland Sound, Georgia, 1983-1984

Bay include use of copper-based anti-fouling paints on Naval vessels. However, no cause and effect relations have yet been documented.

No chlorinated hydrocarbons or PCB's were detected in oyster tissues collected during 1983-1984.

Polycyclic aromatic hydrocarbon analysis results show total oyster tissue concentrations of these compounds were approximately 80-85 percent less during 1984 than in 1983. Prior data indicate that PAH concentrations in oyster tissues generally increase as the stations get closer to the St. Marys entrance channel (Jones, Edmunds & Associates, Inc., 1984). This pattern and the fact that most PAH's detected are by-products of combustion of hydrocarbon fuels indicate that these contaminants may be a result of boat traffic in the St. Marys entrance, or from industrial operations in St. Marys and Fernandina Beach. Since the Navy does not generate all the boat traffic in the area PAH's documented in oyster tissues are not necessarily a result of Navy activity in the area.

3.8.5 Swamp Vegetation/Wells

In order to assess the impacts from construction activities on hardwood swamps of SUBASE, six permanent vegetative quadrats were established. These swamps included one floodplain forest, four cypress-gum swamps, and one gum swamp. Monitoring wells were established to provide long-term information on hydrological and vegetative relationships.

Because this was the initial sampling year, impacts from construction activities on hydroperiod were not readily apparent (Table 3-43). Thus, an analysis of the relationships between hydrological changes and vegetative responses was not attempted. With continued monitoring, these relationships may be evaluated.

Station S-1 (North of Family Housing)

Station S-1 contained three species in the overstory with pond-cypress (*Taxodium ascendens*) the most abundant species (see Table 3-44). Other species included swamp tupelo (*Nyssa biflora*) and slash pine (*Pinus elliotti*) . These same species occurred in the understory although swamp tupelo was much more abundant in this stratum (relative density of 80.6 percent). Other common species in the understory were wax myrtle (*Myrica cerifera*), dahoon holly (*Ilex cassine*) , and red maple (*Acer rubrum*) . Total stem density for the overstory and understory were 310 and 1,750 stems/hectare (ha), respectively. Although somewhat less dense, Station S-1 was very similar to Station S-6 in the shrub layer (4,700 stems/ha). Ground cover vegetation was very sparse (less than 2 percent) and included 5 species (Table 3-45). None of the overstory species were present in the ground cover.

Station S-2 (Near Sprayfield East of Family Housing)

Results of the survey at Station S-2 are shown in (Table 3-46)

TABLE 3-43. Results of Swamp Well Water Level Monitoring, Naval Submarine Base, Kings Bay, Georgia, December 1983 to August 1984

Well	Total Well Depth Below Surface (m)	Distance to Water Table from Ground Surface (m) DEC 83	MAR 84	MAY 84	AUG 84
S-1	1.07	-0.17	0	-0.65	-0.05
S-2	1.52	-0.70	+0.24	-1.03	-0.50
S-3	0.61	+0.21	+0.33	DRY	-0.34
S-4	1.07	+0.06	+0.41	0	0
S-5	1.22	-0.26	+0.15	-0.06	0
S-6	1.22	-0.28	-0.22	-0.49	-0.45

m = meters

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-44. Vegetational Characteristics of Hardwood Swamp Station S-1, Naval Submarine Base, Kings Bay, Georgia, May 1984

Stratum (Size Range)	Species	Density (Stems/Hectare)	Relative Density (% of Total)
Overstory (25.0-64.0 cm dbh*)	Nyssa biflora	60	19.4
	Taxodium ascendens	240	77.4
	Pinus elliotti	10	3.2
	TOTAL	310	100
Understory (12.7-25.0 cm dbh)	Nyssa biflora	1,410	80.6
	Taxodium ascendens	240	13.7
	Myrica cerifera	40	2.3
	Ilex cassine	30	1.7
	Pinus elliotti	20	1.1
	Acer rubrum	10	0.6
	TOTAL	1,750	100
Shrub Layer (0-12.7 cm dbh)	Lyonia lucida	3,180	67.7
	Nyssa biflora	930	19.8
	Myrica cerifera	280	6.0
	Ilex cassine	230	4.9
	Cephalanthus occidentalis	50	1.1
	Juniperus silicicola	10	0.2
	Fraxinus caroliniana	10	0.2
	Salix caroliniana	10	0.2
	TOTAL	4,700	100.1

*dbh = diameter at breast height.

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-45. Ground Cover Vegetation at Hardwood Swamp Station S-1, Naval Submarine Base, Kings Bay, Georgia, May 1984

Species	% Cover	% Frequency
Ilex cassine	0.1	4.0
Lyonia lucida	0.04	4.0
Cepthalanthus occidentalis	0.30	12.0
Woodwardia virginica	1.0	8.0
Smilax bona-nox	0.04	4.0
TOTAL	1.48	

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-46. Vegetational Characteristics of Hardwood Swamp Station S-2, Naval Submarine Base, Kings Bay, Georgia, May 1984

Stratum (Size Range)	Species	Density (Stems/Hectare)	Relative Density (% of Total)
Overstory (25.0-64.0 cm, dbh*)	*Nyssa biflora*	230	51.1
	Taxodium ascendens	210	46.7
	Pinus elliotti	10	2.2
	TOTAL	450	100.0
Understory (12.7-25.0 cm, dbh)	*Nyssa biflora*	290	90.6
	Taxodium ascendens	20	6.3
	Ilex cassine	10	3.1
	TOTAL	320	100.0
Shrub Layer (0-12.7 cm, dbh)	*Lyonia lucida*	200	43.5
	Persea palustris	250	54.3
	Acer rubrum	10	2.2
	TOTAL	460	100.0

*dbh = diameter at breast height.

Source: Alvarez, Lehman & Associates, Inc., 1985

indicated that this system was very similar to Site S-4 with pond cypress and swamp tupelo the dominant species in the two upper strata. Both were also present in the understory. Swamp tupelo was much more important with a relative density of 90.6 percent compared to 6.3 percent for cypress. Shrub and ground cover (Table 3-47) were very similar to the corresponding strata at Site S-4. This swamp has been undergoing long term changes due to the effects of a nearby drainage ditch. The system has been burned in the recent past which may in part explain some of the missing lower age classes of trees.

Station S-3 (Family Housing)

Three tree species dominated the overstory stratum of Station S-3 (Table 3-48). Pond cypress was by far the most abundant species with 300 stems/ha, while swamp tupelo (60 stems/ha) and slash pine (60 stems/ha) occurred in similar abundance. Total density was 420 stems/ha.

The understory component included the same species as in the overstory. However, swamp tupelo comprised a much more significant percentage of the understory (38.1 percent) compared to the overstory (14.3 percent). Slash pine accounted for approximately the same proportion of each of the upper two layers. Other species present included dahoon holly and wax myrtle. Total stem density was nearly twice that of the overstory with 813 stems/ha.

TABLE 3-47. Ground Cover Vegetation at Hardwood Swamp Station S-2, Naval Submarine Base, Kings Bay, Georgia, May 1984

Species	% Cover	% Frequency
Nyssa biflora	0.24	40.0
Acer rubrum	0.22	36.0
Osmunda cinnacomea	0.64	12.0
Smilax bona-nox	0.08	8.0
Woodwardia areolata	0.60	16.0
Persea palustris	1.2	12.0
Rhus radicans	0.1	4.0
Serenoa repens	0.5	4.0
TOTAL	3.58	

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-48. Vegetational Characteristics of Hardwood Swamp Station S-3, Naval Submarine Base, Kings Bay, Georgia, May 1984

Stratum (Size Range)	Species	Density (Stems/Hectare)	Relative Density (% of Total)
Overstory (25.0-64.0 cm, dbh*)	Nyssa biflora	60	14.3
	Taxodium ascendens	300	71.4
	Pinus elliotti	60	14.3
	TOTAL	420	100.0
Understory (12.7-25.0 cm, dbh)	Nyssa biflora	310	38.1
	Taxodium ascendens	410	50.4
	Pinus elliotti	70	8.6
	Ilex cassine	20	2.5
	Myrica cerifera	3	0.4
	TOTAL	813	100.0
Shrub Layer (0-12.7 cm, dbh)	Lyonia lucida	701	51.5
	Pinus elliotti	10	0.07
	Ilex cassine	150	11.0
	Sabal palmetto	10	0.7
	Myrica cerifera	60	4.4
	Litsea aestivalis	430	31.6
	TOTAL	1,361	99.9

*dbh = diameter at breast height.

Source: Alvarez, Lehman & Associates, Inc., 1985

The shrub layer contained six species with fetter bush occurring in the greatest abundance (201 stems/ha). Pond spice (Litsea aestivalis) occurred at a relative density of 31.6 percent. This species is presently being considered for inclusion on the Federal Endangered Species list and should be monitored for possible impacts. Other species were numerous but occurred much less frequently than the above mentioned species. Total stem density in the shrub layer was 1,361 stems/ha. Ground cover vegetation (Table 3-49) was very sparse with litter accounting for approximately 97 percent of the area in the subquadrats. A total of four species were observed, including sedges (Carex spp.), Virginia chain fern (Woodwardia virginica), swamp tupelo, and fetter bush (Lyonia lucida).

This system is a cypress dome surrounded by cut-over pine flatwoods. Cypress were notably absent in all layers except the overstory. Swamp tupelo and red maple are reproducing in the lower strata. This system is likely to change with increased impacts on the hydroperiod due to nearby base development.

Station S-4 (West of DPDO Site)

Three species occurred in the overstory at Station S-4 with pond cypress and swamp tupelo the dominant species (Table 3-50). Slash pine occurred as scattered old individuals throughout the system. Total density was 350 stems/ha.

TABLE 3-49. Ground Cover Vegetation at Hardwood Swamp Station S-3, Naval Submarine Base, Kings Bay, Georgia, May 1984

Species	% Cover	% Frequency
Carex, sp.	0.56	28.0
Woodwardia virginica	1.4	12.0
Nyssa biflora	0.4	4.0
Lyonia lucida	0.4	4.0
TOTAL	2.76	

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-50. Vegetational Characteristics of Hardwood Swamp Station S-4, Naval Submarine Base, Kings Bay, Georgia, May 1984

Stratum (Size Range)	Species	Density (Stems/Hectare)	Relative Density (% of Total)
Overstory (25.0-64.0 cm, dbh*)	*Nyssa biflora*	100	28.6
	Taxodium ascendens	190	54.3
	Pinus elliotti	60	17.1
	TOTAL	350	100.0
Understory (12.7-25.0 cm, dbh)	*Nyssa biflora*	800	86.0
	Taxodium ascendens	110	11.8
	Ilex cassine	10	3.1
	TOTAL	930	100.0
Shrub Layer (0-12.7 cm, dbh)	*Nyssa biflora*	750	9.4
	Lyonia lucida	7,110	89.5
	Acer rubrum	10	0.1
	Ilex cassine	20	0.3
	Cephalanthus occidentalis	10	0.1
	Myrica cerifera	10	0.1
	Persea palustris	30	0.4
	TOTAL	7,940	99.9

*dbh = diameter at breast height.

Source: Alvarez, Lehman & Associates, Inc., 1985

The understory contained four species and included all species occurring in the overstory. Swamp tupelo (86.0 percent) was the most abundant species. Pond cypress was second with a relative density of 11.6 percent while slash pine and dahoon holly were present but at a low relative density (1.1 percent each). Sapling density for the stand as a whole was 930 stems/ha.

In the shrub layer, swamp tupelo was an abundant species (750 stems/ha). However, fetter bush was by far the most abundant with 7,110 stems/ha. Total stem density was 7,940 stems/ha.

Five species occurred in the herbaceous layer (ground cover). One species, swamp tupelo, comprised 0.56 percent of the ground cover. The remaining four species occupied another 1.08 percent of the ground cover. Hence, vegetation only covered 2 percent of the forest floor with the remaining 98 percent being covered by leaf litter (Table 3-51).

Swamp tupelo and pond cypress occurred about equally in the overstory. The dominance of swamp tupelo and the decline of pond cypress in the other strata suggest that hydrological conditions have changed in the recent past. The existing dirt road and/or the ditching in the area may have changed surface water flow movements in the area producing hydrological conditions more suitable for swamp tupelo. Since pond cypress in not presently reproducing, the overall structure of this system is likely to continue to change. Future monitoring surveys will address the possibility

TABLE 3-51. Ground Cover Vegetation at Hardwood Swamp Station S-4, Naval Submarine Base, Kings Bay, Georgia, May 1984

Species	% Cover	% Frequency
Nyssa biflora	0.56	44.0
Taxodium ascendens	0.04	8.0
Woodwardia virginica	0.4	4.0
Lyonia lucida	0.6	12.0
Acer rubrum	0.04	4.0
TOTAL	1.64	

Source: Alvarez, Lehman & Associates, Inc., 1985

of relationships between SUBASE development and changes in hardwood swamp vegetation in this area.

Station S-5 (Cypress Dome Island in Lake D)

At Station S-5, swamp tupelo was the only species in the overstory and occurred at a density of only 20 stems/ha (see Table 3-52). Compared to the other systems studied, this one contained only 15 percent as many trees as the next lowest stand (Station S-6). The understory contained 460 stems/ha with swamp tupelo accounting for 97.8 percent of the coverage.

The shrub layer was similar to the overstory in containing only 11.5 percent of the shrub coverage observed at the other five systems. The shrub layer contained six species. Swamp tupelo was the most abundant species with a relative density of 54.3 percent. The other five species accounted for an average of 9 percent of the shrub layer. Because of the open characteristics of the upper strata, ground cover was the most extensive of the systems surveyed, with a percent cover of 30.5. Sedge species contributed 16.7 percent followed by grasses (*Panicum* sp.) and pickeral weed (*Pontederia cordata*) (Table 3-53).

Station S-6 (Transmission Line Corridor Near St. Marys Gate)

Four tree species occurred in the overstory sample at Station S-6 (Table 3-54). Live oak (*Quercus virginiana*) had a relative density of

TABLE 3-52. Vegetational Characteristics of Hardwood Swamp Station S-5, Naval Submarine Base, Kings Bay, Georgia, May 1984

Stratum (Size Range)	Species	Density (Stems/Hectare)	Relative Density (% of Total)
Overstory (25.0-64.0 cm, dbh*)	*Nyssa biflora*	20	100.0
	TOTAL	20	100.0
Understory (7.6-25.0 cm, dbh)	*Nyssa biflora*	450	97.8
	Taxodium ascendens	10	2.2
	TOTAL	460	100.0
Shrub Layer (0-7.6 cm, dbh)	*Nyssa biflora*	190	54.3
	Myrica cerifera	40	11.4
	Ilex glabra	40	11.4
	Vaccinium sp.	30	8.6
	Lyonia lucida	30	5.7
	TOTAL	350	100.0

*dbh = diameter at breast height.

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-53. Ground Cover Vegetation at Hardwood Swamp Station S-5, Naval Submarine Base, Kings Bay, Georgia, May 1984

Species	% Cover	% Frequency
Carex sp.	16.7	88.0
Panicum sp.	6.0	52.0
Pontederia cordata	5.2	48.0
Juncus sp.	2.6	4.0
TOTAL	30.5	

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-54. Vegetational Characteristics of Hardwood Swamp Station S-6, Naval Submarine Base, Kings Bay, Georgia, May 1984

Stratum (Size Range)	Species	Density (Stems/Hectare)	Relative Density (% of Total)
Overstory (25.0-64.0 cm, dbh*)	Quercus virginiana	90	69.2
	Acer rubrum	10	7.7
	Juniperus silicicola	10	7.7
	Fraxinus caroliniana	20	15.4
	TOTAL	130	100.0
Understory (12.7-25.0 cm dbh)	Persea palustris	80	20.0
	Cornus foemina	30	7.5
	Acer rubrum	20	5.0
	Juniperus silicicola	20	5.0
	Ulmus americana	60	15.0
	Magnolia virginiana	20	5.0
	Liquidambar styraciflua	40	10.0
	Morus rubra	10	2.5
	Fraxinus caroliniana	80	20.0
	Quercus hemisphnerica	20	5.0
	Nyssa biflora	10	2.5
	Celtis laevigata	10	2.5
	TOTAL	400	100.0
Shrub Layer (0-12.7 cm, dbh)	Persea palustris	130	3.4
	Cornus foemina	400	10.6
	Myrica cerifera	680	18.0
	Serenoa repens	1,900	50.3
	Sabal palmetto	30	0.8
	Acer rubrum	30	0.8
	Juniperus silicicola	60	1.6
	Ulmus americana	10	0.3
	Berchemia scandens	130	3.4
	Parthenocissus quinguefolia	60	1.6
	Toxicodendron radicans	210	5.6
	Fraxinus caroliniana	40	1.1
	Ilex vomitoria	10	0.3
	Vitis rotundifola	50	1.3
	Cepthalanthus occidentalis	30	0.8
	Vitis cinerea	10	0.3
	TOTAL	3,780	100.2

*dbh = diameter at breast height.

Source: Alvarez, Lehman & Associates, Inc., 1985

69.2 percent while water ash (Fraxinus caroliniana) had 15.4 percent and red maple and red cedar (Juniperus silicicola) each had a relative density of 7.7 percent. Total stem density was 130 trees/ha. Site 6 had about 37.0 percent as many trees in the overstory as Site 4.

Sapling density was 400 stems/ha. Swamp red bay (Persea palustris) and water ash each accounted for 20 percent of the understory. American elm (Ulmus americana) was the next most common species accounting for 15 percent of the trees in the quadrat. The remaining 9 species accounted for 45 percent of the total. All species present in the overstory, except live oak were present in the understory. This site was much more diverse, particularly in the understory, than Site 4. The shrub layer contained 16 species. Saw palmetto (Serenoa repens) was the most abundant species with 1,900 stems/ha (50.3 percent). Wax myrtle and swamp dogwood (Cornus foemina) were the two next most abundant species. All overstory species, except live oak, were present in this strata. Total stem density was 3,780 stems/ha.

Ground cover vegetation (Table 3-55) amounted to just over 10 percent and leaf litter occupied just under 90 percent of the subquadrat. A total of 12 species were encountered of which 10 averaged less than 1 percent of the vegetation cover. Two species, lizard's tail(Saururus cernuus) and poison ivy (Toxicodendron radicans) accounted for 5.7 and 1.98 percent of the cover, respectively.

TABLE 3-55. Ground Cover Vegetation at Hardwood Swamp Station S-6, Naval Submarine Base, Kings Bay, Georgia, May 1984

Species	% Cover	% Frequency
Cladium jamaicense	0.04	4.0
Saururus cernuus	5.7	28.0
Berchemia scandens	0.6	24.0
Toxicodendron radicans	1.98	36.0
Arisaena triphyllum	0.50	12.0
Myrica cerifera	0.50	4.0
Cornus foemina	0.14	12.0
Persea palustris	0.30	4.0
Viola sp.	0.06	8.0
Ampelopsis arborea	0.04	4.0
Parthenocissus quinquefolia	0.06	8.0
Acer rubrum	0.10	4.0
TOTAL	10.02	

Source: Alvarez, Lehman & Associates, Inc., 1985

This is a floodplain forest which occurs along a small stream. As indicated by the diversity of vegetation and tree reproduction in the lower strata, this is a stable climax association.

In general, all systems surveyed were relatively healthy and reproducing. Some change in species dominance may have occurred because of past impacts on surface water drainage patterns. Because of the relatively short period of time between these monitoring studies and base development-related changes to surface and groundwater systems, no impact assessment was possible. These impacts will be assessed as this monitoring study proceeds.

3.8.6 Saltmarsh Vegetation

Development of SUBASE has resulted in loss of saltmarsh in the area. Waterfront construction, including bulkhead construction, development of dredged material disposal areas, effluent discharges from disposal areas, and hydraulic dredge pipeline placement have impacted saltmarshes along Kings Bay, Cumberland Sound, and Mill Creek. Additional impacts to SUBASE area saltmarshes may occur from runoff which introduces contaminants and deposits sediments to the marshes. Any alteration of marsh surface elevation would impact the frequency, depth, and duration of tidal inundation, all of which affect growth form zonation within the marsh (Johnson, *et al.*, 1974).

Saltmarsh monitoring has been conducted as part of environmental monitoring at SUBASE since 1978. Historical records show SUBASE marshes have high productivity typical of Georgia saltmarsh systems. Past monitoring was conducted on a quarterly basis and station locations did not allow for data interpretation in terms of SUBASE construction effects.

From 1978-1982, general areas monitored were Kings Bay, Cumberland Sound, and North River. Monitoring during 1982-1983 attempted to focus on SUBASE-related effects on saltmarsh habitats near Kings Bay by shifting station locations to points likely to be affected by base drainage and adding control station sampling. Sites monitored included two locations on the North River near SUBASE surface runoff drains, and one site adjacent to the Big Crab Island dredged material disposal area effluent outfall. In addition to biomass estimation, analyses were directed toward assessing stalk height and leaf width characteristics at each site.

Saltmarsh monitoring during 1983-1984 was performed on a monthly basis. Only one of the six sites monitored monthly from February to August 1984 was monitored between 1978 and 1983 (summer) making meaningful comparison of results with historical data on a station by station basis difficult. General monitoring of saltmarsh conditions along North River, Mill Creek, Crooked River, and Cumberland Island near Greyfield Inn was also conducted. Monthly sampling between February and August spanned a standard growing season to allow estimation of annual saltmarsh vegetative production within the Kings Bay study area.

Results of monthly saltmarsh monitoring surveys are detailed by replicate for February through August 1984 in Appendix D. Three randomly selected sites were sampled each month along a 50-meter transect established at each station. Data presented by replicate showed considerable variability between replicates during a given month due to saltmarsh vegetation zonation within the 50-meter zone. Monthly mean values reflected the influence of relative position of each quadrat, and logical growth increments were not always documented.

Monthly means for stalk height, stalk biomass (live and dead fractions), and below-ground (root) biomass were calculated for each station. These means were used to generate parameter means for the entire 7-month period at each station (Tables 3-56 to 3-61). Review of study period means showed saltmarsh vegetation within the North River basin was distinctively different from that in Mill Creek, Crooked River, and Cumberland Island. Stations located along North River north of the New Point Peter Road Bridge (M1 and M5) had mean stalk heights of approximately 100 cm in contrast to mean heights of 45 and 57 cm at Mill Creek sites, and 40 and 50 cm on Cumberland Island and along Crooked River, respectively (Figure 3-36). Live stalk dry-weight biomass at North River sites was three to four times as high as at any of the other sites (Figure 3-37). In contrast, root biomass at the North River stations averaged 40 to 50 percent of the below-ground biomass estimates for the other locations (Figure 3-38).

TABLE 3-56. Monthly and Study Period Means for Smooth Cordgrass Parameters at Station M1, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia February Through August 1984

STATION	MONTH	STALK HEIGHT (CENTIMETERS)	DRY WEIGHT BIOMASS (GRAMS/SQUARE METER)			
			LIVE	DEAD	TOTAL	ROOTS
M1	FEBRUARY	76	223	918	1141	2708
	MARCH	111	699	1045	1744	2875
	APRIL	100	809	951	1761	4500
	MAY	109	1303	919	2222	ND
	JUNE	132	1565	680	2245	3250
	JULY	105	847	398	1245	3042
	AUGUST	92	811	315	1126	4583
	MEAN	104	894	747	1641	3493
	STANDARD DEVIATION	17	432	289	483	832
	STANDARD ERROR	7	163	109	183	340

ND = No data

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-57. Monthly and Study Period Means for Smooth Cordgrass Parameters at Station M2, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia February Through August 1984

STATION	MONTH	STALK HEIGHT (CENTIMETERS)	DRY WEIGHT BIOMASS (GRAMS/SQUARE METER)			
			LIVE	DEAD	TOTAL	ROOTS
M2	FEBRUARY	31	90	391	481	5333
	MARCH	49	126	345	471	6542
	APRIL	42	191	255	446	8000
	MAY	47	215	329	544	ND
	JUNE	49	227	238	465	8667
	JULY	45	333	145	478	6917
	AUGUST	50	425	134	559	8625
	MEAN	45	230	262	492	7347
	STANDARD DEVIATION	7	116	99	42	1318
	STANDARD ERROR	3	44	37	16	538

ND = No data

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-58. Monthly and Study Period Means for Smooth Cordgrass Parameters at Station M3, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, February Through August 1984

STATION	MONTH	STALK HEIGHT (CENTIMETERS)	DRY WEIGHT BIOMASS (GRAMS/SQUARE METER)			
			LIVE	DEAD	TOTAL	ROOTS
M3	FEBRUARY	19	113	354	467	4917
	MARCH	35	118	269	387	4083
	APRIL	47	202	321	523	4417
	MAY	40	209	218	427	ND
	JUNE	54	467	348	815	8292
	JULY	42	199	115	314	5167
	AUGUST	44	293	117	409	7750
	MEAN	40	229	249	477	5771
	STANDARD DEVIATION	11	121	102	162	1792
	STANDARD ERROR	4	46	39	61	731

ND = No data

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-59. Monthly and Study Period Means for Smooth Cordgrass Parameters at Station M4, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, February Through August 1984

STATION	MONTH	STALK HEIGHT (CENTIMETERS)	DRY WEIGHT BIOMASS (GRAMS/SQUARE METER)			
			LIVE	DEAD	TOTAL	ROOTS
M4	FEBRUARY	27	79	333	412	4000
	MARCH	42	109	339	449	6542
	APRIL	52	281	202	483	11292
	MAY	49	283	276	559	7438
	JUNE	71	591	401	991	5333
	JULY	54	243	173	416	7250
	AUGUST	58	418	178	596	5625
	MEAN	50	286	272	558	6783
	STANDARD DEVIATION	14	176	90	203	2317
	STANDARD ERROR	5	67	34	77	876

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-60. Monthly and Study Period Means for Smooth Cordgrass Parameters at Station M5, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, February Through August 1984

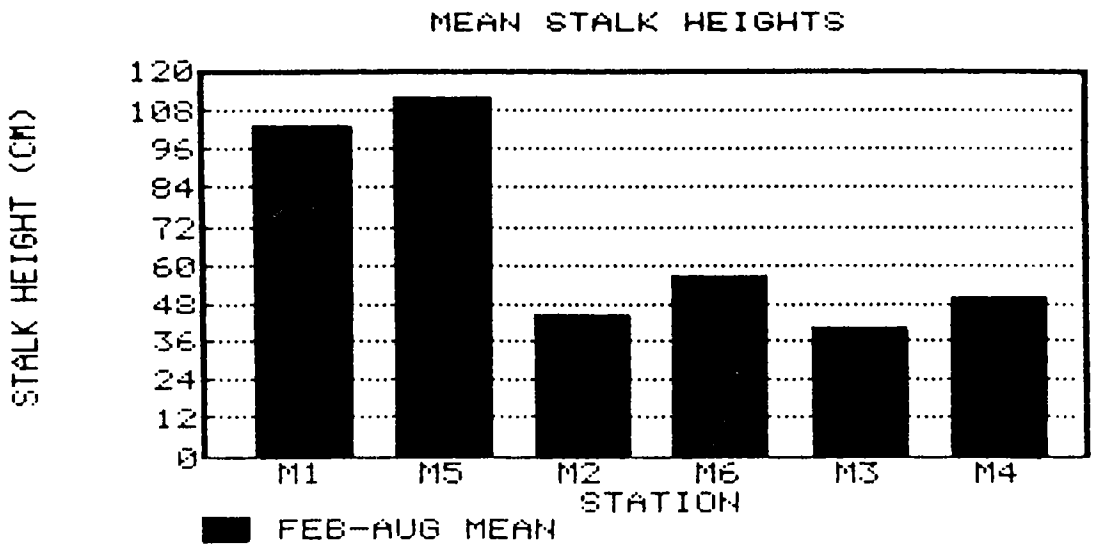
STATION	MONTH	STALK HEIGHT (CENTIMETERS)	DRY WEIGHT BIOMASS (GRAMS/SQUARE METER)			
			LIVE	DEAD	TOTAL	ROOTS
M5	FEBRUARY	75	116	1004	1117	3125
	MARCH	99	651	1110	1761	3000
	APRIL	88	1148	661	1109	4958
	MAY	119	740	551	1291	3083
	JUNE	147	913	630	1543	2625
	JULY	141	759	417	1177	917
	AUGUST	118	830	148	978	3042
	MEAN	112	737	646	1282	2964
	STANDARD DEVIATION	27	317	330	276	1178
	STANDARD ERROR	10	120	125	104	445

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-61. Monthly and Study Period Means for Smooth Cordgrass Parameters at Station M6, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, February Through August 1984

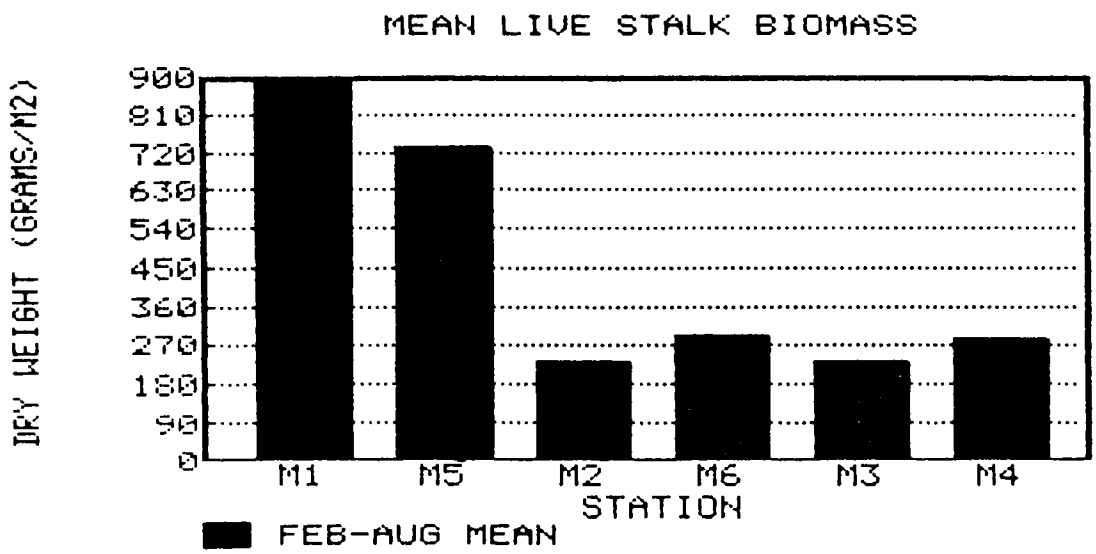
STATION	MONTH	STALK HEIGHT (CENTIMETERS)	DRY WEIGHT BIOMASS (GRAMS/SQUARE METER)			
			LIVE	DEAD	TOTAL	ROOTS
M6	FEBRUARY	32	66	367	433	4292
	MARCH	49	92	316	408	4583
	APRIL	55	255	407	662	6125
	MAY	55	298	411	709	5458
	JUNE	80	711	363	1075	6875
	JULY	63	240	171	411	4250
	AUGUST	63	378	153	531	4917
	MEAN	57	291	313	604	5214
	STANDARD DEVIATION	15	215	108	240	993
	STANDARD ERROR	6	81	41	91	375

Source: Alvarez, Lehman & Associates, Inc., 1985



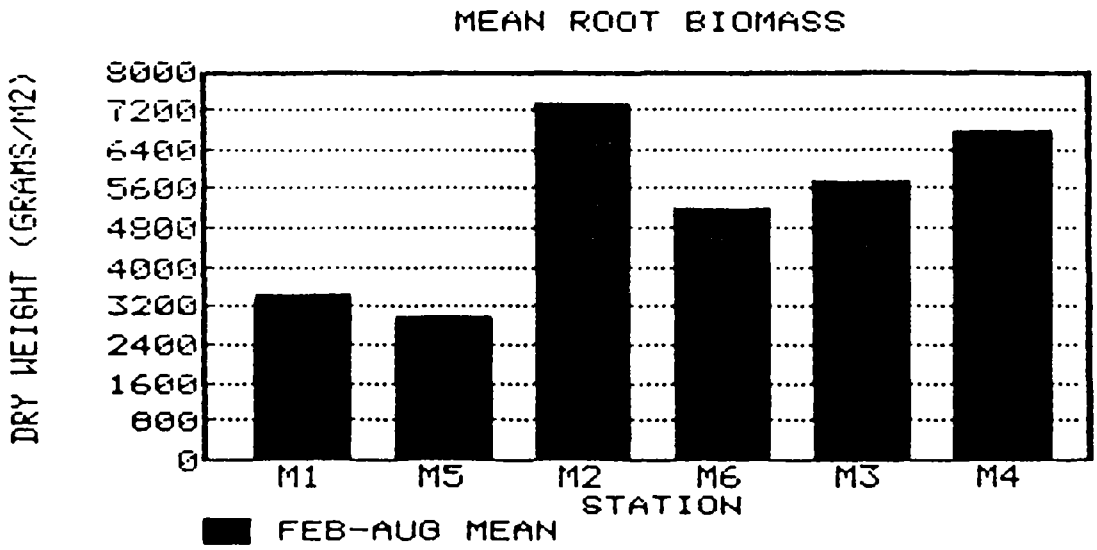
Alvarez, Lehman & Associates, Inc.

FIGURE 3-36. Mean Smooth Cordgrass Stalk Heights in Saltmarsh, Naval Submarine Base, Kings Bay, Georgia, February Through August 1984



Alvarez, Lehman & Associates, Inc.

FIGURE 3-37. Mean Smooth Cordgrass Live-Stalk Biomass in Saltmarsh, Naval Submarine Base, Kings Bay, Georgia, February Through August 1984

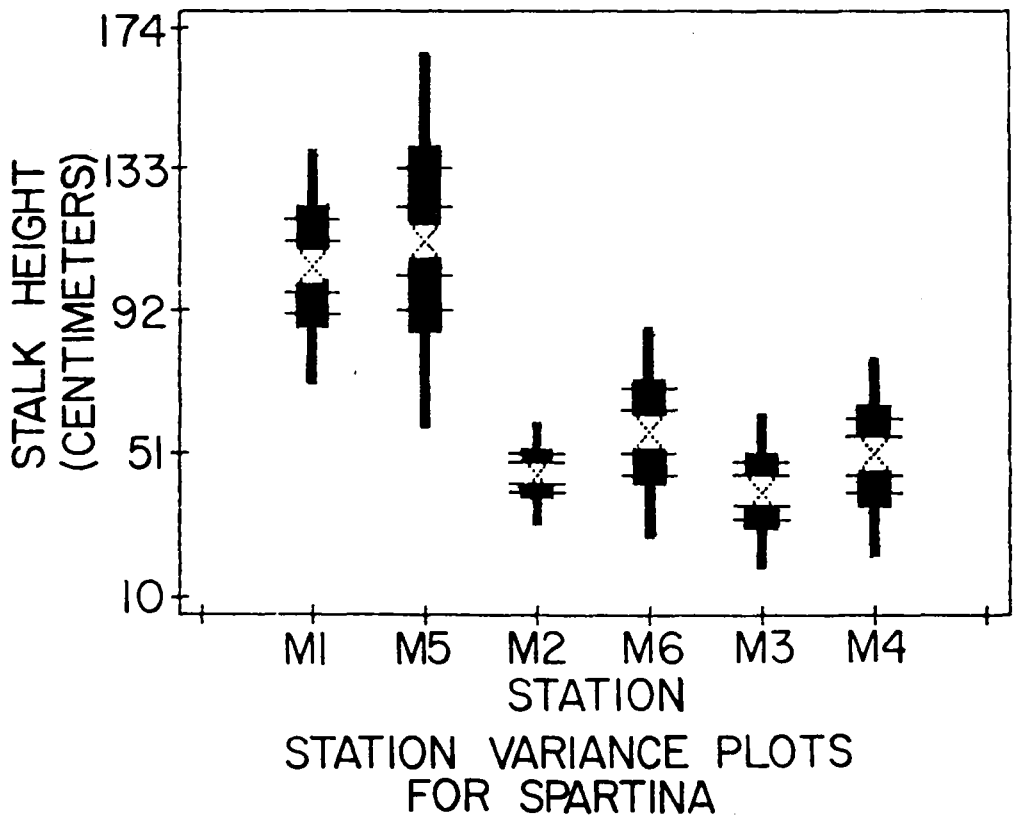


Alvarez, Lehman & Associates, Inc.

FIGURE 3-38. Mean Smooth Cordgrass Root Biomass in Saltmarsh, Naval Submarine Base, Kings Bay, Georgia, February Through August 1984

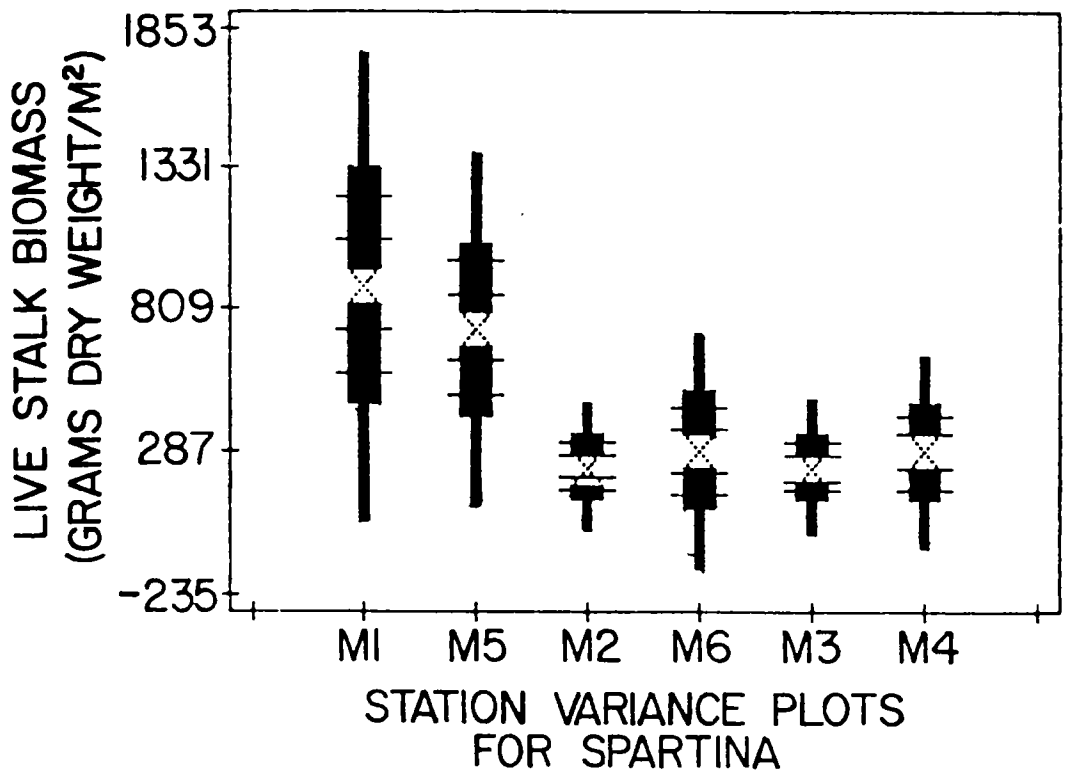
Station means for these parameters over the seven-month period were compared using variance plots, which are a graphical method for evaluating the significance of differences between parameter means. By convention for small sample sizes, means overlapping by $\pm$ 2 standard errors are considered not statistically different from each other. Figures 3-39, 3-40, and 3-41 show the North River site means for stalk height, live stalk dry-weight biomass, and dead stalk dry-weight biomass were significantly higher than the means for these parameters at the other four sampling locations. Root biomass at the North River sites was significantly lower than the estimates at all the other sites (Figure 3-42).

Nutrient availability and salinity have commonly been suggested as sources of within-region saltmarsh variability (Turner, 1976). Salinity within North River near Stations M-1 and M-5 is normally below 10 to 15 parts per thousand in contrast to salinities of above 20 to 25 parts per thousand in Cumberland Sound, Mill Creek, and Crooked River (lower reach). North River marsh habitats are sheltered from storm-related turbulence and tend to retain higher fractions of dead material which implies high nutrient retention. The river also receives SUBASE and municipal stormwater drainage and industrial wastewater discharges which may lead to nutrient enrichment. Known differences in salinity regime and probable differences in nutrient availability are potential factors contributing to observed differences between saltmarshes of the North River and those in the other areas monitored.



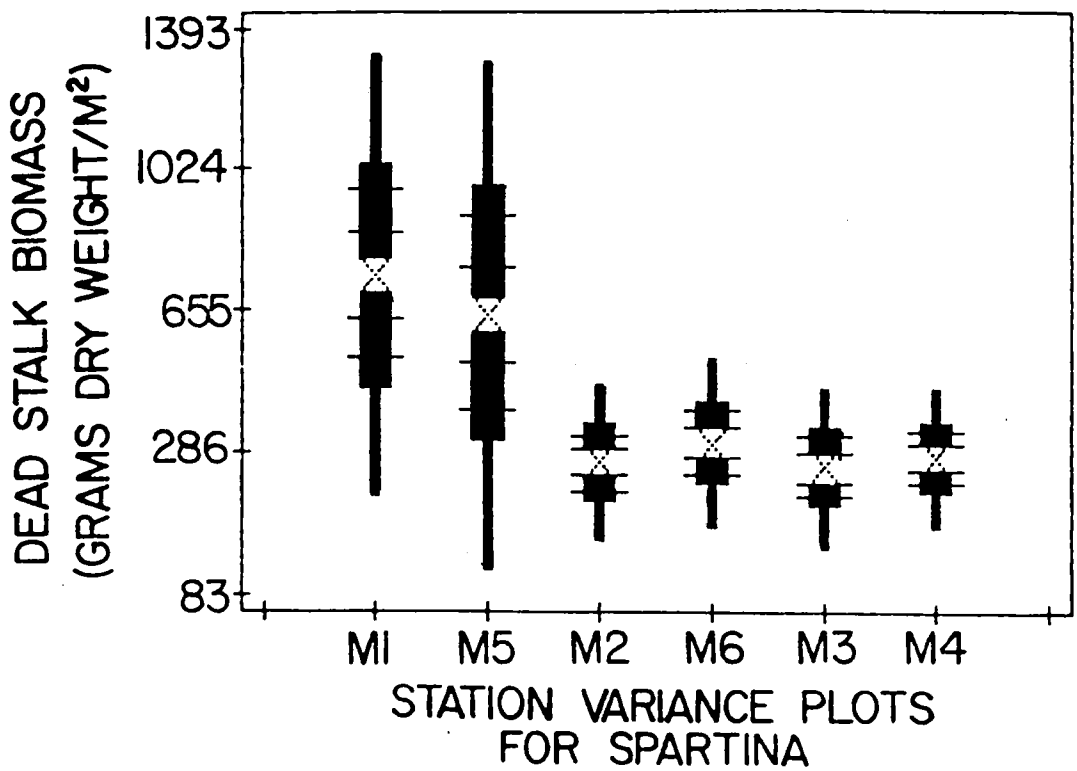
Alvarez, Lehman & Associates, Inc.

FIGURE 3-39. Variance Plot of Mean Stalk Heights in Saltmarsh, Naval Submarine Base, Kings Bay, Georgia, February Through August 1984



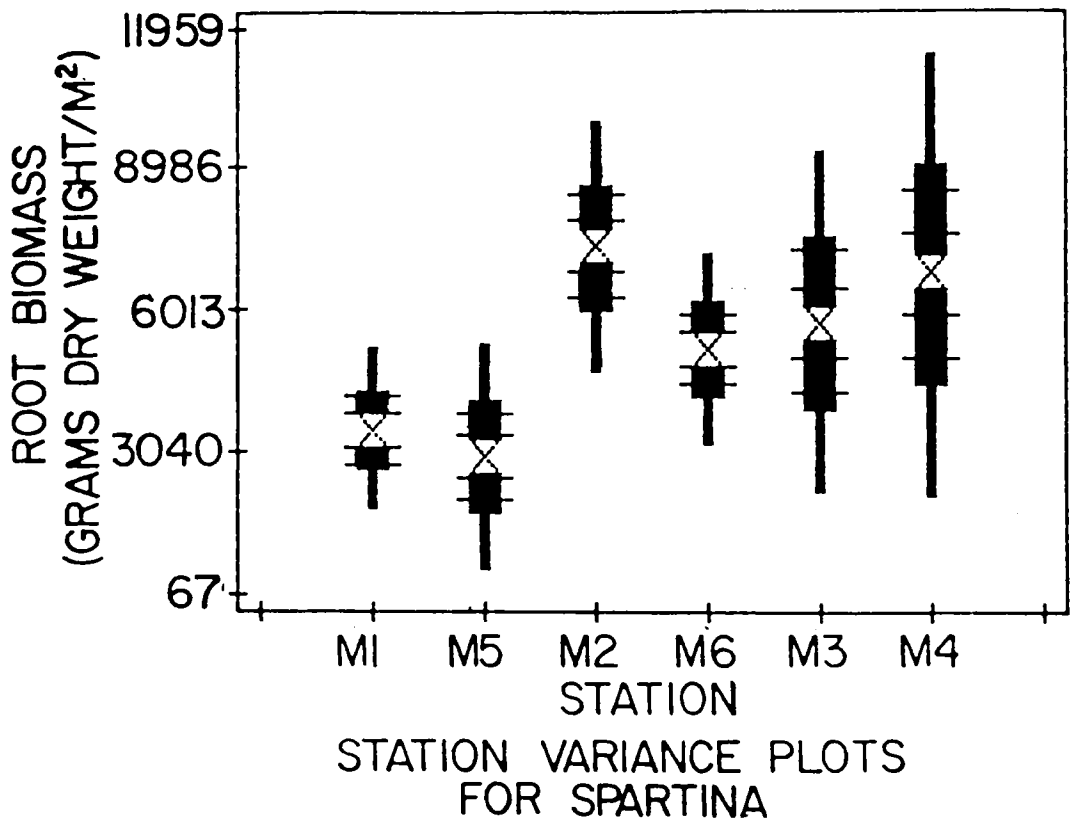
Alvarez, Lehman & Associates, Inc.

FIGURE 3-40. Variance Plot of Mean Live-Stalk Biomass in Saltmarsh, Naval Submarine Base, Kings Bay, Georgia, February Through August 1984



Alvarez, Lehman & Associates, Inc.

FIGURE 3-41. Variance Plot of Mean Dead-Stalk Biomass in Saltmarsh, Naval Submarine Base, Kings Bay, Georgia, February Through August 1984



Alvarez, Lehman & Associates, Inc.

FIGURE 3-42. Variance Plot of Mean Root Biomass in Saltmarsh, Naval Submarine Base, Kings Bay, Georgia, February Through August 1984

Saltmarsh net primary production has been evaluated through a variety of methods. Frequently used techniques include marsh average end of season live biomass (EOSL), maximum-minimum estimates, and the incremental method of Smalley (1958). The EOSL method assumes peak live biomass approximates net production for a given growing season. The maximum-minimum method assumes the difference between the highest and the lowest observed biomass values represents net production. Smalley's method assumes net annual production is approximated by the sum of all production increments documented within a full growing season. Turner (1976) concluded that these techniques underestimate actual net production since they do not account for biomass loss between sampling efforts. Typical export from smooth cordgrass marshes has been included in some productivity estimates for sites in Georgia (Odum and Fanning, 1973).

Net production at the six sites monitored in 1983-1984 was estimated using maximum-minimum, EOSL, and the methods of Smalley (1958) and Odum and Fanning (1973). Annual production estimates were based on biomass data from the spring intensive growth period collected prior to the mid-summer phase of senescence (Turner, 1979). Production values generated for each site by the different methods varied markedly, with the maximum-minimum method consistently yielding the lowest values and Odum and Fanning's method yielding the highest values (Table 3-62). Based on the February to June 1984 records, EOSL and Smalley's method generated similar estimates of net productivity. Although the magnitude of the production estimates

TABLE 3-62. Comparison of Net Production* Estimates for Saltmarsh Stations M1 to M6, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, February to June 1984

Method of Productivity Estimate	North River		Mill Creek		Cumberland Sound Crooked River	
	M1	M5	M2	M6	M3	M4
Maximum-Minimum	1342	797	137	645	354	512
EOSL	1565	913	227	711	467	591
Smalley (1958)	1489	1390	211	740	536	717
Odum and Fanning (1973)	2425	1723	645	1254	995	1172
Mean Estimate	1705	1206	305	838	588	748

* grams per square meter per year

Maximum-Minimum = Difference between maximum and minimum live biomass
EOSL = End of season live biomass
Smalley (1958) = Sum of monthly live/dead biomass increments
Odum & Fanning (1973) = Sum of peak live and dead biomass + export estimate

Source: Alvarez, Lehman & Associates, Inc., 1985

varied according to the method employed, station ranks by productivity values were consistent (Table 3-63).

Turner (1976) noted that EOSL and Smalley's method are curvilinearly related with divergence increasing with higher EOSL. Smalley's method is most accurate during the spring growing season when dead biomass export is lowest. Since the productivity estimates presented in Table 3-62 are based on a period of intensive growth, it is reasonable to assume that actual production during 1984 was best approximated by the Smalley method.

Annual net primary productivity of smooth cordgrass in the study area was estimated for each year since 1978 (Table 3-64) with the method of Odum and Fanning (1973) since most of the data was collected on a quarterly basis. Annual net productivity was estimated by summing the maximum standing crop of living stalks, the standing dead stalk biomass for the same period, and an estimate of exported biomass (leaves and sheaths). Odum and Fanning's estimate for exported biomass from medium-form smooth cordgrass of Sapelo Island, Georgia was used in these calculations since no measures of exported biomass were taken during monitoring studies at SUBASE.

Over the seven year period of record net productivity in North River marshes has consistently exceeded all estimates for marshes of upper Kings Bay, Cumberland Sound, and Mill Creek. Available records for Upper Kings Bay and Mill Creek suggest marshes of these areas are comparable in

TABLE 3-63. Saltmarsh Station Ranks by Net Production Values, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia, February to June 1984

Station	Location	Rank by Productivity Estimate			
		Maximum-Minimum	EOSL	Smalley (1958)	Odum and Fanning (1973)
M1	North River	1	1	1	1
M5	North River	2	2	2	2
M6	Mill Creek	3	3	3	3
M4	Crooked River	4	4	4	4
M3	Cumberland Sound	5	5	5	5
M2	Mill Creek	6	6	6	6

Maximum-Minimum = Difference between maximum and minimum live biomass
EOSL = End of season live biomass
Smalley (1958) = Sum of monthly live/dead biomass increments
Odum & Fanning (1973) = Peak live and dead biomass + export estimate

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE 3-64. Estimated Annual Net Productivity of Smooth Cordgrass, *Spartina alterniflora*, at Naval Submarine Base, Kings Bay, Georgia, 1978 to 1984

	UPPER KINGS BAY			NORTH RIVER			CUMBERLAND SOUND			MILL CREEK		
YEAR	TOTAL * BIOMASS	EXPORT + ESTIMATE	NET ** PRODUCTION	TOTAL BIOMASS	EXPORT ESTIMATE	NET PRODUCTION	TOTAL BIOMASS	EXPORT ESTIMATE	NET PRODUCTION	TOTAL BIOMASS	EXPORT ESTIMATE	NET PRODUCTION
1978	783	180	963	1156	180	1336	668	180	848	NS	NS	NS
1979	1292	180	1472	1900	180	2080	903	180	1083	NS	NS	NS
1980	1550	180	1730	5011	180	5191	977	180	1157	NS	NS	NS
1981	1549	180	1729	4011	180	4191	814	180	994	NS	NS	NS
1982	2009	180	2189	2642	180	2822	1021	180	1201	NS	NS	NS
1983	NS	NS	NS	3596	180	3776	2175	180	2355	2180	180	2360
1984	NS	NS	NS	1894	180	2074	904	180	1084	770	180	950
MEAN	1437	180	1617	2887	180	3067	1066	180	1246	1475	180	1655
ST. DEV.	448	0	448	1372	0	1372	502	0	502	997	0	997
ST. ERR.	200	0	200	519	0	519	190	0	190	705	0	705

* Peak live and associated dead stalk dry weight biomass in grams per meter square
\+ Export from living medium form smooth cordgrass estimated by Odum and Fanning (1973), in grams dry weight per meter square
** Estimated annual net production, in grams dry weight per meter square
NS = No sampling done
ST. DEV. = Standard deviation
ST. ERR. = Standard error

Source: Alvarez, Lehman & Associates, Inc., 1985

productivity. Cumberland Sound marshes have generally shown the lowest above-ground productivities in the study area. Standing crop and productivity estimates for the 1984 monitoring year were somewhat lower than those of previous monitoring periods but were within the range of values for comparable saltmarshes along the Atlantic and Gulf coasts (Table 3-65).

Based upon above-ground estimates alone, smooth cordgrass biomass production would appear to be the greatest within this study area in the North River basin. However, it appears that total above and below-ground biomass at sites on Mill Creek, Crooked River, and Cumberland Island actually exceeds that at the North River sites (Figure 3-43). Greater resource allocation to below-ground structures may reflect physiological response to low nutrient levels, low soil oxygen, higher ambient salinities, longer periods of inundation, greater exposure to wave-induced erosion, and other sources of stress (Smith, et al., 1979).

Adaptation to physical stress may provide these marshes with some abilities to recover from short-term construction-related impacts. Damage to the marsh above-ground may not be acute so long as below-ground components survive providing some natural regenerative capacity to revegetate the area following removal of the impact source (Alvarez, Lehman & Associates, Inc., 1985g). Of greater concern is the potential for saltmarsh response to chronic inputs of suspended solids and related chemical constituents through SUBASE drainage and effluent discharges. Chronic SUBASE development impacts may have the most significant long-term consequences for saltmarsh conditions in this area.

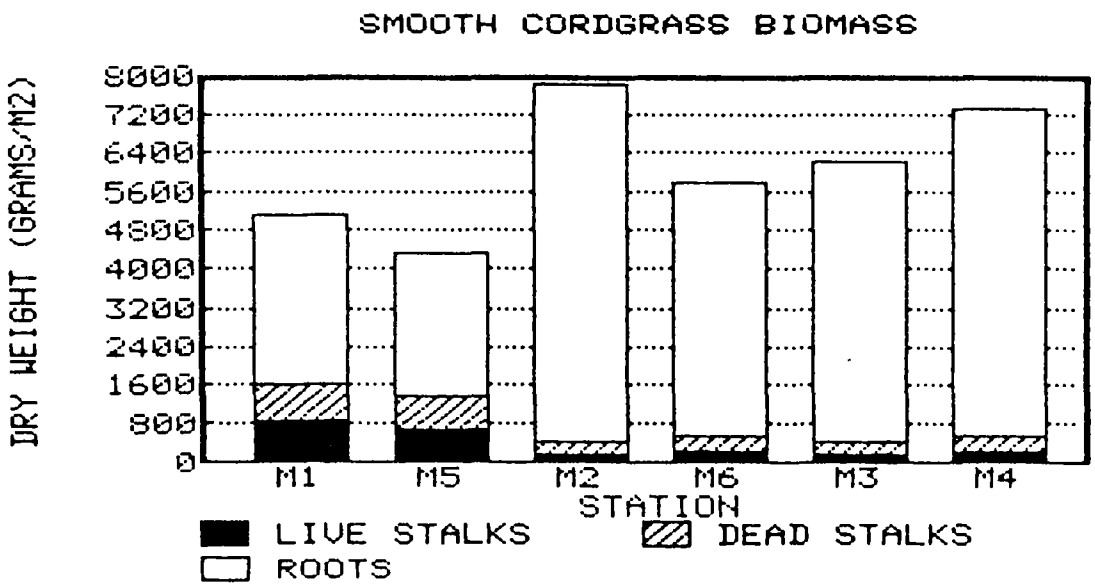
TABLE 3-65. Comparison of Standing Crop and Annual Productivity Estimates for Smooth Cordgrass from the Kings Bay Area in 1984 With Reference Values from Other Saltmarsh Studies

		Biomass (grams/m2)		Net Productivity (grams/m2/year)	
Study Area (Reference)	Comments	Above Ground	Below * Ground	Above Ground	Total Above and Below Ground
North River, Georgia (1)	1984 Mean	1894	2938	2074	
Mill Creek, Georgia (1)	1984 Mean	770	7771	950	
Cumberland Sound, Georgia (1)	1984 Mean	904	6813	1084	
Kings Bay, Georgia (2)	1978-1982 Mean	1437		1617	
North River, Georgia (2)	1978-1983 Mean	3053		3233	
Mill Creek, Georgia (2)	1983	2180		2360	
Cumberland Sound, Georgia (2)	1978-1983 Mean	1093		1273	
Sapelo Island, Georgia (3)	Tall Form	3315		3990	
	Medium Form	2182		2362	
Georgia Marshes (4)	Tall Form	750-1800			
	Short Form	300-900			
St. Marks, Florida (5)	Low Marsh	250-700		700	
	Middle Marsh	120-335		335	
	High Marsh	20-130		130	
Mississippi Marshes (6)		318-762	1450-2930	110-240	
Alabama Marshes (7)	Short Form			621	
Lake Ponchartrain, La. (8)	(Spartina patens)	1248-2466		2541-4411	
Barataria Bay, La. (9)	Inland Marsh			581	
Little Egg Harbor, N.J. (10)	Short Form		5000	429-525	2700-2800

* Root biomass within the top 10 centimeters of substrate

1. Alvarez, Lehman & Associates, Inc., 1985
2. Jones, Edmunds & Associates, Inc., 1979-1984
3. Odum and Fanning, 1973
4. Teal, 1962
5. Kruczynski, et al., 1978
6. Hackney, et al., 1978
7. de la Cruz, et al., 1978
8. Cramer, et al., 1981
9. Kirby and Gosselink, 1976
10. Smith, et al., 1979

Source: Alvarez, Lehman & Associates, Inc., 1985



Alvarez, Lehman & Associates, Inc.

FIGURE 3-43. Total Smooth Cordgrass Biomass in Saltmarsh, Naval Submarine Base, Kings Bay, Georgia, February Through August 1984

3.9 Non-Routine Monitoring

Five non-routine monitoring tasks were conducted during 1983-1984. The following sections provide brief accounts of work accomplished and major results of each of these tasks. Detailed presentations of results and discussion appear in separate reports submitted to the Navy.

3.9.1 Analysis of Fuel Saturated Soils (A120983-5)

Soils saturated with fuels from a small spill on SUBASE (December 1983) were collected by OICC, TRIDENT and analyzed to assess the need to handle the cleanup as a hazardous material cleanup. Most information regulating oil-related spills is directed toward spills to water rather than land; consultation with the Environmental Protection Agency, Region IV (EPA) determined that soils contaminated with materials having a flashpoint exceeding 140 degrees Fahrenheit would not be categorized as hazardous.

As long as stormwater runoff could be controlled, the EPA recommended land spreading and air drying of the material followed by use in roadbed or other construction site preparation which would isolate the material from runoff and other means of material distribution. An EPA-recommended method was used by the laboratory for soil sample analyses. Results indicated that the SUBASE soils were not contaminated by hazardous materials (Alvarez, Lehman & Associates, Inc., 1984a).

3.9.2 Water Quality in Roadside Ditches (B011284-5)

Roadside ditches along U.S.S. James Monroe Drive near the waterfront wastewater treatment plant (WWTP) were impacted by unidentified substances in January 1984. Surface films, oily residues, and red/orange flocculent material were present in ditch waters. Field reconnaissance and water quality sampling determined that some water quality parameters (biochemical oxygen demand, chemical oxygen demand, total organic carbon, and total Kjeldahl nitrogen) were present at levels comparable to those found in moderate-strength sewage influents to a WWTP. Some potential for public health hazards was indicated.

Metal oxides and sulfur-based compounds were identified as possible causative agents. Potential sources identified included leachate from Mainside Disposal Area, accidental discharge of organic wastes or herbicides, and leakage of sewage effluent from a 12-inch pipeline connecting the ARDM to the waterfront WWTP. Additional evaluation of ARDM-WWTP wastewater flows was recommended since ditch waters contained sewage-strength concentrations of selected parameters. ARDM-generated wastewater could contain sulfuric acid cleaning compounds, metal oxides, or organic polysulfides. Although follow up discussions with SUBASE Public Works were held, no verification sampling or follow up studies were requested, and contamination confirmation was beyond the scope of this non-routine task (Alvarez, Lehman & Associates, Inc., 1984b).

3.9.3 Assessment of Potential Fly Ash Use on SUBASE (C053084-14, Part 1)

The environmental suitability of fly ash produced by combustion of bituminous coal as a subgrade road base material in SUBASE road construction was assessed as a non-routine work order. Samples of fly ash placed along roads in the Family Housing Area were analyzed for selected metals content. Additionally, a literature search for precedents on fly ash utilization, contaminant content, and environmental effects was conducted.

Chemical analysis of fly ash samples found high aluminum concentrations in fly ash used at SUBASE. All other metals levels were similar to previously reported content in fly ash generated elsewhere in the United States.

Existing literature suggested that the greatest environmental problems in use of fly ash as roadbed material would occur during construction and handling. Once the road was built, the potential for problems would be small. Careful storage and handling of fly ash during construction would be necessary to minimize impacts due to site runoff (Alvarez, Lehman & Associates, Inc., 1984g).

3.9.4 Assessment of Disposal Area No. 2 Leachate (C053084-14, Part 2)

Leachate through dredge spoil disposal area dikes is one problem associated with upland disposal techniques. Water from Disposal Area No. 2 was observed seeping through the dikes; leakage was severe enough that vegetation along the west and south dikes was physically stressed. Aerial and ground reconnaissance were conducted to evaluate the nature and extent of impacts on soil and water systems adjacent to the disposal area.

In situ surveys of water and sediment quality verified that ponded waters around the disposal area were saline, ie. were leachate rather than rainwater collection. Negative redox potentials were demonstrated in soils along the south and west dike. In these areas, conductivity, salinity, oil and grease, and degree of soil saturation were also very high. Vegetation appeared more stressed in these zones. No single causative agent of vegetation stress was identified.

Areas drained by roadside ditches showed less vegetation stress, suggesting that seepage control through better drainage might improve conditions in areas impacted by disposal area leachate. Perimeter collection systems around Disposal Area No. 2 and Mainside were recommended to minimize environmental impacts of seepage (Alvarez, Lehman & Associates, Inc., 1984h).

3.9.5 Disposal Area No. 2 Plume Assessment (D062884-16)

Turbidity plumes associated with dredged material disposal area effluent outfalls have been observed in Kings Bay (Jones, Edmunds & Associates, Inc., 1983a). A non-routine task was initiated to document turbidity plumes associated with effluent discharge from Disposal Area No. 2. Light meter profiles were taken at four sites located along the plume axis and at one ambient site removed from plume influence. Profiles were collected on a total of 15 days between August 25 and October 3, 1984.

Light profile data in conjunction with secchi disc records demonstrated that plumes significantly reduced light penetration through the water column. The major photosynthetic zone of the water column was reduced by a mean of 44 percent. This level of reduction will result in lower primary production in the aquatic communities of Kings Bay, and could cause a rippling effect on higher levels of the fisheries food chain.

It was recommended that OICC, TRIDENT encourage better weir management practices to improve effluent quality, continue monitoring dredging and dredge disposal area operations to better document plume incidence and areal extent, and consider conducting productivity studies to assess impacts of turbidity plumes on planktonic and other estuarine communities within Kings Bay.

4.0 CONCLUSIONS

Environmental monitoring between October 1983 and September 1984 detected the following conditions which may reflect SUBASE construction and operation:

1. Surface runoff from SUBASE in February 1984 was highly turbid, and was a likely source of high turbidities found in North River. Turbidity in SUBASE runoff during February and August exceeded the reference water quality standard used by the State of Florida for this parameter.

2. Storm event monitoring detected higher turbidity and lower dissolved oxygen levels in stormwater drainage from developed watersheds when compared to drainage from an undeveloped watershed.

3. Groundwater monitoring confirmed the presence of contaminated ground waters immediately east of Personnel Support Area stormwater Lake Y. A confirmation well produced water samples having comparably elevated levels of conductivity, dissolved solids, alkalinity, calcium, and chloride. Field observations showed that both wells contained oily residues. The source of contamination can not be determined without an intensive site survey.

4. Sprayfield surface waters contained lower levels of total Kjeldahl nitrogen and total phosphorus than surface runoff from other areas of SUBASE. No significant impacts to surface waters due to sprayfield operations were found for the parameters measured.

5. Sprayfield groundwater observation wells produced few consistent results from quarter to quarter, perhaps due to variable levels of silts in waters pumped from the wells. Lead, copper, and zinc concentrations exceeded reference drinking water standards at several stations during the 1983-1984 period of record. Comparisons were made for reference only since the shallow water aquifer is not suitable for use as a potable water supply. Total dissolved solids, total Kjeldahl nitrogen, total phosphorus, and several metals were often considerably higher in sprayfield well water samples when compared with wells located elsewhere on SUBASE. Long-term operations impacts to the shallow groundwater aquifer are implied by these results.

6. Sprayfield soil sampling was inconclusive. No surface soils were sampled outside the sprayfield. Consequently, comparisons with parameter levels outside the sprayfield area was not possible.

7. Estuarine water quality surveys documented that Kings Bay remains

well mixed and unstratified despite recent channel expansion and deepening. A subsurface turbidity plume documented in November 1983 near the existing wharf along the lower turning basin in Kings Bay was probably related to ongoing dredging operations. The Florida water quality standard for turbidity was exceeded by the November sample. Although several occasions of elevated metals concentrations were documented, no chronic metals contamination was demonstrated for any specific parameter.

8. Analysis of sediments from surface water drainage stations on SUBASE showed some evidence of chronic oil and grease contamination. Additionally, lead and zinc levels were slightly elevated at Station NR5 which receives drainage from the most developed areas of SUBASE. However, metals levels generally were lower than those documented during 1982-1983 monitoring indicating no metals buildup over the past year.

9. Sediments in Kings Bay had higher metals levels than reference sediments from undredged channels in Crooked River and Cumberland Sound. Construction dredging has increased the area covered by fine-grained materials which absorb metals. Higher metals levels which result from construction dredging sediments do not necessarily mean recent metals contamination. Sediment resuspension during dredging operations or by ship passage could result in continuous metals release to the overlying water column.

10. Dredge monitoring conducted daily between March and September 1984 documented several periods of discharge of turbid effluents from Mainside Disposal Area. Monthly mean turbidity for June and September exceeded the respective monthly mean ambient Kings Bay turbidities by more than 29 NTU; this differential between effluent and ambient turbidities would be prohibited in the State of Florida to protect surface waters from anthropogenic degradation. No similar standard exists for the State of Georgia.

11. Benthic invertebrate communities in Kings Bay during February 1984 showed high total densities and very low diversity and evenness values in comparison with stations in Cumberland Sound and other adjacent areas. Population explosion by opportunistic species in response to bottom disruption due to construction dredging was the probable cause of low diversity in Kings Bay compared to benthic communities outside the bay. Extreme fluctuation in benthic community densities is a direct result of SUBASE-related dredging in Kings Bay which ultimately may reduce bay suitability as a foraging habitat for early life stages of commercially valuable finfish species.

12. Areawide decrease in macroinvertebrate abundance in the study area probably reflects the severe freeze which occurred in December 1983. Lower macroinvertebrate catches in Kings Bay compared to control sites may reflect a faunal response to year-round dredging of Kings Bay and its approach channel.

13. Lower fish abundance and diversity within Kings Bay in comparison to control areas during February and August 1984 was probably caused by year-round dredging within Kings Bay. However, no significant between-station differences in mean fish abundance or diversity were found by analysis of long-term trawl records for stations sampled since 1976.

14. Oyster tissue analyses provided no conclusive evidence of any impacts associated with SUBASE development and operations. Copper levels in oysters from upper Kings Bay were slightly higher than those from any of the sites located outside of Kings Bay.

15. Vegetation surveys within six hardwood swamps on SUBASE indicated that all systems contained species which were healthy and reproducing. However, changes to surface water drainage patterns may have impacted some of these sites by altering natural hydrologic periods and ranges. Such impacts were suggested by missing size classes of certain species in some of the swamps.

16. Saltmarsh vegetation surveys demonstrated that North River marshes had significantly greater above-ground biomass and significantly lower below-ground biomass than marshes of Crooked River, Mill Creek or Cumberland Sound. A higher tolerance of short-term above-ground impacts was inferred for marshes of Cumberland Sound. Greater below-ground biomass provides greater

regenerative capability. North River marsh above-ground productivity was the highest for the study area and comparable in magnitude to other estimates for smooth cordgrass marshes in the Southeast.

5.0 RECOMMENDATIONS

It is recommended that:

1. A site-specific weather monitoring station be established at SUBASE. Data gathered as a minimum should include wind speed and direction, rainfall, pan evaporation and total suspended particulates. Such data would strengthen the Kings Bay database and allow better interpretation of surface runoff, storm event, and other routine water quality monitoring program results.

2. SUBASE surface runoff impacts to North River and Marianna Creek be minimized through judicious and efficient use of silt/sediment barriers, gravel, haybales, or other appropriate erosion control measures. Problem swales should be dried out and reseeded with appropriate grasses which can tolerate intermittent flooding and entrap suspended solids. Dewatering of construction sites should be closely monitored for compliance with environmental protection requirements contained within construction contracts.

3. Groundwater flow net analysis be performed for SUBASE as drainage system installation is completed to allow more precise prediction of direction of groundwater flows.

4. New observation wells in the wastewater sprayfield (WLA) are

necessary to ensure acquisition of representative groundwater samples from the sprayfield. Additional upgradient and down gradient monitoring wells should be constructed to determine if contaminants in sprayfield groundwater are migrating off site to other areas. Analysis of wastewater treatment plant effluent samples for relevant parameters would be helpful in determining potential impacts to surface and groundwaters near the sprayfield.

5. Estuarine water quality monitoring should include activity-defined sampling efforts (waterfront construction sites, dredge contractor laydown areas, etc.) to determine cause and effect relations. Activity-defined sampling could be accomplished through non-routine sampling tasks.

6. Monitoring for lead and oil and grease deposition in aquatic sediments be performed in depositional habitats of receiving water systems rather than at surface water runoff sampling stations. Potential environmental impacts associated with estuarine sediment resuspension might be better addressed by conducting elutriate analyses or liquid and suspended phase sediment bioassays on indigenous species of fishes and invertebrates.

7. Continued commitment to monitoring dredge operations and disposal

area effluent discharge be maintained due to the impacts associated with those activities. Assessment of turbidity plume impacts on primary productivity and larval recruitment to benthic habitats in Kings Bay are recommended as integrated measurements which would help bridge the gap between water quality monitoring and species or population related measurements of impact.

8. OICC, TRIDENT conduct a thorough compilation and statistical analysis of all available SUBASE dredge and disposal area monitoring data including that produced by dredge contractors for the Army Corps of Engineers with the objective of identifying site specific operations which correlate to effluent quality. Better disposal area design and operation will result from such analysis.

9. The artifical lakes being created on SUBASE be monitored to detect and prevent degradation. Water quality and biological monitoring should be included to support SUBASE lake management.

10. An effort be made to standardize environmental monitoring program station locations and designations to facilitate long-term data analysis and evaluation.

11. In-depth statistical analysis of available SUBASE environmental data should be performed with the objective of developing

site-specific water quality standards to be used in protection of SUBASE natural resources.

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APPENDICES

APPENDIX A

Partial List of Environmental Studies
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Kings Bay, Georgia

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APPENDIX B

Benthic Invertebrates

TABLE B-1. Benthic Invertebrates Collected at Station TD in February 1984
Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia

TAXON	REPLICATE 1	2	3	TOTAL	MEAN
Rhynchocoela	3	10		13	4
Oligochaeta	2	3	1	6	2
Polychaeta					
Heteromastus filiformis	11	35	5	51	17
Notomastus sp.	1			1	0
Glycera americana	1			1	0
Glycinde sp.	1	1		2	1
Lumbrineris tenuis	1			1	0
Clymenella torquata		1		1	0
Nereis succinea	1			1	0
Haploscoloplos fragilis	2	3	7	12	4
Eteone heteropoda	18	21	23	62	21
Paraprionospio pinnata	208	176	159	543	181
Spiophanes bombyx			1	1	0
Streblospio benedicti	10	55	33	98	33
Unid. terebellid	2		2	4	1
Gastropoda					
Ilyanassa obsoleta	2	2	1	5	2
Odostomia sp.	10	6		16	5
Bivalvia					
Mulinia lateralis	9	12	3	24	8
Abra aequalis	3	1		4	1
Tellina sp.	4	8	2	14	5
Crustacea					
Unid. mysid	1			1	0
Leucon americanus	6	14	17	37	12
Edotea montosa			1	1	0
Monoculodes sp.	1		1	2	1
Number of Taxa	21	15	14	24	17
Number of Individuals	297	348	256	901	300
Individuals/Square Meter	5,614	6,578	4,839	5,677	5,677
Shannon-Weaver Diversity	1.98	2.46	1.97	2.27	2.14
Evenness	0.24	0.29	0.25	0.23	0.26

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE B-2. Benthic Invertebrates Collected at Station W1 in February 1984
Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia

TAXON	REPLICATE 1	2	3	TOTAL	MEAN
Platyhelminthes	5	5	1	11	4
Rhynchocoela	3	2	1	6	2
Oligochaeta	2		2	4	1
Polychaeta					
Arabella iricolor		2		2	1
Heteromastus filiformis	9	16	7	32	11
Tharyx setigera			2	2	1
Glycinde sp.	1			1	0
Clymenella torquata	1			1	0
Nephtys picta		1		1	0
Nereis succinea	1	1		2	1
Diopatra cuprea		1		1	0
Haploscoloplos fragilis	10		4	14	5
Eteone heteropoda	16	22	9	47	16
Paranaitis sp.			1	1	0
Lepidonotus sublevis		1		1	0
Sabella microphthalma		1		1	0
Paraprionospio pinnata	86	109	133	328	109
Spiophanes bombyx		1		1	0
Streblospio benedicti	16	18	22	56	19
Unid. syllid			1	1	0
Unid. terebellid		1		1	0
Gastropoda					
Unid. nudibranch	1	3	1	5	2
Polinices sp.	1		2	3	1
Bivalvia					
Mulinia lateralis	911	832	746	2489	830
Geukensia demissa			1	1	0
Tagelus sp.	1			1	0
Tellina sp.	8			8	3
Crustacea					
Neomysis americana	1			1	0
Leucon americanus	18	14	23	55	18
Oxyurostylis sp.	2	2	1	5	2
Eudorella sp.			2	2	1
Edotea montosa	5	5	1	11	4
Unciola sp.	1		2	3	1
Cerapus sp.	3	1	2	6	2

-----continued-----

TABLE B-2. Continued

TAXON	REPLICATE 1	2	3	TOTAL	MEAN
Monoculodes sp.	15	9	9	33	11
Caprellids	2			2	1
Unid. amphipods		2		2	1
Ogyrides limicola		1	4	5	2
Unid. xanthids		1		1	0
Sipunculida	1			1	0
Bryozoa					
Bugula neretina		0		0	0
Echinodermata					
Unid. ophiuroids		2		2	1
Number of Taxa	25	26	23	42	25
Number of Individuals	1120	1053	977	3150	1,050
Individuals/Square Meter	21,172	19,905	18,469	19,849	19,849
Shannon-Weaver Diversity	1.29	1.34	1.37	1.37	1.33
Evenness	0.13	0.13	0.14	0.12	0.13

P = colonial form present

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE B-3. Benthic Invertebrates Collected at Station TE in February 1984
Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia

TAXON	REPLICATE 1	2	3	TOTAL	MEAN
Platyhelminthes		14	17	31	10
Rhynchocoela		1		1	0
Oligochaeta	13	66	28	107	36
Polychaeta					
Ampharete americana	1		1	2	1
Heteromastus filiformis	4	5	3	12	4
Glycera americana	1	1		2	1
Glycinde sp.			1	1	0
Gyptis vittata		1		1	0
Lumbrineris tenuis	2	1		3	1
Haploscoloplos fragilis	4	5	1	10	3
Cistena gouldii	1			1	0
Eteone heteropoda	33	30	28	91	30
Malmgrenia sp.	1			1	0
Ancistrosyllis sp.			1	1	0
Sigambra tentaculata	1	5	4	10	3
Paraprionospio pinnata	121	169	136	426	142
Streblospio benedicti	21	63	28	112	37
Gastropoda					
Unid. gastropod		50		50	17
Unid. nudibranch	1	1	1	3	1
Ilyanassa obsoleta		2		2	1
Polinices sp.	3	8		11	4
Bivalvia					
Mulinia lateralis	2295	1728	2436	6459	2,153
Abra aequalis	8			8	3
Tagelus sp.	1			1	0
Tellina sp.		1		1	0
Crustacea					
Unid. mysid		1		1	0
Leucon americanus	6	21	6	33	11
Oxyurostylis sp.	1	1	1	3	1
Edotea montosa		1		1	0
Ampelisca spp.	1	1		2	1
Unciola sp.		2		2	1
Cerapus sp.	3		1	4	1

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TABLE B-3. Continued

TAXON	REPLICATE 1	2	3	TOTAL	MEAN
Monoculodes sp.	2	7	2	11	4
Caprellids	1			1	0
Ogyrides limicola	3	2	1	6	2
Pycnogonida		1		1	0
Number of Taxa	24	27	18	36	23
Number of Individuals	2528	2188	2696	7412	2,471
Individuals/Square Meter	47,788	41,361	50,964	46,704	46,704
Shannon-Weaver Diversity	0.69	1.37	0.69	0.93	0.92
Evenness	0.06	0.12	0.06	0.07	0.08

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE B-4. Benthic Invertebrates Collected at Station DD2 in February 1984 Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia

TAXON	REPLICATE 1	2	3	TOTAL	MEAN
Platyhelminthes	1			1	0
Rhynchocoela	4	19	11	34	11
Oligochaeta	63	138	114	315	105
Polychaeta					
Ampharete americana		3	2	5	2
Heteromastus filiformis	79	218	296	593	198
Tharyx setigera	7	5	4	16	5
Glycera americana	4	2	10	16	5
Glycinde sp.		4	2	6	2
Podarke obscura	1	1		2	1
Lumbrineris tenuis	3	15	11	29	10
Clymenella torquata	1	1	5	7	2
Nephtys picta	3	6	1	10	3
Nereis succinea		3	3	6	2
Diopatra cuprea	2	11	15	28	9
Haploscoloplos fragilis	1			1	0
Cistena gouldii	1	3	6	10	3
Eteone heteropoda	10	7	11	28	9
Lepidonotus sublevis		2	3	5	2
Sigambra tentaculata		1	6	7	2
Sabella microphthalma		3		3	1
Paraprionospio pinnata	30	31	73	134	45
Polydora ligni			1	1	0
Prionospio sp.		3	1	4	1
Scolelepis squamata	1			1	0
Spiophanes bombyx		1	1	2	1
Streblospio benedicti	38	100	54	192	64
Exogone dispar	7	62	46	115	38
Odontosyllis sp.		3		3	1
Unid. terebellid	2	2	2	6	2
Gastropoda					
Unid. gastropod	1	1	1	3	1
Polinices sp.	2	5		7	2
Bivalvia					
Mulinia lateralis	142	25	55	222	74
Abra aequalis	2	8	2	12	4
Tellina sp.	8	20	8	36	12
Unid. arcid		1		1	0
Unid. bivalve	1			1	0

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TABLE B-4. Continued

TAXON	REPLICATE 1	2	3	TOTAL	MEAN
Crustacea					
Leucon americanus	8	1	1	10	3
Oxyurostylis sp.	1		1	2	1
Edotea montosa	2	3	7	12	4
Lembos sp.		1	6	7	2
Unciola sp.	2	2	2	6	2
Batea catharinensis		1	4	5	2
Cerapus sp.			7	7	2
Corophium spp.		1	1	2	1
Gammarus palustris		1		1	0
Elasmopus sp.		1		1	0
Melita nitida		2	2	4	1
Monoculodes sp.	5	1	15	21	7
Paraphoxus sp.		1	1	2	1
Caprellids	3	1	12	16	5
Unid. pagurids			1	1	0
Unid. xanthids		1	1	2	1
Bryozoa					
Bugula neretina		0		0	0
Pycnogonida		2	1	3	1
Echinodermata					
Unid. ophiuroid	8	3		11	4
Number of Taxa	32	47	42	55	40
Number of Individuals	443	726	806	1975	658
Individuals/Square Meter	8,374	13,724	15,236	12,445	12,445
Shannon-Weaver Diversity	3.29	3.47	3.44	3.60	3.40
Evenness	0.37	0.36	0.36	0.33	0.36

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE B-5. Benthic Invertebrates Collected at Station CR1 in February 1984
Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia

TAXON	REPLICATE 1	2	3	TOTAL	MEAN
Rhynchocoela	1		14	15	5
Oligochaeta	4	2	7	13	4
Polychaeta					
Arabella iricolor	1			1	0
Heteromastus filiformis	31	5	110	146	49
Spiochaetopterus oculatus	1			1	0
Tharyx setigera	7	1	6	14	5
Glycera americana			1	1	0
Glycinde sp.		1	1	2	1
Gyptis vittata	5		1	6	2
Lumbrineris tenuis			1	1	0
Clymenella torquata			3	3	1
Nereis succinea	2			2	1
Haploscoloplos fragilis	5	1	3	9	3
Scoloplos rubra	32	2	10	44	15
Eteone heteropoda	2	1	4	7	2
Ancistrosyllis sp.	4	5	1	10	3
Sabella microphthalma	9			9	3
Paraprionospio pinnata	59	61	80	200	67
Polydora ligni	1		3	4	1
Prionospio sp.	1		1	2	1
Spiophanes bombyx			1	1	0
Streblospio benedicti	154		554	708	236
Unid. syllid	4		1	5	2
Unid. terebellid	2			2	1
Gastropoda					
Unid. gastropod		11	7	18	6
Unid. naticid			1	1	0
Bivalvia					
Mulinia lateralis	1	1	1	3	1
Abra aequalis	1			1	0
Crustacea					
Leucon americanus	7	7	7	21	7
Oxyurostylis sp.	15	16	20	51	17
Edotea montosa	2	2	2	6	2
Aegothoa sp.		1		1	0
Ampelisca spp.	87	23	91	201	67
Unciola sp.	15		3	18	6
Batea catharinensis	1			1	0
Cerapus sp.	13	1	18	32	11

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TABLE B-5. Continued

TAXON	REPLICATE 1	2	3	TOTAL	MEAN
Corophium spp.	5	1	5	11	4
Erichthonius brasiliensis	29		1	30	10
Listriella sp.	1	1	1	3	1
Monoculodes sp.	1	4	4	9	3
Synchelidium sp.	5	1		6	2
Trichophoxus sp.	1			1	0
Caprellids		2	4	6	2
Pinnixa sp.			1	1	0
Echinodermata					
Unid. ophiuroids	8			8	3
Number of Taxa	35	22	34	45	30
Number of Individuals	517	150	968	1635	545
Individuals/Square Meter	9,773	2,836	18,299	10,302	10,302
Shannon-Weaver Diversity	3.57	3.05	2.41	3.11	3.01
Evenness	0.40	0.42	0.24	0.29	0.33

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE B-6. Benthic Invertebrates Collected at Station SI1 in February 1984
Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia

TAXON	REPLICATE 1	2	3	TOTAL	MEAN
Unid. anenome	1			1	0
Rhynchocoela	1	4		5	2
Oligochaeta	23	53	1	77	26
Polychaeta					
Ampharete americana		1		1	0
Heteromastus filiformis		7		7	2
Tharyx setigera	3	6	2	11	4
Glycera americana	1	1		2	1
Parahesione luteola		2		2	1
Clymenella torquata		2		2	1
Haploscoloplos fragilis		4		4	1
Scoloplos rubra	15	6	18	39	13
Eteone heteropoda	10	5	5	20	7
Aricidea sp.	1		1	2	1
Lepidonotus sublevis	1			1	0
Sabellaria vulgaris	9	6	1	16	5
Paraprionospio pinnata	1			1	0
Polydora ligni	1			1	0
Scolelepis sp.	1			1	0
Spiophanes bombyx		2		2	1
Streblospio benedicti	15	6	18	39	13
Exogone dispar	1	10		11	4
Unid. syllid	1	2		3	1
Gastropoda					
Unid. gastropod		1		1	0
Nassarius vibex			1	1	0
Bivalvia					
Mulinia lateralis	1	1	1	3	1
Tellina sp.	3	3		6	2
Crustacea					
Eudorella sp.	4	4	5	13	4
Oxyurostylis sp.	4	1		5	2
Edotea montosa	1			1	0
Ampelisca spp.	1	1		2	1
Unciola sp.		2		2	1

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TABLE B-6. Continued

TAXON	REPLICATE 1	2	3	TOTAL	MEAN
Listriella sp.			1	1	0
Monoculodes sp.	9	1		10	3
Synchelidium sp.	2			2	1
Echinodermata					
Unid. ophiuroids	1			1	0
Number of Taxa	25	24	11	35	20
Number of Individuals	111	131	54	296	99
Individuals/Square Meter	2,098	2,476	1,021	1,865	1,865
Shannon-Weaver Diversity	3.74	3.45	2.51	3.84	3.23
Evenness	0.55	0.49	0.44	0.47	0.49

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE B-7. Benthic Invertebrates Collected at Station TF in February 1984
Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia

TAXON	REPLICATE 1	2	3	TOTAL	MEAN
Platyhelminthes	4			4	1
Rhynchocoela	7	10	15	32	11
Oligochaeta	5	13	16	34	11
Polychaeta					
Ampharete americana	3	9	3	15	5
Heteromastus filiformis	125	240	134	499	166
Notomastus sp.	10	3	20	33	11
Tharyx setigera	1	5		6	2
Glycera americana	1	2	2	5	2
Glycinde sp.	6	3	3	12	4
Gyptis vittata	9	2	4	15	5
Lumbrineris tenuis	2		1	3	1
Clymenella torquata	1	2	7	10	3
Magelona sp.	4	3	1	8	3
Nephtys picta	1			1	0
Nereis succinea		1		1	0
Cistena gouldii	10	11	11	32	11
Eteone heteropoda	7	9	10	26	9
Paranaitis sp.		1	1	2	1
Sigambra tentaculata		1	1	2	1
Unid. polynoid		1		1	0
Sabellaria vulgaris			1	1	0
Paraprionospio pinnata	19	18	17	54	18
Polydora ligni		1		1	0
Prionospio sp.	9	43	17	69	23
Spiophanes bombyx	7	7	12	26	9
Streblospio benedicti	142	166	104	412	137
Unid. syllid		1		1	0
Gastropoda					
Unid. gastropod			1	1	0
Bivalvia					
Abra aequalis	1	2	4	7	2
Tagelus sp.		2		2	1
Tellina sp.	7	5	8	20	7
Unid. bivalve		1		1	0
Crustacea					
Leucon americanus	7	4	3	14	5
Oxyurostylis sp.	6	3	5	14	5
Eudorella sp.			1	1	0
Ampelisca spp.	3	29	23	55	18
Lembos sp.			1	1	0
Unciola sp.		2		2	1
Batea catharinensis			1	1	0
Cerapus sp.	1	8	3	12	4

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TABLE B-7. Continued

TAXON	REPLICATE 1	2	3	TOTAL	MEAN
Listriella sp.	1			1	0
Monoculodes sp.	10	2	3	15	5
Synchelidium sp.	1	2	2	5	2
Caprellids		3	1	4	1
Ogyrides limicola	1			1	0
Sipunculida			1	1	0
Echinodermata					
Unid. holothuroid	5		4	9	3
Unid. ophiuroids	5	29	53	87	29
Number of Taxa	32	36	36	48	35
Number of Individuals	421	644	494	1559	520
Individuals/Square Meter	7,958	12,174	9,338	9,824	9,824
Shannon-Weaver Diversity	3.22	3.11	3.64	3.43	3.33
Evenness	0.37	0.33	0.41	0.32	0.37

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE B-8. Benthic Invertebrates Collected at Station ML1 in February 1984
Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia

TAXON	REPLICATE 1	2	3	TOTAL	MEAN
Rhynchocoela	3	2	5	10	3
Oligochaeta	2		2	4	1
Polychaeta					
Ampharete americana	1			1	0
Drilonereis longa			1	1	0
Heteromastus filiformis	12	14	2	28	9
Glycera americana		2		2	1
Gyptis vittata		1		1	0
Nephtys picta	1			1	0
Haploscoloplos fragilis	2	1		3	1
Scoloplos rubra	17	42	22	81	27
Cistena gouldii	1			1	0
Eteone heteropoda	4	2	6	12	4
Ancistrosyllis sp.		1	2	3	1
Sigambra tentaculata	2	1	1	4	1
Paraprionospio pinnata	39	24	37	100	33
Polydora ligni	2			2	1
Prionospio sp.	1			1	0
Spiophanes bombyx	2	1	1	4	1
Streblospio benedicti	7	8	6	21	7
Gastropoda					
Unid. gastropod	2			2	1
Bivalvia					
Mulinia lateralis	1			1	0
Tellina sp.		1	3	4	1
Abra aequalis		1		1	0
Crustacea					
Unid. mysid		1		1	0
Leucon americanus	10	10	8	28	9
Oxyurostylis sp.	1	2	1	4	1
Ampelisca spp.	2	4	1	7	2
Listriella sp.		1	1	2	1
Monoculodes sp.	1	7	2	10	3
Synchelidium sp.			1	1	0
Pinnixa sp.		1		1	0
Unid. phoronid	1			1	0
Number of Taxa	22	21	18	32	20
Number of Individuals	114	127	102	343	114
Individuals/Square Meter	2,155	2,401	1,928	2,161	2,161
Shannon-Weaver Diversity	3.34	3.19	3.04	3.39	3.19
Evenness	0.49	0.46	0.46	0.40	0.47

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE B-9. Benthic Invertebrates Collected at Station TD in August 1984
Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia

TAXON	REPLICATE 1	REPLICATE 2	REPLICATE 3	TOTAL	MEAN
Oligochaeta		1		1	0
Polychaeta					
Heteromastus filiformis	2	1	1	4	1
Tharyx setigera	6			6	2
Glycinde sp.		2		2	1
Haploscoloplos fragilis	2			2	1
Sigambra tentaculata	1			1	0
Paraprionospio pinnata	17	36	37	90	30
Streblospio benedicti			2	2	1
Crustacea					
Leucon americanus	1	2		3	1
Edotea montosa	1			1	0
Number of Taxa	7	5	3	10	5
Number of Individuals	30	42	40	112	37
Individuals/Square Meter	567	794	756	706	706
Shannon-Weaver Diversity	1.94	0.87	0.45	1.28	1.09
Evenness	0.40	0.16	0.09	0.19	0.21

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE B-10. Benthic Invertebrates Collected at Station W1 in August 1984
Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia

TAXON	REPLICATE 1	REPLICATE 2	REPLICATE 3	TOTAL	MEAN
Oligochaeta	2	4	11	17	6
Polychaeta					
Heteromastus filiformis	2		7	9	3
Glycera americana			1	1	0
Nereis succinea		1		1	0
Haploscoloplos fragilis			1	1	0
Eteone heteropoda			1	1	0
Sigambra tentaculata			1	1	0
Paraprionospio pinnata	86	22	50	158	53
Streblospio benedicti	1			1	0
Crustacea					
Neomysis americana	1		1	2	1
Leucon americanus	20	2	2	24	8
Edotea montosa	1	1		2	1
Number of Taxa	7	5	9	12	7
Number of Individuals	113	30	75	218	73
Individuals/Square Meter	2,136	567	1,418	1,374	1,374
Shannon-Weaver Diversity	1.13	1.30	1.67	1.50	1.37
Evenness	0.17	0.27	0.27	0.19	0.22

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE B-11. Benthic Invertebrates Collected at Station TE in August 1984
Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia

TAXON	REPLICATE 1	2	3	TOTAL	MEAN
Rhynchocoela	1			1	0
Oligochaeta	2	8	19	29	10
Polychaeta					
Heteromastus filiformis	1	12	8	21	7
Haploscoloplos fragilis		1		1	0
Eteone heteropoda			1	1	0
Sigambra tentaculata	3			3	1
Paraprionospio pinnata	10	58	113	181	60
Streblospio benedicti		5	4	9	3
Crustacea					
Mysidopsis sp.			1	1	0
Neomysis americana	1	3	2	6	2
Leucon americanus		18	8	26	9
Edotea montosa		1		1	0
Number of Taxa	6	8	8	12	7
Number of Individuals	18	106	156	280	93
Individuals/Square Meter	340	2,004	2,949	1,764	1,764
Shannon-Weaver Diversity	1.95	2.03	1.46	1.84	1.81
Evenness	0.47	0.30	0.20	0.23	0.28

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE B-12. Benthic Invertebrates Collected at Station DD2 in August 1984
Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia

TAXON	REPLICATE 1	2	3	TOTAL	MEAN
Rhynchocoela	6	4	2	12	4
Oligochaeta	3	1	2	6	2
Polychaeta					
Heteromastus filiformis	19	12	23	54	18
Spiochaetopterus oculatus	1			1	0
Tharyx setigera	35			35	12
Glycinde sp.	5	5	4	14	5
Gyptis vittata	1			1	0
Magelona sp.	5			5	2
Nereis succinea		1		1	0
Diopatra cuprea	5	3	2	10	3
Scoloplos rubra	1	1	1	3	1
Cistena gouldii			1	1	0
Sigambra tentaculata	3			3	1
Lepidonotus sublevis	8			8	3
Paraprionospio pinnata	57	69	75	201	67
Prionospio sp.	3	1	1	5	2
Streblospio benedicti	1	1	2	4	1
Exogone dispar		4		4	1
Odontosyllis sp.	1	2		3	1
Unid. terebellid	1	1	1	3	1
Bivalvia					
Lyonsia hyalina	1			1	0
Tellina sp.	1			1	0
Crustacea					
Unid. mysid			1	1	0
Leucon americanus	11	14	14	39	13
Edotea montosa	2	3	6	11	4
Ampelisca spp.			1	1	0
Batea catharinensis	2	2	2	6	2
Cerapus sp.	1	1		2	1
Erichthonius brasiliensis		1		1	0
Monoculodes sp.	1			1	0
Echinodermata					
Unid. ophiuroids	5	8	2	15	5
Number of Taxa	25	19	17	31	20
Number of Individuals	179	134	140	453	151
Individuals/Square Meter	3,384	2,533	2,647	2,854	2,854
Shannon-Weaver Diversity	3.38	2.72	2.41	3.14	2.84
Evenness	0.45	0.38	0.34	0.36	0.39

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE B-13. Benthic Invertebrates Collected at Station CR1 in August 1984
Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia

TAXON	REPLICATE 1	2	3	TOTAL	MEAN
Oligochaeta		1	2	3	1
Polychaeta					
Heteromastus filiformis			2	2	1
Spiochaetopterus oculatus			1	1	0
Tharyx setigera			1	1	0
Glycera americana			1	1	0
Lumbrineris tenuis	1	1		2	1
Nereis succinea	2			2	1
Diopatra cuprea		1		1	0
Haploscoloplos fragilis	1		1	2	1
Scoloplos rubra	19	12	29	60	20
Aricidea sp.	1			1	0
Ancistrosyllis sp.		1		1	0
Sabella microphthalma		3		3	1
Paraprionospio pinnata	64	139	129	332	111
Polydora ligni	1			1	0
Exogone dispar		1		1	0
Unid. terebellid		1		1	0
Crustacea					
Leucon americanus	21	19	2	42	14
Edotea montosa	4	2		6	2
Ampelisca spp.	1	1	1	3	1
Batea catharinensis	1			1	0
Cerapus sp.		3		3	1
Number of Taxa	11	13	10	22	11
Number of Individuals	116	185	169	470	157
Individuals/Square Meter	2,193	3,497	3,195	2,962	2,962
Shannon-Weaver Diversity	1.97	1.45	1.18	1.63	1.53
Evenness	0.29	0.19	0.16	0.18	0.21

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE B-14. Benthic Invertebrates Collected at Station SI1 in August 1984
Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia

TAXON	REPLICATE 1	2	3	TOTAL	MEAN
Rhynchocoela		2		2	1
Oligochaeta	1	1	1	3	1
Polychaeta					
Heteromastus filiformis	1	2		3	1
Tharyx setigera	5	7	1	13	4
Glycinde sp.	1	1		2	1
Scoloplos rubra	6	9	3	18	6
Paraprionospio pinnata	16	5		21	7
Gastropoda					
Unid. gastropod	1			1	0
Crustacea					
Unid. mysids	2			2	1
Pinnixa sp.			1	1	0
Echinodermata					
Unid. ophiuroid	1			1	0
Number of Taxa	9	7	4	11	7
Number of Individuals	34	27	6	67	22
Individuals/Square Meter	643	510	113	422	422
Shannon-Weaver Diversity	2.35	2.39	1.79	2.62	2.18
Evenness	0.46	0.50	0.69	0.43	0.49

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE B-15. Benthic Invertebrates Collected at Station TF in August 1984
Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia

TAXON	REPLICATE 1	2	3	TOTAL	MEAN
Oligochaeta	1			1	0
Polychaeta					
Heteromastus filiformis			4	4	1
Glycera americana			1	1	0
Glycinde sp.	1		1	2	1
Sigambra tentaculata		2	4	6	2
Paraprionospio pinnata	33	21	102	156	52
Streblospio benedicti			3	3	1
Crustacea					
Neomysis americana	1		4	5	2
Leucon americanus	2		31	33	11
Edotea montosa			1	1	0
Ogyrides limicola			1	1	0
Number of Taxa	5	2	10	11	6
Number of Individuals	38	23	152	213	71
Individuals/Square Meter	718	435	2,873	1,342	1,342
Shannon-Weaver Diversity	0.81	0.43	1.57	1.42	0.94
Evenness	0.16	0.09	0.22	0.18	0.15

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE B-16. Benthic Invertebrates Collected at Station ML1 in August 1984
Environmental Monitoring, Naval Submarine Base, Kings Bay, Georgia

TAXON	REPLICATE 1	REPLICATE 2	REPLICATE 3	TOTAL	MEAN
Polychaeta					
Arabella iricolor		1	1	2	1
Heteromastus filiformis	2		1	3	1
Notomastus sp.		1	3	4	1
Glycinde sp.			1	1	0
Scoloplos rubra	3	2		5	2
Sigambra tentaculata	1	1	3	5	2
Lepidonotus sublevis	8			8	3
Paraprionospio pinnata	32	20	17	69	23
Prionospio sp.	3	1	1	5	2
Streblospio benedicti	1	1	2	4	1
Exogone dispar		4		4	1
Odontosyllis sp.	1	2		3	1
Unid. terebellid		2		2	1
Crustacea					
Leucon americanus	1		5	6	2
Erichthonius brasiliensis		1		1	0
Listriella sp.		2	2	4	1
Number of Taxa	9	12	10	16	10
Number of Individuals	52	38	36	126	42
Individuals/Square Meter	983	718	681	2,382	794
Shannon-Weaver Diversity	1.94	2.55	2.54	2.68	2.34
Evenness	0.34	0.49	0.49	0.38	0.43

Source: Alvarez, Lehman & Associates, Inc., 1985

APPENDIX C

Demersal Fish

TABLE C-1. Fish Community Species Composition and Abundance in Replicate Trawl Samples, Environmental Monitoring Surveys at Naval Submarine Base, Kings Bay, Georgia in March 1984 (Catch/two 15-minute tows)

	Station-Replicate															
TAXON	TD1	TD2	W11	W12	TE1	TE2	DD21	DD22	CR11	CR12	SI1	SI2	TF1	TF2	ML11	ML12
CLUPEIFORMES																
Anchoa mitchilli	9	3	1	5	69	15	10		712	363	662	237	141	141		
Brevoortia tyrannus	4	5								23			1			
GADIFORMES																
Urophysis floridanus					1		10	1	10	3	1	10	3	20		
Urophysis regius	1				26	3	2		3	2		7	36	108		
ATHERINIFORMES																
Menidia menidia									1							
GASTEROSTEIFORMES																
Syngnathus fuscus									2							
PERCIFORMES																
Hypsoblennius hentzi														1		
Peprilus alepidotus				1							1		4	1		
Peprilus triacanthus			1		1				4	1						
Bairdiella chrysura		1				2						98	29	31		
Cynoscion regalis								3				1	2	5		
Leiostomus xanthurus	1						2					2				
Menticirrhus americanus					1											
Menticirrhus littoralis												1				
Micropogon undulatus				2			1	1	1	17			14	146		
Stellifer lanceolatus			1		5								568	509		
Lagodon rhomboides							3									
Trichiurus lepturus													1			
Prionotus scitulus					1											
PLEURONECTIFORMES																
Ancylopsetta quadrocellata					1						1					
Symphurus plagiusa													13	51		
Number of Taxa	4	3	3	3	8	3	6	3	7	6	4	7	11	10	NS	NS
Number of Individuals	15	9	3	8	105	20	28	5	733	409	665	356	812	1013	NS	NS
Catch/Minute	1	0	0	0	4	1	1	0	24	14	22	12	27	34	NS	NS

NS = Station not sampled this quarter

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE C-2. Fish Community Species Composition and Abundance in Replicate Trawl Samples, Environmental Monitoring at Naval Submarine Base, Kings Bay, Georgia in August 1984 (Catch/two 15-minute tows)

	Station-Replicate															
TAXON	TD1	TD2	W11	W12	TE1	TE2	DD21	DD22	CR11	CR12	SI11	SI12	TF1	TF2	ML11	ML12
SQUALIFORMES																
Sphyrna tiburo										1						
CLUPEIFORMES																
Anchoa hepsetus									5	3					3	
Anchoa mitchilli	2	1		38	33	1	1	6	592	1082	3	39	4	251	146	68
Brevoortia tyrannus		1														
Opisthonema oglinum																
SILURIFORMES																
Arius felis	1	1							5	448	10			3		1
Bagre marinus									14			13		10		4
BATRACHOIDIFORMES																
Opsanus tau										1						
GASTEROSTEIFORMES																
Syngnathus louisianae										1						
PERCIFORMES																
Chloroscombrus chrysurus			2		2	1	4		79	67			2	8	30	
Selene vomer							1		3	1	1				1	
Trachinotus carolinus														1		
Chaetodipterus faber		3						2	8	2	10	2		6	1	8
Eucinostomus gula										1					10	
Gobiosoma bosci															1	
Peprilus alepidotus					1		1									
Bairdiella chrysura										3		7		3		4
Cynoscion regalis		2	1	1		1			1	1				7		10
Leiostomus xanthurus										2						1
Menticirrhus americanus				1					1					8		1
Micropogon undulatus		1							1	1				13	1	9
Stellifer lanceolatus			3		7	40		8				1		247		
Centropristis ocyurus		1														
Larimus fasciatus														1		
Sphyraena barracuda															3	
Trichiurus lepturus								2					7			
PLEURONECTIFORMES																
Etropus crossotus														1		
Symphurus plagiusa					1							1		1		1
Trinectes maculatus												1		2		
TETRAODONTIFORMES																
Chilomycterus schoepfi									2		1					
Number of Taxa	2	7	3	3	5	4	4	4	11	14	5	7	3	15	9	10
Number of Individuals	3	10	6	40	44	43	7	18	711	1614	25	64	13	562	196	107
Catch/Minute	0	0	0	1	1	1	0	1	24	54	1	2	0	19	7	4

Source: Alvarez, Lehman & Associates, Inc., 1985

APPENDIX D

Saltmarsh Vegetation

TABLE D-1. Smooth Cordgrass Stalk Height and Biomass Data for Stations M1 Through M6, Environmental Monitoring Studies, Naval Submarine Base, Kings Bay, Georgia in February 1984

COLLECT DATE	STATION	REPLICATE NUMBER	DISTANCE (M)	STALK HEIGHT (CM)	WET WEIGHT BIOMASS (GRAMS/SQUARE METER)				DRY WEIGHT BIOMASS (GRAMS/SQUARE METER)			
					LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS	LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS
022684	M1	1	9	57	890	2403	3292	ND	282	1016	1298	3125
		2	12	91	754	2876	3630	ND	204	986	1190	2000
		3	27	80	680	2886	3566	ND	182	752	934	3000
		mean		76	775	2722	3496	ND	223	918	1141	2708
		st. dev.		17	106	276	180	ND	53	145	187	617
		st. err.		10	61	160	104	ND	30	83	108	356
022684	M2	1	23	37	189	827	1016	ND	40	352	392	5625
		2	34	25	215	930	1145	ND	106	460	566	4750
		3	45	30	255	850	1106	ND	124	360	484	5625
		mean		31	220	869	1089	ND	90	391	481	5333
		st. dev.		6	33	54	66	ND	44	60	87	505
		st. err.		3	19	31	38	ND	26	35	50	292
022684	M3	1	15	20	412	1039	1451	ND	122	376	498	4500
		2	22	20	244	1038	1283	ND	96	370	466	5000
		3	29	18	322	978	1301	ND	120	316	436	5250
		mean		19	326	1019	1345	ND	113	354	467	4917
		st. dev.		1	84	35	92	ND	14	33	31	382
		st. err.		1	48	20	53	ND	8	19	18	220
022684	M4	1	12	20	252	865	1117	ND	78	326	404	2375
		2	17	30	283	1066	1349	ND	80	424	504	3875
		3	47	30	217	652	869	ND	78	250	328	5750
		mean		27	250	861	1112	ND	79	333	412	4000
		st. dev.		6	33	207	240	ND	1	87	88	1691
		st. err.		3	19	119	138	ND	1	50	51	976
022684	M5	1	10	70	558	3515	4074	ND	98	1066	1164	1375
		2	12	80	580	2427	3007	ND	112	710	822	5625
		3	18	75	608	2352	2960	ND	138	1228	1366	2375
		mean		75	582	2765	3347	ND	116	1001	1117	3125
		st. dev.		5	25	651	630	ND	20	265	275	2222
		st. err.		3	14	376	364	ND	12	153	159	1283

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TABLE D-1. Continued

COLLECT DATE	STATION	REPLICATE NUMBER	DISTANCE (M)	STALK HEIGHT (CM)	WET WEIGHT BIOMASS (GRAMS/SQUARE METER)				DRY WEIGHT BIOMASS (GRAMS/SQUARE METER)			
					LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS	LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS
022684	M6	1	19	30	95	782	876	ND	52	238	290	4250
		2	26	35	160	976	1137	ND	66	442	508	4250
		3	14	30	200	954	1155	ND	80	420	500	4375
		mean		32	152	904	1056	ND	66	367	433	4292
		st. dev.		3	53	107	156	ND	14	112	124	72
		st. err.		2	31	62	90	ND	8	65	71	42

ND = No data

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE D-2. Smooth Cordgrass Stalk Height and Biomass Data for Stations M1 Through M6, Environmental Monitoring Studies, Naval Submarine Base, Kings Bay, Georgia in March 1984

COLLECT DATE	STATION	REPLICATE NUMBER	DISTANCE (M)	STALK HEIGHT (CM)	WET WEIGHT BIOMASS (GRAMS/SQUARE METER)				DRY WEIGHT BIOMASS (GRAMS/SQUARE METER)			
					LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS	LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS
032984	M1	1	2	119	2220	2518	4738	14000	864	894	1758	1625
		2	22	106	1876	3288	5164	31000	616	1324	1940	3625
		3	35	107	1920	2766	4686	30250	618	916	1534	3375
		mean		111	2005	2857	4863	25083	699	1045	1744	2875
		st. dev.		7	187	393	262	9606	143	242	203	1090
		st. err.		4	108	227	151	5546	82	140	117	629
032484	M2	1	5	56	372	796	1168	40375	116	400	516	6750
		2	16	45	418	842	1260	36250	138	348	486	5250
		3	22	47	330	752	1082	46125	124	288	412	7625
		mean		49	373	797	1170	40917	126	345	471	6542
		st. dev.		6	44	45	89	4960	11	56	54	1201
		st. err.		3	25	26	51	2864	6	32	31	693
032684	M3	1	17	40	428	620	1048	33875	124	278	402	4625
		2	25	35	366	450	816	27500	120	226	346	3500
		3	39	31	334	662	996	30875	110	302	412	4125
		mean		35	376	577	953	30750	118	269	387	4083
		st. dev.		5	48	112	122	3189	7	39	36	564
		st. err.		3	28	65	70	1841	4	22	21	325
032684	M4	1	6	39	424	1432	1856	40250	104	484	588	6000
		2	14	46	326	526	852	44750	88	266	354	6375
		3	26	41	482	508	990	52000	136	268	404	7250
		mean		42	411	822	1233	45667	109	339	449	6542
		st. dev.		4	79	528	544	5928	24	125	123	641
		st. err.		2	46	305	314	3423	14	72	71	370
032984	M5	1	12	114	1302	2490	3792	31000	426	1114	1540	27
		2	18	88	1930	1596	3526	22125	740	930	1670	23
		3	47	96	1658	2564	4222	20000	786	1286	2072	22
		mean		99	1630	2217	3847	24375	651	1110	1761	24
		st. dev.		13	315	539	351	5835	196	178	277	3
		st. err.		8	182	311	203	3369	113	103	160	2

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TABLE D-2. Continued

COLLECT DATE	STATION	REPLICATE NUMBER	DISTANCE (M)	STALK HEIGHT (CM)	WET WEIGHT BIOMASS (GRAMS/SQUARE METER)				DRY WEIGHT BIOMASS (GRAMS/SQUARE METER)			
					LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS	LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS
032484	M6	1	19	46	364	1018	1382	34000	102	370	472	5375
		2	36	44	240	840	1080	34500	64	304	368	5125
		3	42	57	408	806	1214	22875	110	274	384	3250
		mean		49	337	888	1225	30458	92	316	408	4583
		st. dev.		7	87	114	151	6572	25	49	56	1161
		st. err.		4	50	66	87	3794	14	28	32	671

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE D-3. Smooth Cordgrass Stalk Height and Biomass Data for Stations M1 Through M6, Environmental Monitoring Studies, Naval Submarine Base, Kings Bay, Georgia in April 1984

COLLECT DATE	STATION	REPLICATE NUMBER	DISTANCE (M)	STALK HEIGHT (CM)	WET WEIGHT BIOMASS (GRAMS/SQUARE METER) LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS	DRY WEIGHT BIOMASS (GRAMS/SQUARE METER) LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS
042984	M1	1	12	102	2100	2298	4398	27375	786	964	1750	4000
		2	27	100	1964	2004	3968	28875	700	1040	1740	4500
		3	32	99	2520	2254	4774	33375	942	850	1792	5000
		mean		100	2195	2185	4380	29875	809	951	1761	4500
		st. dev.		2	290	159	403	3122	123	96	28	500
		st. err.		1	167	92	233	1803	71	55	16	289
042684	M2	1	3	38	406	364	770	41500	156	274	430	7000
		2	11	34	460	260	720	37125	176	192	368	7875
		3	40	54	630	416	1046	43500	242	298	540	9125
		mean		42	499	347	845	40708	191	255	446	8000
		st. dev.		11	117	79	176	3260	45	56	87	1068
		st. err.		6	67	46	101	1882	26	32	50	617
042384	M3	1	8	61	834	1066	1900	30875	284	524	808	4250
		2	27	39	380	354	734	32875	150	202	352	4375
		3	34	41	454	480	934	38875	172	236	408	4625
		mean		47	556	633	1189	34208	202	321	523	4417
		st. dev.		12	244	380	624	4163	72	177	249	191
		st. err.		7	141	219	360	2404	41	102	144	110
042384	M4	1	35	46	678	366	1044	64500	246	210	456	11875
		2	42	57	782	276	1058	54500	328	164	492	10625
		3	50	53	732	652	1384	55750	270	232	502	11375
		mean		52	731	431	1162	58250	281	202	483	11292
		st. dev.		6	52	196	192	5449	42	35	24	629
		st. err.		3	30	113	111	3146	24	20	14	363
041984	M5	1	5	82	1502	1160	2662	33500	408	600	1008	5875
		2	19	114	2154	1248	3402	34625	632	826	1458	5000
		3	42	69	1304	1646	2950	33125	304	558	862	4000
		mean		88	1653	1351	3005	33750	448	661	1109	4958
		st. dev.		23	445	259	373	781	168	144	311	938
		st. err.		13	257	150	215	451	97	83	179	542

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TABLE D-3. Continued

COLLECT DATE	STATION	REPLICATE NUMBER	DISTANCE (M)	STALK HEIGHT (CM)	WET WEIGHT BIOMASS (GRAMS/SQUARE METER)				DRY WEIGHT BIOMASS (GRAMS/SQUARE METER)			
					LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS	LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS
042684	M6	1	2	62	664	650	1314	35250	222	430	652	6000
		2	9	54	758	670	1428	36375	328	450	778	5500
		3	16	49	530	560	1090	53750	216	340	556	6875
		mean		55	651	627	1277	41792	255	407	662	6125
		st. dev.		7	115	59	172	10371	63	59	111	696
		st. err.		4	66	34	99	5988	36	34	64	402

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE D-4. Smooth Cordgrass Stalk Height and Biomass Data for Stations M1 Through M6, Environmental Monitoring Studies, Naval Submarine Base, Kings Bay, Georgia in May 1984

COLLECT DATE	STATION	REPLICATE NUMBER	DISTANCE (M)	STALK HEIGHT (CM)	WET WEIGHT BIOMASS (GRAMS/SQUARE METER)				DRY WEIGHT BIOMASS (GRAMS/SQUARE METER)			
					LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS	LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS
052884	M1	1	4	113	3154	4072	7226	60375	1364	876	2240	ND
		2	18	105	3744	4468	8212	40625	1288	966	2254	ND
		3	32	110	3236	3668	6904	42375	1258	914	2172	ND
		mean		109	3378	4069	7447	47792	1303	919	2222	ND
		st. dev.		4	320	400	682	10933	55	45	44	ND
		st. err.		2	185	231	393	6312	32	26	25	ND
052784	M2	1	12	40	650	1260	1910	44000	212	328	540	ND
		2	22	47	584	1080	1664	33875	192	274	466	ND
		3	37	53	676	1244	1920	48125	240	386	626	ND
		mean		47	637	1195	1831	42000	215	329	544	ND
		st. dev.		7	47	100	145	7333	24	56	80	ND
		st. err.		4	27	58	84	4233	14	32	46	ND
052684	M3	1	15	48	694	862	1556	25125	248	234	482	ND
		2	28	42	582	904	1486	42750	232	278	510	ND
		3	42	31	388	682	1070	35625	148	142	290	ND
		mean		40	555	816	1371	34500	209	218	427	ND
		st. dev.		9	155	118	263	8866	54	69	120	ND
		st. err.		5	89	68	152	5119	31	40	69	ND
052784	M4	1	10	44	788	988	1776	56375	286	264	550	ND
		2	17	50	540	1044	1584	40000	174	268	442	5875
		3	25	54	1048	1162	2210	64875	388	296	684	9000
		mean		49	792	1065	1857	53750	283	276	559	7438
		st. dev.		5	254	89	321	12644	107	17	121	2210
		st. err.		3	147	51	185	7300	62	10	70	1563
052884	M5	1	12	129	2486	1730	4216	15500	964	440	1404	1875
		2	16	124	1830	2384	4214	26000	730	728	1458	4125
		3	21	103	1406	2236	3642	21125	526	486	1012	3250
		mean		119	1907	2117	4024	20875	740	551	1291	3083
		st. dev.		14	544	343	331	5254	219	155	243	1134
		st. err.		8	314	198	191	3034	127	89	141	655

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TABLE D-4. Continued

COLLECT DATE	STATION	REPLICATE NUMBER	DISTANCE (M)	STALK HEIGHT (CM)	WET WEIGHT BIOMASS (GRAMS/SQUARE METER)				DRY WEIGHT BIOMASS (GRAMS/SQUARE METER)			
					LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS	LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS
052784	M6	1	6	67	1090	2026	3116	40000	380	516	896	4625
		2	17	51	720	1370	2090	48250	236	304	540	5625
		3	27	46	892	1756	2648	49375	278	414	692	6125
		mean		55	901	1717	2618	45875	298	411	709	5458
		st. dev.		11	185	330	514	5119	74	106	179	764
		st. err.		6	107	190	297	2955	43	61	103	441

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE D-5. Smooth Cordgrass Stalk Height and Biomass Data for Stations M1 Through M6, Environmental Monitoring Studies, Naval Submarine Base, Kings Bay, Georgia in June 1984

COLLECT DATE	STATION	REPLICATE NUMBER	DISTANCE (M)	STALK HEIGHT (CM)	WET WEIGHT BIOMASS (GRAMS/SQUARE METER)				DRY WEIGHT BIOMASS (GRAMS/SQUARE METER)			
					LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS	LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS
062684	M1	1	3	167	3684	2776	6460	13875	1932	732	2664	1875
		2	9	115	2686	1944	4630	22625	1196	606	1802	3625
		3	22	113	3446	2084	5530	26375	1568	702	2270	4250
		mean		132	3272	2268	5540	20958	1565	680	2245	3250
		st. dev.		31	521	445	915	6415	368	66	432	1231
		st. err.		18	301	257	528	3703	212	38	249	711
062584	M2	1	15	43	494	664	1158	56875	206	198	404	9250
		2	18	60	524	758	1282	50875	226	238	464	7875
		3	32	43	488	732	1220	45875	250	278	528	8875
		mean		49	502	718	1220	51208	227	238	465	8667
		st. dev.		10	19	49	62	5508	22	40	62	711
		st. err.		6	11	28	36	3180	13	23	36	410
062984	M3	1	9	82	2134	2750	4884	26875	890	718	1608	4625
		2	33	35	604	436	1040	40125	238	120	358	8375
		3	45	46	704	770	1474	48125	272	206	478	11875
		mean		54	1147	1319	2466	38375	467	348	815	8292
		st. dev.		25	856	1251	2105	10733	367	323	690	3626
		st. err.		14	494	722	1215	6196	212	187	398	2093
062884	M4	1	4	91	1598	940	2538	22125	824	352	1176	5000
		2	7	74	1696	2178	3874	22750	626	646	1272	5250
		3	21	47	582	684	1266	25750	322	204	526	5750
		mean		71	1292	1267	2559	23542	591	401	991	5333
		st. dev.		22	617	799	1304	1938	253	225	406	382
		st. err.		13	356	461	753	1119	146	130	234	220
062684	M5	1	5	144	2530	1544	4074	11000	1246	408	1654	1750
		2	11	140	2276	1124	3400	16000	566	848	1414	3500
		3	30	156	2162	2328	4490	13625	928	634	1562	2625
		mean		147	2323	1665	3988	13542	913	630	1543	2625
		st. dev.		8	188	611	550	2501	340	220	121	875
		st. err.		5	109	353	318	1444	196	127	70	505

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TABLE D-5. Continued

COLLECT DATE	STATION	REPLICATE NUMBER	DISTANCE (M)	STALK HEIGHT (CM)	WET WEIGHT BIOMASS (GRAMS/SQUARE METER)				DRY WEIGHT BIOMASS (GRAMS/SQUARE METER)			
					LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS	LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS
062984	M6	1	2	116	2598	2324	4922	25375	1380	618	1998	5250
		2	13	63	686	688	1374	44250	380	232	612	8000
		3	29	62	742	830	1572	35750	374	240	614	7375
		mean		80	1342	1281	2623	35125	711	363	1075	6875
		st. dev.		31	1088	906	1994	9453	579	221	800	1442
		st. err.		18	628	523	1151	5458	334	127	462	832

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE D-6. Smooth Cordgrass Stalk Height and Biomass Data for Stations M1 Through M6, Environmental Monitoring Studies, Naval Submarine Base, Kings Bay, Georgia in July 1984

COLLECT DATE	STATION	REPLICATE NUMBER	DISTANCE (M)	STALK HEIGHT (CM)	WET WEIGHT BIOMASS (GRAMS/SQUARE METER)				DRY WEIGHT BIOMASS (GRAMS/SQUARE METER)			
					LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS	LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS
070984	M1	1	2	97	2918	722	3640	32125	984	324	1308	3375
		2	9	112	2620	1112	3732	19750	790	466	1256	2250
		3	42	105	2582	946	3528	30125	768	404	1172	3500
		mean		105	2707	927	3633	27333	847	398	1245	3042
		st. dev.		8	184	196	102	6643	119	71	69	688
		st. err.		4	106	113	59	3835	69	41	40	397
071184	M2	1	20	40	780	438	1218	36375	298	40	338	5875
		2	33	46	822	358	1180	44375	312	140	452	7375
		3	34	48	1022	654	1676	45000	388	256	644	7500
		mean		45	875	483	1358	41917	333	145	478	6917
		st. dev.		4	129	153	276	4809	48	108	155	904
		st. err.		2	75	88	159	2777	28	62	89	522
071284	M3	1	9	44	604	156	760	42250	226	82	308	5750
		2	14	38	524	220	744	35000	212	134	346	4500
		3	50	44	402	214	616	38875	160	128	288	5250
		mean		42	510	197	707	38708	199	115	314	5167
		st. dev.		3	102	35	79	3628	35	28	29	629
		st. err.		2	59	20	46	2095	20	16	17	363
071284	M4	1	14	50	674	268	942	49625	250	150	400	7625
		2	29	63	694	426	1120	45250	254	242	496	6875
		3	36	50	618	212	830	53375	226	126	352	7250
		mean		54	662	302	964	49417	243	173	416	7250
		st. dev.		8	39	111	146	4067	15	61	73	375
		st. err.		4	23	64	84	2348	9	35	42	217
071084	M5	1	13	140	2794	718	3512	6875	860	374	1234	875
		2	25	136	2206	1166	3372	10250	720	462	1182	875
		3	39	147	1998	906	2904	9750	698	416	1114	1000
		mean		141	2333	930	3263	8958	759	417	1177	917
		st. dev.		6	413	225	318	1821	88	44	60	72
		st. err.		3	238	130	184	1052	51	25	35	42

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TABLE D-6. Continued

COLLECT DATE	STATION	REPLICATE NUMBER	DISTANCE (M)	STALK HEIGHT (CM)	WET WEIGHT BIOMASS (GRAMS/SQUARE METER)				DRY WEIGHT BIOMASS (GRAMS/SQUARE METER)			
					LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS	LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS
071284	M6	1	17	63	676	456	1132	38000	230	254	484	5000
		2	35	56	958	268	1226	41500	264	146	410	5125
		3	38	70	632	216	848	21125	226	112	338	2625
		mean		63	755	313	1069	33542	240	171	411	4250
		st. dev.		7	177	126	197	10895	21	74	73	1409
		st. err.		4	102	73	114	6290	12	43	42	813

Source: Alvarez, Lehman & Associates, Inc., 1985

TABLE D-7. Continued

COLLECT DATE	STATION	REPLICATE NUMBER	DISTANCE (M)	STALK HEIGHT (CM)	WET WEIGHT BIOMASS (GRAMS/SQUARE METER)				DRY WEIGHT BIOMASS (GRAMS/SQUARE METER)			
					LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS	LIVE STALKS	DEAD STALKS	TOTAL STALKS	ROOTS
082684	M6	1	7	63	1328	374	1702	32000	572	172	744	4375
		2	22	59	724	328	1052	40000	298	140	438	5000
		3	32	68	648	326	974	43625	264	146	410	5375
		mean		63	900	343	1243	38542	378	153	531	4917
		st. dev.		5	373	27	400	5948	169	17	185	505
		st. err.		3	215	16	231	3434	97	10	107	292

Source: Alvarez, Lehman & Associates, Inc., 1985