TONGUE POINT MONITORING PROGRAM

1989-1992

FINAL REPORT

by

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PREFACE

This report presents data collected during four years of physical and environmental monitoring at the Tongue Point dredge site and the Ocean Dredged Material Disposal Site F (ODMDS F), off the mouth of the Columbia River (MCR). ODMDS F received fine grained material in 1989 from the Tongue Point, Oregon Navigation Improvements Project. This multidisciplinary investigation was conducted by the United States Corps of Engineers (USACE), Portland District staff, National Marine Fisheries Service (NMFS), Hammond, Oregon staff, the North Pacific Division Materials Testing Laboratory as well as private contractors. Data presented here include bathymetry, physical and chemical analysis of sediment and a description of benthic infauna and demersal fish/invertebrates. The contents of this report are not to be used for advertising, publication or promotional purposes. Citation of trade names does not constitute official endorsement or approval of the use of such commercial products. This report does not constitute NMFS's formal comment under the Fish and Wildlife Coordination Act or the National Environmental Policy Act.

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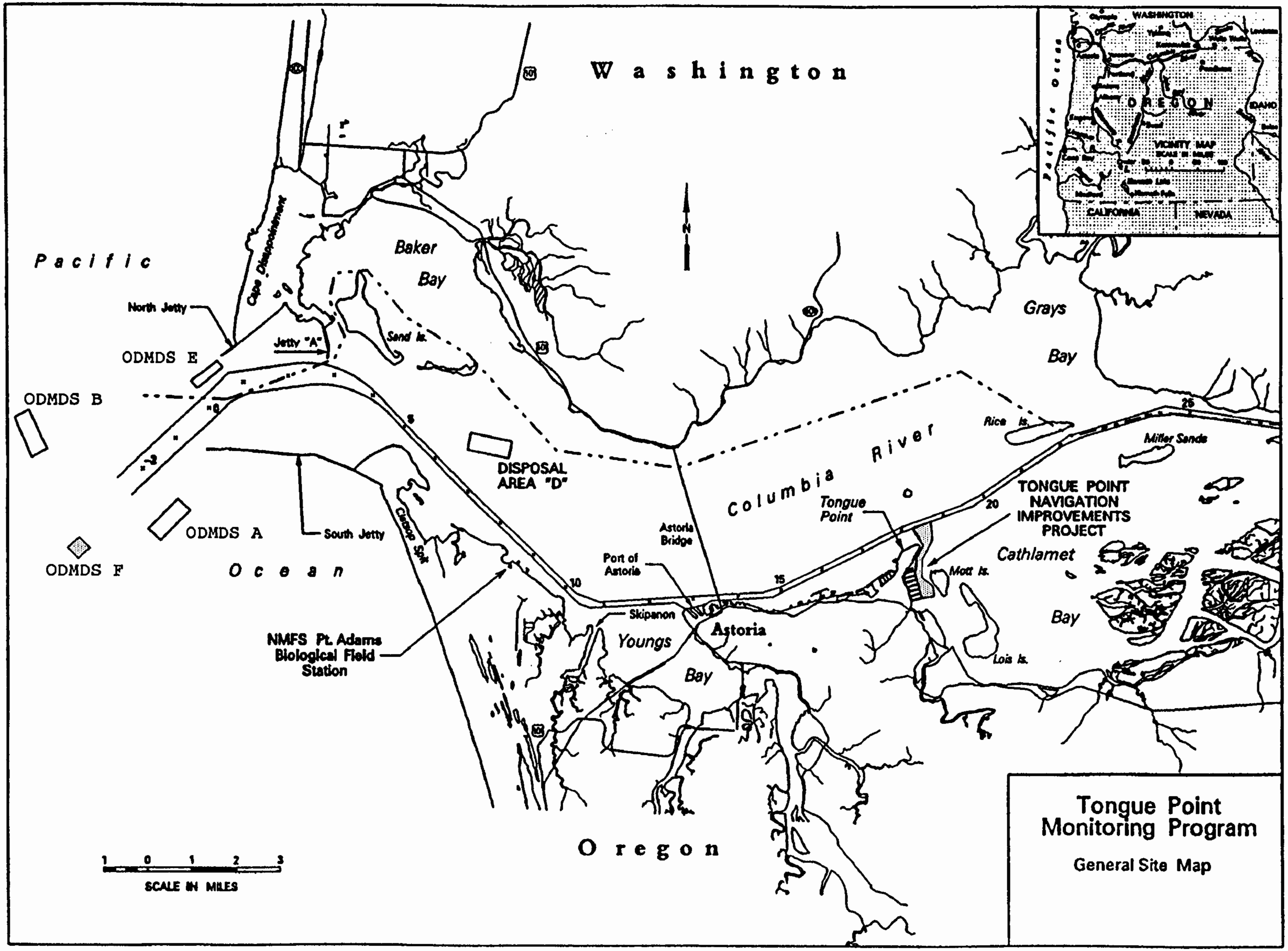
INTRODUCTION

The Tongue Point harbor and port facilities is located near Astoria, Oregon (Figure 1) approximately 18 miles from the mouth of the Columbia River (MCR). It was first developed in the 1930's as a U.S. Naval base and after World War II as a temporary berthing area for ships. In 1980 the State of Oregon purchased 45 acres and five of the eight finger piers of the Tongue Point facilities from the Federal Government. The remaining three finger piers and 316 acres are still federally owned and used by the U.S. Department of Commerce as a Job Corps Center and the U.S. Coast Guard as a buoy tender station.

The State of Oregon has promoted various development projects for the site, including an auto importing facility. In order to provide access for large vessels, the turning basin and the navigation channel connecting the site to the main Columbia River channel needed to be deepened. The State of Oregon and U.S. Army Corps of Engineers (USACE) entered into an agreement to study the benefits and impacts of deepening the Tongue Point access channel and turning basin. In April 1989 the USACE, Portland District completed the Final Detail Project Report (DPR) and Environmental Assessment (EA) titled "Tongue Point, Oregon, Navigation Improvements" (USACE, Portland District, 1987). The DPR recommended construction of a 34-foot deep by 350-foot wide channel, 1.75-miles long, from the Columbia River Federal Navigation Channel to the Tongue Point docks (Figure 2). Also, near the piers, a 25-foot deep by 1,050-foot wide turning basin would be needed. Dredging was accomplished in the late summer and fall of 1989. Disposal of the dredged sediments occurred at Ocean Dredged Material Disposal Site F (ODMDS F), located approximately 4.2 miles southwest from the mouth of the Columbia River.

The Tongue Point Navigation Project lies in an area of important wildlife habitat. It borders the western edge of Cathlamet Bay and Lewis and Clark Wildlife Refuge. The area includes habitat for resident and anadromous fish species, waterfowl and a breeding pair of bald eagles *(Haliaeetus leucocephalus)*. The area is also an important rearing area for juvenile salmonids, particularly fall chinook salmon *(Oncorhynchus tshawytscha)*.

Figure 1.--Tongue Point Monitoring Program Site Map.



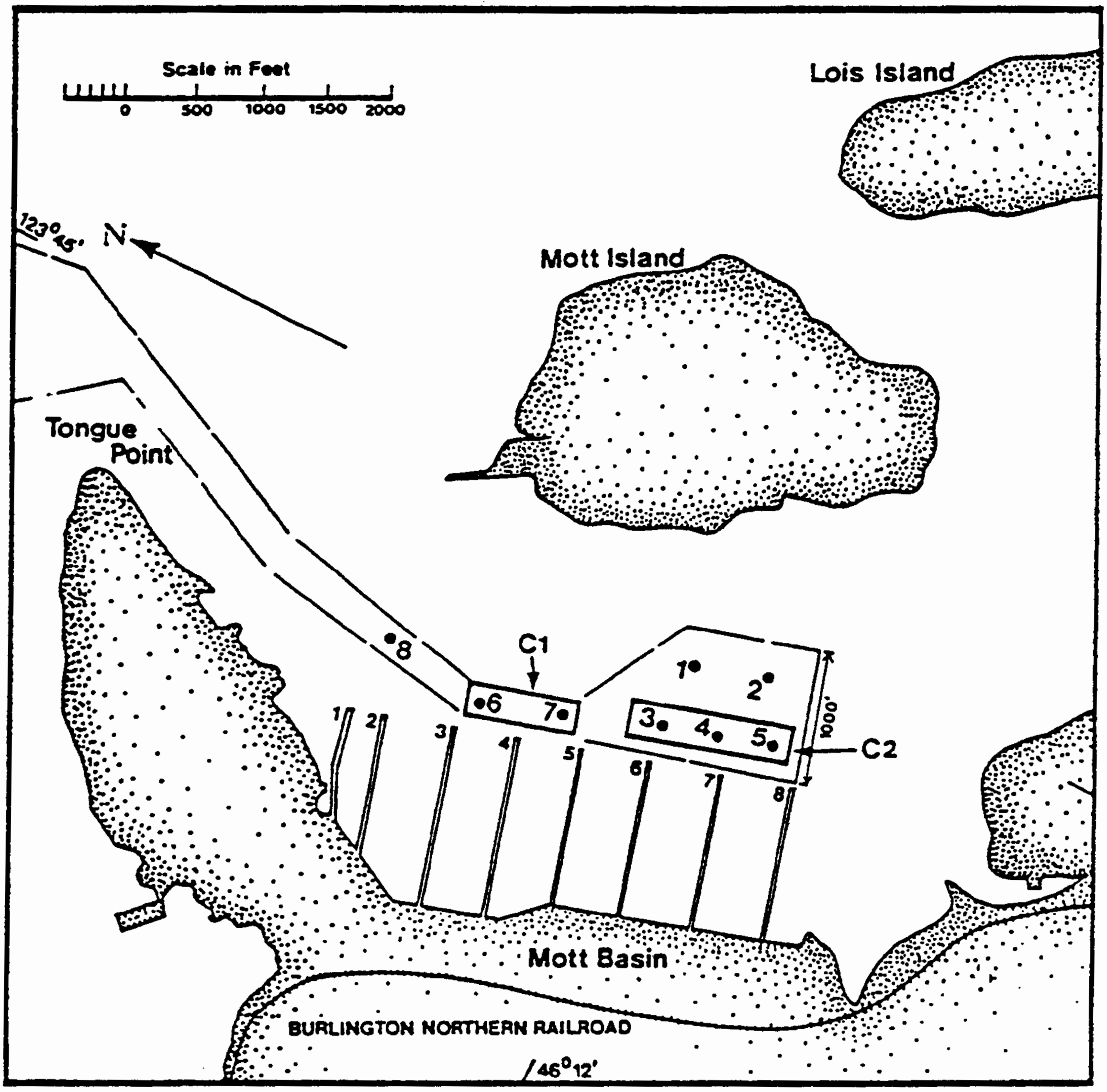


Figure 2.--Tongue Point Sediment Sampling Stations. (From Enviro Science Inc., 1983)

Resident fish species in this area include the three-spined stickleback *(Gasterosteus aculeatus)*, peamouth *(Mylocheilus caurinus)* and starry flounder *(Platichthys stellatus)*. Besides bald eagles, peregrine falcons *(Falco peregrinus)*, open water birds and harbor seals *(Phoca vitulina)* have been seen in the area. Beaver *(Castor canadensis)*, river otter *(Lutra canadensis)*, mink *(Mustela vison)*, muskrat *(Ondatra zibethica)* and black-tailed deer *(Odocoileus hemionius columbianus)* are also residents.

Dredging in 1989 was accomplished by two clamshell dredges with material barged to the disposal site. Equipment used included two barge mounted cranes equipped with 15 and 24 cubic yard (CY) clamshell buckets. Four 3,000 CY capacity bottom-dump transport barges transported the dredged material to ODMDS F. Tug captains were given one coordinate (46°11.68′ N, 124°09.57′ W) as a dump target. Dredging began on July 28, 1989 and was completed on December 1, 1989.

The Tongue Point Navigation Improvement Project dredged approximately 2 million cubic yards (MCY) of material and disposed this fine grained material on the sandy substrate at ODMDS F. Because of the dissimilarity of disposal sediments to the coarser ambient sediment and possible sediment contamination, there was concern that negative environmental impacts to the local habitat for crabs, fish and benthic invertebrates would occur at the disposal site. There was also a concern that the dredging operation would suspend and redistribute contaminated sediments in and around the dredge site. Various natural resource agencies identified the need for monitoring the project both at ODMDS F and at Tongue Point because of its wildlife habitat. Therefore, a dredge site and disposal site monitoring program was developed in 1989. In order to assess environmental impacts, physical, chemical and biological studies would be conducted at both sites pre-and post-dredging and during maintenance dredging for four years. A copy of the original 1989 Tongue Point Monitoring Program is presented in Appendix A. The results and findings of the Tongue Point Monitoring Program are the subject of this report.

PREDICTED IMPACTS

The Final Detailed Tongue Point, Oregon Navigation Improvements Project Report and Environmental Assessment (USACE, Portland District, 1987), made predictions of the possible effect that dredging and unconfined disposal would have on the dredge site and disposal site. The Tongue Point Monitoring Program was designed to provide verification of the predictions as follows:

1. Based on pre-dredging sediment chemistry, bioassay, and bioaccumulation studies relevant to this project, no significant toxicity or bioaccumulation impacts due to contaminant loading were anticipated with dredging and ocean disposal of project sediments. Bioassay and bioaccumulation tests were conducted under a "worst-case" scenario, with organisms exposed to a layer of pure dredged material. In the field, these sediments would interact with the water column and ambient sediments, causing some reduction of effects due to dilution. Ocean disposal of Tongue Point sediments could result in temporary elevations of low levels of dichlorodiphenyltrichloroethane (DDT), mercury, cadmium, copper, and several polynuclear aromatic hydrocarbons (PAHs) within and adjacent to the disposal site (see Battelle 1988). However, strong mixing processes which occur seasonally at the disposal site due to storm events, tides, and Columbia River discharges will disperse and dilute dredged sediments and their associated contaminants.

2. Battelle (1988) and Enviro Science (1987) reported dredged sediments from Tongue Point were composed of finer material (40 to 70 percent silt/clay size range) than the disposal site sediments (less than 4 percent fines). This indicated that ODMDS F was a dispersive site, at least for the fine-grain fraction of the dredged sediments. Based on available current and sediment transport information on the area offshore of the Columbia River mouth (Borgeld et al. 1978, USACE Portland District 1987), most sediment transport is expected to be northward along depth contours, with some offshore component. Sediment transport will occur mostly during the winter following disposal. Inshore transport of large quantities of fine sediments was not anticipated.

3. The project required the disposal of 2.0 MCY of silty sands and sandy silts at ocean disposal ODMDS F over a 4 month period during July to December 1989. This calculates to a layer of dredged material up to 15-feet thick which would cover an area 5 to 15 times the disposal site area. However, bulking and water column dispersal factors, as well as movement off-site of sediments deposited early in the project, was expected to result in a layer at least several feet less than calculated from dredged material volume and site area.

4. Complete smothering of benthic infaunal organisms was expected within the disposal site, with recolonization expected within several months. In addition, benthic habitats outside the disposal site would be altered due to mixing of finer grained dredged material with ambient sands. Monitoring studies conducted in 1986 and 1987 at ODMDS H, a fine grained ocean dredged material disposal site off Coos Bay, Oregon, indicated an impact area about twice the size of the disposal site (Fletcher 1988). By 1988 the Coos Bay ODMDS H impact zone had enlarged to about five times the disposal site area, with some locations having as high as 30 percent fines in sediments normally having less than 3 percent fines. This impact resulted from the disposal of 1.2 MCY during a two year period (1985 to 1987). The calculated layer of dredged material at ODMDS H was about 3 feet thick. Most of the dredged material mixed with the sands in the area, especially away from the disposal site. Coos Bay ODMDS H is located in water depths of 165 to 200 feet and with an area 1,500 ft x 3,500 ft, or 31 percent greater than that of ODMDS F off the mouth of the Columbia River. The Coos Bay benthic macroinfauna communities shifted in the impact zone towards greater dominance of polychaetes, with fewer mollusc and crustacean species.

A similar and more pronounced effect was anticipated at ODMDS F for the Tongue Point project, since more dredged material was to be deposited, the disposal rate higher (total deposition was in 4 months), the disposal site smaller, and the water depths shallower than Coos Bay ODMDS H. Sediment transport at Coos Bay ODMDS H has corresponded to average current directions with material moving northward along depth contours and downslope to the west. Columbia River ODMDS F was expected to exhibit similar patterns. Averaged current directions near ODMDS F are to the north and northwest. Currents close to shore move southeast in the summer, but should not effect ODMDS F, which is in water deeper than where these currents normally occur. Given sediment movements observed at Coos Bay, the projected 15-foot layer of dredged material at ODMDS F was expected to disperse and cover an area at least five times the disposal site area. Since the disposal layer is expected to be five times thicker than at ODMDS H, the disposal impact zone could be as much as 10 to 15 times greater than the dumping area. Therefore, based on observed changes at ODMDS H, an impact zone between 5 to 15 times the area of ODMDS F was anticipated for the Tongue Point project,with this impact zone existing primarily north and offshore of the site.

5. The use of a clamshell bucket dredge with minimum disposal barge overflow was expected to minimize the possibility of suspension and redistribution of contaminated sediment at the dredge site.

PREVIOUS STUDIES

May and December 1980 - The United States Geological Survey (USGS) (1984) under contract with USACE, Portland District conducted analysis of native euryhaline water from Tongue Point as reference for elutriates and native water samples collected at Baker Bay, Astoria and Youngs Bay. No collection of Tongue Point bottom material for analysis was made as part of this study.

April and August 1982 - The USGS (1984) under contract with USACE, Portland District conducted analyses of native water, elutriates and bottom material collected from the mouth of the Columbia River to Cathlamet Bay. Analyses of elutriate and bottom material included heavy metal and phenolic compounds but did not include pesticide analyses.

October 1983 - Sediment samples were collected from between the existing Tongue Point finger piers by Dames & Moore (1984) as part of a geotechnical investigation and environmental assessment of a 15 acre fill for a proposed sawmill facility. Samples were analyzed by the USACE, North Pacific Division Materials Testing Laboratory for gradation, heavy metals and organic content. As part of the same evaluation Enviro Science, Inc. (1983) conducted an assessment intended to provide environmental information primarily focused on the aquatic environment.

September and October 1984 - As part of the Columbia River Coal Export Channel study (USACE, Portland District 1987, USGS 1989) the USGS was contracted to evaluate the distribution of selected trace metals and organic compounds in Columbia River bottom material including Tongue Point sediments. This was the first detailed trace metals and organic compounds analysis of material from the Tongue Point area. Analyses included, but was not limited to, the evaluation of chemical concentrations as related to vertical distribution, particle size and organic carbon content. Bottom material was obtained using a 20-foot vibra-core. Organochlorine compounds detected and quantified, including Aldrin, DDD, DDE, gross polychlorinated biphenyls (PCBs) and gross polyclorinated naphalenes (PCNs), were found to be confined to the upper 3 feet of sediment. Of the nine groups of acid/base/neutral extractable compounds for which analyses were conducted, only polynuclear aromatic hydrocarbons (10 out of 16 PAHs) were detected, with concentrations ranging from 8 to 278 mg/kg. Metal concentrations were found to vary with depth and between sediment size fractions. The highest metal concentrations were generally found in the upper sections of the sediment core sorbed to the finer particle size fractions. Sedimentation rates in Cathlamet Bay were estimated using ^{210}Pb and ^{137}Cs analysis. Since ^{210}Pb and ^{137}Cs were confined to the upper 0-20 inches, the earliest date that can be assigned to this layer is 1953. This corresponds to when naval vessels were maintained at the Tongue Point site.

September 1987 - Enviro Science, Inc. (1987) collected eight sediment samples (Figure 2) within the project area as part of a sediment evaluation study by the Columbia River Estuary Study Task Force (CREST). Bulk chemistry was conducted for heavy metals, PAHs and pesticides. Elutrial analyses were conducted for heavy metals. Physical (grain size) and volatile solid analysis were also conducted. Three analytical schemes for evaluating the sediments were used. They included: 1) physical analysis (grain size) and volatile solid determination for all eight samples; 2) bulk analyses of three composite samples [stations 1+2; 3+4+5(C2); 6+7(C1)] which were analyzed for oil and grease, total organic carbon (TOC), ph, ammonia, heavy metals and organic compounds (pesticides/PCBs and base/neutral extractables); and 3) elutriate analyses of the three composite samples for TOC, pH, ammonia and heavy metals. This study is of little comparative value since most of the detection limits reported are too high to be of use in the evaluation of sediment quality at the dredge site. However, the sample plan of eight sample locations and the compositing scheme was sound and was used in all further studies.

August 1988 - Sediment cores were collected by Battelle Pacific Northwest Laboratory (Battelle 1988) under contract with USACE, Portland District for confirmatory chemical analysis and solid phase bioassays for the Tongue Point Navigation Improvements Project. The purpose for this study was to determine the suitability of the Tongue Point sediments for ocean disposal.

Sediment samples were collected from five stations (Figure 2) and mixed into two composite batches [stations 3+4+5; (C2) and stations 6+7; (C1)]. Ten day flow-through, solid-phase bioassays were conducted on four species of organisms (*Macoma nasuta, Nephtys caecoides, Rhepoxynius abronius, Grandidierella japonica*). Ten day static, solid-phase bioassays were conducted on two species (*R. abronius* and *G. japonica*). Clams (*M. nasata*) were also subjected to a 20 day flow-through, solid-phase survival and bioaccumulation test. Sediment composites were chemically analyzed for 8 metals or metaloids, 65 polynuclear aromatic hydrocarbons, 19 pesticides, 5 polychlorinated biphenyls and 5 conventional contaminants. The sediments were also physically analyzed for grain size. Chemical contaminants that were identified as elevated in sediments were then analyzed in the bioaccumulation tissues.

One pesticide (DDD) and 10 PAHs were found either above method detection limits or were considered present by the analyst. The pesticide DDD was below the calculated method detection limit but considered real. No PCB aroclors were detected. Measured PAHs totaled 1,059 mg/kg and 1,013 mg/kg (C2 and C1, respectively) and were composed primarily of fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b,k)-floranthene, indeno(1,2,3-cd)pyrene, and benzo(a)pyrene. Bis(2-ethylhexyl)phthalate was considered present in one composite and was the only phthalate ester encountered. Cadmium, lead and zinc in the Tongue Point sediments were the enriched when compared to world soils and reference sediments.

Only one bioassay test, *R. abronius* (static) showed statistically significant differences between reference or control samples and test sediment. Survival ranged from 60 to 95% in C1 and 70 to 90% in C2 indicating patchiness to the toxicity. Under flow-through conditions survival of *R. abronius* was not significantly different from survival in control or reference sediments. There was no statistically significant increase in the bioaccumulation of metals or PAHs. Concentrations of the pesticide DDD was above the analytical method detection limit. Low levels of Aroclor-1254 and DDE were measured but were below the calculated method detection limit.

PRESENT STUDY

The Tongue Point Monitoring Program (Appendix A) focused on determining bathymetric, sediment, contaminant and benthic invertebrate community changes in and adjacent to ODMDS F and sediment and contaminant changes in and around the Tongue Point dredge site. The dredge site and disposal site monitoring program was followed to the greatest extent possible. Boat and equipment scheduling, weather and equipment problems caused some delay in the scheduled sampling dates, however these delays are considered minor.

Several major changes were made. The "during construction" bathymetry survey was deleted. Late construction start delayed dredging completion until December 1, 1989. The post-construction disposal site bathymetry survey was conducted on December 11, 1989 and annually thereafter during regularly scheduled offshore hydrosurveys.

Due to rough weather and boat scheduling, post-dredge disposal ODMDS F sediment sampling did not occur until March 1, 1990. Based on the results of these analysis, chemical analysis was not conducted on the June 1990 and July 1991 disposal site sediment samples. However, chemical analysis was conducted on eight disposal site sediment samples collected in July 1992. Chemical analysis of fish tissue was completely dropped due to the lack of any identifiable sediment contamination.

Based on the 1989 and 1990 dredge site monitoring results and the lack of maintenance dredging, scheduled 1991 and 1992 Tongue Point dredge site sediment sampling and analysis was dropped. The 1990 "eagle sites" sediment sampling was also discontinued based on the December 1989 monitoring results.

Tongue Point Dredge Site

Pre-dredging Baseline Survey 1988-1989

Five sediment core samples from each of five sample stations (Figure 2) were collected in 1988 at Tongue Point near the finger piers (Battelle, 1988). Two composites were made from these; composite C1 from stations 6 and 7, and composite C2 from stations 3, 4, and 5. The composited samples were used in survival tests, solid-phase bioassays and bioaccumulation tests. Physical and chemical analyses were also performed on the composited sediment samples to determine grain size and to survey possible contaminants.

The two Tongue Point composites (C1 and C2) were chemically analyzed for 65 PAHs, 19 pesticides and 5 PCBs. Only 10 PAHs and 1 pesticide were considered detected in the samples. The total of measured PAHs averaged 1,036 mg/kg. The one pesticide detected was 4,4'-DDD, a degradation product of DDT. The detected 4,4'-DDD concentrations of 1.9 and 2.4 mg/kg were below the calculated method detection limit yet considered real by the analyst therefore reported as detected values. No PCBs were detected or considered present at Tongue Point. Detection limits for all pesticides and PCBs were low and considered acceptable.

Additional surface sediment samples were collected on September 13, 1988 from four stations up river from Tongue Point, along a distance of about 3.6 miles, at various creek outlets (Figure 3). The purpose of is sampling was to provide background data for the bald eagle mitigation/monitoring plan. These stations were chosen to determine if there were contaminated sediments in areas where bald eagles were known to forage. Although these stations were outside the Tongue Point dredging project, it was postulated that dredging could suspend and redistribute contaminated sediment into bald eagle foraging areas. Composites were made from three samples collected at Mill Creek (TP-9), South Tongue Point (TP-10), and Twilight Swamp (TC-12). One sample was collected east of Lois Island (TP-11). Samples were collected from the surface in situ.

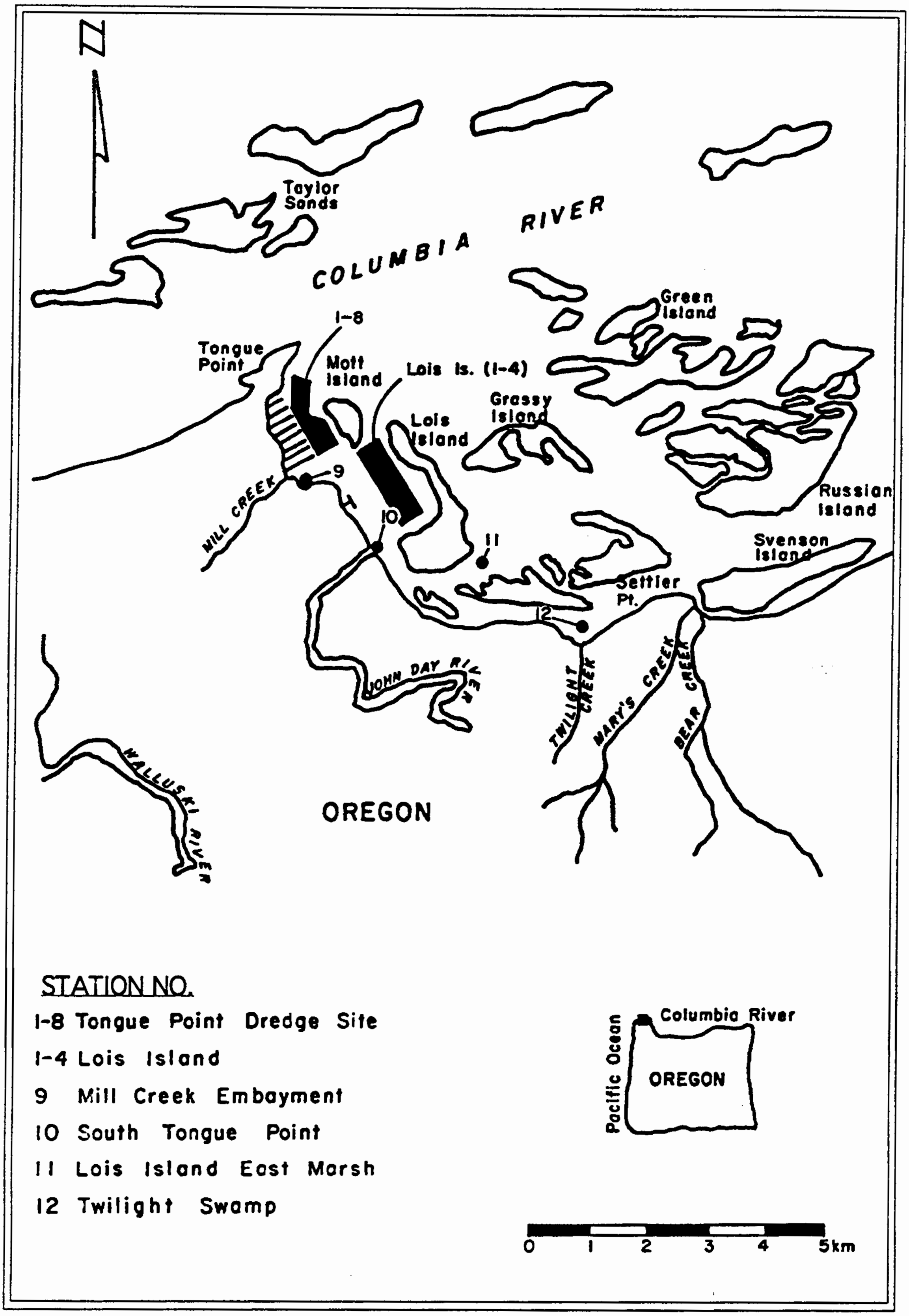


Figure 3:--Location of the Tongue Point Navigation Project, Lois Island and Eagle Study Sediment Sampling Stations.

Four sediment samples were collected on July 25, 1989 in a line near the western edge of Lois Island (Figure 3). These were combined into two composites (LI-1/2 & LI-3/4) for chemical analysis. The purpose of these samples was to obtain physical and chemical information on sediments near the Tongue Point dredging project in a deep-water area. Samples were taken from the undisturbed top two inches of the bottom material collected using a box corer (described under methods).

The results of the Tongue Point sediment physical and chemical analyses are presented in Appendix B Tables B-1 through B-4. Analyses for heavy metals showed no indication of significant contamination. No pesticides or PCBs were detected in any of the "bald eagle" study areas or Lois Island deep water sites. The "bald eagle" samples were not subjected to PAH analysis and no PAHs were detected in the Lois Island composites.

Post-dredging Survey December 1989

On December 7 & 14, 1989, seven and fourteen days after dredging ceased, Tongue Point post-dredging sediment samples were collected. To determine if the dredging operation had exposed contamination to the environment, samples were taken from all stations corresponding to the pre-dredge sample locations. These samples were collected consistent with the pre-dredging sampling protocol. Grain size, volatile solids, TOC, oil & grease, metals, pesticides, PCBs and PAHs were measured.

The surface sediments at the dredge site after dredging were about 50% sand and 50% fines (silt/clay) compared to the pre-dredge sediments which were about 34% sand and 65% fines (Appendix B Table B-1). There was an apparent increase in oil & grease from pre-dredge to post-dredge sediments (55.2 and 334.0 ppm, respectively). The amount of total organic carbon (TOC) in post-dredge sediment was similar to pre-dredge sediment. Generally, concentrations of metals remained the same or decreased slightly in post-dredge sediments; these differences were not considered significant. No pesticides, PCBs or PAHs were detected except in sample, TP-BC-5, taken near finger pier number eight which indicated a possible "hit" for 4,4'-DDD (3.0 ppb); however, this was an estimated value below the method detection limit (Appendix B Table B-4).

Post-dredging Survey August 1990

On August 14, 1990 the eight Tongue Point dredge site stations were sampled and the sediments were subjected to physical and chemical analyses. Based upon the previous monitoring results (Appendix B Tables B-2 through B-5), the Lois Island deep water sites and the four eagle monitoring stations were dropped from the monitoring program. Samples were taken by box corer and sub-samples collected from the entire depth of the material retained in the box corer. Previous post-dredging monitoring samples had been restricted to the top two inches. These samples were primarily collected to determine the sediment quality if maintenance dredging was necessary, however due to the lack of infill and need, maintenance dredging has not occurred.

Grain size, volatile solids, TOC, metals, pesticides, PCBs and PAHs were measured. Metal values were similar to previous analyses and below established levels of concern. All pesticides were below method detection limits except for sample TP-S-4 which had a hit for endosulfin at the method detection limit (3.4 ppb). Method detection levels for PAHs were several orders of magnitude below previous analyses and PAHs were detected in all samples at low levels. All PAH values were below established levels of concern.

Ocean Dredged Material Disposal Site F

Pre-disposal and Post-disposal Surveys

A pre-disposal baseline survey was conducted as outlined in the Tongue Point Monitoring Program (Appendix A). The pre-dredge bathymetry survey was conducted on May 22, 1989. Sediment, benthic infauna and demersal fish/invertebrates samples were collected between June 21, 1989 and July 10, 1989. Twenty-nine stations centered around the disposal site were sampled and analyzed to determine sediment characteristics (Figure 4). Thirteen of these stations were also sampled for benthic infauna and sediment chemistry evaluation, though only seven stations were actually analyzed chemically (Appendix B Tables B-5 through B-12). Three trawls were conducted on June 21, 1989, one in the disposal site and one each north and south of the disposal area. Post-disposal surveys were conducted as indicated in Table 1.

Bathymeteric Studies Methods/Results/Discussion

Pre-dredge, post-dredge and annual bathymeteric ODMDS F surveys were conducted by the USACE, Portland District's 65 foot Survey boat Hickson. Water depths were recorded using a Krupp Atlas DESO 20 dual frequency (40 and 200 kHz) depth sounder with a HECO-10 swell compensator. Though somewhat dependent on sea conditions accuracy is generally ±1.5 foot. Positioning was by Del Norte Trisponders w/DMU 540 and has an accuracy of ±3.3 feet. Table 2 lists the dates surveys were conducted.

Plots showing the disposal site, 13 sampling stations and depth contours are presented in Figures 5 through 9. To best illustrate the bathymetric changes to the disposal area over time, difference plots were created by subtracting the baseline data (May 22, 1989) from subsequent surveys. The resultant difference plots are presented in Figures 6 through 9 and represent thickness of the dredged material disposal mound as compared to the May 22, 1989 baseline survey. These difference plots have been massaged to eliminate background noise to better define the disposal mound.

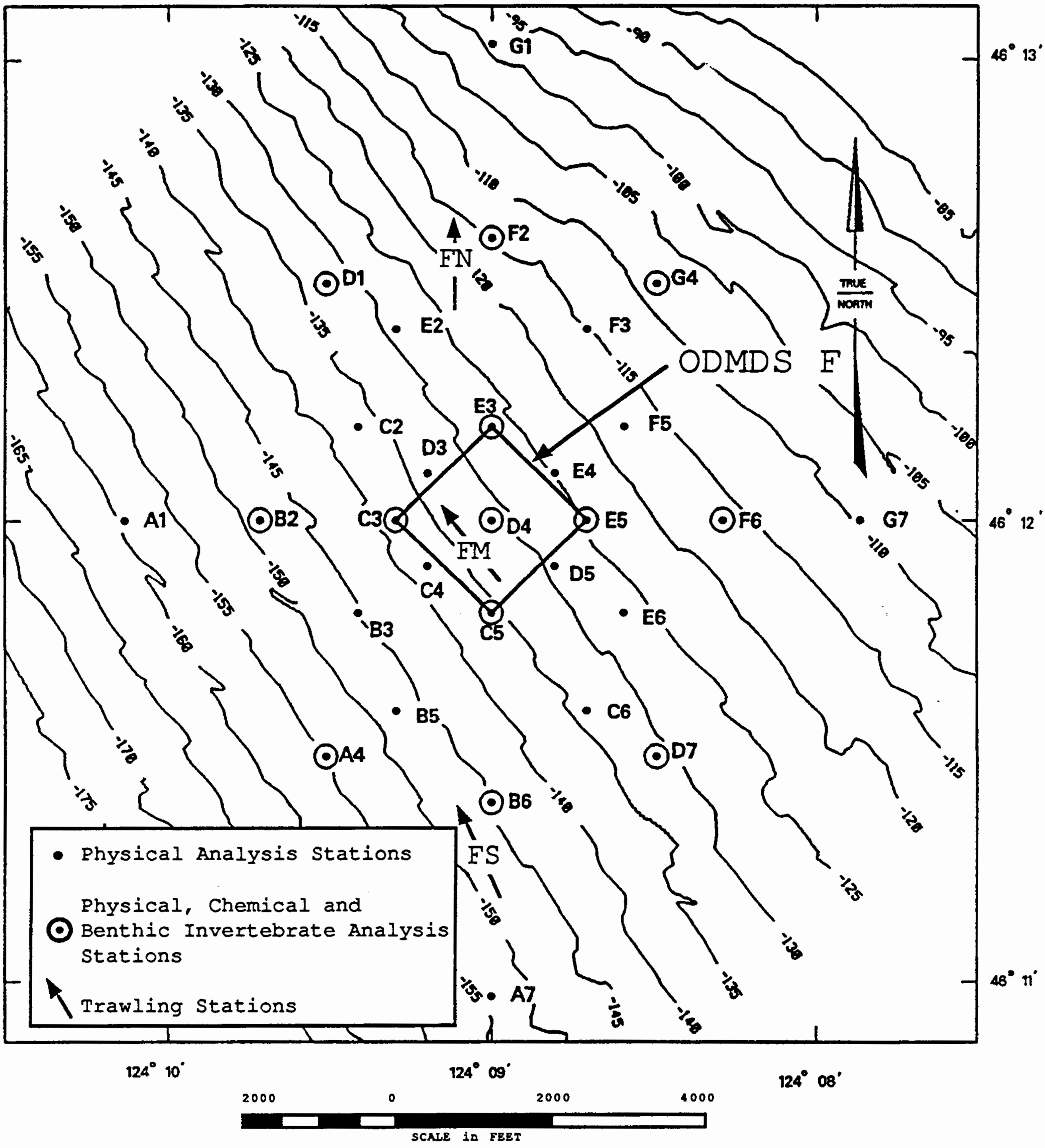


Figure 4:--ODMDS F station locations and surrounding area (depth coutours are shown in feet).

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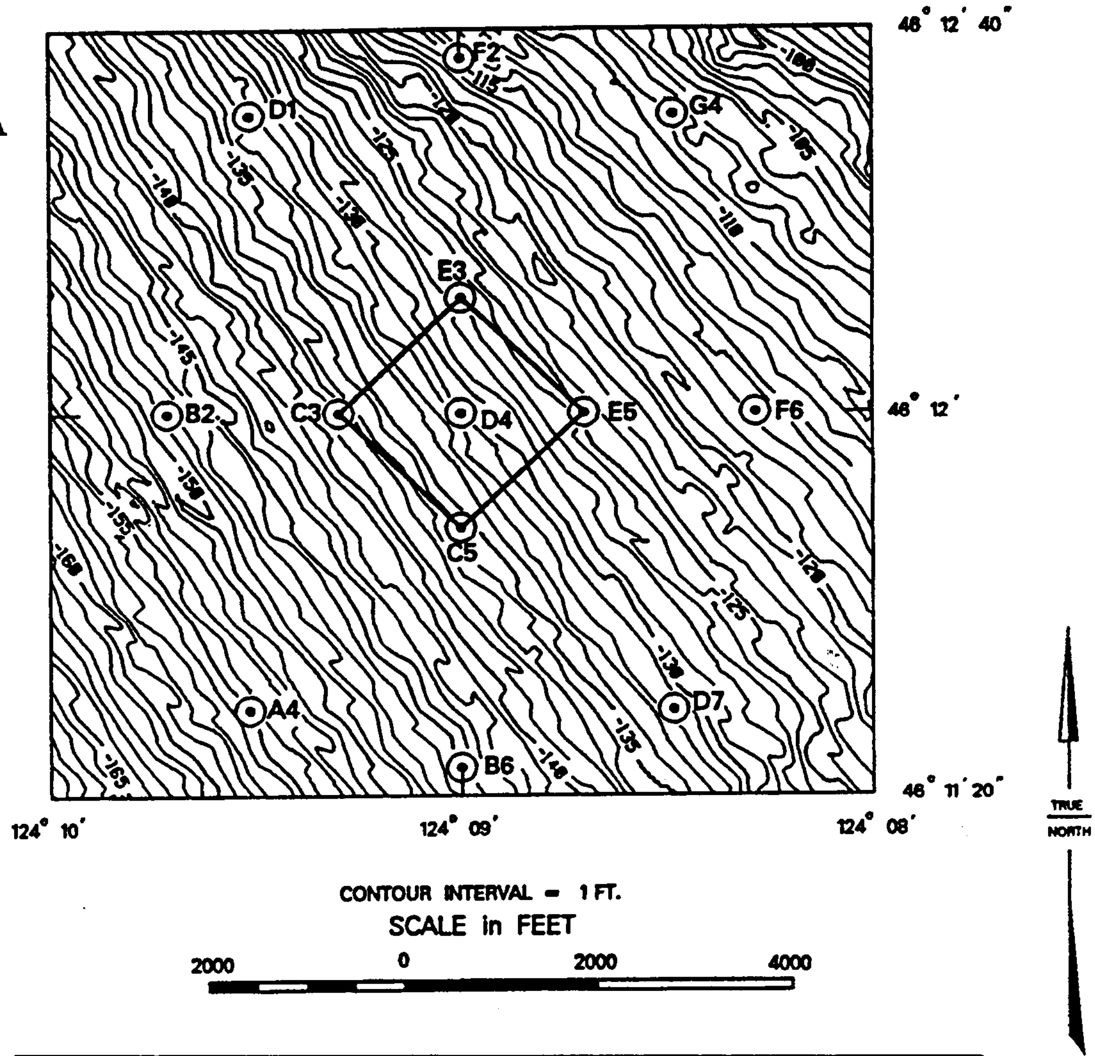

KEY (Figures 5 through 9)
◇ ODMDS F
Drawing "A"-Raw Survey Data Drawing "B"-Bathymeteric Difference Plot
Depths and Contours are in Feet
⊙ Physical, Chemical and Benthic Invertebrate Sampling Stations

Figure 5:--ODMDS F bathymetery (A) for May 22, 1989 (pre-disposal).

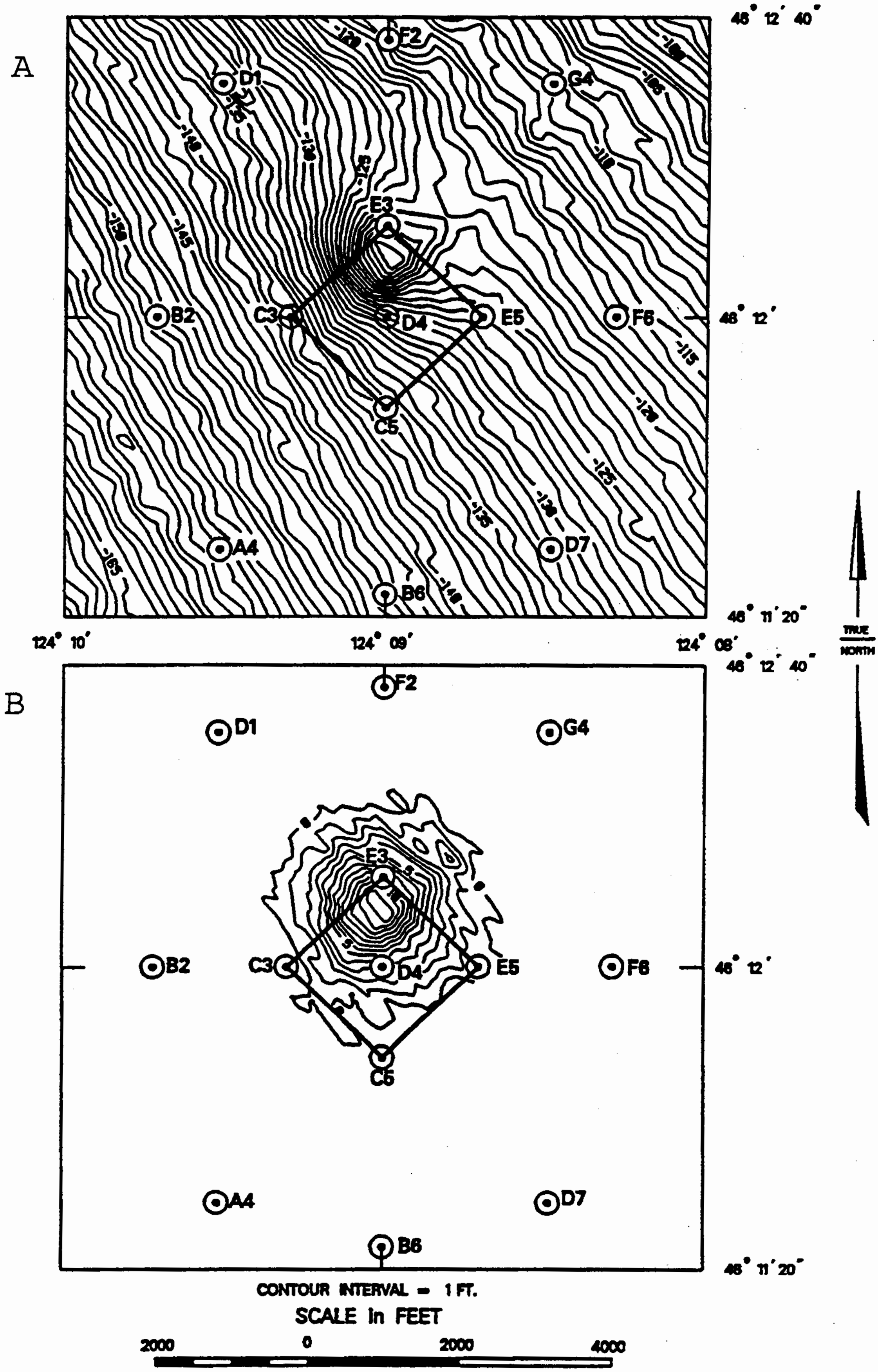

Figure 6:--ODMDS F bathymetery (A) and bathymeteric difference plot (B) for December 11, 1989.

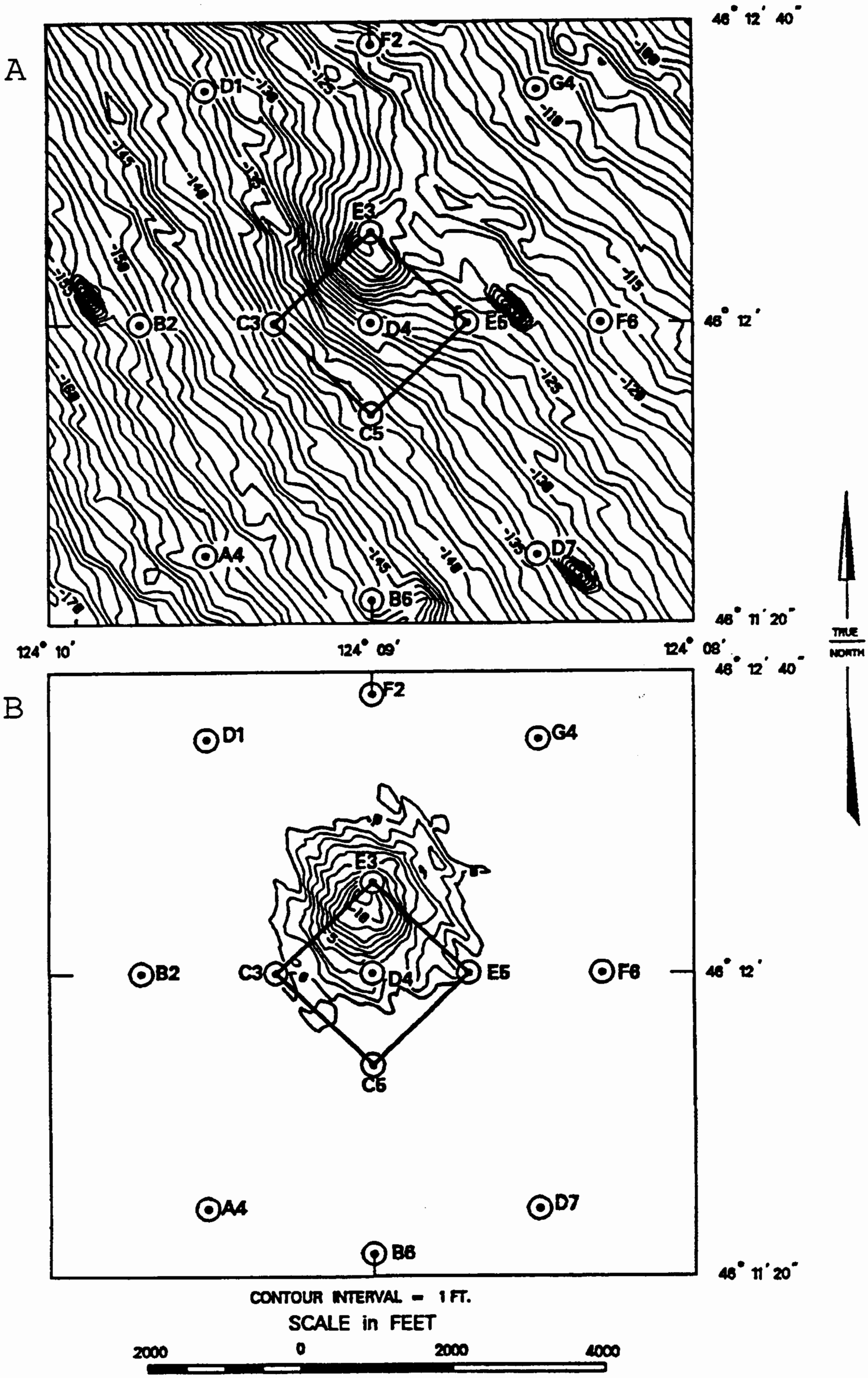

Figure 7:--ODMDS F bathymetery (A) and bathymeteric difference plot (B) for July 19, 1990.

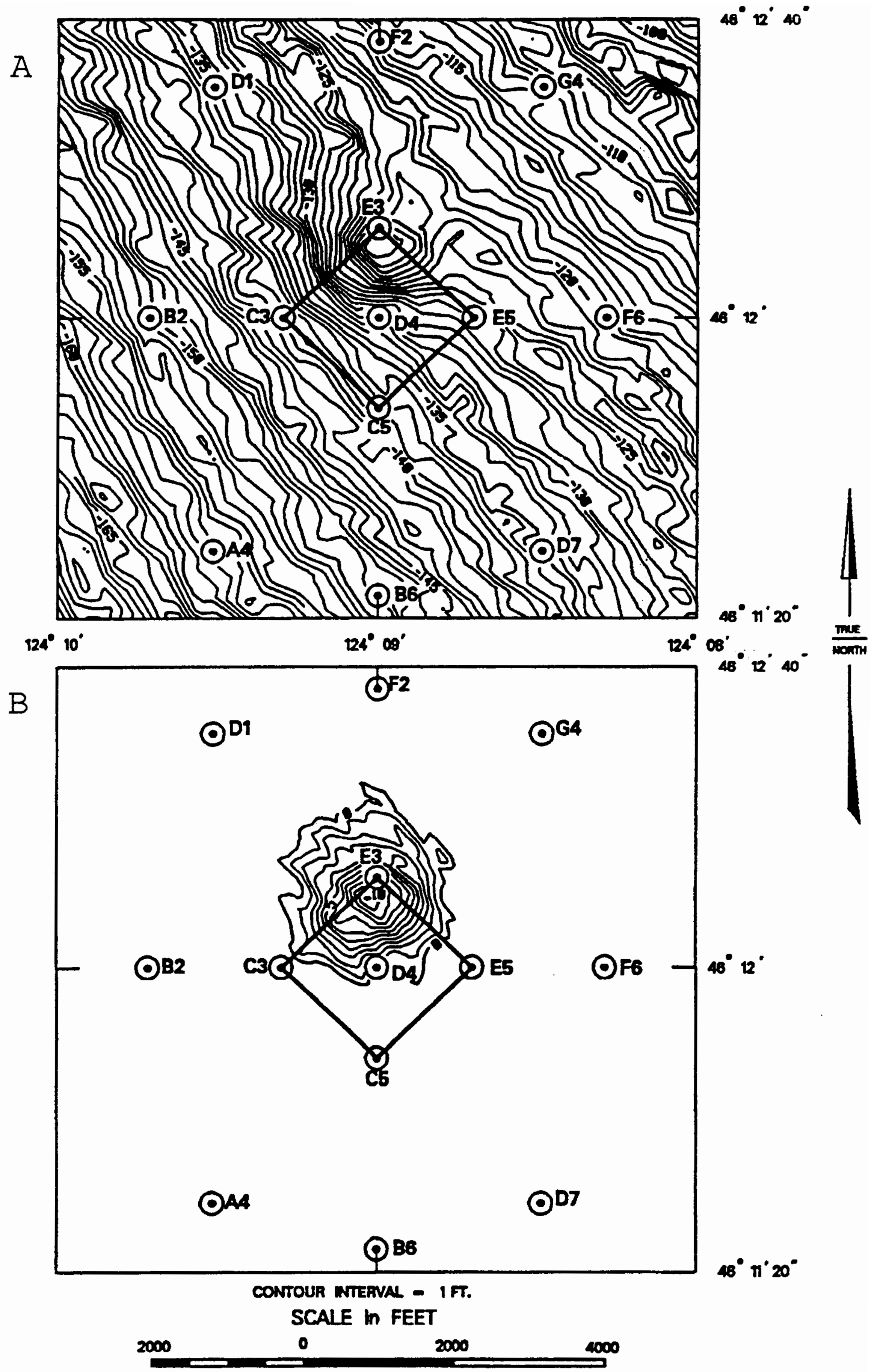

Figure 8:--ODMDS F bathymetery (A) and bathymeteric difference plot (B) for June 4, 1991.

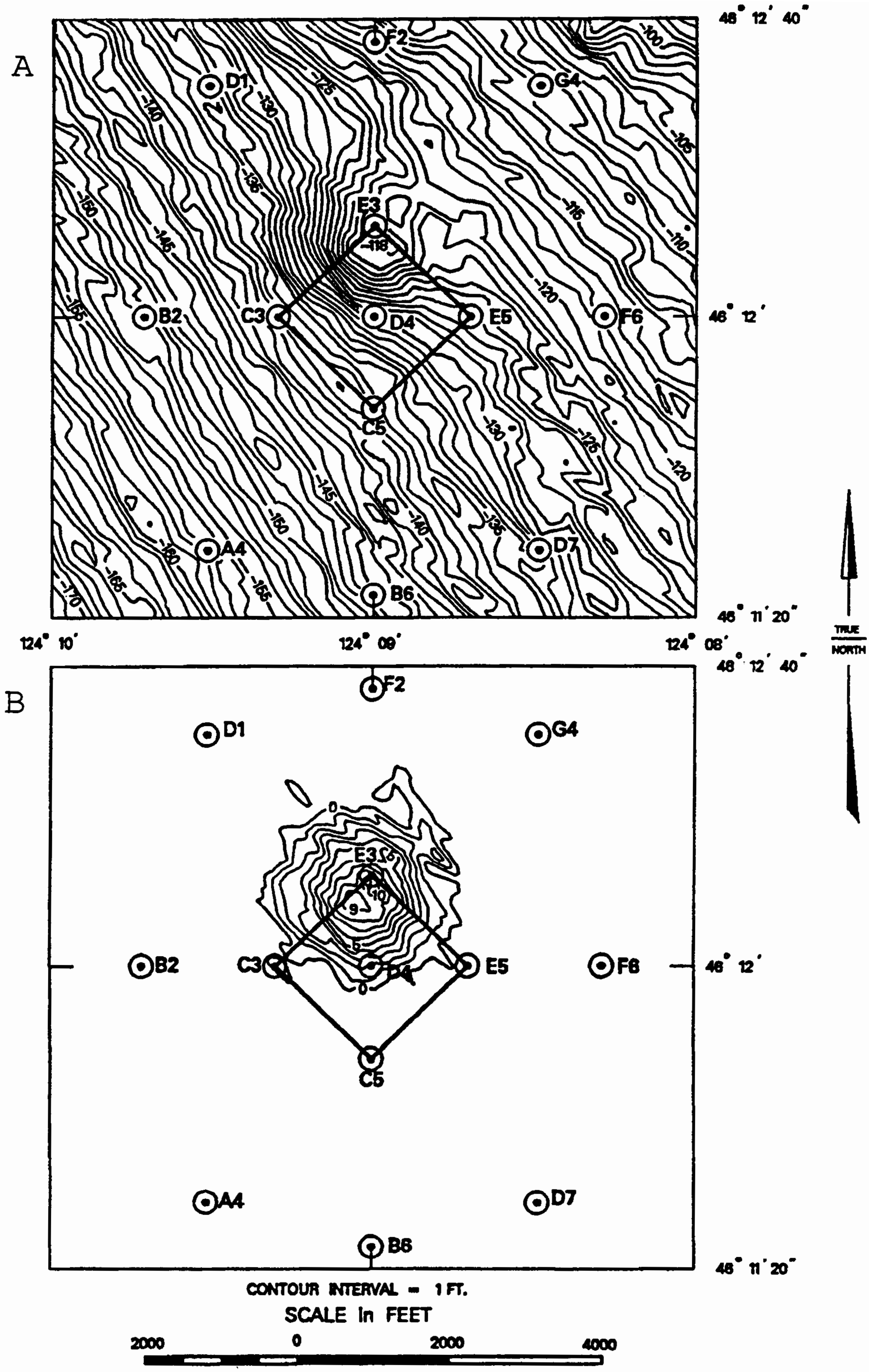

Figure 9:--ODMDS F bathymetery (A) and bathymeteric difference plot (B) for June 22, 1992.

Table 1:--ODMDS F Sampling Dates.

Date Sampled	Analyses Conducted
June 21, July 5 & 10, 1989	29 stations physical properties 7 stations chemical properties 13 stations benthic infauna 3 trawls
March 1, 1990	29 stations physical properties 13 stations chemical properties
June 13, 26 & 27, 1990	29 stations physical properties 13 stations benthic infauna 3 trawls
July 8, 9 & 10, 1991	29 stations physical properties 13 stations benthic infauna 3 trawls
July 1, 3, 1992	29 stations physical properties 8 stations chemical properties 13 stations benthic infauna 3 trawls

The December 1989-May 1989 plot (Figure 6) shows the disposal mound 10 days after cessation of dredging on December 1, 1989. The mound was solely created by Tongue Point material (no other material was deposited at the site). A fairly symmetrical mound was created with a maximum height of 12 feet. This resulted because tugboat operators were given one coordinate to discharge the hopper barges. The symmetry and integrity of the mound indicates that discharging of dredged material at this coordinate was strictly adhered to and no "short dumping" occurred. Volume calculations show the mound to contain approximately 740,000 CY of material. This is significantly less than the total calculated volume of material removed from the dredge site

Table 2:--ODMDS F bathymetric survey dates.

Time After Disposal		Dates
Baseline	(Pre-disposal)	May 22, 1989
10 days	(Post-disposal)	December 11, 1989
7.5 months	(Post-disposal)	July 19, 1990
18 months	(Post-disposal)	June 4, 1991
30 months	(Post-disposal)	June 22, 1992

(2,030,954 CY). Earlier studies with coarser grained dredged material at experimental ODMDS G (Sternberg, 1977) showed a loss of 29% of the disposal volume. The initial dispersal of the finer grained Tongue Point dredged material along with the difficulty of resolving depths to ±1.5 feet probably accounts for the bulk of the material not accounted for in the bathymeteric surveys.

The 1990, 1991 and 1992 surveys (Figures 7 through 9) show a slight decrease in the foot print of the mound with perhaps a minor shift to the north. The overall height decreased from 12 feet to 10 feet after 30 months including three winter seasons. Considering the accuracy of hydrosurveys, the shape and height of the mound created by the deposition of the Tongue Point dredged material has been fairly stable.

Sediments and Benthic Invertebrates Methods

Sediment samples were collected at 29 stations centered around ODMDS F for physical analysis (Figure 4). Sediment chemistry and benthic invertebrate samples were collected at 13 stations; 5 stations within the disposal site and

8 stations surrounding ODMDS F in 1989, 1990, 1991 and 1992. Station depths ranged from 105 to 160 feet. Loran-C navigational readings for each station were recorded and are presented in Appendix B Table B-1 and Appendix C Table C-1. A modified 0.1-m^2 Gray-O'Hara box corer (Pequegnat et al. 1981) was used to collect one sample at 16 stations and six samples at the remaining 13 benthic invertebrate stations. At the 13 benthic invertebrate stations five of the box-core samples were individually sieved through a 0.5-mm mesh screen, and the residues containing the macroinvertebrates preserved in jars with a buffered 5% formaldehyde solution containing rose bengal (a protein stain). Benthic organisms were sorted from the preserved samples, identified to the lowest practical taxonomic level (usually species), and counted. All specimens were placed in vials containing 70% ethanol and stored at the NMFS Point Adams Biological Field Station, Hammond, Oregon (See Appendix C for a complete description of data analysis methods). Subsamples of the sixth box-core sample were used for physical and chemical sediment analysis. Sediment grain size was determined by sieving, and organic content (volatile solids) by burning for 1 hour at 600^0C. Physical sediment analysis was done by the North Pacific Division Materials Testing Laboratory at Troutdale, Oregon. Chemical analysis included TOC, heavy metals, polyaromatic hydrocarbons (PAHs), pesticides and PCBs were conducted by private contract laboratories.

Fishes and Large Epibenthic Invertebrates Methods

Three trawling efforts were conducted during each survey, one in the disposal area and one each north and south of the disposal area (Figure 4). Depths along the trawling transects ranged from 109 feet to 148 feet. All trawling efforts were five minutes long and were made in a northwesterly direction as currents allowed. Bottom trawling was done with an 26.5-foot semiballoon shrimp trawl that had an overall mesh size of 0.15-inch (stretched); a 0.05-inch mesh liner was inserted in the cod end to ensure retention of small fishes and epibenthic invertebrates. Fishing width of the trawl was estimated to be 16.4 feet (See Appendix C for complete description of data analysis methods). Location and distance traveled during each trawling effort were determined using Loran-C navigational equipment (Appendix C Table C-1).

All organisms captured by trawling were weighed (g) and measured (mm)--total lengths for fishes, and carapace widths for Dungeness crabs. Shrimp were measured from the rostrum to the distal end of the telson.

Sediment Physical Properties Data Results/Discussion

Physical properties of the sediment samples collected are presented in Appendix B Tables B-5 through B-9. Selected physical properties are also presented in Appendix B Figures B-1 through B-15. Mean sediment grain size in the pre-disposal ODMDS F samples was 0.16 mm with a maximum of 0.18 mm and a minimum of 0.12 mm with a standard deviation of 0.012 mm. The mean percent fines (% of material passing a 230 mesh sieve [0.0625 mm]) was 0.91 % by weight with a maximum of 2.10%, a minimum of 0.40% and a standard deviation of 0.47%. The sediments were also low in organic content, with a mean volatile solids content of 0.61%, a maximum of 1.00%, a minimum of 0.30% and a standard deviation of 0.14%. The ODMDS F pre-disposal sediments were uniform through out the area and showed no indication of previous dredged material disposal events.

As indicated by the isopach contour drawings for median grain size, percent fines and volatile solids (Appendix B Figures B-1 through B-15) the dredged material from Tongue Point can be readily identified at ODMDS F. The March 1, 1990 data, taken three months after disposal, has a minimum median grain size of 0.03 mm, a maximum percent fines of 68.1% and a maximum percent volatile solids of 6.9%. When compared to the July 10, 1989 data, it reveals that any station with a median grain size <0.11 mm, more than 2.5% fines or more than 1.14% volatile solids indicates alteration by dredged material disposal.

While the bathymetric surveys show a rather well defined conical mound created as a result of dredge material disposal at ODMDS F, the plots of the physical characteristics of the March 1, 1990 sediment samples shows a wider distribution of dredged material. As noted in earlier studies (Sternberg, 1977), sediment character is much more sensitive than bathymetry change when defining the extent of dredged material deposit because of the difficulty in resolving depths to ±1.5 foot and the distinct difference between the disposed and ambient sediments.

Though the structural characteristics of the mound, as shown by the bathymetry difference plots, were relatively stable over time, the distribution of the physical characteristics of the sediment samples changed significantly. By July 1992, the physical characteristics of the sediments collected in the immediate area of the mound were indistinguishable from those of the pre-disposal (July 10, 1989) sediments. Apparently, the coarser ambient sediments migrated over and covered the fine grained Tongue Point dredged material. This sand "cap" will further stabilize the disposal mound. The July 1992 data revealed some organic rich fine grained sediments to the north of the disposal site. However, during sampling at these stations we observed that the fine grained material consisted of a 2-3 inch layer with "reg [sic] sand underneath". This may indicate some movement of dredged material to the north, however, similar movement was not observed during earlier sampling.

<u>Sediment Chemical Properties Data Results/Discussion</u>

Chemical analyses were conducted on selected sediment samples from the ODMDS F study area (Appendix B Tables B-10 through B-12). Pre-disposal analyses were conducted on 7 samples collected in July 1989. Post-disposal chemical analyses were conducted on 13 samples collected in March 1990 and 8 samples collected in June 1992. No pesticides or PCB's were detected in any of the ODMDS F samples. With the one exception of Pyrene (20.0 ppb) in sample F2 (June 1992), no PAH's were detected. Heavy metal concentrations in all samples were below established levels of concern, though metal concentrations increased as percent fines increased. The potential for unacceptable adverse environmental impacts due to sediment contamination was not evidenced by these analyses. Because of no evidence of sediment contamination, much of the originally scheduled chemical contaminate testing, including that of fish tissue, was dropped from the monitoring program.

Benthic Invertebrates, Fishes and Large Epibenthic Invertebrates

Benthic Invertebrates Results

The five benthic invertebrate samples from each station were treated as replicates, allowing calculation of a mean number/m^2 and standard deviation for each species, and total mean number/m^2 and standard deviation for each station. Two community structure indices, diversity (H) and species evenness (E), were also calculated for each station (Appendix C Table C-3).

A total of 192 benthic invertebrate taxa were identified from the June 1989 survey (Appendix C Table C-2); a mean of 67 taxa were found at each station (Table 3), with the mean invertebrate density 1,072/m^2 (Table 4). The highest benthic invertebrate density was found at Station D1 (1,517/m^2), which is northwest of ODMDS F at a depth of 138 feet (Appendix C Table C-3). The lowest density was found at Station D7 (788/m^2), located southeast of ODMDS F at a depth of 129 feet. The number of benthic invertebrate taxa/station ranged from 58 (Station E3) to 80 (Station D1).

Table 3.--Number of invertebrate taxa found at and adjacent to ODMDS F, offshore from the Columbia River, in June/July 1989, 1990, 1991, and 1992.

	Year			
Station	**1989**	**1990**	**1991**	**1992**
A4	71	73	99	110
B2	68	93	105	121
B6	68	72	107	108
C3	63	109	102	117
C5	67	109	106	110
D1	80	86	89	107
D4	64	58	106	109
D7	59	71	100	92
E3	58	88	108	111
E5	61	74	93	103
F2	71	73	92	93
F6	72	71	97	89
G4	65	68	101	83
Mean	67	80	100	104

Table 4.--Densities (number/m^2) of the benthic invertebrate community at and adjacent to ODMDS F, offshore from the Columbia River, in June/July 1989, 1990, 1991, and 1992. Station densities were calculated by combining replicates from each station.

	Year			
Station	**1989**	**1990**	**1991**	**1992**
A4	1,223	2,238	3,599	13,759
B2	1,294	3,262	4,362	14,027
B6	871	2,574	3,872	11,479
C3	967	3,712	5,937	14,171
C5	1,142	2,978	3,833	7,821
D1	1,517	3,587	4,001	14,819
D4	882	724	3,416	10,072
D7	788	2,584	3,660	6,646
E3	992	2,793	6,823	9,820
E5	798	2,270	4,379	8,709
F2	1,046	1,588	5,760	9,422
F6	1,132	2,538	4,739	7,332
G4	1,278	1,555	4,987	7,207
Mean	1,072	2,492	4,567	10,406

A total of 209 benthic invertebrate taxa were identified from the June 1990 survey (Appendix C Table C-2); the mean invertebrate density in 1990 was 2,492/m^2 (Table 4). The highest benthic invertebrate density was found at Station C3 (3,712/m^2) (Table 4), located on the west corner of ODMDS F at a depth of 171 feet (Appendix C Table C-2) . The lowest density was found at Station D4 (724/m^2), located in the center of the ODMDS F at a depth of 132 feet. The number of benthic invertebrate taxa/station ranged from 58 (Station D4) to 109 (Stations C3 and C5) (Table 3).

A total of 224 benthic invertebrate taxa were identified from the July 1991 survey (Appendix C Table C-2); the mean invertebrate density was 4,567/m^2 (Table 4). The highest benthic invertebrate density was found at Station E3 (6,823/m^2), located at the north end of ODMDS F at a depth of 138 feet (Appendix C Table C-3). The lowest density was found at Station D4 (3,416/m^2), located at the center of the ODMDS F. The number of benthic invertebrate taxa/station ranged from 89 (Station D1) to 108 (Station E3) (Table 3).

A total of 235 benthic invertebrate taxa were identified from the July 1992 survey (Appendix C Table C-2); the mean invertebrate density was 10,406/m^2 (Table 4). The highest benthic invertebrate density was found at Station D1 (14,819/m^2), located at the north end of ODMDS F at a depth of 138 feet (Appendix C Table C-3). The lowest density was found at Station D7 (6,646/m^2), located south of the ODMDS F. The number of benthic invertebrate taxa/station ranged from 83 (Station G4) to 121 (Station B2) (Table 3).

The overall mean benthic invertebrate density (all stations combined) changed significantly during the four survey years (Kruskal-Wallis, $P < 0.05$). Benthic invertebrate densities essentially doubled each survey year (Table 4).

The number of taxa also increased significantly during our survey years (Kruskal-Wallis, $P < 0.05$), rising from a overall mean of 67 taxa in 1989 to a high of 104 in 1992 (Table 3).

Diversity (H) dropped significantly during our survey years (Kruskal-Wallis, $P < 0.05$), from a high mean of 4.89 in 1989 to a low of 3.82 in 1992 (Table 5).

Evenness (E) followed a similar pattern, falling from a high mean of 0.81 in 1989 to a low of 0.57 in 1992. These values were also found to be significantly different (Kruskal-Wallis, $P < 0.05$) (Table 6).

Polychaetes and amphipods were the most abundant taxa captured during each survey, with molluscs also being important (Table 7). Dominant species in June 1989 included the polychaetes *Nephtys* spp., *Leitoscoloplos elongatus*, and *Chaetozone spinosa*; and the amphipods *Eohaustorius sencillus* and *Rhepoxynius* spp. Dominant species in June 1990 included the polychaetes *Spiophanes bombyx*, *Spiophanes berkeleyorum*, and *Magelona sacculata*; and the amphipods *Orchomene* cf. *pinguis* and *Rhepoxynius daboius*. Dominant species in July 1991 was the bivalve *Olivella baetica*, and the polychaetes *Magelona sacculata* and *Spiophanes berkeleyorum*. In 1992, dominant species where the polychaetes *Spiochaetopterus costaum, Spiophanes bombyx,* and *Spiophanes berkeleyorum.*

The increases in benthic invertebrate densities during each concurrent survey were typically not related to any specific increase in any specific taxa, but a result in increases in many different taxa (Table 7). One of the major polychaete species, *Spiophanes bombyx,* increased from 69.4 mean individuals/m^2 in 1989 to 1,309.2 mean individuals/m^2 in 1992. However, one taxa, *Spiochaetopterus costarum,* was not found in 1989 but was the most abundant taxa in 1992 (3,316.4 mean individuals/m^2) (Table 7).

Table 5.--Diversity (H) of the benthic invertebrate community at and adjacent to ODMDS F, offshore from the Columbia River, in June/July 1989, 1990, 1991, and 1992. Station values were calculated by combining replicates from each station.

	Year			
Station	**1989**	**1990**	**1991**	**1992**
A4	4.88	4.75	5.13	3.81
B2	4.97	4.90	4.95	3.50
B6	5.08	4.28	5.27	3.98
C3	4.54	4.80	4.82	3.38
C5	4.92	5.20	5.17	4.17
D1	4.89	4.84	4.60	3.66
D4	4.82	4.91	5.18	4.00
D7	5.02	4.19	4.70	3.96
E3	4.71	4.33	4.95	4.04
E5	4.85	4.40	4.56	3.97
F2	4.94	4.71	4.03	3.46
F6	4.93	4.10	4.59	3.71
G4	4.96	4.46	4.62	4.03
Mean	4.89	4.61	4.81	3.82

Table 6.--Evenness (E) of the benthic invertebrate community at and adjacent to ODMDS F, offshore from the Columbia River, in June/July 1989, 1990, 1991, and 1992. Station values were calculated by combining replicates from each station.

	Year			
Station	**1989**	**1990**	**1991**	**1992**
A4	0.79	0.77	0.77	0.56
B2	0.82	0.75	0.74	0.51
B6	0.83	0.69	0.78	0.59
C3	0.76	0.71	0.72	0.49
C5	0.81	0.77	0.77	0.61
D1	0.77	0.75	0.71	0.54
D4	0.80	0.84	0.77	0.59
D7	0.85	0.68	0.71	0.61
E3	0.80	0.67	0.73	0.59
E5	0.82	0.71	0.70	0.59
F2	0.80	0.76	0.62	0.53
F6	0.80	0.67	0.70	0.57
G4	0.82	0.73	0.69	0.63
Mean	0.81	0.73	0.72	0.57

Groups of stations identified from the Principal Component Analysis (PCA) are shown graphically in Figures 10 through 13. These figures reveal that the study area had an unstable benthic invertebrate community that helps to mask or overrides any changes in the benthic invertebrate community which could be statistically attributed to the disposal of dredged material. Nevertheless, Station D4, at the middle of the disposal site, did appear to be affected by the dredged material disposal in 1990. This is indicated by its low benthic invertebrate densities (724 individuals/m^2) in 1990 compared with the other stations, and the fact it was not included with any other station groupings (i.e., had different major species) (Figure 11). However, by 1991, the benthic invertebrate species composition and densities at Station D4 were similar to Stations C3 and E3 (Figure 12). This station grouping (D4, C3, and

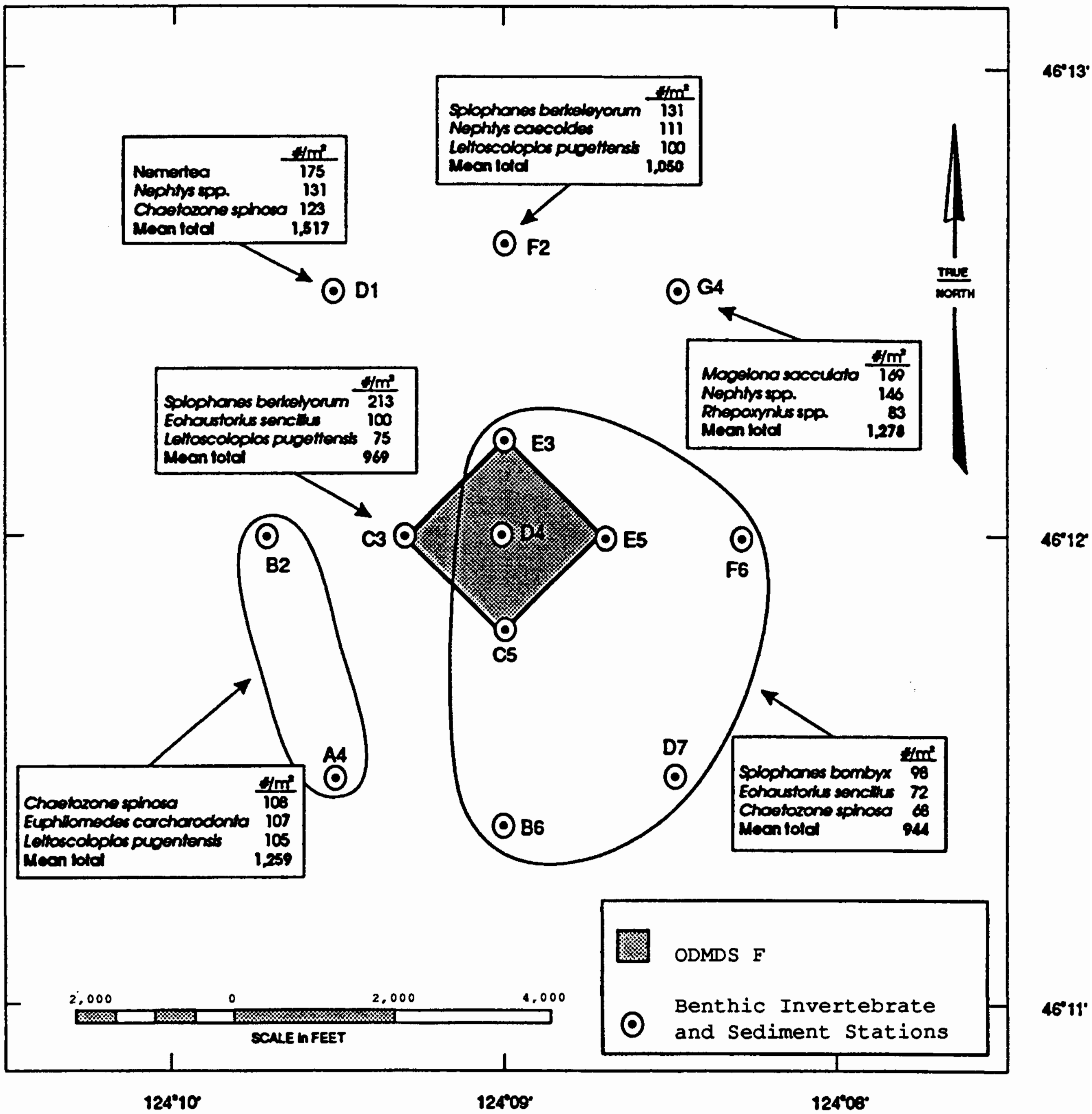

Figure 10.--Benthic invertebrate PCA groups and their top three major taxa identified at and adjacent to ODMDS F, offshore from the Columbia River, July 1989.

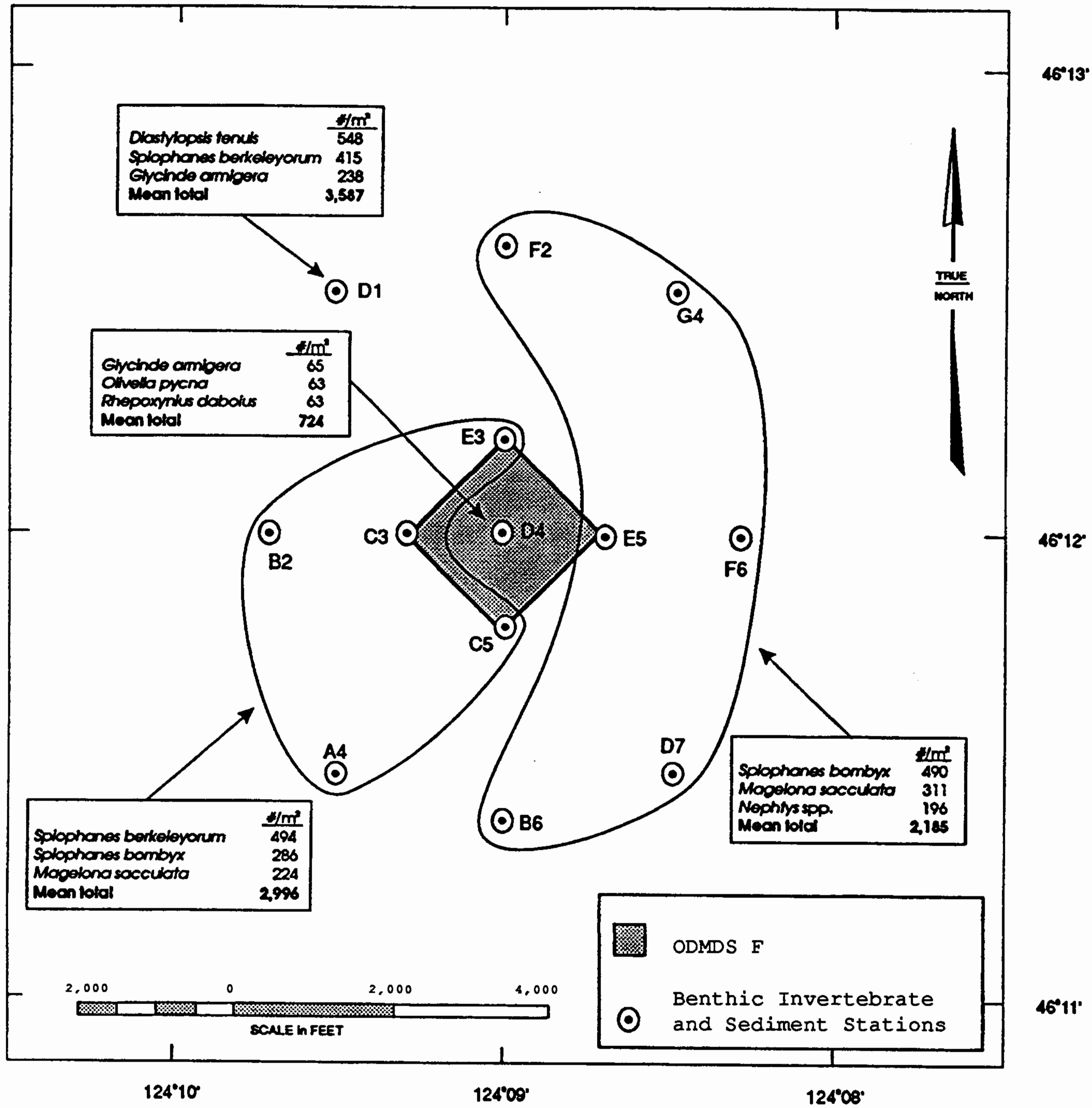

Figure 11.--Benthic invertebrate PCA groups and their top three major taxa identified at and adjacent to ODMDS F, offshore from the Columbia River, June 1990.

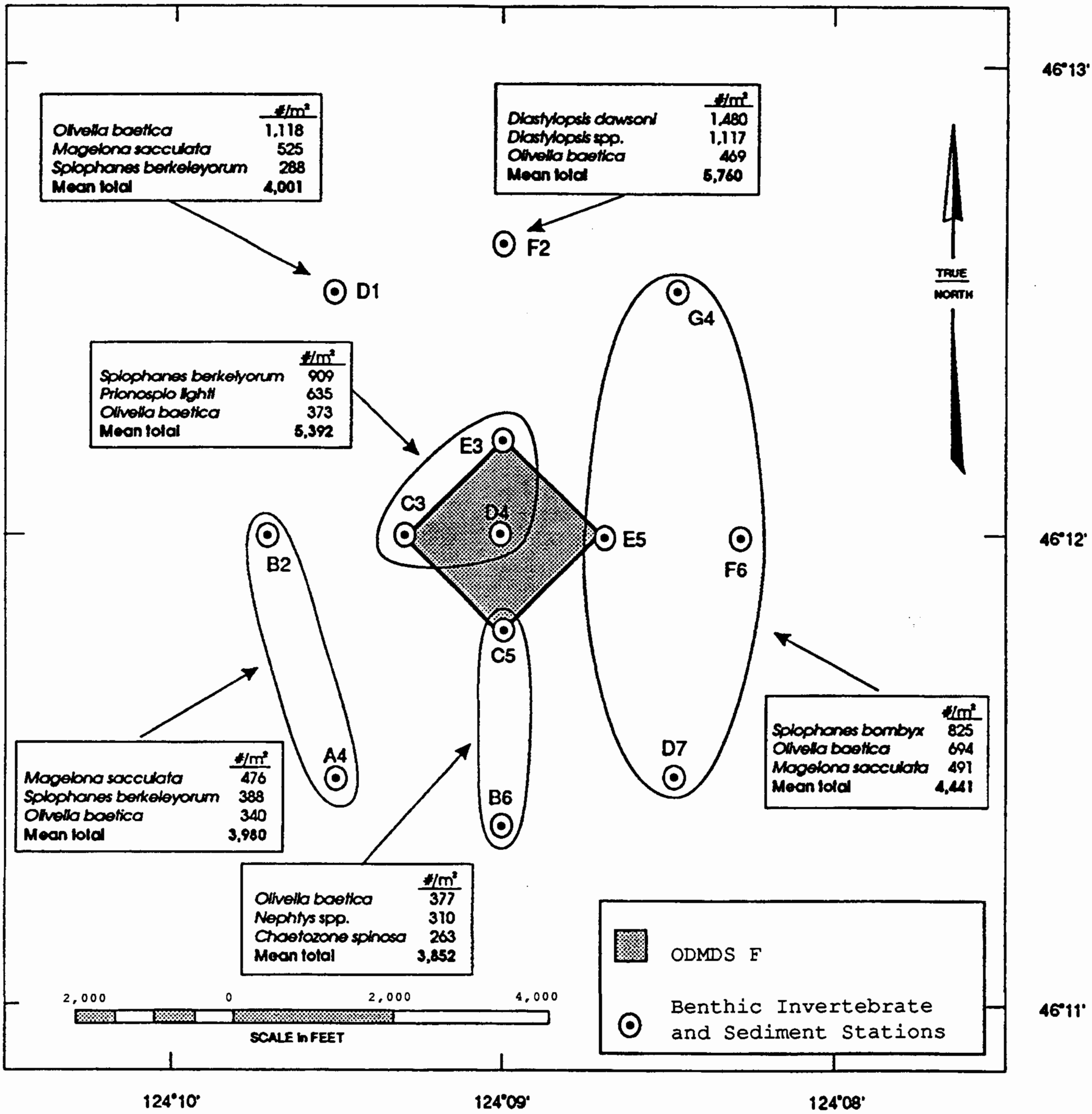

Figure 12.--Benthic invertebrate PCA groups and their top three major taxa identified at and adjacent to ODMDS F, offshore from the Columbia River, July 1991.

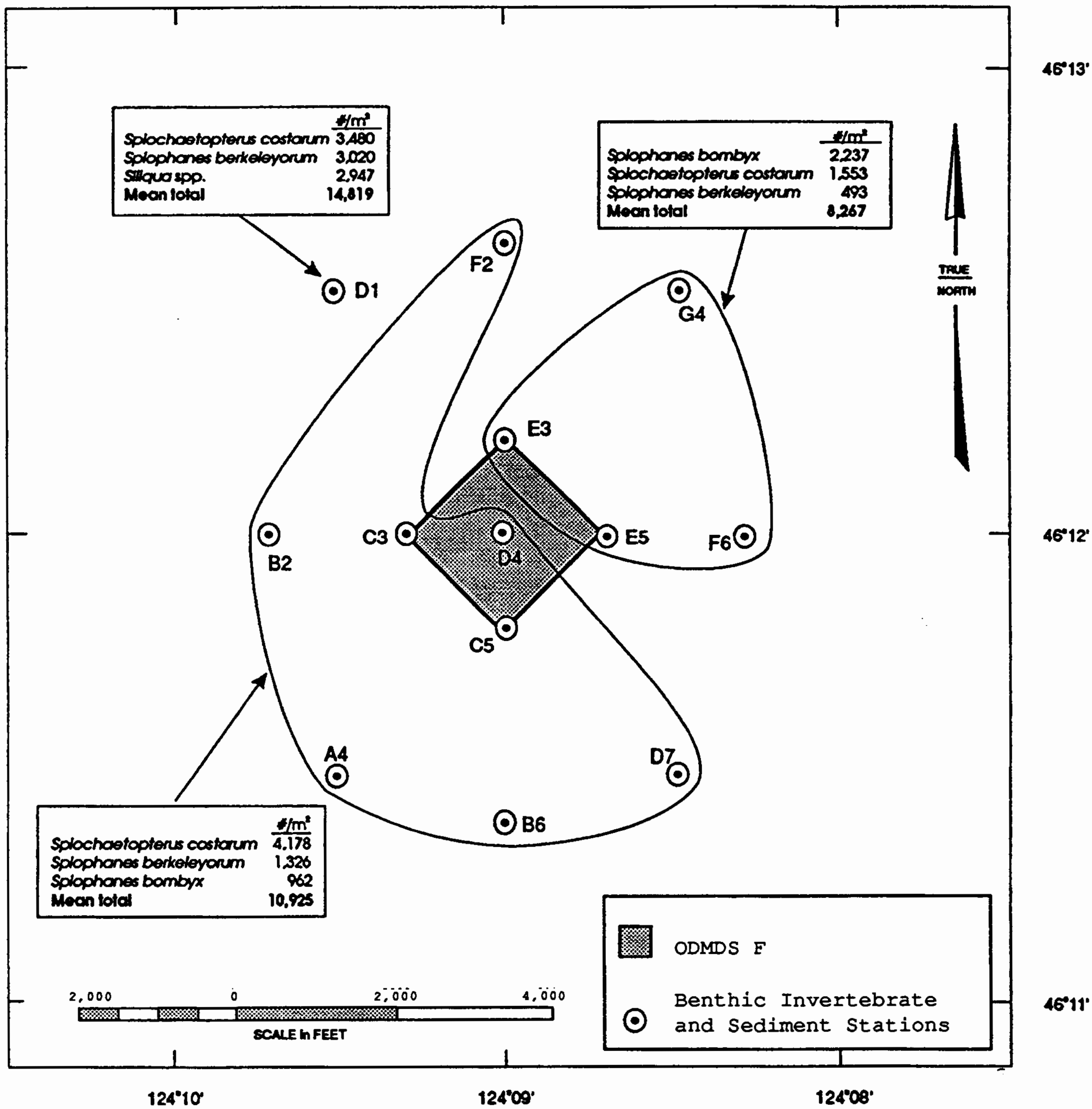

Figure 13.--Benthic invertebrate PCA groups and their top three major taxa identified at and adjacent to ODMDS F, offshore from the Columbia River, July 1992.

Table 7.--Densities (number/m^2) of dominant benthic invertebrates collected at and adjacent to ODMDS F, offshore from the Columbia River, in June/July 1989, 1990, 1991, 1992. Densities were calculated by combining all replicates for each year.

	Year			
Taxa	**1989**	**1990**	**1991**	**1992**
Polychaeta				
Spiochaetopterus costarum		1.5	0.3	3,316.4
Spiophanes bombyx	69.4	359.2	303.5	1,309.2
Spiophanes berkeleyorum	68.6	268.3	382.9	1,200.2
Owenia fusiformis	0.2	8.5	0.3	622.3
Glycinde armigera	33.3	149.1	96.6	334.4
Magelona sacculata	60.9	250.2	384.2	312.3
Nephtys caecoides	43.8	62.5	99.9	161.1
Chaetozone spinosa	72.9	62	175	137.4
Phyllodoce hartmanae	9.3	12	15.2	93.6
Nephtys spp.	80.2	178.4	181.3	71
Prionopsio lighti	2.4	14.2	164.2	42.5
Leitoscoloplos pugettensis	72.3	143.6	112.6	39.8
Magelona spp.		5.2	55.7	35.6
Miscellaneous	110	204.9	577.7	403.1
Mollusca				
Olivella baetica	1.6	19.5	513.2	238.5
Siliqua spp.			0.2	227.2
Olivella spp.	6.1	9.9	1	109
Gastropteron pacificum	0.3		4.5	77.6
Nitidella gouldi	14.1	22	36.9	58.7
Olivella pycna	8.8	57.8	3.5	57.4
Axinopsida serricata	22.9	37.8	50.3	49.9
Macoma spp.	2.9	4.1	17.9	38.3
Tellina spp.	9.5	1.3	23.7	3.8
Miscellaneous	28	49.9	55.5	72.9
Mysidacea/Cumacea				
Leucon spp.			8.6	44.4
Leuconidae	0.8	0.2	19.4	
Diastylopsis tenuis	0.2	45.4	28	34.1
Diastylopsis dawsoni	1.6	4.7	148.7	27.7
Hemilamprops californica		33.5		24
Diastylis spp.	0.2	4.1	48.8	11.4
Diastylopsis spp.	0.2		104.7	1.3
Colurostylis occidentalis	0.5	22.1	54.7	1
Miscellaneous	4.5	25.3	9.2	2.1

Table 7.--Continued.

Taxa	Year 1989	 1990	 1991	 1992
Amphipoda				
Orchomene pinquis				115.3
Rhepoxynius daboius	28.1	83.2	32.7	89.1
Protomedeia articulata		0.2		87.8
Orchomene cf. *pinquis*	9.6	52.3	7.9	81.4
Orchomene pacifica	0.8		94.3	0.3
Rhepoxynius spp.	43.1	0.7	100.9	68.1
Photis macinerneyi	3	19	39.9	44.7
Synchelidium shoemakeri		8.6	14.4	42.2
Synchelidium spp.	0.2		41.3	
Eohaustorius sencillus	57.4	32.2	12.7	36.9
Ampelisca careyi	5.6	19	24.6	16.7
Rhepoxynius abronius	26.6	12.7	4.3	16
Miscellaneous	52.9	55	213.4	93
Echinodermata				
Echinoidea				80.3
Amphiodia spp.	5.8		3.3	47.8
Amphiodia urtica	0.5		9.4	
Dendraster excentricus	1	4.6	0.8	1.6
Ophiuroidea		8		0.5
Miscellaneous	1.5	1.1	1.2	0.3
Miscellaneous taxa				
Nemertea	70.5	60.2	105.5	176.8
Euphilomedes carcharodonta	22.6	38.1	51.1	81.3
Echiuridae				57.2
Synidotea angulata	2.4	17.6	34.9	12.8
Cylindroleberididae	4.8	9.1	6.9	31.4
Phoronida	1	7.2	35.6	19.2
Miscellaneous	9.1	6	53.7	47
Total	1,072.0	2,492.0	4,567.0	10,405.9

E3) may be related to dredged material disposal since all three sites are in the disposal area, but the high benthic invertebrate densities (5,392 individuals/m^2) and large number of taxa (Table 3), indicates a healthy benthic invertebrate community (see **DISCUSSION** for information regarding sediment composition [% fines] and Benthic Community Structure).

By 1992, a large change had taken place in the benthic invertebrate community at our study area. Only three station groupings were identified using PCA. The polychaete species, *Spiochaetopterus costarum*, became a dominant invertebrate in 1992 and this species help define the station groupings (Figure 13). At eight stations (one station grouping) it was the overwhelming dominant species; at the other station groupings it was also abundant but secondary species help define the station groupings.

Fishes and Large Epibenthic Invertebrates Results

During the June 1989 survey, a total of 2,469 fishes and epibenthic invertebrates were captured, representing 25 different taxa (Appendix C Tables C-4 and C-5). Overall density was 4,820 fish and large epibenthic invertebrates/ha (Table 8). Numerically dominant species were whitebait smelt, *Allosmerus elongatus;* northern crangon, *Crangon alaskensis;* and Pacific sanddab, *Citharichthys sordidus*_(Table 8). The South trawling station had the highest catch of the three stations (Table 9). Community structure indices H and E were highest at the ODMDS F and the North trawling stations in 1989, indicating relatively high number of taxa and fairly equal proportional abundances among the species. The low values at the South station indicated lower diversity and less equal distribution among the species, caused by the dominance of whitebait smelt (Appendix C Table C-5).

During the June 1990 survey, fish and epibenthic invertebrate mean density was 9,606/ha, representing 31 different taxa (Table 8 and Appendix C Table C-4). Numerically dominant species were whitebait smelt, northern crangon, and butter sole (Table 8). The ODMDS F had the highest trawl catch of the three stations (Table 9). Community structure indices H and E were highest at the North station, indicating a high number of species and a relatively equal proportional abundances among the species. H and E were lower at the South and ODMDS F stations because of the dominance of one or several species and fewer species (Appendix C Table C-5).

During the August 1991 survey, fish and epibenthic invertebrate mean density was 2,924/ha, representing 26 different taxa (Table 8 and Appendix C Table C-4). Numerically dominant species were English sole, Pacific sanddab and Pacific tomcod (Table 8). The ODMDS F had the lowest trawl catch of the three stations (Table 9). Community structure indices H and E were highest at the North station, indicating high number of species and relatively equal proportional abundances among the species. H and E were lower at the ODMDS F station because of fewer species and the dominance of a couple of species (Appendix C Table C-5).

During the July 1992 survey, fish and epibenthic invertebrate mean density was 9,118/ha, representing 32 different taxa (Table 8 and Appendix C Table C-4). Numerically dominant species were whitebait smelt, Dungeness crab (*Cancer magister*), and Pacific sanddab (Table 8). The ODMDS F had the highest

Table 8.--Major fish and large epibenthic invertebrates densities (mean number/ha) captured by bottom trawl at and adjacent to ODMDS F, offshore from the Columbia River, in summer (June\July\August) of 1989 through 1992. Three trawling efforts were conducted during each survey.

	Year			
Species	**1989**	**1990**	**1991**	**1992**
Whitebait smelt	2,963	7,905	194	5,553
Pacific tomcod	212	158	280	177
Pacific sanddab	326	147	403	697
Butter sole	271	268	104	410
English sole	184	214	1,471	544
Northern crangon	422	294	122	38
Dungeness crab	25	6	2	799
Miscellaneous taxa	415	615	348	899
Total	4,820	9,606	2,924	9,118

Table 9.--Summary of fish and large epibenthic invertebrate catches for three trawling stations at and adjacent to ODMDS F, offshore from the Columbia River, in summer (June\July\August) of 1989 and 1992. The North and South stations were outside of ODMDS F (Figure 2).

Station [depth (m)]	Number of taxa	Total number captured	Number/ha	Wt.(g)/ha	H	E
		June 1989				
North (41.1)	21	441	1,904	84,518	3.28	0.75
ODMDS F (41.1)	19	718	1,683	147,694	3.04	0.72
South (41.1)	15	1,310	10,872	231,120	1.26	0.32
		June 1990				
North (37.8)	24	992	3,796	103,950	3.59	0.78
ODMDS F (36.9)	26	10,112	22,743	215,771	0.54	0.11
South (41.8)	11	1,372	2,280	39,785	0.91	0.26
		August 1991				
North (38.4)	24	625	3,262	317,588	3.05	0.67
ODMDS F (38.1)	15	368	1,494	77,706	2.31	0.59
South (33.5)	14	749	4,015	297,459	1.69	0.44
		July 1992				
North (33.2)	27	1338	6,878	328,445	2.94	0.62
ODMDS F (37.8)	20	3,530	16,572	344,601	1.03	0.24
South (40.2)	16	904	3,904	816,851	2.12	0.53

trawl catch of the three stations (Table 9). Community structure indices H and E were highest at the North station, indicating high number of species and relatively equal proportional abundances among the species. H and E were lower at the ODMDS F station because of fewer species and the dominance of a couple of species (Appendix C Table C-5). In 1992, the trawl at the south station was unusually high in the number of Dungeness crab captured (453), 1,957/ha.

Excluding whitebait smelt from the trawl catches analysis (a schooling pelagic fish that often resides near the bottom) indicates that overall highest demersal fish and shellfish densities were similar in 1989 and 1990 (1,855/ha and 1,702/ha, respectively)and increased in 1991 (2,730/ha) and 1992 (3,564/ha). The increase in demersal fish and shellfish densities corresponds with the observed overall increase in benthic invertebrate densities from 1989 to 1992.

Most of the dominant fish and shellfish species captured at and adjacent to ODMDS F in 1989 through 1992 were represented by multiple size classes, with the total length of most fishes >75 mm. All northern crangon were ≤70 mm long. With the exception of Pacific sanddab, the size ranges for individual species were similar for all surveys.

Benthic Invertebrates, Fishes and Large Epibenthic Invertebrates Discussion

Previous benthic surveys off the Oregon/Washington coast conducted at similar depths have found comparable species compositions (Lie and Kisker 1970; Richardson et al. 1977; Hancock et al. 1984; Emmett et al. 1987; Marine Taxonomic Services 1990; U.S. Environmental Protection Agency 1988, 1991a, 1991b; U.S. Army Corps of Engineers 1992). In particular, our study area closely resembles the shallow water sand-bottom community identified by Lie and Kisker (1970) using factor analysis. The shallow water sand-bottom community is easily identified from other deep-water offshore benthic communities by having less than 10% mud in the sediments. All our stations met this criteria prior to dredged material disposal.

Benthic invertebrate densities during 1989, 1990, and 1991 generally resemble previous benthic surveys off the Columbia River (Richardson et al. 1977). However, the high benthic invertebrate community observed in 1992 are unusual with respect to densities and species compositions. Other Northwest nearshore ocean areas where high benthic invertebrate densities have been reported include off Tillamook Bay, Oregon (Emmett and Hinton 1992) and off Willapa Bay, Washington (Miller et al. 1988). At these two areas the polychaete, *Owenia fusiformis*, was a dominant species. Emmett and Hinton (1992) attributed the high densities of benthic invertebrates at these nearshore areas to the "outwelling" (Odem 1980) of large amounts of organic material from adjacent estuaries. At ODMDS F the polychaete, *Spiochaetopterus costarum*, which did not occur in 1989, became the dominant organism in 1992. Besides *S. costarum*, densities of most taxa increased dramatically from 1989 to 1992. The reason for the large increase in benthic invertebrate densities is unclear. The Columbia River is physically and biologically much different from Tillamook and Willapa Bays and probably does not export large amounts of organic material. For example, the Columbia River estuary has very little eelgrass (*Zostera* spp.), an abundant macrophyte in Tillamook and Willapa Bays that may contribute substantial amounts of organic material to these systems.

Apparently, oceanographic conditions from 1989 to 1992 were favorable for the ODMDS F benthic invertebrate community, with conditions between our 1991 and 1992 benthic surveys particularly positive for recruitment of *Spiochaetopterus costarum*. Many of the dominant polychaetes found in our study are surface deposit feeders (*Spiochaetopterus costarum, Spiophanes bombyx, Spiophanes berkeleyorum, Chaetozone spinosa* and *Magelona sacculata*) (Fauchald and Jumars 1979). We believe that oceanographic conditions (particularly from 1991 to 1992) must have either 1) increased the amount of food available to the benthic invertebrate community or 2) been relatively stable (i.e., few strong storms or currents), permitting the successful recruitment and growth of many benthic invertebrate species.

Preliminary information indicates that downwelling (the opposite of upwelling) off the Oregon coast was very intense during the winter of 1991/1992 (unpublished data). This was also a very mild winter with only minor storms. Since downwelling and wind stress can have major effects on benthic invertebrate communities (Wulff and Field 1983; Emerson 1989), the high benthic invertebrates densities in July 1992 may simply reflect these oceanographic conditions. Only long-term benthic invertebrate data sets will enable scientists to identify how changing ocean conditions effect benthic invertebrate communities. These type of data sets presently do not exist for areas off the Oregon/Washington coast. This study shows that long-term benthic data would be extremely valuable when discerning natural variations.

Whatever the causative factor for the high benthic invertebrate densities in 1992, our data indicate the disposal of fine-grained dredge material had only a very localized effect on the benthic invertebrate community and was over shadowed by large annual variations in benthic invertebrate species compositions and densities.

Previous research trawling off the Columbia River found similar fish and shellfish taxa and diversity (Durkin and Lipovsky 1977). Conducting only three trawls at ODMDS F per year did not permit rigorous statistical testing of biological changes in the demersal fish and shellfish community as a result of dredge material disposal. However, these efforts did permit us to identify the demersal species composition and densities which utilizes this area and would have been affected by dredged material disposal. No changes or differences in species composition and densities between the disposal site and trawls north and south of the disposal site could be attributed to dredge-material disposal. Excluding whitebait smelt from the trawl data analysis indicates that overall demersal fish and shellfish densities increased from 1989 to 1992. This is not surprising since benthic invertebrate densities (the food source of most of these species) (Durkin and Lipovsky 1977) also increased significantly during this period.

OVERALL SURVEY SUMMARY

Discussion

The effect of dredged material disposal at ODMDS F can best be evaluated by combining information from several sources onto individual plots. By plotting bathymetry and percent fines (Figures 14 through 17) or benthic invertebrate PCA Station Groups and percent fines (Figures 18 through 21) comparative evaluation of cause and effect can be achieved.

In July 1989 (pre-disposal), sediment structure at ODMDS F was relatively uniform, with no stations having percent fines greater than 2.5% (Figure 14). However, the PCA of the benthic invertebrate community did not reflect this uniformity, as exhibited by the four stations that did not associate with any other stations (Figure 18).

In March 1990 (post-disposal), the dredged material placed at ODMDS F was clearly evident by the distribution of percent fines and bathymetric changes (Figure 14). Percent fines and other physical characteristics (Appendix B Figures B-1 through B-15) of the dredged material are clearly more sensitive for determining the presence of dredged material over bathymetric changes.

In June 1990 (post-disposal), the dredged material placed at ODMDS F was still evident by the distribution of percent fines and bathymetric changes (Figure 15). While the foot print for both decreased, the decrease in percent fines was more dramatic. As stated previously, sediment analysis revealed that stations with sediments having >2.5% fines indicated alteration by dredged material disposal. Three stations (E3, C3 and C5) had percent fines greater than 20%. These three stations, together with stations B2 and A4 were classified as a group using PCA of benthic invertebrate taxa densities (Figure 19). Station B2 was probably associated with the other three stations because it had recently been affected (sediments had a high percentage of fines in March 1990, Figure 14). It is unclear why Station A4 (a station whose sediments had not been affected) had a similar benthic invertebrate structure as the other four stations. At least four stations were affected by dredge

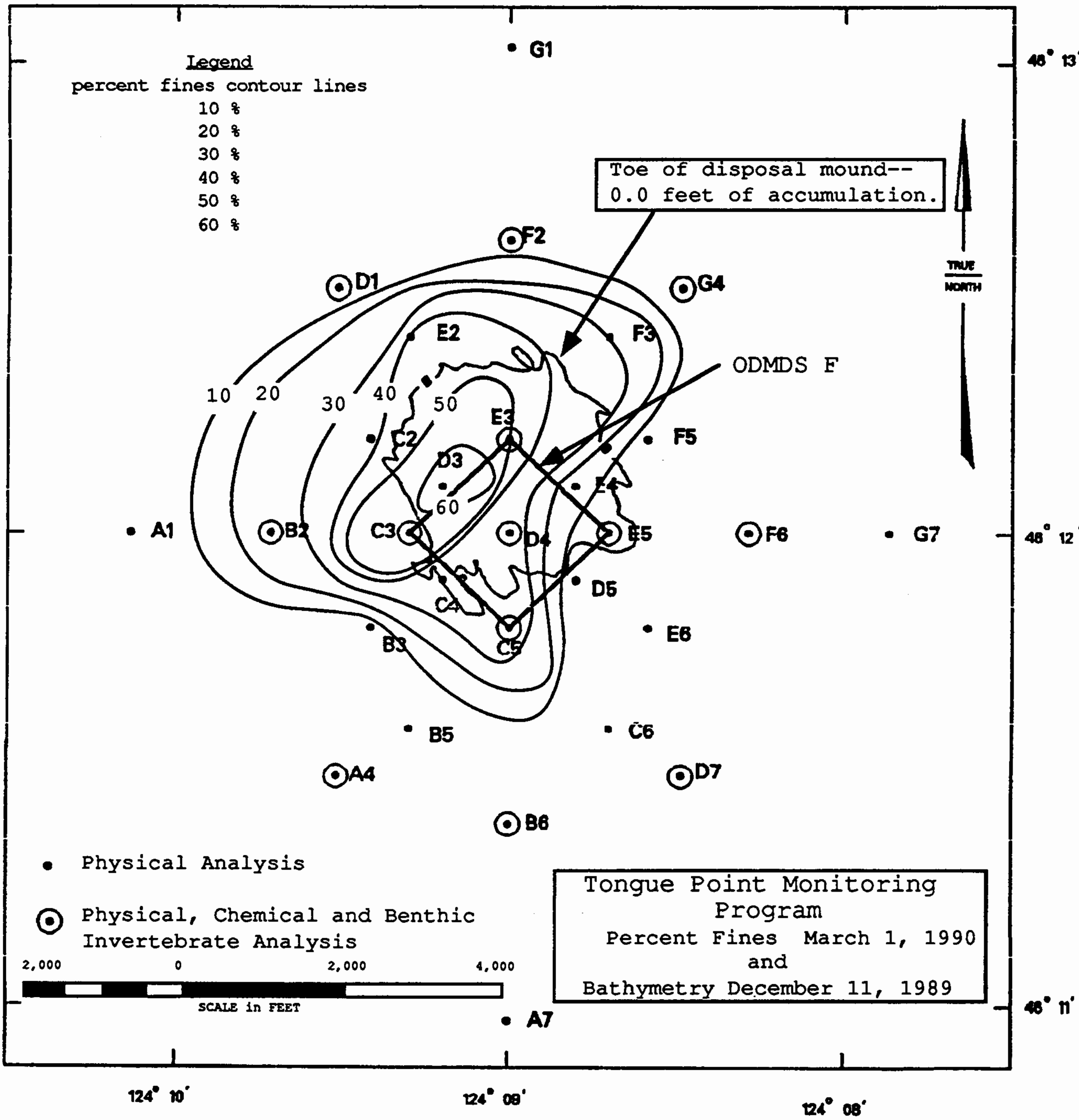

Figure 14.--Percent fines (March 1, 1990) and bathymetric diffrence plot (December 11, 1989 vs. May 22, 1989) at ODMDS F, off the mouth of the Columbia River.

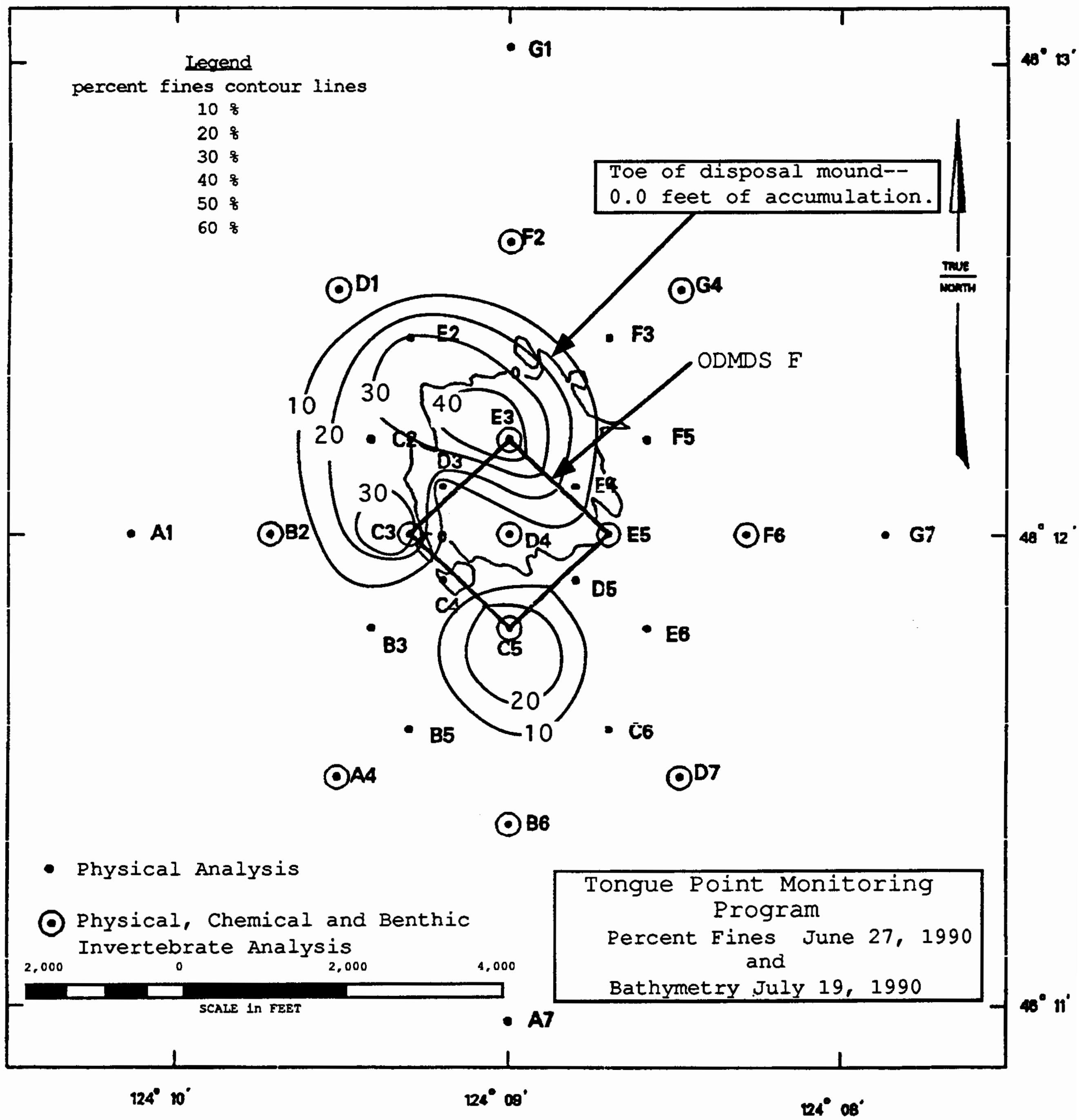

Figure 15.--Percent fines (June 27, 1990) and bathymetric diffrence plot (July 19, 1990 vs. May 22, 1989) at ODMDS F, off the mouth of the Columbia River.

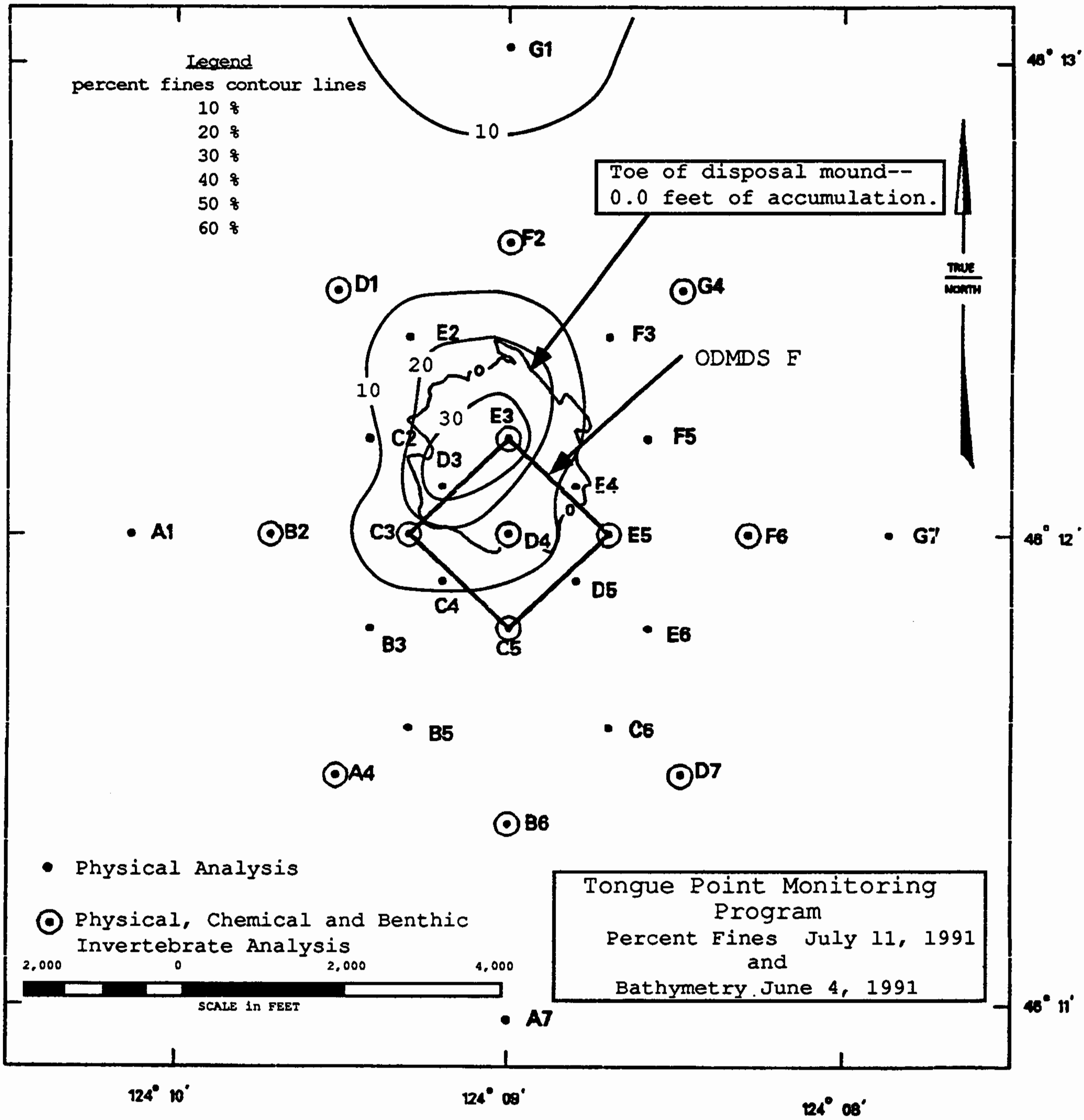

Figure 16.--Percent fines (July 11, 1991) and bathymetric diffrence plots (June 4, 1991 vs. May 22, 1989) at ODMDS F, off the mouth of the Columbia River.

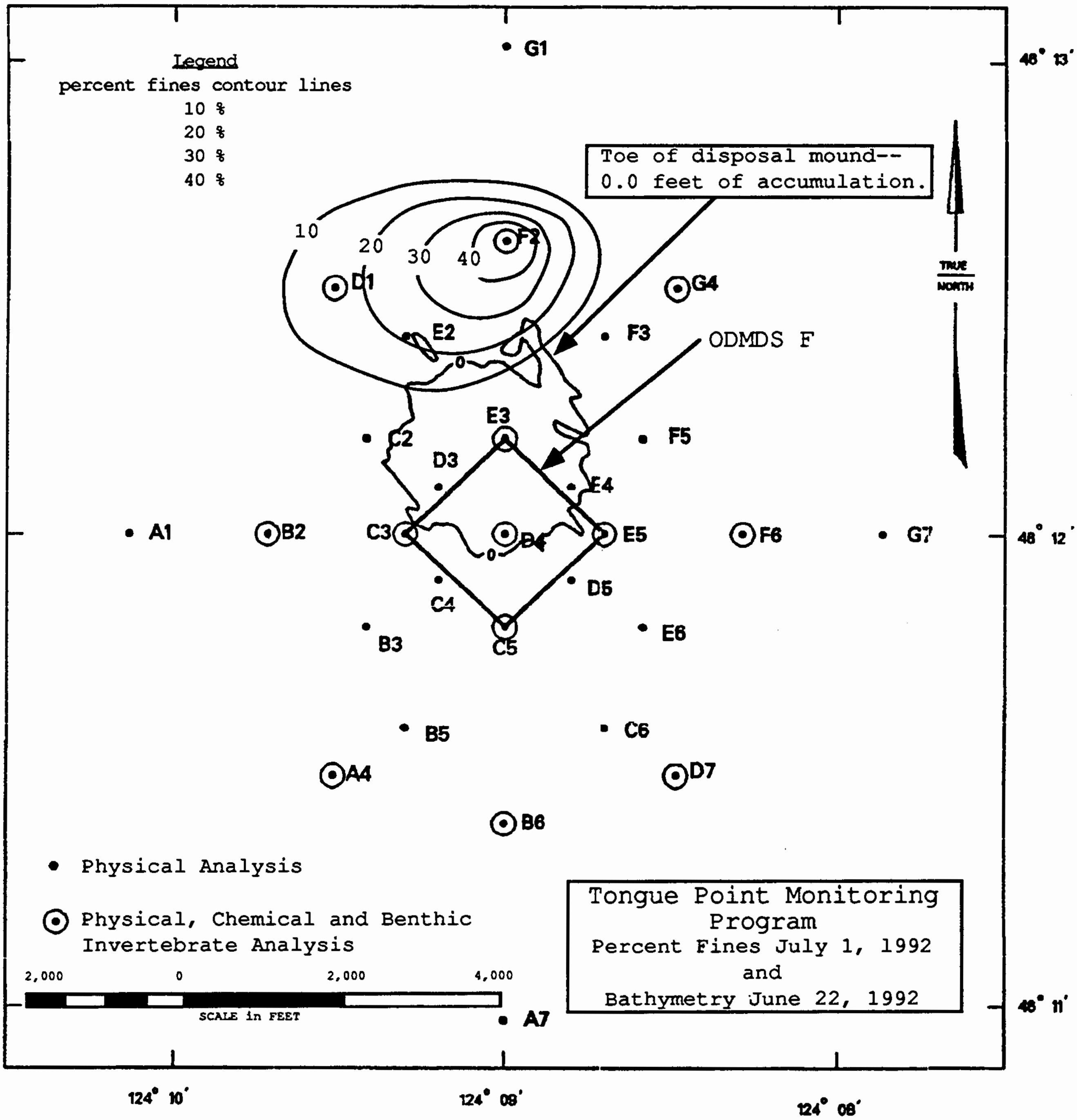

Figure 17.--Percent fines (July 1, 1992) and bathymetric diffrence plot (June 22, 1992 vs. May 22, 1998) at ODMDS F, off the mouth of the Columbia River.

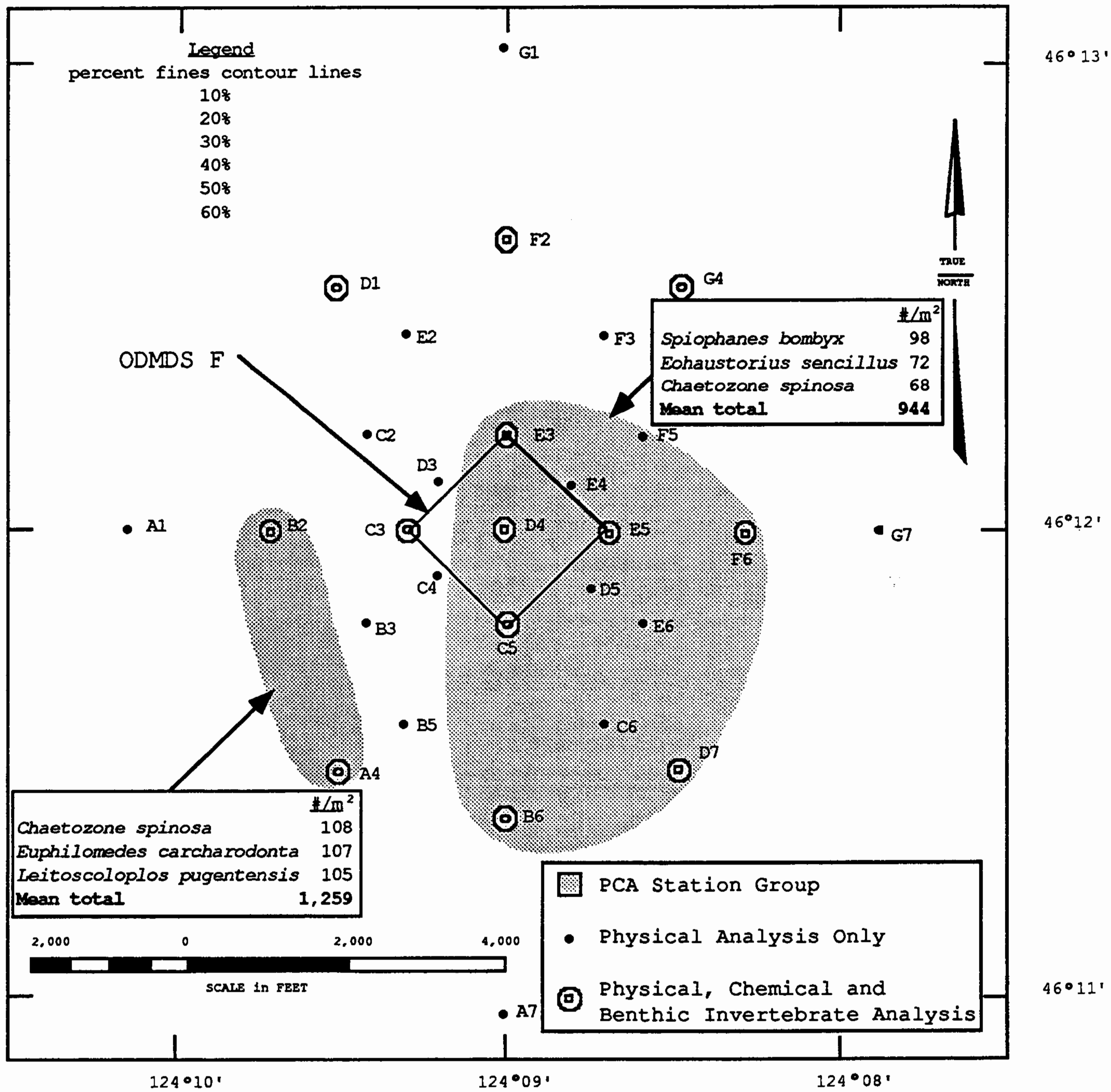

Figure 18.--Percent fines and benthic invertebrate PCA groups adjacent to ODMDS F, offshore from the Columbia River, July 1989.

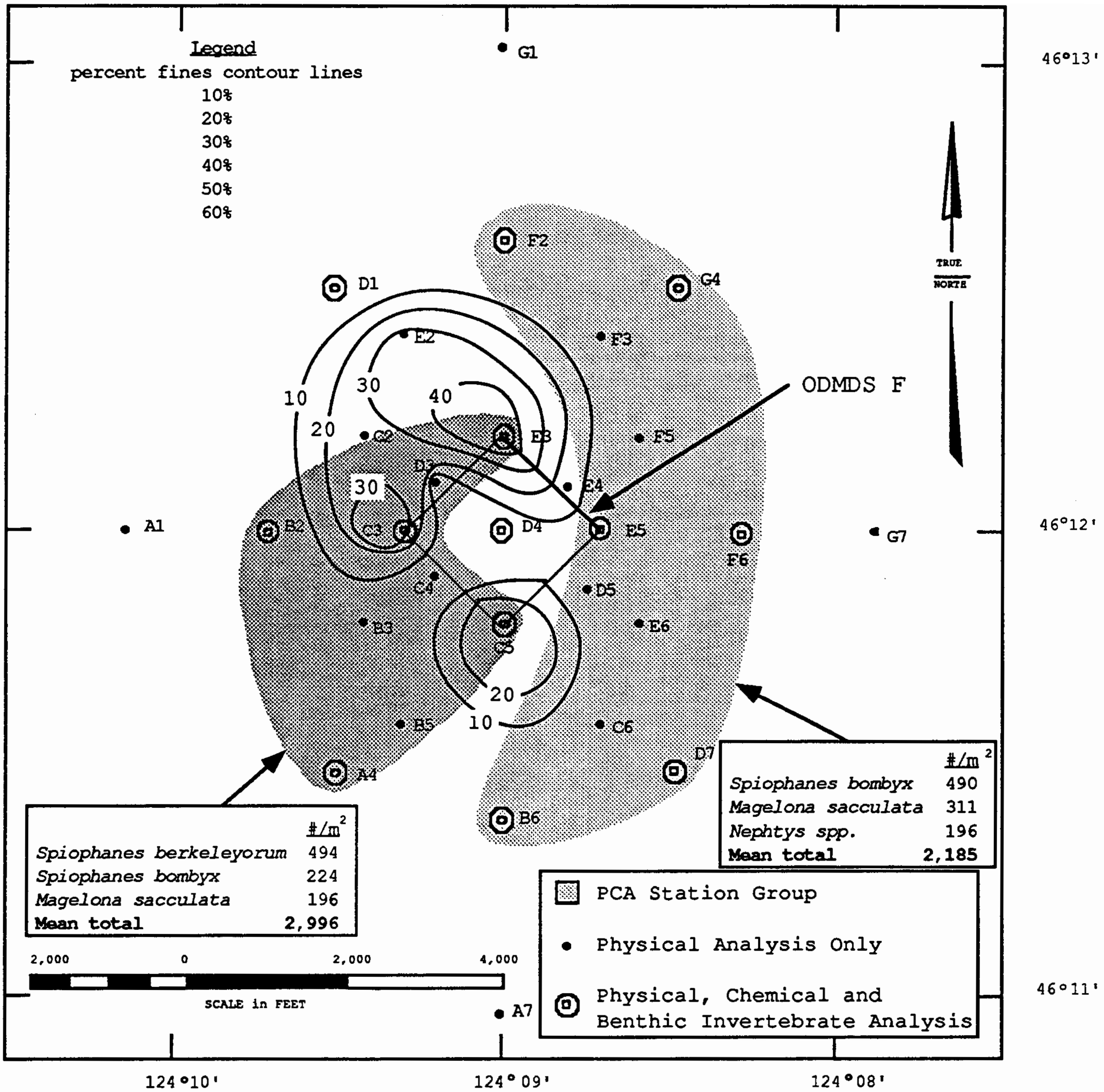

Figure 19.--Percent fines and benthic invertebrate PCA groups adjacent to ODMDS F, offshore from the Columbia River, June 1990

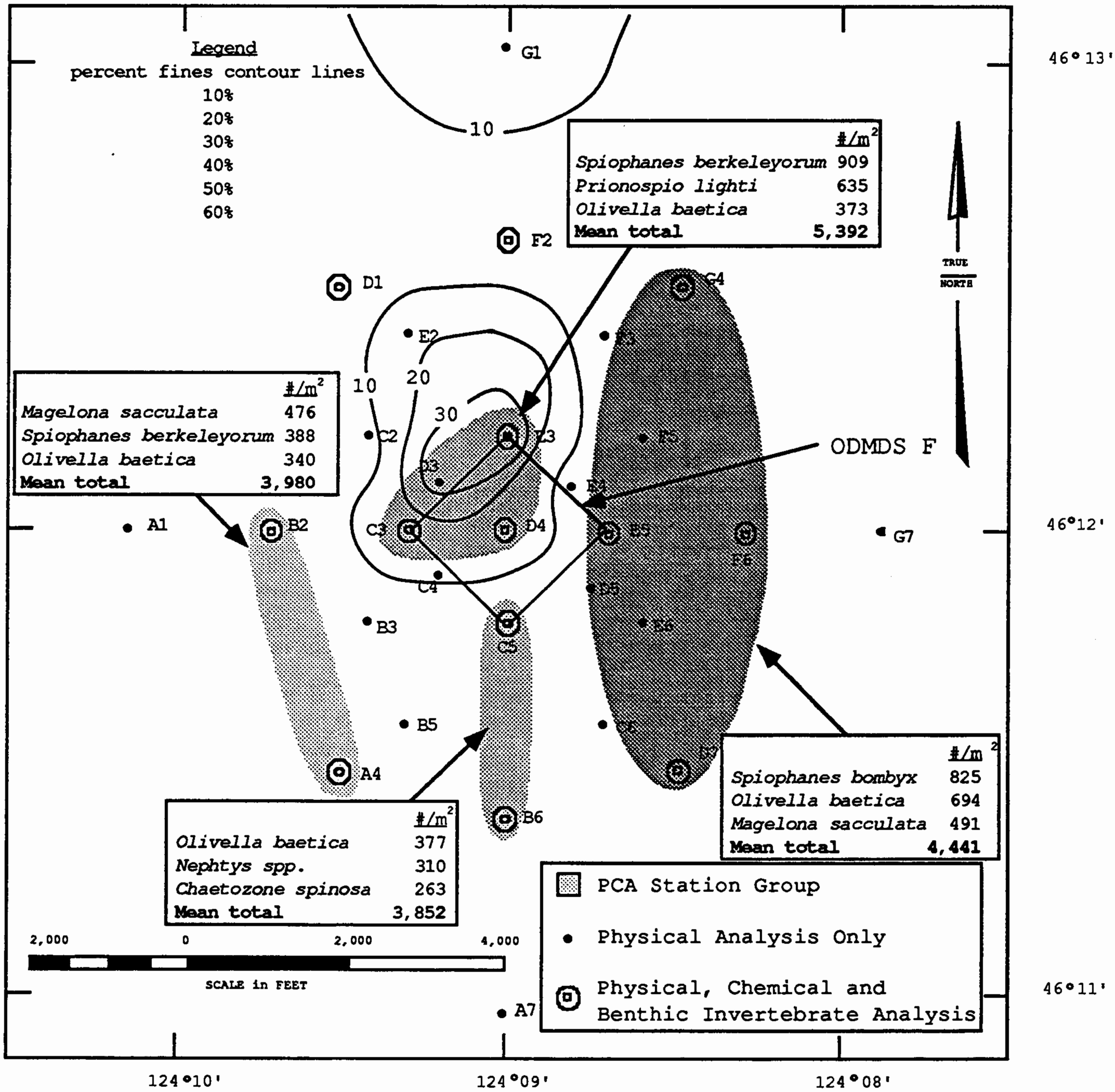

Figure 20.--Percent fines and benthic invertebrate PCA groups adjacent to ODMDS F, offshore from the Columbia River, July 1991.

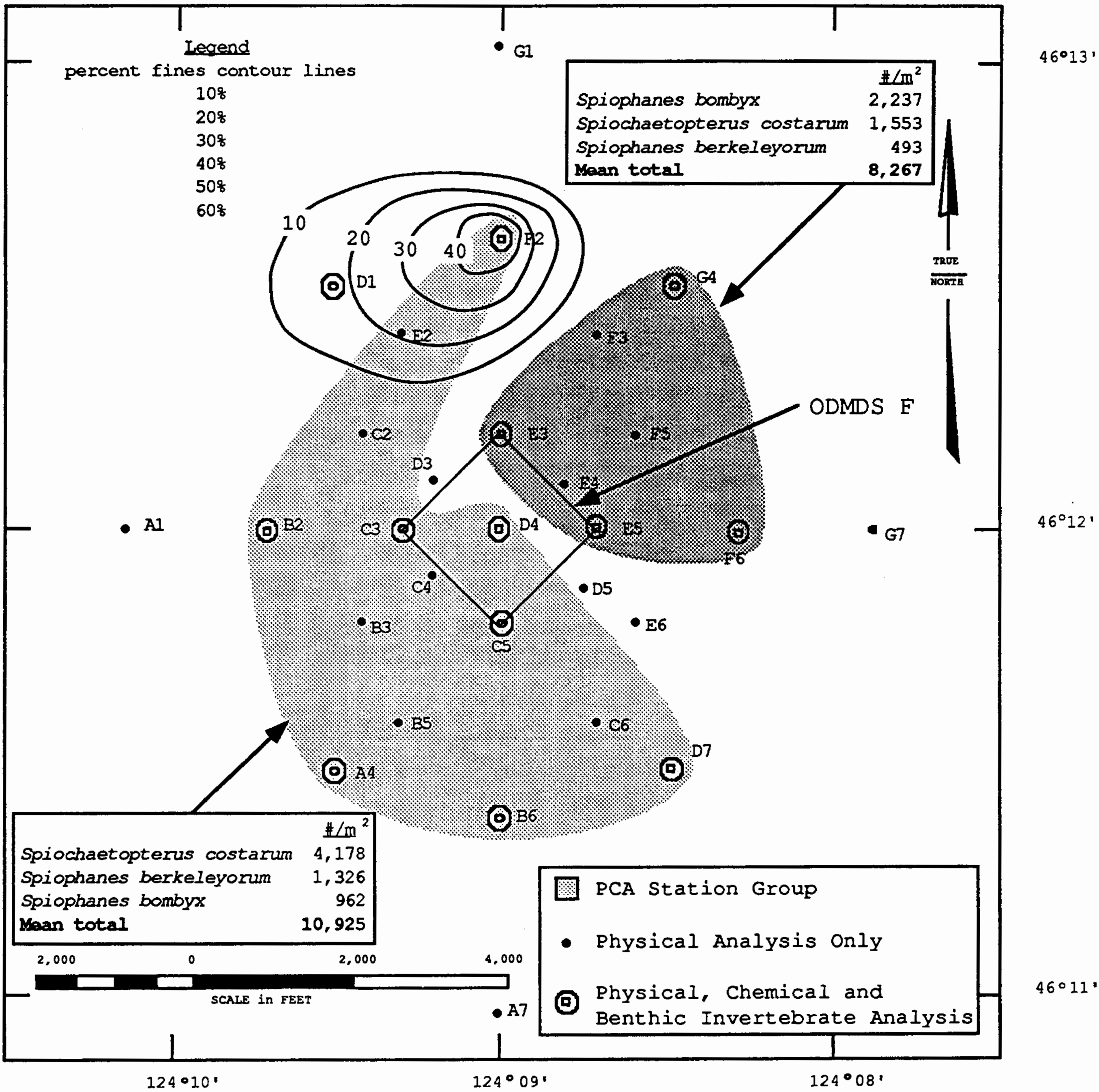

Figure 21.--Percent fines and benthic invertebrate PCA groups adjacent to Site F, offshore from the Columbia River, July 1992.

material disposal in 1989, which probably buried the native fauna. Nevertheless, benthic invertebrate recruitment was so successful that mean benthic invertebrate densities for these stations in June 1990 was higher than invertebrate densities observed in July 1989. Species composition of the benthic invertebrate community of these stations also changed. However, nearly all stations had significant changes in their species composition from 1989-1990, apparently a result of wide spread differential recruitment of various species of benthic invertebrates.

Bathymeteric data from July 1990 revealed that D4 (the center of ODMDS F) contained dredge material, but this was not reflected in the sediment structure data (Figure 15). Evidently a layer of ambient material (sand low in silt/clay) overlayed the fine-grained dredge material by June 1990. Station D4 appeared to lie at the edge of the deposited dredged material and had relative unstable sediment structure (i.e., had changing sediment characteristics between surveys). This appeared to be reflected in the low benthic invertebrate densities (Figure 11) and the kind of species found at this station. The three top species, the polychaete, *Glycinde armigera,* mollusc, *Olivella pycna*, and amphipod, *Repoxynius daboius*, are species which can move relatively quickly compared to other benthic invertebrate taxa, and may be early colonizers at this station.

By July 1991, the sediment analysis revealed only benthic invertebrate Stations E3, C3, and D4 had sediments with percent fines above ambient levels (Figures 16 and 20). Not surprisingly, these three stations were classified as a station grouping from the PCA of benthic invertebrate taxa densities. However, while these stations differed from other stations in benthic invertebrate taxa, they were similar in overall benthic invertebrate densities.

By July 1992, only two benthic invertebrate stations (D1 and F2), located north of the disposal site, had sediments with percent fines above ambient levels (Figures 17 and 21). Here the high percentage of fines may not be related to the ODMDS F dredge material. The bathymetric data shows no positive change in relief at Stations D1 and F2 that could account for the sediment change from 1991 to 1992. We speculate that either surface sediments were scoured away to reveal historic sediments or a thin layer of fine sediments was recently deposited. Similar fine grained material was noted at Station G1 in 1991 not associated with the disposal of the Tongue Point dredged material. In addition, fine grained material was collected in two of four consecutive samples collected at a single station east of ODMDS B during a separate study in 1992. Apparently small patches of fine grained material exist offshore of the mouth of the Columbia River in areas normally low in fines (<1%). The origin of these patches is unknown at this time but cannot be directly associated with any known dredge material disposal event. Sediment analysis did not reveal the high percentage of fines that identify the dredged material mound at ODMDS F (Figure 17). Evidently ambient sediments completely covered the dredged material mound.

The July 1992 PCA of the benthic invertebrate data revealed no station grouping that could be attributed to the presence of dredged material (Figures 13 and 21). By July 1992 the benthic invertebrate community in the study area was a consequence of factors other than the 1989 dredged material disposal. There was wide-spread large scale recruitment of the polychaetes, *Spiochaetopeterus costarum*, *Spiophanes berkelorum* and *S. bombyx* whose abundance primarily determined PCA Station Grouping (Figure 21).

Conclusions

No significant contamination, toxicity or bioaccumulation impacts due to dredging and disposal activities could be documented at either Tongue Point or ODMDS F.

The dredged material deposited at ODMDS F consisted of sediments finer than the ambient material, and formed a relatively stable and recognizable mound. Bathymetry surveys of the dredged material mounds indicates its area remained relatively unchanged while the maximum height decreased from 12 feet to 10 feet 30 months after disposal. The coarser ambient material covered the finer grained Tongue Point dredged material, further stabilizing the mound.

Dredged material disposal affected sediment characteristics at ODMDS F but this was not clearly reflected in the benthic invertebrate community structure. Recolonization of the dredged material mound by benthic invertebrates was very rapid. Six months (June 1990) after the cessation of dredged material disposal (December 1989) benthic invertebrate densities were higher at all stations except one when compared to the previous year. Only Station D4 (the center of ODMDS F) showed a decline in benthic invertebrate density six months after dredged material disposal. However, sediment characterization of the Station D4 sediments indicated it had reverted to ambient conditions by June 1990.

The presence of dredged material did not reduce benthic invertebrate densities but altered the benthic community structure compared to the surrounding stations. In 1991, three stations (E3, C3 and D4), whose sediments consisted of dredged material, as shown by the large percentage of fine sediment, had different major benthic invertebrate taxa compared to stations unaffected by dredged material disposal. However, E3 and C3 had the two highest benthic invertebrate densities of the 13 benthic invertebrate stations analyzed. All benthic invertebrate stations showed changes in community structure form year to year.

Benthic invertebrate densities increased significantly (an order of magnitude) in the study area from 1989 to 1992. This appears to reflect long-term annual variation and not a result of dredged material disposal. The large annual variations of benthic invertebrate communities (changes in species composition and densities) off the mouth of the Columbia River over shadowed the ecological effect of dredged material disposal at ODMDS F. Long-term benthic invertebrate data sets are needed to provide perspective on the ecology of nearshore benthic communities and the effect of dredged material disposal.

The benthic invertebrate community off the mouth of the Columbia River is very dynamic and was only slightly affected by dredged material disposal. Although the dredged material deposited at ODMDS F was unlike ambient material, recolonization of this material was rapid. The recolonization species appeared to come from adjacent areas, an indication that many of these benthic species can tolerate a wide range of sediment characteristics.

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