4.4.5 Sediment Quality Testing Evaluation for Humboldt Harbor Deepening Project

Chemical and physical sediment analysis evaluations on sediments for the Humboldt Harbor Deepening Project navigation channels were conducted and reported by EVS Consultants in a report titled " Bioassays and Bioaccumulation Testing - Humboldt Harbor Deepening Project", dated February 1993. The results of the sediment chemical and toxicological results will be used to determine the suitability of dredged material from Humboldt Harbor Deepening Project for disposal at the HOODS, in compliance with Section 103 of the Marine Protection Research and Sanctuaries Act (MPRSA). The following is a summary of the sediment chemical and biological tests results.

a. Sediment Collection: Sediment samples were obtained in the Humboldt Harbor Deepening Project navigation channels during December 4-6, and on December 11, 1991. Samples were taken at a total of ten coring locations: samples HB1 and HB2 were taken in the Bar and Entrance Channel (from mudline to project depth of -55 feet MLLW); samples HB3 and HB4 were taken in the North Bay Channel (from mudline to project depth of -44 feet MLLW); sample HB5 was taken in the Outer Eureka Channel (from mudline to project depth of -44 feet MLLW); sample HB7 was taken in the Samoa Channel (from mudline to project depth of -44 feet MLLW); and samples HB8, HB9, HB10, and HB11 were taken in the Samoa Turning Basin (from mudline to project depth of - 44 feet MLLW). Sampling at location HB6 was deleted from the study because the area represented by the this sample was removed from the deepening study. (Refer to plates 4.1-4.8, in the Humboldt Harbor and Bay Deepening Feasibility Study, for environmental sample locations)(Figure 4.4.5-1).

b. Sediment Physical Analyses: Grain size analyses was conducted initially on the ten samples to determine which project sediments were predominately sand, and met the exclusionary criteria for further testing as outlined in 40 CFR Section 227.13(b)(1). The EPA/Corps Regional Implementation Agreement (RIA) for the San Francisco District region, defines predominately sand as that material having at least 80 percent with a diameter larger than 0.062 mm (phi #+4) (COE 1993c). Dredged material from the Bar (HB1), Entrance (HB2), and North Bay (HB3, HB4) Channel of Humboldt Harbor were found to be composed predominately of sand, having 98.6, 98.4, 97.1 percent sand respectively. The 1992 and 1993 baseline surveys of these channels for the Corps maintenance dredging program show similar grain size patterns for these channels. Based on the grain size being predominantly sand in these channels, sediments in these areas have been determined to meet the exclusionary critria as defined in 40 CFR 227.13 and environmentally acceptable for ocean disposal without further testing. Samples in the Samoa Turning Basin, HB8 and HB9, did not meet the exclusionary critria. Sediment HB8 consisted of 2.2 percent gravel, 46.5 percent sand, 35.6 percent silt, and 15.7 percent clay, while HB9 sediment had 0.6 percent gravel, 65.1 percent sand, 25.2 percent silt, and 9.1 percent clay.

Due to their finer grain size, further evaluation of HB8 and HB9 sediments consisting of chemical and biological tests was determined necessary. Biological evaluations included the suspended particulate phase toxicity (SPP), 10-day solid phase toxicity, and 28-day bioaccumulation.

c. Bulk Sediment Chemistry Evaluations: The two sediment samples, HB8 and HB9, and the reference sediment from the HOODS, were analyzed for the following parameters: grain size, total organic carbon (TOC), chlorinated pesticides, polychlorinated biphenyls (PCBs), metals (Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Silver, Zinc), Organotins, and dioxins.

Total organic carbon was found to be 0.73 and 0.75 and .25 for sediments HB8, HB9, and reference respectively. Total petroleum hydrocarbons and oil and grease were not detected in project sediments or reference sediments (0.75 ppm). Sediments HB8 and HB9 were found to have slightly higher levels of metals compared to that of the reference site (less than 2.5 times for the 10 metals). The contaminants tributyltin and dibutlytin, were not detected (0.2ppb dl) in either project or reference sediments. Butyltin was detected at 0.3 ppb in the HB8 sediment. Of the 16 polyaromatic hydrocarbons analyzed, only Fluorene was detected in HB-8 sediments at 9 parts per billion. Phenanthrene was detected in the reference sediments at 10 parts per billion. Organochloride pesticides were not detected in either project sediment or the reference sediments. Similarly, no PCBs were detected. Results of the 1992 and 1993 baseline surveys are similar to the above. Total organic carbon <0.5 for the Samoa and Eureka channels and no detectable concentrations of oil and grease or organochloride pesticides, with the exception of 44-DDE detected in one Samoa channel sample at 3.3 ppb. Total Organotins for either channel has never exceeded 2 ppb for either survey, while polyaromatic hydrocarbons have been at negligible concentrations <160 ppb.

The ubiquitous Octachlorodibenzodioxin (O_8 CDD) was detected at 79, 2.2, and 11 parts per trillion (pptr) in sediments HB8, HB 9, and the reference sediment. Octachloro dibenzo dioxin (O_8 CDD) was also detected at 1 and 4.5 parts per trillion in the procedural blank and control (Whidbey Island, Washington) respectively. Project sediment HB-8 showed detectable levels of several other chlorinated dibenzodioxin and chlorinated dibenzofuran congeners including the most toxic congeners 2,3,7,8 Tetrachloro dibenzo dioxin (2,3,7,8 TCDD at 0.3 parts per trillion) and dibenzofuran (2,3,7,8 TCDF at 1.6 parts per trillion). HB-9 sediment did not have detectable levels of these more toxic congeners.

The dioxin congener 2378-TCDD has not been detected in sediments from Eureka or Samoa channel sediments during the 1992 and 1993 maintenance dredging baseline surveys. However, the furan congener 2378-TCDF was detected in the 1993 baseline survey at 0.51 parts per trillion in the Samoa Turning Basin.

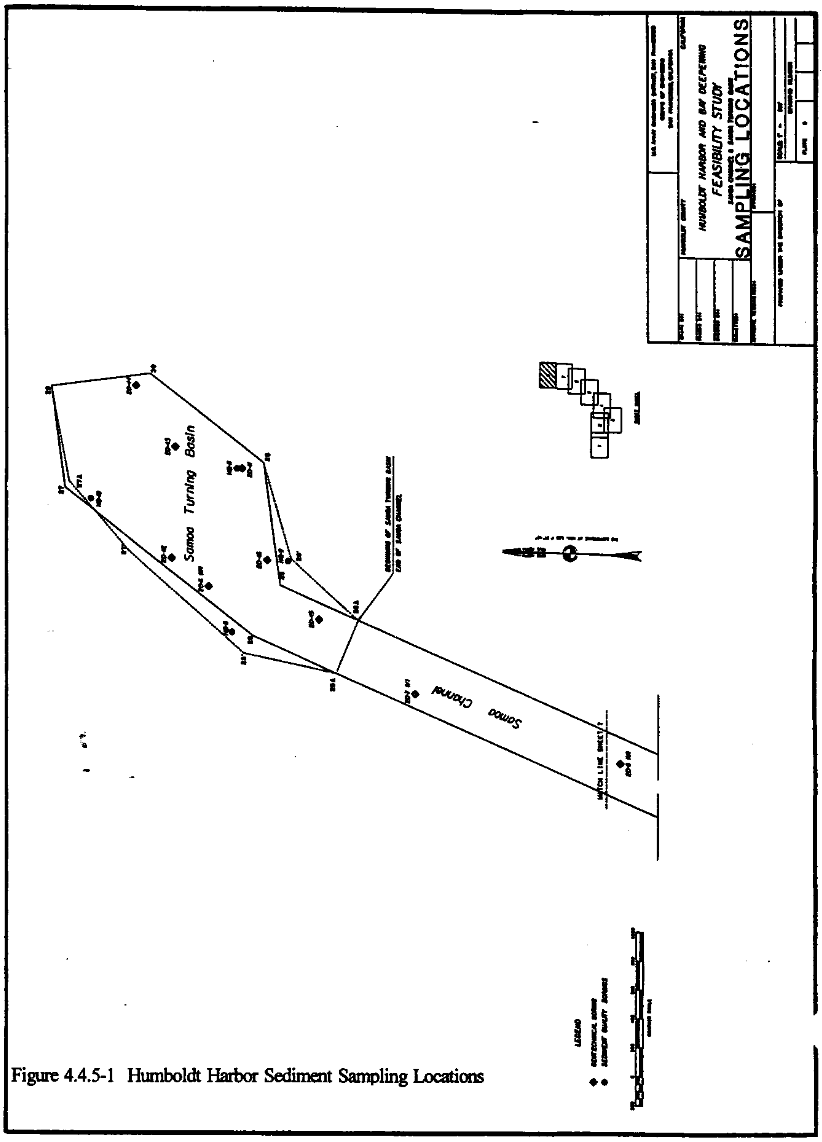

Figure 4.4.5-1 Humboldt Harbor Sediment Sampling Locations

d. Suspended Particulate Phase (SPP) Toxicity Results: Results of SPP toxicity tests are used to determine compliance with water quality criteria during open-water disposal of dredged material. The SPP test results were analyzed to determine the water column effects by comparing survival and normal development in 0%, 10%, 50,% and 100% SPP concentrations. The EC50 is that concentration of the suspended particulate phase (as defined in the joint COE/EPA 1991 "Green Book") which produces a 50 percent reduction of normal development during the test. Similarly the LC50 is that concentration that causes mortality in 50% of the test species.

After LC50 and EC50's are determined, interpretation of the suspended particulate phase test data requires an analysis of mixing and dilution after disposal. The implementing guidance states that dredged material may be considered environmentally acceptable if the bioassay results indicate that the limiting permissible concentration (LPC) will not be exceeded. The LPC of the suspended particulate phase is defined as that concentration which, after initial mixing, will not exceed a toxicity threshold of 0.01 of the acutely toxic concentration (0.01 times the LC50 value).

Suspended particulate phase (SPP) tests on sediments HB8 and HB9 were performed using three aquatic, marine species: juvenile speckled sanddabs (flatfish), mysids, and larvae of the blue mussel. Results of the three SPP tests showed no calculable LC50's for any of the three tests. Therefore, mixing calculations were not required and the Limiting Permissible Concentration (LPC) for water column impacts would not be exceeded during the disposal of HB8 and HB9 sediments.

e. Solid Phase Toxicity Tests: Solid Phase Toxicity Tests were performed on two species: the infaunal amphipod, *Rhepoxynius abronius* and the polychaete worm, *Nephtys caecoides*. In the *Rhepoxynius abronius* test mean survival was 14.0 out of 20 (70%) for HB8, 16.0 out of 20 (80%) for HB9, and 19.4 out of 20(97%) for the reference sediment. Mean percent survival in the control sediment was 19.6 out of 20 (98%). Based on these results, HB8 was determined to have statistically greater mortality (P<0.05) when compared to reference.

In the *Nephtys caecoides* test, mean survival was 17.6 out of 25 ((70.4%) for HB8, 20.6 out of 25 (82.4%) for HB9, and 23.2 out of 25 (92.8%) for the reference sediment. Mean percent survival in the control sediment was 24.8 out of 25 (99.2%). Based on these results, HB8 sediment was determined to have statistically greater mortality (P<0.05) when compared to the reference sediment.

The "Green Book" defines dredged material not meeting the LPC for benthic toxicity when bioassay organism mortality (1) is statistically greater than in the reference sediment and (2) exceeds mortality in the reference sediment by at least 10% or a value that is in accordance with approved testing methods (e.g., 20% for amphipod bioassays is recommended by EPA and USACE). Based on this criteria, sediment HB8 exceeds the LPC (limiting permissible concentration) for the solid phase test. This sediment caused statistically greater mortality compared to the reference sediment in both solid phase bioassays and the associated mortality was greater then the recommended limit of 10 and 20 percent for the *Nephtys caecoides* and *Rhepoxynius abronius* toxicity tests respectively.

f. Solid Phase Bioaccumulation Tests: Bioaccumulation potential, as well as toxicity, has to be in compliance with the regulations before a dredged material can be considered acceptable for ocean dumping. The Tier III benthic-bioaccumulation tests provide for the determination of bioavailability through 28-day exposure tests.

The initial contaminants of concern analyzed in the sediment chemistry evaluations included 17 organochloride pesticides, 4 polychlorinated biphenyls aroclors (PCB Aroclors 1242, 1248, 1254, 1260), 10 metals (Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Silver, Zinc), three Organotins (Tri-, Di-, and Butyltin), and dioxin congeners (polychlorinated dibenzodioxins and dibenzofurans). With the exception of 0.3 ppb butyltin detected in HB8 sediment, no other organic contaminants of concern, other than dioxin, were detected in sediments HB8 and HB. Therefore, it was determined that tissues chemistry in the bioaccumulation study did not require analyses for polychlorinated biphenyls, organochloride pesticides, or Organotins.

HB-8 sediments had detectable levels of several chlorinated dibenzodioxin and chlorinated dibenzofuran congeners including the most toxic congeners 2,3,7,8 Tetrachloro dibenzo dioxin and dibenzo furan (2,3,7,8-TCDD and 2,3,7,8 TCDF), while HB-9 (along with a procedural blank) only showed detectable amounts of Octachloro dibenzo dioxin (O8CDD). The presence of the two toxic congeners 2,3,7,8-TCDD and 2,3,7,8 TCDF in HB-8 at detectable levels of 0.3 and 1.6 parts per trillion (pptr) constituted a "reason-to-believe" that further study was warranted on the HB-8 sediments. Theoretical Bioaccumulation Potential (TBP) calculations were conducted by the Army Corps of Engineers Waterways Experiment Station (WES) using protocols outlined in the Green Book Tier II evaluations, assuming a TOC value of 0.75% and a lipid value of 1.5%. The TBP calculations showed values of 0.6 pptr and 2.4 pptr assuming apparent preference factors of 1 and 4 respectively. Although these values were extremely low, it was concluded that there was sufficient reason to include analyses for the Dioxin congeners in the tissue samples for HB-8.

Solid Phase bioaccumulation tests were performed using two species: the clam *Macoma nasuta*, and the polychaete worm *Nephtys caecoides*. Statistical analyses of tissue chemistry for metals show concentrations of chromium and nickel in the clam tissue to be statistically greater in HB8 and HB9 sediments when compared to reference sediment. The levels of chromium and nickel, however, were less than 2 times that of the reference. Lead levels in HB9 clam tissues were also statistically greater than the reference tissue (1.3 times higher than reference). Copper levels in HB9 worm tissue was statistically greater than the reference tissue (2 times higher than reference).

Certain replicates of the background, control, reference and HB-8 clam and worm tissues contained detectable levels of dioxins and furans. Statistical comparisons could not be performed on the worm tissue data because a shortage of sample necessitated the compositing of the individual replicates for each sample prior to analyses.

Worm Tissues: The ubiquitous dioxin congener O8CDD was detected at levels between 0.7 and 2.1 pptr in all treatments (HB8, background, control, and reference tissues). No other congener was detected.

Clam Tissues: The toxic dioxin and furan congeners 2378-T4CDD and 2378-T4CDF were detected at 0.12 and 0.14 pptr respectively in the control. Statistical analyses of both total T4CDD and 2378-T4CDD indicated there were no significant differences (P,0.05) between the control and the reference. H7CDD was detected in two HB-8 replicates (0.4 pptr), but no significant differences between the test and reference tissues were detected by an analysis of variance and Dunnett's t-test. The most persistent dioxin, O8CDD, was detected in all treatments but the reference. Concentrations in HB8 were significantly higher ($P<0.05$) than the reference sediment.

g. Conclusions for the Bioaccumulation Tests for Humboldt Harbor Deepening Project Sediments:

According to the "Green Book", concentrations of contaminants of concern in tissues of benthic organisms following 28-day exposure to the dredged material are compared initially against applicable Food and Drug Administration (FDA) Action Levels for Poisonous or Deleterious Substances in Fish and Shellfish for Human Food, when such levels have been set for the contaminants. Current FDA action levels have been set for only a handful of contaminants, mostly pesticides. No metals or dioxin limits are currently listed. In the case where no FDA levels exist for the contaminants of concern, the "Green Book" states that information is insufficient to determine compliance with the bioaccumulation aspects of the benthic criteria of 40 CFR paragraph 227.13(c)(3), and the dredged material has to be further evaluated in Tier III. In Tier III one of the following conclusions is reached:

☼ Tissue concentrations of contaminants of concern in organisms exposed to dredged material do not statistically exceed those of organisms exposed to the reference sediment, and therefore the dredged material meets the LPC for bioaccumulation and complies with the benthic criteria of paragraph 227.13(c)(3).

☼ Tissue concentrations of contaminants of concern in organisms exposed to dredged material statistically exceed those of organisms exposed to the reference material. The magnitude to determine compliance with paragraph 227.13(c)(3), when bioaccumulation of contaminants in dredged-material tests statistically exceeds that in the reference-material tests, the "Green Book" recommends the following factors that should be assessed to evaluate LPC compliance.

1. Number of species in which bioaccumulation from the dredged material is statistically greater than bioaccumulation from the reference material.

2. Number of contaminants for which bioaccumulation from the dredged material is statistically greater than bioaccumulation from the reference material.

3. Magnitude by which bioaccumulation from the dredged material exceeds bioaccumulation from the reference material.

4. Toxicological importance of the contaminants whose bioaccumulation from the dredged material statistically exceeds that from the reference material.

5. Phylogenetic diversity of the species in which bioaccumulation from the dredged material statistically exceeds bioaccumulation from the reference material.

6. Propensity for the contaminants with statistically significant bioaccumulation to biomagnify within aquatic food webs.

7. Magnitude of toxicity and number and phylogenetic diversity of species exhibiting greater mortality in the dredged material than in the reference material.

8. Magnitude by which contaminants whose bioaccumulation from the dredged material exceeds that from the reference material also exceed the concentrations found in comparable species living in the vicinity of the proposed disposal site.

HB8 SEDIMENTS: Tissue concentrations of the metals, chromium, and nickel in the clam tissue were statistically greater than the reference. The magnitude by which bioaccumulation from the dredged material exceeds bioaccumulation from the reference material is less than 2X the reference. This magnitude is considered insignificant. Natural bioaccumulation magnitude differences of about 2X of metals are commonly observed within a species in bioaccumulation tests. In addition, because of the low absolute levels of these metals in the sediments to begin with, and because only two metals bioaccumulated at a statistically determinable higher concentration, there is not a significant risk for environmental effects due to metals in the HB8 sediments.

The most persistent dioxin congener, O8CDD, was also shown to be statistically higher ($P<0.05$) than the reference. Because there was no detection of O8CDD in the reference tissue (clam), a determination of the magnitude by which the levels in HB8 tissue exceeds the reference can not be calculated. The presence of O8CDD is not considered toxicologically important by itself, but is a indicator of the potential presence of the planar congener 2378 TCDD, which EPA considers the most potent known animal carcinogen, as likely human carcinogen. Therefore, because is not the planar toxic 2379 TCDD congener, and because of the extremely low O8CDD levels bioaccumulated (1.59 pptr), the presence of the contaminant dioxin and it's associated congeners, is considered to be a trace contaminant that would not pose potential significant undesirable effects due to bioaccumulation in marine organisms.

HB9 SEDIMENTS: Tissue concentrations of the metals chromium, nickel, and lead in the clam tissue were statistically greater than reference. Copper levels in worm tissue was statistically greater than the reference tissue (2 times higher than reference). Because of the lack of tissue, statistical comparison of HB9 to reference for the detected congener, O8CDD, could not be conducted. However, the pooled tissue analyses showed that a O8CDD concentration of 0.7 pptr, which was equal to the average values detected in the control and reference tissues. Therefore, it is estimated that the HB9 sediments would not have caused bioaccumulation greater then that caused by the reference sediment for this dioxin congener.

h. Conclusions for the Suitability of Humboldt Harbor Deepening Project Sediments for Aquatic Disposal:

1. Sediments HB1, HB2, HB3, HB4, HB5, HB7, HB10, and HB11: These sediments were determined to meet the grain size exclusionary criteria outlined in 40 CFR Section 227.13 (b)(1), and acceptable for ocean disposal without further testing.

2. Sediment HB8: This sediment did not produce any calculable LC50 in the suspended particulate phase tests. However, this sediment showed statistically greater mortality in both the *Nephtys caecoides* and *Rhepoxynius abronius* solid phase tests. Only minor elevated bioaccumulation of a few metals was shown by HB8 sediments. The dioxin congener O8CDD was shown to bioaccumulate statistically higher than the reference sediments, but at levels not considered significant. Based on the results of the 10 day toxicity tests, these sediments are considered unsuitable for unconfined aquatic disposal and will need to be properly placed in an upland disposal area such as the proposed LP Site.

3. Sediment HB9: This sediment did not produce any calculable LC50 in the suspended particulate phase tests, nor did it show any statistically significant toxicity in the solid phase tests. Bioaccumulation of contaminants from this sediment was shown to be insignificant when compared to reference sediments. Based on these results, sediments represented by HB9 do not exceed any LPC requirements and are suitable for unconfined aquatic disposal.

4.4.6 Seismicity and Tsunamis

Humboldt Bay is located near one of the most seismically active regions in California. The local seismic history is relatively active, extremely complex, and not fully understood. The majority of the earthquakes occur on active faults in the ocean floor off the coast of Cape Mendocino and extending seaward along the Gorda Escarpment in an area about 50-80 miles southwest of Eureka. A branch of the active San Andreas Fault Zone extends inland at Shelter Cove some 50 miles southwest of Eureka while the main fault zone swings northwestward to intersect the Mendocino Fault Zone. The Freshwater Fault, located south of Arcata, and projected beneath Arcata Bay is considered active. Geologically recent earthquakes include: one in 1954 with a richter magnitude 6.5, which centered on the Mad River fault zone about 10 miles from Eureka; a magnitude 7.0 earthquake occurred in November 1980, approximately 26 miles offshore of Patrick's Point, and approximately 33 miles north of Eureka; and a magnitude 7.0 earthquake occurred in April 1992, 27 miles south-southwest of the Humboldt Bay Entrance channel and near the town of Petrolia. This 1992 earthquake was quickly followed by two aftershocks of magnitude 6.0 and 6.5, respectively.

The aftershocks were located approximately 10 miles offshore of Cape Mendocino along the southern end of the subduction zone. These three earthquakes caused extensive damage in the town of Ferndale, located 13 miles south-southeast of the Humboldt Bay Entrance channel. No damage to the jetties along the Entrance channel was detected, and no damage was found to the breakwater and jetty at Buhne Point, located approximately one mile southeast of the Entrance channel. In addition, in late December 1994, a magnitude 5.3 earthquake occurred approximately 11 miles offshore of Eureka.

A tsunami is a sea wave produced by an offshore earthquake. Historically, the tsunamis that have reached the California coast originated as a result of distant earthquakes. California earthquakes have not produced any recorded tsunamis. The most recent tsunamis to strike the northern California coast occurred in the years 1960 and 1964. Moderate to severe damage with loss of life occurred at Crescent City to the north while Humboldt Bay incurred little or no damage as a result of the seismically induced waves. Inundation of lowlying peripheral areas of the Bay did not occur during either tsunami; however, potentially damaging, strong currents resulted from the rapid changes in the water level within the Bay. Although, tsunamis have reached Humboldt Bay only infrequently in the past, the possibility exists for future recurrence of tsunamis.

4.4.7 Humboldt Shoreline Monitoring Program

In 1990, when the Corps first proposed the use of HOODS for disposal of dredged material from Spring and Fall maintenance dredging of Humboldt Bay, the California Coastal Commission (CCC) expressed concern about the potential loss of sand from the Eel River littoral cell. In response, the Corps developed a multi-year shoreline monitoring program to monitor erosive and accretionary trends that may result in shoreline changes attributable to removal of material from the littoral cell. The Shoreline Monitoring Program had been scheduled to occur every 3 years from 1990 to 1999, then at 5 year intervals thereafter. However, due to the concerns of the CCC, the monitoring program was stepped up one year, and the first post-baseline data setwas collected in November of 1992. The established program will be re-evaluated after each data set is collected and is collected and analyzed.

The data to be gathered during the monitoring program include: aerial photography pof the coastline from the mouth of the Eel River to the mouth of the Mad River (approximately 37 kilometers (km); scale of 1:12,000); 14 dune and beach profiles spaced evenly 9.6km north and 9.6km south of the Humboldt north and south jetties, respectively; and eight additional profiles up to 3km north of the north jetty in order to monitor dune building.

The data analysis will include zoom-transfer scope work on the aerial photography and profile change analysis on the survey data. Zoom-transfer scope work will be apllied to the Mean High Water Line (MHWL) as depicted by the wetted bound to produce a Fall shoreline. This shoreline will be compared with the trend lines and confidence limits developed for 16 measurement stations discussed in a Moffatt & Nichol Engineers report (August 1991). The vegetation line will be digitized and compared to earlier vegetation lines. Profiles will be analyzed for area changes from the profiles taken in February of 1991. Additional profiles taken north of the north jetty will serve as a basis for comparison of future surveys in that area.

Any new data points which occur over 37 meters below the corresponding extrapolated trend line will require that some action be taken. The 37-meter allowable shoreline change limit is based on the average 95% confidence limit for all trend lines presented in the Moffatt and Nichols report (20 meters) plus 17 meters allowed for error in wetted bound location. The action to be taken will first describe the extent of the deviation and probable cause of the deviation. If the probable cause of the deviation is not readily available, the monitoring program, if deemed necessary, shall be changed to determine the most probable cause. Finally, if the dredging disposal practices are deemed responsible for any detrimental shoreline effects, alternate sediment management practices will be recommended.

Results of the FY 1992 Shoreline Monitoring Program are detailed in a case study on the "Dependence of Shoreline Change on Channel Dredge Material Disposal Practices, Humboldt Bay, CA" (Appendix D; Madalon and Kendall 1993). Presently, no relation between shoreline change and dredge disposal at HOODS has been determined. Due to the variety of factors affecting shoreline position, effects of dredge disposal at HOODS may not be realized for 10 to 20 years. Continued regular shoreline monitoring of the dynamic Humboldt shoreline will help identify any significant trends (i.e., erosion or accretion) earlier, and would be compared to the historic trends established in the Moffat & Nichol report.

4.4.8 Concern About Jetty Alignment and Maintenance Dredging

One of the concerns raised by an individual during the NOI/NOP comment period was the following:

> "Dredging of the channels is needed because ocean and Bay currents deposit sediment into Humboldt Harbor navigation channels. One of the main problems is that jetties are not positioned according to the "natural" (original) current patterns making Bay flushing more effective. What would be the "natural" flushing of Humboldt Bay without the jetties? How effective would the "natural" flushing action be in maintaining 40-50 feet channel depth? What would be the cost/benefit analysis of realigning the jetties in terms of annual dredging cost savings? What would be the environmental effects upon the fisheries and wildlife values of Humboldt Bay in the longterm?"

After examination of seven bathymetric surveys of the Humboldt Bay entrance before jetty construction, by the Corps, the following was found: The alignment of the entrance to Humboldt Bay varied from "south of west to west to north of west". If there were no jetties, the entrance orientation is dependent, for the most part, on sediment transport up and down the coast, not on hydraulic flushing by the tidal prism. In these "natural channels", the natural depth can shoal to less than 10 feet. It is believed that repositioning the jetties would not benefit in reduced dredging quantities. Formerly, it was believed that dominant sand transport was from the north, however, with the benefit of better wave data and advances in sediment transport theory, it is now believed that the dominant direction of transport in the Humboldt area is from south to north. Only the largest swells, which are from the west southwest, are capable of transporting sands around the jetty heads and into the channel. Repositioning the jetties to the south could actually allow more sand to enter the Entrance Channel and increase dredging quantities. This increase in shoal material would be minor, however, since the water depths at the ends of the jetties tend to dictate the amount of sand that enters the channel more than changes in jetty orientation. The jetty orientation would have little environmental impact within the Bay itself, and there would be no benefit associated with re-orientation of the jetties.

4.5 BIOLOGICAL RESOURCES

4.5.1 Humboldt Harbor and Bay, Navigation Channels, and HOODS

4.5.1.1 Marine Wildlife

California's coastal waters support an abundance of diverse marine life. This diversity can be attributed to rich food sources, warm and cold currents, seasonal upwellings, a mild climate, and a variety of habitats including: shallow and deep reefs; kelp forests; surf-pounded sandy beaches; deep submarine canyons and trenches; and quiet, soft-bottom habitats away from shore (Ricketts *et al.* 1939, Winzler and Kelly 1977).

Offshore Humboldt Bay, the open coastline is pounded by surf from ocean swells. The ocean bottom consists of sandy to silty clay and there is little cover, protection from waves, or rocky structures to provide habitat. The species in this area are adapted to seasonal changes such as wave height, substrate type, and circulation patterns. Although this habitat seems suboptimal, these sandy bottoms actually support a wide variety of epifaunal and infaunal organisms that support an abundance of fish life (Winzler and Kelly 1977).

Within the affected environment, commercially important biological resources include groundfish (English sole, Dover sole, Pacific sanddab, rockfish), Dungeness crab, and salmon, all of which seasonally inhabit the area proposed for dredged material disposal. A variety of seabirds and marine mammals also occur near the Humboldt Open Ocean Disposal Site (HOODS). Of lesser importance commercially, but of great importance ecologically, are the planktonic and benthic communities that provide food for higher trophic level organisms.

4.5.1.2 Plankton Community

The open waters off Humboldt Bay are part of the California current region, an area where biological components from a variety of marine biotic provinces mix (Jones and Stokes 1981). Few endemic species or distinct neritic (shallow coastal) assemblages are found in this pelagic environment (Jones and Stokes 1981), but warm-water species from the central Pacific province and warmer water cosmopolitan species occasionally occur (Jones and Stokes 1981). Plankton biomass and species composition in this region are influenced by the southerly flowing California current and the Davidson Current that flows sporadically northward in winter. In addition, the upwelling of cold, nutrient-rich deep water during late spring and summer fertilizes surface waters, promoting plant growth.

Phytoplankton

Phytoplankton are chlorophyll-bearing microscopic algae that passively drift or have limited means of locomotion and are, therefore, carried by waves and currents. Phytoplankton forms the basis of marine food chains by using solar energy to convert inorganic nutrients into organic matter through photosynthesis. The distribution and abundance of phytoplankton depends on light intensity, nutrient concentrations, intensity of grazing, turbulence, turbidity, upwelling, and circulation. The abundance and variety of phytoplankton in surface waters, in turn, influences the subsequent production of zooplankton and benthic organisms.

Phytoplankton concentrates in surface waters where light is available, but vertical distribution is affected by waves and currents. Phytoplankton biomass (as indicated by chlorophyll a concentrations) is usually lower offshore (15-20 mg chlorophyll a/m^2 in the upper 150 m) than nearshore (approximately 300 mg chlorophyll a/m^2 in the upper 150 m) (Owen 1974).

Phytoplankton populations in the coastal waters of northern California are generally composed of diatoms, dinoflagellates, coccolithophores, and flagellates (Hood et al. 1990). Primary production and phytoplankton biomass increase after persistent upwelling periods when cold, nutrient-rich waters induce intense blooms of diatoms. Photosynthetic carbon production rates can be two to ten times higher in areas of pronounced upwelling than in open ocean waters. The rate of primary production in northern California coastal waters is about 150 g C/m^2/year but may reach 300 g C/m^2/year in upwelling regions (Jones and Stokes 1981). Following blooms, phytoplankton biomass declines as nutrients become limiting and phytoplankton is eaten by grazers.

The warmer, nutrient-poor oceanic water of the California Current supports less biomass and relatively smaller species of phytoplankton species than those present during upwelling (Hood et al. 1990). During the stormy fall and winter season, primary production rates are low due to reduced solar radiation, reduced upwelling, increased mixing of surface waters below the euphotic (sunlit) zone, and increased turbidity due to wave action and increased flow of sediment-laden river water. The northerly flowing Davidson Current occasionally influences phytoplankton composition offshore Humboldt Bay during winter months by bringing warm water phytoplankton species from central Pacific waters.

Zooplankton

Zooplankton are aquatic invertebrates that have limited mobility or passively drift with water currents. Zooplankton transfer some of the energy of primary producers to larger invertebrates, fish, birds, and marine mammals. Zooplankton are divided into two main groups: holoplankton, which spend their entire life cycle in the water column; and meroplankton, which consists mostly of the larvae of benthic macroinvertebrates that are temporary members of the zooplankton community. The larvae of polychaetes, bivalves, gastropods, and crustaceans are typical meroplanktonic organisms while holoplanktonic organisms include copepods, mysids (opossum shrimp), euphausiids (krill), and chaetognaths (arrow worms). Microzooplankton, which includes the larval stages of larger zooplankton as well as single-celled organisms, are not discussed here.