FINAL
PALOS VERDES SHELF SUPERFUND SITE
REMEDIAL INVESTIGATION REPORT

EPA CONTRACT NO. 68-W-98-225
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CH2M HILL PROJECT NO. 335398.RR.01

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Acronyms and Abbreviations

°C	Celsius
µg/cm^2	micrograms per square centimeter
µg/cm^2/year	micrograms per square centimeter per year
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µm	micrometer
^{14}C	carbon-14
ADCP	Acoustic Doppler Current Profiler
ATSDR	Agency for Toxic Substances and Disease Registry
Bight '03	2003 Southern California Bight Regional Monitoring Program
Bight '94	1994 Southern California Bight Pilot Project
Bight '98	1998 Southern California Bight Regional Monitoring Program
BIO	bioturbating infaunal organisms
BSAF	biota-sediment accumulation factors
Cal-EPA	California Environmental Protection Agency
CAS	chemical abstract service
CDFG	California Department of Fish and Game
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
cm	centimeter(s)
cm/sec	centimeter(s) per second
cm/year	centimeter(s) per year
cm^2/day	square centimeter(s) per day
cm^2/year	square centimeter(s) per year
cm^3	cubic centimeters(s)
cm^3/day	cubic centimeter(s) per day
CSM	conceptual site model

CTE	central tendency exposure
D_b	biodiffusivity
DBP	dichlorobenzophenone
DDA	dichlorodiphenylacetate
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethene
DDMU	1-chloro-2,2-bis (p-chlorophenyl) ethylene
DDNU	unsym-bis (p-chlorophenyl) ethylene
DDOH	2,2-bis (p-chlorophenyl) ethanol
DDT	dichlorodiphenyltrichloroethane
DDTs	dichlorodiphenyltrichloroethane and its metabolites
DNAPL	dense nonaqueous phase liquid
DSPI	digital sediment-profile image
DTSC	Department of Toxic Substances Control
EE/CA	engineering evaluation/cost analysis
ELCR	excess lifetime cancer risk
EPA	United States Environmental Protection Agency
EqP	equilibrium partitioning
ERA	ecological risk assessment
ERDC	Engineering Research and Development Center
FAV	final adjusted value
FS	feasibility study
g	gram(s)
g/cm^2	gram(s) per square centimeter
g/cm^3	gram(s) per cubic centimeter
g/day	gram(s) per day
$g/m^2/day$	gram(s) per square meter per day
$g/m^2/year$	grams per square meter per year
g/mol	gram(s) per mole
GC	gas chromatography

GIS	geographic information system
H_2S	hydrogen sulfide
Hc	Henry's Law constant
HHRE	human health risk evaluation
HI	hazard index
HQ	hazard quotient
JWPCP	Joint Water Pollution Control Plant
kg	kilogram(s)
km	kilometer(s)
km/day	kilometer(s) per day
km^2	square kilometer(s)
K_{OC}	organic carbon normalized sediment-water partition coefficient
K_{OW}	octanol – water partition constant
kPa	kilopascal(s)
LACSD	Los Angeles County Sanitation District
LC	Landward Center
LD	Landward Downstream
LOAEL	lowest observed adverse effect level
LOEC	lowest observed effects concentration
LU	Landward Upstream
M	magnitude
m	meter(s)
m^2	square meter(s)
m^3	cubic meter(s)
mg/kg	milligram(s) per kilogram
mg/L	milligrams per liter
mgd	million gallon(s) per day
MHHW	mean higher high water
MLLW	mean lower low water
mm	millimeter(s)

mm/year	millimeter(s) per year
Montrose	Montrose Chemical Corporation of California
MS	mass spectrometry
MSRP	Montrose Settlements Restoration Program
ng/L	nanogram(s) per liter
NIST	National Institute of Standards
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observed adverse effect levels
NOEC	no observed effects concentration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRDA	Natural Resources Damage Assessment
NW	northwest
O_2	oxygen
OEHHA	Office of Environmental Health Hazard Assessment
OUT	outfall
Pa	pascal(s)
Pa-m^3/mol	pascals per cubic meter per mole
PCBs	polychlorinated biphenyls
ppm	parts per million
ppt	parts per thousand
PV Shelf	Palos Verdes Shelf
RfD	reference dose
RI	Remedial Investigation
RME	reasonable maximum exposure
SAIC	Science Applications International Corporation
SCB	Southern California Bight
SCBPP	Southern California Bight Pilot Project
SCCWRP	Southern California Coastal Water Research Project
SD	Seaward Downstream

SE	southeast
SEC	sediment effect concentration
Sedflume	High Shear Stress Sediment Erosion Flume
SMBRP	Santa Monica Bay Restoration Project
SPI	sediment-profile image/imagery
SU	Seaward Upstream
TAB3	tetrapropylene-based alkylbenzene isomer
TM	technical memorandum
TOC	total organic carbon
Trustees	state and federal natural resource trustee agencies
TSS	total suspended solids
UCL	upper confidence limit
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WES	Waterways Experiment Station
WRCC	Western Region Climate Center

Executive Summary

This Palos Verdes Shelf (PV Shelf) Remedial Investigation (RI) report was prepared by CH2M HILL for the United States Environmental Protection Agency (EPA) under Work Assignment No. 282-RICO-09CA (EPA Contract No. 68-W-98-225).

The PV Shelf is located off the coast of the Palos Verdes Peninsula, Los Angeles County, California. It forms part of the continental shelf between Santa Monica Bay and the San Pedro Shelf. Since 1937, Los Angeles County has discharged treated sewage effluent onto the PV Shelf from outfalls at White Point. Marine sediments on the PV Shelf became contaminated with the pesticide dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyls (PCBs), metals, and other contaminants when treated effluent was discharged onto the PV Shelf. The primary source of the DDT and its metabolites (hereafter collectively referred to as DDTs) was the Montrose Chemical Corporation of California (Montrose), which, at one time, was the largest manufacturer of DDT in the United States. Montrose discharged tons of DDT and associated manufacturing waste into the Los Angeles County Sanitation District (LACSD) sewer system from the 1950s to 1970s. Other industries, notably Westinghouse, Simpson Paper Company, and Potlatch Corporation, discharged PCBs into the sewer system. DDT was banned in 1972 and PCBs in 1976. Nevertheless, these persistent pollutants remain in the PV Shelf sediments. Because the conveyance mechanism for these contaminants was outfall effluent, the sediments are referred to as effluent-affected sediments.

Montrose dismantled its Los Angeles County plant in 1983. However, waste-related contamination at the former plant site led to its placement on the National Priorities List of hazardous sites in 1989. Further investigations found DDT-related contamination in groundwater, soils, sewer system, and the PV Shelf sediments. EPA is managing Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) response activities on the PV Shelf as part of the response activities being conducted by EPA in connection with the Montrose Chemical Superfund Site.

Purpose and Scope

The RI presents current understanding of the PV Shelf Study Area. It characterizes the PV Shelf Study Area, compiles and evaluates information on the nature and extent of DDT and PCB contamination, and discusses the long-term transport and fate of the contaminants. Additionally, the RI assesses the risks to human health and the environment from the effluent-affected sediments. The purpose of this RI is to provide the information and analysis needed to support the development, evaluation, and selection of appropriate response alternatives.

Methodology

The contaminated sediment on the PV Shelf has been the subject of numerous investigations and monitoring activities since the early 1970s. These studies contribute to EPA's understanding of the nature and extent of the contamination and its effects on human health and the natural environment. The following are principal non-EPA data sources and investigations used to prepare this RI:

- Sediment characterization studies conducted by the United States Geological Survey (USGS) for a Natural Resources Damage Assessment (NRDA) in 1992
- The PV Shelf ocean monitoring program conducted by LACSD to fulfill its NPDES (National Pollutant Discharge Elimination System) permit as well as LACSD's voluntary sediment profile analyses from the 1970s through 2005
- Regional surveys on the health of the Southern California Bight (SCB) coordinated by the Southern California Coastal Water Research Project (SCCWRP) in 1994, 1998, and 2003

EPA began its investigation of the PV Shelf sediment contamination in 1996. Since then, EPA has authored or sponsored studies to better understand the risk posed by the contaminated sediment along with investigations to assist in remedy selection. These studies include:

- Human health risk evaluation (HHRE) for the PV Shelf (Science Applications International Corporation [SAIC], 1999) and its update using 2002 fish data (CH2M HILL, 2006)
- Ecological risk assessment (ERA) for the PV Shelf (CH2M HILL, 2003) and update to the food web exposure model completed by CH2M HILL in 2006
- Engineering evaluation/cost analysis (EE/CA) for the PV Shelf (EPA, 2000a)
- Options for in situ capping of PV Shelf contaminated sediments (Palermo et al., 1999) and post-cap monitoring studies (Fredette et al., 2002; SAIC, 2003; SAIC, 2005d)
- 2004 field studies (including the sediment displacement study and the oceanographic, geotechnical, and bioturbation measurement programs) (SAIC, 2005a, 2005b, 2005c, 2005d)
- *2002-2004 Southern California Coastal Marine Fish Contaminants Survey* (EPA and NOAA, 2007)

Site Description

The PV Shelf is about 1.5 to 4 kilometers (km) wide, up to 25 km long, and has a slope of 1 to 4 degrees (Figure 1-1). Kelp beds and rocky patches are found in shallower waters near shore; however, most of the shelf is covered in thick sediment. A shelf break (i.e., a zone of transition from the relatively flat shelf to the steeper continental slope) occurs at water

depths of 70 to 100 meters (m). The continental slope drops seaward from the shelf, with a width of approximately 3 km and an average slope of 13 degrees, to a depth of approximately 800 m (Lee, 1994).

For the purposes of this RI, the PV Shelf Study Area is defined as the area of the shelf and slope off the Palos Verdes Peninsula between Point Fermin and Redondo Canyon, from the shore to the 200-meter (m) isobath (depth contour). This is the study area used in the ERA and represents a recognizable geographic area. It includes the deposit of highly contaminated effluent-affected sediment and the area around it.

The oceanographic setting of PV Shelf is complicated. The PV Shelf is a narrow strip of relatively shallow water next to a deep basin, but is located between two much wider embayments: Santa Monica and San Pedro Bays. The regional topography is diverse, and the water over the PV Shelf is stratified by temperature and salinity gradients. In addition to currents forced by regional alongshore pressure gradients, winds and tides, currents are caused by internal oscillations of the stratified waters. These include internal tides, internal waves, and solitons. Seasonal changes in water temperature influence the internal motions. Flow on the PV Shelf tends to the northwest, but strength and direction varies seasonally and sometimes reverses in surface waters during summer. Strength and spatial variability of near-bottom currents is usually higher at both ends of the PV Shelf Study Area.

Key Findings

Nature and Extent of Contamination

A 5- to 60-centimeter (cm)-thick effluent-affected deposit extends over most of the shelf and slope from Point Fermin to Point Vicente. Vigorous wave activity has kept the effluent-affected sediment from accumulating in shore from the 40-m isobath, while on the ocean side, the deposit extends over the PV Shelf break, thinning as it moves down the mid- to lower slope. The deposit consists of cohesive, fine-grained, organic-rich, contaminated material that includes outfall effluent combined with natural sediment, most of which likely came from the Portuguese Bend Landslide.

The thickest part of the effluent-affected deposit extends along the 60-m isobath. The deposit is thickest (80 cm) near the 90-inch outfall (Figure 1-3), and thins rapidly toward the southeast, barely exceeding 15 cm a kilometer from the outfall. It tapers more gradually toward the northwest. About 12 km northwest from the outfalls, the effluent-affected deposit is still 25 cm thick. This elliptical shape of the deposit is consistent with bi-directional dispersion from the outfall that has been skewed upcoast, in the direction of the long-term average current. On the northwest end, the increased thickness of the effluent-affected deposit and lower contaminant concentrations also suggest admixture of Portuguese Bend Landslide sediment.

The thickest part of the effluent-affected deposit has two distinct layers. The lower layer has the highest levels of contamination (about 80 to 200 milligrams per kilogram [mg/kg] DDTs[1]) and slightly higher water content, consistent with the more rapid deposition that

[1] The term DDTs is used in the RI to represent the sum of the six common DDT isomers: o,p'-DDT, p,p'-DDT, o,p'-DDE, p,p'-DDE, o,p'-DDD, and p,p'-DDD.

occurred when large amounts of highly contaminated sediment was discharge from the outfalls. The upper sediment layer has generally lower levels of contamination (about 1 to 5 mg/kg DDTs) and is more uniform, indicating physical reworking by waves, currents, and benthic fauna. The thickness of these two layers varies across the deposit. The upper layer can include the top 10 to 30 cm; the lower layer represents an additional 30 cm, with peak concentrations at 35 to 45 cm below surface.

The spatial extent of the deposit has not changed appreciatively since the NRDA in 1992; however, contaminant concentrations within that footprint have dropped. In 1992, the area with surface (0 to 2 cm) concentrations of DDTs over 10 mg/kg was 8.2 square kilometers (km^2); in 2004, the area was 3.6 km^2. Similarly, the area with surface concentrations of PCBs over 1 mg/kg has dropped from 8.4 km^2 in 1992 to 6.2 km^2 in 2004.

The exception to the overall reduction in surface concentrations has been the area adjacent to the outfall, where surface concentrations have increased dramatically since the 1992 NRDA, from 27 to 205 mg/kg DDTs and from 2.7 to 3.36 mg/kg PCBs[2]. This increase in surface concentrations suggests net erosion in this area.

Fate and Transport

The overall reduction in contaminant concentrations on the PV Shelf results from physical, chemical, and biological processes acting on the effluent-affected sediment deposit. Physical processes (e.g., resuspension, transport, deposition, and mixing of sediment) govern fate and transport of the contaminants. Chemical and biological processes appear to be less significant than physical processes. All of these processes interact to varying degrees in different parts of the effluent-affected deposit.

Large storm-induced waves are the dominant mechanism for resuspension of bottom sediments in the PV Shelf Study Area at depths greater than 40 m. Multi-year oceanographic data show storm events sufficient to suspend bottom sediments at a depth of 60 m occur on average 10 times per year and last an average of 1.6 days. At 90 m, the number of storm events of sufficient magnitude to suspend sediment drops to 3 per year. When sediment was suspended, the scour depth was less than 1 cm.

Resuspension of effluent-affected sediment and subsequent desorption of contaminants from the particles into seawater are other potential mechanisms for transport. Mixing and transport of seawater disperses the contaminants throughout the SCB; the sediment that settles back to the bottom is slightly less contaminated. Desorption also occurs during horizontal transport. This process is responsible for an estimated annual transfer of about 10 percent of the DDTs in the top 5 cm of sediment to the overlying water column.

Resuspension and transport moves sediment off of and onto the shelf. Average burial rates during the 1980s and 1990s ranged between 0.6 and 0.7 centimeters per year (cm/year). Burial rates have dropped with the decrease in sediment output from the outfalls. It is not known whether the effluent-affected deposit will be eroded or stay buried. The shape and location of the effluent-affected sediment deposit and relevant current meter studies indicate

[2] PCBs as sum of Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260.

that transport of sediment within the study area by bottom currents is predominantly to the northwest, with a subcomponent of the flow moving offshore and off-shelf to the west.

Invertebrates that populate the shelf are significant sediment mixers. Bioturbation, the mixing and turning of sediment by fauna living in the sediment, is most intense in the top 10 cm; however, deep-burrowing organisms, such as ghost shrimp, are capable of excavating and transporting sediment from depths of a meter. These large organisms can bring sediment up from the peak contamination layer directly to the surface. Bioturbation plays an important role in mixing contaminated sediment and pore water from deeper, more contaminated layers to surface layers. The rate and depth of biological activity varies with depth in the sediment and has changed over time along with infauna populations.

The effluent-affected deposit is changing over time chemically as well. There is limited DDT in the sediment because it was quickly transformed to dichlorodiphenyldichloroethane (DDD) or dichlorodiphenyldichloroethene (DDE). The most common DDT compound found on the shelf is p,p'-DDE, hereafter referred to as DDE. Recent analysis of sediment cores indicate further breakdown is occurring. These changes vary by location and depth in the deposit, suggesting that local sediment geology and chemistry play a role in providing the right conditions for microbial activity. Transformation of DDE to DDMU (1-chloro-2,2-bis [p-chlorophenyl] ethylene) has been documented. Recent data indicate that DDMU is not the terminal product of this transformation because DDNU (unsym-bis [p-chlorophenyl] ethylene) also has been detected in sediment (Eganhouse and Pontolillo, 2007). Further work to identify end products on the PV Shelf from reductive dechlorination is necessary. Additionally, there are limited data on these compounds concerning their toxicity and bioaccumulation potential; therefore, it is unclear if these transformations represent a reduction in risk or have less impact on ecosystem health. Unlike DDT, there is no evidence that PCBs are degrading at the PV Shelf.

Risk Assessments

Human Health Risk Evaluation

A streamlined HHRE was conducted for the PV Shelf in 1999 to assess the risk to human health posed by the contaminants onsite. The HHRE found that consumption of fish caught from the PV Shelf Study Area, particularly bottom feeders like white croaker, posed a health risk because of their high levels of DDTs and PCBs. DDTs and PCBs are probable human carcinogens and have deleterious health effects.

For noncancer effects, the likelihood that a receptor will develop an adverse effect is estimated by comparing the predicted level of exposure for a particular chemical with the highest level of exposure that is considered protective, or the reference dose (RfD). When the exposure exceeds the RfD (when the hazard quotient for a chemical exceeds 1), there would be a concern for potential noncancer health effects. EPA assumes there is no safe exposure threshold for carcinogens; therefore, EPA calculates risk from carcinogens as potential increased cancer risk over a lifetime.

This RI includes a supplemental HHRE that used 2002 fish data from LACSD and the *2002-2004 Southern California Coastal Marine Fish Contaminants Survey*. These two sources combined provided sufficient data set to perform a statistically valid assessment of risk from

six species: white croaker, kelp bass, rockfish, surfperch, California scorpionfish, and barred sandbass.

The supplemental HHRE used two fish fillet consumption scenarios: a reasonable maximum exposure (RME) (i.e., consumption) of 107.1 grams of fish a day and, for high-end consumers, 115.7 grams per day (g/day). The central tendency exposure (CTE) scenario represents a mixed-species diet, where fish consumption would equal 21.4 g/day. Under the RME scenario, cancer risk from DDTs and PCBs for three species (white croaker, California scorpionfish, and barred sandbass) ranged from 3 $x10^{-4}$ to 7 x 10^{-3}, based on 95 percent upper confidence limit (UCL) concentrations. Risks from the other species (kelp bass, rockfish, and surfperch) ranged from 7 x 10^{-5} to 1 x 10^{-4}. The HI values for all six species ranged from 2 to 198.

Under the CTE conditions for consumption of fish fillets, cancer risks from DDTs and PCBs for one species (white croaker) was 6 x 10^{-4} based on 95 percent UCL concentrations. Risks from the other five species ranged from 6 x 10^{-6} to 3 x 10^{-5}. The hazard index (HI) values from three of the six species (white croaker, California scorpionfish, and barred sandbass) ranged from 2 to 37. Kelpfish, rockfish, and surfperch have HI values below 1.

These health risks only address concentrations of DDTs and PCBs in fish fillet muscle. DDTs and PCBs are lipophilic, which means they tend to accumulate in fat. Because whole fish concentrations are typically 8 to 10 times higher than tissue concentrations, these risk values underestimate exposure for people who consume whole fish, such as in stews and other dishes.

Ecological Risk Assessment

EPA prepared an ERA in 2003 to identify and characterize existing levels of contaminants at the PV Shelf Study Area and assess potential exposure pathways to resident biota. In 2006, the food web model used for the 2003 ERA was updated with sediment and fish data collected since 2003. An updated risk screening of benthic invertebrates for DDTs and PCBs also was conducted concurrently with the food web model update and new depictions of surface sediment contamination.

Several lines of evidence, including sediment and pore water HQs, benthic community effects, toxicity tests, effects on fish, and modeling of food chain transfer to birds and mammals, were evaluated as part of the ERA. A combination of literature-derived and site-specific effects data were used to develop effects levels for benthic macroinvertebrates, fish, birds, and sea lions. Effects data for benthic macroinvertebrates included site-specific sediment and literature-derived water quality benchmarks, as well as site-specific toxicity tests and benthic community assessments. For fish, literature-derived water quality and tissue residue-based benchmarks were used to determine risk from external and internal exposure, respectively. Both dietary exposure and target-organ-based internal tissue benchmarks (eggs for birds and blubber for sea lions) were developed from literature sources to assess external and internal risk to birds and mammals. In addition, site-specific studies outlining potential chronic effects from exposure to DDTs and PCBs (e.g., population declines, nest failures, juvenile mortality, impaired growth rates) were available and used as appropriate for birds and mammals.

All lines of evidence show some evidence of risk. The results show the highest risks near the LACSD outfalls. Intermediate-risk areas are found generally to the south and southwest of the outfalls, as well as areas to the northwest off Point Vicente. Finally, low-risk areas occur at the northeastern areas of the PV Shelf Study Area (near Redondo Canyon) and throughout the remainder of the SCB.

Results for birds and mammals indicate some far-reaching risks, including out to the Channel Islands, driven by seasonal patterns and extent of foraging area or high levels of biomagnification from assimilation from lesser contaminated areas beyond the PV Shelf. The risks from DDTs and PCBs have not changed from the 2003 ERA, and have indicated risk for all receptors, with the greatest risk from DDTs.

1.0 Introduction

This Palos Verdes Shelf (PV Shelf) Remedial Investigation (RI) report was prepared by CH2M HILL for the United States Environmental Protection Agency (EPA) under Work Assignment No. 282-RICO-09CA (EPA Contract No. 68-W-98-225).

The PV Shelf is located off the coast of the Palos Verdes Peninsula near Los Angeles, California. Marine sediments on the PV Shelf have been contaminated with the pesticide dichlorodiphenyltrichloroethane (DDT) and its metabolites (hereafter referred to collectively as DDTs), polychlorinated biphenyls (PCBs), metals, and other contaminants. For many years, the now-defunct DDT manufacturer, Montrose Chemical Corporation of California (Montrose), as well as other industries, discharged their wastes into the Los Angeles County Sanitation District (LACSD) sewer system. The LACSD's Joint Water Pollution Control Plant (JWPCP) connects to four White Point outfalls that discharge onto the PV Shelf. The PV Shelf forms Operable Unit 5 of the Montrose Chemical Superfund Site.

1.1 Purpose and Scope

The purpose of this RI is to characterize the PV Shelf Study Area (Figure 1-1) and to compile and evaluate information on the nature and extent of DDT and PCB contamination at the study area. Additionally, the RI provides information to assess the risks to human health and the environment and to support the development, evaluation, and selection of appropriate response alternatives. Numerous studies conducted since the early 1990s (described in Section 2.0) form the basis for this RI.

1.2 Site Background

1.2.1 Geographic Description

The PV Shelf refers to that part of the continental shelf off the Palos Verdes Peninsula. The PV Shelf is about 1.5 to 4 kilometers (km) wide, up to 25 km long, and has a slope of 1 to 4 degrees. A shelf break (i.e., a zone of transition from the relatively flat shelf to the steeper near-shore continental slope) occurs at water depths of 70 to 100 meters (m). The continental slope extends seaward from the shelf, with a width of approximately 3 km and an average slope of 13 degrees, to a depth of approximately 800 m (Lee, 1994). For the purposes of this RI, the PV Shelf Study Area is defined as the area of the shelf and near-shore continental slope between Point Fermin and Redondo Canyon from the shore to the 200-m isobath, as shown on Figure 1-1.

In general, the PV Shelf region is characterized by (1) hard-bottom (rocky) habitat, including some kelp bed areas and associated invertebrate, fish, and algae communities, from shore to at least 20 m of water depth; (2) soft-bottom habitat, including invertebrate and fish communities, over most of the rest of the shelf and slope region to a water depth of at least 600 m; and (3) pelagic or water column zones, representing important habitat for fish, invertebrates, birds, and mammals from near the sea floor to the water surface. The exception to this pattern is the hard-substrate, artificial reef habitat represented by the

White Point outfall pipes that extend primarily over soft-bottom areas to a water depth of approximately 60 m, some hard-bottom areas scattered along the shelf, and more extensive hard-bottom areas paralleling the shelf break.

The dominant physical oceanic features in the Southern California Bight (SCB) include the southward-flowing California Current, the northward-flowing Southern California Countercurrent, and seasonal influences by the northward-trending Davidson Countercurrent (Drake, 1994). The California Current is a surface current that originates in colder, more nutrient-rich northern waters and flows southward along the west coast of North America. At Point Conception, where the coastline verges to the east, the California Current continues southward and offshore. The current speed varies annually and seasonally, with a maximum speed of 10 to 15 centimeters per second (cm/sec). The California Current forms the western boundary of SCB. The northern and southern boundaries of the bight are Point Conception, California, and Cabo Colnett in Baja California, respectively.

The Southern California Countercurrent, a poleward flowing undercurrent, enters the bight from the south along the continental margin. Figure 1-2 shows typical current flow directions in the SCB, including the California Current and the Southern California Countercurrent. Net currents on the PV Shelf generally flow northwest, toward Santa Monica Bay, however, a narrow zone of southward surface flow sometimes occurs shoreward of the Southern California Countercurrent in the northern part of the SCB (Tsuchiya, 1980; Huyer, 1983).

In addition to the primary currents discussed above, several other physical oceanographic processes also influence the dispersion of effluent and sediments near the White Point outfalls. These include tidal and along-shore currents, orbital motion from storm waves impinging on the ocean floor, localized upwelling of bottom waters to the surface, and water movements associated with large-scale oceanographic phenomena such as the Pacific Decadal Oscillation and the shorter-term, but intense, El Niño/La Niña events. Combined, these currents and oceanographic circulation patterns create an extremely variable mixing environment on the shelf.

1.2.2 Site History

1.2.2.1 Montrose Chemical Superfund Site

From 1947 until 1982, Montrose operated a DDT-manufacturing plant on 13 acres at 20201 Normandie Avenue in Los Angeles County, California. The land was owned by Stauffer Chemical Company. The Montrose plant operated 24 hours a day, 7 days a week, 365 days a year, except for occasional plant shutdowns. During its 35 years of operation, Montrose produced approximately 726,000 metric tons of DDT.

When the plant first opened, it discharged DDT-contaminated wastewater from its production operations to a city sewer line through a private pressure sewer line owned by Stauffer Chemical Company. This connecting line periodically clogged, resulting in the discharge of Montrose DDT-contaminated wastewater to the natural stormwater drainage. When EPA investigated the natural stormwater drain in the 1990s, residual levels of DDT in the drainage immediately downstream of the Montrose plant property were in excess of 8,000 milligrams per kilogram (mg/kg).

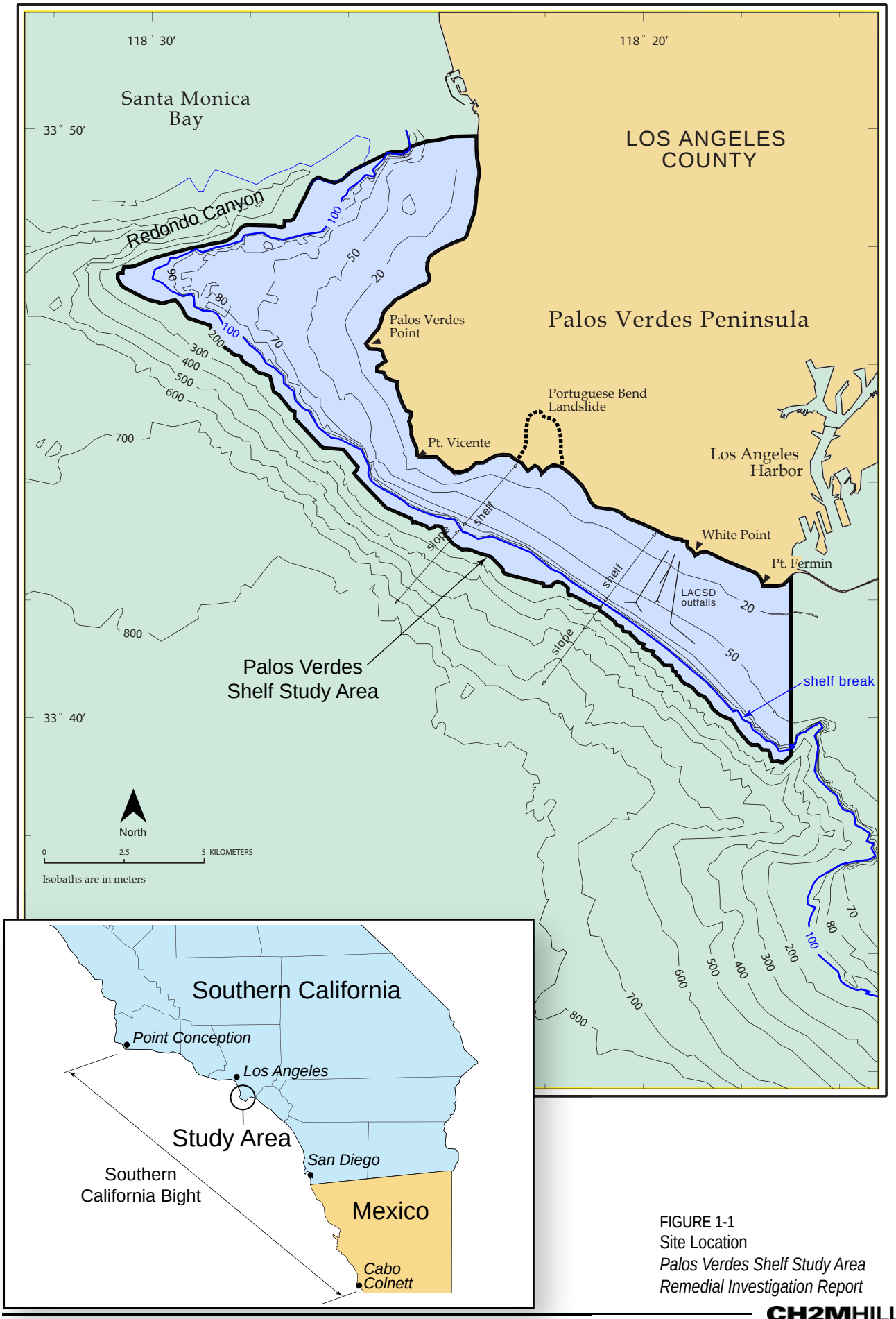


FIGURE 1-1
Site Location
Palos Verdes Shelf Study Area
Remedial Investigation Report

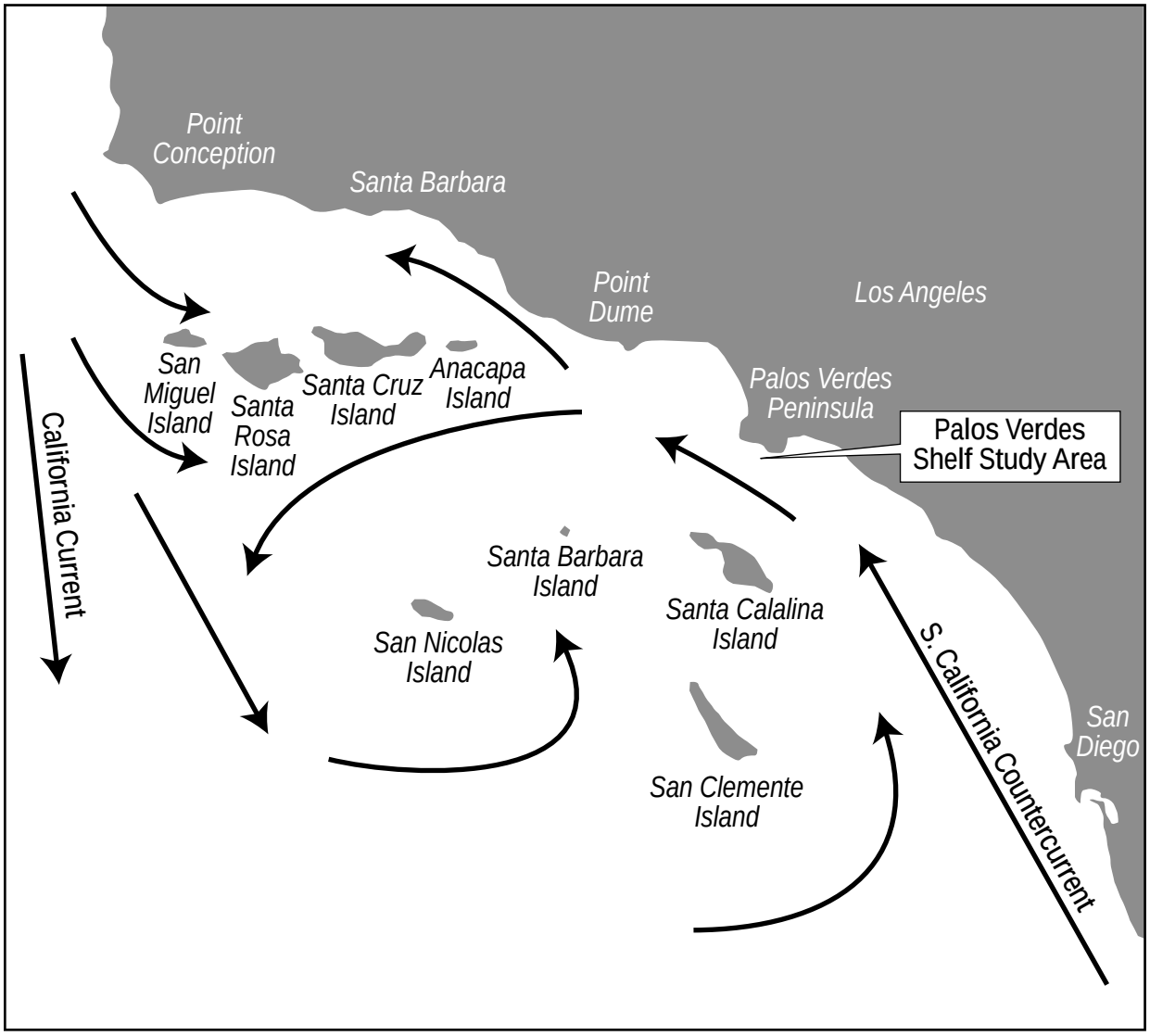


FIGURE 1-2
Net Water Movement
in the Southern California Bight
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: After Hickey, B.M., 1992, Progress in Oceanography, V30: 37-115.

The Montrose plant property was contaminated by its operations. Investigations directed by EPA beginning in 1985 found significant contamination (primarily DDT and chlorobenzene) in the shallow and deep soil at the Montrose plant property, groundwater beneath and downgradient from the Montrose plant property, soil adjacent to and near the property, the sewer line adjacent to and downstream of the Montrose plant property, in addition to the portions of the stormwater pathway leading from the Montrose plant to the Consolidated Slip in Los Angeles Harbor. Groundwater at the Montrose site is contaminated with monochlorobenzene and other contaminants across six hydrostratigraphic units and to distances up to 2.1 km from the former Montrose plant. Dense nonaqueous phase liquid (DNAPL) is present under the former plant property to great depth and is serving as a continuous source of groundwater contamination.

The Montrose Chemical Superfund Site was included on the National Priorities List (NPL) of federal sites (i.e., Superfund) on October 4, 1989. There are five operable units at the Montrose Chemical Superfund Site covering contamination found in soil, groundwater, and stormwater pathways. Based on EPA decisions made in 1996, EPA is managing Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) response activities with respect to the PV Shelf as part of the response activities being conducted by EPA in connection with the Montrose Chemical Superfund Site.

1.2.2.2 Sewer Lines to Palos Verdes Shelf

From 1953 until 1971, Montrose discharged DDT-contaminated wastewater from its DDT production and other operations at the Montrose plant property to two sewers operated by LACSD. These sewers conveyed the wastewater to the JWPCP, where the wastewater received primary treatment and was discharged to the ocean through outfalls located on the PV Shelf off White Point.

In the early 1970s, LACSD initiated an investigation to identify and eliminate discharge of DDTs and PCBs into its sewer system. LACSD identified the Montrose plant as the only significant source of DDT in sewer flows to the JWPCP. PCBs entered the LACSD sewer system from several industrial sources in the Los Angeles area, most notably from the Westinghouse Electric Corporation, which manufactured and repaired electrical equipment at its Los Angles County plant; from a paper-manufacturing plant in Pomona owned by Potlatch Corporation; and from Simpson Paper Company. Like DDT from the Montrose plant, PCBs from these plants were sent to and through the JWPCP and eventually were discharged to the ocean from the LACSD outfalls on the PV Shelf.

LACSD estimated that the discharge from the Montrose plant was contributing 297 kilograms (kg) of DDT per day to the LACSD system. In 1971, LACSD revoked Montrose's discharge permit and Montrose ceased discharging waste into the LACSD sewer system. During this time, LACSD conducted cleaning operations in the two sewer lines adjacent to and downstream of the Montrose property. Sediments in the two sewer lines contained more than 3,500 kg of DDT, according to LACSD estimates.

Despite cleaning efforts by LACSD in its sewer line, significant quantities of DDT-contaminated sediment remained in the Montrose-maintained portion of the sewer line. After the Montrose plant closed in 1983, under EPA order, Montrose removed approximately 73,500 kg of sediment from the sewer line downstream from the plant.

Sewer sediment samples from this removal operation showed levels of DDT in the sediment at 490,000 mg/kg and chlorobenzene at 2,200 mg/kg.

Until 1971, when Montrose ceased using the LACSD sewer system, treated wastewater from the JWPCP discharging to the White Point outfalls at the PV Shelf contained high levels of DDT. The discharge of DDT- and PCB-contaminated wastewater through the LACSD outfalls resulted in contamination of the sediments on the PV Shelf. Other minor sources contributed contaminants to the PV Shelf and SCB. Contaminant concentrations at depth exceed 200 mg/kg DDT and 15 mg/kg PCB. Sediment from the outfalls combined with material from other sources (particularly erosion from the Portuguese Bend landslide) formed an effluent-affected deposit on the PV Shelf ranging in thickness from 5 to 60 centimeters (cm), with a volume of more than 9 million cubic meters (m^3), and covering approximately 40 square kilometers (km^2) on the shelf and adjacent continental slope (Lee et al., 2002).

Historically, the waters of the PV Shelf have been used extensively by sport and commercial fishermen. Sport fishermen angle from party boats, private boats, rocky intertidal areas, and sandy beaches. Currently, high levels of DDTs and PCBs are found in the active biologic zone of the PV Shelf sediments, and fish from the shelf are contaminated with DDTs and PCBs. Concentrations of DDTs and PCBs are usually highest in benthic species (bottom-feeding fish) with small home ranges such as the white croaker, and are significantly lower in pelagic fish species that live higher up in the water column and roam over significantly larger geographic areas.

1.2.3 Source Description

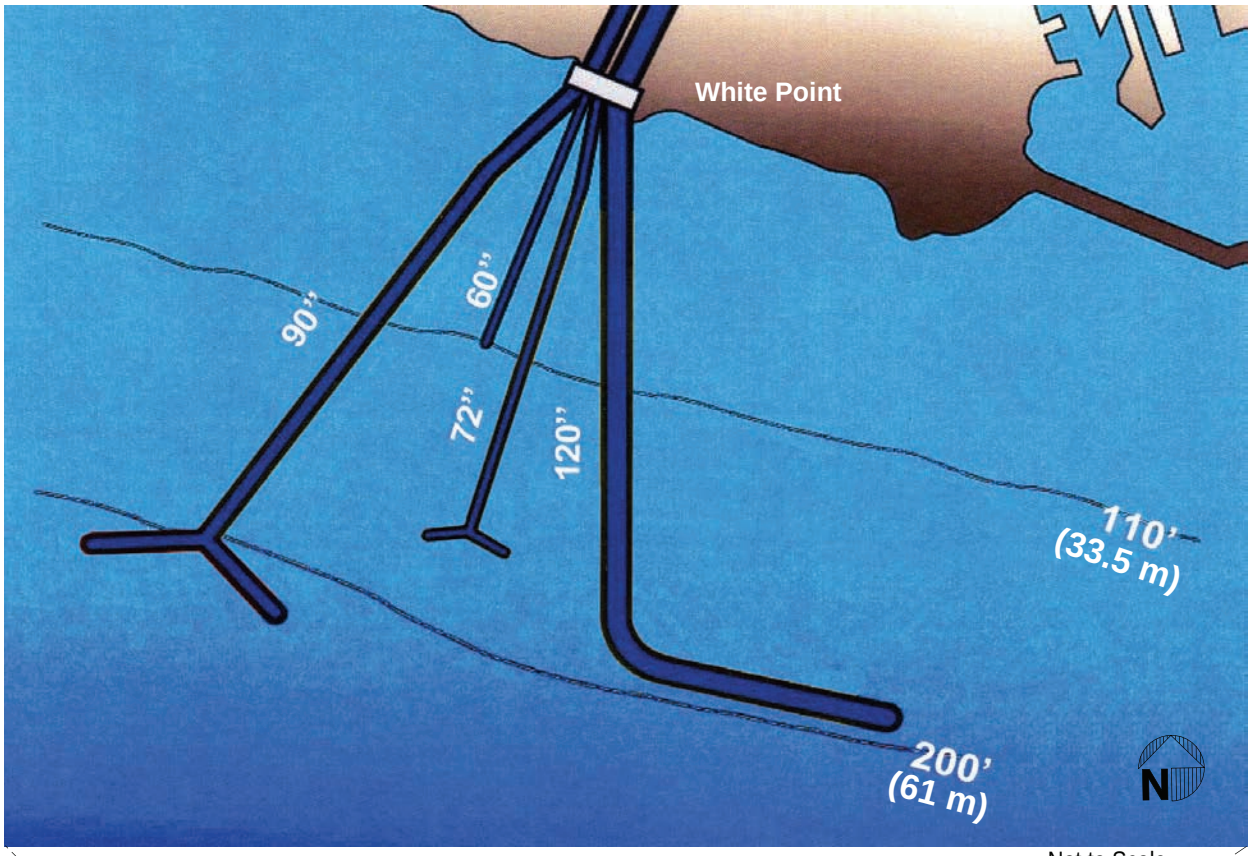
1.2.3.1 Los Angeles County Sanitation District Outfalls

Treated effluent from the JWPCP is conveyed through two tunnels under the Palos Verdes Peninsula to a manifold at White Point, where four ocean outfalls originate (Figure 1-3). Table 1-1 summarizes information on the four outfalls.

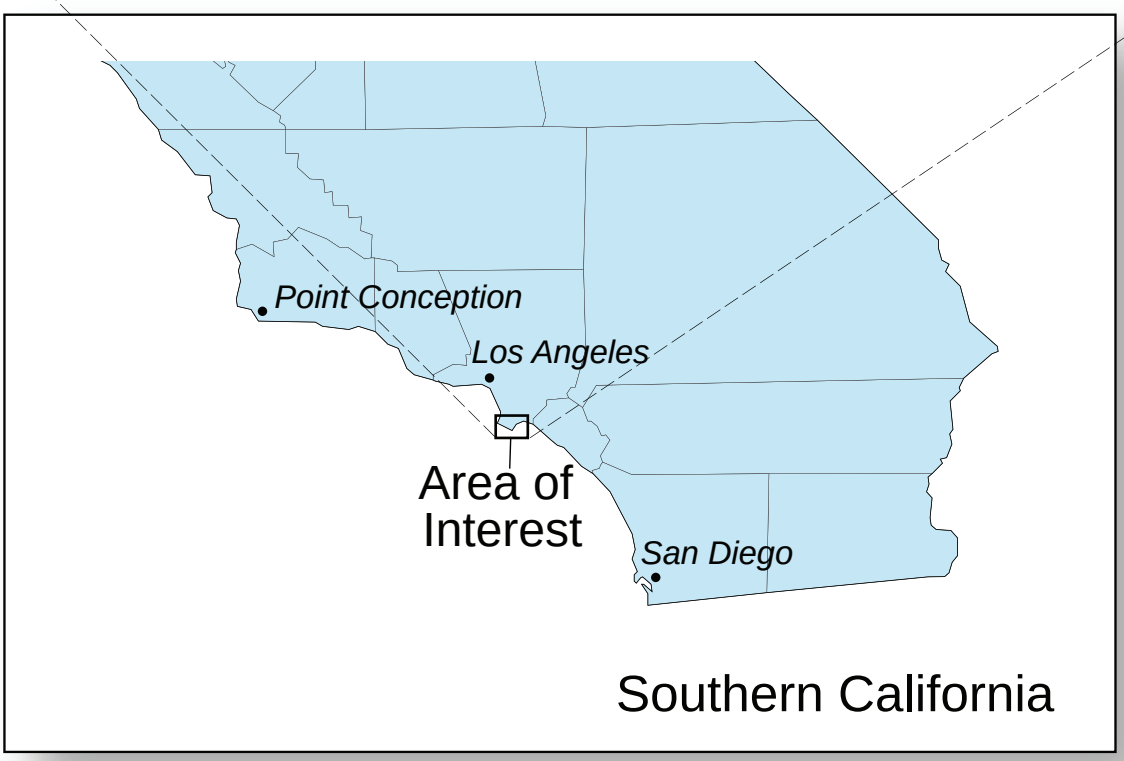
TABLE 1-1
Description of Los Angeles County Sanitation District Outfalls

Inside Diameter of Outfall Pipe (inches)	Date Placed into Operation	Water Depth at Outfall Terminus in Feet (meters)	Length (feet)	Number of Diffuser Ports	Use
120	1967	190 (58)	12,000	740	Continuously operated
90	1957	210 (64)	10,400	100	Continuously operated
72	1947	160 (49)	6,700	40	Backup during heavy rainfall
60	1937	110 (33.5)	5,000	20	Emergency backup

Currently, the 120- and 90-inch-diameter outfalls are the two primary outfalls discharging treated effluent through diffusers approximately 2.4 km offshore. In 2005, LACSD discharged approximately 323 million gallons per day (mgd), primarily through the 120-inch- and 90-inch-diameter outfalls (LACSD, 2006a). LACSD performs regular inspections to evaluate the condition of the outfalls and ballast using a remotely operated vehicle and, in 1999, performed an extensive ballast replacement project on the three largest outfalls (LACSD, 2005).



Not to Scale



90" - outfall diameter

~110' (33.5m) - isobath

Note: The 120-inch- and 90-inch-diameter outfall are the primary outfalls.
Please refer to Section 1.2.3.1 for more information on the outfalls.

Source: Annual Report 2004 - Palos Verdes Ocean Monitoring, LACSD, 2005.

FIGURE 1-3
LACSD Outfalls Schematic
Palos Verdes Shelf Study Area
Remedial Investigation Report

1.2.3.2 Effluent-affected Sediments

As shown on Figure 1-4, the annual volume of treated water that LACSD discharges to the ocean has remained relatively constant over the last 35 years at about 350 million gallons per day (mgd) (LACSD, 2005). Although the volume of wastewater flows has increased in the county, the construction of upstream water reclamation plants has maintained a relatively constant flow to the JWPCP.

The JWPCP discharged approximately 4 million metric tons of suspended solids between 1937 and 1987, mostly in the 1960s and 1970s, to the PV Shelf (Kayen et al., 2002). Mass emissions of solids peaked in 1971, when an estimated 167,000 metric tons of effluent solids were released (Science Applications International Corporation [SAIC], 2004a). Since then, a number of significant upgrades have been made to the JWPCP to reduce the total suspended solids (TSS) in the effluent. In the late 1970s, advanced primary treatment and improved solids handling equipment was installed, and in the mid-1980s, partial secondary treatment was phased in. Full secondary treatment was achieved in November 2002. Implementation of source control measures, including the cessation of Montrose discharge to the sewers, and upgrades to the wastewater treatment processes at the JWPCP significantly reduced the discharge of pollutants and suspended solids to the marine environment as compared with the 1971 emissions (LACSD, 2005). The reduction in suspended solids (about 96 percent) in the effluent is shown on Figure 1-4. The average effluent TSS concentration for 2005 and 2006 was 16 milligrams per liter (mg/L) (LACSD, 2006a and 2007). The average effluent discharge flow in 2005 and 2006 were 323 and 316.5 mgd, respectively (LACSD, 2006a and 2007). Therefore, the estimated mass emissions of solids in 2005 and 2006 were approximately 7,140 and 6,990 metric tons, respectively.

Although DDT was banned in 1972, LACSD is required under its National Pollutant Discharge Elimination System (NPDES) permit to sample wastewater for DDT and other contaminants before it is discharged through White Point outfalls. The effluent concentrations of DDTs have been near or below the detection limit since 1989 and have not been detected since 2002. PCBs have not been detected above the detection limit since 1985 (LACSD, 2006a). The reporting limits are currently 0.01 microgram per liter (µg/L) for the six isomers of DDT (p,p'-DDT; o,p'-DDT; p,p'-DDD; o,p'-DDD; p,p'-DDE; and o,p'-DDE), and between 0.05 and 0.5 µg/L for PCBs (Aroclors 1016, 1221, 1232, 1242, 1248, 1254, and 1260) (LACSD, 2007).

Despite the reductions in the discharge of suspended solids, a large mass of effluent-affected sediments remains on the PV Shelf and slope (LACSD, 2005). The effluent-affected sediments can be distinguished from the native underlying sediments by a finer grain size and lower bulk density. Lee et al. (2002) indicated that a 5- to 60-cm-thick deposit extends over most of the shelf and slope from Point Fermin to Point Vicente, had an estimated total volume of over 9 million m^3 and covered more than 40 km^2. Of that total, 70 percent occurs on the shelf in water depths less than 100 m, and 30 percent on the slope in deeper waters.

This survey and the biennial sediment monitoring conducted by LACSD showed that almost the entire deposit was contaminated with DDT and PCBs. Contaminant concentrations are lower in the surface sediment (top 5 to 20 cm of the deposit), tend to peak around depths of 30 to 40 cm, and then taper off below 60 cm. The accumulated masses of DDT and PCBs in sediments at the PV Shelf Study Area have been estimated at 100 and 10 metric tons, respectively (EPA, 2001a).

1.2.4 Actions to Date

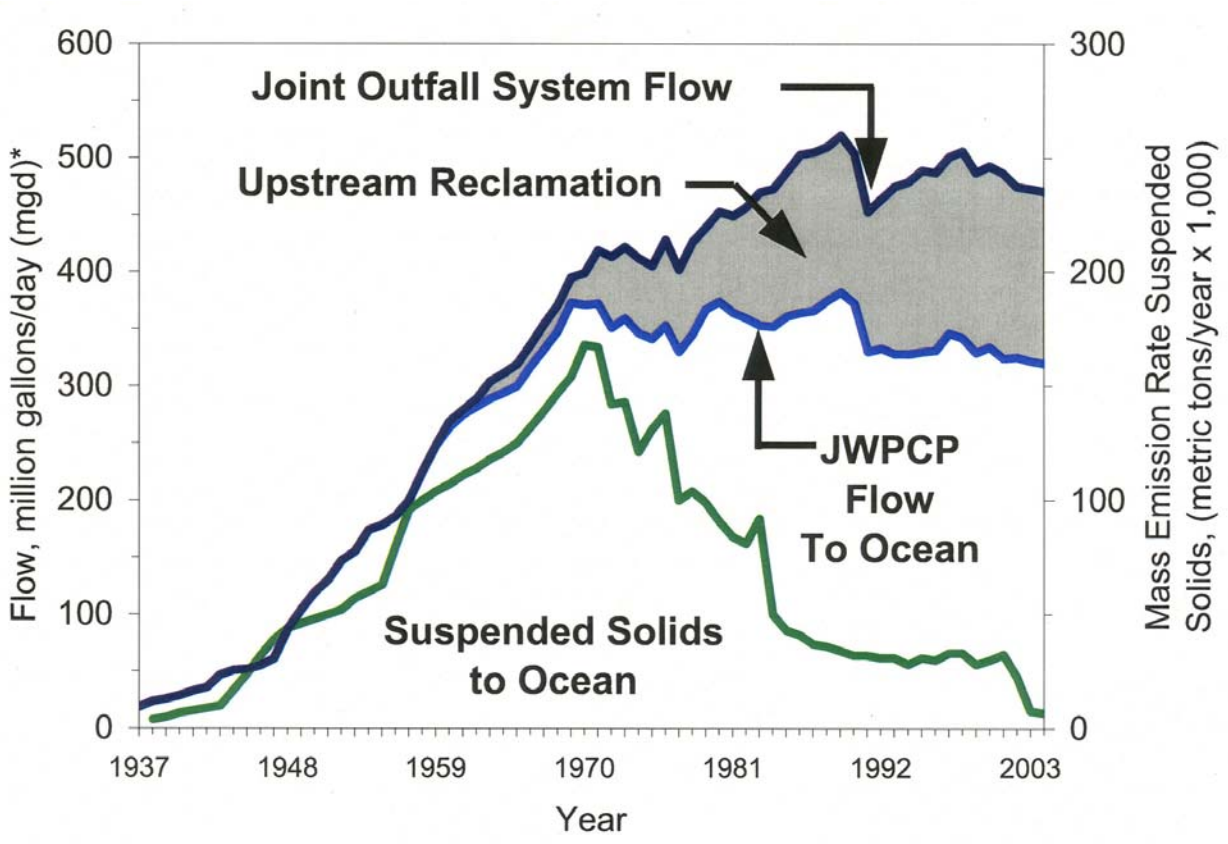
In 1985, the State of California issued an interim health advisory recommending limitations on the consumption of sport fish and discouraging consumption of white croaker caught in the Santa Monica Bay, PV Shelf, and Los Angeles/Long Beach Harbor area because of DDT and PCB contamination in the fish. Subsequently, based on a 1991 study, the California Environmental Protection Agency (Cal-EPA) Office of Environmental Health Hazard Assessment (OEHHA) expanded the health advisory recommending no or limited consumption of white croaker caught in most areas offshore of Los Angeles and Orange Counties, and that anglers significantly limit consumption of other fish species caught on or near the PV Shelf because of the levels of DDT and PCBs in fish tissue. These advisories have been included in the California sport fishing regulations since March 1, 1992.

In 1990, the California Department of Fish and Game (CDFG) imposed a commercial fishing ban for white croaker on the PV Shelf because of the threat to human health posed by concentrations of DDTs and PCBs in fish tissue. The commercial fishing ban extends from Point Vicente to Point Fermin and from the shoreline out 3 miles.

A 1997 study by Heal the Bay, a local environmental organization, found elevated levels of DDT and PCBs in white croaker (also known as kingfish or tomcod) being sold in a number of Los Angeles and Orange Counties fish markets (Gold et al., 1997). In March 1998, in response to concerns about white croaker being illegally sold by sport fishermen to commercial fish markets, CDFG revised the white croaker recreational catch limit from unlimited to 10 fish per day. The state will determine whether the existing white croaker commercial catch ban area should be modified using the data in the *2002-2004 Southern California Coastal Marine Fish Contaminants Survey* (EPA and NOAA, 2007).

In 1994, the results of a multiyear study by the federal and state natural resource trustee agencies (Trustees) of ecological impacts caused by sediment contamination in the area offshore of Palos Verdes Peninsula were compiled and released to the public. In July 1996, following its review of these reports and other available information, EPA began its Superfund investigation of the PV Shelf. Through a process known as an engineering evaluation/cost analysis (EE/CA), EPA evaluated response actions and the potential alternatives for cleaning up the contaminated sediment in this area. The EE/CA was completed in March 2000 (EPA, 2000a).

Based on the evaluation in the EE/CA, EPA's recommended immediate response action was institutional controls to address the significant human health risks associated with consumption of fish, particularly white croaker, contaminated by exposure to DDT and PCBs in the sediment. The institutional controls program was implemented in 2002 to enforce existing state fishing regulations such as white croaker catch ban and bag limit. The institutional controls program has three components: (1) public outreach and education, (2) fish monitoring, and (3) enforcement.



*1mgd = 3.79 x 10^6 liters per day

FIGURE 1-4
Joint Outfall System Flow and Suspended Solids, 1937-2004
Palos Verdes Shelf Study Area Remedial Investigation Report

Source: Annual Report 2004 - Palos Verdes Ocean Monitoring, LACSD, 2005.

A pilot capping program was conducted in 2000 at the PV Shelf Study Area to evaluate the effectiveness of in situ capping to reduce potential environmental impacts from contaminated PV Shelf sediments. The main objective of the pilot capping program was to determine if a uniform, clean, stable cap could be placed with minimal disturbance of effluent-affected (in situ) sediments. Analysis and evaluation of the pilot capping project is ongoing.

1.3 Report Organization

This RI report is organized into the following sections:

- **Section 1.0 – Introduction:** Includes purpose and scope of the RI, site background and history, actions to date, and an overview of report organization.
- **Section 2.0 – Palos Verdes Shelf Investigations:** Briefly summarizes the major site characterization studies; human health and ecological risk assessments; oceanographic studies describing the physical, chemical, and biological environment of the PV Shelf Study Area; and the pilot capping program.
- **Section 3.0 – Site Characteristics:** Presents results of studies to establish the physical and biological characteristics of the PV Shelf Study Area.
- **Section 4.0 – Nature and Extent of Contamination:** Presents the results of site characterization, including the nature and extent of concentrations of DDTs and PCBs.
- **Section 5.0 – Contaminant Fate and Transport:** Presents a discussion of fate and transport processes occurring at the PV Shelf Study Area.
- **Section 6.0 – Summary of Risk:** Presents a summary of the human health and ecological risk assessments.
- **Section 7.0 – Palos Verdes Shelf Study Area Conceptual Site Model:** Summarizes the information presented in the RI report and provides a conceptual understanding of the PV Shelf Study Area.
- **Section 8.0 – References:** Lists references for this RI report.

This RI report also includes the following appendices:

- **Appendix A –** Palos Verdes Shelf Sediment Data
- **Appendix B –** Human Health Risk Evaluation Memorandum
- **Appendix C –** Updated Food Web Exposure Model Memorandum
- **Appendix D** – Primer on Waves, Currents, and Bottom Stress
- **Appendix E –** Response to Comments

2.0 Palos Verdes Shelf Investigations

The nature, extent, and magnitude of sediment contamination on the PV Shelf, and associated effects on the environment, have been the subject of numerous investigations and monitoring activities since the early 1970s. This section identifies and summarizes the principal data sources and documents used to prepare this RI report, including:

- Primary site characterization studies conducted at PV Shelf (Section 2.1)
- Human Health Risk Evaluations (HHRE) conducted in 1999 and 2006 (Section 2.2)
- Ecological risk assessment (ERA) completed in 2003 and the update to the food web exposure model completed in 2006 (Section 2.3)
- EE/CA (Section 2.4)
- Action Memorandum (Section 2.5)
- In situ pilot capping and High Shear Stress Sediment Erosion Flume (Sedflume) studies (Section 2.6)
- 2004 field studies (including the sediment displacement study and the oceanographic, geotechnical, and bioturbation measurement programs) (Section 2.7)
- 2002-2004 Southern California Coastal Marine Fish Contaminants Survey (Section 2.8)

Sections 4.0 and 5.0 provide a more detailed presentation of the results of most of these investigations.

2.1 Site Characterization Studies

The primary sources of data on concentrations of DDTs and PCBs in sediment at the PV Shelf Study Area have been sampling activities conducted by the United States Geological Survey (USGS) for the Natural Resources Damage Assessment (NRDA), the ocean monitoring program conducted by LACSD, and regional surveys conducted by the Southern California Coastal Water Research Project (SCCWRP). A summary of these sampling programs is provided below.

2.1.1 Natural Resources Damage Assessment

The National Oceanic and Atmospheric Administration (NOAA), acting on behalf of the Trustees initiated several studies in the early 1990s as part of an NRDA to evaluate the potential losses in natural resources associated with the presence of contaminated sediments at the PV Shelf. The NRDA included the following components:

- Collection and analysis of sediment core samples on the shelf, slope, and adjacent basins to describe the vertical and horizontal extent of contamination.
- Evaluation of potential biological effects levels for sediment concentrations of DDTs and PCBs.

- Evaluation of potential effects on different receptors including fish, birds, and mammals.
- Predictive models of changes in concentrations of DDTs (the majority of DDT has been converted to dichlorodiphenyldichloroethene [DDE]) at two shelf locations (through the year 2100) as a result of natural physical and biological processes.

Results from the NRDA were summarized in a series of documents (Lee, 1994; Drake, 1994; Drake et al., 1994; HydroQual, Inc., 1997; MacDonald, 1997; Wiberg, 1994; Sherwood, 1994; Sherwood et al., 1996; Eganhouse et al., 2000; Eganhouse and Pontolillo, 2000; and Wheatcroft and Martin, 1994) and papers (Continental Shelf Research, 2002). The NRDA indicated that contamination from the PV Shelf Study Area has affected ecological receptors. Below is a summary of some of the findings from the NRDA:

Collection of Sediment Core Samples. Sediment core samples were collected in 1992 by USGS to measure the thickness of the effluent-affected sediments, measure concentrations of DDTs and PCBs, evaluate sedimentation processes, and measure geotechnical properties. Chemical analyses were conducted on samples from 37 locations (Figure 2-1) (Lee, 1994). Sediment concentration data collected in 1992 by USGS for the NRDA are provided in Section 4.0.

As a result of the investigation, USGS delineated a 43.1-km^2 area on the PV Shelf and slope where concentrations of DDTs exceeded 1 part per million (ppm) in surface sediments 0 to 4 cm deep. The investigation estimated that the effluent-affected sediments form a 5- to 60-cm-thick deposit that extends over most of the shelf and slope from Point Fermin to Point Vicente. The total volume of the deposit was estimated to be 9 million m^3, 70 percent on the shelf in depths less than 100 m, and 30 percent on the slope in deeper waters. The area with the thickest deposit, and sediments with the highest concentrations of contaminants, were shown to be nearest the LACSD outfalls and form a band at the 60-m isobath that tapers off to the northwest, under cleaner sediments about 30 cm (1 foot) thick (Lee, 1994).

Biological Effects Levels for Sediment. MacDonald (1997) established sediment effect concentration (SEC) thresholds for benthic invertebrates for DDT, DDE, dichlorodiphenyldichloroethane (DDD), DDTs, Aroclor 1254, and PCBs using a tiered strategy and a weight-of-evidence approach. The SEC thresholds for DDTs and PCBs are 2.0 and 0.577 mg/kg dry weight, respectively. Exceedances of these established thresholds would indicate that survival and reproductive effects were likely. MacDonald (1997) concluded that some SCB sediments would likely cause injury to sediment-dwelling organisms.

Biological Effects on Fish, Birds, and Mammals. In 1994, a damage assessment food web/pathways study was performed and then revised in 1997 as part of the NRDA (HydroQual, Inc., 1997). The goal of the study was to determine whether sediment serves as the source of contamination for organisms that do not have direct contact with the contaminated sediment. Results indicate that contaminants found in sediments, fish, and water of the SCB originated from the PV Shelf. Similar results concluded that the DDE and PCB concentrations in these media are sufficient to account for all of the DDE and PCBs observed in fish living on the shelf.

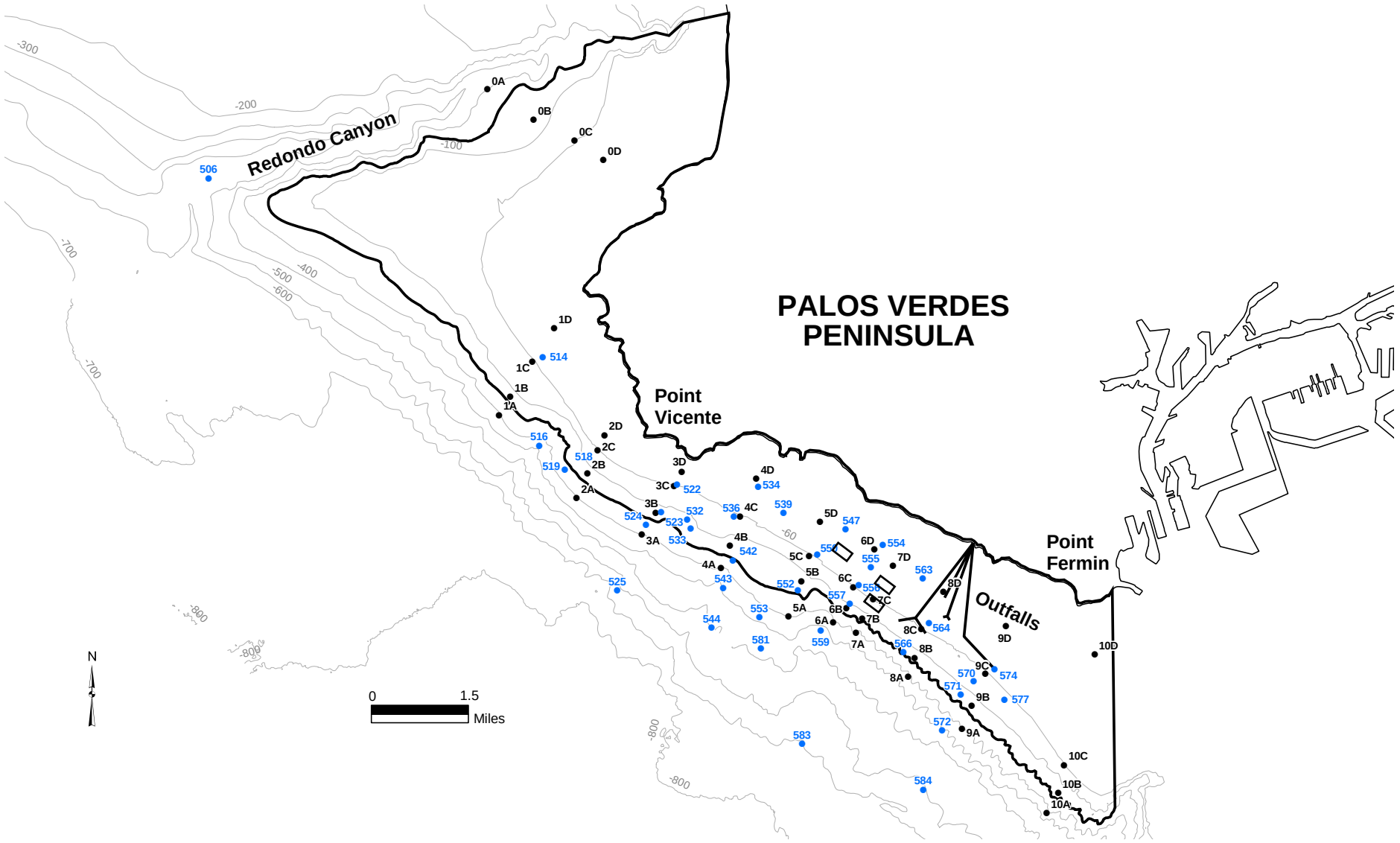


FIGURE 2-1
LACSD and USGS Sediment Sampling Locations
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: Los Angeles County Sanitation District (LACSD). 2005. Annual Report, 2004 Palos Verdes Ocean Monitoring. July.

For marine mammals, while concentrations in prey observed at low-level contaminant areas (i.e., those areas farther from the outfalls such as Santa Catalina Island and the Northern Channel Islands) are insufficient to account for the DDE and PCB levels found in female sea lions, concentrations in prey living closer to the outfalls are more than sufficient to account for the measured concentrations. Therefore, the total exposure area, including the PV Shelf, must be modeled to fully account for the observed tissue bioaccumulation of these contaminants. Additionally, at least half of the contaminant exposure to the peregrine falcon and bald eagle originates from the SCB-wide exposures.

Predictive Models of Changes in Concentrations of DDTs and PCBs. USGS also conducted modeling to predict the fate of the effluent-affected deposit and concentrations of DDTs and PCBs at the PV Shelf Study Area under natural recovery conditions (Drake et al., 1994; Wiberg, 1994; Drake, 1994). Drake (1994) concluded that wave and current erosion and the diminishing supply of sediments from the LACSD outfalls and the Portuguese Bend Landslide will cause DDTs and PCBs to persist at elevated levels for many years.

2.1.2 Palos Verdes Shelf Monitoring by Los Angeles County Sanitation District

Since 1971, LACSD has performed annual monitoring of the marine environment on the PV Shelf according to the requirements of its NPDES permit. The discharge permit requires LACSD to monitor regional marine conditions to assess the long-term ecological impacts from the effluent discharged from the White Point outfalls. The monitoring consists of water sampling, sediment and infauna sampling, invertebrate and fish trawls, and bioaccumulation studies.

LACSD sediment sampling grid consists of 11 transects positioned on the shelf and slope between Redondo Canyon and Point Fermin. The sample locations occur at four depths (Figure 2-1): 30 m (D stations), 61 m (C stations), 152 m (B stations), and 305 m (A stations). Sediment grab samples are collected annually from these 44 stations using a Van Veen sampler to assess the benthic infauna and sediment characteristics. Biennially, sediment samples are analyzed from the same stations for metals and pollutants, including DDTs and PCBs. Fish trawls are conducted in three separate zones (Figure 2-2). Detailed information on the program and marine conditions can be found in the LACSD annual reports on its ocean monitoring program (LACSD, 2005; LACSD, 2006b). Section 4.0 draws from LACSD extensive database of historical and current site conditions, presenting sediment grab sample data from 2002 and 2004, and fish tissue data from bioaccumulation studies conducted between 1999 and 2005 for the NPDES permit monitoring.

In addition to the annual monitoring required under NPDES, LACSD voluntarily has collected sediment core samples from select stations every 2 years since 1981. Analysis of 2-cm increments in each sediment core was conducted for DDE, the primary DDT isomer occurring at the PV Shelf Study Area, to obtain depth profiles of contamination. A summary of this LACSD sediment core data also is provided in Section 4.0; detailed results for each station sampled are provided in Appendix A.

2.1.3 Southern California Bight Projects

The SCCWRP is a joint powers agency that focuses on collecting scientific information so that agencies can effectively protect the Southern California marine environment. SCCWRP is supported by 13 member agencies that include representatives of city, county, state, and

federal government agencies responsible for monitoring and protecting the marine environment. SCCWRP was established in 1969 to increase knowledge about the effects of wastewater and other discharges on the Southern California coastal marine environment (SCCWRP, 2007).

The SCCWRP has coordinated regional surveys to assess the spatial extent and magnitude of ecological disturbances on the mainland continental shelf of the SCB. The first survey, the Southern California Bight Pilot Project (SCBPP), began in 1994 as a collaborative effort between 12 governmental organizations, including the 4 largest municipal wastewater dischargers, and the 5 agencies that regulate discharges in Southern California (SCCWRP, 1998). Additional assessments of the SCB were performed in 1998 and 2003 when 58 organizations were involved.

The goals of the 1994 SCBPP (Bight '94) were to assess the amount of pollutant exposure, the condition of biological resources, and the quantity of marine debris in the SCB. To accomplish the first two objectives, the field sampling and analyses focused on evaluating water quality, sediment chemistry, sediment toxicity, and communities of benthic infauna and demersal fish and megabenthic invertebrates. For Bight '94, 261 sites were sampled; the sites were located within the mainland continental shelf at depths ranging 10 to 200 m along the Southern California coast from Point Conception to San Diego. These sites were selected randomly so that conditions would be representative of the SCB. Eight sample sites from Bight '94 were located within the PV Shelf Study Area.

In 1998, the Southern California Bight Regional Monitoring Program (Bight '98) collected samples at 415 sites within the SCB. Eight sample sites from Bight '98 were located within the PV Shelf Study Area. In 2003, the Southern California Bight Regional Monitoring Program (Bight '03) collected samples from 228 sites across the SCB. One sample site from the Bight '03 was located within the PV Shelf Study Area. Bight '98 and '03 studies involved monitoring three primary components of the SCB: (1) coastal ecology, (2) shoreline microbiology, and (3) water quality. The objective of the coastal ecology portion was to assess sediment chemistry, sediment toxicity, and the populations of benthic macrofauna and fish. Studies included analyses of water and sediment quality, benthic and epifaunal communities, and tissue contaminant concentrations. Results from these regional monitoring studies provide an appropriate context for comparing conditions on the PV Shelf with those in other portions of the bight. Sediment chemistry data and fish tissue data from Bight '94 and '98 were used for the ERA and food web model, described in Section 6.0. The contours of DDTs and PCBs shown on figures in Section 4.0 use sediment chemistry data from several Bight '94 samples.

2.2 Human Health Risk Evaluation

An HHRE was issued in 1999 that described the human health risks posed by the presence of DDTs and PCBs in the PV Shelf (SAIC, 1999). The contaminated sediments at the PV Shelf occur away from the shore, on the ocean floor in water depths of 30 m or greater. The highest concentrations occur under cleaner sediments; therefore, people are not exposed directly to DDTs and PCBs. The human health risk originates from consumption of fish from the PV Shelf Study Area that contain elevated concentrations of DDTs and PCBs. The HHRE was based on the consumption of contaminated fish by boat anglers as the primary exposure pathway.

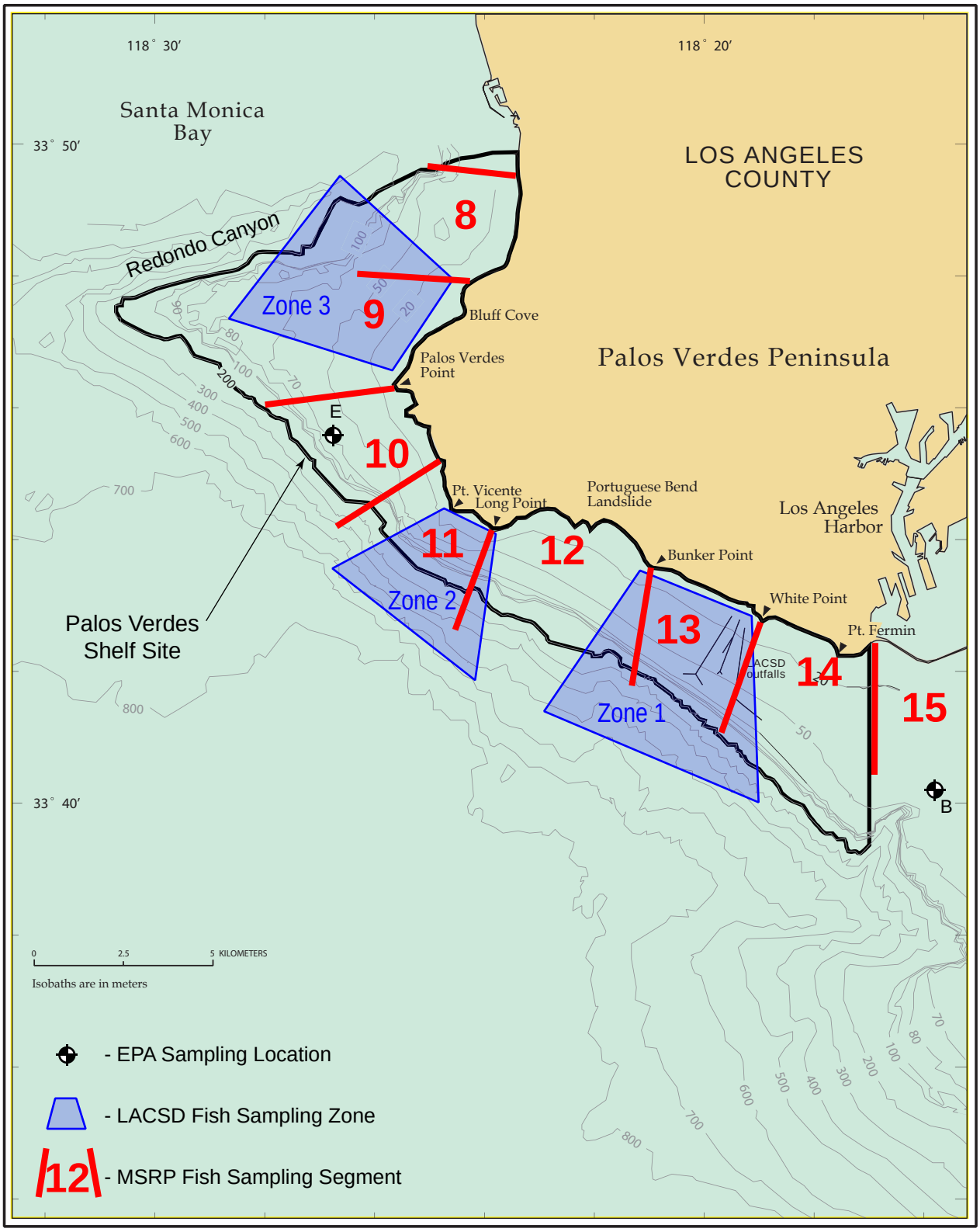


FIGURE 2-2
EPA, MSRP and LACSD 2002
Fish Sampling Locations
Palos Verdes Shelf Study Area
Remedial Investigation Report

The HHRE focused on risks for two types of exposure scenarios: (1) a reasonable maximum exposure (RME) scenario (27.9 grams/day [g/day] or six 150 grams [g] meals per month), and (2) a central tendency exposure (CTE) scenario (21.4 g/day). The RME scenario is a high-end exposure scenario based on white croaker fish consumption rates (i.e., consumption rates averaged over boat anglers who consume a particular species). The CTE, or average, scenario assumes a mixed-species diet and uses median consumption rates averaged over all boat anglers. Single-point estimates of risks were calculated and a Monte Carlo simulation was employed to quantitatively evaluate uncertainty and variability in the risk estimates. Human health risks were evaluated in terms of both cancer risk and noncancer health hazard. Potential cancer risk was estimated by calculating the increased probability of an individual developing cancer during his or her lifetime as a result of exposure to DDTs and PCBs. DDTs and PCBs are classified as probable human carcinogens. The potential for adverse noncancer health effects was evaluated by comparing the estimated average daily intake of DDTs or PCBs with the respective reference dose (RfD) of DDTs or PCBs. When the hazard index (HI) for exposures to multiple chemicals exceeds 1 (in this case, DDTs and PCBs), there is a concern for potential noncancer health effects. The results of the 1999 HHRE are summarized in Section 6.0.

As part of this RI, the 1999 HHRE was updated in 2006 to include fish data collected in 2002. To address the potential for high fish ingestion rates found in some Asian communities and other ethnic groups, high-end fish consumer scenarios were evaluated. Ingestion rates were obtained from the *Santa Monica Bay Seafood Consumption Study* (Santa Monica Bay Restoration Project [SMBRP], 1994). The increase in estimated rate of fish consumption was also influenced by changes in EPA guidance, *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories Vol. 1 (EPA, 2000c)*, and the revised fish consumption rates based on new data in the *1994-1996 Continuing Survey of Food Intake by Individuals (United States Department of Agriculture, Agricultural Research Service, 1998)*. For both all-angler and Asian-angler consumers under RME consumption of fish fillets (107.1 g/day for all anglers and 115.7 g/day for Asian anglers), cancer risks from DDTs and PCBs for three species (white croaker, California scorpionfish, and barred sandbass) ranged from 3×10^{-4} to 7×10^{-3}, based on 95 percent upper confidence limit (UCL) concentrations. Risks from the other three species (kelp bass, rockfish, and surfperch) ranged from 7×10^{-5} to 1×10^{-4}. The HI values for all six species ranged from 2 to 198.

For both all-angler and Asian-angler consumers under CTE conditions for consumption of fish fillets (21.4 g/day), cancer risks from DDTs and PCBs for one species (white croaker) was 6×10^{-4} based on 95 percent UCL concentrations. Risks from the other five species ranged from 6×10^{-6} to 3×10^{-5}. The HI values from three of the six species (white croaker, California scorpionfish, and barred sandbass) ranged from 2 to 37. Kelpfish, rockfish, and surfperches have HI values below 1. Section 6.0 of this RI report provides further discussion of the 1999 HHRE and the 2006 HHRE update using 2002 fish data. Appendix B provides the 2006 HHRE update memorandum.

2.3 Ecological Risk Assessment

An ERA is a qualitative and/or quantitative appraisal of the actual or potential impacts of contaminants from a hazardous waste site on plants and animals besides humans and domesticated species. An ecological risk does not exist unless an exposure has the ability to

cause one or more adverse effects, and that exposure co-occurs with or contacts an ecological component long enough and at a sufficient intensity to elicit the identified adverse effect (EPA, 1997). An ERA for the PV Shelf Study Area was completed in December 2003 (CH2M HILL, 2003). The purpose of this ERA was to describe the risk of adverse effects of DDTs and PCBs on marine biota that inhabit or might use the PV Shelf for at least some portion of their lives.

The baseline ERA incorporates a comprehensive literature review and database summary that describe the physical, chemical, and ecological settings, and the methods for evaluating ecological risk. The selection of chemicals of potential ecological concern (DDTs and PCBs), key ecological receptors, habitats, pathways, and selection of methods for describing and evaluating ecological risk are summarized in the conceptual site model (CSM) that describes the contaminant sources and release mechanisms, evaluates potential exposure pathways, and identifies the representative species that were used to assess potential ecological risk to those and other similar species.

The primary mechanisms for ecological exposure are from the sediment to resident invertebrates and bottom-dwelling fish. From there, bioaccumulated DDTs and PCBs continue through the food web to benthic and water-column invertebrates and water-column fish, and then fish-eating consumers (marine birds and sea lions). In addition, ecological receptors were assessed for exposure and risk through consumption of sea lion carcasses (bald eagles) and seabirds (bald eagles and peregrine falcons). A food web exposure model was used to help assess the effects of sediment contamination through the food chain.

High, intermediate, and low risks were assessed comparatively in a weight-of-evidence approach. Multiple lines of evidence for several receptor groups show a gradient of ecological risk that is greatest near the PV Shelf outfalls and extends along a band up the coast to the northwest. Intermediate risks were found in the immediate vicinity of the PV Shelf, and the lowest risks were estimated for the more distant SCB locations. The receptor groups vary in spatial and temporal scales of exposure and, consequently, risk.

The fish and benthic invertebrate risk estimates show a predictable spatial pattern of risk for the PV Shelf Study Area with a significant relationship between sediment concentrations and risks affecting the upper trophic-level consumers. Risks to fish and invertebrates were greater for concentrations of DDTs than for concentrations of PCBs and were greatest in area near the outfalls. The exposure and risk from DDTs and PCBs to birds and sea lions (as the representative marine mammal) in the SCB and PV Shelf were important components of the ERA. Continuing risk is shown for birds throughout the SCB for DDTs and PCBs. Evidence indicates that DDTs (rather than PCBs) pose the greatest risk to birds.

As part of this RI, the food web model used in the initial ERA was revised to include recent data. Section 6.0 presents a summary of the revised food web model and further discussion of the ecological risk at the PV Shelf Study Area. A memorandum presenting the results of the food web model revision is provided in Appendix C.

2.4 Engineering Evaluation/Cost Analysis

EPA prepared an EE/CA for the PV Shelf in March 2000 (EPA, 2000a). An EE/CA is a streamlined evaluation that considers response actions representing a reasonable range of

alternatives that would individually, or in combination, reduce risks to human health and the environment. The objective of the EE/CA was to evaluate whether a response action could be implemented at the PV Shelf Study Area that would result in a rapid and cost-effective reduction in the quantity of hazardous substances (i.e., DDTs and PCBs) released to the environment.

The initial screening considered three general response actions: (1) institutional controls, (2) in situ containment (i.e., capping), and (3) removal and treatment or disposal. Several specific options for removal (e.g., dredging) followed by treatment or disposal were evaluated. Response actions were screened using three criteria: effectiveness, implementability, and cost. Those actions that were considered impractical or infeasible were eliminated from the more detailed evaluations performed for the EE/CA.

Of the alternatives screened by EPA, institutional controls and in situ containment (capping) were retained for evaluation in this EE/CA. The "No Action" alternative also was evaluated. Other alternatives requiring dredging with containment, treatment, or deep-sea disposal of contaminated sediments were not retained for further evaluation as a result of potentially significant issues with legal requirements, capacity or technology limitations, and/or prohibitive costs. The following alternatives were evaluated in the EE/CA:

- Alternative 1: No Action with Monitoring
- Alternative 2: Institutional Controls
- Alternative 3: 45-cm In Situ Cap with Institutional Controls
- Alternative 4: 30-cm In Situ Cap with Institutional Controls
- Alternative 5: 15-cm In Situ Cap with Institutional Controls

2.5 Action Memorandum

Based on the evaluation of alternatives in the EE/CA, EPA released a proposed plan in March 2000 that recommended, as an initial action, Alternative 2, Institutional Controls. In the Action Memorandum for Palos Verdes Shelf (EPA, 2001a), EPA selected Alternative 2, Institutional Controls, as a non-time critical removal action for the PV Shelf. The institutional controls program has three major elements: (1) public outreach and education, (2) fish monitoring, and (3) enforcement. The outreach and education portion of the institution controls program is designed to improve public awareness and understanding of the health risks of eating contaminated fish and to establish local capacity to address fish contamination issues. The public outreach and education program is being implemented by EPA in collaboration with several federal, state and local agencies, environmental groups and community-based organizations. To facilitate coordination and cooperation among these entities, EPA created a Seafood Contamination Task Force (now known as the Fish Contamination Education Collaborative), which meets regularly to discuss implementation activities and issues.

The fish monitoring component calls for periodic monitoring of contaminant levels in fish to evaluate the effectiveness of fishing restrictions and enforcement actions in eliminating contaminated fish from markets and restaurants. This fish monitoring involves sampling fish in the ocean and in retail markets. NOAA, on behalf of the Montrose Settlements Restoration Program (MSRP), and EPA undertook an extensive ocean fish sampling program from 2002 to 2004. This program is discussed in Section 2.8.

2.6 In Situ Capping Pilot Study and Project

The enforcement component of the action memorandum addresses two goals: (1) to the extent practicable, prevent the commercial catch and sale of contaminated fish from the PV Shelf, and (2) ensure that state regulations against catching white croaker at or near the PV Shelf are not violated. For this component, EPA has primarily relied on CDFG, which is the lead agency, to enforce the white croaker commercial fishing ban off Palos Verdes Peninsula and the daily catch limit on white croaker for noncommercial anglers.

In the mid- to late-1990s, the United States Army Corps of Engineers (USACE) Waterways Experiment Station (WES, now called Engineering Research and Development Center [ERDC]) performed a study of in situ capping options under an interagency agreement with EPA Region 9. This study included assessing areas of the PV Shelf Study Area to be capped, developing cap designs, developing an equipment selection and operations plan for placement of the cap, developing a monitoring plan to ensure successful cap placement and long-term cap effectiveness, and preparing preliminary cost estimates. This study also included an evaluation of physical isolation, physical armoring, chemical isolation, and numerical modeling. The study was documented in a report titled, *Options for In-situ Capping of Palos Verdes Shelf Contaminated Sediments* (Palermo et al., 1999).

Following this study and concurrent with the implementation of the institutional controls program, a pilot capping project was performed on the PV Shelf to evaluate the effectiveness of in situ capping to reduce potential environmental impacts from contaminated (i.e., effluent-affected) sediments. The main objective of the project was to determine if a uniform, clean, stable cap could be placed with minimal disturbance of the effluent-affected sediments. The pilot capping project was documented in *Field Pilot Study of In Situ Capping of Palos Verdes Shelf Contaminated Sediments* (Fredette et al., 2002).

The pilot capping project, conducted from July to September 2000, provided an opportunity to evaluate cap constructability using a variety of placement methods under varying site conditions. A layout of four 300-m by 600-m capping placement cells was recommended for the pilot. One pair of cells in the layout was located adjacent to the landward limit of the potential capping area in a comparatively shallow site with comparatively flat bottom slope (40- to 45-m depth contour with an average slope across the cell of about 1 degree). A second cell pair in the layout was located adjacent to the seaward limit in a deeper site with steeper bottom slope (60- to 70-m depth contour with average slope across the cell of about 3 degrees). The two cells within each pair were separated by a full cell length in the along-shore direction and by a full cell width in the cross-shore direction to avoid the potential for interferences during monitoring. The four cells were named according to their relative geographic locations: LU (Landward Upstream), LD (Landward Downstream), SU (Seaward Upstream), and SD (Seaward Downstream). The LU and SU cells are considered upstream cells because they are upstream (southeast) from LD and SD according to the prevailing northwesterly, along-shore current.

The baseline monitoring program was conducted for these four cells. However, as project planning evolved, it became apparent that the project scope would have to be decreased to stay within budget; therefore, the least critical cell, Cell SD, was not capped. The final pilot study went forward with three cells: LU, LD, and SU (Figure 2-3).

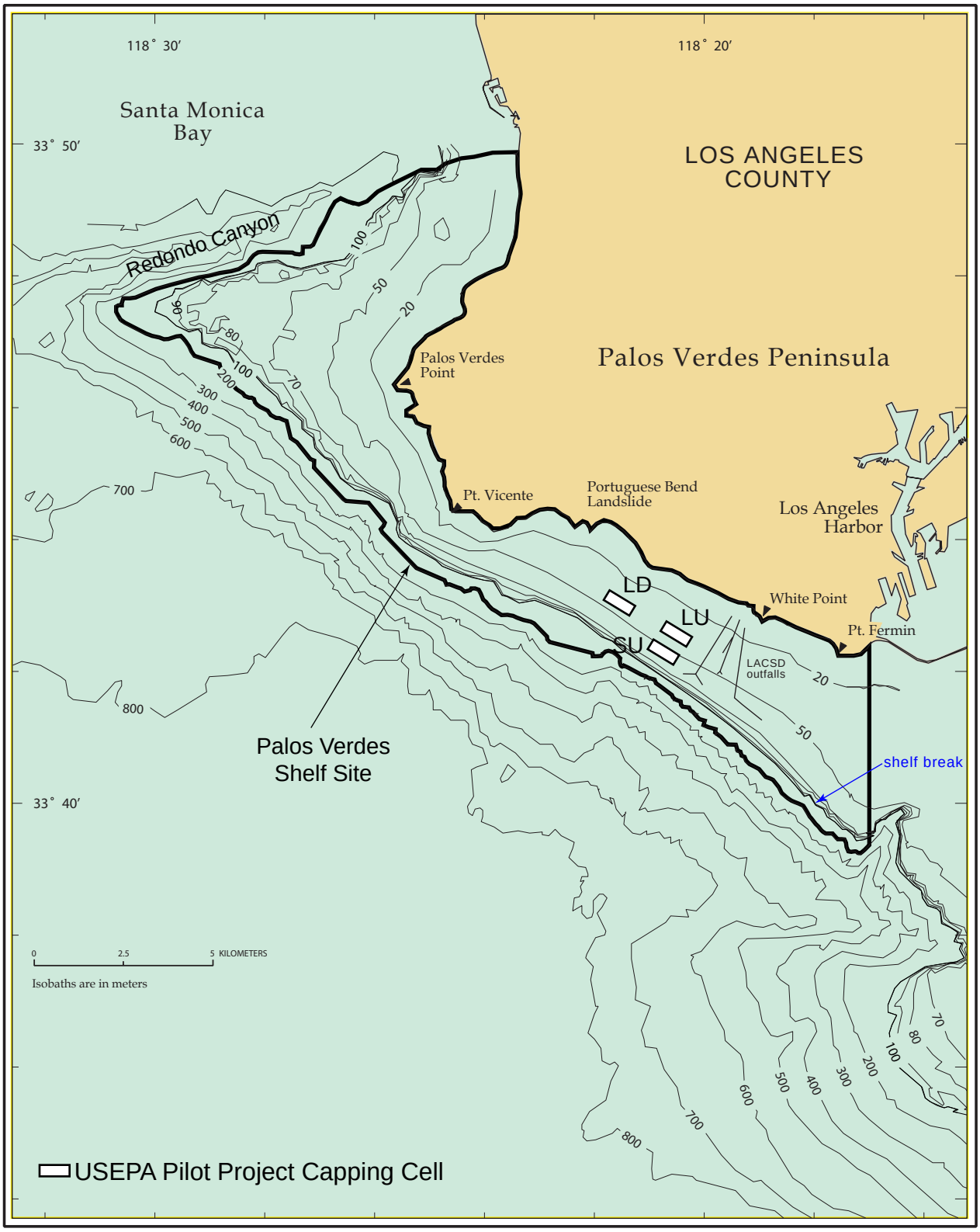


FIGURE 2-3
Location of Pilot Capping Cells
Palos Verdes Shelf Study Area
Remedial Investigation Report

Pilot cap placement occurred within the limits of these three cells. During the pilot capping, the 600-m by 300-m area between Cells LU and LD was used to test direct pump-out through a diagram of the hopper dredge and was named Cell LC (Landward Center).

An important component of the pilot capping project was cap construction and post-construction monitoring. The monitoring program for the pilot capping project was designed to answer the following questions:

- Can a uniform cap be constructed?
- Can disturbance to in situ contaminated sediments be kept within tolerable limits?
- Does the cap remain clean?
- Does the cap remain stable during placement?
- Does cap placement occur as modeled?

Monitoring tasks associated with the pilot capping project occurred in three phases: precapping (baseline), cap placement, and postcapping. Baseline monitoring occurred from May through September 2000, and cap placement monitoring was conducted from July through September 2000. The initial postcap monitoring survey was performed during February and March 2001, and a supplemental survey was conducted in March 2002. Results of baseline, cap placement, and postcap monitoring are presented in three reports: *Monitoring Results from the Field Pilot Study of In Situ Capping of Palos Verdes Shelf Contaminated Sediments* (SAIC, 2002), *Monitoring Results from the March 2002 Post-Cap Survey on the Palos Verdes Shelf* (SAIC, 2003), and *Field Pilot Study of In Situ Capping of Palos Verdes Shelf Contaminated Sediments* (Fredette et al., 2002).

2.6.1 In Situ Capping Pilot Study Results

Sediment cores from capped areas were analyzed before, during, and after capping to determine sediment DDE concentrations and sediment physical characteristics. Conditions of cap thickness, sediment physical characteristics, and sediment macrofaunal activity were assessed using cross-sectional photographs of the seafloor obtained with a sediment-profile image (SPI) camera and plan-view surface photographs. Simultaneous photographs of the sediment surface were taken using a plan-view camera mounted to the SPI frame. Although the SPI camera has a maximum penetration depth of 20 cm, in practice, the depth of camera penetration into the sand cap was less. As a result, cap thickness could not be measured accurately by the SPI camera when it exceeded 6 to 8 cm.

In addition to the SPI cap evaluation, cap thickness and areal extent were assessed by analyzing sediment cores taken from the cells. Sediment cores from the capped areas were collected using vibracores and box cores in February through March 2001. In March 2002, additional sediment cores were collected using box corers. The sediment cores were analyzed at 4-cm intervals for DDE and geotechnical properties to better identify cap coverage and thickness.

2.6.1.1 Cell Landward Upstream

Precapping DDE concentrations were measured in surface sediments (0 to 8 cm depth) at each pilot cell. Concentrations varied as a function of location, water depth, and grain size. Cell LU, up-current at 40-m depth, had average precapping surface concentrations of 1.5 ppm DDE. Cell LU was capped with sandy sediments dredged from the Queen's Gate

Channel. Sand for Cell LU was placed with a hopper dredge using conventional (point) placement methods at predefined locations. A total of 69,800 m^3 of sand was placed in Cell LU during 71 placement events. In general, initial placement events occurred in the center of each cell. Subsequent cap loads were placed at locations that overlapped with previous placements to minimize potential impacts on existing, effluent-affected bottom sediments. Postcapping concentrations were slightly higher than during-capping concentrations in Cell LU, ranging from 0.095 to 0.87 mg/kg, but lower than the precapping concentrations.

2.6.1.2 Cell Seaward Upstream

Sandy sediments dredged from the Queen's Gate Channel were placed with a hopper dredge using conventional (point) placement methods at predefined locations in Cell SU. A total of 22,800 m^3 was placed in Cell SU during 21 placement events. Precapping DDE concentrations in Cell SU averaged 6.3 mg/kg. Postcapping concentrations showed variation in Cell SU, ranging from 0.50 to 8.2 mg/kg. The reason for increased DDE concentrations in the postcapping surface have not been identified (SAIC, 2002).

Ancillary data, including SPI and plan-view photographs of the seafloor and sediment grain size, also indicated a heterogeneous cap in Cell SU, with conflicting results for several of the indicators of cap thickness. For example, postcapping SPI data for Cell SU indicated a contiguous cap 2 to 4 cm thick, compared with a noncontiguous cap 8 to 18 cm thick as indicated by DDE core concentrations. Results from DDE profiles for Cell SU were inconsistent with trends in sediment grain size and other geotechnical characteristics (SAIC, 2002). Differences were attributed mainly to variability in sample locations between methods and possible problems with surficial sediment loss during coring. Sampling-induced artifacts that might have contributed to varying results were evaluated in a subsequent field validation study (SAIC, 2005d).

2.6.1.3 Cell Landward Downstream

Cell LD was capped using a spreading method, in contrast to the point placement method used for Cells LU and SU. The spreading method, in which the hopper dredge is partially opened and continually moved while the sand leaves the hull, is considered lower-impact. Cell LD was capped during nine placement events using the spreading method to place 10,300 m^3 of sand-sized sediment dredged from the A-III Borrow Area. The amount of cap material for Cell LD was less than that used at Cells SU and LU. Precapping DDE concentrations in Cell LD ranged from 0.75 to 2.7 mg/kg. Postcapping sampling was performed for only two stations within Cell LD, with surface concentrations being essentially the same as precapping concentrations at 0.63 and 2.7 mg/kg. At the 0 to 4 cm depth, both samples collected in 2001, and four of five samples collected in 2002, exceeded 1 mg/kg, suggesting the absence of a cap. Subsurface concentrations at these stations were more than four times higher than baseline values, indicating that subsurface DDE distributions could be fairly heterogeneous; however, additional data are required to confirm this. Similar to the results for Cells LU and SU, SPI and plan-view photographs were inconsistent with the DDE concentrations, and indicated a cap thickness ranging from 5.3 to more than 8.7 cm. Grain size results supported the presence of a cap with a maximum thickness of more than 11 cm along the centerline of the cell.

Estimates of cap thickness using DDE concentrations, SPI, and grain size results displayed inconsistencies for all cells; however, results for Cell LU, which received the highest volume of material, displayed the greatest consistency between results and the highest estimate of cap thickness, as shown in Table 2-1. However, these results might be ambiguous because Cell LU also had the lowest precapping DDE concentrations, which might have contributed to artificially high estimates of cap thickness.

TABLE 2-1
Estimated Cap Thickness

Station ID[1]	SPI Estimated Cap Thickness (cm)	Geotechnical Estimated Cap Thickness, Including Mixed Horizons (cm)	Geochemical Estimated Cap Thickness (cm)
LUUT2	> 4.5	44	48
LUU08	> 2.6	24	> 36
LUU12	> 2.0	> 36	> 36
LUU15	> 3.2	8	0
LUU18	> 2.4	16	16
SUU20	> 7.6	12	12
SUU21	5.4	8	8
SUU22	> 6.1	16	12
SUU23	> 6.0	12	12
SUU24	> 6.2	12	> 20
LDU26	5.5	4	0
LDU27	> 5.5	20	> 16
LDU28	5.0	4	> 4
LDU29	> 6.6	12	4
LDU30	> 6.7	16	> 8

[1] Select cores illustrating the variability within each cell and method of analysis.
Source: SAIC, 2003.

2.6.2 Sedflume Studies

The monitoring conducted after the in situ pilot capping project indicated that there was significant mixing of cap and effluent-affected sediment in the top cap layers. Sedflume testing was conducted in 2002 and 2004 to evaluate the stability of the contaminated surface layer on top of the caps, the capping materials, and the effluent-affected sediment under the caps. A Sedflume is a device used to measure erosion rates for sediment. In 2002, Sedflume analysis was performed on the three pilot test cells at the PV Shelf at seven locations (Gailani et al., 2004). The results of the 2002 Sedflume experiments indicated that:

- The surface layer was moderately resistant to erosion.
- Cap material moved as bedload at low shear stresses.
- Effluent-affected sediment under the cap was highly consolidated by cap placement and subsequent self-weight consolidation.
- Effluent-affected sediment under the cap was predominantly resistant to erosion.

- The slower-moving (bedload) cap material might have been entombed by faster-moving (suspended load) effluent-affected sediment.

Further postplacement monitoring indicated continued transport of effluent-affected sediment onto the pilot caps. Postcap placement oceanographic monitoring indicated the existence of irregular but strong internal waves at the site, which might explain the recontamination of the pilot caps through lateral transport of effluent-affected sediment.

EPA, stakeholders, and scientific review panel members agreed that additional field information was required to understand processes leading to this mixed layer on top of the caps and revision of the CSM to account for the high level of transport activity. Therefore, additional Sedflume experiments were conducted in July and August 2004 to characterize the erosion potential of effluent-affected sediments below the surface layer (Borrowman et al., 2005). These Sedflume experiments had the following primary objectives:

- Develop an understanding of sediment erosion rates for effluent-affected sediments from three regions of the PV Shelf Study Area.
- Develop an understanding of how sediment erosion rates vary with depth below the sediment-water interface for locations analyzed.
- Where appropriate, develop algorithms to estimate critical shear stress for initiation of erosion for surficial and buried sediments.
- Where appropriate, develop algorithms to estimate erosion rates as a function of bulk density and applied shear stress. Where appropriate, develop relationships for erosion as a function of organic content and grain size distribution and applied shear stress.
- Develop an understanding of how sediment bulk density, organic content, and grain size distribution vary with depth at various locations on the PV Shelf.

A total of 10 sediment cores were collected from different areas of the shelf for Sedflume analysis: the northwest (NW) section, the outfall (OUT) section, and the southeast (SE) section (Figure 2-4). These three areas have distinct sediment types. The SE section is dominated by coarser, native sediment with significant amount of sand and shell hash. The OUT section is a combination of native sediment and thick deposits of effluent-affected sediment. The NW section of the shelf includes a layer of fine sediment that predominantly originated from the outfalls. Core collection locations were selected to represent a broad range of hydrodynamic and sediment conditions on the PV Shelf. The sediment samples collected in the field were approximately 15 to 40 cm deep. Measurements of the erosion rates as a function of depth and applied shear stress were then determined using Sedflume. For most cores, bulk density, grain size distribution, and organic content were measured as a function of depth. Cores were eroded during July and August 2004. The report from the 2004 investigation, *Sediment Erosion Study for the Palos Verdes Shelf Effluent-Affected Sediment (Draft)* (Borrowman et al., 2005), provides core description, data analysis, and erosion algorithm development for each core, and compares results from the various locations. Results of the Sedflume experiments are further discussed in Section 5.0 of this report.

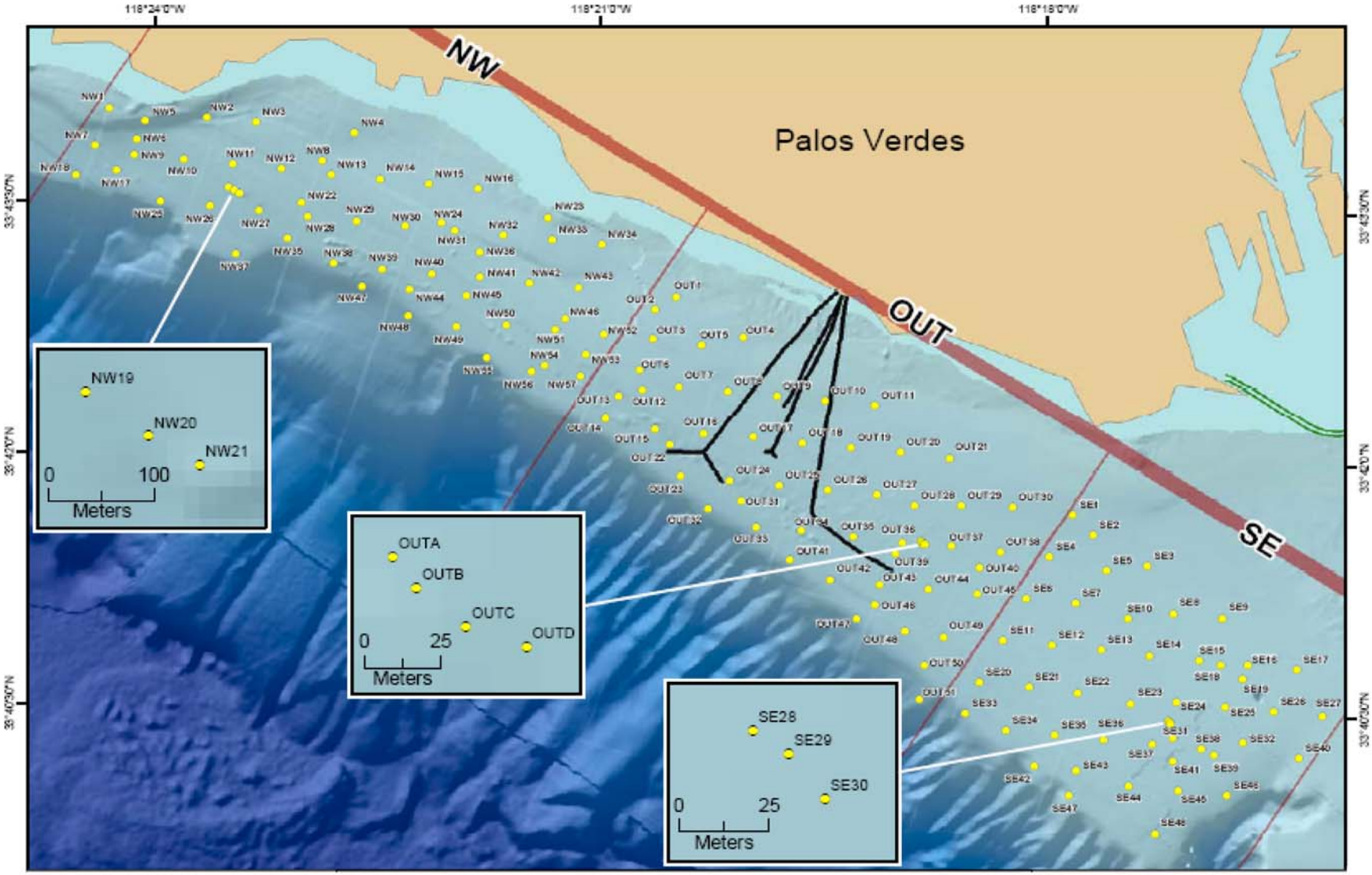


FIGURE 2-4
Sediment Core Locations for Sedflume Study
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: Borrowman et al., 2005

2.6.3 Pilot Capping Conclusions

Based on the pilot capping monitoring program, USACE concluded "the construction of a cap to substantially isolate the contaminated sediments on the PV Shelf from the marine environment is an achievable objective" (Fredette et al., 2002). Although this conclusion was based primarily on estimates of cap thickness, it is somewhat inconsistent with results presented by SAIC (2003) for the same data. SAIC provided interpretations of discrete data, but did not draw overall conclusions in its report. The main difference in the interpretation of monitoring results between SAIC and USACE stems from SAIC's reliance on all indicators of cap thickness, compared with the rejection of DDE data by the USACE based on potential sampling artifacts, such as loss of sample during coring.

High spatial and temporal variability within and between cells was discussed qualitatively by SAIC; however, neither report quantified variability nor discussed its potential impact on the interpretation of results. SAIC provided possible explanations for the high variability in DDE surface concentrations between during-capping and postcapping (including supplemental sampling) surveys, including commingling of in situ and cap sediments through bioturbation; resuspension from capping, fishing (trawling), storm events, and transportation of adjacent in situ sediment; sampling artifacts, including mislabeling of samples, coring artifacts (resulting in sediment loss or displacement); and patchy placement of cap material. Therefore, based on the uncertainties remaining and variability of DDE data, the pilot capping results appear inconclusive.

The pilot capping project was primarily an engineering test to assess cap placement feasibility using a variety of material types and placement techniques at sites having different water depths and bottom slopes. Although valuable information was obtained from this pilot capping project, other questions concerning the feasibility and effectiveness of capping on the PV Shelf were identified that were not addressed as part of the project.

2.7 Palos Verdes Shelf 2004 Field Studies

After the pilot capping project was completed, EPA, USGS, and USACE identified the need for additional field measurements, data analyses, and modeling efforts to assist in interpretation of the data and to prepare the RI/feasibility study (FS). The following questions regarding the RI/FS still needed to be addressed:

1. What are the oceanographic processes acting to resuspend and transport sediment on the PV Shelf?
2. How significant is the erosion, if any, that is occurring southeast of the outfalls?
3. What was the degree of effluent-affected sediment mixing that occurred during placement?
4. Will a cap be eroded or moved as a result of currents, etc.?
5. What is the thickness of surface effluent-affected sediment displaced laterally by a point dump?
6. Will a cap be recontaminated by effluent-affected sediment from uncapped areas, or from beneath the cap, because of bioturbators?

7. What is the small-scale variability in the erodibility (and other geotechnical properties) of the near-surface sediments across the PV Shelf?
8. How well can existing rapid sampling techniques be used to measure or predict the erodibility of the near-surface sediments?
9. Do deep-burrowing bioturbators occur in substantial numbers and sizes/weights to contribute substantially to mixing and disturbance of sediments within the potential capping area on the PV Shelf?
10. What is the thickness of surface effluent-affected sediment displaced, and what is the spatial extent of effluent-affected displacement associated with a placement event?

Four field investigations were designed to address these questions. In 2004, EPA, with the support of USGS and USACE, performed the following high-priority field studies:

- **Oceanographic Measurement Program -** Field investigation to assess the oceanographic conditions across the PV Shelf and Upper Slope**.** This field program began in late February 2004 with the deployment of oceanographic instrumentation and moorings. Instruments and moorings were maintained (e.g., cleaned, data downloaded, new batteries installed) periodically over the approximately 4-month deployment period. All instrumentation was retrieved by early July 2004.
- **Geotechnical Measurement Program -** Field investigation to assess spatial variations in geotechnical properties of sediments on the PV Shelf and Upper Slope. This field program began in late June 2004 with the acquisition of acoustic side-scan sonar data. After a quick review of the side-scan sonar data, an extensive sediment-profile and plan-view imaging survey was conducted in mid-July 2004. The field program was completed in late July after 8 days of gravity coring and related geotechnical analyses to assess the erodibility of near-surface sediments across the PV Shelf.
- **Bioturbation Measurement Program -** Field investigation to characterize large bioturbating infaunal organisms and to conduct sediment dating on the PV Shelf. This field program began in late July 2004 and extended through early August 2004. The primary field investigation entailed extensive box-coring operations and subsequent analysis of large bioturbating organisms. In addition, multiple gravity cores were collected at several of the key bioturbation sampling stations so that detailed radiometric dating analyses could be conducted.
- **Sediment Displacement Study -** Field investigation on the existing pilot cap to assess the degree of effluent-affected material resuspension that occurred during cap placement in 2000. This 4-day field program occurred in mid-July 2004 and entailed the collection of numerous cores within pilot cap Cell SU. In addition, a small coring comparison survey was also conducted between the primary corer used during this program and the LACSD corer that has been used for other PV Shelf sampling operations. Extensive chemical and geotechnical laboratory analyses were conducted on these core samples to assess the degree of effluent-affected sediment resuspension that could have occurred during pilot cap placement.

These four investigations and one earlier study, which involved the analysis of LACSD moored oceanographic data, are summarized in the following section. These studies provide valuable insight into the fate and transport processes occurring at the PV Shelf

Study Area over defined time periods. Additional studies might be needed to address uncertainties over the long term.

2.7.1 LACSD Moored Oceanographic Data

To better understand the oceanographic processes affecting sediment transport, EPA initiated an additional analysis of oceanographic data collected by LACSD during 2000 to 2003. A report on the analysis of LACSD moored oceanographic data can be found in *Analysis of Moored Oceanographic Data Acquired on the Palos Verdes Shelf by the LACSD during the Period from November 2000 to August 2003* (SAIC, 2004b).

In 2000, LACSD deployed an array of moored instruments at nine locations across the PV Shelf, from Point Vicente in the northwest to the western edge of the San Pedro Shelf, south of Point Fermin (Figure 5-12). Various moored instruments were deployed along the 35- or 65-m isobaths to acquire physical oceanographic data (vertical structure in current and temperature fields) for assessment of along-shelf and cross-shelf processes. In 2002, four additional moorings were placed on the San Pedro Shelf to extend the array farther to the southeast. These moorings were placed on either the 35- or 65-m bathymetric contour. LACSD maintained instrumentation at this 13-site array until fall 2004.

Analysis of the LACSD moored oceanographic data collected between November 2000 and August 2003 (SAIC, 2004b) yielded the following conclusions:

- Currents on the PV Shelf are governed by a variety of complex processes having a broad range of timescales from minutes to seasons. Some of these processes had horizontal length scales significantly greater than the PV Shelf, which implied that a hydrodynamic model developed for predictions of horizontal transport on the PV Shelf would have to include large-scale processes with varying sources of forcing and boundary conditions.

- Sediment resuspension and transport are affected not only by low-frequency currents, tidal currents, and surface wave-generated currents, but also tidally driven, baroclinic currents and more likely high-frequency internal waves. None of these processes can be eliminated when predicting bottom sediment resuspension on the PV Shelf, and its spatial and temporal likelihood. The PV Shelf is a dynamic, complex coastal region.

- Starting with the analysis of low-frequency currents on the PV Shelf, mean currents were determined to significantly vary with season and location, but were less than 10 cm/sec at heights of a few meters above the seabed, and predictably less in the bottom boundary layer. Mean currents were greater southeast of the LACSD outfalls, especially near the surface in the spring and summer of some years. For horizontal transport of suspended sediment, near-bottom mean flows of approximately 10 cm/sec would be sufficient for particulate matter to travel nearly the entire length of the PV Shelf in one day. Although cross-shelf mean flows were substantially weaker, suspended material could be swept off the shelf by offshore flow in a fraction of a day given the optimum conditions.

- Water column temperatures and stratification varied as a result of solar radiation, lateral advection of water masses into and out of the region, and vertical displacements of isotherms associated with the passage of internal wave phenomena. Such vertical

displacements of isotherms helped to identify events when periodic wave phenomena were occurring.

- Observed tidal currents on the PV Shelf reflected a system that is more complex than typically observed in shelf regions. One hypothesis for this high degree of spatial and seasonal variability in tidal current amplitude is that the entire shelf water mass (i.e., more than 65 m deep) is actually the upper layer of a larger-scale system that includes the San Pedro Basin and offshore ridges and islands. This upper layer could have represented the upper layer of low mode, semidiurnal internal tides that were generated at some distance over topography in deeper water and that propagate toward shore. This type of internal tidal motion would effectively appear as a surging layer over the entire shelf, and be difficult to distinguish from the barotropic tidal motions.

- Baroclinic (internal) tides undeniably represent a significant mechanism for sediment resuspension on the PV Shelf. The source (forcing mechanism) for these internal tides is not known; similarly, their frequency of occurrence and local intensification patterns are not well understood, although the multiyear LACSD records provided sufficient data from which to identify events. These internal, tide-driven currents seem to have occurred at all locations on the PV Shelf, with the strongest near-bottom amplitudes occurring in the southeast region. All of the strong events identified were characterized by pulses of offshore flow in the lower water column, which would have resulted in net transport of any suspended material. This offshore movement could couple to surface wave-induced resuspension to provide an effective mode of offshore transport of fine-grained sediments.

2.7.2 Oceanographic Measurement Program

Although the LACSD moored arrays provided a long-term record of tides and currents, they did not collect data from the water-sediment interface because they were extended to a meter above the ocean floor. To fill this data gap, USGS and USACE deployed their own arrays in 2004 to collect water-sediment interface data. A summary of this oceanographic measurement program, and the data quality processing and data quality review effort, is provided in the *Data Report for the 2004 Oceanographic Measurement Program Conducted on the PV Shelf*, which was issued in October 2005 (SAIC, 2005a).

The purpose of the oceanographic measurement program was to assess oceanographic conditions across the PV Shelf and to enhance the understanding of processes responsible for the resuspension and transport of sediments on the PV Shelf. The program was designed to address some of the following key questions:

- What are the oceanographic processes acting to resuspend and transport bottom sediments on the PV Shelf?

- How significant is the erosion, if any, that is occurring southeast of the outfalls, and what are the processes and frequency of occurrences contributing to this erosion?

- Will a cap be eroded or moved by currents?

- Will a cap be recontaminated by effluent-affected sediment from uncapped areas (e.g., from deeper regions on the Upper Slope)?

The program was also designed to address the following scientific questions:

- Is there significant along-shelf variability in the tidal and high-frequency processes (such as internal waves and solitons) that has yet to be measured adequately?
- Are resuspension processes more frequent and/or energetic in the region southeast of the LACSD outfalls than along the shelf to the northwest of the outfalls?
- What is the cross-shelf variability in the local internal tides and internal wave processes that are expected to contribute significantly to sediment resuspension and transport on the shelf?

Field sampling activities for the oceanographic measurement program were conducted from February through July 2004. During that interval, moored arrays were deployed at six locations (Figure 2-5). Three of the mooring locations (B2, B3, and B6) were aligned along the 60-m contour, and the other three stations (B7, B6.5, and BX) were aligned across the shelf in line with Station B6. The major tasks associated with the program consisted of sediment coring, water column profiling and sampling, and the moored instrument deployment. The sediment coring and moored instrument program are described below.

2.7.2.1 Sediment Coring

On February 24, 2004, sediment cores were collected at each of the six mooring locations (Figure 2-5). One core sample from each of the six mooring locations was subsampled into five 4-cm intervals for laboratory geotechnical analyses. The sediment subsamples were analyzed for grain size, bulk density, water content, and total organic carbon (TOC). A summary of each core was prepared to include laboratory geotechnical results, core photographs, and descriptions.

2.7.2.2 Moored Instrument Program

Of the three field elements that comprised the oceanographic measurement program, the largest and most complex was the moored instrument element. Instrument arrays were deployed at six locations on the PV Shelf. The primary purpose was to obtain high-frequency data on the physical oceanographic conditions and suspended sediment load in the bottom boundary layer within the effluent-affected area of the PV Shelf. These high-frequency data were needed to better characterize the high-frequency processes (e.g., internal tides) that could be the significant cause of sediment resuspension and transport on the PV Shelf.

The moored instruments acquired the following data:

- Moored current velocity data from sensors mounted near the seafloor, as well as from moored profilers capable of acquiring velocity data throughout the water column
- Moored temperature, salinity, and turbidity data from near the seafloor and throughout the water column

- Data for assessment of large-amplitude surface waves using moored pressure and velocity sensors
- Particulate samples from moored particle traps
- Sequential bottom photographs of bedform characteristics from a single bottom platform containing a strobe and camera

Preliminary findings from these field investigations are discussed in Section 5.0 of this RI report.

2.7.3 Geotechnical Measurement Program

The purpose of the geotechnical measurement program was to assess spatial variations in geotechnical properties (e.g., resistivity, grain size) and the erodibility of near-surface sediments on the PV Shelf to address the following questions:

1. What is the small-scale variability in the erodibility (and other geotechnical properties) of the near-surface sediments across the PV Shelf?
2. How well can existing rapid sampling techniques be used to measure or predict the erodibility of the near-surface sediments?

The program consisted of three primary field activities conducted in June and July 2004: (1) side-scan sonar survey, (2) sediment-profile and plan-view imaging survey, and (3) sediment coring and Gust Chamber analysis. The Gust Chamber is a device that can be used to calculate erodibility by applying shear stress to sediment.

A summary of the geotechnical measurement program, and the data quality processing and data quality review effort, is provided in the *Data Report for the Summer 2004 Geotechnical Measurement Program Conducted on the Palos Verdes Shelf*, which was issued in June 2005 (SAIC, 2005b). Analysis of the data collected during the geotechnical measurement program is being used in conjunction with the data obtained from the oceanographic measurement program to address sediment resuspension and transport, and cap stability modeling approaches and constraints.

2.7.3.1 Side-scan Sonar Survey

The geotechnical measurement field program began with collection of broad-scale side-scan sonar data to help delineate regions of the shelf with slightly varying sediment or surface roughness characteristics. The interpretation of the broad-scale acoustic data was aided by numerous high-resolution sediment-profile and plan-view images that were collected across the different regions of the shelf. These images helped confirm the broad-scale acoustic interpretation and provided quantitative and qualitative data on the physical and biological characteristics of the shelf.

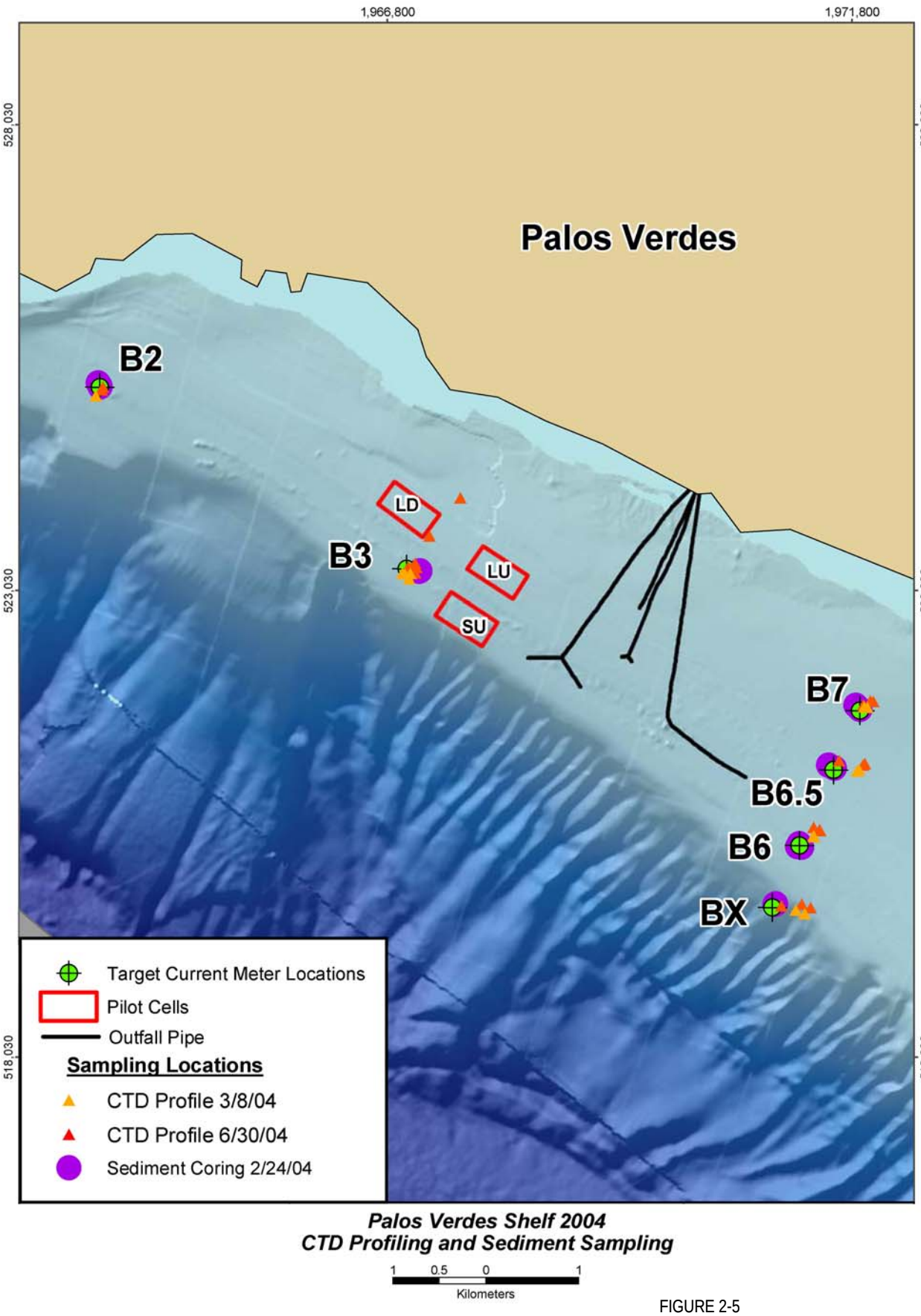


FIGURE 2-5
Mooring Locations for Oceanographic Measurement Program
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: SAIC, 2005a

2.7.3.2 Sediment-profile and Plan-view Imaging Surveys

The sediment-profile and plan-view imaging survey was conducted to provide high-resolution imagery data of the seafloor across the PV Shelf. This survey was conducted using a deployment frame that was configured with a digital sediment-profile image (DSPI) system and a downward-looking, film-based, plan-view camera system. The sediment-profile and plan-view imaging survey was completed over a 4-day period from July 9 through July 12, 2004. Approximately 170 stations were occupied during this survey, with at least three replicate sediment-profile and plan-view images collected at most stations. These images captured sedimentary and biological conditions at the sediment-water interface to camera penetration 0 to 20 cm deep.

The final sediment-profile data were analyzed to provide an assessment of the sedimentary environment and benthic habitat conditions over a broad area of the PV Shelf. Computer-aided analysis of each image yielded a suite of standard measured parameters, including sediment type, camera prism penetration depth (an indirect measure of sediment bearing capacity/density), small-scale surface boundary roughness, depth of the apparent redox potential discontinuity (a measure of sediment aeration), infaunal successional stage, and organism-sediment index (a summary parameter reflecting overall benthic habitat quality).

The plan-view image data were analyzed to provide an assessment of the sedimentary environment and benthic habitat conditions over a broad area of the PV Shelf. The plan-view analysis consisted of qualitative descriptions of key sediment characteristics (e.g., sediment type, bedforms, and biological features) based on a manual review of the scanned 35-millimeter (mm) slides. Because the surface sediment descriptions are based on a manual interpretation, only the presence of rock, gravel, sand, and/or fines was noted. Likewise, the presence of shell debris and any evidence of epifaunal or infaunal organisms (e.g., tubes, burrow openings) were recorded.

2.7.3.3 Sediment Coring and Gust Chamber Analysis

While the side-scan sonar and SPI surveys were intended to provide a broad-scale view of the sediment characteristics across the PV Shelf, sediment coring and subsequent Gust Chamber analysis program were designed to provide detailed quantitative data on key sediment properties and characteristics (e.g., erodibility, resistivity, bulk density). The sediment coring and Gust Chamber analysis survey were conducted over a 9-day field effort and 15 detailed geotechnical stations were sampled. Although most of the detailed coring stations were subjected to both Gust Chamber and laboratory geotechnical analyses, the Gust Chamber analysis was not run at a few of these stations. At the detailed stations, up to five separate cores were analyzed for replicate resisitivity profiles, and at least two separate cores were analyzed for replicate Gust Chamber erosion results.

Resistivity profiles were obtained using an in situ resistivity profiler on board the survey vessel soon after the cores were collected using the hydraulically dampened gravity corer. In addition, one core sample from each of the 15 detailed stations was subsampled into five 4-cm intervals for eventual laboratory geotechnical analyses of aggregate and disaggregate grain size, bulk density, water content, and TOC.

Additional cores were collected during this field event for Sedflume analysis by ERDC (formerly WES). This study was discussed in Section 2.6.2.

2.7.3.4 Data Analysis

The data from the geotechnical measurement program has shown consistent and logical agreement among the various datasets. Detailed visual comparisons were made between the side-scan sonar acoustic imagery and the numerous sediment-profile and plan-view photographs, primarily to assist with the interpretation and analysis of the side-scan sonar data. There was consistent agreement between the acoustic and photographic data.

Based on the quantitative results obtained through the analytical elements of the coring program, the first study question has been adequately addressed. A review of the mass eroded values obtained through the Gust Chamber analyses indicated that there was statistically significant variability in the computed erosion values from the northwest to the southeast along the 60-m contour of the PV Shelf. Likewise, the laboratory geotechnical results (e.g., grain size, bulk density, water content, porosity) also showed considerable variability across different areas of the shelf. The Sedflume results support the Gust Chamber analyses regarding the variability of the geotechnical properties of the PV Shelf sediments.

The second study question addresses the ability to use the more rapidly sampled datasets (e.g., side-scan sonar imagery, sediment-profile images, and resistivity profiles) to measure or predict erodibility of the near-surface sediments. Although data were collected to address this question, they were inadequate for measuring and predicting erodibility of near-surface sediments. The erodibility question requires further study, which is currently underway.

2.7.4 Bioturbation Measurement Program

The objectives of the bioturbation measurement program were to characterize large bioturbating infaunal organisms (BIO), to evaluate sediment mixing/bioturbation rates on the PV Shelf, and to conduct sediment dating. Bioturbation is the displacement and mixing of sediment by organisms. This field program began in late July 2004 and extended through early August 2004 (SAIC, 2005c). A summary of the measurement program, and the data quality processing and data quality review effort, is provided in the *Study Report for the Summer 2004 Bioturbation Measurement Program on the Palos Verdes Shelf*, (SAIC, 2005c).

This field program entailed extensive box-coring operations and subsequent analysis of large BIO. Multiple gravity cores were also collected at several of the key bioturbation sampling stations so that detailed radiometric dating analyses could be conducted. More specifically, the primary intent of the bioturbation measurement program was to address the following questions:

- Will a cap be recontaminated from beneath the cap by bioturbators?
- Do deep-burrowing bioturbators occur in sufficient numbers and sizes/weights to contribute substantially to mixing and disturbance of sediments within the potential capping area on the PV Shelf?

To address these questions concerning the effects of bioturbators, sediment cores were collected to evaluate BIO and sediment mixing/bioturbation rates. Triplicate samples were targeted at 19 coring stations for large BIO; and 12 and 4 dating stations were used for thorium-234 and lead-210, respectively.

The BIO survey used a large box corer (30-cm-long by 20-cm-wide by 60-cm-high) to collect samples across six transects at three different depths: 40 m, 55 m, and 70 m (Figure 2-6). Each box core sample was sectioned into three intervals representing the surface (0 to 15 cm), mid-region (15 to 30 cm), and deep (more than 30 cm) part of the core. Each interval was evaluated for the presence of large burrowing bioturbators, including species occurrence, abundance, sizes, and weights (biomass).

Information on sediment mixing rates and bioturbation was obtained from radionuclide analyses of sediment cores to assess the likelihood or degree of biological contributions to mixing and disturbance of sediments within the potential capping area on the PV Shelf. The goal of these evaluations was to assess the likely contribution of biological mixing to contaminant redistribution with depth and, specifically, the potential for upward migration of contaminants (in sediment and pore water) that could affect cap integrity and contaminant availability. Supporting information from other data sources, including SPI and plan-view photographs collected during the geotechnical measurement program, LACSD infauna data from summer 2003, and a bioturbation literature search were used to compare results from the bioturbation assessment.

2.7.4.1 Data Analysis and Results

The most common BIO taxa were polychaetes (20 taxa), followed by crustaceans (6), nemerteans (5), and other phyla (1 to 3 per phylum). Relatively higher abundance and biomass of BIO taxa generally occurred northwest of the LACSD outfall region, with corresponding lower values to the southeast. The majority of BIO occurred in the top two core depth intervals (0 to 15 cm and greater than 15 to 30 cm), with substantially fewer at deeper intervals (greater than 30 cm). Key species, based on frequency of occurrence and abundance across the three main core depth intervals, included the ghost shrimp (*Neotrypaea californiensis*; formerly *Callianassa californiensis*) and the polychaete worm (*Marphysa disjuncta*).

Biodiffusivity values based on thorium-234 profiles, coupled with sedimentation rate data from lead-210 analyses, indicate low sediment mixing intensities (e.g., average of 19 +/- 21 square centimeters per year [cm^2/year] versus 1992/1993 values of 31 +/- 20 cm^2 /year). Sediment accumulation rates from the lead-210 data indicated that pre-effluent deposit rates were low (about 0.8 to 1.6 millimeters per year [mm/year]).

The report from the bioturbation monitoring program concluded that there are relatively low abundance and biomass of BIO at the PV Shelf Study Area, including principal species such as ghost shrimp, which represent the greatest potential source of bioturbation. Sediment dating and biodiffusion results suggest a low potential for substantial upward mixing, consistent with the low potential for bioturbation. Based on the bioturbation monitoring program report, large bioturbators do not have a high potential for substantial disruption of a cap in the study region, even though there might be an expanded range of occurrence for ghost shrimp and other species that prefer sandier habitats if sand is applied as capping material.

Other researchers disagree with the characterization that the PV Shelf has relatively low abundance and biomass of BIO because ghost shrimp are difficult to sample, and often burrow to depths greater than 1 m, which is below the sampling depth of the bioturbation monitoring program. In addition, the range (1 to about 90 cm^2/year) of biodiffusivities estimated from thorium-234 analyses during the bioturbation measurement program is comparable to other locations (Wheatcroft, 2006). Densities of deep-dwelling BIO were also comparable with other SCB locations.

Recent studies of deep-burrowing invertebrates suggest typical SCB densities in the PV Shelf Study Area (in general), but with a local pattern of higher densities to the northwest of the outfalls. In addition, future capping with sand could act as an attractant for colonization of the new cap by the deepest burrowers (*Neotrypaea*), which prefer this type of substrate. Bioturbators exist in the PV Shelf Study Area. Whether the densities of BIOs are low or average, bioturbation as a sediment-mixing process appears to be most significant in the top sediment layer.

2.7.5 Sediment Displacement Study

The purpose of the sediment displacement study was to assess the degree of effluent-affected material resuspension that occurred during the placement of the pilot cap in 2000 (SAIC, 2005d). Another purpose of this study was to compare the primary corer used during this program and the LACSD corer used for other Palos Verdes Shelf sampling operations. The results of the sediment displacement study are provided in the *Final Report for the Summer 2004 Sediment Displacement Study on the Palos Verdes Shelf* (SAIC, 2005d).

This study was conducted for 4 days in mid-July 2004 and involved collecting numerous cores within pilot cap Cell SU (Figure 2-7). Sampling was focused in Cell SU for the following reasons: (1) conventional, point-dump placement methods were used to place cap material at this site; (2) effluent-affected sediments within this cell are fine-grained with a high water content and low density and, therefore, potentially more susceptible to displacement from point-placement methods than coarser-grained sediments at shallower areas of the shelf; (3) DDE profiles exhibit clear subsurface maxima (peaks) that can be used as markers to evaluate displacement during cap placement operations; and (4) cores collected during the March 2002 supplemental survey at Station SU22 and cores collected by LACSD at 7C (within the boundaries of Cell SU) suggested that displacement of effluent-affected sediments occurred during cap placement within this cell. Because of the low-density properties of effluent-affected sediments within Cell SU, evaluations of effluent-affected sediment displacement at this site were considered a "worst-case" condition. The sediment displacement study addressed the following key question:

- What is the thickness of surface effluent-affected sediment displaced, and what is the spatial extent of effluent-affected displacement associated with a placement event?

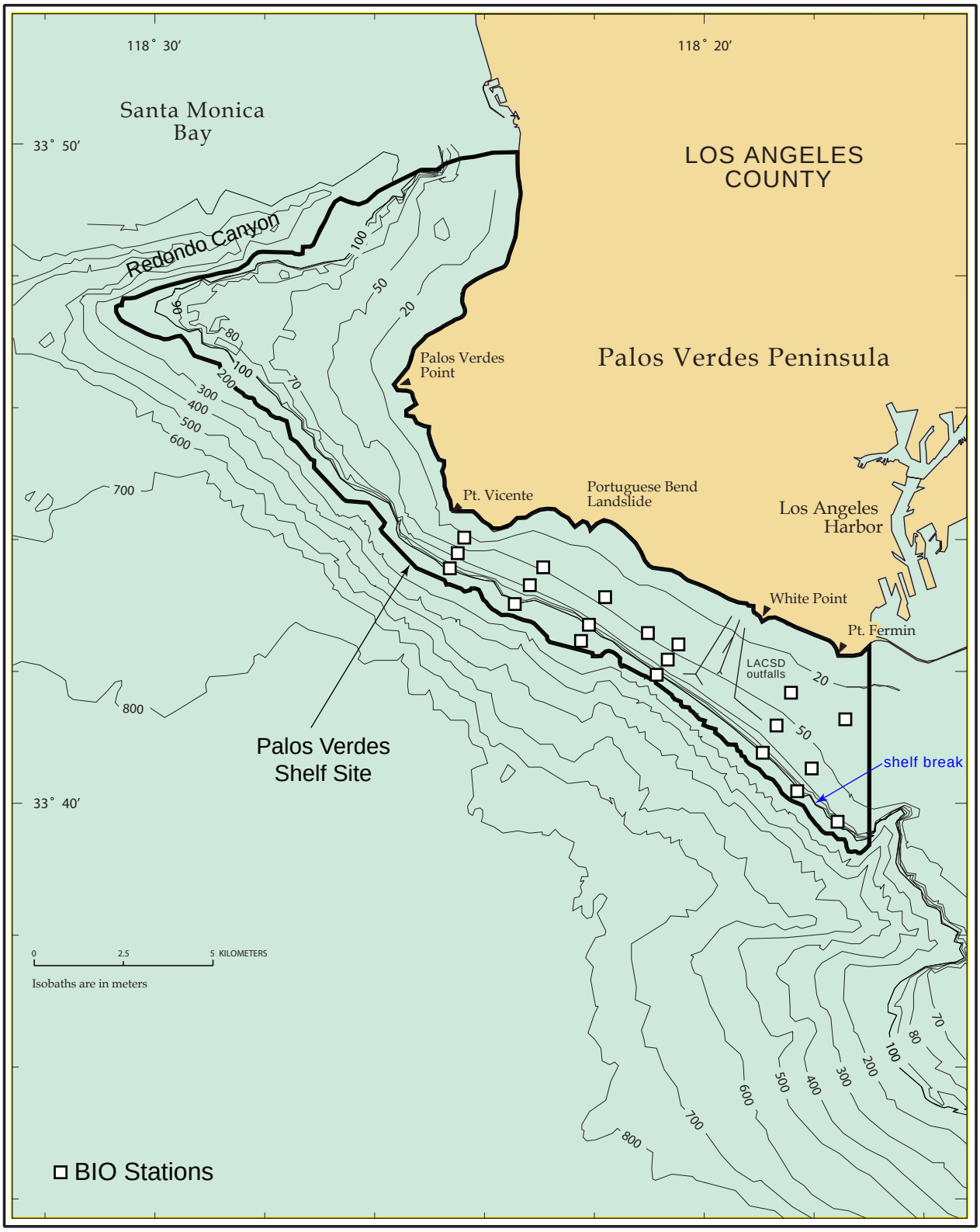


FIGURE 2-6
BIO Survey Sampling Location
Palos Verdes Shelf Study Area
Remedial Investigation Report

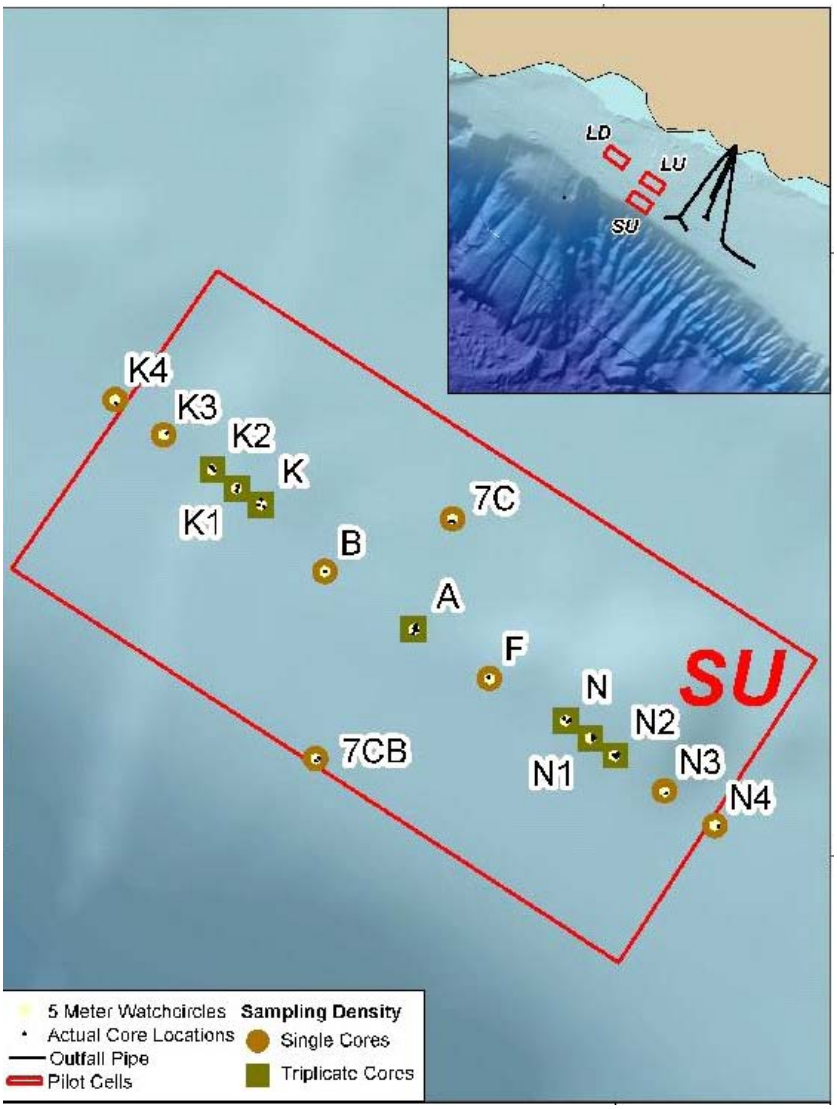


FIGURE 2-7
Locations of Sediment Core Samples for Sediment Displacement Study
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: Final Report for the Summer 2004 Sediment Displacement Study on the Palos Verdes Shelf, SAIC, 2005.

Accurate assessments of whether effluent-affected sediments were displaced as a result of conventional (point-dump) placement events during the pilot capping project are required to evaluate the constructability of a full-scale sediment cap on the PV Shelf. Sufficient data for assessing the potential magnitude and spatial extent of this impact are not available, and the key question of whether disturbances to in situ sediments can be minimized is not completely resolved. This study included the following primary tasks:

- Demonstrate the performance of the hydraulically damped piston corer, and collect and analyze cores that can be used to intercalibrate the present sampling methods with the gravity coring method used in the LACSD long-term study of effluent-affected sediments.
- Collect undisturbed sediment cores at selected sites within and adjacent to a pilot capping cell, and analyze specific geotechnical and chemical characteristics of the sediment cores.
- Review core data collected by LACSD and USGS before and after placement of the pilot cap.
- Review the postcapping side-scan sonar records and SPI data for the pilot capping cells to support interpretations of the sediment core data.

In total, 29 cores were analyzed, including 5 cores used for the intercalibration exercise. The sampling design included a set of sampling sites (stations) that corresponded to actual cap placement locations along the centerline of Cell SU, and two transects that extended outward, up to 150 m up-coast or down-coast and parallel to bottom isobaths, from cap placement positions where a single load was placed along the outer edge of the Cell SU cap.

2.7.5.1 Data Analysis and Results

The sediment displacement study results indicated that the thickness of the effluent-affected sediment layer displaced during capping can vary from a few centimeters at sites where cap placements overlapped, up to decimeters at sites where cap material was placed directly on top of effluent-affected sediments. This conclusion was based on the relatively uniform depths for the peak DDE concentrations (typically from 30 to 36 cm) with increasing distance from placement sites (i.e., Stations K and N). There was also an apparent absence of upward shifts in the DDE peaks within the sediment column following cap placement using the overlapping placement approach. Instead, cap placement at these locations achieved a net downward displacement of the DDE peak of up to approximately 7 to 10 cm, although the magnitude of the displacement was less than the cap layer thickness. Maximum scour depths up to 5 cm were estimated for these areas within Cell SU.

Capping also achieved reductions in the magnitude of sediment contaminant concentrations, although there was some overlap in the DDE concentration ranges for the precapping and recent sediment samples. The current DDE concentrations, combined with the other grain size and physical/chemical properties, suggest that the present surface sediment layer represents a mixture of cap material with varying proportions of effluent-affected sediments that likely have been advected onto, and mixed into, the cap layer during the 4-year period following cap placement.

While the distinction between the cap layer and effluent-affected sediment has become less apparent, the overall reductions in contaminant concentrations in surface sediments have persisted for several years after cap placement. These characteristics are consistent with the concept of a "thin cap" described by Palermo et al. (1999), in which a cap layer with a thickness of approximately 15 cm is used to dilute contaminated sediments and slow contaminant remobilization rates. Thus, the net burial depth of the subsurface contaminant layers, without significant scouring of effluent-affected sediments, along with dilution to achieve lower contaminant concentrations of the surface layers, appear to be consistent with USACE's original design objectives for the pilot cap in Cell SU.

The conclusions for Stations A and 7C are different from those for areas along the N and K transects. Conditions near Station A are highly variable. The magnitude of scouring at some locations appears to be greater than the thickness of the cap layer; while at immediately adjacent locations, the remaining cap layer is up to several decimeters thick. Current information cannot determine whether this difference in thickness is due to the presence of small-scale bathymetric features such as mounds or scoured depressions that were back-filled with cap material.

The results for Station A were not surprising given that the cap material was dumped directly on top of effluent-affected sediments. The DDE profiles for Stations B and F, which were the closest sites to Station A, were similar to those at the K and N stations. Therefore, scouring at Station A does not appear to extend to the adjacent sites along the cell centerline. The actual spatial extent of scouring near Station A cannot be determined from the present data because of the high variability among cores. The reason for the apparent scouring at Station 7C is not obvious because cap placement in this area used an overlapping placement approach that was similar to that used at the K and N locations.

2.8 2002-2004 Southern California Coastal Marine Fish Contaminants Survey

EPA and NOAA, on behalf of MSRP, initiated a comprehensive ocean fish sampling effort in fall 2002 to assess current fish contamination levels in the SCB. This program had the following primary goals:

- **Update health advisories and commercial fishing bans –** EPA is working with appropriate California state agencies to examine the existing fish consumption advisories for Southern California marine waters and the ban of commercial fishing for white croaker near the PV Shelf. The Cal-EPA OEHHA will use the collected data to update the existing sport fish consumption advisories and existing commercial catch ban area, as appropriate, for white croaker near the PV Shelf.

- **Provide information for EPA site remediation –** The fish data will be used as one of the scientific bases to design cleanup action to reduce the extent which DDTs and PCBs are released into the environment from effluent-affected sediments. This includes human health and ecological risk evaluations.

- **Determine restoration of lost fishing opportunities –** The Trustees, through MSRP, are investigating several potential approaches to increase the availability of wholesome fish to catch along the coast of Southern California. The collected fish data will provide information for the MSRP to plan and conduct its restoration projects.

The fish species collected during this survey included pacific barracuda, pacific (chub) mackerel, pacific sardine, yellowtail, opaleye, sargo, kelp (calico) bass, surfperches, rockfishes, California sheephead, barred sandbass, top smelt, halfmoon, California scorpionfish (sculpin), white seabass, black croaker, white croaker, yellowfin croaker, jacksmelt, California corbina, California halibut, shovelnose guitarfish and queenfish. These fish were caught at 29 designated locations from Ventura to Dana Point, mostly in the Los Angeles area.

Approximately 1,000 fish samples have been analyzed for DDT, PCBs, dieldrin, chlordane, and mercury. Forty-five white croaker were collected at the PV Shelf Study Area. The concentrations of DDTs in tissue in all fish ranged from not detected to 6,770 micrograms per kilogram (µg/kg). The range of concentrations of PCBs was not detected to 648 µg/kg. (EPA and NOAA, 2007). Figure 2-2 shows the sampling locations for this survey. Preliminary results for the PV Shelf Study Area sampling are further discussed in Section 4.0.

3.0 Site Characteristics

The SCB, which includes the PV Shelf, is unique among coastal environments on the Pacific Coast of the United States. The SCB is characterized by a large open bay, the turn of coastline to the east, the narrow shelf in the Palos Verdes Study Area, and the shelter from distant waves formed by the offshore islands. Because of these characteristics, water properties and circulation at the PV Shelf, and the SCB in general, can be very different from other Pacific Coast areas (LACSD, 2005).

This section describes the general physical characteristics and ecology of the PV Shelf Study Area including information on the physical setting, meteorological setting, oceanographic climate, currents and waves, geology and sediments, and ecological characteristics. Section 5.0, Contaminant Fate and Transport, provides more site-specific details on some of the topics in this section, particularly waves and currents.

3.1 Physical Setting

The PV Shelf is located within the SCB, an area of the coastal Pacific Ocean between Point Conception and Cabo Colnett, south of Ensenada, Mexico (Figure 1-1). Within the bight lies a protrusion of the coastline bordered by San Pedro Bay to the south and Santa Monica Bay to the north. This protrusion forms the PV Shelf, a small section of the continental shelf. The PV Shelf is very narrow, having a width of 1.5 to 4 km, a length of up to 25 km, and a slope of 1 to 4 degrees. A steep increase in slope exists between 50 and 100 m in depth, producing an edge to the continental shelf in water depths of 70 to 100 m. Beyond the shelf break is the continental slope, which extends about 800 m deep. The slope is also narrow and steep in this region, having a width of approximately 3 km and a mean slope of 13 degrees (Lee, 1994). The slope contains gullies, shallow-seated landslides, and several large, deep-seated slope failures (Lee et al., 2002). In addition to the shelf and slope, the immediate area of the PV Shelf also includes adjacent parts of the San Pedro Basin, which is south of the slope in water depths of at least 800 m (Lee, 1994). Redondo Canyon is northwest of Point Vicente and north of the PV Shelf. The Redondo Canyon and San Pedro Shelves are to the west and east of the PV Shelf, respectively (Lee, 1994).

The PV Shelf Study Area is defined as the area of the shelf and slope between Point Fermin and Redondo Canyon from the shore to the 200-m isobath, as shown on Figure 1-1.

3.2 Climate

3.2.1 Meteorological Setting

The PV Shelf is characterized by warm dry summers, tempered by ocean breezes, with mild winters. Data from Long Beach, California, indicate that the annual average rainfall of about 13 inches occurs primarily between November and March (NOAA, 2003). The 25-year, 24-hour precipitation event for the PV Shelf Study Area is approximately 4.8 inches (Western Regional Climate Center [WRCC], 2006). Fog and low clouds typically occur from February to April. In summer, morning fog and low clouds usually persist until mid-

afternoon, keeping summer temperatures mild. In Long Beach, California, the average daily temperature in the summer is 23 degrees Celsius (°C), winter temperatures average 14°C, and record temperatures range from -3.8 to 44°C (NOAA, 2003). The prevailing winds that blow onshore from the southwest help lower the summer temperatures and dissipate the summer fog. In the fall, strong gusty winds from the inland deserts, known locally as Santa Ana winds, cause unseasonably warm days.

3.2.2 Oceanographic Climate

Table 3-1 presents a summary of average water quality parameters including temperature, salinity, light transmittance, dissolved oxygen, and pH, collected at the PV Shelf by LACSD in 2004 (LACSD, 2005). The following information on temperature and salinity is important to understanding the conditions at the PV Shelf:

- temperature mediates the rate of biological and chemical processes
- temperature and salinity determine water density, which affects vertical mixing of water masses and diffusivity of suspended and dissolved contaminants
- stratification that includes a low-density surface layer prevents the low-density effluent plume from rising to the surface
- internal waves and tides can form and propagate on density interfaces

LACSD has noted that annual cycles of temperature and salinity in 2004 are typical of observations in recent years (LACSD, 2005). Water temperatures in the bight are typically warmer than water temperatures farther offshore (LACSD, 2005). The temperature ranged between a minimum of 9.74°C in May to 20.53°C in August with a calculated annual average temperature of 12.25°C in 2004. Dissolved oxygen ranged from 3.51 to 12.34 mg/L with an average of 6.5 mg/L in 2004 (LACSD, 2005). Salinity ranged from 31.91 to 33.99 parts per thousand (ppt) with an average of 33.39 ppt (LACSD, 2005).

In the ocean, density normally increases with increasing salinity and depth. However, in the waters of the PV Shelf, a unique feature can occur, particularly when a strong thermocline is present (LACSD, 2005). Although the warm water at the surface increases in salinity because of evaporation, it remains less dense because its temperature is higher than the water below the thermocline. Consequently, a sub-thermocline low in salinity forms frequently in the summer and fall (LACSD, 2005).

Vertical water temperature stratification generally follows a seasonal pattern. Ocean water temperatures are fairly cool and rarely vary near the bottom. Density stratification is almost always present, and is greatest in the summer when enhanced by thermal stratification, oxygen (O_2) levels and water clarity are always high, but are lowest in spring, reflecting algal primary productivity above the thermocline. May has the coldest temperatures at depth, but a thermocline begins to develop as shallow waters begin to warm (LACSD, 2005). In August, the water at the surface can be up to 8°C warmer than the water 61 m deep, forming a strong thermocline in the waters of the SCB that persist until late fall. In the winter, shorter days and less direct sunlight allow the water to cool, and the thermocline becomes less pronounced and increases in depth (LACSD, 2005). By February, typically, there is limited vertical temperature stratification at the PV Shelf (LACSD, 2005).

TABLE 3-1
Water Quality Parameters Over Depth Ranges 0-30, 31-60, 61-100, and 0-100 Meters

Variable (Units)	Depth MIN	Depth MAX	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG	MIN	MON	MAX	MON
Temperature (°C)	1	30		13.18			14.66			15.83			17.37		15.26	13.18	Feb	17.37	Nov
	31	60		11.48			10.75			11.15			13.22		11.65	10.75	May	13.22	Nov
	61	100		10.42			10.04			10.14			11.17		10.44	10.04	May	11.17	Nov
	1	100		11.57			11.64			12.15			13.64		12.25	11.57	Feb	13.64	Nov
															Extreme	9.74	May	20.53	Aug
Salinity (ppt)	1	30		33.16			33.28			33.26			33.08		33.20	33.08	Nov	33.28	May
	31	60		33.34			33.52			33.28			33.14		33.32	33.14	Nov	33.52	May
	61	100		33.71			33.79			33.55			33.32		33.59	33.32	Nov	33.79	May
	1	100		33.43			33.56			33.38			33.19		33.39	33.19	Nov	33.56	May
															Extreme	31.91	Feb	33.99	May
Light Transmittance (percent)	1	30		82.73			77.74			82.41			85.14		82.01	77.74	May	85.14	Nov
	31	60		87.97			86.20			86.77			87.69		87.16	86.20	May	87.97	Feb
	61	100		89.60			88.07			88.63			89.55		88.96	88.07	May	89.60	Feb
	1	100		87.05			84.41			86.21			87.67		86.34	84.41	May	87.67	Nov
															Extreme	31.75	Feb	90.48	Nov
Dissolved Oxygen (mg/L)	1	30		7.60			8.08			8.11			9.43		8.31	7.60	Feb	9.43	Nov
	31	60		6.06			4.91			5.98			8.75		6.43	4.91	May	8.75	Nov
	61	100		4.65			4.17			4.84			7.15		5.20	4.17	May	7.15	Nov
	1	100		5.96			5.57			6.16			8.32		6.50	5.57	May	8.32	Nov
															Extreme	3.51	Aug	12.34	May
pH (pH units)	1	30		8.10			8.05			8.11			8.22		8.12	8.05	May	8.22	Nov
	31	60		7.96			7.74			7.91			8.09		7.93	7.74	May	8.09	Nov
	61	100		7.84			7.67			7.79			7.95		7.81	7.67	May	7.95	Nov
	1	100		7.95			7.80			7.92			8.07		7.94	7.80	May	8.07	Nov
															Extreme	7.58	May	8.470	May

TABLE 3-1 (CONTINUED)
Water Quality Parameters Over Depth Ranges 0-30, 31-60, 61-100, and 0-100 Meters

Variable (Units)	Depth MIN	Depth MAX	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG	MIN	MON	MAX	MON
Dissolved Oxygen Saturation (percent)	1	30		88.73			97.58			99.63			118.61		101.14	88.73	Feb	118.61	Nov
	31	60		68.69			54.94			67.31			102.23		73.29	54.94	May	102.23	Nov
	61	100		51.73			46.10			53.51			80.51		57.96	46.10	May	80.51	Nov
	1	100		67.92			64.20			71.48			98.46		75.52	64.20	May	98.46	Nov
															Extreme	38.71	Aug	160.53	May
Chlorophyll Fluorescence	1	30		2.10			3.08			2.58			2.53		2.57	2.10	Feb	3.08	May
	31	60		0.66			0.22			0.71			1.63		0.81	0.22	May	1.63	Nov
	61	100		0.42			0.00			0.08			0.47		0.24	0.00	May	0.47	Nov
	1	100		1.00			1.84			1.60			1.44		1.47	1.00	Feb	1.84	May
															Extreme	0.00	May	35.14	May

Water column properties over three depth ranges are summarized in this table. (Statistics calculated using a depth weighted mean profile produced using all data from each survey)
Source: LACSD *Annual Report 2004, Palos Verdes Ocean Monitoring* (LACSD, 2005).
The "extreme" values represent the minimum and maximum values observed for the year from all stations and depths and the month in which it occurred.

3.3 Currents and Waves

Tides (and associated tidal currents), nontidal currents, and waves have the capacity to mobilize, suspend, and/or transport sediment. This is of specific interest in the PV Shelf area because of the presence of contaminated sediments. This section examines the general trends in wave and current patterns and provides a brief summary of how these factors affect the contaminated sediments. An in-depth evaluation of site-specific studies is presented in Section 5.0. The San Pedro embayment, PV Shelf, and Santa Monica embayment have unique tidal, wave, and current processes that interact to influence the distribution and transport of the contaminated effluent-affected sediments.

Currents are typically described as velocity vectors that comprise speed and direction. Water motions are continuous three-dimensional fields that can be described by time series of instantaneous three-dimensional vectors. Conventionally, these three-dimensional vectors consist of two orthogonal horizontal components (u, positive eastward or shoreward in rotated coordinates and v, positive northward or poleward in rotated coordinates) and a vertical component, w, that is significantly smaller (especially in a time-averaged sense, so it could be excluded); the vector sum of the horizontal components has a magnitude and a direction. Velocity time series can be considered as the sum of many oscillations at different frequencies and amplitudes. Low-frequency motions (with oscillations at periods longer than a few hours) are usually associated with tides, inertial motions, wind-driven currents, or circulation driven by regional-scale forcing in the atmosphere or ocean. High-frequency motions (oscillations with periods less than 2 seconds) are associated with turbulence (or instrument noise). Between these extremes are motions induced by surface waves (local wind waves or swell from distant storms with periods of 2 to 20 seconds) and internal waves (could be aperiodic, and measured in time scales of minutes to hours).

The following descriptions can be useful in interpreting information on currents and waves:

- Currents can transport sediment from one location to another. Currents can transport clean or contaminated suspended sediment into the PV Shelf Study Area from other locations, or transport contaminated sediments around and out of the study area.
- If the current flowing over the bottom substrate has sufficient speed (magnitude), it can mobilize, suspend, and transport bottom sediments, as discussed in Section 5.0.
- Studying near-bottom currents is integral to assessing sediment mobilization and resuspension by currents.
- Short-period oscillatory (back and forth) currents are associated with waves. The intensity of wave-induced currents depends on the wave height and period and the water depth. Wave-generated currents decrease with distance below the surface and might not be detectable at the bottom of the ocean.
- Wave action usually does not result in a significant net movement of water or sediment, but could be responsible for the suspension of sediments that are then transported by tidal or other advective currents.

3.3.1 Tides and Tidal Currents

Tidal currents on continental margins are one of the principle mechanisms by which pollutants are dispersed across the shelf (SAIC, 2004b). Tidal phenomena are usually divided into two types: surface and internal tides. The first is associated with the astronomical tide and is responsible for the familiar tidal rise and fall of the sea surface. If the water column has a vertical density gradient, internal waves can occur, particularly at locations with relatively large vertical changes in density (pycnoclines). Surface tidal currents are oriented along-shelf; internal tides are oriented cross-shelf (Noble et al., 2006). Based on the studies of the tidal currents in the PV Shelf Study Area, internal semidiurnal tides are usually a relatively small part of the average tidal oscillations (SAIC, 2004b). However, occasionally, internal tidal currents can be relatively large for periods of a few days and could be responsible for resuspending and transporting contaminated sediments.

The largest astronomical tidal forces are the diurnal (oscillations with periods of nearly 1 day) and semidiurnal (oscillations with periods of nearly 12 hours) tidal constituents. Tides and associated tidal currents are significantly influenced by the interaction with solid boundaries of the major land masses. The semidiurnal M2 tidal constituent dominates tidal currents along the PV Shelf (Wiberg et al., 2002; Noble et al., 2006). Sea level oscillations are approximately 50 cm over the shelf (Noble et al., 2006).

LACSD conducted extensive current-meter studies along the PV Shelf, which included tidal analysis, and concluded that barotropic (surface) tides drove along-isobath currents on the PV Shelf. The magnitude of depth-averaged, semidiurnal tidal currents was less than 10 cm/sec except south and southeast of Point Fermin, where the San Pedro Shelf broadens. Diurnal tidal currents were less than 10 cm/sec in the PV Shelf Study Area.

Tidal information provided by NOAA Tide Gauge Station Number 941, located in the Port of Los Angeles, indicated the mean tidal range is 1.16 m (3.81 feet) and the diurnal range is 1.67 m (5.49 feet). The minimum tide of record (timeframe of 1923 to 2006) was -0.83 m (-2.73 feet) below mean lower low water (MLLW). The maximum water level of record was 0.71 m (2.33 feet) above mean higher high water (MHHW).

Internal semidiurnal tides travel in wave patterns at density gradients (pycnoclines). Studies conducted by LACSD indicated that M2 internal tidal motion on the PV Shelf was clearly demonstrated in the temperature data during winter with semidiurnal vertical excursions of approximately 25 to 30 m in the thermocline (SAIC, 2004b).

3.3.2 Nontidal Currents

The long-term, mean current velocity at most measurement sites at the PV Shelf Study Area is toward the northwest. However, monthly, and even seasonal mean current velocities vary considerably. Currents in the water column over the PV Shelf Study Area are not uniform, and can vary significantly with depth, time, and location. Dominant circulation patterns in the SCB include the southward-flowing California Current, the northward-flowing California Countercurrent, and seasonal influences by the northward-trending Davidson Countercurrent (Drake, 1994; Hickey, 1992). The primary circulation patterns (for depth-averaged currents) are shown on Figure 1-2.

Far offshore of the PV Shelf, the California Current flows southward, over deep water, along the western edge of the SCB. Between the California Current and the nearshore continental shelf, a large counterclockwise eddy centered over the islands offshore of Santa Monica and San Pedro Bays, known as the Southern California eddy, generally occurs within the SCB (Hickey, 1992; Noble et al., 2002). The currents on the eastern edge of this eddy come close to the continental margin, causing poleward flow over the continental slope during most of the year, although they could be weak or nonexistent in the spring (Noble et al., 2002; Bray et al., 1999). The California Countercurrent, a poleward flowing undercurrent, enters the bight from the south along the continental margin. This undercurrent increases the tendency for poleward flow over the slope of the Palos Verdes Peninsula (Noble et al., 2002). The surface expression of this poleward flow is often known as the Davidson Countercurrent (Hickey, 1992; Noble et al., 2002). Smaller-scale regional currents also occur and are best described in site-specific terms.

The Palos Verdes Peninsula extends prominently into the bight, and is bordered by embayments. This geographic configuration produces a complex current environment. Mean currents vary significantly with season and location (SAIC, 2004b). The current variance over the Palos Verdes margin is usually forced by fluctuations in the along-shelf pressure gradients, rather than local wind stress. Large-scale forcing (large-scale pressure gradients) sets up currents in the adjacent embayments, which then flow onto the shelf and over the slope (Noble et al., 2002). Currents flow toward the northwest along the PV Shelf and Upper Slope and generally have maximum speeds of approximately 20 to 30 cm/sec (Noble et al., 2002). A comprehensive study of the central SCB shows that subtidal currents are dominated by relatively long durations (10 to 25 days) (Hickey et al., 2003).

Surface currents on the PV Shelf are most likely wind- and wave-dominated and are unlikely to be strong except during storms. Mean surface currents on the PV Shelf are less than 5 cm/sec (LACSD, 1996; Palermo et al., 1999). Subsurface currents on the PV Shelf are also usually weak. During fair weather, subsurface currents range from 7 to 10 cm/sec, with maximum along-shelf currents of up to 40 cm/sec and cross-shelf currents of 20 cm/sec (LACSD, 1996; Palermo et al., 1999). Although currents oscillate alongshore and crosshore, long-term average flow is to the northwest, parallel to bathymetric contours. Mean currents a few meters from the bottom of the ocean were less than 10 cm/sec and are predicted to be less in the bottom boundary layer (SAIC, 2004b).

3.3.3 Waves

Compared with other coastal areas in Southern California, the area off the Palos Verdes Peninsula has a relatively mild wave climate, primarily because of the sheltering effects of the offshore islands, with Santa Catalina and San Clemente providing protection from waves approaching from the south. Waves are most severe in the winter (December to March) and mildest in the summer and early fall (July to October). Mean wave height is 1.0 m, with significant waves greater than 1.5 m occurring only 18 percent of the time. Higher waves usually approach from west to south. Large winter storms have produced maximum significant wave heights of 3 to 4 m (Wiberg et al., 2002).

Sediment resuspended by wave events (which are generally not correlated with currents) could go in any direction but, on average, the transport direction is along-shelf toward the northwest. Wave action frequently suspends bottom sediments at depths less than 30 m.

A 17-year record of wave events for the PV Shelf (Wiberg et al., 2002) indicated that waves with orbital velocities sufficient to reach the bottom at 60 m occur, on average, 10 times per year with an average duration of 1.6 days. The number of wave events drops to 3 at 90 m. One wave event was indicated to have suspended bottom sediment at a depth of 170 m.

3.3.4 Effects on Contaminated Sediments

Sediment transport follows predominant current flow directions near the bottom (net near-bottom velocity patterns), extending northwestward along the PV Shelf (Drake, 1994). This also is reflected in the shape of the effluent-affected sediment deposit and previously defined contaminant "footprint" from the LACSD outfalls. Because of the local wave climate and continuous resuspension and sorting, the effluent deposit does not extend shoreward from the 30-m isobath (Lee, 1994).

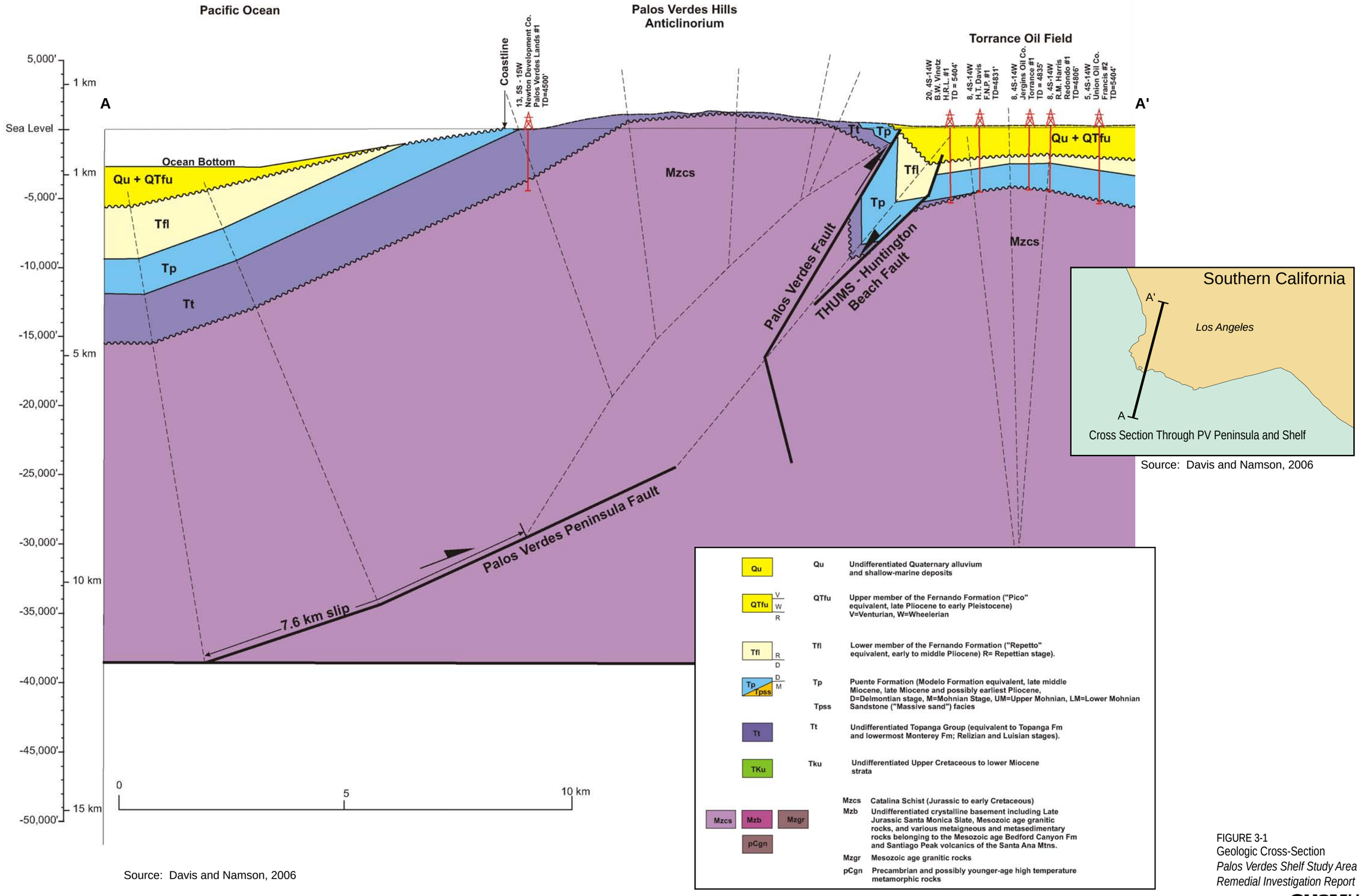
On a smaller scale, the local PV Shelf currents generally flow to the northwest from the PV Shelf Study Area toward Santa Monica Bay, where the currents meet a south-flowing current from Santa Monica Bay. Although currents tend to move contaminants from the PV Shelf toward Santa Monica Bay, the flows from Santa Monica Bay typically reduce contaminant movement from progressing farther northward or northwestward (Hickey et al., 2002). The predominant southerly flows from Santa Monica Bay tend to push particulate-associated contaminants from the PV Shelf west off the southern boundary of Santa Monica Bay to deeper water. When the Santa Monica Bay south-flowing currents are weak, contaminated sediments could enter the southern portion of Santa Monica Bay, but northward movement of some sediments is limited by the Redondo Canyon. Redondo Canyon intercepts bedload transport, but during storms fine sediment that travels as suspended load can be transported over the canyon because the settling velocity in storm conditions is too slow.

3.4 Geology

3.4.1 Geologic Setting

The PV Shelf and Peninsula are parts of the California continental borderland, which extends from Santa Barbara to Vizcaino Peninsula in Baja California. It includes the Los Angeles Basin and the offshore islands of Southern California (Francis et al., 1999). The Palos Verdes Peninsula is a tectonic fault block of seafloor sediments and volcanic debris draped atop a submerged mountain of metamorphic rocks that began rising out of the Pacific Ocean 1.5 million years ago (Morris, 2000). The PV Shelf is a submerged continuation of the peninsula and extends approximately 4 km offshore to the southwest.

As shown on Figure 3-1, the rocks underlying the PV Shelf indicate at least two cycles of marine transgression and regression. Basement rock in the region is the Tertiary Catalina Schist, a remnant of the subducted Farralon Plate. The schist is disconformably succeeded by approximately 1,000 m of mid-Miocene rocks of either the Topanga Group, which includes the Topanga Formation and the Monterey Formation (Davis and Namson, 2006), or the Monterey Formation by itself (USGS, 2004).



Source: Davis and Namson, 2006

Source: Davis and Namson, 2006

FIGURE 3-1
Geologic Cross-Section
Palos Verdes Shelf Study Area
Remedial Investigation Report

The Topanga Formation consists of fossiliferous marine sandstone and conglomerates in its basal layers, which give way to finer marine shelf sediment deposits higher up in its sequence.

Lava flows erupted upon or within the sediments during the early phases of deposition, leaving behind significant basalts and volcanic ash within the marine sediments. The Monterey Formation is a deep marine deposit consisting of diatomaceous mudstone and shale. Much of the surface outcrop on the Palos Verdes Peninsula consists of Topanga Group mudstone, volcanic tuff, and basalt (USGS, 2004).

The Topanga Group/Monterey Formation is succeeded by approximately 750 m of the late-Miocene Puente Formation. The Puente Formation is a sequence of deep marine shale, graded sandstone beds of subsea fan origin, a diatomaceous fine-grained deep basin deposit, and a mudstone-to-sandstone sequence that records the eventual shallowing of the northern part of the Los Angeles Basin (Eisentraut and Cooper, 2002). The present-day shoreline of the Palos Verdes Peninsula is intersected by the outcropping of the Puente Formation (Davis and Namson, 2006).

Overlying the Puente Formation are coastal and shallow marine deposits of the Pliocene Fernando Formation. The Fernando Formation might have little or no sea-floor outcropping because it is disconformably covered by quaternary sea floor and continental margin sediments (Davis and Namson, 2006). This geologic sequence describes rocks that were first dragged deep into the earth on a sinking plate to form the Catalina schist, and were uplifted and eroded, dropped to deep ocean depths to catch the late Topanga and Monterey Formations, and later uplifted during deposition of the Puente and Fernando Formations (Morris, 2000). The Tertiary rocks under the Palos Verdes Peninsula have undergone rapid uplift during the Quaternary period, causing a flight of wave-cut terraces to develop (USGS, 2004). The local Tertiary formations and upper surface of the Catalina Schist dip westward at approximately 40 degrees.

The Portuguese Bend Landslide covers approximately 260 acres on the seaward (west) side of the Palos Verdes Peninsula (Figure 1-1). This landslide results from an active mass-wasting process that indicates local instability in the rocks of the Palos Verdes Peninsula. Recent movement in the landslide came from a 50-m bed of volcanic ash that has been altered to bentonite. Recent landslide activity most likely has occurred because of the dipping bedding plane and the tendency of bentonite to lose cohesiveness when wet (Morris, 2000). Movement of the landslide is correlated with rainfall and engineering practices, such as drainage and dewatering by pumping from wells, which has stabilized the landslide in the past. Continued efforts, which might not be entirely effective during rainy spells, are needed to stabilize the landslide.

The thickness of the PV Shelf sediments varies from 32 m on the southeastern part of the shelf to less than 10 m near Point Vicente. Owing to strong currents, a patchy thin sediment layer with areas of bare rock occurs at the PV Shelf break (Palermo, 1994). Similar bedrock outcrops also occur over the sea floor to the east of the outfall and over the Redondo Shelf to the west (Lee, 1994). Less than 1 m of sediment covers the Redondo Shelf (Drake, 1994). In the immediate area of the PV Shelf, sediments southeast of the outfall are eroding and being deposited to the northwest (Zeng and Venkatesan, 1999).

3.4.2 Sedimentology

Sediments in the PV Shelf come from several sources: natural sources, such as local urban rivers, cliff erosion, and the San Pedro Basin, as well as anthropogenic sources, such as the Portuguese Bend Landslide and the discharge from the LACSD outfalls at White Point (Lee et al., 2002). The primary sources of sediments in the last half century are the Portuguese Bend Landslide, an ancient landslide that was reactivated in 1956 during construction of a road, and the LACSD outfalls, which began discharging in 1937. After it reaches the beach, littoral currents move the landslide material southeast toward White Point, while bottom currents at depths of 30 m or more tend to move the material northwest (LACSD, 2005). Sediments in San Monica Bay are usually transported south, but Redondo Canyon prevents them from being transported onto beach and near-shore zones of the PV Shelf (Kolpack, 1987).

The Portuguese Bend Landslide has traveled an average of 150 to 175 m downslope since reactivation in 1956. The landslide movement accelerated in years of heavy rainfall (late 1970s and mid- to late 1990s), but mitigation efforts significantly slowed the movement of the landslide and source of sediments to the PV Shelf Study Area by the early 2000s (Kayen et al., 2002).

The discharge of solids from the LACSD outfalls peaked in 1971 and has steadily declined in response to a series of treatment plant upgrades, culminating in the implementation of full secondary treatment at the JWPCP in November 2002, which reduced the TSS in the effluent (Figure 1-4).

Kayen et al. (2002) estimates that between 1937 and 1987 the LACSD outfalls contributed 4.0 million metric ton (7.6 million m^3) of sediment to the PV Shelf and that the Portuguese Bend Landslide has contributed between 5.7 and 9.4 million metric tons (3.7 to 6 million m^3). Myers (1974) has documented that the effluent solids have a significantly higher organic matter content than the Portuguese Bend Landslide sediment.

3.4.2.1 Description of Effluent-Affected Deposit

The effluent-affected deposit has been described as an elliptical mound with a height of 60 cm, and with the long axis extending northwest along the 50- to 70-m depth contours (LACSD, 2005). The southeast end of the deposit has a steep rise while the northwest end has a gentle slope. The shore side of the effluent-affected deposit ends relatively sharply at the 30-m depth contour, while the ocean side extends over the PV Shelf break to the mid- to lower shelf (LACSD, 2005).

Studies by the USGS in 1992 and 1993 showed that the layer of DDT-contaminated sediment ranges from 5 to 60 cm thick, with the highest concentrations located near the outfall pipes. The sediments at the PV Shelf can be considered to have the following three different layers:

- **Surficial Sediments –** These sediments in the upper 15 to 20 cm are characterized by relatively low concentrations of DDTs, low bulk densities, and slightly elevated organic carbon concentrations. This biologically active layer of sediment likely has been deposited from 1971 to the present during a period of declining DDT concentrations in the LACSD effluent as a result of source control (Eganhouse and Pontolillo, 2000). This layer is characterized by declining and fairly uniform concentrations of waste-

derived contaminants (e.g. about 2 ppm DDTs along the outfall depth contour), except in the immediate outfall vicinity where elevated contaminant levels persist (about 200 ppm DDTs in 2004). Bulk densities are increasing in the surface layer and presently are around 1 gram per cubic centimeter (g/cm^3) (Sherwood et al., 2006). Surface sediments are more dense than the heavily contaminated layer, but less dense than the underlying native sediment layer (Eganhouse and Pontolillo, 2000). Full secondary treatment at the JWPCP was implemented in 2002, further reducing sediment output from the diffuser. The nature and effect of this modern (post-2002) effluent has not been fully quantified, but likely results in a near-zero contribution to effluent-derived sediments in the PV Shelf Study Area.

- **Heavily Contaminated Sediment** – Beneath the surficial sediment exists a more heavily contaminated layer 20 to 25 cm thick deposited from 1937 to 1970, before treatment improvements at JWPCP were designed to remove suspended solids from the discharge. This period included the highest output of sediments and contaminants from the outfall. This layer contains concentrations of DDTs and PCBs exceeding 200 mg/kg and 20 mg/kg, respectively. This layer was not contaminated by DDTs until Montrose operations began in 1947. Drake et al. (1994) indicated that this layer has low bulk density (1.2 to 1.3 g/cm^3) and was predominately silt and clay.
- **Native Sediments** – Below the effluent-affected sediments, there is a layer of slightly to noncontaminated sediments of varying thickness. The native sediment layer is characterized by 80 percent sand-sized particles on the inner-shelf (water depth less than 40 m), to about 80 percent silt and clay-sized particles on the outer shelf and slope (Lee, 1994). These native sediments have higher bulk densities (1.8 to 2.1 g/cm^3) and lower organic carbon concentrations (less than or equal to 1 percent) than the effluent-affected layer, which has a bulk density of 1.2 to 1.3 g/cm^3. The depth of this natural sediment layer is of variable thickness (Eganhouse and Pontolillo, 2000) and can be as thick as 30 m (Hampton et al., 2002; Sherwood et al., 2002).

The total volume of contaminated sediments was estimated at over 9 million m^3 (Lee et al., 2002). The accumulated masses of DDTs and PCBs in sediments at the PV Shelf Study Area have been estimated to be 100 and 10 metric tons, respectively (EPA, 2001a).

Section 4.0 further describes the nature and extent of contamination.

3.4.2.2 Sediment Properties

The 2004 geotechnical measurement program (described in Section 2.0) and other investigations (including the LACSD Ocean Monitoring Program) have resulted in the collection of a significant amount of geotechnical data on the sediments at the PV Shelf, including grain size, bulk density, resistivity, water content, and total organic carbon. The side-scan sonar survey conducted as part of the geotechnical measurement program indicated that softer, finer-grained sediments cover most of the study area. A region with generally continuous coarser sediments and rocky patches exists in the near-shore area, around the outfall pipes, and to the northwest (Figure 3-2).

The sediment profile imaging was used to determine sediment types and benthic habitat classifications. The SPI indicated that the surface sediments at a majority of the sampling stations were fine-grained, tan and gray sandy silt (Figure 3-3). However, the SPI also

indicated that a significant number of the stations in the southeast had surface sediments consisting of silty sand. Northwest of the outfalls, the surface sediments are finer, consisting primarily of silts. In addition to the SPI, plan-view images were used to provide additional information on surface sediment types, physical and biogenic surface features, and debris.

The plan-view images indicated that a few of the stations displayed bedforms (visible ripples), particularly in the northwest sample area. The plan-view images indicated that the majority of the southeast and outfall stations contained shell material.

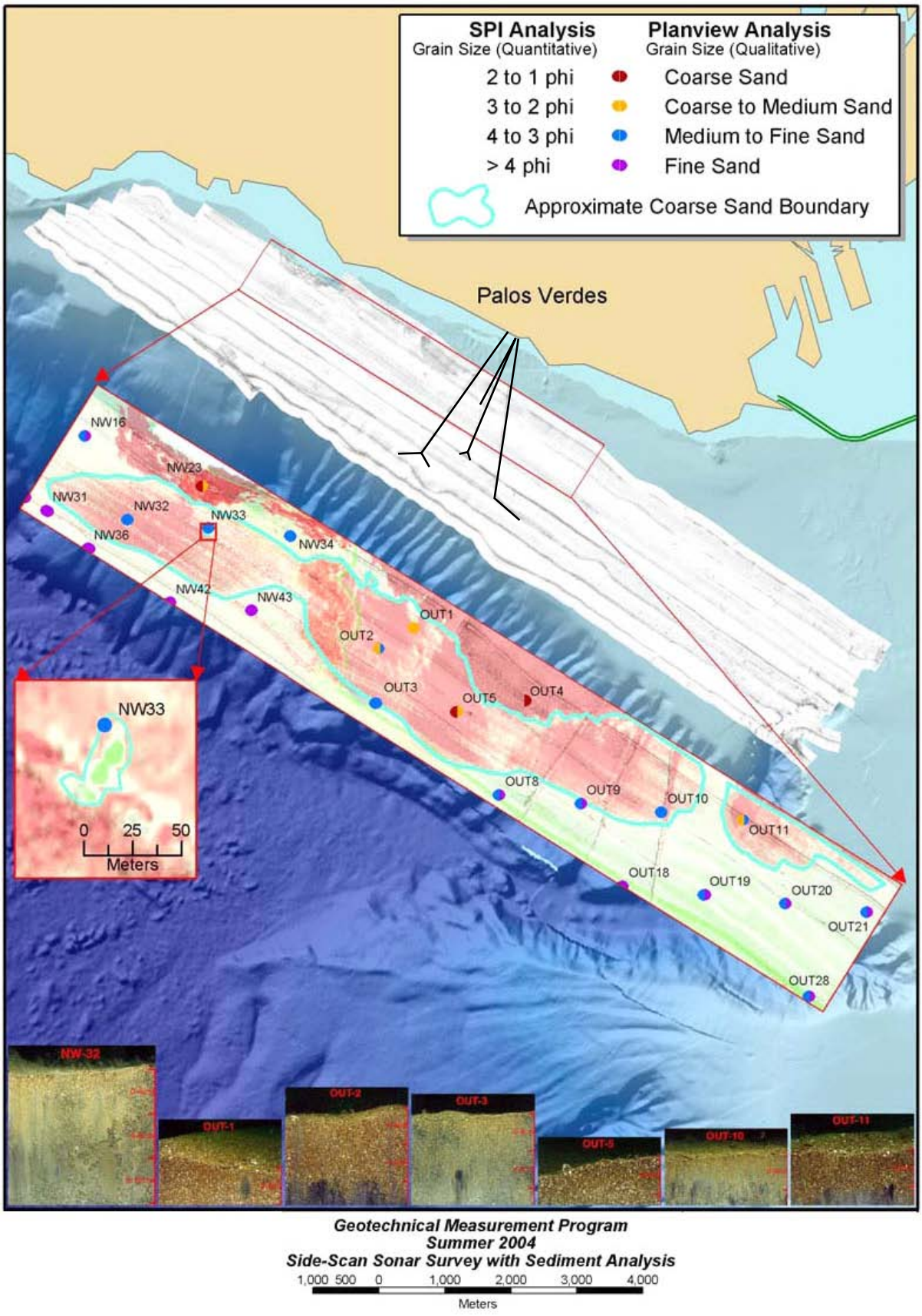
Figure 3-4 provides a view of the grain size, bulk density, and TOC results for this surface sediment (0 to 4 cm) at each of the geotechnical stations sampled during the geotechnical measurement program. Consistent with the results from many of the other complementary data sets, the laboratory geotechnical analyses showed that the finer-grained, less dense, and higher TOC surface sediments generally fell to the northwest of the outfall pipes, primarily in waters deeper than 50 m. To the south and east of the outfalls, the surface sediments were consistently coarser-grained and denser, and had lower TOC concentrations. Typically, sands (silicate and carbonate) do not promote binding of organic carbon, whereas the fine-grained sediments (e.g., silts and clays) bind readily with organic carbon; therefore, higher TOC concentrations are usually in fine-grained sediments. However, at the PV Shelf Study Area, the coarse sediments near the outfalls have higher TOC content because of their proximity to the outfall.

The 2004 LACSD Ocean Monitoring Program also provided data on sediment characteristics such as grain size, organic nitrogen, TOC, and hydrogen sulfide (H_2S) of pore water from 44 sampling stations across the PV Shelf Study Area. A summary of the LACSD data is shown on Figure 3-5. The maps indicate that sediment becomes finer as distance from the shoreline increases. The finest sediments at the outfall depth are located in an elliptical pattern northwest of the LACSD outfalls and near the Redondo Canyon (LACSD, 2005).

3.4.3 Seismology

The Palos Verdes Fault is one of several faults in the area that comprise the Palos Verdes Fault Zone. This fault zone is only one of several major fault zones in the Los Angeles Basin and adjoining offshore areas in the California continental boundary (e.g., the Newport-Inglewood and Thums-Huntington Beach Fault Zones), as shown on Figure 3-6. The Palos Verdes Fault is a major fault that extends northwest to southeast, approximately parallel to the southwest coastline. The fault cuts the land northeast of the Palos Verdes Peninsula approximately 6 km from the southwest shore, and continues southeastward through the San Pedro Shelf (USGS, 2004).

Based on seismic reflection data, some researchers have concluded that the active fault does not extend northward into Santa Monica Bay (Nardin and Henyey, 1978). Near the Palos Verdes Peninsula, the total fault-slip rate appears to be around 3 mm/year based on analysis of wave-cut terraces and offset stream courses (USGS, 2004). The Palos Verdes Fault dips westward and is probably an oblique-slip fault (USGS, 2004), although other researchers assume that mainly thrust or reverse movement occurs (Namson and Davis, 1990; Shaw and Suppe, 1996). Achieving a meaningful assessment of the earthquake threat posed by the local faults will require that conceptual differences among researchers be resolved.



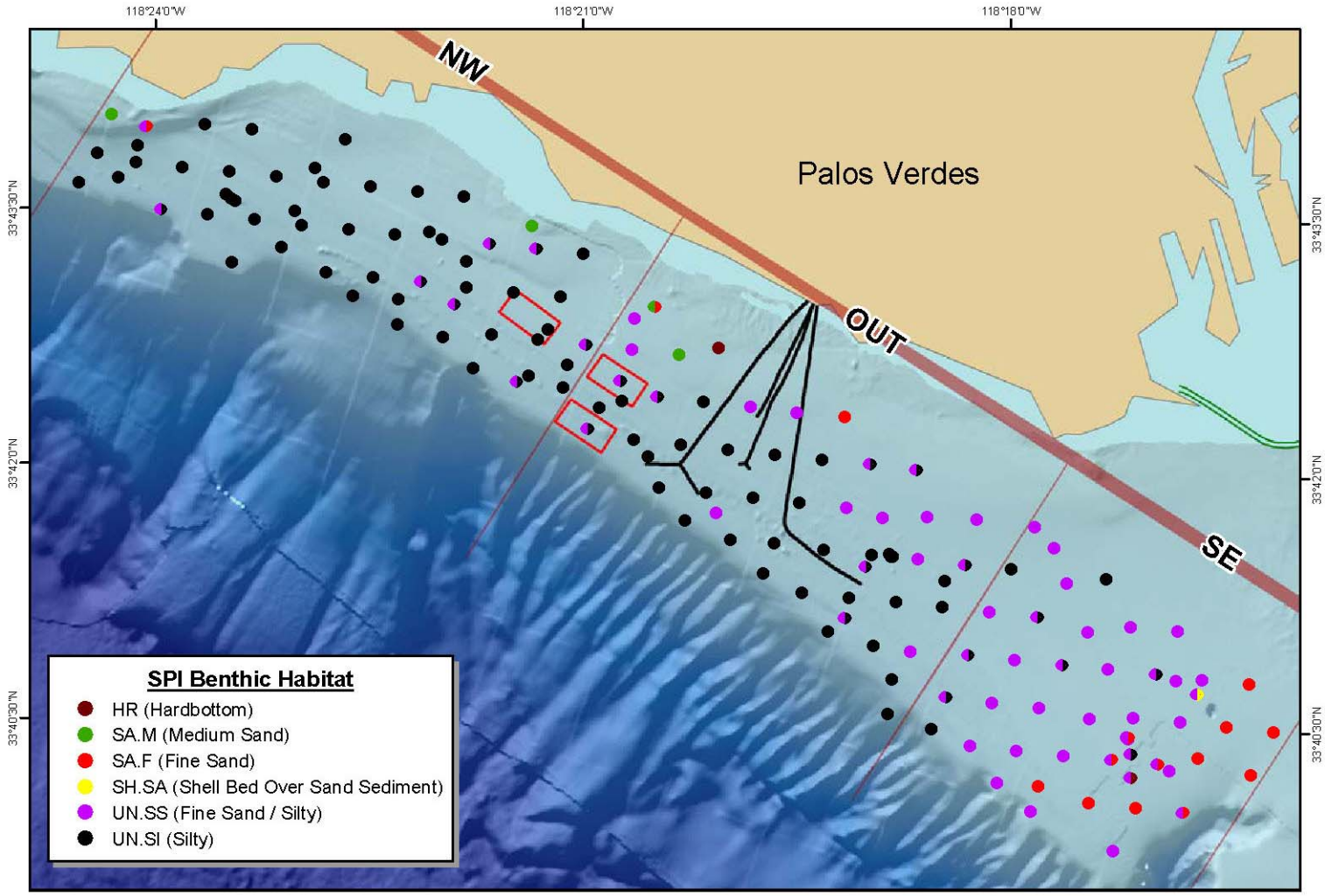
Geotechnical Measurement Program
Summer 2004
Side-Scan Sonar Survey with Sediment Analysis

1,000 500 0 1,000 2,000 3,000 4,000
Meters

North

FIGURE 3-2
Sediment Grain Size Estimates from Sediment Profile and Plan View Imaging Analysis
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: Data Report for the Summer 2004 Geotechnical Measurement Program Conducted on the Palos Verdes Shelf, SAIC, June 2005.



Note that NW, OUT, and SE are zones used by SAIC for sample labeling.

FIGURE 3-3
Benthic Habitat Classifications at the July 2004 SPI Stations over the Palos Verdes Shelf
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: Data Report for the Summer 2004 Geotechnical Measurement Program Conducted on the Palos Verdes Shelf, SAIC, June 2005.

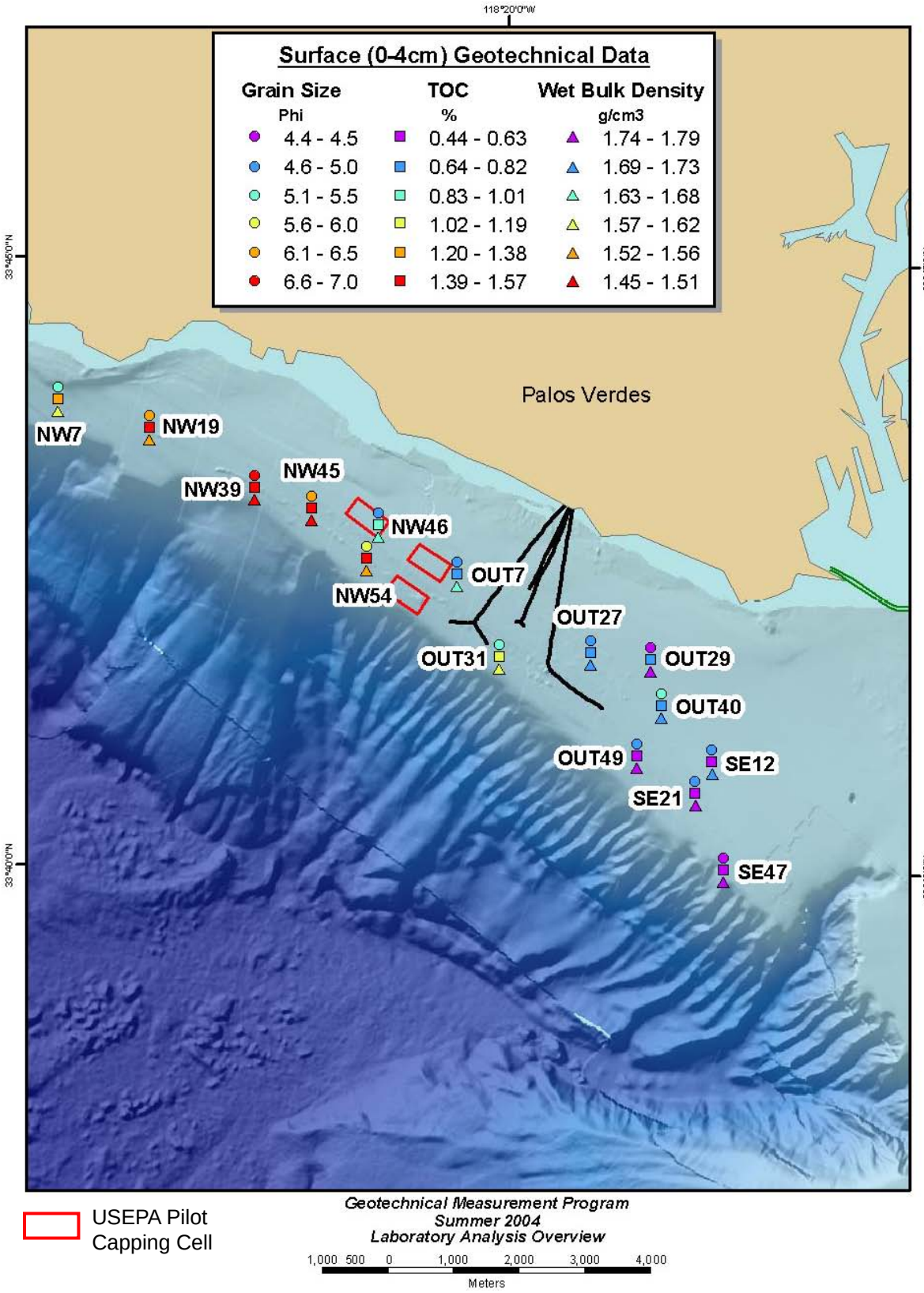


FIGURE 3-4
Overview of the Laboratory Geotechnical Results within the Surface Interval (0 to 4 cm) at each of the Detailed Geotechnical Station
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: Data Report for the Summer 2004 Geotechnical Measurement Program Conducted on the Palos Verdes Shelf, SAIC, June 2005.

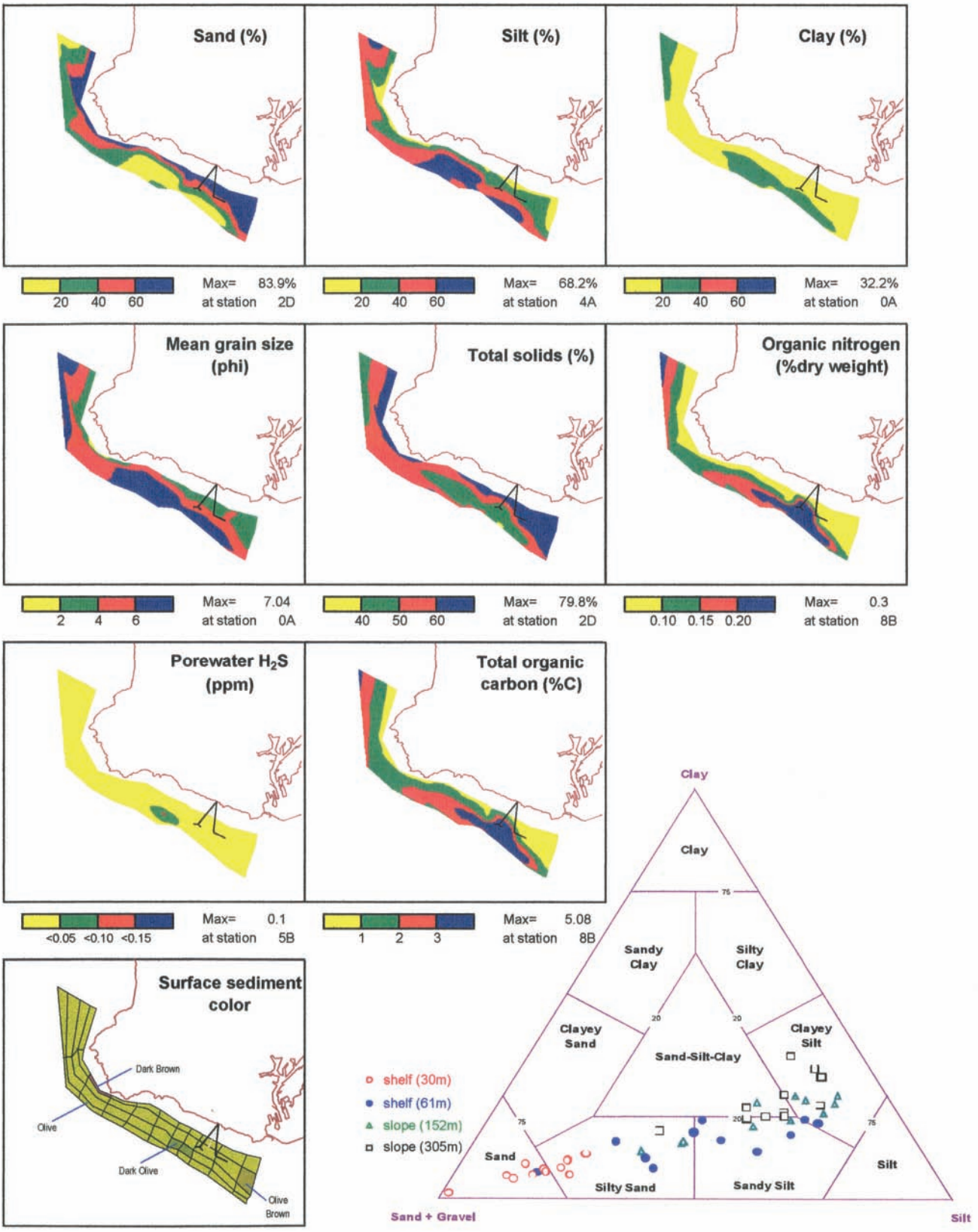


FIGURE 3-5
Sediment Properties of PV Shelf Sediments
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: Annual Report 2004, Palos Verdes Ocean Monitoring, LACSD, 2005.

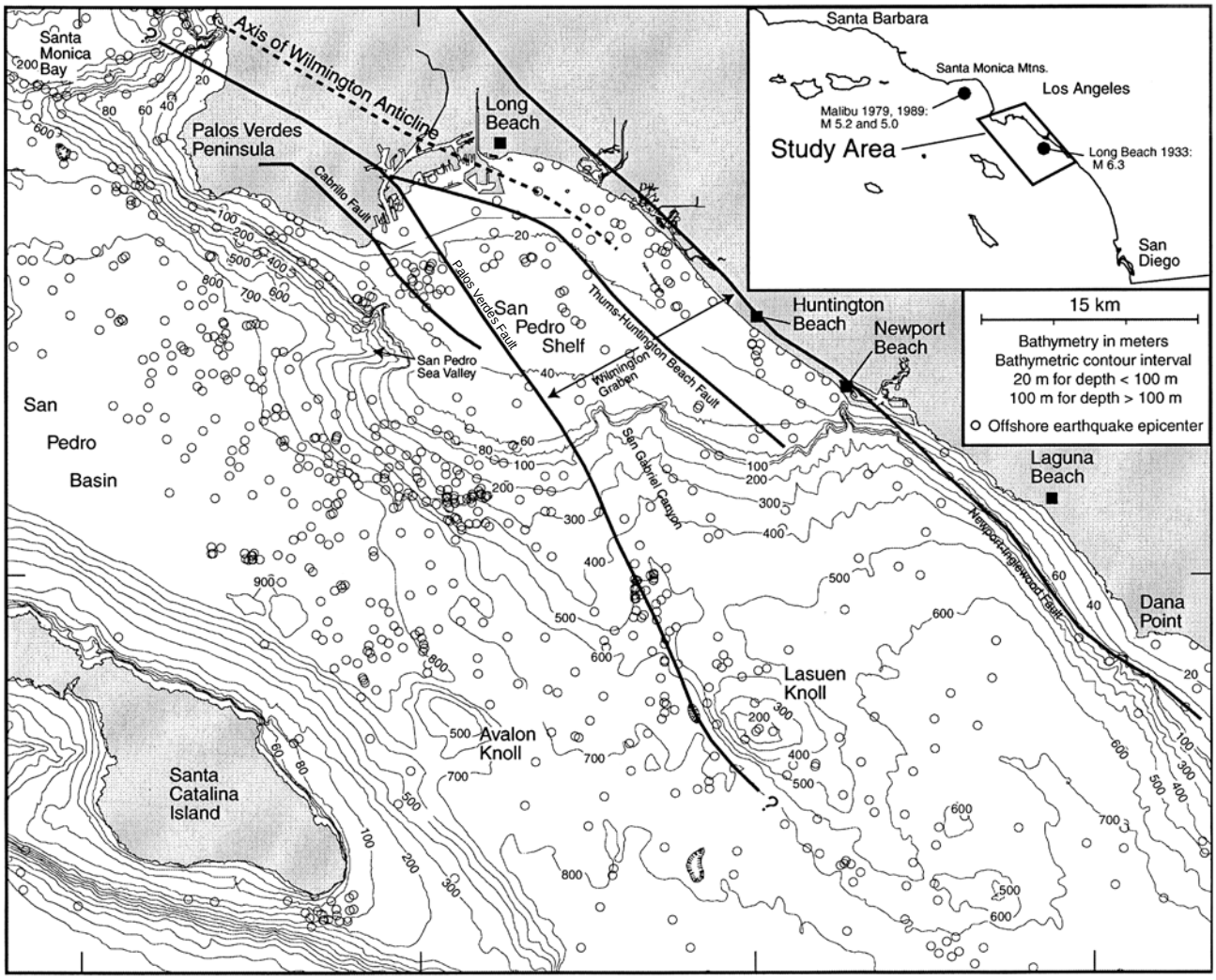


FIGURE 3-6
Main Faults and Earthquake Epicenters Near PV Shelf
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: USGS Professional Paper 1687, "Marine Geology and Earthquake Hazards of the San Pedro Shelf Region, Southern California", 2004.

However, one estimate suggests that the Palos Verdes Fault could produce an earthquake of magnitude (M) 7 (Richter scale) (McNeilan et al., 1996), which is considered a major earthquake, or one that is capable of damaging buildings more than 100 km (62 miles) from the epicenter. Recent earthquakes at Whittier Narrows (occurred in 1987 at M 5.9) and at Northridge (occurred in 1994 at M 6.7) provide a measure of the regional seismic hazard along onshore faults. Because ongoing landslide activity exists on Palos Verdes Peninsula under relatively calm seismic conditions, large, sudden mass-wasting events from the peninsula could occur during a significant earthquake. Approximately 0.8 cubic kilometers of sediment was involved in the submarine Palos Verdes debris avalanche that occurred 7,500 years ago (Normark et al., 2004).

3.5 Ecology

The PV Shelf is characterized by (1) soft-bottom subtidal habitat, including invertebrate and fish communities, over most of the continental shelf and slope region to water depths of approximately 800 m; (2) hard-bottom habitat, including some kelp bed areas and associated invertebrate, fish, and algae communities, from shore to at least 20 m deep; and (3) pelagic (i.e., water column) zones, representing critical habitat for fish, invertebrates, birds, and mammals from near the bottom to the surface. The exception to this pattern is the hard-substrate, artificial reef habitat represented by the wastewater outfall structure that extends primarily over the soft bottom to a depth of approximately 60 m, some scattered hard-bottom areas on the PV Shelf and more extensive hard-bottom areas along some parts of the shelf break. Sediments near the outfall are fine-grained, organically enriched, and variably contaminated as a result of historic discharges (LACSD, 2002). Areas of highest chemical contaminant concentrations are located in the soft-bottom habitat at some depth below the sediment surface.

Diverse marine habitats and biological communities typify the PV Shelf and the broader SCB. The special-status ecological receptors that either have been observed or are expected to occur in the SCB are listed in Table 3-2, along with observed or expected special-status species.

TABLE 3-2
Summary of Special-status Wildlife Species Potentially Occurring in the Southern California Bight Marine Environment

Common Name	Scientific Name	Federal Status	State Status
Birds			
Ashy storm petrel	*Oceanodroma homochroa*		CSC
Baird's sandpiper	*Calidrus bairdii*		CSC
Bald eagle	*Haliaeetus leucocephalus*		CE
Black storm petrel	*Oceanodroma melania*		CSC
Black tern	*Chlidonias niger*		CSC
California black rail	*Laterallus jamaicensis coturniculus*	FE	CT
California brown pelican	*Pelecanus occidentalis californicus*	FE	CE

TABLE 3-2
Summary of Special-status Wildlife Species Potentially Occurring in the Southern California Bight Marine Environment

Common Name	Scientific Name	Federal Status	State Status
California gull	*Larus californicus*		CSC
California least tern	*Sterna antillarum browni*	FE	CE
Common loon	*Gavia immer*		CSC
Double-crested cormorant	*Phalacrocorax auritus*		CSC
Elegant tern	*Sterna elegans*		CSC
Fork-tailed storm petrel	*Oceanodroma furcata*		CSC
Light-footed clapper rail	*Rallus longirostris levipes*	FE	CE
Long-billed curlew	*Numenius americanus*		CSC
Marbled murrelet	*Brachyrampus marmoratus*	FT	CE
Osprey	*Pandion haliaetus*		CSC
Peregrine falcon	*Falco peregrinus*	[a]	
Rhinoceros auklet	*Cerorhinca monocerata*		CSC
San Clemente loggerhead shrike	*Lanius ludovicianus mearnsi*	FE	
Tufted puffin	*Fratercula cirrhata*		CSC
Western snowy plover	*Charadrius alexandrinus nivosus*	FT	CSC
Xantus's murrelet	*Synthliobramphus hypoleucus*		SCT
Mammals			
Blue whale	*Balaenoptera musculus*	FE	
California sea lion	*Zalophus californianus*		CP
Fin whale	*Balaenoptera physalus*	FE	
Harbor seal	*Phoca vitulina*		CP
Humpback whale	*Megaptera novaeangliae*	FE	
Northern elephant seal	*Mirounga angustirostrus*		CFP
Northern fur-seal	*Callorhinus ursinus*		CP
Northern sea lion	*Eumetopias jubatus*	FT	CP
Sei whale	*Balaenoptera borealis*	FE	
Southern sea otter	*Enhydra lutris nereis*	FT	CFP

TABLE 3-2
Summary of Special-status Wildlife Species Potentially Occurring in the Southern California Bight Marine Environment

Common Name	Scientific Name	Federal Status	State Status
Sperm whale	*Physeter macrocephalus*	FE	

Notes:
[a] Peregrine falcon is a former federally endangered species that was delisted on August 25, 1999. Its current status is "Delisted Taxon, Recovered, Being Monitored First Five Years."

Sources: CDFG, Natural Diversity Data Base (2002); Ventura Fish and Wildlife Office website.
Counties searched: Ventura, Santa Barbara and Los Angeles; and Channel Islands (Anacapa, San Clemente, Santa Barbara, San Miguel, Santa Rosa, Santa Cruz, Santa Catalina, San Nicolas)

Federal Status Codes:
FE federally listed, endangered
FT federally listed, threatened

State Status Codes:
CE California-listed, endangered
CT California-listed, threatened
CFP California fully protected
CP California-protected
CSC California species of special concern
SCT State Candidate Threatened (California)

3.5.1 Soft-bottom Subtidal Habitats

Soft-bottom habitats with gradations from sand to mud typify most of the sea bottom that is deeper than approximately 20 m off the Palos Verdes Peninsula. Key inhabitants of soft-bottom subtidal habitats include infaunal and epifaunal invertebrates, both of which live in close association with the sediments and typically reside (especially infauna) in discrete areas as adults. Numerous bottom-feeding fish also are characteristic of these habitats. Typically, bottom-feeding fish are much more motile than the invertebrates, and some fish species migrate over broad depth ranges.

3.5.2 Infaunal Community

The infaunal community (invertebrates living in soft sediments) on the PV Shelf and slope is dominated by deposit feeders, primarily polychaete worms, crustaceans, and small bivalves, comprising 75 percent, 9 percent, and 7 percent, respectively, of the total abundance in benthic macrofauna collected at 44 monitoring stations in 2004 (LACSD, 2005). Most of the dominant species show significant correlations in their distribution with depth, grain size, and sediment chemistry within the PV Shelf.

The macrofauna included the full range of feeding types, such as deposit feeders, suspension feeders, and predators representing numerous phyla. The community is numerically dominated by surface and subsurface deposit-feeding polychaete worms, primarily in the families Cirratulidae, Spionidae, and Capitellidae. In the 2004 survey, more than 600 species were recorded; approximately half of them were polychaete worms. Twenty-seven species comprised more than 80 percent of total abundance.

The benthic macrofaunal community represents an important food source for many fish species and other invertebrates. In the 2004 survey, the most abundant species (ranked) were the polychaete worms *Spiophanes duplex, Mediomastus sp*., *Spiophanes berkeleyorum, Aphelochaeta glandari, Prionospio jubata, Paraprionospio pinnata, A. monilaris, Chloeia pinnata, Heterophoxus oculatus, Polycirrus sp. A*, *Spiochaetopteris costarum,* and the phoronid worm *Phoronis sp.*

Macrofaunal abundance is elevated near the outfall, and shoreward, typically exceeding 7,500 organisms per square meter (m^2). Numbers generally decline proceeding to the northwest and offshore. Changes in abundance have occurred in the past decade in response to climatic change and the decrease of discharged organic matter from the outfall. Higher abundances in the 1970s and 1980s typically exceeded 10,000 per m^2 along most of the PV Shelf. Since the early 1990s, declines have been evident over much of the PV Shelf, and currently are typified by abundances in the range of 2,500 to 7,500 organisms per m^2.

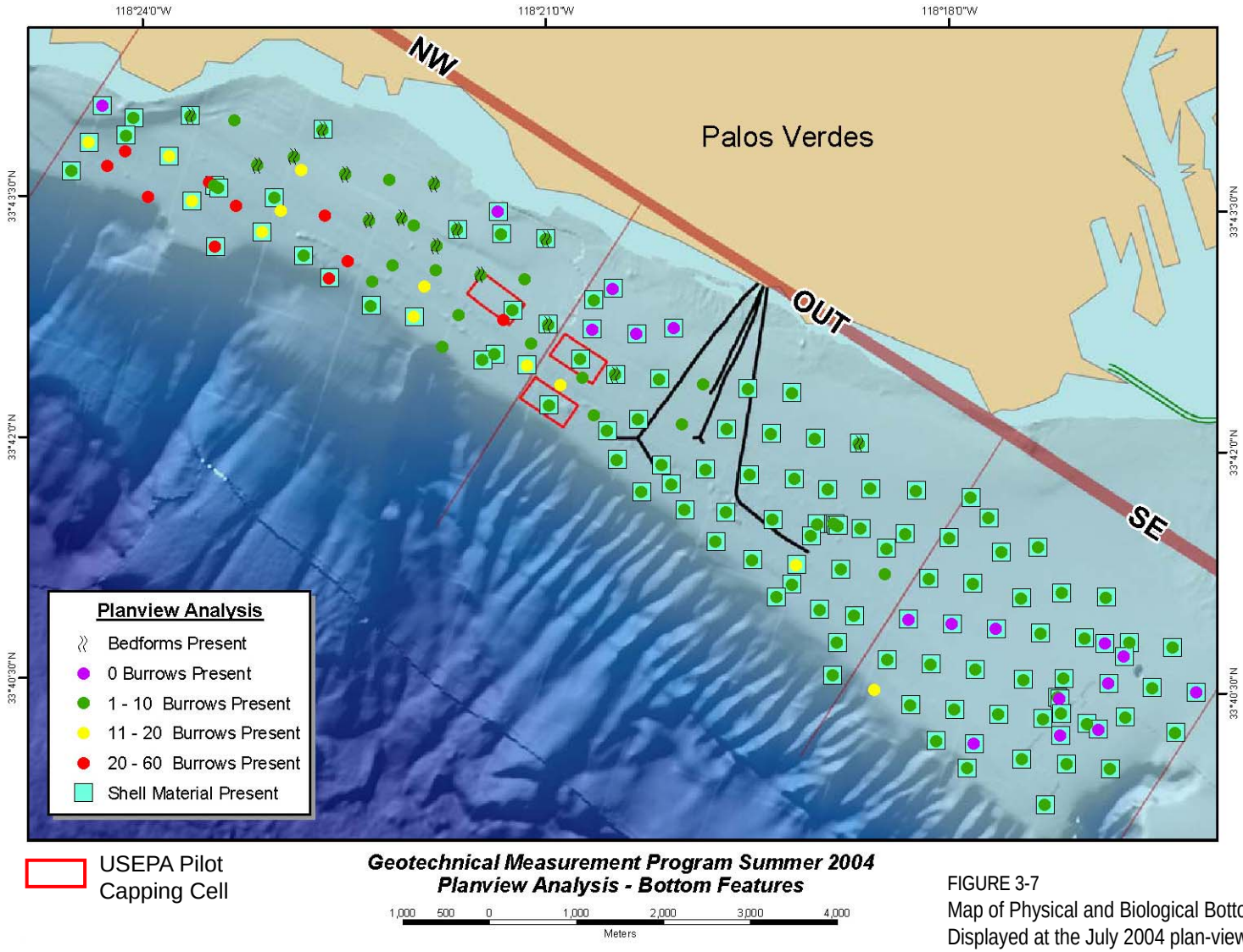
Species diversity has consistently increased since the 1970s in direct relation to the decrease in effluent solids discharged, and concomitant decline in sediment organic matter loading and biological oxygen demand. The average number of species in grab samples has approximately tripled during this period.

Macrofaunal biomass has decreased in conjunction with the declining organic food source. This has been most obvious in the molluscan population, which has significantly declined since the 1970s, accompanied by relative increases in numbers, species, and biomass of polychaete worms.

Recent studies have demonstrated that deep-burrowing organisms, capable of producing bioturbation of the bottom sediments, are found throughout the PV Shelf Study Area. A series of plan-view photographs of the bottom sediments revealed an increasing density of burrows moving from an area without burrows southeast of the outfalls, to mid-densities near the outfalls, and the highest densities approximately 5 km northwest of the outfalls (Figure 3-7). A separate study of deep-burrowing bioturbators collected in box cores showed that the deepest burrowers, the shrimp *Neotrypaea gigas*, is found in greatest densities in that same area northwest of the outfalls (SAIC, 2005c).

3.5.2.1 Epifaunal Invertebrate Community

In addition to the infaunal community surveys, LACSD has conducted trawl surveys of fish and invertebrates along the PV Shelf and slope since the early 1970s. Trawls were conducted at stations located at depths of 23, 61, 137, and 305 m. Populations have fluctuated significantly over the years in response to climatic factors and outfall discharge trends. Temporal variability has exceeded spatial variability, with major shifts in abundance associated with El Niño events. Wastewater discharge has not significantly affected the distribution of large epibenthic invertebrates. While outfall-related gradients in distribution were evident in the 1970s, they have decreased over time and have been minor since the 1980s, in conjunction with declining mass emissions and improved sediment quality.



Note that NW, OUT, and SE are zones used by SAIC for sample labeling.

FIGURE 3-7
Map of Physical and Biological Bottom Features Displayed at the July 2004 plan-view stations over the Palos Verdes Shelf
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: Data Report for the Summer 2004 Geotechnical Measurement Program Conducted on the Palos Verdes Shelf, SAIC, June 2005.

Four species have dominated the catch, comprising nearly 95 percent of organisms sampled from 1978 to the present. These species and their respective percentages of total abundance are as follows:

- Ridgeback Rock Shrimp (*Sicyonia ingentis*): 35 percent; abundant on silty slope sediments from 1983 to 1986 and common from the mid-1990s, with peaks following El Niño events.
- White Sea Urchin (*Lytechinus pictus*): 33 percent; numbers have generally declined since the 1997 through 1998 El Niño events, but showed an increase in the most recent 2004 survey.
- Pelagic Red Crab (*Pleuroncodes planipes*): 17 percent; a species with high inter-annual variability, with peak abundances after the 1984 through 1985 El Niño events, and again in 1994 through 1995.
- Fragile Sea Urchin (*Allocentrotus fragilis*): 8 percent; increasing in abundance with time on the upper slope, with encroachment toward the outfall since 1989, and peak abundances in 2001 through 2002 and 2005.

The most recent (2005) survey of 16 sites collected more than 100 invertebrate species. Crustaceans were the most diverse group, followed by echinoderms and mollusks. The most abundant species were all echinoderms: *Allocentrotus fragilis, Lytechinus pictus, Brisaster latifrons* (Northern Heart Urchin), and the seastar *Astropectin verrillii*, collectively comprising 95 percent of the epibenthic invertebrate catch.

Spatial patterns in the epifaunal community primarily are related to depth, sediment type, and (historically) effects from the wastewater discharge (Stull, 1995).

3.5.2.2 Fish Community

LACSD has been conducting trawl surveys of fish and invertebrates along the PV Shelf and slope since the early 1970s. The LACSD trawl catches have varied greatly over time. Conditions that could have influenced these changes include variations in water temperature, El Niño events, water mass movement (e.g., upwelling), kelp (*Macrocystis pyrifera*) coverage, food availability, habitat variability, and contaminants from the outfall (LACSD, 2002).

The PV Shelf and upper slope sediments are characterized by several species of flatfish (Pleuronectiformes) that have been dominant over 33 years of trawl sampling, with relative abundance increasing since the mid-1990s. Rockfishes (Scorpaeniformes) also are common and diverse, as are several families represented by a single, or few, species. The most recent sampling (2005) collected representatives of 31 families.

While single surveys have regularly recorded more than 100 species in quarterly trawl surveys from 12 stations, seven species have accounted for 65 percent of the total catch between 1973 and 2005, from all depths, as summarized below (percent of total abundance indicated):

- Dover Sole (*Microstomus pacificus*): 14 percent; this deeper-water flatfish was most common on slope sediments near the outfalls. Numbers have declined since the 1970s.

- Pacific Sanddab (*Citharichthys sordidus*): 14 percent; most abundant in the 60- to 130-m depth range, with notable shifts onshore and offshore. More abundant in recent years.
- Slender Sole (*Lyopsetta exilis*): 10 percent; inhabits slope sediments and has significantly increased in abundance since 1986. Larger fish migrate down slope.
- Stripetail Rockfish (*Sebastes sxaicola*): 7 percent; inhabits outer shelf and upper slope habitat, feeding on pelagic prey in the lower water column.
- Plainfin Midshipman (*Porichthys notatus*): 6 percent; prefers outer shelf, upper slope habitat, showing high temporal variability with a tendency of increased abundance following El Niños.
- Yellowchin Sculpin (*Icelinus quadriseriatus*): 6 percent; temporally variable and common along the outfall depth contour.

White croaker (*Genyonemus lineatus*) is an inner shelf species that has DDE tissue burdens that are of human health concern. They are a dominant species in the Los Angeles Harbor and generally common in near-shore SCB waters (Cross and Allen, 1994). The distribution of white croaker in relation to contaminants is of particular importance because of historically high levels of DDT bioaccumulation in the species, which led to a commercial-catch ban and recreational-catch limits for this fish at the PV Shelf Study Area. White croaker was one of the top three fish species taken on the 23- and 61-m isobaths during the mid-1970s and early 1980s, and it was more common near the outfall. In the past 15 to 20 years, its abundance at the outfall depth has declined significantly and it is no longer a dominant member of the demersal fish catch.

Fish species that were characteristic of the Palos Verdes outfall area during the early 1970s included shiner surfperch (*Cymatogaster aggregata*), curlfin sole (*Plueronichthys decurrens*), white seaperch (*Phanerodon furcatus*), English sole (*Pleuronectes vetulus*), and Dover sole. These species decreased from 1973 to 1995. In contrast, California tonguefish (*Symphurus atricauda*), hornyhead turbot, California halibut, and blackbelly eelpout (*Lycodopsis pacifica*) increased near the outfall (LACSD, 2002). These species had been rare near the outfall in the early 1970s. This change in fish assemblages near the outfall is likely related to improved quality of the wastewater discharges, but warmer water temperatures also could be a factor (LACSD, 1996 and 2002).

White croakers are caught sporadically, especially near the White Point outfall and Los Angeles Harbor (LACSD, 1995). Extensive fish collections were conducted in between 2002 and 2004 to assess contaminant concentrations in edible species throughout a large area of the Southern California coast, including some samples collected in the PV Shelf Study Area (EPA and NOAA, 2007). Species collected at the PV Shelf included kelp bass, white croaker, surfperch, rockfish, barred sandbass, California scorpionfish, opaleye, black croaker, sargo, queenfish, California sheephead, pacific sardine, top smelt, and mackerel.

3.5.3 Hard-Bottom Habitats

Hard-bottom habitats include near-shore rocky intertidal to subtidal areas. Hard-bottom habitats in the PV Shelf Study Area primarily are documented from shore to approximately 20 m deep, although scattered outcrops and reefs also occur in some deeper shelf areas.

Within these habitats, the most diverse communities, which include numerous epifaunal invertebrate, fish, and plant (algae and surfgrass) species, are associated with kelp beds. These communities are generally in the shallower rather than the principal areas of chemical contamination on the PV Shelf Study Area.

3.5.3.1 Kelp Community

The giant kelp (*Macrocystis pyrifera*) is a keystone species that provides refuge and a source of food for many fish and invertebrate species, although the extent of kelp beds has been extremely variable over time. In 1911 surveys, kelp canopy coverage near the PV Shelf Study Area was estimated to be over 1,500 acres (LACSD, 1996). By the late 1950s, giant kelp had disappeared from PV Shelf rocky subtidal areas, attributed, in part, to wastewater discharges that introduced toxicants, buried the substrate, and reduced light penetration (which restricted photosynthesis) (Stull, 1995). Transplantation efforts helped to reestablish kelp near the Palos Verdes Peninsula, although the kelp beds suffered severe damage during winter storms in 1983 and 1988. Kelp beds near the PV Shelf Study Area were estimated at 1,124 acres in 1989, and declined to 300 acres in 1993. The decline could have been caused by El Niño events and overgrazing by sea urchins (LACSD, 1996). The Portuguese Bend Landslide area also contributed to increased sedimentation and turbidity, which continued to affect some kelp bed populations (LACSD, 2002; Stull, 1995).

Common algae within the kelp community include *Pterygophora californica*, *Eisenia arborea*, and *Agarum fimbriatum*, in addition to numerous species of red, green, and other brown algae.

3.5.3.2 Invertebrate Community

Common members of the invertebrate community associated with the kelp beds include three species of sea urchins that graze on kelp: the purple sea urchin (*Strongylocentratus purpuratus*), red sea urchin (*S. franciscanus*), and white sea urchin. Other species include various polychaetes, bivalves, sea stars, sea cucumbers, brittle stars, cnidarians (e.g., anemones and sea fans), and crustaceans.

3.5.3.3 Fish Community

Fish species common in the kelp beds include kelp bass, señorita (*Oxyjulis californica*), surfperch (e.g., *Embiotoca* species), half-moon (*Medialuna californiensis*), sculpins (*Cottidae*), blacksmith (*Chromis punctipinnis*), gobies (e.g., *Coryphopterus* species), and opaleye (*Girella nigricans*).

3.5.4 Pelagic Habitats

The pelagic environment includes the water column from near the bottom to the sea surface. This environment provides habitat for many species of plankton, invertebrates, fish, seabirds, and marine mammals.

3.5.4.1 Plankton Community

Phytoplankton and zooplankton communities in the Palos Verdes region exhibit species composition, abundance, and biomass changes that reflect seasonal variations in physical and chemical parameters (e.g., light, temperature, salinity, available nutrients, upwelling, current regimes, and hydraulic conditions) (Cloern, 1979). These community dynamics have a strong

influence on the feeding ecology of plankton-feeding organisms (e.g., many fish, invertebrates, and mysticete whales). Coastal phytoplankton typically observed in marine habitats include diatoms (*Bacillariophyceae*), coccolithophores (*Haptophyta*), dinoflagellates (*Pyrrophyta*), silicoflagellates (*Chrysophyta*), cryptomonads (*Cryptophyceae*), and green algae (*Chlorophyceae*). Because phytoplankton growth depends on availability of light, they occur in the photic zone, generally the top 20 to 50 m in the water column in the SCB (Mullin, 1986). Typically, dinoflagellates are the predominant phytoplankton in near-shore coastal waters, while diatoms are generally abundant in deeper, colder waters (Eppley et al., 1978).

Predominant zooplankton off Southern California includes various copepods, euphausiids, juvenile and larval fish and invertebrates, salps, chaetognaths (arrow worms), and pelagic mollusks. The abundance of zooplankton reflects changes in abundance of the phytoplankton. Salps and pelagic mollusks generally are observed offshore, while other zooplankton types are found both near-shore and offshore. Juvenile fish and crustaceans tend to be more prevalent in near-shore areas.

3.5.4.2 Fish Community

Pelagic fish include many relatively large, far-ranging species (e.g., tuna, mackerel, bonito, and barracuda), but also numerous small "bait" or forage fish (e.g., anchovies, sardines, and smelts). Mackerel and forage fish, in particular, can be abundant in the Palos Verdes region, although their transient nature and feeding ecology make them difficult to evaluate for the present risk evaluation. Analysis of the 1995 through 1996 CDFG recreational catch block data for Palos Verdes (Catch Blocks 719 and 720) indicates the most commonly caught pelagic fish include ocean whitefish (*Caulolatilus princeps*), chub mackerel (*Scomber japonicus*), Pacific barracuda (*Sphryraena argentea*), Pacific bonito (*Sarda chiliensis*), and jack mackerel (*Trachurus symmetricus*). Other pelagic fish species collected in the Palos Verdes region include yellowtail (*Seriola lalandi*), skipjack tuna (*Euthynnus pelamis*), yellowfin tuna (*Thunnus albacares*), and a variety of sharks such as thresher (*Alopias vulpinus*), blue (*Prionace glauca*), shortfin mako (*Isurus oxyrinchus*), and soupfin (*Galeorhinus zyopterus*).

3.5.4.3 Marine and Aquatic-feeding Birds

Many migratory and resident marine and aquatic-feeding bird species occur near the PV Shelf Study Area along the shelf and slope. These include a variety of pelagic, shelf, and near-shore species, many of which are far-ranging throughout the bight or are seasonally migratory. Some of the most common species are cormorants (*Phalacrocorax* spp.), California brown pelicans, gulls (*Larus* spp.), terns (e.g., *Sterna* spp.), storm petrels (Hydrobatidae), murrelets and guillemots (Alcidae), and grebes (Podicipedidae). Juvenile bald eagles can disperse over large areas. For example, one fostered juvenile bald eagle was sighted in Klamath, California, more than 600 miles from its fledging site on Catalina Island (Sharpe, 2003). However, the adult breeding bald eagles feed primarily on fish in the pelagic zone and have a relatively localized range. Populations that feed around Santa Catalina Island generally do not feed directly at the PV Shelf Study Area.

Of these birds, those listed by the federal government and State of California as threatened or endangered species include bald eagle (threatened), peregrine falcon (recently delisted), and California brown pelican (endangered). Brown pelicans nest on the Northern Channel Islands (Anacapa and Santa Barbara Islands) offshore of Southern California and feed near

the PV Shelf. Additional breeding colonies exist on Islas Los Coronados in Mexico off the Baja California peninsula. Historically, bald eagles nested on Santa Catalina, Santa Cruz, Anacapa, San Miguel, Santa Rosa, Santa Cruz, Santa Barbara, San Nicolas, San Clemente, and Los Coronados Islands (Kiff, 1980). Peregrine falcons nested historically on Los Coronados, San Clemente, Santa Catalina, San Nicolas, Santa Barbara, Anacapa, Santa Cruz, Santa Rosa, and San Miguel Islands (Kiff, 1980). Populations of peregrine falcons currently nest on the Channel Islands, including San Miguel, Santa Rosa, Santa Cruz, Anacapa, and Santa Barbara (Walton, 1997).

3.5.4.4 Marine Mammals

Marine mammals (e.g., pinnipeds, dolphins, and toothed whales) are important predators of many fish species and some invertebrates, particularly in the pelagic zone, with many pinnipeds also feeding extensively in kelp bed habitats. In contrast, feeding by mysticete whales (e.g., blue whales [*Balaenoptera musculus*]) is more exclusive on planktonic organisms in the pelagic zone.

Marine mammals occurring in the Palos Verdes region include both migratory and year-round residents (e.g., dolphins, porpoises, whales, seals, and sea lions). Seals and sea lions have well-established breeding colonies in several areas of the bight, particularly in the northern Channel Islands, (e.g., San Miguel Island). Historically, sea otters (*Enhydra lutris nereis*) occurred in the region. Currently, a breeding population of transplanted sea otters exists near San Nicolas Island and a few transplanted individuals inhabit areas around San Miguel Island (DeLong, 2002). Some of the more common mammal species include harbor seals (*Phoca vitulina*), California sea lions, common dolphins (*Delphinus delphis*), Pacific white-sided dolphins (*Lagenorhynchus obliquedens*), bottlenose dolphins (*Tursiops truncatus*), and Minke whales (*Balaenoptera acutorostrata*) (Calambokidis and Francis, 1994). Gray whales (*Eschrichtius robustus*) are sighted seasonally along the coast as they migrate between northern feeding and southern breeding and calving areas outside the bight. Blue whales have become more commonly sighted in the northern bight.

Several threatened or endangered species of marine mammals are known to occur in the SCB. These include the humpback whale (*Megaptera novaeangliae*), blue whale, fin whale (*Balaenoptera physalus*), sperm whale (*Physeter macrocephalus*), stellar sea lion (*Eumetopias jubatus*), sei whale (*Balaenoptera borealis*), and northern right whale (*Eubalaena glacialis).* Most of these species are uncommon in the bight and are found in deep waters offshore or near the Channel Islands, north of the Palos Verdes Peninsula.

4.0 Nature and Extent of Contamination

This section describes the nature and extent of contamination at the PV Shelf Study Area in surface water, sediment, and fish. The primary data sources for the information in this section were investigations conducted at the PV Shelf Study Area between 1992 and 2005, including:

- USGS sediment data collected in 1992 as part of the NRDA
- LACSD NPDES monitoring data (surface sediment grab samples) collected in 1992, 2002, and 2004
- LACSD sediment core sampling data collected in 2001, 2003, and 2005
- SCCWRP water column data collected in 1997
- EPA and MSRP study fish data collected in 2002 through 2004

Details of these and other site investigations conducted to evaluate the nature and extent of contamination are discussed in Section 2.0. Section 4.1 provides a brief review of the sources that have contributed to the contamination at the PV Shelf Study Area. Section 4.2 discusses the chemicals of concern and analytes. Sections 4.3, 4.4, and 4.5 provide detailed discussion of the nature and extent of contamination in sediment, fish, and surface water, respectively.

4.1 Source Description

The primary historical source of chemical contaminants on the PV Shelf is effluent discharged through the JWPCP outfalls. Starting in 1937, LACSD discharged treated sewage to PV Shelf offshore of White Point:

- From 1937 to 1958 – through a 60-inch-diameter, three-outlet diffuser at a depth of 34 m
- From 1947 to 1966 – through a 72-inch-diameter diffuser at a depth of 34 m (1947 to 1953) and at a depth of 49 m (1953 to 1966)
- Since 1957 – through a 90-inch-diameter, Y-shaped diffuser at a depth of 64 m
- Since 1967 – through a 120-inch-diameter, L-shaped diffuser at a depth of 58 m

Currently, the 120- and 90-inch-diameter outfalls are the two primary outfalls discharging treated effluent through diffusers approximately 1.5 miles offshore. The 60- and 72-inch-diameter outfalls can be used for backup or emergency operations. Wastewater contaminants in the discharge have included chlorinated hydrocarbons (e.g., DDTs and PCBs) as well as trace metals (e.g., cadmium, copper, lead, zinc, and other metals), and organic matter. The primary source of DDTs was wastewater from Montrose, which manufactured DDT from 1947 to 1982; however, the discharge of wastewater from Montrose stopped in 1971. Sources of PCBs included various industries in the greater Los Angeles area. The peak annual mass emissions of effluent solids (167,000 metric tons), DDT (21.1 metric tons), and PCBs (5.2 metric tons) occurred in 1971 (EPA, 2000a).

Effluent-affected sediments in the area of the outfalls and those transported away from White Point by ocean currents and deposited on the ocean floor serve as the main repository for contaminants. Other potential sources of contaminants (e.g., atmospheric deposition, stormwater runoff, and ocean currents) are considered minor compared with the existing reservoir of deposited contaminants originating from the LACSD outfall (EPA, 2000a).

Contaminant emissions decreased after 1971 as a result of the disconnection of Montrose from the sewer system and improved treatment of the effluent before discharge. LACSD conducted cleaning operations in the two sewer lines adjacent to and downstream of the Montrose property. Sediments in the two sewer lines contained more than 3,500 kg of DDT, according to LACSD estimates. The effluent concentrations of DDTs have been near or below the detection limit since 1989 and have not been detected since 2002. PCBs have not been detected above the detection limit since 1985 (LACSD, 2006a). The reporting limits are currently 0.01 µg/L for the six isomers of DDT, and between 0.05 and 0.5 µg/L for the PCB Aroclors (LACSD, 2007).

Because the effluent being discharged after 1971 was less contaminated, the contaminated sediments became buried by progressively cleaner deposits. However, surface contaminant concentrations remain significantly elevated, which reflects mixing with and upward mobilization of the buried contaminated sediments.

4.2 Chemicals of Concern

The chemicals of concern at the PV Shelf Study Area are DDTs and PCBs. In general, DDTs consist of the sum of the isomers of DDT and all isomers of the DDT metabolites DDD and DDE, unless otherwise specified. These isomers are p,p'-DDT; o,p'-DDT; p,p'-DDD; o,p'-DDD; p,p'-DDE; and o,p'-DDE. For PCBs, LACSD analyzed for Aroclors while USGS analyzed for congeners. The lists of Aroclors or congeners for each specific investigation are provided in the sections below.

4.3 Sediment

In this section, the extent of contamination in sediment is illustrated in several ways, including contour maps for DDTs and PCBs derived from LACSD surface grab samples, diagrams presenting relatively recent DDE sediment core data in 15-cm intervals at individual stations, and historical sediment profiles from DDE sediment core data.

4.3.1 Surface Concentrations of DDTs and PCBs

4.3.1.1 Recent Sediment Concentrations

Figure 2-1 shows the locations of the 44 sampling stations used by LACSD for its annual sediment monitoring program. LACSD's sampling grid consists of 11 transects from Redondo Canyon to Point Fermin, with the following sampling locations at four water depths:

- 30 m (D Stations)
- 61 m (C stations)
- 152 m (B stations)
- 305 m (A stations)

Table 4-1 summarizes concentrations of DDTs and PCBs in surface sediment samples (approximately 0 to 2 cm, as collected using a Van Veen sampler) collected from these 44 stations in 1992, 2002 and 2004. For the LACSD data, DDTs consisted of the sum of the detected isomers p,p'-DDT; o,p'-DDT; p,p'-DDD; o,p'-DDD; p,p'-DDE; and o,p'-DDE. The PCBs consisted of the sum of the detected Aroclors: 1016, 1221, 1232, 1248, 1254, and 1260.

In 2002, the concentrations of DDTs ranged from 0.15 mg/kg at Station 1D to 76 mg/kg at Station 8C, while in 2004, concentrations of DDTs ranged from 0.13 mg/kg to 205 mg/kg. In 2002, the concentrations of PCBs ranged from not detected at several stations to 4.61 mg/kg at Station 7B. In 2004, concentrations of PCBs ranged from not detected at several stations to 3.56 mg/kg at Station 8B. As expected, the highest concentrations of DDTs occurred at stations closest to the outfalls, with the highest concentrations at Stations 8C, 8D, 8B, and 7B in 2002, and at Stations 8B and 8C in 2004. The highest concentrations of PCBs occurred at Stations 7B, 8C, and 6B in 2002, and at Stations 8B and 8C in 2004.

TABLE 4-1
Surface Sediment (0 to 2 cm) Concentrations of DDTs and PCBs

Station	1992		2002		2004		Percent Change from 1992 to 2002		Percent Change from 2002 to 2004	
	DDTs (mg/kg dry weight)	PCBs (mg/kg dry weight)	DDTs (mg/kg dry weight)	PCBs (mg/kg dry weight)	DDTs (mg/kg dry weight)	PCBs (mg/kg dry weight)	DDTs	PCBs	DDTs	PCBs
OA	NA	NA	0.7	ND	0.85	0.21	NA	NA	22	720
0B	0.64	ND	0.92	0.14	0.75	0.14	44	460	-18	-4
0C3	0.943	ND	0.86	0.09	0.79	0.14	-9	267	-8	56
0D	0.2	ND	0.21	ND	0.25	ND	5	0	20	0
1A	NA	NA	7.4	0.89	4.25	0.77	NA	NA	-43	-13
1B	2.42	0.25	2.1	0.19	1.28	0.17	-13	-24	-39	-12
1C3	3.37	0.38	1.9	0.2	2.35	0.30	-44	-47	24	50
1D	0.64	ND	0.15	ND	0.54	0.11	-77	0	262	356
2A	NA	NA	1.9	0.18	1.62	0.26	NA	NA	-15	42
2B	NA	NA	1.8	0.19	1.78	0.24	NA	NA	-1	27
2C	NA	NA	1.9	0.21	1.77	0.24	NA	NA	-7	14
2D	NA	NA	0.19	ND	0.13	ND	NA	NA	-33	0
3A	NA	NA	5.1	0.64	4.85	0.75	NA	NA	-5	17
3B	4.02	0.46	4	0.6	3.24	0.38	0	30	-19	-37
3C3	5.1	0.5	2.43	0.50	1.96	0.29	-52	1	-19	-43
3D	1.18	ND	0.4	ND	0.52	0.13	-66	0	31	404
4A	NA	NA	10.1	1.15	2.59	0.25	NA	NA	-74	-79
4B	NA	NA	5.8	0.65	13.50	2.04	NA	NA	133	213
4C	NA	NA	4.3	0.55	3.50	0.44	NA	NA	-19	-20
4D	NA	NA	0.726	0.13	0.48	0.12	NA	NA	-34	-5
5A	NA	NA	4.02	0.52	4.04	0.48	NA	NA	0	-8

TABLE 4-1 (CONTINUED)
Surface Sediment (0 to 2 cm) Concentrations of DDTs and PCBs

Station	1992		2002		2004		Percent Change from 1992 to 2002		Percent Change from 2002 to 2004	
	DDTs (mg/kg dry weight)	PCBs (mg/kg dry weight)	DDTs (mg/kg dry weight)	PCBs (mg/kg dry weight)	DDTs (mg/kg dry weight)	PCBs (mg/kg dry weight)	DDTs	PCBs	DDTs	PCBs
5B	19.9	2.46	2.3	2.11	10.30	1.62	-88	-14	348	-23
5C	11.3	1.64	3.8	1.11	1.42	0.37	-66	-32	-63	-66
5D	0.94	0.13	0.69	0.09	0.25	ND	-27	-31	-63	-72
6A	NA	NA	6.43	0.92	4.03	0.81	NA	NA	-37	-12
6B	17.3	3.23	11	2.29	7.18	1.90	-36	-29	-35	-17
6C3	12.4	1.57	4.3	1.03	3.63	0.54	-65	-34	-16	-47
6D	0.8	ND	0.57	0.161	0.40	ND	-29	544	-30	-84
7A	NA	NA	1.95	0.23	2.30	0.20	NA	NA	18	-14
7B	18.7	1.48	15	4.61	11.30	1.68	-20	211	-25	-64
7C	15.3	2.1	3.8	0.6	2.85	0.36	-75	-71	-25	-40
7D	0.56	ND	0.63	ND	0.45	ND	13	0	-29	0
8A	NA	NA	2.27	0.29	2.54	0.43	NA	NA	12	49
8B	27.7	2.39	13	1.84	18.60	3.56	-53	-23	43	94
8C3	21	2.06	76	2.83	205	3.34	262	37	170	18
8D	0.56	ND	26	0.092	0.42	ND	4543	268	-98	-73
9A	NA	NA	4.24	0.65	4.92	0.78	NA	NA	16	21
9B	8.97	0.91	10	1.72	5.75	0.77	11	89	-43	-55
9C	1.78	ND	1.2	0.11	2.04	0.11	-33	340	70	1
9D	0.63	0.077	0.41	ND	0.32	ND	-35	-68	-21	0
10A	NA	NA	0.81	0.15	0.95	ND	NA	NA	17	-83
10B	NA	NA	0.74	0.091	0.72	ND	NA	NA	-3	-73
10C	NA	NA	0.46	ND	0.49	ND	NA	NA	6	0
10D	NA	NA	0.38	ND	0.66	ND	NA	NA	73	0
Median	3.4	0.4	2.0	0.2	1.9	0.2	-32.6	0.0	-11.4	-4.1

Notes:

ND = Not detected (<0.05 mg/kg). One-half the detection limit for PCBs (0.025 mg/kg) was used for nondetections in percent change and median analysis.

NA = Percent change could not be calculated because samples were not collected or PCBs were not analyzed for in one or both years.

DDTs consist of the sum of the p,p'-DDT; o,p'-DDT; p,p'-DDD; o,p'-DDD; p,p'-DDE and o,p'-DDE isomers.

PCBs are the summed detected concentration of up to seven Arcolors: 1016, 1221, 1232, 1242, 1248, 1254, and 1260.

Additional information including detection limits for PCB Aroclors and DDT isomers is available in the Annual Report 2002 Palos Verdes Ocean Monitoring and Annual Report 2004 Palos Verdes Ocean Monitoring (LACSD, 2003 and 2005).

For stations with replicate samples, the average concentration of the replicates was used.

= Concentrations increased more than 10 percent.

= Concentrations decreased more than 10 percent.

Near the outfalls (Station 8C), the highest concentrations of DDTs were located at the 61-m isobath. Northwest of the outfalls, the water depth at which the highest surface sediment concentrations occur increases with distance from the outfalls. In most instances at the 5, 6, and 7 transects, the highest concentrations of DDTs and PCBs are found at C stations at the 61-m depth; while at the 1, 2, and 3 transects, the highest concentrations have moved farther offshore to the B stations at the 152-m depth.

Figure 4-1 and 4-2 are contour maps showing average surface sediment concentrations (LACSD 2002 and 2004 data) for DDTs and PCBs, respectively. These contour maps interpolate sediment concentrations (using kriging) between individual sampling stations to provide the least biased description of contaminant spatial distribution throughout the PV Shelf Study Area. Spatial reliability of estimates is greatest in the areas of highest sampling density and is lowest on the margins of the sampling field. An average of the LACSD 2002 and 2004 data was used to smooth highly variable data.

In addition to the average of 2002 and 2004 LACSD data, Figure 4-1 uses four Bight' 94 samples, one 1993 LACSD sample, and two 1992 NOAA samples to provide actual concentrations of DDTs (sum of the p,p'-DDT; o,p'-DDT; p,p'-DDD; o,p'-DDD; p,p'-DDE and o,p'-DDE isomers) between the 0 and 1 transects and north of the 0 transect. Similarly, Figure 4-2 uses two simulated transects inserted between the 0 and 1 transects to approximate sediment concentrations where no data exist. The simulated transects were set as an average of the 0 and 1 transect concentrations. For both figures, shoreline concentrations have been set at 0.05 mg/kg for contouring.

The contour maps show the highest concentrations of DDTs and PCBs centered on Station 8C and extending southeast and northwest along the 60-m, 100-m, and 200-m isobaths. The contour maps indicate the transport of sediment contamination predominantly to the northwest: concentrations of DDTs up to 10 mg/kg and concentrations of PCBs up to 2 mg/kg generally extend twice as far northwest of the Station 8 transect as they do southeast. Concentrations of DDTs above 3 mg/kg have been found up to approximately 9 miles northwest of the LACSD outfalls.

The concentrations of DDTs drop off rapidly in-shore from the 60-m isobath at the PV Shelf Study Area. In 2002 and 2004, only one station at the 30-m isobath (Station 8D) had concentrations of DDTs exceeding 0.8 mg/kg (Table 4-1). Likewise, the concentrations of PCBs fall off shoreward. In 15 of 22 stations sampled in 2002 and 2004, concentrations of PCBs were below detection limits.

4.3.1.2 Changes Since the Early 1990s

To assess changes in surface sediment concentrations from the early 1990s to 2002 and 2004, 1992 surface sediment data also are provided in Table 4-1 and contours are shown on Figure 4-3 and 4-4. The concentrations of DDTs ranged from 0.2 mg/kg at Station 0D to 27.7 mg/kg at Station 8B. As in 2002 and 2004, the highest concentrations of DDTs were found near the outfalls (Stations 8B and 8C); however, the maximum concentration detected in 1992 (27.7 mg/kg) was significantly lower than the concentrations detected in 2002 (76 mg/kg) and 2004 (205 mg/kg). The concentrations of PCBs in 1992 ranged from 0.077 mg/kg at Station 9D to 3.23 mg/kg at Station 6B. For PCBs, in 1992 the highest concentrations were found at Stations 6B and 5B, northwest of the outfall, followed by

Stations 8B and 8C3 near the outfall. The concentrations of PCBs are relatively consistent from the early 1990s to 2004; maximum concentrations of PCBs are 3.23 mg/kg, 4.61 mg/kg, and 3.56 mg/kg for 1992, 2002, and 2004, respectively.

In addition to the 1992 LACSD data, Figure 4-3 uses four samples collected during Bight '94, one 1993 LACSD sample, and two 1992 NOAA samples to provide actual concentrations of DDTs between the 0 and 1 transects and north of the 0 transect. Likewise, Figure 4-4 uses two simulated transects inserted between the 0 and 1 transects to approximate sediment concentrations where no data exist. The simulated transects were set as an average of the 0 and 1 transect concentrations. For both figures, shoreline concentrations have been set at 0.05 mg/kg for contouring.

The 1992 contour maps also show that the highest concentrations of DDTs and PCBs are centered on the area around the outfalls, extending northwest along the 60-m and 100-m isobaths. As shown in Table 4-2, a comparison of the 1992 and 2002/2004 contour maps of DDTs indicates that the area with concentrations over 10 mg/kg has significantly reduced in size over the last 10 years. In 1992, concentrations of DDTs over 10 mg/kg covered approximately 8 km^2, extending from north of the 9 transect to the 4 transect and encompassing the 60-m isobath and extending to the 200-m isobath. In contrast, the 2002/2004 contour shows the area of concentrations of DDTs exceeding 10 mg/kg covered approximately 3.6 km^2, was generally confined to the 8 transect, and extended northwest only along the 100-m and 200-m isobaths to Station 7B. However, concentrations of DDTs near outfalls increased from 1992 to 2002/2004. In 1992, concentrations of DDTs did not exceed 50 mg/kg. In 2002/2004, concentrations of DDTs above 150 mg/kg were detected in Station 8C.

There was a smaller decrease in the area of surface sediments contaminated by PCBs; the contour maps indicate the area of concentrations of PCBs exceeding 1 mg/kg has decreased from 8.4 to 6.2 km^2 (Table 4-2). In 1992, the concentrations of PCBs exceeding 1 mg/kg extended from between the 8 and 9 transects almost to the 4 transect and encompassed the 60-m and 100-m isobaths, extending to the 200-m isobath. In 2002/2004, the concentrations of PCBs exceeding 1 mg/kg extended past the 4 transect, but were generally restricted to the 100-m isobath except near the outfalls where it extended to the 60-m isobath.

TABLE 4-2
Area of Surface Contamination of DDTs and PCBs

	DDTs		PCBs	
	Area > 1 mg/kg	**Area > 10 mg/kg**	**Area > 0.3 mg/kg**	**Area > 1 mg/kg**
1992 Surface Sediment Data	44.5 km^2	8.2 km^2	22.5 km^2	8.4 km^2
2002/2004 Surface Sediment Data	39.1 km^2	3.6 km^2	13.7 km^2	6.2 km^2

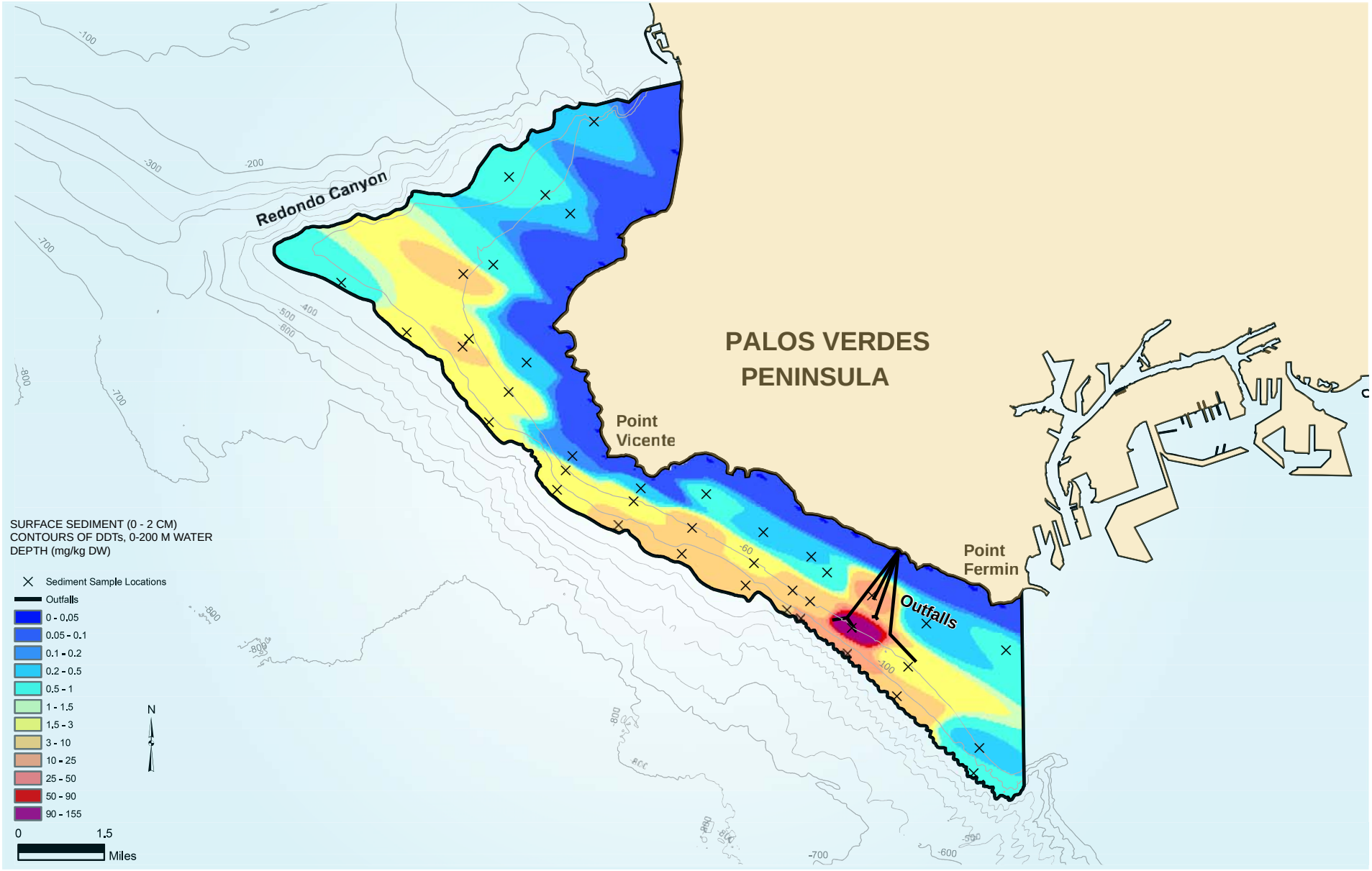


FIGURE 4-1
Surface Sediment Contours of DDTs - 2002/2004 Average
Palos Verdes Shelf Study Area
Remedial Investigation Report

Note: In addition to the 2002/2004 LACSD data, this figure uses four Bight '94 samples, one 1993 LACSD sample, and two 1992 NOAA samples to provide actual concentrations of DDTs between the 0 and 1 transects and north of the 0 transect. Shoreline concentrations have been set at 0.05 mg/kg for contouring.

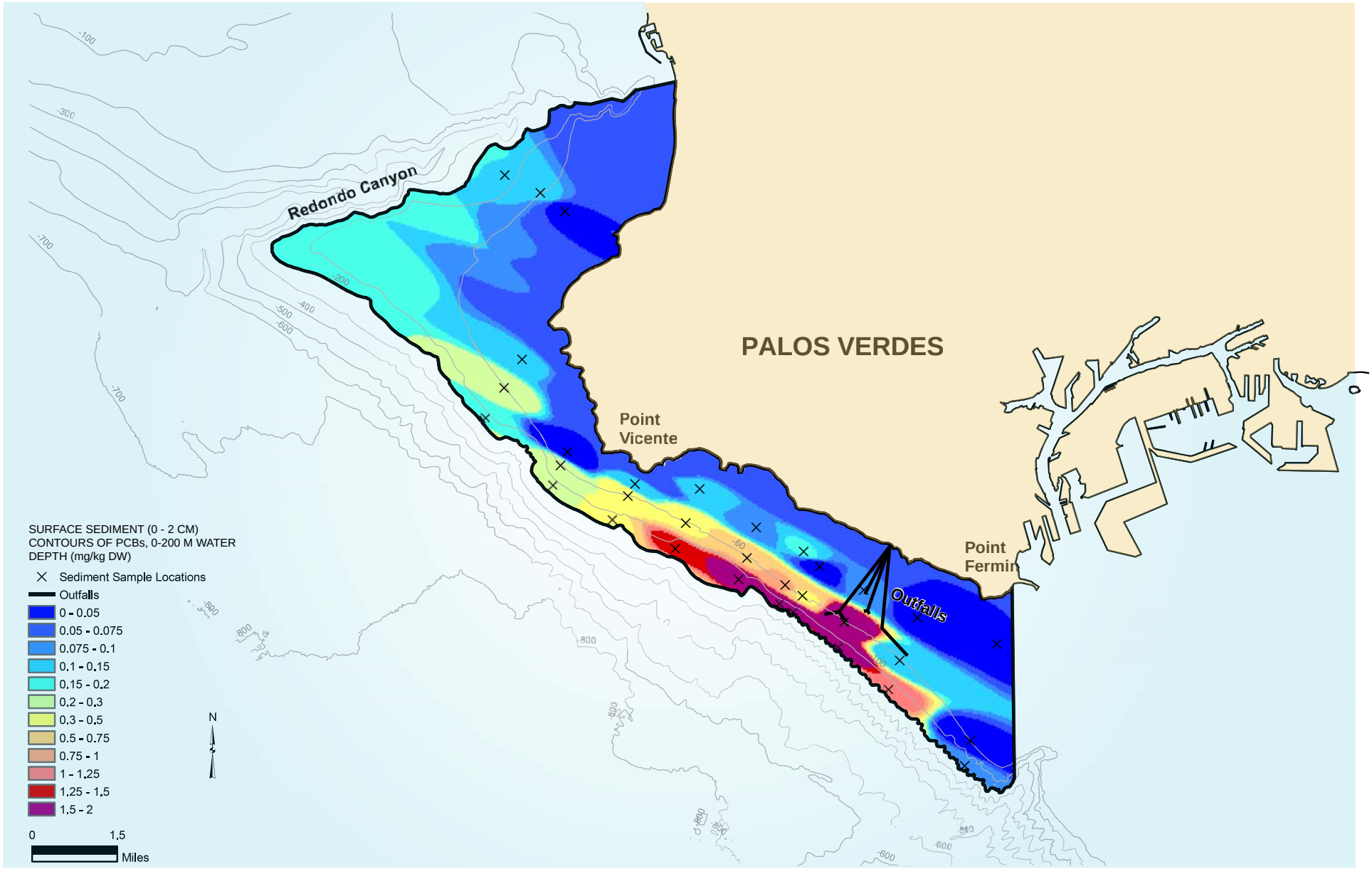


FIGURE 4-2
Surface Sediment Contours of PCBs - 2002/2004 Average
Palos Verdes Shelf Study Area
Remedial Investigation Report

Note: In addition to the 2002/2004 LACSD data, two simulated transects were inserted between the 0 and 1 transects to approximate sediment concentrations where no data exist. The simulated transects were set as an average of the 0 and 1 transect concentrations. Shoreline concentrations have been set at 0.05 mg/kg for contouring.

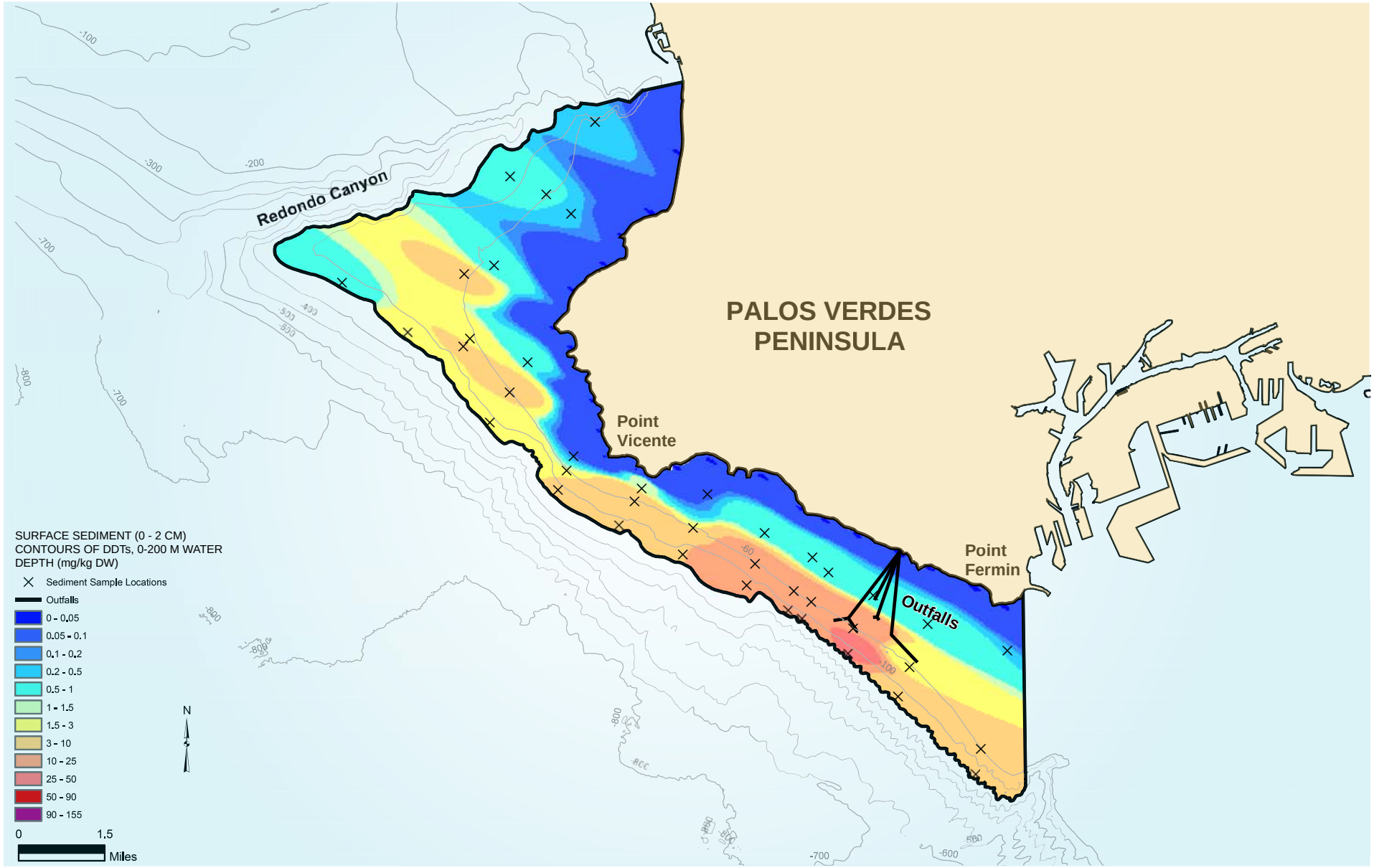


FIGURE 4-3
Surface Sediment Contours of DDTs - 1992
Palos Verdes Shelf Study Area
Remedial Investigation Report

Note: In addition to the 1992 LACSD data, this figure uses four Bight '94 samples, one 1993 LACSD sample, and two 1992 NOAA samples to provide actual concentrations of DDTs between the 0 and 1 transects and north of the 0 transect. Shoreline concentrations have been set at 0.05 mg/kg for contouring.

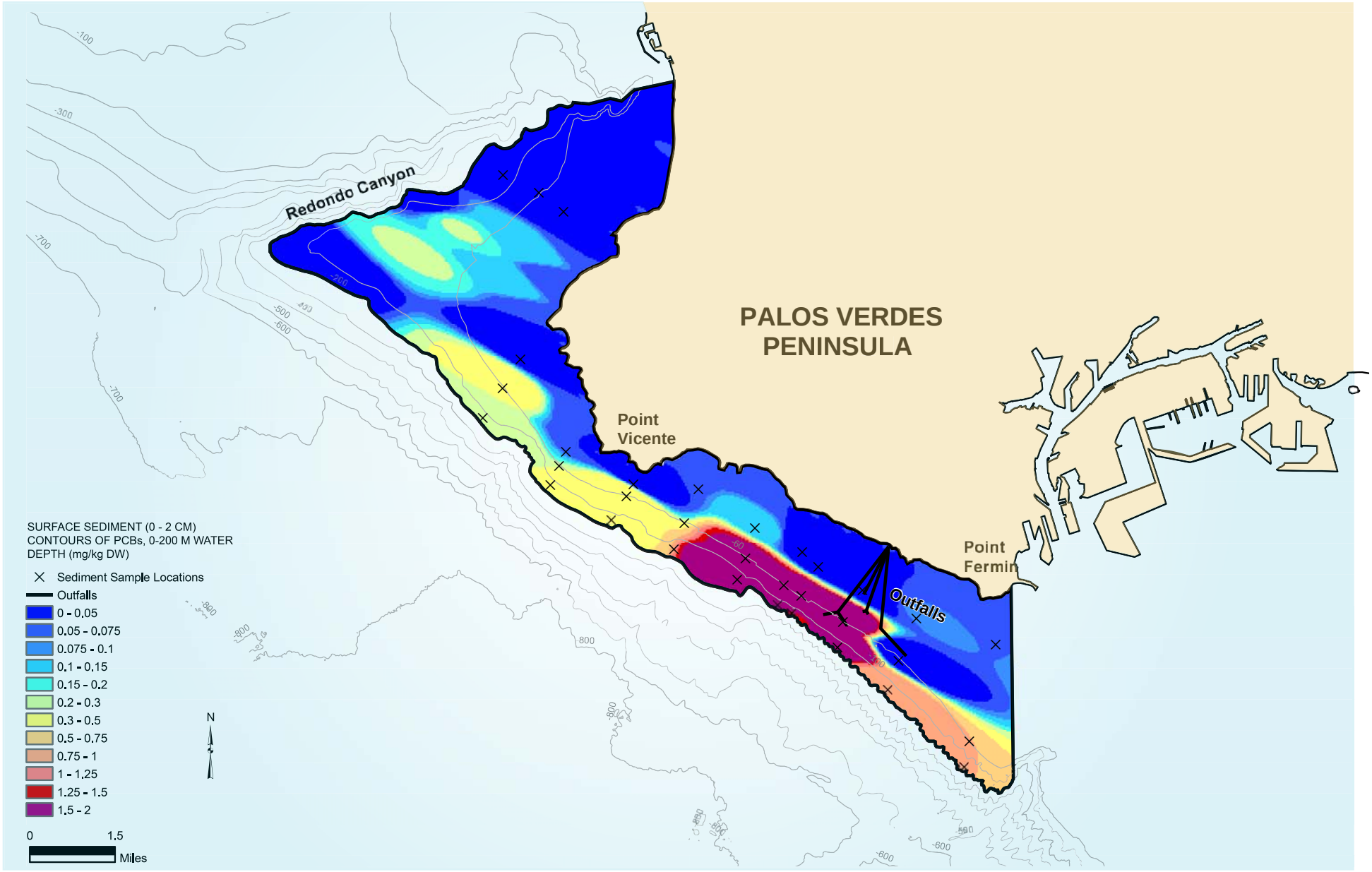


FIGURE 4-4
Surface Sediment Contours of PCBs - 1992
Palos Verdes Shelf Study Area
Remedial Investigation Report

Note: In addition to the 1992 LACSD data, two simulated transects were inserted between the 0 and 1 transects to approximate sediment concentrations where no data exist. The simulated transects were set as an average of the 0 and 1 transect concentrations. Shoreline concentrations have been set at 0.05 mg/kg for contouring.

Table 4-1 also presents a more detailed evaluation of the change in concentrations of DDTs and PCBs between 1992 and 2002 as well as between 2002 and 2004. Between 1992 and 2002, concentrations of DDTs decreased by more than 10 percent at two-thirds of the stations (16 of 24 stations sampled) and increased by more than 10 percent at about 20 percent of the stations (5 of 24). Between 2002 and 2004, concentrations of DDTs decreased by more than 10 percent at half of the stations (22 of 44) and increased by more than 10 percent at approximately one-third of the stations (15 of 44). The median concentration of DDTs was 3.4 mg/kg, 2.0 mg/kg, and 1.9 mg/kg for 1992, 2002, and 2004, respectively. The median percent decrease in concentrations of DDTs was 32.6 percent between 1992 and 2002 and was 11.4 percent between 2002 and 2004.

Between 1992 and 2002, concentrations of PCBs decreased by more than 10 percent at approximately 42 percent of the stations (9 of 24) and increased at 38 percent of the stations (10 of 24). Between 2002 and 2004, concentrations of PCBs decreased by more than 10 percent at approximately 45 percent of the stations (20 of 44) and increased at 32 percent of the stations (14 of 44). The median concentration of PCBs was 0.4 mg/kg, 0.2 mg/kg, and 0.2 mg/kg for 1992, 2002, and 2004, respectively. The median percent decrease in concentrations of PCBs was zero between 1992 and 2002 and was 4.1 percent between 2002 and 2004.

These data indicate a significant drop in concentrations of DDTs from 1992 to 2002 and from 2002 to 2004 at the PV Shelf Study Area, with the exception of Station 8C. For PCBs, there was no significant decrease between 1992 and 2002, but a slight, measurable decrease between 2002 and 2004.

4.3.2 Concentrations of DDTs and PCBs at Depth

Both LACSD and USGS have collected sediment cores at the PV Shelf Study Area (Figure 2-1). Figures 4-5, 4-6, and 4-7 summarize sediment core data collected by LACSD from 2001, 2003, and 2005, respectively, for the most dominant DDT isomer, p,p'-DDE (or DDE). Average and maximum DDE concentrations are shown for 15-cm depth intervals (0 to 15 cm, 16 to 30 cm, 31 to 45 cm, and deeper until concentrations of DDE stayed below 1 ppm, assumed to indicate pre-effluent sediment) at selected LACSD sampling stations, most of which are located along the 61-m isobath (C Stations). In general, as shown on Figures 4-5 and 4-7, the average and maximum DDE concentrations southeast of the outfalls were highest in the shallow or surface sediment interval (0 to 15 cm). Northwest of the outfalls, the highest DDE concentrations occurred in the 16- to 30-cm or 31- to 45-cm intervals. The maximum DDE concentration detected in the three sampling events was 238 mg/kg, found at Station 8C in the 16- to 30-cm depth interval. Complete results for these core samples are provided in Appendix A.

Sediment core data showing concentrations of PCBs within sediment depth strata are shown on Figure 4-8. Average and maximum concentrations of PCBs are shown for 15-cm depth intervals. Figure 4-8 shows sediment core data collected by USGS in 1992 at 17 sampling stations located in water depths from 26 to 167 m. The 1992 USGS data for PCBs is the sum of the following congeners: 8, 18, 28, 44, 52, 66, 101, 105, 118, 128, 138, 153, 170, 180, 187, 195, 206, and 209.

As with DDE, in general, the average and maximum concentrations of PCBs southeast of the outfalls were highest in the shallow or surface sediment interval (0 to 15 cm). Northwest of the outfalls, the highest concentrations of PCBs occurred in the 16- to 30-cm or the 31- to 45-cm intervals. The highest average concentrations of PCBs were at Stations 564, 557, 556, and 550, which are located between or immediately northwest of the outfalls with the average interval concentrations ranging from 1.3 to 18 ppm. The highest concentrations of PCBs are located in water depths between 50 and 60 m; the maximum concentration of PCBs (20.6 mg/kg) was found along the 56-m isobath at Station 564 in the 31- to 45-cm sediment depth interval.

For comparison, sediment core data for DDTs collected by USGS in 1992 at 23 stations are shown on Figure 4-9. The 1992 USGS data for DDTs consisted of the isomers p,p'-DDT; o,p'-DDT; p,p'-DDD; o,p'-DDD; p,p'-DDE; o,p'-DDE and DDMU (1-chloro-2,2-bis [p-chlorophenyl] ethylene). However, DDMU is not included in the concentrations of DDTs in this report to make the values comparable with other studies. The average and maximum concentrations of DDTs southeast of the outfalls were highest in the shallow or surface sediment interval (0 to 15 cm). Northwest of the outfalls, the highest concentrations of DDTs occurred in the 16- to 30-cm or 31- to 45-cm intervals. Like PCBs, the highest concentrations of DDTs were located in water depths of 50 to 60 m; the maximum concentration of DDTs (305 mg/kg) was detected at Station 564 at a water depth of 56 m in the 16- to 30-cm sediment depth interval.

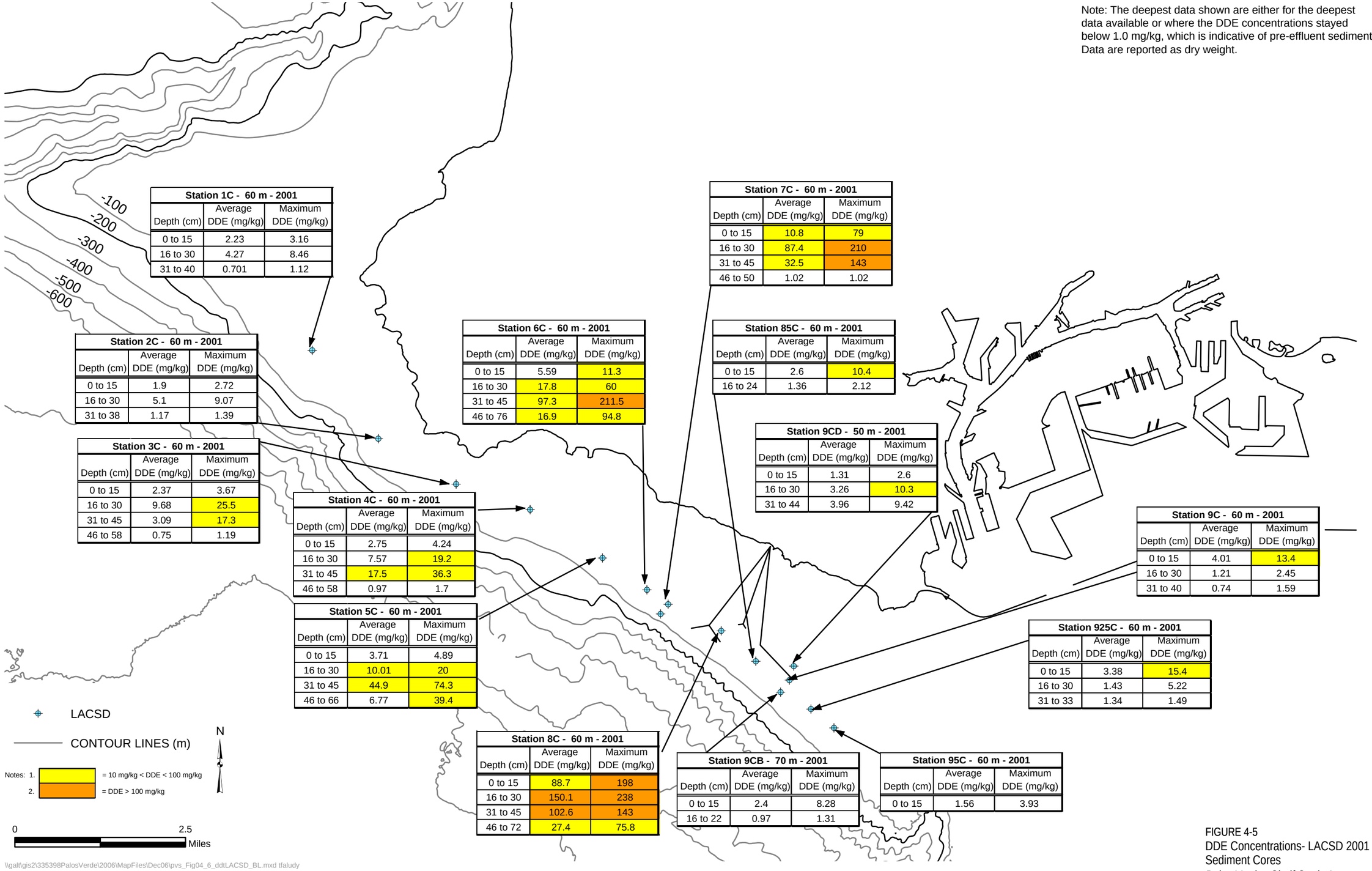
4.3.2.1 Historic DDE Profiles

USGS has performed an extensive evaluation of DDE sediment core data collected by LACSD from as early as 1981 to as late as 2005 to demonstrate temporal changes in the DDE deposit (Sherwood et al., 2006). Figure 4-10 shows depth profiles of DDE concentrations (shaded in gray) at Stations 1 through 9C, all of which are located along the 61-m isobath, typically spaced at 2-year intervals. Data from LACSD Stations 3C, 6C, and 8C begin in 1981; data from most other sites begins in 1987. The profiles show DDE concentrations at 2-cm intervals and the points on profiles are connected with colored lines to illustrate trends such as the depths at which the concentration falls below 1 mg/kg, assumed to be the approximate depth of the pre-effluent layer (red dashed lines); depths at which the cumulative inventory of the profile reaches 25 percent, 50 percent, and 75 percent (blue dashed lines); and the depth of peak DDE concentrations (solid red lines). The scale bar in the key is 100 mg/kg (mass concentration of DDE in dry sediment).

At Site 3C, there has been a decrease in the DDE inventory (mass of DDE) as evidenced by the declining profile area. The depth to the center of the mass of DDE (50th percentile) and to the peak increases each year to 1993, then increases slightly and levels off. This suggests burial occurred initially at Station 3C, but then stopped. The profile has widened since the initial years as shown by the increasing distances between the 25th and 50th percentile lines. This indicates that mixing has occurred, particularly in the upper half of the profile.

At Station 6C, there has been a significant reduction in the DDE inventory from the early 1980s to the early 2000s. A gradual increase in the depth to the center of the mass of DDE and the peak DDE concentrations has occurred. The profile has broadened, but has remained relatively constant since the early 1990s.

Note: The deepest data shown are either for the deepest data available or where the DDE concentrations stayed below 1.0 mg/kg, which is indicative of pre-effluent sediment. Data are reported as dry weight.



Station 1C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	2.23	3.16
16 to 30	4.27	8.46
31 to 40	0.701	1.12

Station 2C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	1.9	2.72
16 to 30	5.1	9.07
31 to 38	1.17	1.39

Station 3C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	2.37	3.67
16 to 30	9.68	25.5
31 to 45	3.09	17.3
46 to 58	0.75	1.19

Station 4C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	2.75	4.24
16 to 30	7.57	19.2
31 to 45	17.5	36.3
46 to 58	0.97	1.7

Station 5C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	3.71	4.89
16 to 30	10.01	20
31 to 45	44.9	74.3
46 to 66	6.77	39.4

Station 6C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	5.59	11.3
16 to 30	17.8	60
31 to 45	97.3	211.5
46 to 76	16.9	94.8

Station 7C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	10.8	79
16 to 30	87.4	210
31 to 45	32.5	143
46 to 50	1.02	1.02

Station 85C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	2.6	10.4
16 to 24	1.36	2.12

Station 9CD - 50 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	1.31	2.6
16 to 30	3.26	10.3
31 to 44	3.96	9.42

Station 9C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	4.01	13.4
16 to 30	1.21	2.45
31 to 40	0.74	1.59

Station 925C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	3.38	15.4
16 to 30	1.43	5.22
31 to 33	1.34	1.49

Station 8C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	88.7	198
16 to 30	150.1	238
31 to 45	102.6	143
46 to 72	27.4	75.8

Station 9CB - 70 m - 2001

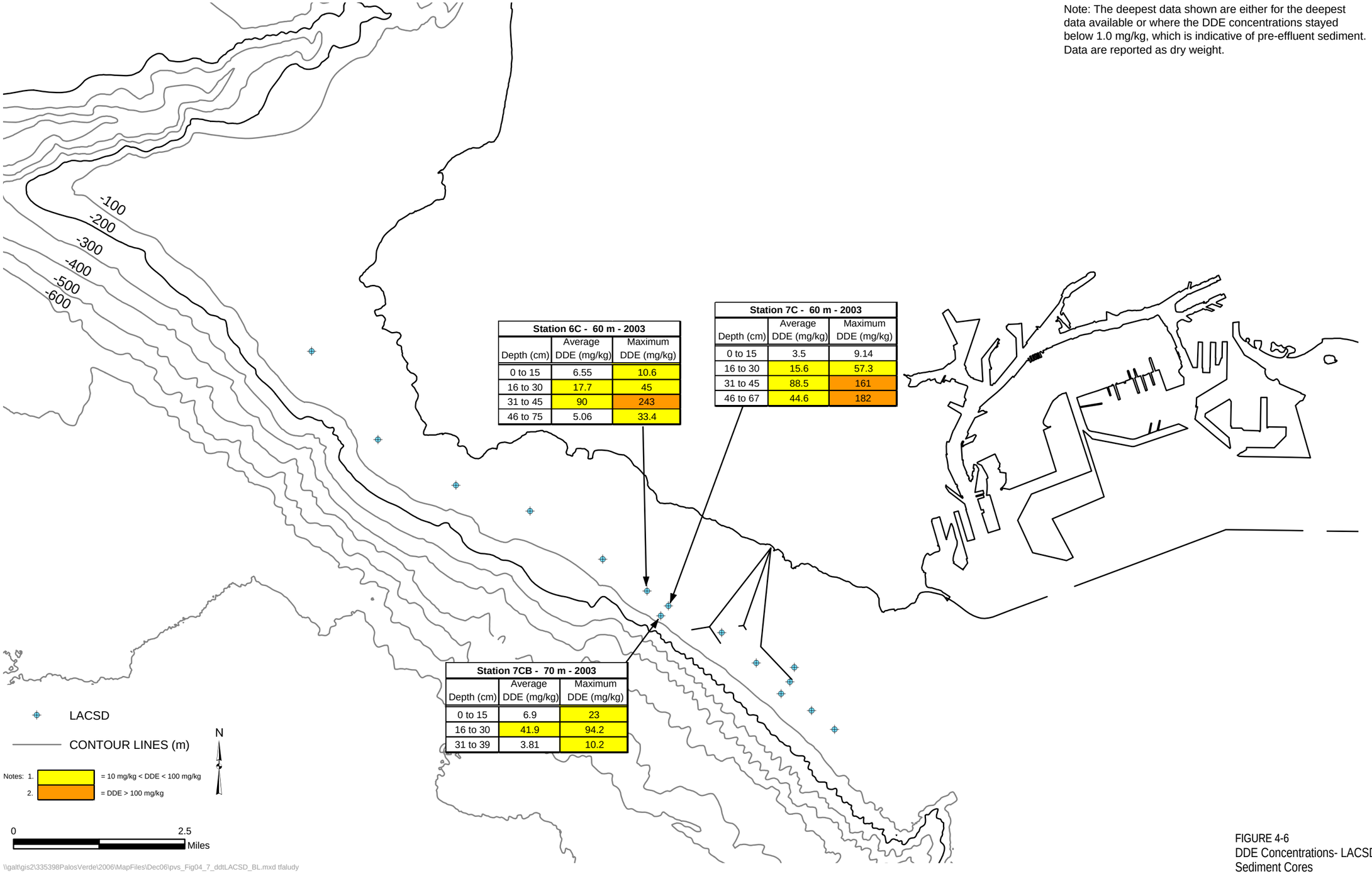
Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	2.4	8.28
16 to 22	0.97	1.31

Station 95C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	1.56	3.93

FIGURE 4-5
DDE Concentrations- LACSD 2001
Sediment Cores
Palos Verdes Shelf Study Area
Remedial Investigation Report

Note: The deepest data shown are either for the deepest data available or where the DDE concentrations stayed below 1.0 mg/kg, which is indicative of pre-effluent sediment. Data are reported as dry weight.



Station 6C - 60 m - 2003

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	6.55	10.6
16 to 30	17.7	45
31 to 45	90	243
46 to 75	5.06	33.4

Station 7C - 60 m - 2003

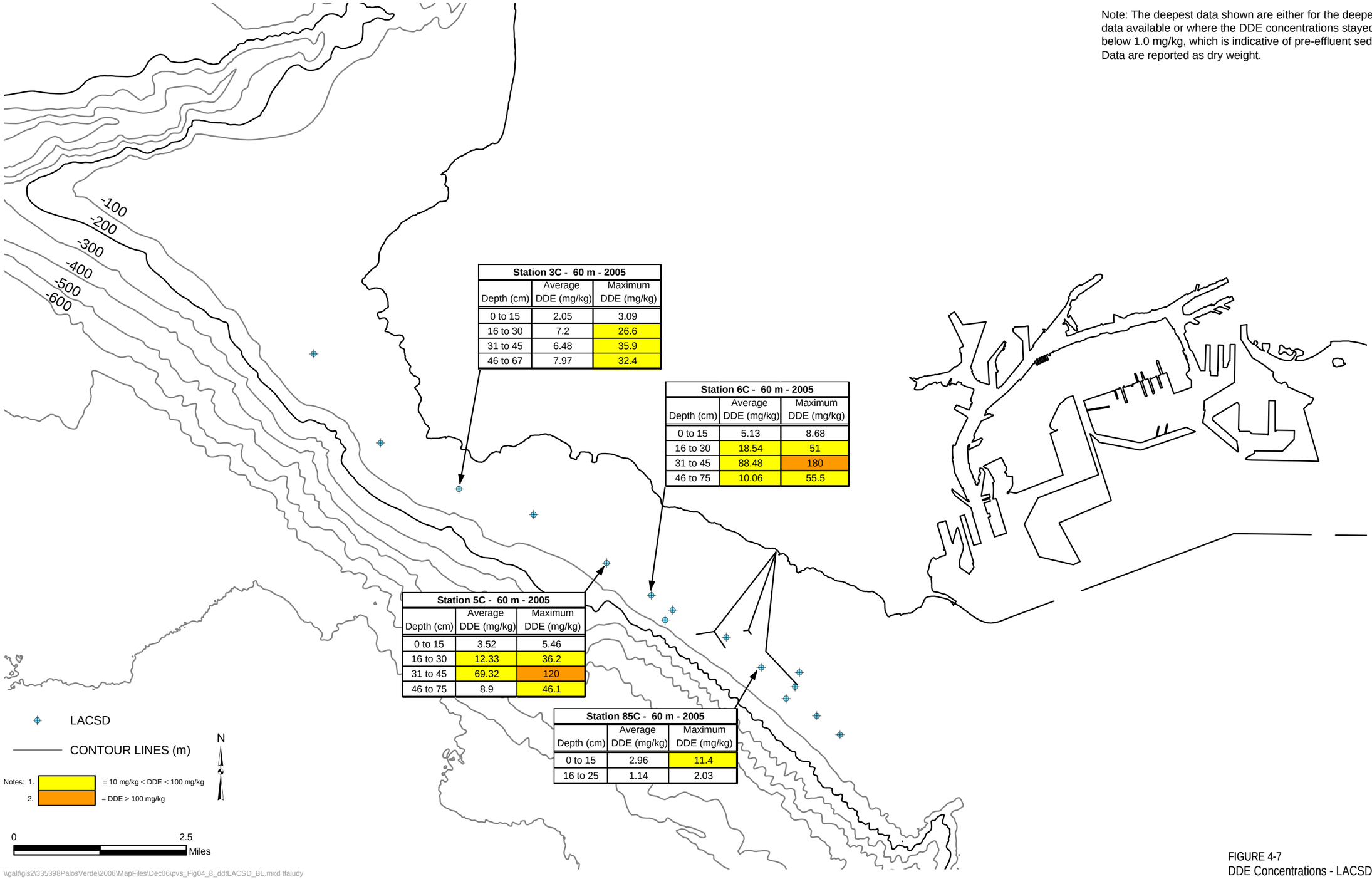
Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	3.5	9.14
16 to 30	15.6	57.3
31 to 45	88.5	161
46 to 67	44.6	182

Station 7CB - 70 m - 2003

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	6.9	23
16 to 30	41.9	94.2
31 to 39	3.81	10.2

FIGURE 4-6
DDE Concentrations- LACSD 2003 Sediment Cores
Palos Verdes Shelf Study Area
Remedial Investigation Report

Note: The deepest data shown are either for the deepest data available or where the DDE concentrations stayed below 1.0 mg/kg, which is indicative of pre-effluent sediment. Data are reported as dry weight.



Station 3C - 60 m - 2005

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	2.05	3.09
16 to 30	7.2	26.6
31 to 45	6.48	35.9
46 to 67	7.97	32.4

Station 6C - 60 m - 2005

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	5.13	8.68
16 to 30	18.54	51
31 to 45	88.48	180
46 to 75	10.06	55.5

Station 5C - 60 m - 2005

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	3.52	5.46
16 to 30	12.33	36.2
31 to 45	69.32	120
46 to 75	8.9	46.1

Station 85C - 60 m - 2005

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	2.96	11.4
16 to 25	1.14	2.03

FIGURE 4-7
DDE Concentrations - LACSD 2005
Sediment Cores
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: Lee et al., The Distribution and Character of Contaminated Effluent-affected Sediment, Palos Verdes Margin, Southern California, 1994

Note: The deepest data shown are either for the deepest data available or where the concentrations of PCBs stayed below 1.0 mg/kg, which is indicative of pre-effluent sediment. Data are reported as dry weight.

Station 522 - 57 to 59 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.471	0.732
16 to 30	0.584	1.230
31 to 48	0.967	2.740

Station 536 - 65 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.585	0.943
16 to 30	2.168	4.97
31 to 40	3.599	5.29

Station 534 - 38 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.265	0.323
16 to 30	0.372	0.492
31 to 48	0.497	0.818

Station 539 - 44 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.361	0.419
16 to 30	0.463	0.510
31 to 44	0.531	0.553
45 to 60	1.363	2.270

Station 514 - 53 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.422	0.489
16 to 30	0.544	0.780
31 to 45	0.115	0.115

Station 547 - 26 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.871	3.730
16 to 24	0.217	0.593

Station 554 - 28 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.103	0.155
16 to 32	0.157	0.211

Station 518 - 89 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 12	0.506	0.851

Station 555 - 42 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.320	0.644
16 to 30	0.362	0.420
31 to 45	0.511	0.604

Station 556 - 56 to 57m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	1.356	1.800
16 to 30	2.062	7.010
31 to 45	6.977	19.900

Station 532 - 137 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.92	1.04
16 to 32	2.182	3.55

Station 564 - 56 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	1.756	2.730
16 to 30	6.200	13.900
31 to 45	6.217	20.600

Station 523 - 141 to 59 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.643	1.3

Station 566 - 181 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 16	0.680	1.940

Station 574 - 58 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	4.524	7.610
16 to 30	2.377	4.160
31 to 45	0.425	0.425

Station 533 - 167 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	1.353	2.44
16 to 28	1.961	4.31

Station 570 - 74 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	1.406	3.680
16 to 32	1.571	3.340

Station 542 - 207 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 4	0.163	0.163

Station 552 - 192 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	1.666	3.730
16 to 24	0.347	0.593

Station 577 - 66 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.812	1.470
16 to 28	0.197	0.300

Station 550 - 57 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	1.312	3.660
16 to 30	1.929	4.440
31 to 45	6.022	18.400

Station 557 - 104 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	1.565	3.940
16 to 30	8.970	12.600
31 to 38	2.673	4.150

Station 571 - 144 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	1.471	2.890
16 to 20	0.111	0.111

-100
-200
-300
-400
-500
-600

USGS

CONTOUR LINES (m)

Notes: 1. = 10 mg/kg < PCBs < 100 mg/kg
2. = PCBs > 100 mg/kg

N

0 .5 Miles

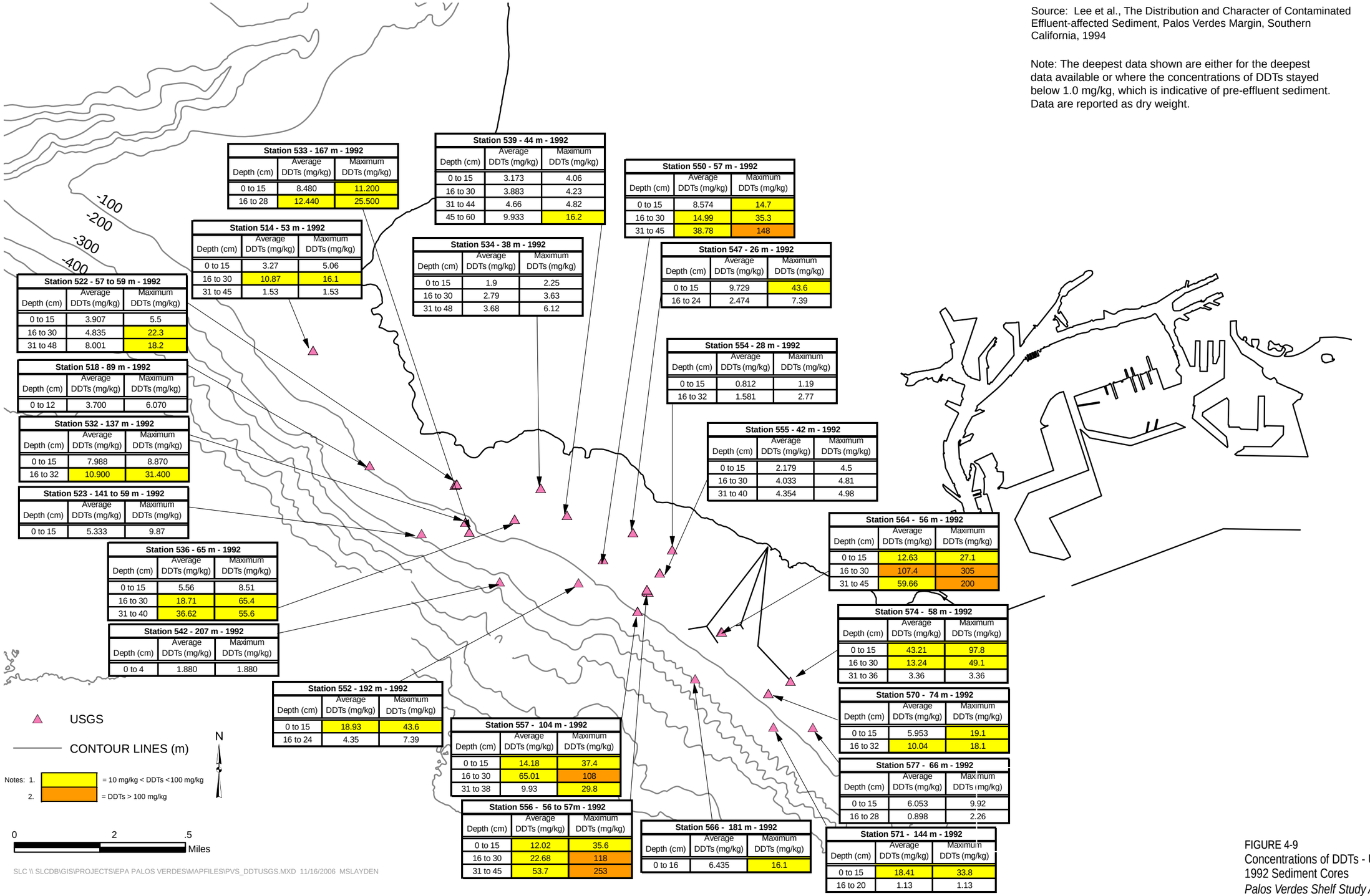
SLC \\SLCDB\GIS\PROJECTS\EPA PALOS VERDES\MAPFILES\PVS_PCBUSGS.MXD 11/16/2006 MSLAYDEN

FIGURE 4-8
Concentrations of PCBs - USGS 1992 Sediment Cores
Palos Verdes Shelf Study Area
Remedial Investigation Report

CH2MHILL

Source: Lee et al., The Distribution and Character of Contaminated Effluent-affected Sediment, Palos Verdes Margin, Southern California, 1994

Note: The deepest data shown are either for the deepest data available or where the concentrations of DDTs stayed below 1.0 mg/kg, which is indicative of pre-effluent sediment. Data are reported as dry weight.



Station 533 - 167 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	8.480	11.200
16 to 28	12.440	25.500

Station 539 - 44 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	3.173	4.06
16 to 30	3.883	4.23
31 to 44	4.66	4.82
45 to 60	9.933	16.2

Station 550 - 57 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	8.574	14.7
16 to 30	14.99	35.3
31 to 45	38.78	148

Station 514 - 53 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	3.27	5.06
16 to 30	10.87	16.1
31 to 45	1.53	1.53

Station 534 - 38 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	1.9	2.25
16 to 30	2.79	3.63
31 to 48	3.68	6.12

Station 547 - 26 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	9.729	43.6
16 to 24	2.474	7.39

Station 522 - 57 to 59 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	3.907	5.5
16 to 30	4.835	22.3
31 to 48	8.001	18.2

Station 554 - 28 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	0.812	1.19
16 to 32	1.581	2.77

Station 518 - 89 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 12	3.700	6.070

Station 555 - 42 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	2.179	4.5
16 to 30	4.033	4.81
31 to 40	4.354	4.98

Station 532 - 137 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	7.988	8.870
16 to 32	10.900	31.400

Station 523 - 141 to 59 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	5.333	9.87

Station 564 - 56 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	12.63	27.1
16 to 30	107.4	305
31 to 45	59.66	200

Station 536 - 65 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	5.56	8.51
16 to 30	18.71	65.4
31 to 40	36.62	55.6

Station 574 - 58 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	43.21	97.8
16 to 30	13.24	49.1
31 to 36	3.36	3.36

Station 542 - 207 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 4	1.880	1.880

Station 570 - 74 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	5.953	19.1
16 to 32	10.04	18.1

Station 552 - 192 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	18.93	43.6
16 to 24	4.35	7.39

Station 577 - 66 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	6.053	9.92
16 to 28	0.898	2.26

Station 557 - 104 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	14.18	37.4
16 to 30	65.01	108
31 to 38	9.93	29.8

Station 556 - 56 to 57m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	12.02	35.6
16 to 30	22.68	118
31 to 45	53.7	253

Station 566 - 181 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 16	6.435	16.1

Station 571 - 144 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	18.41	33.8
16 to 20	1.13	1.13

FIGURE 4-9
Concentrations of DDTs - USGS 1992 Sediment Cores
Palos Verdes Shelf Study Area
Remedial Investigation Report

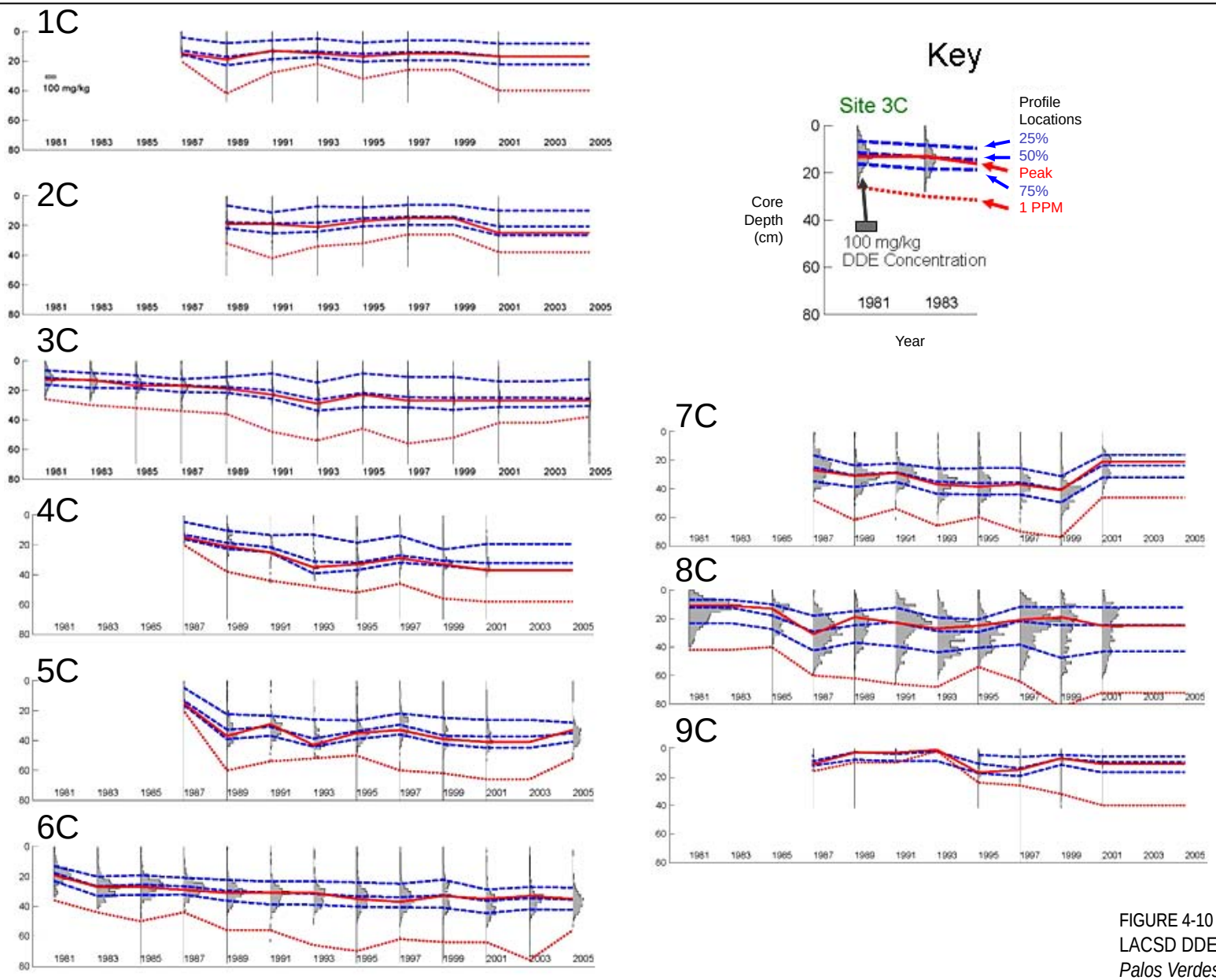


FIGURE 4-10
LACSD DDE Profiles
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: Christopher R. Sherwood, Bénédicte Ferré, Robert P. Eganhouse, Patricia L. Wiberg, 2006. Evolution of the contaminated sediment deposit on the Palos Verdes (CA) Shelf: physical, chemical, and biological processes. Presented at the Eastern Pacific Oceanograpy Conference, Mt. Hood, Oregon, October 2006.

At Station 7C, the plots indicate a gradual increase in the depth of the center of the DDE mass since 1987, slight change in inventory until 2001, and some broadening (mixing) in the upper half of the profile. A notable feature of this plot is the sudden upward shift of the profile in 2001, when the peak concentration moved from a depth of close to 40 cm up to 20 cm. The most likely reason for this shift is that cap placement at Cell SU during the pilot capping study scoured the surface sediments near Station 7C (SAIC, 2005d).

At Station 8C, the center of the mass of DDE (50 percent) had an initial drop, but has remained relatively close to 20 cm in depth since the early 1990s. The profile has widened significantly, especially in the lower half. The inventory of DDE has also decreased since the late 1990s.

These plots indicate that, at most stations, the burial of DDE occurred more rapidly (as evidenced by increasing profile depths) in the initial years, but has slowed down in recent years, as would be expected with declining suspended solids emissions from the LACSD outfall. However, at a few stations (7C and 5C), it appears the depth of the DDE profile has moved closer to the sediment surface, indicating possible erosion, scouring, or changes in biological activity. The profiles have broadened (as indicated by an increased distance between the 25th and 50th percentile or the 50th and 75th percentile lines) since the initial years, which indicates that mixing has occurred.

4.3.2.2 Thickness of the Effluent-affected Deposit

Several researchers have used the DDE data to estimate the thickness, total mass, spatial and temporal distribution, and predictive fate of the effluent-affected deposit (Lee et al., 2002; Sherwood et al., 2002).

Sherwood et al. (2002) presented an along-shore cross-section of the effluent-affected deposit showing the thickness of the deposit at the 61-m isobath as it changed from 1987 to 1993, establishing the depth at which the concentration of DDE first reaches 1 mg/kg to approximate the surface of the pre-effluent sediment (Figure 4-11). Figure 4-11 shows the location of Stations 3C through 10C, the Portuguese Bend Landslide, and the LACSD outfalls (JWPCP diffusers). The shaded areas under the 1987 surface indicate that sediment with higher DDE concentrations (greater than about 20 mg/kg) are overlaid by sediment with lower DDE concentrations (Sherwood et al., 2002).

Figure 4-11 also shows that the thickness of the effluent-affected deposit falls rapidly southeast of the outfalls (Stations 9C and 10C) and falls more gradually to the northwest (Stations 8C through 3C). The 1993 surface indicates that the sediment surface has eroded near Stations 8C and 9C, and deposition of lower-DDE-concentration sediment has occurred between Stations 3C and 8C. In 1987, the thickness of the deposit at the 60-m isobath ranged from approximately 30 cm at Station 3C to about 60 cm at Station 8C. In 2001, the deposit was approximately 45 cm thick at Station 3C and about 60 cm thick at Station 8C. Figure 4-11 shows potential erosion and deposition of the less contaminated surface sediment layer along the 61-m isobath (C stations). Sherwood et al. (2006) concludes that there are no areas with net erosion along this contour.

A cross-section of the effluent-affected deposit perpendicular to the shore was prepared by Lee et al. (2002) using 1992 USGS DDE data. The cross-section indicates that the deposit is approximately 50 cm thick near the outfalls (Station 556), thinning to approximately 10 cm on the slope (Station 581). The DDE concentrations are close to 1 mg/kg shoreward at the 28-m isobath (Station 554) (Lee et al., 2002). USGS sampling stations are shown on Figure 2-1.

Combining data from density logs of sediment cores and seismic profiles, Murray et al., (2002) also prepared estimates of the thickness of the effluent-affected sediment. The mean and maximum thicknesses of the deposit were found to be 39.2 cm and 79 cm, respectively.

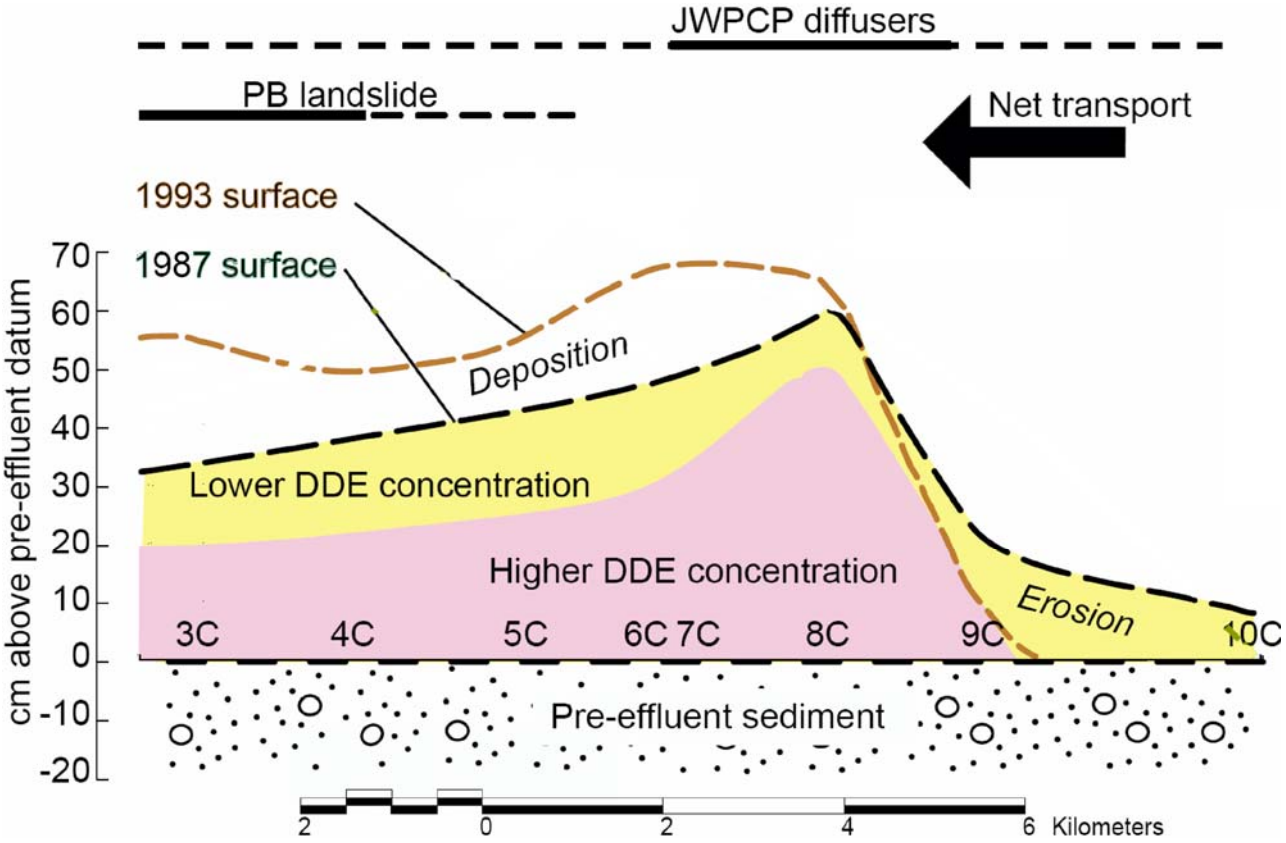
4.4 Fish Tissue

This section presents data from two of the more recent investigations to assess the concentrations of DDTs and PCBs in fish at the PV Shelf: LACSD fish sampling conducted as part of the NPDES ocean monitoring program from 1999 to 2005 (LACSD, 2000, 2002, 2003, 2005, and 2006b) and the *2002-2004 Southern California Coastal Marine Fish Contaminants Survey* (EPA and NOAA, 2007). A summary of these sampling programs is provided in Section 2.0.

Studies have shown that the muscle tissues of bottom-dwelling fish in the PV Shelf Study Area usually have the highest concentrations of DDTs compared with those of other fish in the SCB (SMBRP, 1992). Contaminant concentrations in pelagic fish from the SCB were more uniform over the SCB area, including the PV Shelf Study Area, because these fish travel over a wide range for feeding. Of the various species analyzed, white croaker has the highest concentrations of DDTs and PCBs at every location for studies conducted between 1990 and 2005 (CH2M HILL, 2003; LACSD, 2005; EPA and NOAA, 2007).

Fish tissue is discussed in this section because fish are a source of contamination for other ecological receptors and humans; Section 6.0 discusses ecological and human health risks in more detail. Specifically, white croaker and sanddabs are discussed because they are bottom-feeding fish with a small home range. Therefore, they have a high exposure to the contaminated sediments in the PV Shelf Study Area.

The distribution of white croaker is related to contaminated sediments because this fish species found these areas to be a good source of abundant food. The historically high levels of DDT bioaccumulation in this species has led to a commercial catch ban and recreational catch limits for white croaker in the PV Shelf Study Area. White croaker was one of the top three fish species taken during LACSD (LACSD, 2002) trawls on the 23- and 61-m isobaths during the mid-1970s and early 1980s. However, in the past 15 to 20 years, its abundance at the outfall depth has declined significantly and it is no longer a dominant member of the demersal fish catch.



Source: Sherwood, Christopher R.; Drake, David E.; Wiberg, Patricia L.; Wheatcroft, Robert A.; Prediction of the Fate of p,p'-DDE in Sediment on the Palos Verdes Shelf, California, USA, Continental Shelf Research 22 (2002), 1025-1028.

FIGURE 4-11
Cross-Section of Effluent-Affected Deposit
Palos Verdes Shelf Study Area
Remedial Investigation Report

4.4.1 2002-2004 Southern California Coastal Marine Fish Contaminants Survey

As discussed in Section 2.0, NOAA, on behalf of MSRP, and EPA initiated a comprehensive ocean fish sampling effort in fall 2002 to assess current fish contamination concentrations in the SCB. Twenty-three species of fish were caught at designated locations from Ventura to Dana Point, mostly in the Los Angeles area. Figure 2-2 shows the EPA and MSRP fish study sampling locations located within the PV Shelf Study Area. Fish fillet samples were analyzed for DDTs, PCBs, dieldrin, chlordane, and mercury.

Results for DDTs and PCBs for all species, including white croaker, are shown in Table 4-3. Approximately 1,000 fish muscle fillet samples were analyzed with approximately 177 fish collected at the PV Shelf Study Area. Forty-five white croaker were collected from the PV Shelf Study Area. The tissue concentrations of DDTs ranged from not detected to 6,770 µg/kg. The concentrations of PCBs ranged from not detected to 648 µg/kg.

TABLE 4-3
Fillet Tissue[a] Concentrations
2002-2004 Southern California Coastal Marine Fish Contaminants Survey (EPA and NOAA, 2007)

Fish Common Name	Number of Fish	Average DDTs[c] (µg/kg)	Minimum DDTs (µg/kg)	Maximum DDTs (µg/kg)	Average PCBs[d] (µg/kg)	Minimum PCBs (µg/kg)	Maximum PCBs (µg/kg)
Barred Sandbass	21	744	46.2	4320	84.0	5.47	294
Benthic-feeding Surfperches	20	112	18.6	430	14.8	2.72	60
Black Croaker	5	127	23	185	22.2	4.68	29.5
California Scorpionfish	18	605	38.1	2,630	66.8	8.9	243
Jacksmelt	10	10.4	2.51	29.7	2.34	ND	7.27
Kelp Bass	10	249	65.9	605	40.3	15	71.5
Opaleye	10	0.656	ND	1.53	5.96	1.53	16.9
Pacific Mackerel	10	28.6	[b]	[b]	9.19	[b]	[b]
Pacific Sardine	5	262	[b]	[b]	92.6	[b]	[b]
Rockfishes	13	225	77.1	427	28.8	12.8	48.5
Topsmelt	10	198	83.1	347	36.5	19.7	74.6
White Croaker	45	794	127	6,770	187	58	648

[a] Includes samples from Segments 8, 9, 12, 13, 14, and EPA E; no samples from Segments 10 and 11.
[b] Analysis was conducted on a composite sample; therefore, no maximum and minimum are available.
[c] DDTs consist of p,p'-DDT; o,p'-DDT; p,p'-DDD; o,p'-DDD; p,p'-DDE; and o,p'-DDE.
[d] PCBs consist of congeners 8, 18, 28, 31, 37, 44, 49, 52, 66, 70, 74, 77, 81, 87, 99, 101, 105, 110, 114, 118, 119, 123, 126, 128, 138, 149, 151, 153, 156, 157, 158, 167, 168, 169, 170, 177, 180, 183, 187, 189, 194, 195, 201, 203, and 206.

Table 4-4 shows the distribution of samples collected at the PV Shelf Study Area. The concentrations of DDTs in white croaker ranged from 127 to 6,770 µg/kg, with an average concentration of 794 µg/kg. The concentrations of PCBs ranged from 15.3 to 648 µg/kg, with an average concentration of 187 µg/kg.

TABLE 4-4
White Croaker Fillet Concentrations[a,b] for PV Shelf Study Area
2002-2004 Southern California Coastal Marine Fish Contaminants Survey (EPA and NOAA, 2007)

Sample Location	Number of Samples	Average DDTs (µg/kg)	Minimum DDTs (µg/kg)	Maximum DDTs (µg/kg)	Average PCBs (µg/kg)	Minimum PCBs (µg/kg)	Maximum PCBs (µg/kg)
12	9	1,830	589	6,770	200	72.3	619
13 to 14	7	742	186	1,400	90.8	24.8	161
EPA E	29	992	127	3,590	120	15.3	356
Summary	45	794	127	6,770	187	58	648

[a] DDTs consist of p,p'-DDT; o,p'-DDT; p,p'-DDD; o,p'-DDD; p,p'-DDE; and o,p'-DDE.
[b] PCBs consist of congeners 8, 18, 28, 31, 37, 44, 49, 52, 66, 70, 74, 77, 81, 87, 99, 101, 105, 110, 114, 118, 119, 123, 126, 128, 138, 149, 151, 153, 156, 157, 158, 167, 168, 169, 170, 177, 180, 183, 187, 189, 194, 195, 201, 203, and 206.

White croaker from Segment 12, located just north of the outfalls, had the highest concentration of DDTs and PCBs. The EPA E sample location, on the northwestern half of the PV Shelf had the next highest concentrations of DDTs and PCBs. Segments 13 to 14, encompassing the areas just northwest and southeast of the outfalls had the lowest concentrations of DDTs and PCBs in the white croaker fillet tissue. Section 6.0 provides a discussion of the risk to human health from the consumption of fish from the PV Shelf Study Area.

4.4.2 LACSD Fish Sampling

The current NPDES permit for the JWPCP includes monitoring requirements for determining accumulation levels of DDTs and PCBs within tissues of various fish and invertebrate species. The purpose of the monitoring is to evaluate the temporal and spatial trends associated with bioaccumulation of DDTs and PCBs in biota collected within the following three zones across the PV Shelf (Figure 2-2):

- Zone 1, from White Point to Bunker Point
- Zone 2, from Long Point to Point Vicente
- Zone 3, from Palos Verdes Point to Bluff Cove

In compliance with the NPDES permit requirements, fillet tissue samples of white croaker were collected and analyzed in 1999, 2001, 2002, 2004, and 2005. Each year, 10 white croaker fish samples were collected in each of three zones off the Palos Verdes Peninsula in approximately 50 m of water. In 2005, an additional 20 white croaker were collected in Zone 1 from areas in shallow water with lower concentrations of DDTs and PCBs in the sediment. Table 4-5 summarizes the average, minimum, and maximum concentrations of DDTs and PCBs for the white croaker fillet tissue from 1999 to 2005. The 20 white croaker samples collected in 2005 from the less-contaminated shallow water areas in Zone 1 are not included in Table 4-5 so that comparisons can be made to previous years.

From 1999 to 2005, the concentrations of DDTs in white croaker ranged from 50 to 78,800 µg/kg across all three zones. The average concentration in the most recent sampling event (2005) was 3,847 µg/kg in Zone 1. For PCBs, the concentrations ranged from 20 to 6,500 µg/kg across all three zones from 1999 to 2005. The average concentration in 2005 was 402 µg/kg in Zone 1. For Zones 1 and 2, which are closest to the outfalls, the highest concentrations of DDTs and PCBs occurred in 2002; since then, concentrations have declined by approximately an order of magnitude in Zone 1. For Zone 3, located just south of Redondo Canyon, the highest concentrations occurred in 1999; and similar to Zones 1 and 2, concentrations have declined since then, though to a lesser degree. Based on the most recent data, the concentrations of DDTs and PCBs appear to be decreasing in the white croaker fillet tissue, most significantly in the Zone 1 outfall vicinity. As described in Section 6.0, the concentrations of DDTs and PCBs in fish pose a significant risk to human health.

The LACSD fish data in Table 4-5 show a relationship between the DDTs and PCBs in the effluent-affected sediment and the DDTs and PCBs in fish. As the sediment contaminant concentrations decrease from the outfall northwest to Redondo Canyon, the contaminant levels in the fish decrease from Zone 1 (encompassing the outfalls) northwest to Zone 3 (near Redondo Canyon).

TABLE 4-5
LACSD White Croaker Fillet Data
1999-2005

Year	No. of Samples	Average DDTs[a] (µg/kg)	Minimum DDTs (µg/kg)	Maximum DDTs (µg/kg)	Average PCBs[b] (µg/kg)	Minimum PCBs (µg/kg)	Maximum PCBs (µg/kg)
ZONE 1							
1999	10	26,407	540	61,300	1,600	30	3,320
2001	10	25,398	8,610	47,900	1,881	570	3,590
2002	10	33,735	13,700	78,800	2,946	1,130	6,500
2004	10	10,819	1,310	19,100	1,190	220	2,110
2005	10	3,847	140	7,430	402	50	730
ZONE 2							
1999	10	6,009	610	13,020	679	80	1,420
2001	10	5,451	1,930	10,440	537	130	1,070
2002	10	8,605	2,440	20,230	880	290	1,960
2004	10	7,046	400	15,270	924	180	1,730
ZONE 3							
1999	10	4,252	50	13,690	474	20	1,040
2001	10	2,509	550	9,670	395	140	1,050
2002	10	1,470	320	2,640	202	30	410
2004	10	1,611	390	3,810	311	80	640

[a] DDTs consisted of the sum of p,p'-DDT; o,p'-DDT; p,p'-DDD; o,p'-DDD; p,p'-DDE and o,p'-DDE isomers.

[b] PCBs consisted of the sum of Aroclors 1016, 1221, 1232, 1242, 1254, 1248, and 1260.

4.5 Water Column

This section describes the results of surface water sampling conducted at the PV Shelf Study Area. In 1997, the SCCWRP collected water column samples at eight LACSD monitoring stations located at the PV Shelf Study Area during two seasons. Most of these samples were taken from approximately 1 m off the ocean floor and analyzed for DDTs and PCBs (Zeng et al., 1999). As shown on Figure 4-12, six stations were located at the 61-m contour (C stations), and two stations were located, one each at the 30-m contour (D stations) and 152-m contour (B stations). At one mid-shelf station (Station 6C), samples were taken from approximately 2, 5, 20, and 35 m above the ocean floor. These data for DDTs and PCBs are presented in Table 4-6.

For both DDTs and PCBs, in winter and summer, there was a distinct gradient where dissolved, particulate, and total contaminant concentrations were highest near the sediment. The water concentrations at the site ranged from 0.6 to 15.8 nanograms per liter (ng/L) DDTs and 0.06 to 1.14 ng/L PCBs. A study performed in 2003 found the dissolved phase concentration of p,p'-DDE to be 3.8 ng/L at Station 6C at a depth of 2 m above the sediment-water interface (Zeng et al., 2005).

The Clean Water Act national recommended water quality criteria for the protection of human health for DDTs and PCBs are 0.22 ng/L and 0.064 ng/L, respectively. The concentrations in Table 4-6 exceed these criteria. It is highly likely that the elevated concentrations in the near-bottom portion of the water column represent resuspended sediments rather than the dissolved fractions of these highly hydrophobic compounds.

TABLE 4-6
Water-column Concentrations of DDTs and PCBs
PV Shelf Study Area

Station	Station Depth (m)	Sampling Depth (m)	Concentration (DDTs[a]) (ng/L)	Concentration (PCBs[b]) (ng/L)
Winter				
0C-1M	60	59	2.3	0.14
3C-1M	60	59	4.5	0.28
5C-1M	60	59	9.2	0.51
6C-1M	60	59	14.5	0.88
6C-2M	60	58	15.8	0.89
6C-5M	60	55	7.6	0.41
6C-20M	60	40	2.8	0.21
6C-35M	60	25	0.8	0.06
7C-1M	60	59	9.9	0.65
9C-1M	60	59	5.3	0.31
6B-1M	150	149	5.4	0.33
6D-1M	30	29	7.2	0.48

TABLE 4-6
Water-column Concentrations of DDTs and PCBs
PV Shelf Study Area

Station	Station Depth (m)	Sampling Depth (m)	Concentration (DDTs[a]) (ng/L)	Concentration (PCBs[b]) (ng/L)
Summer				
0C-1M	60	59	4.3	0.41
3C-1M	60	59	7.6	0.94
5C-1M	60	59	10.4	1.14
6C-1M	60	59	8.7	0.84
6C-2M	60	58	10.3	1.11
6C-5M	60	55	8.6	0.94
6C-20M	60	40	2	0.28
6C-35M	60	25	0.6	0.21
7C-1M	60	59	5.5	0.56
9C-1M	60	59	5	0.30
6B-1M	150	149	5.6	0.52
6D-1M	30	29	3	0.67

Notes:

These concentrations represent the sum of the dissolved and particulate DDTs measured. Winter samples were collected from January to March 1997. Summer samples were collected from June to July 1997.

[a] DDTs consist of the sum of p,p'-DDT; o,p'-DDT; p,p'-DDD; o,p'-DDD; p,p'-DDE; and o,p'-DDE.

[b] PCBs consist of the sum of 8, 18, 28, 29, 44, 50, 52, 66, 77, 87, 101, 104, 105, 118, 126, 128, 138, 153, 154, 170, 180, 187, 188, 195, 200, 206, and 209.

Source: Zeng et al., 1999

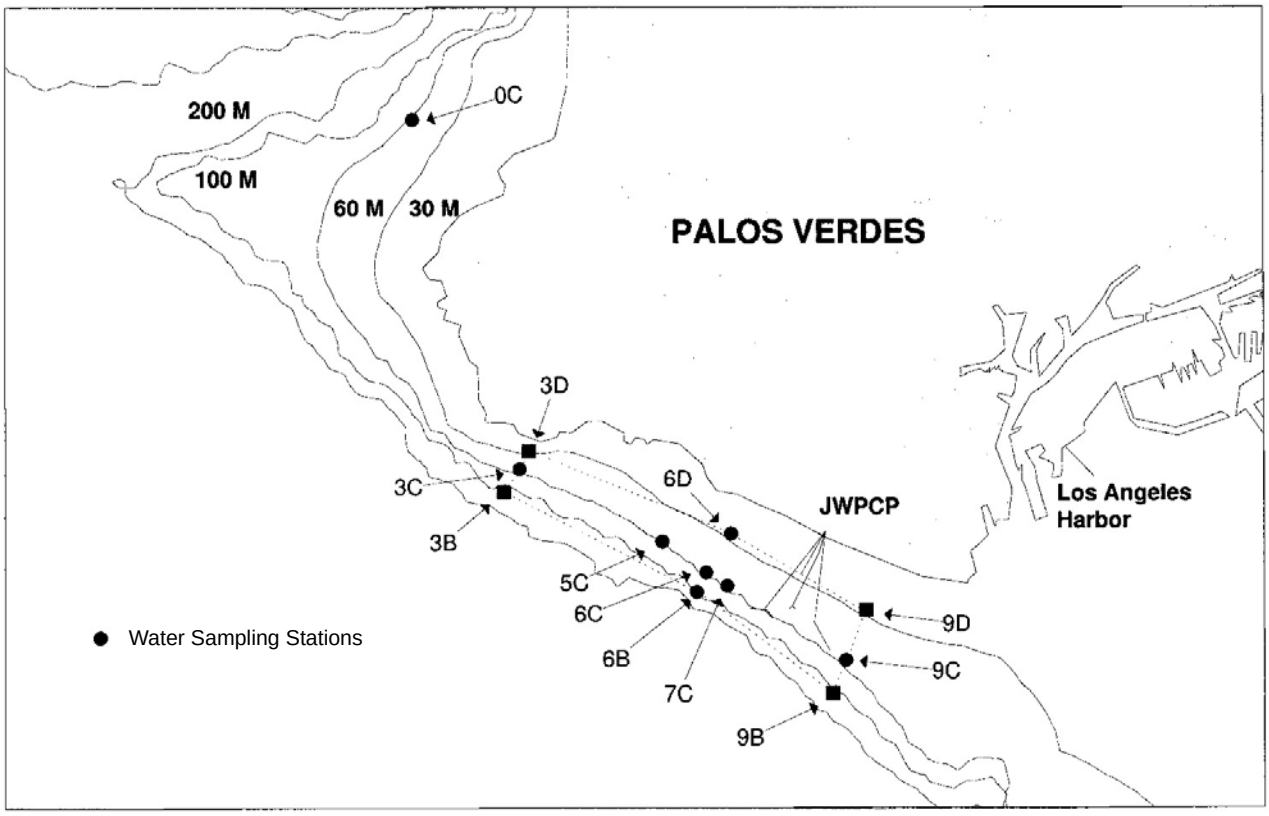


FIGURE 4-12
Sample Locations for Surface Water
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: Zeng et al., 1999.

5.0 Contaminant Fate and Transport

This section describes the fate and transport of DDTs and PCBs at the PV Shelf Study Area. The fate and transport of these contaminants depends on chemical, biological and physical processes and the rates of these processes are required for predicting short-term and long-term conditions at the site.

5.1 Introduction

The release of DDT-related wastes by Montrose into the LACSD sewer system ended in 1971; however, residues in the sewer system continued to be discharged from the ocean outfalls for many years. Concentrations of DDTs in the effluent discharges remained at or near the laboratory detection limit starting in 1989 and have been below the laboratory detection limit since 2002 (LACSD, 2006a). Concentrations of PCBs in effluent discharges have not been detected since 1986 (LACSD, 2006a). Therefore, there are no significant ongoing sources introducing DDTs or PCBs to the PV Shelf Study Area from the LACSD outfalls; the fate and transport of contaminants stored within the sediments will determine future concentrations and affected areas within the site.

In general, fate and transport of contaminants in the ocean sediment can be described by the following processes:

- Affinity – Contaminants can exist as solutes in pore water or seawater, or sorbed onto the solid phase (sediments, particularly the organic components). Exchange between these media and the gaseous phase is not important for these contaminants because none of the sediment is exposed to air and the contaminant concentrations in surface waters are low. Both DDTs and PCBs have a strong affinity with the solid phase, but desorption into the liquid phase (and subsequent movement of the pore water or seawater) is responsible for some of the contaminant dispersal.
- Chemical Transformation – Contaminants can transform into other compounds.
- Physical Transport in the Liquid Phase – Dissolved contaminants can be physically transported by moving fluids. Net transport in the direction of fluid motion (over some period of observation) is termed advection. Advection by small-scale turbulent motions produces mixing and, in combination with gradients in dissolved contamination concentrations, results in transport by eddy diffusion. Over larger scales, advection and mixing by currents produces dispersion. Transport also occurs within fluids by molecular diffusion, but this process occurs over very small space scales and is relatively insignificant.
- Physical Transport in the Solid Phase – Contaminants sorbed to sediment particles can be physically transported along with the particles. Physical mechanisms are important at the PV Shelf Study Area, both within sediments, where the solid phase is moved by organisms, and in the water column, where suspended particulates are transported by currents. The environmental risk posed by contaminants is also affected by transport

of noncontaminated material (e.g., uncontaminated sediment) that can be deposited or eroded.

The contaminant fate and transport discussion in this section will focus on the following specific processes occurring at the PV Shelf Study Area:

- Chemical mobility and persistence of DDTs and PCBs (Section 5.2)
- Transformation of DDTs and PCBs (Section 5.3)
- Bioturbation and biodiffusion (Section 5.4)
- Molecular diffusion of contaminants in pore water (Section 5.5)
- Adsorption/desorption to or from resuspended material (Section 5.6)
- Transport of contaminants by currents and waves (Section 5.7)
- Natural burial through episodic (storm events, earthquakes), chronic, or anthropogenic processes (Section 5.8)

The CSM, discussed in Section 7.0, summarizes the current understanding of nature and extent of contamination, the fate and transport of contaminants at the site, and potential exposure of human and ecological receptors.

5.2 Chemical Mobility and Persistence of PCBs and DDTs

The chemical mobility of a compound refers to its tendency to be transported among environmental media (water, sediment, air, and biota) through sorption, solubilization, volatilization, bioconcentration, and bioaccumulation resulting in widespread distribution away from the original site of deposition. Persistence refers to the tendency of a compound to remain in the environment without transforming into other compounds. Rather than being transformed, persistent compounds will merely be redistributed among environmental compartments. Both DDTs and PCBs have been considered to be highly persistent in the environment. However, under appropriate conditions, they could be transformed through various biogeochemical processes.

The relative importance of these processes for PCBs and DDTs can be assessed by examining interrelated physiochemical parameters for each compound including the solubility in water, vapor pressure, and relevant partition coefficients. The following are relevant partition coefficients:

- The octanol-water equilibrium partition constant (K_{OW}), which is the ratio of the molar concentration of the compound in an organic solvent, octanol, and the concentration of the compound in water at equilibrium. The more hydrophobic the compound, the higher the solubility will be in octanol and the larger the K_{OW} value will be. K_{OW} is also sometimes expressed as its base-10 logarithm, log K_{OW}. K_{OW} values are used to assess the partitioning of organic compounds from water into organic phases and to assess bioaccumulation potential in biota.

- The organic carbon normalized sediment-water partition coefficient (K_{OC}), which is the ratio of the concentration of the compound associated with organic carbon fraction in sediment and the concentration of the compound in water at equilibrium. The more hydrophobic the compound, the higher the solubility will be in the organic carbon fraction and the higher the K_{OC} value will be. K_{OC} is also sometimes expressed as its base-10 logarithm, log K_{OC}. K_{OC} values are used to assess the partitioning of organic compounds between water and the organic carbon associated with sediment.
- The air-water partition coefficient or Henry's Law constant (Hc), which is the ratio of the partial pressure of the compound and the concentration of the compound in water at equilibrium. The Hc value can be used to assess the air-water transport of organic chemicals in dilute solutions such as those encountered for hydrophobic organic chemicals with low water solubility.

On the PV Shelf Study Area, the most important transport pathways for PCBs and DDTs involve sediment-water, water-biota, and sediment-biota. The air-water and air-sediment transport pathways are not significant for PCBs and DDTs, which are strongly sorbed to the bottom sediments. This results in low surface water concentrations and in low air-water transfer. Mixing between the surface and bottom waters is limited so the pathway from sediment to air is also inefficient.

Tables 5-1 through 5-3 present relevant physicochemical parameters for DDTs and PCBs. The physicochemical properties for each Aroclor depend on the distribution of PCB congeners found in the commercial mixture. The PCB congeners selected as illustrative of the range of physicochemical properties observed were those for which Li et al. (2003) presented data and cover the monochloro through octachloro congeners and, thus, span the general range of chlorination levels found in the environment. Each individual congener has its own unique physicochemical properties, toxicities, and potential for transformation.

These parameters can be used with an equilibrium partitioning (EqP) approach to describe the distribution of organic compounds among the air, water, sediment, and biota. Higher K_{OC} and K_{OW} values mean stronger sorption to organic matter in the sediment and an increased tendency for fat solubility, as well as an increased tendency for the organic compounds to bioaccumulate and biomagnify.

The EqP approach does not take into account the effect that highly sorptive organic carbon phases could have on sediment pore water concentrations. Such phases could serve to sequester hydrophobic organic compounds such as DDTs and PCBs or make only a fraction of them available for partitioning, thus reducing their concentrations in the sediment pore water from those predicted using the K_{OC} value, the concentration in the sediment, and the TOC of the sediment. Because pore water concentrations are correlated with bioavailability, EqP could overestimate the concentrations that are bioavailable, including those that are available for transformation by microorganisms.

TABLE 5-1
Physicochemical Properties of DDT-related Compounds

Compound	CAS Number	Molecular Weight (g/mol)	Melting Point (ºC)[a]	Boiling Point (ºC)[a]	Density (g/cm^3, 25ºC)[a]	Log K_{ow} Range	Log K_{oc} Range	PV Shelf Apparent Log K_{oc} Range	Aqueous Solubility (mg/L at 25ºC)[b]	Vapor Pressure (Pa)[b, g]	Henry's Law Constant ($Pa-m^3/mol$)
p,p'-DDT	50-29-3	354.49	109		0.98	6.19[b], 6.31[d], 6.39[c], 6.91[e]	5.4[b], 5.18[a]	----	0.0055	2.0×10^{-5}	1.1[c]
o,p'-DDT	789-02-6	354.49	74.2	----	0.98	6.79[a]	5.35[a]	----	0.026	2.53×10^{-5}	0.347[a]
p,p'-DDD	72-54-8	320.05	109	350	1.385	5.5[b], 6.02[a], 6.22[c]	5.0[b], 5.18[a]	----	0.05	1.30×10^{-4}	0.50[c]
o,p'-DDD	53-19-0	320.05	76 to 78	----	----	6.0[b], 5.87[a]	5.19[a]	----	0.10	2.0×10^{-4}	0.83[a]
p,p'-DDE	72-55-9	318.03	89	336	----	5.7[b], 6.51[a], 6.96[c,d]	5.0[b], 4.8 to 6.0[i]	6.4 to 7.7[h]	0.04	8.66×10^{-4}	4.2[c]
o,p'-DDE	3424-82-6	318.03	----	----	----	5.8[b], 6.00[a]	5.19[a]		0.1	8.0×10^{-4}	2.54[c]
p,p'-DDMU	1022-22-6	283.6	----	----	----	----	----	----	----	----	----
p,p'-DDNU	2642-81-1	249.1	----	----	----	----	----	----	----	----	----
p,p'-DDA	83-05-6	281.1	----	----	----	----	----	----	----	----	----
p,p'-DDOH	2642-82-2	267.2	----	----	----	----	----	----	----	----	----
p,p'-DBP	90-98-2	251.1	147[f]	353[f]	----	----	----	----	----	----	----

Notes:
[a] Agency for Toxic Substances and Disease Registry (ATSDR). 2002. *Toxicological Profile for DDT, DDE, DDD*. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. URL = http://www.atsdr.cdc.gov/toxprofiles/tp35.html
[b] MacKay et al.; 2006; *Physical-Chemical Properties and Environmental Fate for Organic Chemicals*, Volume IV, Table 18.2.2.
[c] Final adjusted value (FAV) from Shen and Wania, 2005, *Journal of Chemical Engineering Data*, 50, p 740-768.
[d] de Bruijn et al. 1989
[e] Brooke et al. 1990
[f] National Institute of Standards (NIST) Data from NIST Standard Reference Database 69, June 2005 Release: NIST Chemistry WebBook. URL = http://webbook.nist.gov/chemistry/
[g] 1-Pascal = 1 $N-m^2$ = 0.0075006 torr = 0.000009869 atm.
[h] Eganhouse and Pontolillo (2007), unpublished data.
[i] Range used by Wiberg and Harris for modeling DDE resuspension at PV Shelf, 2002, *Continental Shelf Research*. 22: 1005-1023.
CAS = Chemical Abstract Service
g/mol = grams per mole
g/cm^3 = grams per cubic centimeter
$Pa-m^3/mol$ = Pascal cubic meters per mole

TABLE 5-2
Physicochemical Properties of PCBs as Aroclors

Compound	CAS Number	Average Molecular Weight	% Cl (by weight)	Melting Point (ºC)	Boiling Point Range (ºC) – same as ASTDR	Density (g/cm^3 at 25 ºC)	Log K_{ow} Range	Log K_{oc} Range	Aqueous Solubility (mg/L at 25 ºC)	Vapor Pressure (Pa)	Henry's Law Constant (Pa - m^3/mol)
Aroclor 1016	12674-11-2	257[a]	41[a]	--	323 to 356[a,b]	1.33[a]	4.4 to 5.8[a]	--	0.22 to 0.84[a]	0.06 to 0.2[a]	70 to 900[a]
Aroclor 1221	111-042-82	192[a]	20.5 to 21.5[a]	1[b]	275 to 320[a,b]	1.15[a]	4.1 to 5.7[a]	--	0.59 to 5.0[a]	0.89 to 2.0[a]	34 to 450[a]
Aroclor 1232	111-411-65	221[a]	31.4 to 32.5[a]	--	290 to 325[a,b]	1.24[a]	4.5 to 5.2[a]	--	1.45[a]	0.54[a]	82 to 270[a]
Aroclor 1242	534-692-19	261[a]	42[a]	--	325 to 366[a,b]	1.35[a]	4.5 to 5.8[a]	--	0.1 to 0.75[a]	0.05 to 0.13[a]	45 to 130[a]
Aroclor 1248	126-722-96	288[a]	48[a]		340 to 375[a,b]	1.41[a]	5.8 to 6.3[a]		0.1 to 0.5[a]	0.0085 to 0.11[a]	5 to 300[a]
Aroclor 1254	110-976-91	327[a]	54[a]	--	365 to 390[a,b]	1.5[a]	6.1 to 6.8[a]	--	0.01 to 0.3[a]	0.008 to 0.02[a]	20 to 260[a]
Aroclor 1260	110-968-25	372[a]	60[a]	--	385 to 420[a,b]	1.58[a]	6.3 to 6.8[a]	--	0.003 to 0.08[a]	0.0002 to 0.012[a]	20 to 60[a]
Aroclor 1262	37324-23-5	389[b]	389[b]	--	390 to 425[b]	1.64[b]	--	--	0.052[b]	--	--
Aroclor 1268	11100-14-4	453[b]	453[b]	--	435 to 450[b]	1.81[b]	--	--	0.300[b]	--	--

Notes:
[a] MacKay et al.; 2006; *Physical-Chemical Properties and Environmental Fate for Organic Chemicals*, Volume II, Tables 7.2.3, 7.2.4.
[b] ATSDR. 2002. *Toxicological profile for polychlorinated biphenyls (PCBs).* Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. URL = http://www.atsdr.cdc.gov/toxprofiles/tp17.html
Pa = pascal(s)

TABLE 5-3
Physicochemical Properties of Selected PCB Congeners

Compound[a]	Number of Chlorines	CAS Number	Molecular Weight (g/mol)	Melting Point (ºC)[b]	Boiling Point (ºC)	Density (g/cm^3, 25 ºC)	Log K_{OW} Range[d]	Log K_{OC} Range[c]	Aqueous Solubility (mg/L at 25 ºC)[e]	Vapor Pressure (Pa)[e,]	Henry's Law Constant[d] ($Pa-m^3/mol$)
PCB-3	1	2051-62-9	188.7	77.7		--	4.65	--	1.2	0.271	23.6
PCB-8	2	34883-43-7	223.1	46	--	--	5.12	--	1	--	22.8
PCB-15	2	2050-68-2	223.1	148 to 149		--	5.36	--	0.06	0.0048	13.4
PCB-28	3	7012-37-5	257.5	57 to 58	--	--	5.66	--	0.16	--	30.5
PCB-29	3	15862-07-4	257.5	78 to 79	--	--	5.60	--	0.14	0.132	30.2
PCB-31	3	16606-02-3	257.5	67	--	--	5.78	--	--	--	34.2
PCB-52	4	35693-99-3	292.0	87 to 89	--	--	5.91	--	0.03	0.0049	25.1
PCB-61	4	33284-53-6	292.0	92 to 92.5	--	--	6.11	--	0.02	--	20.0
PCB-101	5	37680-73-2	326.4	76.5 to 77.5	--	--	6.33	--	0.01	--	24.1
PCB-105	5	32598-14-4	326.4	101 to 105		--	6.82	--	--	--	13.8
PCB-118	5	31508-00-6	326.4	105 to 107	--	--	6.69	--	--	--	14.5
PCB-138	6	35065-28-2	360.9	78.5 to 80	400[c] (calc)	--	7.21	--	--	--	30.1
PCB-153	6	35065-27-1	360.9	103 to 104	--	--	6.87	4.75-7.68	0.001	0.000119	19.8
PCB-155	6	33979-03-2	360.9	112.5	--	--	7.18	--	0.002	0.00048	91.4
PCB-180	7	35065-29-3	395.3	109 to 110		--	7.16	5.78-6.9	0.00031 to 0.00656[c]	--	8.13
PCB-194	8	35694-08-7	429.8	156 to 157	--	--	7.76	--	0.0002	--	4.40

Notes:

[a] Ballschmiter K, M. Zell M, 1980. Fresenius Z. *Analysis of Polychlorinated Biphenyls (PCB) by Glass Capillary Gas Chromatography,* 302:20-31.

[b] Hutzinger, O, S. Safe, S, V. Zitko, 1974. The Chemistry of PCBs. CRC Press, Cleveland, OH, 269 pp.

[c] ATSDR. 2002. Toxicological profile for polychlorinated biphenyls (PCBs). Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

[d] Li, N., F. Wania, Y.D. Lei, G.L. Daly, 2003. A comprehensive and critical compilation, evaluation, and selection of physical-chemical property data for selected polychlorinated biphenyls, Journal of Physical Chemistry Reference Data, 32(4): 1545-1590.

[e] MacKay et al., 2006; Physical-Chemical Properties and Environmental Fate for Organic Chemicals, Volume II, Table 7.2.2.

5.2.1 DDTs

DDTs were deposited on the PV Shelf primarily between 1947 and 1971 as part of an organic-rich effluent discharged at water depths between 33.5 and 64 m. The primary component of technical-grade DDT, and thus probably the waste, p,p'-DDT, is thought to have been quickly transformed to p,p'-DDE during and shortly after deposition (Eganhouse et al., 2000).

While there are documented uncertainties with published log K_{OW} values for p,p'-DDE and p,p'-DDT (Pontolillo and Eganhouse, 2001), the values are in the range such that these compounds are considered strongly hydrophobic. In other words, p,p'-DDE and p,p'-DDT will not readily dissolve in water and will sorb strongly to the sedimentary organic matter and suspended organic-rich particles and colloids in the water column.

These relatively high K_{OW} values and low water solubilities mean that the p,p'-DDT and p,p'-DDE were likely deposited on the seafloor and sorbed to organic particulate or colloidal matter present in the effluent (which was about 60 to 70 percent organic matter [Myers, 1974]).

On the PV Shelf, pore water concentrations of p,p'-DDE in three box cores taken near Station 6C in 1992 were lower than those predicted from log K_{OC} and sediment TOC (Eganhouse and Pontolillo, 2007). This indicates that there is strong sorption of p,p'-DDE occurring at this location and that EqP alone, using standard log K_{OC} values, does not describe the pore water sediment interaction. Site-specific "apparent" log K_{OC} values have been calculated from observed sediment and pore water concentrations and are presented in Table 5-1.

The high log K_{OW} values for p,p'-DDE also indicate that this compound will bioaccumulate. Bioaccumulation of DDTs in the environment is a well-documented problem (ASTDR, 2002). EPA banned all uses of DDT in the United States in 1972 partly as a result of the levels of DDT accumulating in the environment. Fatty tissues (lipids) will accumulate more DDTs than the muscle or whole body of aquatic organisms. Organisms with higher lipid concentrations will accumulate a greater body burden of DDTs.

Literature on the physicochemical properties (calculated or measured) for the transformation products such as p,p'-DDMU (1-chloro-2,2-bis (p-chlorophenyl) ethylene); p,p'-DDNU (unsym-bis (p-chlorophenyl) ethylene); and p,p'-DBP (dichlorobenzophenone) is not available. Parameters could be estimated using suitable quantitative structure-activity relationships (Schwarzenbach et al., 2003). Transformation of p,p'-DDE to p,p'-DDMU and p,p'-DDMU to p,p'-DDNU reduces the number of chlorine atoms on the molecule, but these compounds could still be generally classified as hydrophobic organic compounds that are characterized by low water solubilities, relatively low vapor pressures, small Hc values, and relatively high log K_{OW} and log K_{OC} values.

Further transformation into compounds such as dichlorodiphenylacetate (DDA), 2,2-bis (p-chlorophenyl) ethanol (DDOH), and dichlorodiphenylacetate (DBP) would be expected to increase the water solubility and decrease the K_{OW} values of these organics relating to DDE because of the alcohol, carboxylic acid, and ketone functionalities.

5.2.2 PCBs

PCBs were produced from the chlorination of the aromatic compound biphenyl, $C_{12}H_{10}$. This resulted in a mixture of chlorinated aromatic organic compounds containing the biphenyl structure with the general formula, $C_{12}H_{10-n}Cl_n$, where n ranged from 1 to 10 chlorine atoms. PCBs were sold in the United States under the trade name, Aroclor. Each commercial Aroclor mixture differed in overall chlorine content and (except for Aroclor 1016) the last two digits in the Aroclor name designation referred to the weight percent of chlorine. For example, a mixture designated as Aroclor 1254 contained 54 percent chlorine by weight (Table 5-2).

The 209 possible structures of the general formula $C_{12}H_{10-n}Cl_n$ are referred to as PCB congeners. Congeners that have the same level of chlorination are referred to as homologues. Within each chlorination level there are positional isomers (except where n=10 and all the carbons have a chlorine atom attached). Commercial mixtures, such as Aroclors, contained a distribution of PCB congeners. As the weight percent chlorine increased in the mixture, there were a larger proportion of higher chlorinated compounds present. Thus, Aroclor 1254 contained a higher proportion of the higher chlorination level congeners than did Aroclor 1242.

Tables 5-2 and 5-3 show that PCBs are relatively insoluble in water. Monochlorobiphenyl congeners have the highest reported aqueous solubilities (e.g., PCB-3, 1.2 mg/L), while highly chlorinated congeners such as PCB-194 (octachlorobiphenyl) have much lower solubilities (0.0002 mg/L). Consequently, Aroclor mixtures with a lower weight percentage of chlorine (which corresponds to a prevalence of lower chlorination levels) will generally have a higher water solubility than an Aroclor with a higher percentage of chlorine.

The log K_{OW} values also vary with chlorination level as indicated by the data in Table 5-3. For example, the log K_{OW} for PCB-3 is 4.65 while that for PCB-194 is 7.76. Similar to water solubility, Aroclor mixtures with a lower weight percentage of chlorine will generally have log K_{OW} values lower than an Aroclor with a higher percentage of chlorine. Therefore, PCB congeners containing fewer chlorine atoms or PCB mixtures with a lower abundances of the more highly chlorinated congeners (e.g., Aroclor 1242) are more soluble in water than PCB congeners containing more chlorine atoms or mixtures with a higher proportion of highly chlorinated congeners (e.g., Aroclor 1260). This means that the lower chlorinated PCB congeners are more likely to dissolve in water than the greater chlorinated PCB congeners. Conversely, higher chlorinated congeners have a higher tendency to sorb to sediment particles or be taken up by biota.

The PCBs were deposited as mixtures of congeners at the PV Shelf as part of an organic-rich effluent discharged at depths between 33.5 to 64 m. When deposited, the PCB mixtures were modified by dissolution, evaporation/volatilization and partitioning processes that altered the distribution of congeners. The PCB mixtures found on the PV Shelf are dominated by the tetrachloro (Cl4), pentachloro (Cl5), and hexachloro (Cl6) homologues (Eganhouse et al., 2000). Typical log K_{OW} values range from nearly 6 (e.g., PCB-52, log K_{OW} 5.91) to over 7 (e.g., PCB-138, log K_{OW} 7.21). These PCBs sorb strongly to the sediment and any organic particulate or colloidal matter in the water column.

PCBs can bioaccumulate in aquatic organisms as the result of combined uptake through food, incidental sediment ingestion, and absorption from the water. Greater bioaccumulation of PCBs will occur in the fatty tissues (lipids) than in the muscle or whole body of aquatic organisms, and organisms with higher lipid concentrations will generally accumulate a greater total body burden of PCBs.

5.3 Transformation of DDTs and PCBs

The following are three major processes by which DDTs and PCBs could transform into other products:

- *Chemical* transformations include reactions that occur in the dark and without the aid of organisms. In the effluent discharged at the PV Shelf Study Area, DDT was most likely rapidly transformed to DDE by dehydrochlorination before and after deposition.
- *Photochemical* transformations occur through direct and indirect exposure to sunlight and, as a result, are not significant transformation pathways for DDTs and PCBs at the depths they are found in the effluent-affected sediments.
- *Biological* transformations include reduction-oxidation (redox) or hydrolysis of the compounds catalyzed by organisms. Based on results from microcosm experiments, these biologically mediated reactions are thought to be the most relevant to transformations of p p'-DDE in the effluent-affected sediments.

Combined, the chemical and biologically mediated transformations occurring on the PV Shelf can be referred to as biogeochemical processes. The products of any biogeochemical transformation process will have their own set of physical properties that could result in fate, transport, and toxicological properties different from the parent compound.

5.3.1 DDTs

Data indicate that p,p'-DDT (the major DDT compound in the waste) was aerobically dehydrochlorinated to p,p'-DDE during the earliest stages of digenesis, and that the majority of DDTs has existed as p,p'-DDE since shortly after deposition (Eganhouse et al., 2000). The primary pathways for transformation thought to be occurring at the PV Shelf are shown in Figure 5-1.

The following experiments and observations indicate that DDE is being transformed to DDMU in the effluent-affected sediment:

- Sediment cores spiked with DDE (labeled with the radioactive tracer ^{14}C) showed production of ^{14}C-labeled DDMU. Spiking with radio labeled DDD did not result in the formation of ^{14}C-labeled DDMU. The transformation was demonstrated to be microbially mediated in the microcosm spiking studies by using sterile controls (Deming and Carpenter 2000; Quensen et al., 1998, 2001).
- USGS core samples taken in 1992 and 2003 from locations near LACSD Station 3C show a decrease in the DDE inventory and an increase in DDMU and unsym-bis (p-chlorophenyl) ethylene (DDNU) (the expected transformation products) inventories, while the concentrations of recalcitrant organic compounds such as PCBs remain essentially unchanged (Eganhouse and Pontolillo, 2007).

- The percentage of DDMU (relative to the total [DDE] + [DDMU]) increases with depth in the sediment cores. Because the age of the sediment generally increases with depth, transformation is likely occurring. While the higher abundance of DDMU in the deeper sediments could be attributed to historical differences in DDMU abundance at the time of sedimentation, this can be assessed by comparing data from cores taken at the same locations in different years. There are two sets of data that address this point. The work done by USGS on the cores near LACSD Station 3C (1992 and 2003 cores) and work done by LACSD on cores taken in 1991 and 2005 from Stations 3C and 6C both show an increasing percentage of DDMU with depth. In addition, more recent cores show that the percentage of DDMU is greater at all depths than in the 1990s (Eganhouse et al., 2000; Eganhouse and Pontolillo, 2007).

5.3.2 DDE Transformation at the PV Shelf Study Area

The following questions regarding the transformation of DDT, and specifically transformation of DDE to DDMU and other products should be addressed before this transformation can be assessed for potential remediation processes at the PV Shelf:

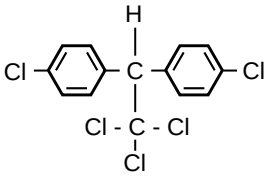
- What is the relative contribution of in situ DDE transformation to observed DDE inventory decreases?
- What are the estimated in situ transformation rates?
- What environmental factors control the transformation of DDE?
- What are the intermediate and terminal products?
- What are the toxicities of the intermediate and terminal products?

5.3.2.1 Relative Contribution of Transformation to DDE Inventory Decreases

While mechanisms, such as desorption from resuspended sediment and diffusion from the pore water, provide transport pathways leading to DDE inventory losses in surface sediment, the laboratory and field studies discussed in this section suggest that reductive dechlorination of DDE provides an additional pathway for DDE loss in buried (anaerobic) sediment. While reductive dechlorination has been demonstrated to occur, the extent to which it could be occurring at PV Shelf is not completely understood.

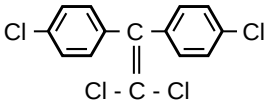
Data from the analysis of USGS cores taken in 1992 and 2003, (both located near LACSD Station 3C), indicate that the inventories of recalcitrant compounds such as a tetrapropylene-based alkylbenzene isomer (TAB3) (Eganhouse et al., 1983), and ΣPCB_{18} only differ by 1.3 percent and 4.1 percent respectively, (both within analytical error of about 10 percent) while there is a significant decrease in the p,p'-DDE inventory (43 percent) and an increase in DDMU and DDNU inventories (34 percent and 33 percent, respectively; Eganhouse and Pontolillo, 2007).

Because DDE, PCBs, and TAB3 are all persistent, hydrophobic organics having similar physicochemical properties, they would be affected by physical processes (e.g., resuspension) in the same manner and degree. Thus, it appears that at Station 3C these data indicate a relatively important role for transformation versus physical losses in the observed decrease in DDE inventory (Eganhouse and Pontolillo, 2007).



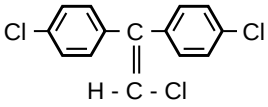
p,p′-DDT – deposited on PV Shelf

Rapid dehydrochlorination
p,p′-DDT before and after deposition



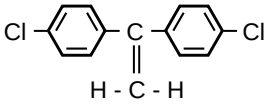
p,p′-DDE – observed major species after deposition

Reductive dechlorination
p,p′-DDE in buried sediment



p,p′-DDMU – observed transformation product

Reductive dechlorination
p,p′-DDMU in buried sediment



p,p′-DDNU – observed transformation product

DDT: dichlorodiphenyltrichloroethane
DDE: dichlorodiphenyldichloroethene
DDMU: 1-chloro-2,2-bis (p-chlorophenyl) ethylene
DDNU: unsym-bis (p-chlorophenyl) ethylene

FIGURE 5-1
Observed DDT Transformation Pathways on PV Shelf
Palos Verdes Shelf Study Area
Remedial Investigation Report

5.3.2.2 Estimated Rate of Transformation

Transformation rates obtained from carbon-14 (^{14}C)-DDE spiking experiments represent upper limits for rates of DDE transformation to DDMU. Hydrophobic organic compounds are less bioavailable to benthic organisms and microbes in aged sediments and soils; therefore, ^{14}C-DDE spiking experiments might not reflect the half-lives obtained under actual field conditions (e.g., Alexander et al., 2000; Boyd et al., 2000; Kosson et al., 2003). Three studies estimating transformation rates for DDE to DDMU were reviewed (Deming and Carpenter, 2000; Quensen et al., 1998 and 2001). These studies examined the transformation of ^{14}C-DDE added to sediment cores to ^{14}C-DDMU. The calculated first-order rate constants were 0.069 - year^{-1} to 0.23 - year^{-1} with resulting half-lives from 10 to 3 years. The rates from the ^{14}C-DDE experiments are presented in Table 5-4.

TABLE 5-4
Transformation Rates from ^{14}C-DDE Experiments

Station	Predicted First Order Rate Constant (yr^{-1})	Predicted Half-life (yr)	Comments
3C	0.23	3	(Deming and Carpenter, 2000) - Experiment conducted at 12°C under sulfate-reducing conditions, experimental length of 55 weeks, using cores collected in 1997. Rates are determined from the median half-lives in the most active subsurface zones (2 to 22 cm at 8C, 2 to 30 cm at 6C, and 30 to 40 cm at 3C).
5C	0.087	8	
6C	0.069	10	
3C	0.102	7	(Quensen et al., 2001) - Rate at 12°C under sulfidogenic conditions predicted from Arrhenius plot of observed rates.

A rate more reflective of the actual transformation process occurring in the field can be obtained from a direct comparison of the p,p'-DDE concentrations in USGS sediment cores taken near Station 3C in 1992 and 2003 where the whole core inventories of the recalcitrant molecular marker TAB3, and the sum of eighteen interference-free PCB congeners ΣPCB_{18} were found to be essentially the same.

Before making the calculations, the cores were aligned so that contemporaneous horizons could be compared. This was accomplished using the concentrations of selected PCBs and TAB3 (because these are presumed to be the most recalcitrant). Direct comparison of p,p'-DDE concentrations in the aligned core sections yielded a mean first-order rate constant of 0.052 year^{-1} which corresponds to a half-life ($t_{1/2}$) of 17 years (Eganhouse and Pontolillo, 2007). Changes in p,p'-DDE inventories have been observed in the LACSD core data. At most sites, the changes indicate apparent loss (or dilution) of DDE through one or more chemical or physical processes. The degradation rates calculated by Eganhouse and Pontolillo (2007) at Station 3C are similar to the mean loss rates by all mechanisms calculated by Sherwood et al. (2006).

5.3.2.3 Factors Controlling Transformation

There are many factors that may control the transformation of DDE to DDMU including, but not limited to, organic carbon content, microbial activity, sulfate concentration, temperature, dissolved oxygen concentration, sediment porosity (e.g., grain size distributions), trace toxic metals (toxic to biota mediating the reaction), and the concentration of DDE and other hydrophobic organics.

Quensen et al. (2001) spiked PV Shelf Study Area sediments with ^{14}C-DDE to examine the effects of sulfate, available carbon, sediment depth, and temperature on the rate and extent of DDE transformation. Increasing sulfate and decreasing temperatures slowed the transformation in these experiments, and dechlorination under methanogenic conditions occurred at a faster rate than under sulfidogenic conditions.

The type and activity of microbial communities could also be a factor in controlling the rate of transformation. Deming and Carpenter (2000) theorized that observed differences in dechlorination rates in microcosms spiked with different amounts of ^{14}C-DDE were the result of diffusional limitations on suitable substrates for bacterial growth and metabolism. Quensen et al. (2001) referred to data indicating that the capacity for DDE transformation varied with depth and suggested that the microbial community responsible for the dechlorination was not uniform in distribution at all depths.

The rates also are observed to change with distance from the outfall. As shown in Table 5-4, the rate of ^{14}C-DDE loss as a result of transformation appears, from this limited data, to increase with distance from the outfall (distance from outfall Station 6C > Station 5C > Station 3C). Because the transformation of DDE is controlled by many natural factors, highly variable results are expected in sediment with a wide range of physicochemical and microbiological properties. Therefore, major controlling factors must be identified and their causal relationships determined before DDE transformation can be adequately predicted from laboratory data.

5.3.2.4 Terminal Products of DDE Transformation

DDMU is not the terminal product in the degradation of DDE at this site. Past reliance on ^{14}C data to support DDMU as the final product is not conclusive (Quensen et al., 2001) and a review of previous gas chromatography/mass spectrometry (GC/MS) data (USGS 1992 and 2003 cores) shows the presence of DDNU as well as DDMU (Eganhouse and Pontolillo, 2007). Little or no DDOH or DDA are observed in historical samples, but a significant amount of DBP might be present (Eganhouse and Pontolillo, 2007).

5.3.2.5 Toxicities of Transformation Products

There are limited data concerning the toxicity and bioaccumulation potential of DDMU and DDNU for either marine ecological receptors or potentially exposed humans, thereby complicating any assessment of the recovery of the PV Shelf Study Area based on the transformation of DDE. There is a recent report that indicates the biomagnification factor for DDMU in a marine aquatic food web was similar to DDE (Hu et al., 2005). There are a limited number of studies from the 1970s and 1980s on the metabolism of DDMU in birds and fish, all of which indicate some potential for toxicity (see for example Westlake et al., 1979; Tarrant et. al., 1983).

5.3.3 PCBs

At the PV Shelf Study Area, the primary mechanism expected for PCB transformation (except at the aerobic surface layer) is biologically mediated anaerobic reductive dechlorination. Evidence for reductive dechlorination would consist of changes in the PCB congener distribution pattern. The pattern would show higher proportions of the ortho-substituted congeners with lower chlorination and lower proportions of the meta- and para-substituted higher chlorination levels (Wiegel and Wu, 2000).

No temporal changes have been observed in the congener distribution profiles for PV Shelf Study Area sediment cores for a group of 18 PCB congeners without analytical interferences from other PCB congeners or other chlorinated organics (ΣPCB_{18}). The congeners comprising this group are 18, 17, 26, 31/28, 52, 49, 44, 42, 74, 97, 153, 141, 187, 174, 177, 180, 196, and 206. The congener-specific PCB distributions in shelf sediments are highly uniform and show no evidence of diagenetic transformation (Eganhouse et al., 2000). Therefore, the PCB concentrations or distributions in the effluent-affected sediments do not appear to be changing through transformation of PCBs.

Monitoring has continued since the Eganhouse paper was published in 2000 and additional recent work confirms that the PCB inventory and congener distribution (ΣPCB_{18}) near LACSD Station 3C have not changed (Eganhouse and Pontolillo, 2007). These additional data are for a single location and it remains to be seen whether these observations continue to hold true at other locations.

5.4 Bioturbation and Biodiffusion

This section discusses potential effects of bioturbation on mobilization and transport of buried contaminated sediment particles and pore water solutes to the sediment water interface.

Bioturbation, which includes both diffusive and advective transport of material in the seabed, is a mechanism that can mix deeper, more contaminated sediment (and the associated pore water) into upper layers. These processes, combined with molecular diffusion and erosion continue to mobilize DDTs and PCBs to the biologically active surface sediment layer, where transfer to epibenthic consumers of infauna, or planktonic particle feeders within the nepheloid layer (the particle-rich layer just above the ocean floor), provide a means of bioaccumulation and transfer to higher trophic levels.

5.4.1 Bioturbation

Bioturbation is conventionally defined as the displacement and mixing of sediment grains by organisms (Wheatcroft et al., 1990). However, several studies indicate that infaunal activity can significantly elevate pore water solute transport rates above those attributable to molecular diffusion alone (Aller and Aller, 1992; Glud and Fenchel, 1999). Consequently, expanded definitions of bioturbation (e.g., Berg et al., 2001) include biologically induced mixing of both solutes and solid particles. The discussion, herein, is focused on sediments, because DDTs and PCBs are predominantly adsorbed to sediment particles, typically at concentrations that are five to six orders of magnitude higher than soluble aqueous-phase concentrations (DiToro et al., 1991; Wiberg and Harris, 2002).

Bioturbation strongly influences geochemical reactions and physical properties of marine sediments (Wheatcroft et al., 1990; Lee and Wiberg, 2002). Sedimentological structure, particle and pore water solute chemical concentrations, microbial activity, rate of degradation of organic matter, and flux of chemicals at the sediment-water interface are significantly controlled by rates of sediment mixing from faunal activity (Yingst and Rhoads, 1980; Aller and Yingst, 1985; Aller and Aller, 1992; Wheatcroft et al., 1990; Wheatcroft, 1992).

Two general modes of bioturbation activity have been described: (1) biodiffusion, and (2) nonlocal mixing.

5.4.2 Biodiffusion

The most widely used descriptive model for sediment mixing by animals is biodiffusion, in which sediment particles are moved randomly in space in a process that is analogous to standard Fickian eddy diffusion (Guissano and Schink, 1975; Boudreau, 1986). Particle movements are of sufficiently small scale (relative to the scale of observation) to be represented as a simple one-dimensional (vertically oriented) diffusive process, which can be measured from down-core distribution of radionuclides. Horizontal mixing is assumed to be random and of equivalent intensity within strata. However, studies examining local horizontal distribution patterns of radionuclide tracers have demonstrated that gradients could exist (Smith and Schafer, 1984), and effects of horizontal mass transfer could be nontrivial, resulting from local patchiness in animal abundance, specific animal behaviors, and sediment structure (Wheatcroft et al., 1990).

The Fickian diffusion model, which previously described the continuous random dispersion of molecules in solution, has been shown in numerous studies to be applicable to bioturbation of sediments that lack continuous particle movement (Berg et al., 2001). Whereas, the diffusive process for sediment particles occurs as a "random walk" over discrete step lengths, transport directions and rest periods. The unit of measure describing the intensity of mixing is mathematically described by a length x velocity vector (e.g., $cm^2\ s^{-1}$), which is the coefficient of biodiffusivity (D_b).

Biodiffusion homogenizes sediments, promoting transport of contaminants from higher to lower concentrations in the direction of the concentration gradient. D_b is estimated by fitting a regression line to the down-core distribution of either impulsive or continuous radioactive tracers (Guissano and Schink, 1975; Wheatcroft et al., 1990). For example, the vertical profile of a short-lived radionuclide such as Thorium-234, with a half-life of 24.1 days, is controlled by the rate of biological mixing, the rate of radioactive decay (which is constant), and the sedimentation rate, which is negligible (assumed to be zero) over the radionuclide half-life timeframe. Thus, intensity of mixing in the sediment profile can be determined directly from the vertical (down-core) distribution of the radionuclide.

The biodiffusivity coefficient provides a bulk measure of mixing that integrates all animal activities including deposit feeding (ingestion and defecation of sediments), locomotion, and construction of tubes and burrows. The animal activity can result in an uneven (small-scale, biogenic) bottom topography. The animal activities are most intense near, and just below, the sediment boundary, where sufficient oxygen is available in pore water to support aerobic metabolism of the fauna. In marine sediments, this surface layer is characterized by

relatively high densities of infauna, primarily deposit-feeding polychaete worms, pericarid crustaceans, and mollusks, usually numbering several thousand per square meter in coastal zone sediments. Their activities result in a uniform mixed layer that typically extends several centimeters from the surface. The mean depth of the mixed layer from worldwide estimates of D_b in marine sediments using radionuclide techniques is about 10 cm (Boudreau, 1994). Estimates of mixed layer depth for PV Shelf sediments vary, but appear to be shallower on the order of 5 cm (Wheatcroft and Martin 1994; Santschi et al. 2001; SAIC 2005c). Rates of mixing and resuspension of sediments in the upper mixed layer are high relative to the rate of sedimentation, with complete mixing of the upper bed frequently occurring on the order of weeks in shallow marine sediments.

Biological activity declines rapidly with depth below the surface mixed layer where organisms are significantly less abundant because of the reduced availability of labile organic matter for food and from demands placed on organisms (tube building, irrigation) resulting from the hypoxic or anoxic state of surrounding interstitial water, requiring animals to maintain connection with the surface. Wheatcroft and Martin (1994) emphasize that depth-dependent mixing rates below the mixed layer cannot be obtained objectively from radionuclide tracer data; thus, they are generally prescribed on the basis of macrofaunal data, which show significant reductions in number with depth.

These deeper organisms tend to be larger and much lower in population density. They often displace sediments by nonrandom advective transport (usually vertical) through such means as excavation of buried sediments to the surface layer for burrow maintenance, or ingestion of surface sediments with defecation into subsurface strata or by directional reversal of this feeding mode (e.g., subsurface ingestion, surface defecation; head-down deposit feeding). These multi-directional (advective) mechanisms of sediment transport by organisms are defined as nonlocal mixing.

Eventually, sedimentation buries particles beneath the transition layer into strata where biological mixing no longer occurs. This depth is typically several tens of centimeters below the surface. The predictive model for bioturbation in PV Shelf sediments (Sherwood et al., 2002) set the depth of permanent burial at 40 cm. However, large arthropod species known to occur on the PV Shelf are capable of excavating sediments from depths greater than 50 cm (Swift et al., 1996) extending through the buried peak contamination stratum. The rates and localities at which nonlocal mixing presently occurs in PV Shelf sediments are significant factors for assessing potential mobilization of effluent-affected sediments to the sediment boundary.

The general pattern of decreasing biodiffusivity with depth has been characterized by Clarke et al. (2001) as being represented by three zones of activity: (1) high mixing rates in the uniform surface mixed layer extending to about 10 cm below the sediment-water interface, (2) mid-depth bioturbation extending from about 10 to 40 cm below the surface with decreases in bioturbation with depth, and (3) deep bioturbation below 40 cm resulting from the activities of larger organisms, which are typified by nonlocal (advective) transport of sediments. Similar stratigraphic description of biodiffusivity was provided by Nittrouer and Sternberg (1981), emphasizing high rates of surface-level mixing and an underlying zone of rapidly declining diffusivity, descending to the zone of permanent burial with no mixing.

5.4.3 Nonlocal Mixing

The biodiffusion model of particle mixing becomes less reliable as the size of bioturbating organisms increases relative to the scale of observation (Boudreau, 1986; Wheatcroft et al., 1990). Biodiffusion ceases to become a continuous process as larger organisms create discrete disturbances, often moving particles in specific (nonrandom) directions over relatively large spatial scales. These organisms are defined as nonlocal mixers. Nonlocal transport of particles is typically unidirectional or bidirectional (anisotropic) and is described as an advective process, in contrast with the random (isotropic) movement of particles from biodiffusion.

Nonlocal mixers could mobilize deep sediments to the surface layer. Swift et al. (1996) emphasized the potential for high rates of mobilization of deep sediments on the PV Shelf, especially by deep-burrowing thalassinid arthropods. The infrequency (usual absence) of these animals in benthic samples, difficulty of sampling, and their spatial and temporal heterogeneity has precluded precise estimation of their sediment reworking activity. Visual observations of the bottom from PV Shelf video transects indicate that densities of large burrowing organisms are higher than estimates determined from conventional grab samplers used in the LACSD benthic monitoring program.

5.4.4 Bioturbation on the PV Shelf

Bioturbation is known to extend down into the contaminated sediment layer in PV Shelf sediments (Niedoroda et al., 1996; Swift et al., 1996; Sherwood et al., 2002). Figure 5-2 shows the vertical distribution of DDE at Station 6C from 1987 to 2005 and shows an increase the depth of peak DDE concentrations and possible mixing by bioturbators.

Studies of bioturbation in PV Shelf Study Area sediments have used conventional radionuclide tracer techniques to estimate D_b from samples collected primarily up-coast from the outfall at similar depths to the outfall discharge (60 m) and along the deeper shelf margin (Wheatcroft and Martin, 1994; Santschi et al., 2001; SAIC, 2005c) (Figure 5-3). An alternative approach, incorporating biological characteristics of the resident infaunal species, was employed by Swift et al. (1996).

Studies conducted by USGS in 1992 and 1993 using Thorium-234 determined that mixing rates in the upper 10 cm sediment interval were in the range of 10 to 20 cm^2/year within 2.5 km of the outfall, increasing to 40 to 50 cm^2/year along the shelf to the northwest (Wheatcroft and Martin, 1994). The authors examined vertical distribution of organisms in cores and reported that more than 90 percent of the macrofaunal organisms were present in the upper 8 cm, while the number of individuals below 20 cm deep was very low. Vertical profiles showing fractional composition within core segments are shown on Figure 5-4. These profiles cannot accurately reflect the presence of larger, deeper burrowing organisms that are interspersed over spatial scales that significantly exceed the areal and vertical coverage of the corer (Swift et al., 1996).

The wide range of USGS reported biodiffusion rates among sampling stations and among replicate samples at individual stations, is indicative of both the small-scale and regional (PV Shelf) heterogeneity in sediment mixing activities of the biological community.

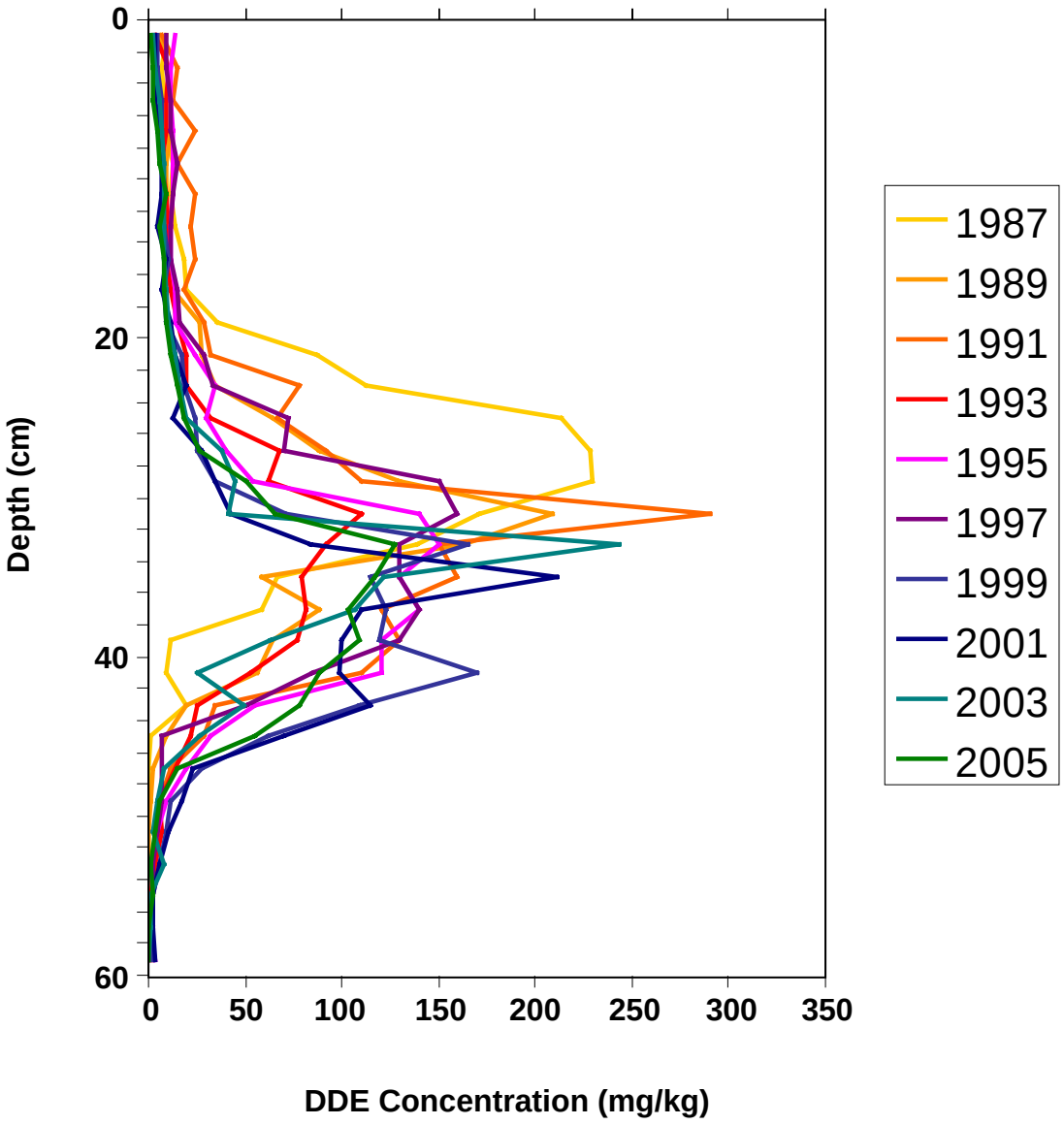
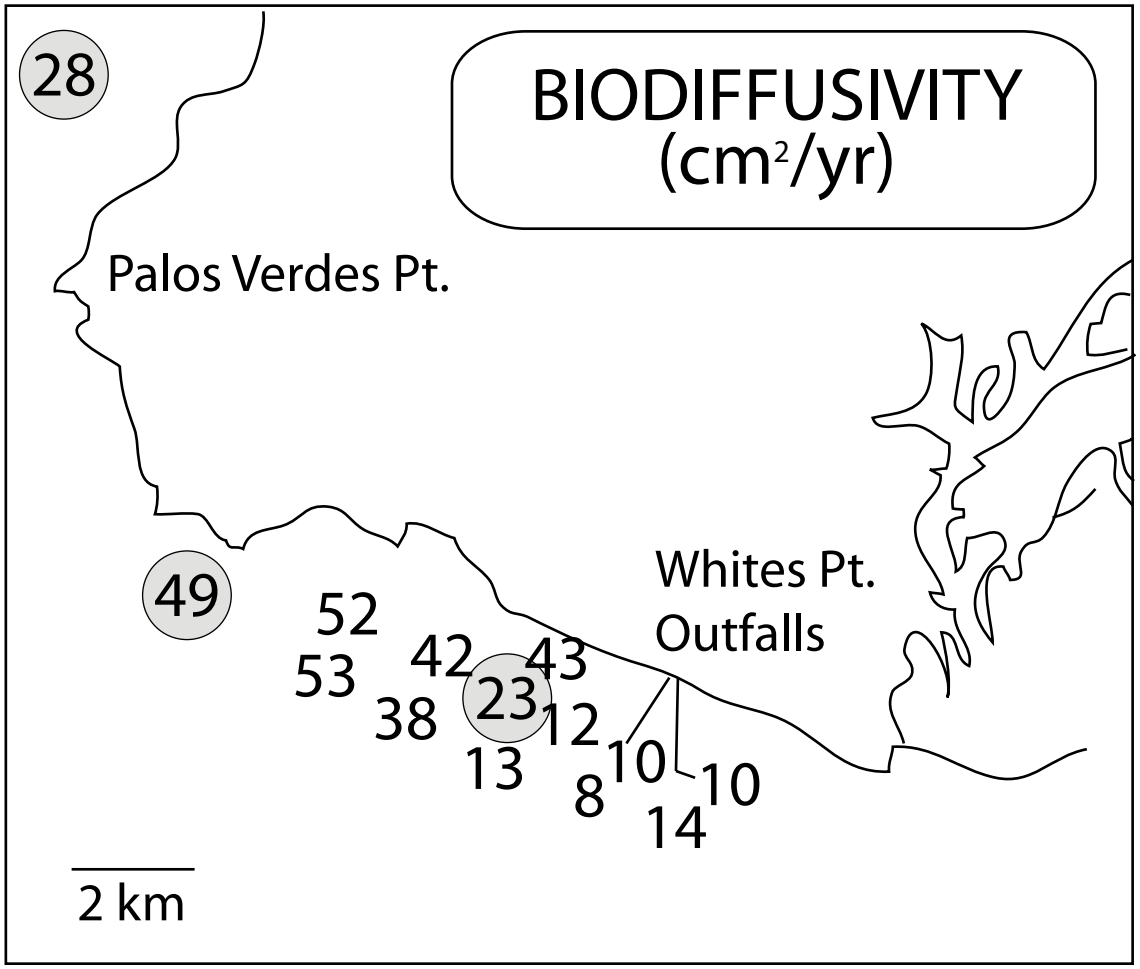


FIGURE 5-2
DDE Vertical Distribution at Station 6C
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: LACSD Sediment Core Data



Source: Wheatcroft and Martin, 1994

Notes: Map of vertical biodiffusivities (cm^2/yr) determined at 14 stations on the Palos Verdes margin. Numbers at the highlighted sites represent average biodiffusivities estimated from replicate profiles.

FIGURE 5-3
Palos Verdes Shelf Bioturbation Rates
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: Data from U.S. Geological Service 1992 Farnella Cruise (Wheatcroft and Martin, 1994)

Note: Cores collected in water depths of 50-56m

FIGURE 5-4
Depth Distribution of Macrofauna from Three Palos Verdes Shelf Stations
Palos Verdes Shelf Study Area
Remedial Investigation Report

Lower rates observed near the outfall were not statistically significant as a result of the high component of variation within sites. USGS biodiffusivity estimates from Stations 3C and 6C were incorporated into the predictive model of PV Shelf contaminant fate and transport developed by Sherwood et al. (2002). Mixed layer D_b rates of 49 cm^2/year and 23 cm^2/year were respectively applied to these two stations, and a mixed layer depth of 5 cm was incorporated into the model, with an assumed underlying exponential decline in D_b to 0.5 cm^2/year at 25 cm deep, and zero mixing (permanent burial) at 30 cm deep. These D_b values for surface-layer sediments indicate that the upper several centimeters of the bed can be remixed on the time scale of a week (Wheatcroft and Martin, 1996; Harris and Wiberg, 1997). This supports the contention that deep bioturbation rates that are 1 to 2 orders of magnitude lower (e.g., 0.5 cm^2/year at 25 cm deep) could remix the bed on the order of months to years, as suggested by continued presence of contaminants at relatively low concentrations in surface sediments.

SAIC (2005c) examined bioturbation of PV Shelf sediments to determine whether capping of sediments would be effective in permanently burying the contaminant layer below any possible mobilization from bioturbation. Palermo et al. (1999) had concluded that "a cap thickness component for bioturbation of 30 cm should accommodate most concerns related to bioturbation effects on cap integrity for areas selected for isolation by the cap."

SAIC measured down-core distribution of Thorium-234 from 26 cores located primarily along 50- and 70-m isobaths, both up- and down-coast from the outfall (Figure 5-5). Biodiffusivity was estimated from conventional analysis of excess thorium profiles (11 cores, 6 stations), and also from an approach (15 cores, 9 stations) that assumed biodiffusive mixing, using the ratio of excess Thorium-234 in 0- to 1-cm and 0- to 5-cm-depth intervals to estimate D_b, based on methods described by Aller et al. (1980) and employed by Wheatcroft and Martin (1996).

D_b values from replicate cores within sampling stations varied significantly, sometimes up to an order of magnitude. Average D_b from all cores, using both methods, was 19 +/- 21 cm^2/year, which is not significantly different from the average of 31 +/- 20 cm^2/ year from all sites in the USGS studies from the early 1990s (Wheatcroft and Martin, 1996).

Biodiffusivity values were highest at greater distances from the outfall, similar to the pattern observed by Wheatcroft and Martin (1996), lending credence to the likelihood that the pattern represents a real phenomenon. Although changes in D_b along the outfall gradient could be influenced by sediment factors, such as TOC and pore space H_2S, which have relatively higher sediment concentrations in the outfall vicinity.

SAIC also sampled the infauna from 64 cores (0.06 m^2 surface area) and recorded the presence of organisms within three vertical core segments: 0 to 15 cm, 15 to 30 cm, and more than 30 cm below the sediment water interface. Most of the cores (83 percent) penetrated beyond 30 cm deep, while 29 (45 percent) penetrated deeper than 40 cm. Retained animals were sieved through a 2 mm screen, identified to species, counted, and weighed. A total surface area of 3.42 m^2 was sampled from 19 stations, including replicates.

The relative (proportional) distribution of abundance, biomass, and average organism weight within core depth strata is shown on Figure 5-6. The upper segment had the highest abundance, but the 15- to 30-cm abundance was relatively high at 62 percent of the surface density. Below 30 cm, densities dropped to 5 percent of surface levels. Mid-core biomass was nearly as high as the surface (92 percent), declining to 30 percent below 30 cm. Average weight of individual organisms was greatest in the deep-core section, where individual organisms were 4 to 7 times as large as organisms from mid- and upper strata. The deeper dwelling species included the burrowing shrimp *Neotrypaea gigas,* which had recolonized, or emerged from beneath, recently capped sediments. Other species included several recognized from earlier studies as occurring in deeper sediments. As pointed out by Stull et al. (1996), with the decline in organic loading of sediments since the 1970s, active burrowing species have become more widely distributed and abundant.

The depth distributions of these organisms in the sediment profile indicate biological activity extending into the contaminant layer, especially above 30 cm, as suggested by the contaminant profile time-series shown on Figure 5-2. Beneath this, much lower densities are evident, but organisms are relatively large. The distribution patterns support the thesis of Swift et al. (1996) that conventional biological sampling and radionuclide profiling from small cores does not adequately depict the potential for widely dispersed large organisms to mobilize sediments. SAIC concluded that, "data from the 2004 assessment indicate low sediment mixing intensities below surface layers and low biomass and abundance of BIO, particularly for key species such as ghost shrimp that have high bioturbation potential and [it] does not appear that bioturbators have a high potential for substantial disruption of a cap in the study region" (SAIC, 2005c). Wheatcroft (2006) criticized this conclusion, emphasizing the likelihood of underestimating shrimp densities with the core sampling method that was employed, while emphasizing that "5 [to] 10 shrimp per square meter can excavate a tremendous amount of sediment over the long term." Ghost shrimp density in SAIC cores was 7.3/m^2.

Santschi et al. (2001) conducted radionuclide studies of sediment accumulation and bioturbation on the PV Shelf at Stations 3C, 5C, and 6C in 1996 and 1997. Thorium-based results indicated the presence of a shallow mixed layer with widely varying D_b rates. They concluded that particle reworking on time scales of several months is restricted to the upper 3 cm, with little evidence of particle reworking at depths greater than 5 cm. Spatial heterogeneity was significant, with D_b values ranging from 13 to 178 cm^2/year (both extremes observed at Station 6C). Compared with other PV Shelf thorium-based estimates of bioturbation (Wheatcroft and Martin, 1994; SAIC, 2005c), results describe a shallower mixed surface layer with lower rates of sediment reworking.

The differing D_b results from various PV Shelf sediment studies indicate high levels of temporal and spatial variability, and significant small-spatial-scale variation as evidenced by wide differences in D_b from single localities within surveys. Because thorium profiles have typically decayed before reaching the depth of peak contamination, predictive modeling of biological mobilization of deeper sediments, based on assumed exponential declines in mixing below the surface layer, is not precise.

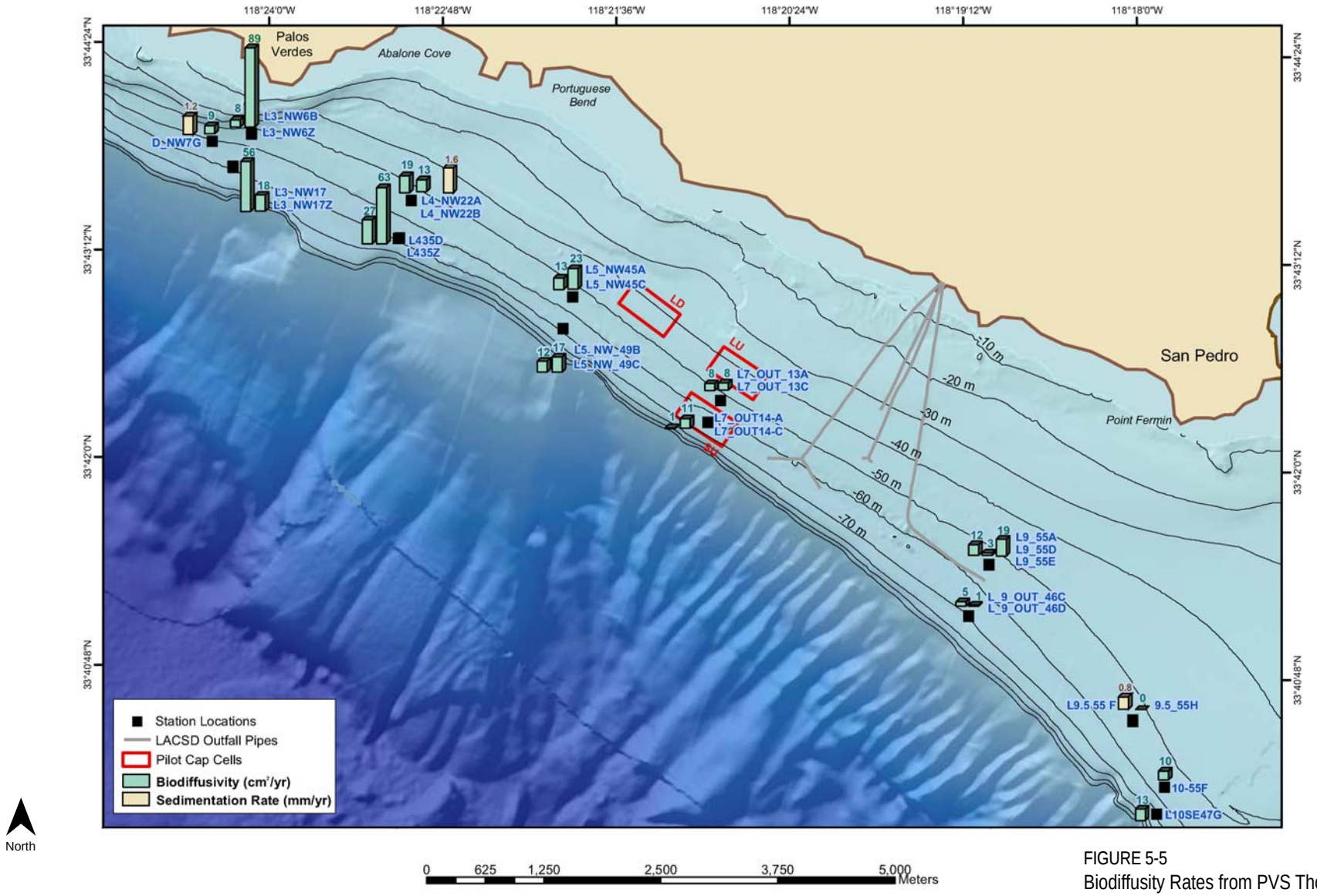


FIGURE 5-5
Biodiffusity Rates from PVS Thorium-234 Radionuclide Profiles
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: SAIC, 2005. Study Report for the Summer 2004 Bioturbation Measurement Program on the Palos Verdes Shelf. SAIC Report 679, July.

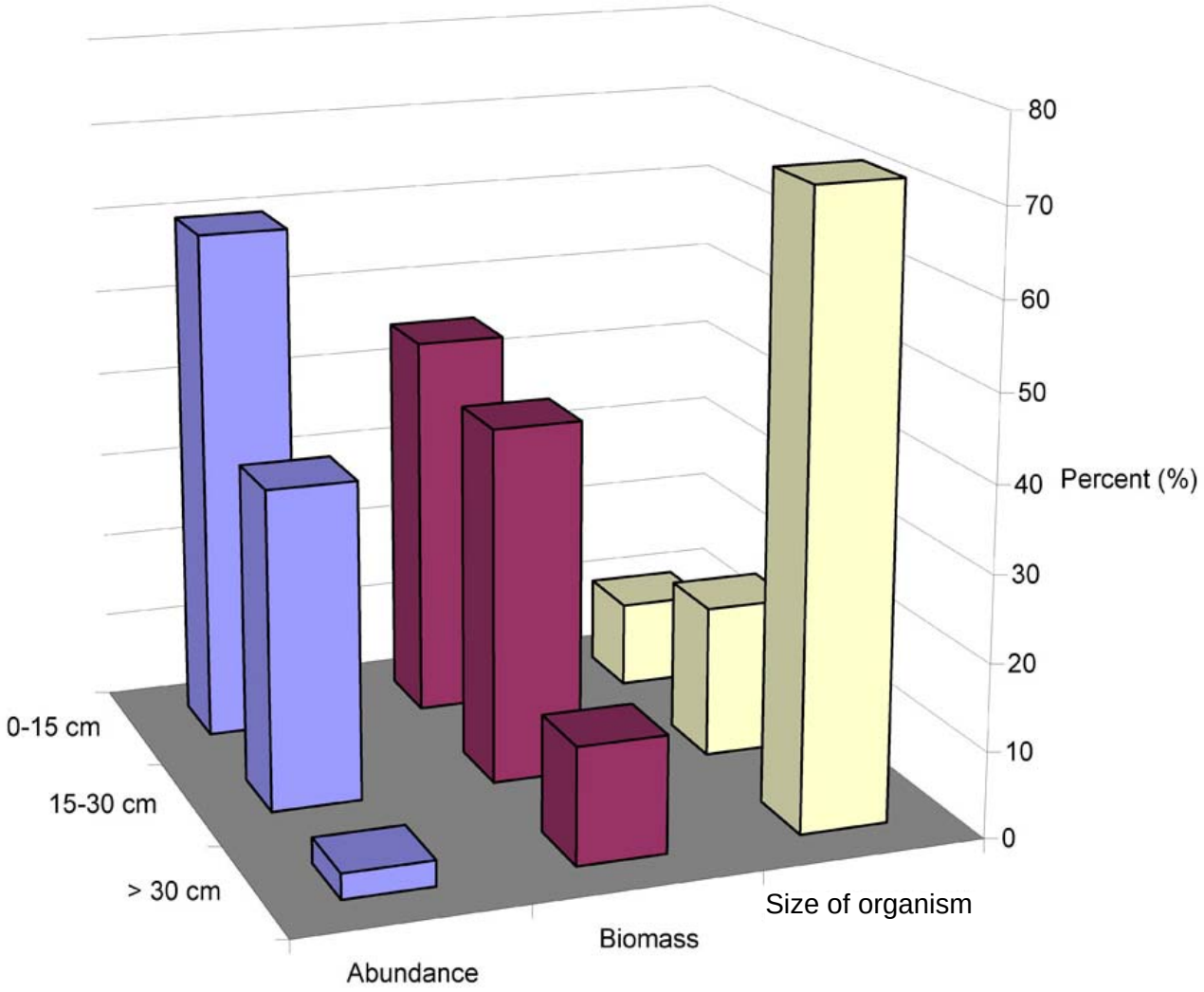


FIGURE 5-6
Relative Distribution of Infaunal Abundance, Biomass and Average Organism Weight
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: SAIC, 2005. Study Report for the Summer 2004 Bioturbation Measurement Program on the Palos Verdes Shelf. SAIC Report 679, July.

Swift et al. (1996), recognizing the limitations of the nuclide-based biodiffusion model, used an alternative approach in which D_b was estimated directly from the known composition and distribution of the PV Shelf infaunal community. Particle-displacement rates, directions, and step lengths for individual species were calculated based on individual species characteristics, and their known sizes, abundances, distributions in the sediment column, feeding modes, and burrowing activities, as derived from published life history information and distribution patterns generated from LACSD monitoring data.

Volumetric mixing rates (cubic centimeters per day [cm^3/day]) were generated for 212 benthic invertebrate species commonly inhabiting the PV Shelf. Results indicate that several arthropod and mollusk species are capable of sediment mixing volumes in excess of 100 cm^3/day, and in the range of 10,000 to 100,000 square centimeters per day (cm^2/day) by species of large burrowing thalassinid shrimp (Figure 5-7). The latter volume estimate represents a potentially high proportion of anisotropic (nonlocal) sediment displacement from biogenic action within the upper meter of sediments, volumetrically indicating potential of volume displacement of 1 to 10 percent per day (10,000 to 100,000 cm).

Swift et al. (1996) concluded that much of the bioturbation of PV Shelf sediments is caused by the behavior of a few large species that are incompletely sampled because of limited core volumes and, where present, their mixing rates accounted for 85 percent of computed bioturbation. Bioturbation by nonlocal mixers may be presumed an even greater influence on vertical (anisotropic) flux in the sediment bed. Much of bioturbation, especially in surface layers, is biodiffusive, indicating random mixing in the sediment bed. However, BIO activities in deeper contaminated layers are significantly more anisotropic (directional) in transporting particles and solutes, deviating from a strictly Fickian diffusion model.

5.5 Molecular Diffusion of Contaminants in Pore Water

5.5.1 Background

Molecular diffusion is the process of small-scale mixing that produces transport of solutes in the direction of decreasing concentrations. Molecular diffusion plays a role in the transport of buried DDTs and PCBs to the sediment boundary. These compounds persist at elevated concentrations, indicating ongoing flux from the buried contaminant layer into surface sediments and the water column. An extensive survey of the SCB found DDT to be the most widespread contaminant, with 71 percent of sediment samples containing detectable levels of DDT metabolite compounds (Schiff et al., 2006).

Rates of diffusion from pore water depend on the strength of the gradient, porosity of the sediments, aqueous diffusivity of the dissolved compounds, and calculated thickness of the diffusive boundary layer, which is a function of bottom shear stress (i.e., bottom friction and wave/current motion). By motion of sediment particles, aqueous exchange between pore spaces is accelerated from physical mixing resulting from animal activity; thus, bioturbation rates play a role in mediating the diffusion process.

Contaminant solute concentrations are assumed to be effectively uniform in the mixed layer (upper 5 to 10 cm) of PV Shelf sediments because solutes are more thoroughly mixed by biodiffusion than associated sediments (Berg et al., 2001). The mixing of solutes by biological action (biogenic diffusion) in this layer significantly exceeds the rate that would occur from molecular diffusion alone (Devol and Christensen, 1993; Aller, 2001), with rates that could be up to 20 to 100 times higher in bioactive and porous sediments (Aller, 1982; Berg et al., 2001). The high water content and relatively high biodiffusion rates that characterize PV Shelf sediments (see Section 5.4, Bioturbation and Biodiffusion) indicate that rates of solute transport from bioturbation are likely to significantly exceed rates from molecular diffusion.

5.5.2 Diffusive Loss of Contaminants from Palos Verdes Shelf Sediments

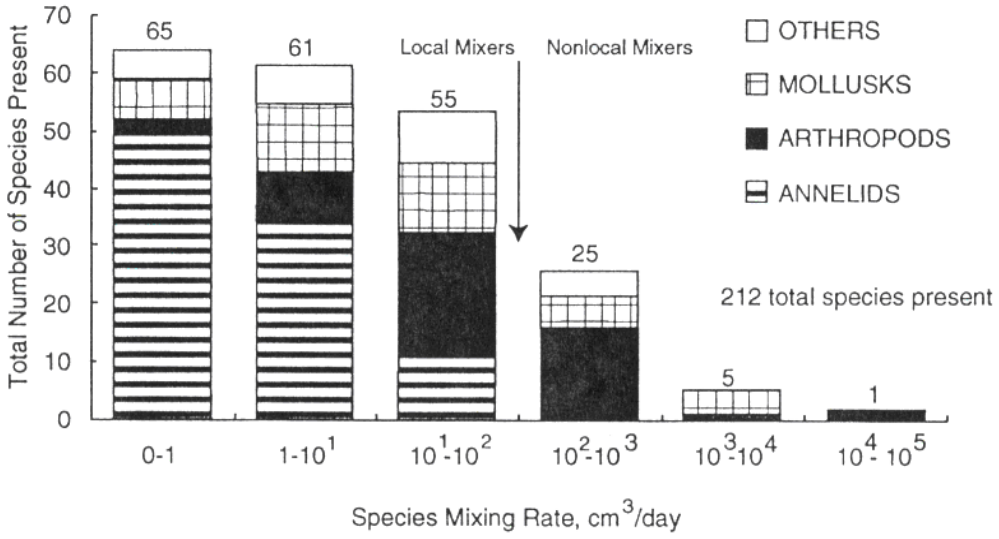
Diffusive loss of soluble DDE from the sediment boundary of PV Shelf sediments has been estimated for USGS Site B (near LACSD Station 6C) by Sherwood et al. (2002).

A two-box model (Chen, 1993) was used by Sherwood et al. (2002) to predict flux of p,p'-DDE into overlying waters. The model included equations for in situ desorption from sediment grains to pore water, movement within the sediment matrix by molecular diffusion, biodiffusion, and diffusive loss through the viscous sublayer to the overlying water at the sediment boundary. Sediment input parameters are described in Sherwood (1994). The estimated rate of transfer of loss of DDE from sediment to overlying water at Site B was 7.2 micrograms per square centimeter per year (μg/cm^2/year), which represented between 10 and 17 percent of the material in the top 10 cm. This was similar to the amount of material lost through resuspension and desorption (Wiberg and Harris, 2002). These calculations did not include the effect of biological circulation of pore waters, which would enhance loss to overlying waters. For example, if deep bioturbating ghost shrimp were to colonize the shelf along buried peak contamination depths of 20 to 30 cm, where the modeled *Db* is near zero, diffusion into the ghost shrimps' extensive burrow networks could facilitate solute transport to the surface layer through bio-irrigation and subsequent advective transport. Estimation of diffusive contaminant loss by this mechanism would require input factors for irrigation volume rates, burrow surface area, and proportion of burrow surface area within various strata.

5.6 Adsorption/Desorption of Contaminants to or from Resuspended Material

Adsorption is the process by which liquid or gaseous compounds are attracted and bind to solid particles. Desorption is the process of changing from an adsorbed state on a surface back into liquid or gaseous phase.

DDTs and PCBs are hydrophobic with very low solubility in water. They are strongly associated with particulate matter (primarily organic carbon) in the water column and bottom sediment of the PV Shelf Study Area. Their partitioning coefficients between adsorptive soil/sediment and water soluble states under various environmental conditions are on the order of one million or more (Pontolillo and Eganhouse, 2001), which means the log K_{OC} values tend to be about 6 or greater.



(A) Histogram of species mixing rate (cm^3/day) for 192 benthic invertebrate species described by Thayer (1983); (B) Species mixing rate (cm^3/day) for 212 benthic invertebrate species from stations on the Palos Verdes shelf. Note break between local and nonlocal mixers.

FIGURE 5-7
Volumetric Mixing Rates (cm^2/day) for Benthic Invertebrate Species
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: Swift et al., 1996

Zeng et al. (2005) measured dissolved p,p'- and o,p'-DDE concentrations from 148 water column samples collected from the surface to near-bottom waters of the SCB. Average concentrations, respectively, for the two compounds were 0.053 and <0.043 ng/L from surface waters and 0.19 and 0.015 ng/L from waters collected 2 m from the ocean floor. Total SCB aqueous-phase mass inventories for these two DDT metabolites were 14.0 and 0.86 kg, respectively, which indicate the high insolubility of the compounds and almost complete residence within the sediment pool. Average SCB sediment and dissolved DDT concentrations reported by the above SCB studies differ by a factor 6.75×10^{-6}. This is reflective of reported chemical partition coefficients between aqueous (soluble) and particle-bound phases, indicating low solubility and strong attraction to particulate matter by contaminant molecules.

Desorption of PCBs and DDTs from sediments occurs when the particles and water surrounding them are not at equilibrium. Desorption could occur along concentration gradients in pore water, across biological interfaces (such as tubes and burrows), and when sediments are suspended at the boundary layer as a result of storm and wave action. These processes are all active in the sediment matrix and at the sediment-water interface of PV Shelf contaminated sediments.

Adsorption could occur when contaminant-free particles are exposed to chemicals in solution. This process occurs in the PV Shelf water column where particulate organic carbon scavenges soluble DDT and PCB molecules from solution. Zeng et al. (1999) conducted measurements of dissolved and suspended particulate concentrations of DDTs and PCBs from water at the PV Shelf Study Area in 1997, from depths of 2, 5, 20, and 35 m above the ocean floor at eight sampling stations. Results from these water column studies indicated that total (dissolved + particulate phase) concentrations of DDTs and PCBs in the water column decline exponentially with distance from the bottom, indicating that most transport is occurring near the bottom. Roughly equal masses of DDTs and PCBs were partitioned between dissolved and particulate phases in these water column samples.

The study concluded that observed partitioning between sediment and aqueous phases, and the steep gradient within the water column, indicated that underlying sediments were the primary source of DDTs and PCBs to the water column. The study also hypothesized that DDTs transported from the historically contaminated zone on the PV Shelf to other areas of the SCB has occurred from a repeated process of sediment resuspension/deposition and short-range advection, consistent with other models and empirical evidence of contaminant distribution in the SCB (Drake et al., 1994; Sherwood et al., 2002; Wiberg and Harris, 2002; Schiff et al., 2006).

The processes of episodic sediment resuspension, advective transport, and associated desorption of the contaminant p,p'-DDE into a soluble phase in the surrounding water column has been modeled for PV Shelf sediments by Wiberg and Harris (2002). Their model used the same USGS sediment core data (Wu and Gschwend, 1986) applied to other model components (e.g., biodiffusion, molecular diffusion) from Site B at the outfall depth (Sherwood et al., 2002). Desorption rates were calculated using a radial diffusion model for porous aggregates during sediment resuspension events. Estimates of near-bed flow and hydrodynamic thresholds for sediment resuspension were generated from wave and current data and hourly averaged light attenuation measurements taken at three water

depths in the bottom 2 m of the water column. Resuspension data were collected at the site with the Geoprobe bottom tripod system in the winter of 1992 to 1993 (Wiberg et al., 2002).

The shelf sediment-transport model of Wiberg (1994), as modified and described by Harris and Wiberg (1997) was used to calculate wave and current shear velocities, and the concentration, size distribution, and volume of sediment in suspension for resuspension events. Sediment resuspension occurred during storm events when near-bed wave orbital velocity exceeded a value of approximately 14 cm/sec and lasted until it dropped below a value of approximately 10 cm/sec. The sediment resuspension correlations observed with the Geoprobe and the 17-year record (1982 to 1999) of the local wave field were used to predict frequency, duration, and seasonal patterns of sediment resuspension. The wave data indicated an average of 10 resuspension events per year on the PV Shelf at 60 m deep.

Organic carbon concentrations (TOC) differed between different particle sizes. Because TOC strongly correlates with sorption capacity for organic contaminants, desorption loss was estimated for individual ranges of particle size, taking into account their relative frequencies in the sediment mix, as well as their duration of resuspension. Uncertainties in applicable partition coefficients between organic particulate and aqueous phases were acknowledged (Pontolillo and Eganhouse, 2001), so three coefficients were input to the model (log K_{OC} = 4.8, 5.4, and 6.0). At this modeled site described by Drake et al. (2002) (Site B, Figure 5-10), the mean concentration of p,p'-DDE in the upper 2 cm of the bed was estimated at 11 mg/kg (Wiberg and Harris, 2002).

Results indicated that p,p'-DDE desorption from the finest-grained sediment fraction (less than 20 micrometer [µm]) can occur quickly even during the shortest resuspension events; while p,p'-DDE desorption from the coarser-grained sediment fractions (greater than 63 µm) is minimal even after the longest resuspension events. Drake et al. (2002) reported that a significant fraction of the particles on the PV Shelf are aggregates, primarily fecal pellets, formed as a result of particle ingestion by organisms followed by elimination as small bundles. Many of these aggregates resist breakage and can be transported intact, thus behave as larger particles characterized by slower sorption rates. Duration of resuspension events averaged 1.6 days. The study concluded that, on average, 25 to 50 percent of the mass of p,p'-DDE in the surface active layer (approximately 0.2 cm) is lost during a resuspension event.

The average estimated loss of p,p'-DDE by desorption during wave-driven resuspension was 3 to 7 µg/cm^2/year. This upper value is similar to the estimate for loss through molecular diffusion at the site (e.g., 7.2 µg/cm^2/year [Sherwood et al., 2002]). This represents about half of the estimated loss from surface sediments.

Although dissolved contaminants are found at elevated concentrations over the PV Shelf (Zeng et al., 1999), it is likely that a significant portion of the desorbed compounds would be subsequently re-adsorbed, partitioning onto relatively uncontaminated particles that are advected into the region, and suspended in the nepheloid layer and near-bottom waters of the SCB. Average water column concentrations of particulate organic carbon in the SCB range from 40 to 160 µg/L at depths shallower than 100 m (Williams, 1986). This suspended material being transported along the PV Shelf could easily scavenge the desorbed molecules and subject them to advective transport by currents. For low-density, organic particles, with relatively low sinking rates, this could be a significant means of transport to farther reaches of

the SCB. Ultimately, with water-column mixing associated with resuspension events, a new equilibrium for DDTs and PCBs is achieved between native and advectively introduced sediments in the water column.

Annual sediment monitoring by LACSD indicates a decrease of more than 25 percent in sediment organic carbon concentration in PV Shelf Study Area sediments over the past decade (from an average 4.2 percent of sediment dry weight in the 1990s to 3.1 percent from 2000 to 2006). The results of these changes (lower contaminant concentration, using a site-specific higher partition coefficient, slightly lower TOC) have the effect of lowering equilibrium based desorption rates to less than 1 percent of the underlying contaminant mass per year. Loss solely from this process represents a half-life of greater than 60 years for the contaminant mass.

Desorption from suspended sediments is a significant portion (approximately 20 percent) of the total of loss of DDTs and PCBs from PV Shelf sediments. However, other fate and transport mechanisms, such as chemical degradation, bioturbation (including nonlocal mixing) and transport of particulate-bound contaminant compounds through currents (Section 5.7) are more significant at the PV Shelf Study Area.

5.7 Transport of Contaminants by Currents and Waves

This section discusses contaminant transport, sediment transport, wave climate, current fields, erodibility, and transport of effluent-affected sediments as follows:

Section 5.7.1 is an overview discussion of the contaminant transport mechanisms considered within the water column and sediment. Because the primary concern is the mobilization and transport of effluent-affected sediments previously deposited, the mechanisms for movement of sediment are summarized in Section 5.7.2. Section 5.7.3 reviews the available site-specific information on the wave component of sediment transport. The available information concerning current patterns, sediment deposition patterns, current speed, and associated scour capacity is presented in Section 5.7.4. A review of sediment erodibility and an evaluation of the expected future mobilization, transport, and redistribution of effluent-affected sediments are provided in Section 5.7.5.

5.7.1 Contaminant Transport

Contaminants adsorbed to sediment particles can be transported by particle movement or, when dissolved, by means of advective-diffusive processes in the water column. Contaminants are desorbed from sediment particles in the water column or are released into the water column from pore water. Water column movement then transports these contaminants. However, because contaminants such as DDTs and PCBs have a strong affinity with particles, physical transport of contaminants will be dominated by sediment particle movement and not contaminants that are dissolved or associated with colloidal particles in solution. In addition, dissolved contaminants will be rapidly diluted and flushed from the immediate vicinity. Therefore, the transport of dissolved contaminants through water movement is considered less significant than the transport of contaminants associated with sediment particles, although transport of dissolved and colloidal contaminants typically results in a loss at the PV Shelf Study Area.

Contaminant transport by means of sediment transport has resulted in dispersion and redistribution of adsorbed contaminants at the PV Shelf Study Area. Transport has redistributed sediments within the study area or into deeper water, subsequently eliminating the potential for future transport. Erosion and net transport of effluent-affected sediments has exposed previously buried sediments that could have elevated contaminant concentrations.

The movement of chemical compounds sorbed to particulates and transported in water will be affected by sediment particle size and shape and specific gravity. Sediment could show a nonuniform distribution of adsorbed organic compounds because of the functional dependence of sorption on particle size (Karickhoff et al., 1979). Dissolved contaminants could be adsorbed to particulate matter and subsequently transported though sediment movement.

5.7.2 Sediment Mobilization and Transport

Sediment can be moved as bedload by the action of currents in the overlying fluid by sliding, rolling, or saltation (jumping along the bed in small trajectories); or as suspended load, when suspended off the bottom and in the water column. The combination of bedload and suspended load is generally referred to as the total transport load. Sediment transport rates are difficult to quantify or measure, and are best considered as estimates with large uncertainties.

A sediment particle can be dislodged from the seafloor when the shear stress (force per unit area parallel to the bottom) is greater than the forces acting to stabilize the particle (gravity, cohesion, friction, and interference by adjacent particles). Shear stress is directly proportional to the square of the overlying fluid speed (velocity), which means the greater the velocity, the greater the shear stress, and as shear stress increases at some point, particles will be mobilized and begin to move as bedload or be resuspended into the water column.

The critical shear stress of noncohesive sediments is a function of particle size, shape, specific gravity, and surface unevenness resulting from biological activity. The greater the size of the particle, the greater the shear stress required to move the particle. However, the critical shear stress of finer-grained cohesive sediments is greater than would be indicated by particle size only. Typically, particles having diameters below approximately 125 μm will require greater critical shear stress increases as grain size decreases. Cohesiveness of sediment is typically caused by the presence of clay and begins to be significant at 5 to 10 percent clay by weight. Cohesiveness of sediment also can be influenced by organic matter.

At the PV Shelf Study Area, two mechanisms that can potentially mobilize and transport sediment, waves and currents, must be considered. If wave orbital velocities at the bottom are sufficient, a critical shear stress is achieved and bottom sediments are mobilized. However, mobilization of sediments generally will not result in significant net transport without currents because the wave orbital velocities are oscillatory and symmetrical. The wave action is a back-and-forth motion that could mobilize sediments into motion, but will not necessarily cause net transport. Appendix D provides a primer on waves, currents, and bottom stress.

If the velocity of the bottom current is equal to or greater than the critical shear stress, the current can both mobilize and transport sediment. Unidirectional currents transport mobilized (e.g., suspended by wave action) sediment in the direction of the current. The distance and direction of transport depends on the nature of the particle and the speed and direction (velocity) of the current. The currents required to maintain sediments in motion on the bed, or in suspension in the water column, are lower than those needed to initiate motion. When mobilized, sediments can be transported until the current velocities drop to a point that allows them to settle, which is typically significantly less than the critical velocity for fine-grained sediments. A review of available information on the capacity for waves to mobilize bottom sediments and currents to mobilize and/or transport sediments at the project site is provided in the following sections (Sections 5.7.3, 5.7.4, and 5.7.5).

In addition to waves and currents, biological activity within the sediment has the potential to disturb sediment and cause suspension just above the bottom. This phenomenon is not well-documented and quantitative data on the subject are limited. Such biological action could suspend sediment in the absence of waves and at current speeds below the critical velocity but sufficient to transport sediment.

5.7.3 Wave Climate and Sediment Mobilization

The ability of waves to suspend bottom sediments is determined by wave orbital velocities at the sediment bed and sediment characteristics (e.g., size, shape, cohesiveness, presence of bedforms, sediment density). The wave orbital velocities are a back-and-forth motion of the water created by the passage of waves. The magnitude and depth of action are determined by the wave characteristics (wave height and period) and distance below the water surface. For sufficiently large waves of the appropriate period, the orbital wave velocity can reach the bottom and create a bottom shear stress that exceeds the threshold for grain motion. When this occurs, and if the velocities are sufficiently large, sediment can be suspended into the overlying water column. This section addresses bottom sediment mobilization by waves, but the mobilized sediment will not result in net transport without superimposed currents, which are discussed in Section 5.7.4.

A review of pertinent studies related to the effects of wave fields on the bottom sediments within the study area was conducted. The results of these studies of wave-induced transport of effluent-affected sediments include the following information:

- Wave heights, periods, and orbital velocities in the study area capable of suspending bottom sediments
- Depths at which wave orbital velocities can suspend bottom sediments
- Frequency at which suspension of these bottom sediments occurs
- Depth (thickness) of the sediment that is being influenced

Based on this information, the significance of waves as a component in the fate and transport of effluent-affected sediments can be evaluated.

Surface gravity waves propagate as shown in the schematic diagram on Figure 5-8. The wave period is the time it takes a particular phase of the wave (crest to following crest) to pass a stationary observer. The wave length (L) is the distance between adjacent crests. The wave height (H) is the distance from trough to crest. As the wave crest passes a given point, the water moves in the direction of the wave; as the trough subsequently passes the same point, the water moves in the opposite direction. Between the crest and trough, the water moves vertically upward or downward. The overall effect is that a parcel of water moves in a circular pattern or orbit (Figure 5-9). The magnitude of the wave-induced orbital velocities decreases with depth, and at some depth disappears. If the water is shallow enough so that the wave orbits impinge on the ocean floor the shape of the orbits becomes elliptical and at the bottom, the motion is simply linear in a back-and-forth manner.

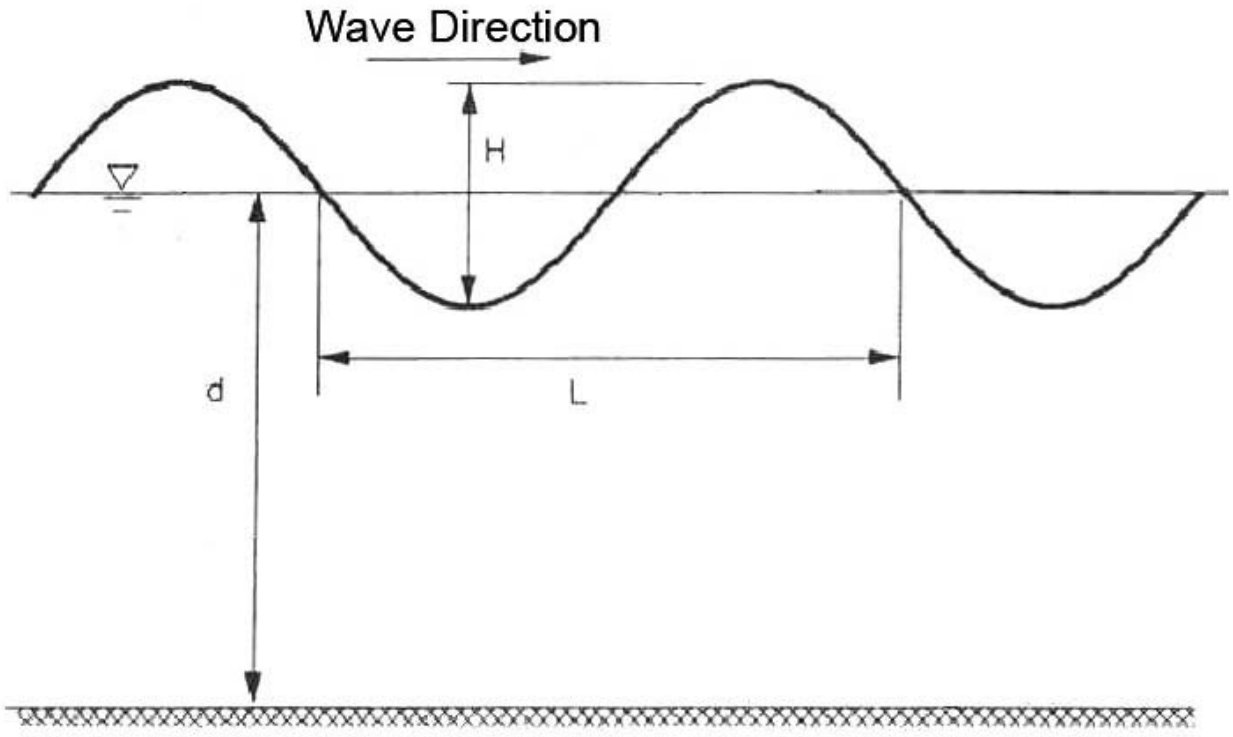
5.7.3.1 Overview of Site-specific Information

A review of the wave climate and characteristics at the PV Shelf was presented in the sediment dynamics workshop document, *Environmental Processes Affecting DDT Contaminated Sediments off Palos Verdes, California*, edited by Kolpack (1987). The general consensus of the contributors to the workshop was that the PV Shelf is sheltered by the Palos Verdes Hills and by offshore islands, which reduce the influence of wind and waves, but that large storm-induced waves are still capable of suspending bottom sediments.

The workshop covered a number of topics including wave-induced suspension of sediments. The proceedings from the workshop included a summary of the wave climate along the PV Shelf, estimates of sediment suspension potential by waves based on models, and comments on areas where the authors thought there were gaps in available data. A summary of the wave-related information discussed in the workshop, as presented by Kolpack (1987), is discussed below. Wiberg et al. (2002) subsequently conducted field studies that partly addressed some of the identified data gaps (Section 5.7.3.2).

Kolpack (1987) described the sediments on the inner shelf (30- to 40-m isobaths) as being exposed to relatively strong wave-generated currents throughout the year and concluded that it is likely that these materials are frequently in motion (based on the work of Drake et al., 1985). These authors also noted that stresses capable of suspending bottom sediments at a depth of 40 m will occur as gravity wave heights near 1 m. Wave heights of this order are infrequent in the summer, but are common in the winter. Calculations of the combined bottom friction velocity, for a range of wave and current situations common to the Palos Verdes region, suggest that sediment resuspension from storm wave activity could occur to water depths of at least 45 m.

In reviewing the work of Drake et al. (1985), Kolpack (1987) noted that natural sediment resuspension at 60-m depths occurs infrequently, and only during brief periods in the winter when the storms produce larger waves. Kolpack (1987) also looked at buoy data and concluded that data from shelf wave-buoys suggest that annual storms off California will generate maximum waves of 3 to 4 m with 14- to 17-second periods. The frequency of those storms is less than one storm per month. On longer time scales (5 to 10 years), the California shelf can expect to experience a storm with maximum waves of 5 to 8 m and 16- to 18-second periods.



L = wave length
H = wave height
d = water depth
Wave Speed (c) = L/T, where T = wave period

Source: Modified after Knauss, John A., Introduction to Physical Oceanography, Prentice-Hall, 1978.

FIGURE 5-8
Schematic Drawing of Components of a Gravity Wave
Palos Verdes Shelf Study Area Remedial Investigation Report

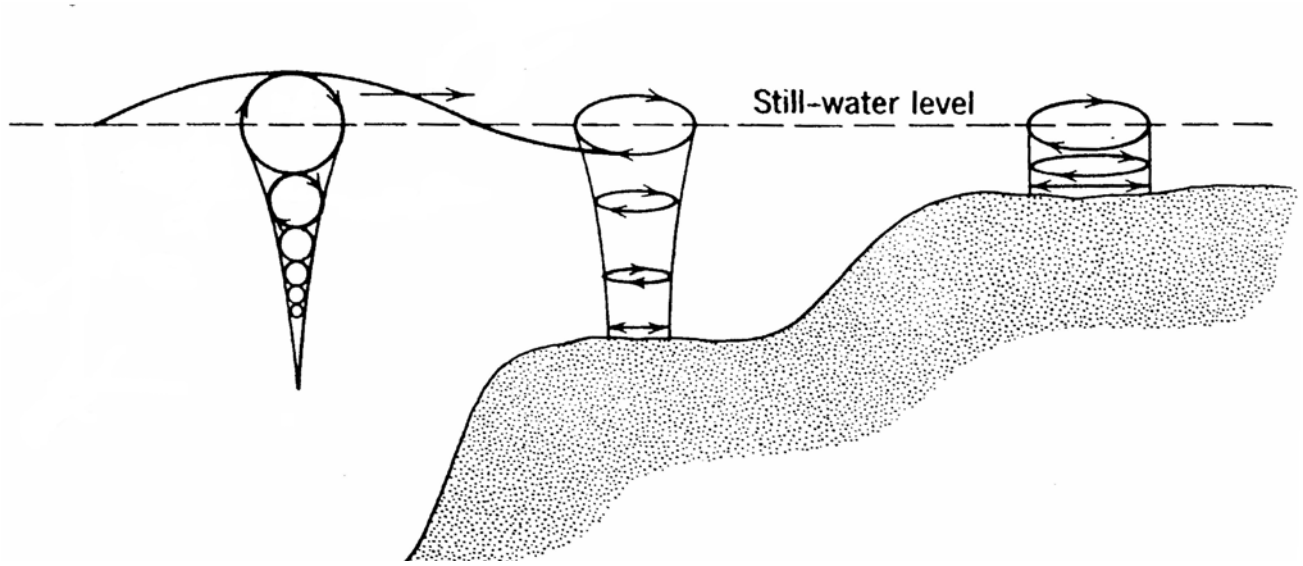


FIGURE 5-9
Schematic Drawing of Wave Orbits Showing Depth Effect on Particle Paths
Palos Verdes Shelf Study Area Remedial Investigation Report

Source: Modified after McCormick, Michael E., Ocean Engineering Wave Mechanics, John Wiley & Sons, 1973.

Kolpack (1987) summarized some of the most relevant wave literature and presented the following three general classes of large waves common in the Palos Verdes region:

- Waves propagating eastward from the open ocean arrive with a period of about 16 to 17 seconds and an approximate height of 3 to 5 m about once in 3 years (Seymour et al., 1984).
- Open-ocean waves, with a height of 2 m and 14- to 17-second periods, arrive about once a year.
- Large waves that are generated on or near the shelf have a wave height of about 2 m, a period of 10 seconds, and arrive between 5 and 10 times a year (Fleet Weather Facility, 1981).

Erosion depths in the sediment during moderate storms were typically only 1 to 2 mm and generally fell below theoretical predictions (Wiberg and Smith, 1983). The available information reviewed by Kolpack (1987) suggested that wave-induced erosion depths from the 60-m isobath to the shelf edge off Palos Verdes are probably less than 1 cm. In fact, observations made after the extreme storm events of 1983 indicated little or no net erosion at 60 m. Erosion depth refers to the sediment disturbance depths and net erosion requires currents sufficient to transport sediment away from the site of disturbance.

Kolpack (1987) concluded that, based on wave-induced suspension and currents, the near-shore edge of the contaminated sediment body will be eroded, with the finer-grained components going into suspension and moving (most frequently) toward the northwest and offshore areas. Erosion of the shallow edge of the DDT-rich layer seems to be occurring, and redeposition offshore offers a potential explanation for the concentrations of DDT measured on the surface of the recent sediments.

5.7.3.2 Field Observations

During 1992 and 1993, USGS and academic researchers conducted studies to gather information on the current patterns and sediment transport patterns over the PV Shelf and slope to assess the fate of contaminated sediments (Noble et al., 2002). Among these studies, were wave-induced sediment suspension studies that addressed data gaps described by Kolpack (1987). Wiberg et al. (2002) combined direct observation, long-term wave data, and model calculations to characterize resuspension and transport of effluent-affected sediments. Direct observation included use of a Geoprobe bottom tripod to collect data on near-bed orbital wave velocities, periods, and directions, as well as pressure (to determine wave height) and light attenuation (turbidity). Video footage and photographs of the seabed also were taken to support the electronic data. The monitoring site was located approximately 1.5 km northwest of the LACSD 60-m outfall (Figure 5-10). This site is near Station 6C, as shown on Figure 2-1, at a depth of 63 m, and was occupied during the winter of 1992 to 1993.

Wiberg et al. (2002) noted that the results of the field data at a depth of 63 m indicated that wave orbital velocities associated with storm events generated seven sediment suspension events during the winter of 1992 to 1993. These storm events were characterized by the highest persistent suspended sediment concentrations observed, which is interpreted as confirming wave-driven resuspension and transport of sediment. Associated average

significant wave heights ranged from 1.9 m to 3.0 m, with a maximum significant wave height range of 2.7 m to 4.2 m.

A sediment-suspension threshold velocity of 10 to 14 cm/sec was determined for the site based on a criterion of a factor of 10 change in observed light attenuation (turbidity) at 0.3 m above the bottom. Near-bed turbidity obscured most of the images; however, an image from February 17, 1993, showed that the effect of a storm was to reconfigure the bed surface into small, low-amplitude, poorly formed ripples whose development was aided by the presence of sand-sized fecal pellets in the surface sediment. The orientation of the ripples indicated that waves were principally responsible for their production.

Wiberg et al. (2002) compared the wave velocities collected during the study with wave height spectra collected at Buoy 46025 by the National Data Buoy Center for the same period. The buoy is located about 80 km west of the PV Shelf. The two data sets were well-correlated (correlation coefficient greater than 0.98). The authors used this correlation to calculate bottom orbital velocities based on wave height spectra measured at the buoy for the period of record (1982 to 1999). This extended record indicated a total of 172 wave events expected to result in sediment suspension at a depth of 60 m between October 1982 and October 1999. This results in an average of 10 resuspension events per year, with an average duration of 1.6 days per event. The number of expected events drops to 3 per year at a water depth of 90 m. Therefore, little resuspension of contaminated sediments is occurring near the outer site boundary (100- to 200-m isobaths).

The peak orbital wave velocity at 60 m deep calculated from the record was 63 cm/sec. These waves were produced during a January 1988 storm and were judged to be sufficient to resuspend sediment to a water depth of approximately 170 m. The longest wave event for the period of record lasted 12.7 days and occurred during the winter of 1997 to 1998, which is an El Niño year. The authors also noted some seasonality in wave events. Over the entire wave buoy record, only three wave events judged capable of suspending sediment at 60 m occurred during the months of June through August. Therefore, it was concluded that there is reasonable probability that in most years there will be a 3-month window during the summer when wave action would not be sufficient to resuspend the bed sediments.

5.7.4 Currents

This section discusses currents in the water column that are not generated by surface gravity waves (as described in Section 5.7.3) or high-frequency internal waves (except for a few comments as noted). The currents discussed in this section come from ocean basin-wide circulation patterns, regional-scale forcing, and tidal forcing. Currents can be characterized in terms of net or average currents that describe the overall circulation pattern in the PV Shelf region, and the fluctuating currents that vary in speed and direction. Fluctuating currents include those induced at semidiurnal frequencies by tidal motion (tidal currents), and at less frequent intervals by cyclical tidal patterns of lower frequency (subtidal currents). In the PV Shelf region, there appear to be internal tides (tidal frequency internal waves), which could be an important factor in sediment transport.

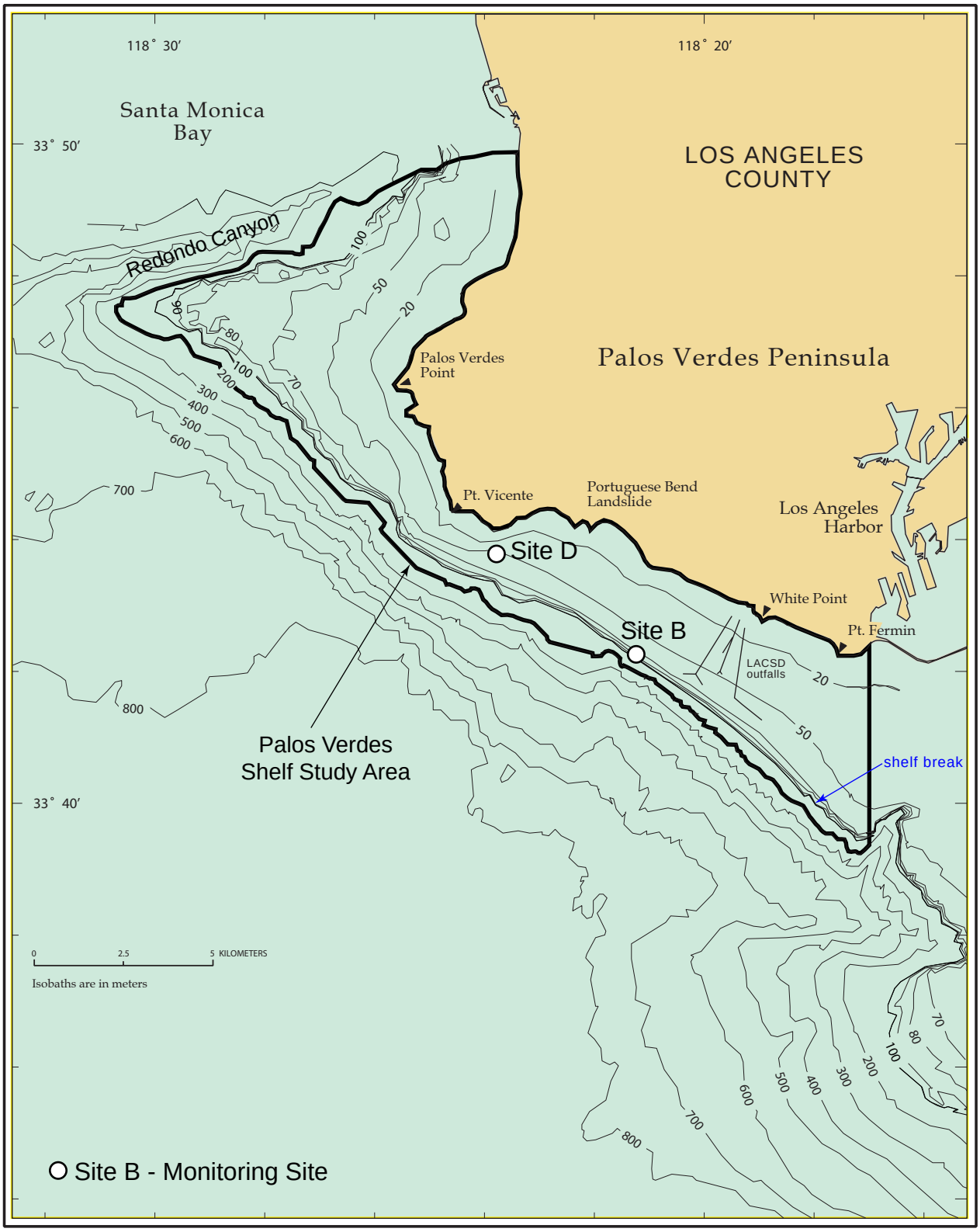


FIGURE 5-10
Monitoring Sites Used by Wiberg et al. (2002)
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: Wiberg et al., 2002.

Tidal phenomena can be divided into two major types: surface and internal tides. Surface tides are associated with the astronomical tide and are responsible for the familiar tidal rise and fall of the sea surface. The currents, coupled with tidal cycles of sea level, are depth-independent or barotropic, except for frictional effects in the bottom boundary layer. Internal tides could occur, sometimes only sporadically, and are associated with density gradients in the water column; these are called baroclinic tides. Internal, semidiurnal tides are a relatively small part of the average tidal current oscillations. Internal tides can be a relatively small compared with barotropic tides, especially because they are oriented more onshore and surface tides are more along-shore, but for periods of a few days, internal tides can dominate the tidal current field, and could resuspend sediment. Surface tides typically have predictable periodicity and do not have aperiodic peaks in energy. However, internal or baroclinic tides are a mechanism for intensification of currents near the seafloor and, therefore, have an influence on sediment resuspension. Though the frequency, duration, and intensity of this process is still not well-defined on the PV Shelf, internal tides are considered to be a significant cause of sediment resuspension on the PV Shelf (SAIC, 2004b).

Tidal currents are usually analyzed in terms of constituents that have specific frequencies, which are derived from the orbits of the earth, moon, and sun. The principal constituents are grouped into the semidiurnal (periods of 12 to 12.5 hours), and diurnal (periods of 24 to 26 hours). Currents within and adjacent to the study area are of interest because currents could mobilize and subsequently transport sediments, or transport sediments mobilized by other processes (such as waves). Sediment introduced by the LACSD outfalls or sediment from outside the PV Shelf Study Area, including those from the adjacent land areas (stream, cliff erosion) will be distributed within the PV Shelf by the ambient current fields. For example, Portuguese Bend Landslide sediments in shallow water could be suspended by wave action and initially transported to the southeast by in-shore and surface currents before moving into deeper water (at least 60 m) and being transported northwestward along and over the PV Shelf by near-bottom currents. Likewise, Los Angeles Basin rivers deliver suspended sediment to San Pedro Bay that is transported by San Pedro Bay current fields. Some of the suspended sediment could be transported by bottom currents northwestward to the PV Shelf. Section 3.0 describes current patterns around the PV Shelf.

Currents, and especially bottom currents, are evaluated in terms of speed, direction, and duration because this information is required for predicting and modeling the transport, accumulation, and erosion of sediment. The speed, direction, duration, and frequency of current events capable of mobilizing bottom sediments are of particular interest because these events could erode the surface layer over the more heavily contaminated effluent-affected sediment and transport contaminated sediment. A discussion of erodibility and transport of effluent-affected sediments is presented in Section 5.7.5. This section reviews studies discussing current fields, with a focus on bottom currents. There is limited information on currents within the bottom boundary layer, which are involved in the development of bottom shear stresses and potential mobilization of sediments. In the absence of bottom boundary layer current records, studies that provided near-bottom current measurements are discussed in this RI report; however, these current measurements provide only semiquantitative assessments of sediment transport phenomena.

Noble et al. (2002) indicated that the PV Shelf forms a passageway between two large embayments that is approximately 15 km in the shore-parallel direction, and less than 3 km wide. An example of timeframes for suspended particles to cross the PV Shelf based on a given current speed is provided in Table 5-5. As indicated in Table 5-5, an along-shelf bottom current of 10 cm/sec could transport fine suspended sediment the length of the PV Shelf (15 km) in less than 2 days (rate = 8.6 kilometers per day [km/day]) and a cross-shelf current of the same speed could transport sediment off the shelf into deep water in less than half a day. Particles suspended in the middle of the shelf would take only half that time to exit the study area. Table 5-5 lists current speeds, frequencies, and durations reported for specific sites in the study area.

TABLE 5-5
Time for a Suspended Particle to Cross the PV Shelf Based on a Given Current Speed

Speed (cm/sec)	Travel Distance (km/day)	Time to Transit PV Shelf (Along-shelf = 15 km) (days)	Time to Transit PV Shelf (Across-shelf = 3 km) (days)
1	0.86	17.4	3.5
2	1.7	8.7	1.7
5	4.3	3.5	0.69
10	8.6	1.7	0.35
20	17	0.87	0.17
30	26	0.58	0.12
40	35	0.43	0.09
50	43	0.35	0.07
60	52	0.29	0.06

Information on bottom currents is available from the following three sources; the latter two are specifically targeted at understanding processes affecting the effluent-affected sediment layer:

- Early summaries of currents along the PV Shelf by Kolpack (1987) and Niedoroda et al. (1996).
- USGS deployments of four moored current meter arrays north of the LACSD outfalls (Figure 5-11) during 1992 to 1993. Data from these deployments were interpreted by Drake et al. (1994), Noble et al. (2002), Wiberg et al. (2002), Sherwood et al. (2002).
- LACSD monthly monitoring program of up to 13 acoustic doppler current profiler current meter stations extending from San Pedro Bay, along the PV Shelf, and into Santa Monica Bay (Figure 5-12). This data set provides a greater number of monitoring sites, a longer record, and greater number of depth increments than previous studies.

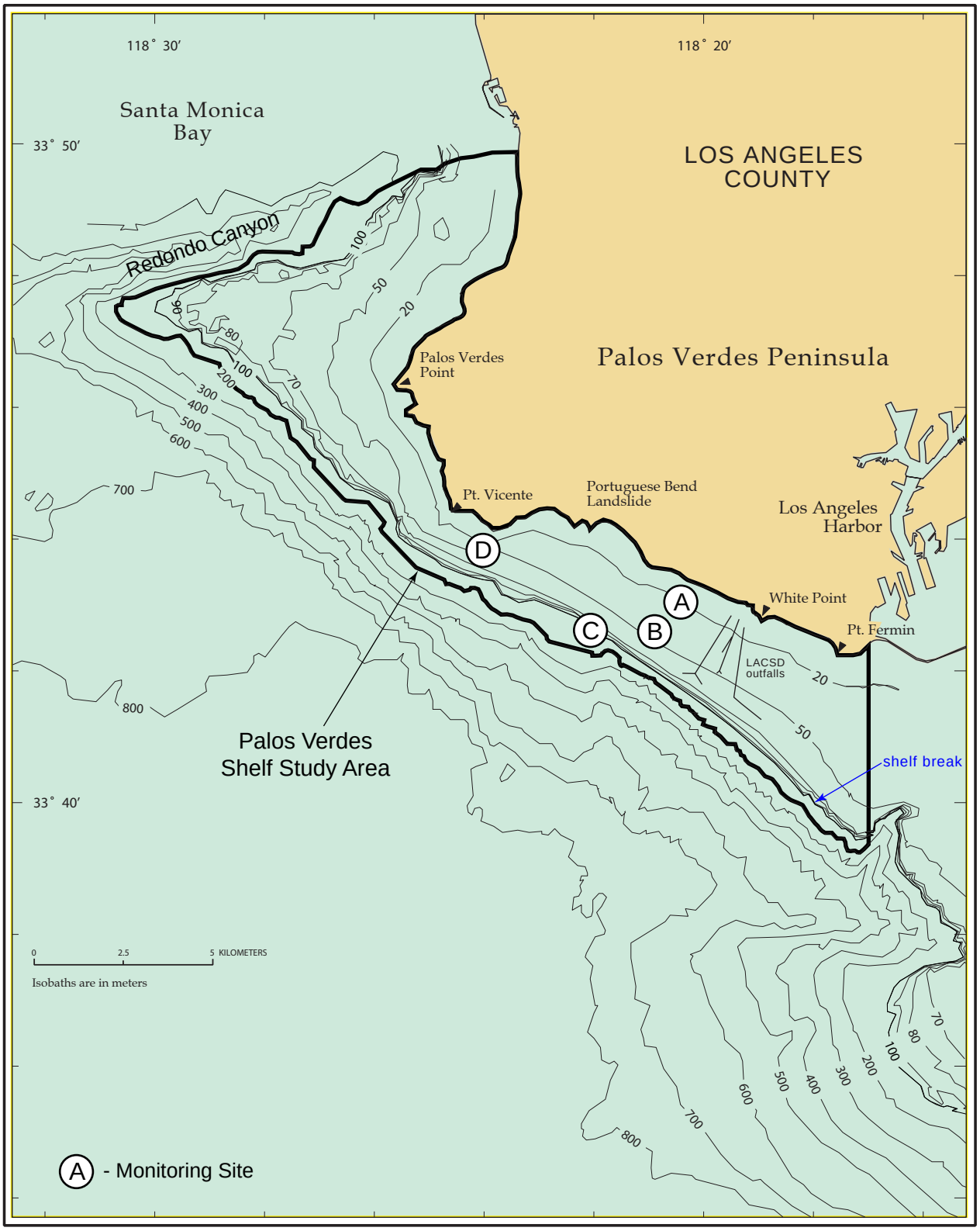
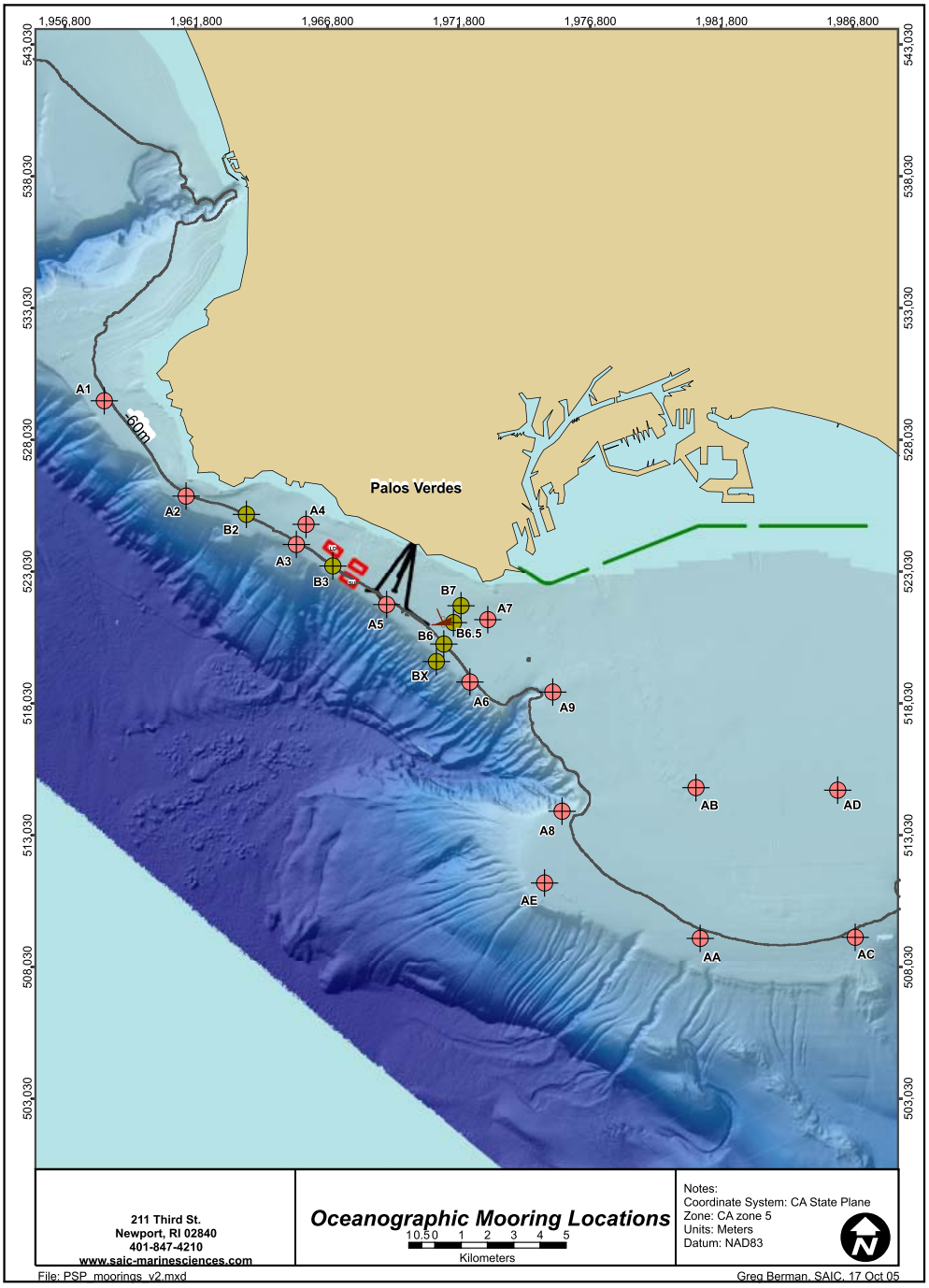


FIGURE 5-11
Monitoring Sites Used by Noble et al. (2002)
Palos Verdes Shelf Study Area
Remedial Investigation Report

Source: Noble et al., 2002.



- USGS/SAIC Mooring Location
- LACSD Mooring Location
- Breakwater
- Outfalls
- 60m isobath
- Pilot Cupping Cells

FIGURE 5-12
Monitoring Sites Used by LACSD Current Monitoring Study
Palos Verdes Shelf Study Area Remedial Investigation Report

Source: SAIC, 2005. Data Report for the 2004 Oceanographic Measurement Program Conducted on the Palos Verdes Shelf. SAIC Report Number 694, October.

Literature based on the results of these studies forms the basis for the discussion in this section. Transport of sediment occurs in all directions. The footprint of the effluent-affected sediments clearly indicates a net depositional pattern leading away from the LACSD outfalls in a northwesterly direction. Literature on currents and deposition along the PV Shelf provides evidence of a mean along-shelf current to the northwest (e.g., Kolpack, 1987; Drake, 1994; Noble et al., 2002; Wiberg et al., 2002). Offshore transport leads to trapping material in deep water, as observed in the available records. On-shore transport is limited by depth because in shallow water the fine material is rapidly removed by wave action.

5.7.4.1 Summaries of Previous Current Information

Current measurements on the PV Shelf and adjoining regions (including Winant and Bratkovich, 1981; Hendricks, 1983; Hickey, 1989a and 1989b) are available. Review of the current meter time series from these measurement programs (Niedoroda et al., 1996) shows that current fluctuations at approximately 22-hour periodicity in the tidal frequency range come from the diurnal and semidiurnal astronomical tide along with inertial currents.

Maximum current speeds in this frequency range on narrow continental shelves of the SCB are typically 10 to 15 cm/sec (Hickey, 1993). Supra-tidal fluctuations related to internal waves are also common and have characteristic speeds of 3 cm/sec (Hickey, 1993).

Kolpack (1987) reported that off PV Shelf current speeds of up to 60 cm/sec have been measured for durations of several days and that these current speeds over the Upper Slope off Palos Verdes are sufficient to cause local resuspension, possibly to water depths of 200 m. However, Kolpack (1987) qualified this information by stating the upper water depth (shoreward) limit of this current with erosive capability has not been defined for the area off Palos Verdes. Kolpack (1987) suggested that particulate matter entrained from the sewage plume or from resuspension of bottom sediments would be rapidly transported northward by a current with speeds of up to 60 cm/sec.

Niedoroda et al. (1996) reported that although near-bottom (within 5 m) current speeds on the order of 15 cm/sec are common at the 60-m water depth, strong currents are very rare. The data collected by Winant and Bratkovich (1981) and Hickey (1993) at other SCB shelf sites show that current speeds are less than 20 cm/sec more that 98 percent of the time and are smaller than 25 cm/sec more than 99 percent of the time. These studies indicate that currents capable of mobilizing sediment and creating bottom scour are infrequent. Niedoroda et al. (1996) also indicated that attempts to develop an approximate relationship between local wind stress and currents were not successful.

5.7.4.2 Site-specific USGS Current Studies

The measurement of currents was a key component of the 1992-1993 USGS studies. Four sites were established to monitor currents (Figure 5-11). Various authors presented the results of these studies including Drake et al. (1994 and 2002), Noble et al. (2002), Sherwood et al. (2002), and Wiberg et al. (2002). While all these authors discussed background conditions that included waves and currents, the dominant interpretation of the current data from all four stations was conducted by (and attributed to) Noble et al. (2002). Wiberg et al. (2002) reviewed the data from the two sites (B and D) along the 60-m isobath and provided additional information on currents.

Current data and associated studies provide the following information:

- Mean along-shelf bottom velocities (6 m above the bottom) ranged between 3 and 4 cm/sec in a northwesterly direction (Noble et al., 2002). Wiberg et al. (2002) provided further information on two of the sites (B and D) and reported that at Site B, mean along-shelf velocity was 1.9 to 3.2 cm/sec to the northwest and 0 to 1.4 cm/sec across-shelf in the seaward direction. Mean current speed (regardless of direction) at Site B was 7.9 to 9.8 cm/sec. At Site D, mean along-shelf velocity was 4.1 to 4.2 cm/sec along-shelf to the northwest and 0.2 to 0.4 cm/sec across-shelf in the landward direction. Mean current speed (regardless of direction) at Site D was 9.6 to 10.7 cm/sec.
- Fluctuating currents typically reached speeds of 20 to 30 cm/sec, and the most energetic currents had periods between 5 and 20 days (Noble et al., 2002). The peak subtidal bottom current (6 m above the bottom) for the study period was 24 cm/sec directed poleward along-shelf (event occurred on February 20, 1993) (Wiberg et al., 2002).
- Currents speeds seem to increase as they move onto the narrow shelf between the two basins.
- Subtidal currents were roughly aligned with the isobaths with a tendency for currents to flow offshore (northwestward) near Point Vicente as the isobaths bend northeastward (Noble et al., 2002). Noble et al. (2002) also reported that because the shelf narrows toward the northwest (near Point Vicente); the subtidal along-shelf currents were stronger near Site D than near the Site B. Wiberg et al. (2002) reported similar findings indicating that mean along-shelf currents were greater at Site D than Site B, and mean across-shelf current was weakly onshore at Site D and offshore at Site B.
- Currents were not significantly correlated with waves and seasons (Noble et al., 2002; Wiberg et al., 2002).
- Along-shelf wind stress accounted for 10 to 15 percent of the variability in the subtidal currents. A 1 dyne/cm^2 wind stress was associated with a 20 to 30 cm/sec along-shore current near the surface (Noble et al., 2002).
- Noble et al. (2002) indicated that the majority of current variance over the Palos Verdes Margin is forced by fluctuations in the along-shelf pressure gradient, not wind stress. Regional forcing processes, both over the shelf and within the adjacent basins, can control the along-shelf current field. Currents accelerate as they are confined and move over the shallow shelf.
- Variance in the currents 6 m above the bottom was split almost equally between tidal and subtidal frequencies (Wiberg et al., 2002).
- Harmonic analysis of the bottom currents indicated that lunar, semidiurnal (M2) tidal constituents dominated tidal currents on the PV Shelf (Wiberg et al., 2002).

5.7.4.3 Site-specific LACSD Current Studies

The LACSD data from 13 mooring locations using Acoustic Doppler Current Profilers (ADCP) (Figure 5-12) along the PV Shelf and adjacent embayments from November 2000 through August 2003 provided the longest published record of current data for the PV Shelf. The ADCP measurements greatly expanded the vertical resolution of the current measurements and significantly advanced the understanding of internal tides, internal bores

and vertical current shear. Interpretation of the data by SAIC in 2004 indicated similar findings for bottom currents in the area of effluent-affected sediments compared with previous studies. Results included the following:

- Mean bottom currents were directed up-coast (northwestward, poleward) and offshore.
- The primary subtidal currents were found between 7- and 25-day periods, with major peaks at 16, 11 to 12, and 7 to 8 days. There was not much energy at periods longer than 25 days for currents, indicating that large seasonal changes in the character of the fluctuations did not occur.
- Mean and maximum current speeds (averaged over 15 minutes) along the 65-m isobath (Stations A3, A5, A6) and the 35-m isobath (A4 and A7) at 3 m above the bottom were as follows (station numbers are shown on Figure 5-12):

Station	Mean Speed (cm/sec)	Maximum Speed (cm/sec)	Standard Deviation (cm/sec)
A3	6.9	36.3	4.5
A4	7.7	33.4	4.9
A5	8.2	44.6	4.9
A6	9.1	47.5	6.3
A7	12	58.8	7.3

The frequency distribution of current speeds at 5 cm/sec intervals for these outfall-depth stations is presented in Table 5-6.

TABLE 5-6
Summary of LACSD Current Speed Data from 2001 to 2003 by Percent Occurrence

Station	Current Speed (cm/sec)										
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55
A3	40.5	40.0	13.6	4.4	1.1	0.3	0.1	0.0	0.0	0.0	0.0
A4	33.7	39.3	18.2	6.4	1.8	0.4	0.1	0.0	0.0	0.0	0.0
A5	28.7	41.8	20.2	6.6	1.8	0.6	0.1	0.0	0.0	0.0	0.0
A6	28.4	37.1	19.5	8.2	4.0	1.9	0.7	0.2	0.1	0.0	0.0
A7	16.8	29.4	23.2	16.6	8.7	3.4	1.0	0.5	0.3	0.1	0.0

Current speeds with a total occurrence of less than 0.1% are not shown.

Data from Stations A3 and A4 show that current speeds are less than 20 cm/sec more than 98 percent of the time and are smaller than 25 cm/sec more than 99 percent of the time.

The LACSD current monitoring stations extended farther south than the previous USGS study in 1992 to 1993. Data from the stations farther south indicated increased near-bottom velocities compared with sites at and northwest of the outfalls. Near-bottom currents in excess of 15 cm/sec were recorded only 5.9 percent and 8.8 percent of the time at Stations A3 and A4 northwest of the outfalls, respectively. Near the diffuser, at Station A5, 9.2 percent of the near-bottom observations were above 15 cm/sec. Near-bottom currents at Stations A6 and A7, southeast of the outfall, were above 15 cm/sec 15 percent and 36 percent of the time, respectively.

Maximum current speeds indicate similar findings with speeds steadily decreasing in the northwestward direction (58.8 cm/sec at Station A7 compared with 33.4 cm/sec at Station A4). While there were more high-velocity occurrences at Stations A6 and A7, the duration of events greater than 21 cm/sec was similar at all stations, and no events above 21 cm/sec lasted more than 6 hours.

In general, strong near-bottom, cross-shore current speeds at 30 to 50 cm/sec were directed to the west-northwest (toward offshore); while at the same time, flow in the upper water column moved toward shore (SAIC, 2004b). Because of the measurements collected at 3 m above the ocean bottom and the bottom-friction effects, the actual currents at the seabed will be considerably less (SAIC, 2004b). Near-bed currents are most energetic in the southeast area of the deposit. Horizontal transport processes cannot be easily modeled because mean currents have substantial spatial, seasonal, and inter-annual variability at all water depths (SAIC, 2004b).

5.7.4.4 Erosional Potential of Currents

At the PV Shelf Study Area, currents play a role in transport and dispersion of sediment and associated contaminants. Currents of sufficient strength could also be a primary mechanism for mobilization of sediments that are then available for transport by much weaker currents than needed for initial mobilization. The potential for currents to act as a primary mechanism to initiate transport by mobilizing the sediments, as discussed by Drake et al. (1994), Wiberg et al. (2002), Noble et al. (2002), SAIC (2004b), and Kolpack (1987) is seldom realized on the PV Shelf. Measured currents are generally not of sufficient strength to mobilize (scour or erode) sediments in this area. More recent data from the LACSD current meter deployments indicated occasional periods of stronger currents that could result in some sediment mobilization. However, the frequency and duration of these events could limit their significance. The uniform offshore direction of many of the near-bed events provides a net transport direction that could be significant over time, even if these events do not occur often.

5.7.5 Erodibility and Transport of Effluent-affected Sediments

Two properties of the sediment bed that affect the transportability of the sediment are the critical shear stress and the erodibility. Appendix D provides more information on the relationship between currents, waves, friction velocity, and shear stress. Critical conditions variously described in the literature as critical velocity, critical shear stress, and critical lift forces are used to define the condition incipient motion of the bed material (Graf, 1971). The critical shear stress is different for waves and unidirectional currents because of the fundamental differences in the hydrodynamics of the two phenomena. Erodibility can describe how much material will erode in a given time under a given shear stress, with erosion increasing as the shear stress increases. Erodability is zero below the critical shear stress. A limited number of measurements related to erodibility have been done on the PV Shelf sediments.

5.7.5.1 Erodibility

The 1992 USGS study included evaluation of the undrained shear strength of sediment samples from the 60-m isobath (Lee, 1994). Results indicated that the upper 30 cm of the effluent-affected sediment deposit is composed almost entirely of a uniformly low strength

layer with a typical vane shear strength of 3 to 6 kilopascals (kPa) (Lee, 1994). Although the measurement of vane shear strength is not related to critical shear stress or erodibility, the vane shear strength values are typical of the upper meter of muddy seafloors and are not anomalously low (Lee, 1994), indicating that the material is expected to behave in a predictable fashion similar to other locations.

Estimates of erosion rates based on shear stress have been conducted on sediments from the study area using the Gust Erosion Chamber and the Sedflume. The following are descriptions of these devices:

- The Gust Erosion Chamber (Gust Chamber) is a device that fits on the top of a core tube to generate a known shear stress on the sediment surface, which is then related to an erosion rate and the characteristics of eroded particles. The erosion chamber is capable of applying shear stresses in the range from 0.01 to 0.4 Pa to the sediment surface of the core.
- The Sedflume is a device designed to evaluate site-specific sediment erosion characteristics (Gailani et al., 2004). Water is pumped through a flow converter into a rectangular duct over a sediment core, which is moved up by the operator using a piston. The shear produced by the flow causes the sediment to erode. The erosion rate is measured as the upward movement of sediments in the coring tube over time. The Sedflume measures both suspended load transport and bedload transport (i.e., total load).

Sedflume analysis was performed at seven locations at the PV Shelf Study Area during the March 2002 pilot cap survey (Gailani et al., 2004). Test results indicated that cap material eroded at shear stresses from 0.25 to 1.0 Pa, and gross erosion (no redeposition) rates ranged from 0.0005 to 0.05 cm/sec. Most of this material moved as bedload, which generally results in less net erosion than suspended load movement per unit time. These tests applied only to the cap material, which is a larger grain size than the effluent-affected sediments, specifically to prevent or minimize erosion of the cap.

Additional Sedflume experiments were conducted in July and August 2004 to characterize the erosion potential of effluent-affected sediments below the surface layer (Borrowman et al., 2005). The tests evaluated erosion of sediments at shear stresses between 0.8 and 3.2 Pa. The study indicated that long-shore erosion rate variation was detectable in the northwest portion of the PV Shelf Study Area. Near the outfalls, erosion varied significantly between sites. The site tested southeast of the outfall showed a slight variation in erosion with depth, representing sediment that is not effluent-affected (Borrowman et al., 2005).

Gust Chamber erosion tests were performed at 10 of the geotechnical stations during the 2004 geotechnical measurement program (SAIC, 2005b). The tests evaluated erosion at a number of shear stresses (0.08 to 0.40 Pa). The highest values of total mass eroded were measured for sediments from approximately 4 to 5 km northwest of the outfalls. Eroded mass values were significantly lower (0.009 to 0.013 g/cm^2) closer to the outfalls (Figure 5-13). Eroded mass values also were significantly lower to the southeast of the outfalls. The results of the Gust Chamber test indicate that sediment in the southeast portion of the PV Shelf Study Area is less erodible, and sediment in the northwest portion of the PV Shelf Study Area is more erodible.

5.7.5.2 Threshold of Movement

The critical shear stress and velocity, or velocity profile, in the overlying fluid that results in the critical shear stress, depends on the fluid properties, the grain size of the bed material, the cohesiveness of the bed material, and in some cases, the interactions between bedforms and fluid velocity that result in near-bed turbulence. The appropriate critical conditions for waves, and wave orbital velocities, at the PV Shelf Study Area have been empirically evaluated as described in Section 5.7.3. There is extensive literature concerning the critical shear stress under unidirectional currents, but the relationship between fluid velocity at a particular elevation and critical shear stress is difficult to predict. The erodibility data from the Gust Chamber experiments provide some information when the erosion rates are extrapolated to zero. There is insufficient information on the near-bottom current velocity profile to make the link to critical shear stress and current velocity at a particular elevation above the bed. For more information, see Appendix D and Graf (1971).

5.7.5.3 Sediment Transport Patterns

Waves and currents affect the sediment water interface and can cause direct physical erosion and resuspension of fine sediments to the overlying water. Resuspension of sediments becomes less important at depths greater than 45 m, although the presence of ripples in surface sediments at 60-m depths observed by Drake (1994) and Wiberg et al. (2002), and extensive resuspension of bottom sediments at 3 and 6 m above the bottom (in water depths of 60 m) observed by Wiberg et al. (2002) are evidence for physical mixing in areas of the mid-shelf.

Wiberg et al. (2002) indicated that the highest near-bed suspended sediment concentrations at depths near 60 m resulted from resuspension produced by large surface waves; therefore, surface wave conditions were expected to be key in identifying high concentration resuspension events (Wiberg et al., 2002). Sediments are not deposited below 30 m because near-bed velocities at the shallower depths are too high for fine-grained sediment deposition. Currents are weak near-shore and in deep water (off-shelf); thus, there is limited sediment transport in these areas. More sand was observed in the in-shore samples of the 2004 geotechnical measurement program (SAIC, 2005b), which indicates that less effluent-affected sediment is present in-shore of the site.

A mathematical model of shelf sediment dynamics (Resuspension Model) was used to explore sediment erosion and deposition during major storms of the early 1980s and 1988. The model showed that storms and concomitant sediment suspension and potential transport alone cannot explain the observed losses of contaminants from the historical deposits of the PV Shelf. It also concluded that both severe and common storm events do re-entrain some of the bottom sediment at all depths (Niedoroda et al., 1996).

Sediment that is resuspended by surface waves, internal waves, or coastal currents can be transported by currents in the mid- to lower portions of the water column. The region of active, suspended load sediment transport is 5 to 10 m above the sediment bed. The thickness of this region decreases as the depth below the water surface increases.

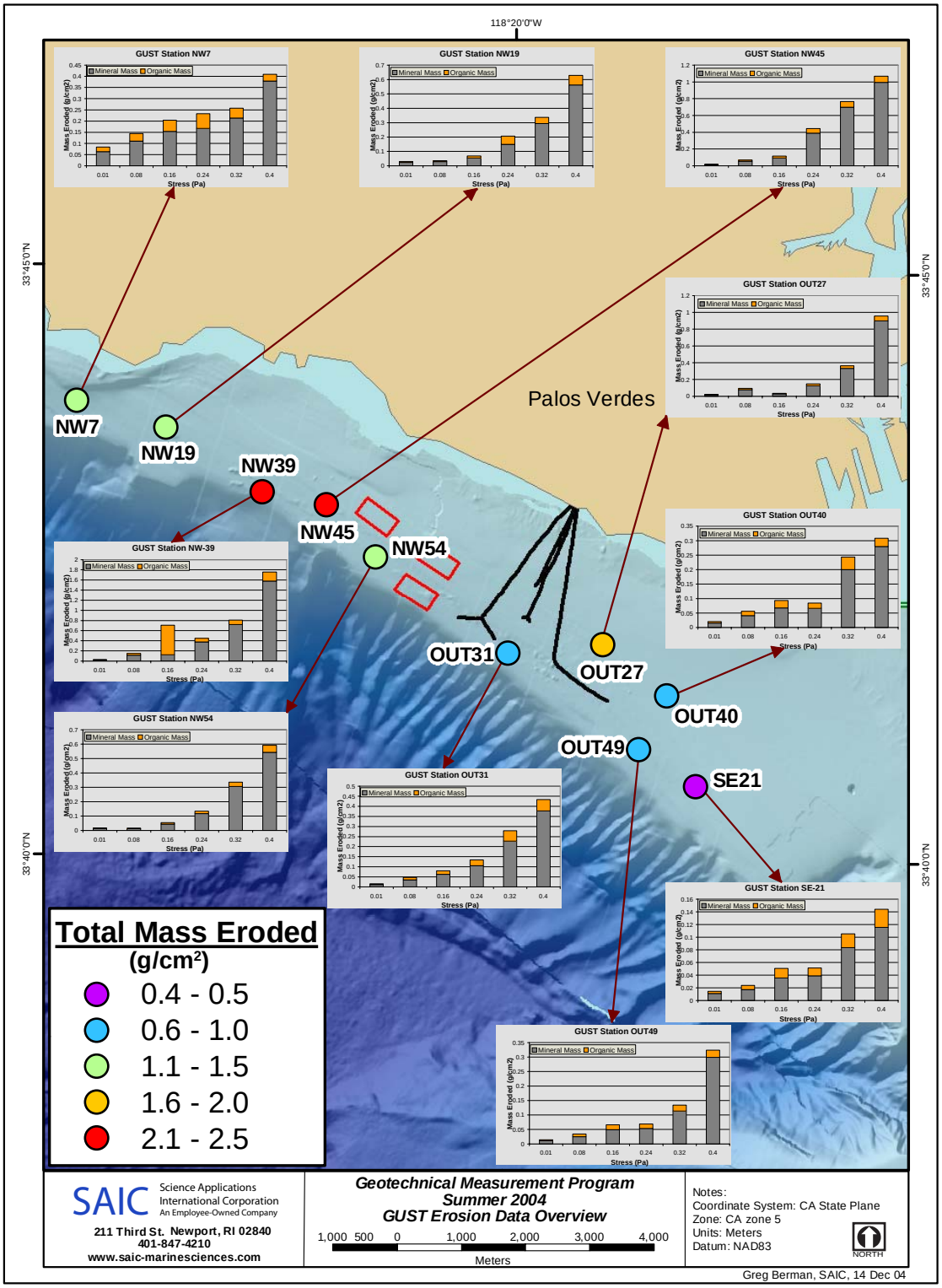


FIGURE 5-13
Summary of the Gust Chamber Erosion Results at Each of the Ten Sampled Stations
Palos Verdes Shelf Study Area
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Note: The mass eroded values (both total and organic) are based on the computed averages from all of the replicates at each of the stations.

Source: SAIC, 2005. Final Data Report for the Summer 2004 Geotechnical Measurement Program Conducted on the Palos Verdes Shelf, July 2005.

Particles suspended within the water column will remain suspended and move with the current until the velocity or energy level drops sufficiently and the force of gravity pulls the particles toward the bottom. These particles can remobilize and be re-transported if sufficient energy were applied across the surface of the bed by the flowing water to uplift and resuspend them. Figure 5-14 shows the relative magnitude and direction of sediment transport at the PV Shelf, as modeled by USGS. The arrows indicate the long-term magnitude and direction of suspended-sediment transport estimated using the same one-dimensional (vertical) model described by Wiberg et al. (2002), 4 years of current-meter data from the LACSD moorings, and estimates of bed sediment properties combined with earlier data (e.g., Drake et al., 2002) with the 2004 geotechnical data. The red numbers are the difference in transport rates between adjacent stations that have been converted to estimates of erosion or deposition using uniform porosity. As shown on Figure 5-14, recent studies performed by USGS support previous findings that sediment transport is primarily up-coast and to the west (Ferre et al., 2006). Transport patterns indicate that transport out of the area of contaminated sediments represents a minor loss of material, if any.

5.8 Contaminant Burial

Since the late 1930s, anthropogenic events (i.e., LACSD outfalls and the Portuguese Bend Landslide continue to significantly influence the rate of burial (burial velocity) of sediments on the PV Shelf (particularly in the case of the Portuguese Bend Landslide). This is of specific interest because burial velocity influences biological access to the layer of highly contaminated sediments. The rates at which new sediments accumulate, or surficial layers are eroded, influence either the continued burial of contaminants or the thinning of the surface layer over the heavily contained sediments. This leads to the potential for increased mobility (remobilization) and increased availability of these contaminants to organisms.

Different investigators used different terminology when discussing sediment accumulation, burial velocity, sedimentation rate, and deposition. The meaning of each term should be clear in context based on the units used and time scale being considered. Deposition rate and sedimentation rate is usually given in units of distance/time (e.g., centimeter per year [cm/year]) and do not make comparisons between locations readily possible because of the variable effects of compaction. Sediment accumulation rate is usually given in units of mass/area-time (g/cm^2-year) and describes the rate at which sediments accumulate on a mass basis.

Sediment accumulation rates change over time, and are especially reactive to large-scale episodic events (e.g., floods, landslides, record storm events). The rate of accumulation can be positive (deposition, accretion), neutral (no net annual change) or negative (erosion). The rate of accumulation depends on sediment supply, the capacity of currents to transport and disperse the sediments delivered, and the ability of physical (e.g., resuspension by wave action and high current speeds) and biological (e.g., bioturbation) processes to remobilize the sediment when it is deposited.

Studies involving determining the depositional rates of sediments on the PV Shelf, for the purposes of assessing changes in the depth of contaminated effluent-affected sediments, have focused efforts on calculating rates based on the analysis of core samples or other sediment depth profiles. While burial velocities have been described for both the PV Shelf and slope, sampling sites and sediment analyses are predominantly located along the 60-m isobath.

This section discusses the sedimentation rates and sources for the following elements: native sediment layer and background sedimentation rates, and future sediments. A review of historic (pre-1930s) and effluent-affected sedimentation rates and sources is included because it provides the foundation for the current and future status of the effluent-affected sediments. Following the historical review is a discussion of the expected future sedimentation rate and sources. A thorough understanding of future sediment rates is important because burial velocity is a key variable and output in many fate and transport models. Natural burial potential is discussed in this section because an understanding of natural burial is integral to developing remedial actions.

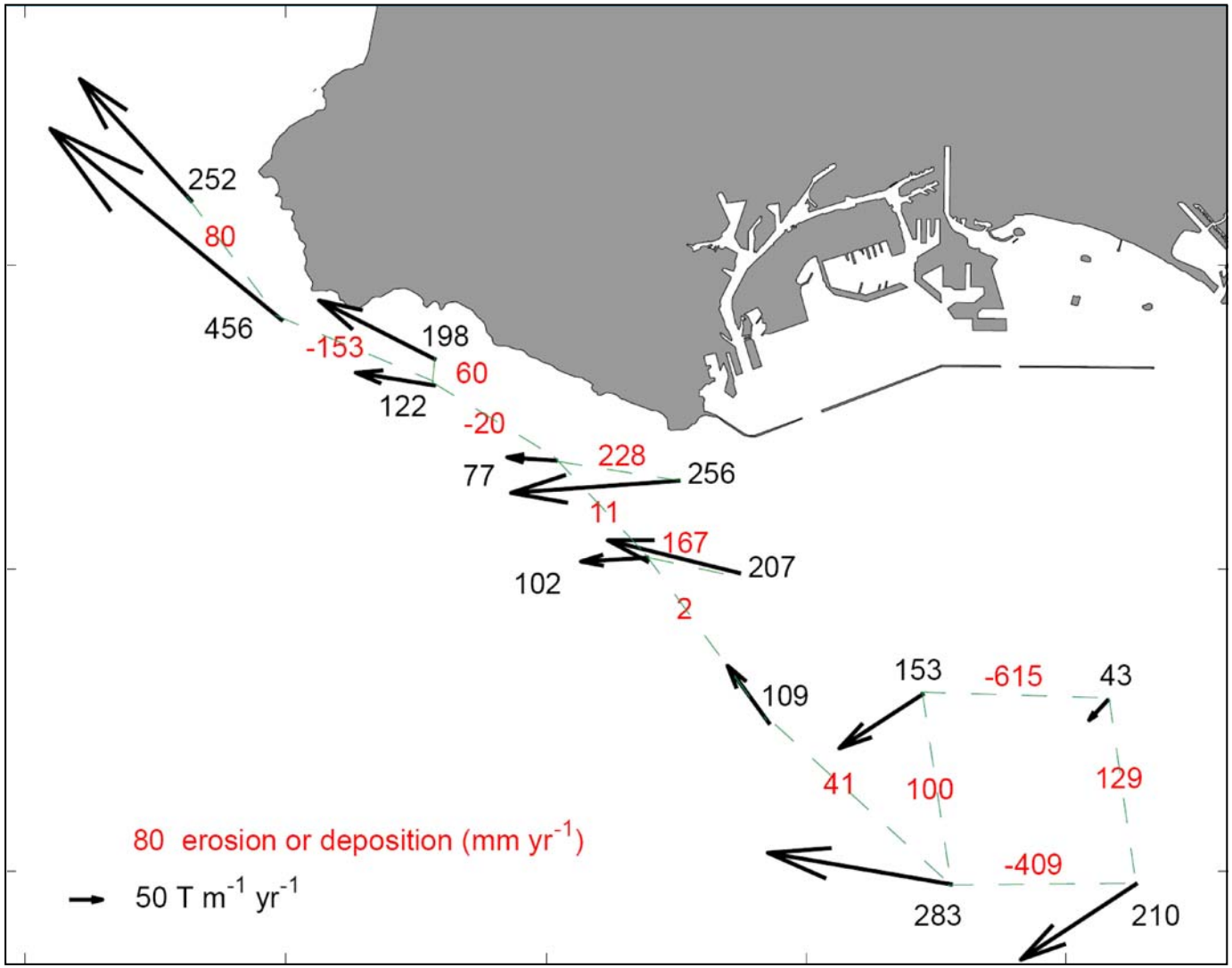
5.8.1 Native Sediment Layer and Background Sedimentation Rates

The historical sediment accumulation rate is based on sediments that have been deposited over the past 10,000 years, excluding the period from the 1930s to present. This layer of sediment is generally referred to as the native sediment layer (Lee et al., 2002; Wong, 2002) and corresponds to the Holocene or modern period of geologic history (Kolpack, 1987; Hampton et al., 2002; Lee and Wiberg, 2002; Wong, 2002).

Various studies have looked at the makeup of these natural sediments. Knowing the source of these sediments helps evaluate future factors affecting the supply. Some of the most current and applicable work was conducted by Wong (2002). A general overview was presented by Kolpack (1987).

Wong (2002) examined the heavy minerals in sediment samples from beach and shelf sites along the PV Shelf. Shelf samples were dominated by heavy minerals common between Palos Verdes and the Mexican border. These sediments indicated regional rather than local sources. Sediments from the San Gabriel Mountains and Peninsular Ranges of Southern California were the probable sources of this material. Sediments are transported by local rivers to San Pedro Bay and carried northwestward to the PV Shelf (Wong, 2002). The Los Angeles, San Gabriel, and Santa Ana Rivers would be the most probable sources of this material (Kolpack, 1987; Wong, 2002). Wong (2002) also provided information on the beach sediment deposits adjacent to the study area, and concluded this material had a higher percentage of material supplied by local landslides and cliff erosion.

Available information suggests that long-term sediment sources for the material deposited on the PV Shelf, and specifically within the study area, are predominantly supplied by the Palos Verdes Hills, the San Pedro Shelf, and local rivers of the Los Angeles Basin (Kolpack, 1987; Wong, 2002). Large episodic events will dominate the shallower waters, and sediments will be transported slowly into deeper waters.



Note: Positive numbers represent deposition, negative numbers represent erosion.

Source: Bénédicte Ferré, Christopher R. Sherwood, Patricia L. Wiberg, and Christopher Murray, 2006. Estimates of Sediment Transport Rates on the Palos Verdes (CA) Shelf. Presented at the Eastern Pacific Oceanograpy Conference, Mt. Hood, Oregon, October 2006.

FIGURE 5-14
Relative Magnitude and Direction of Sediment Transport at the Palos Verdes Shelf
Palos Verdes Shelf Study Area
Remedial Investigation Report

The historical rate of sediment deposition for the PV Shelf over the past 10,000 years, excluding the period from the 1930s to present, has been reported as being no more than 0.2 cm/year. Drake et al. (1994) reported a rate of 0.1 cm/year on the mid- and outer-shelf regions and less than 0.1 cm/year on the inner shelf. Kolpack (1987) indicated a general rate of 0.2 cm/year. Hampton et al. (2002) estimated long-term background sedimentation rates of less than 0.1 cm/year on the inner shelf to a maximum of about 0.3 cm/year on the outer shelf south of Point Fermin, excluding sources from the Portuguese Bend Landslide and JWPCP. Lee et al. (2002) interpreted this information and concluded rates would be 0.1 and 0.2 cm/year at Stations 3C and 6C, respectively.

The natural rate (i.e., pre-effluent-affected sediments or excluding anthropogenic sources) is of value because it is the baseline from which to predict future natural burial rates or background rates. This background rate can then be adjusted for anthropogenic influences (e.g., changes in suspended sediment output to the LACSD outfalls, erosion-control measures for the Portuguese Bend Landslide, and urbanization impacts on local rivers) to predict future rates.

The discussion on the native sediment layer makes use of the following two conventions that need to be interpreted when considering the more recent sediment accumulation rates:

- Sediment deposition or accumulation rates are seldom constant. In semi-arid regions, it is common for most of the sediment delivered to coastal waters to be extremely episodic. Nearly all of the sediment is introduced during very infrequent events. Thus, the use of quantities in fractions of a centimeter per year refers only to long-term averages and should not be assumed to occur every year. For riverine supply, most of the sediment delivered in a 100-year period typically results from one or two events lasting a few days. Sediment supplied by cliff erosion can be less abrupt, but still results from infrequent events.

- Sediment deposition characterized by the vertical dimension or sediment depth (i.e., cm/year) can be misinterpreted. Following deposition, sediment is generally loosely packed and will consolidate with time. As a particular part of the sediment column consolidates, the vertical dimension or "depth" of that part of the column will decrease. Over a relatively short time period, this could lead to a misinterpretation that there is a decrease in the actual sediment present, and in an extreme case, mistakenly indicate net erosion.

When discussing long-term natural burial processes, the use of annual averages in terms of depth accumulations is acceptable because the timeframes are substantially longer than episodic events. However, for the shorter time periods, annual burial rates should be used with caution and not considered precise for short periods.

When discussing long-term sedimentation, the application of long-term geological rates is not practical for predicting events over short periods because of the irregularity and low frequency of episodic events (e.g. large storms, slumping, seismic events) which significantly affect sedimentation and erosion.

5.8.2 Burial Rate

Methodologies for calculating sedimentation rates or sedimentation have been discussed by various authors (e.g., Drake et al., 1994; Eganhouse and Pontolillo, 2000; Lee et al., 2002; Sherwood et al., 2002). When evaluating PV Shelf sediment accumulation rates, the following factors should be considered:

- Estimations of burial velocities within the study area vary based on time period, location, and analysis methodology (Sherwood et al., 2002).
- Interpretation of the sediment record is confounded by spatial and temporary variations in contaminant concentration and other tracers (e.g., ^{210}Pb) within the profile caused by physical and biological mixing and loss from biodiffusion, biodegradation, and compaction (Sherwood et al., 2002).
- The sediment supply source (e.g., LACSD outfalls and Portuguese Bend Landslide) and distance from the source will affect the rate of sediment accumulation.
- Mass emission of suspended sediment from 1940 to present from the LACSD outfalls has declined by approximately an order of magnitude (and by two orders of magnitude from their peak in 1971) as a result of improvements in treatment of effluent accompanied by increased removal of suspended solids. Rates rapidly increased through 1970, and then rapidly decreased through 1985 (Figure 1-4) as a result of implementing advanced primary treatment, leading up to full secondary treatment of discharged effluent. These changes in sediment output are important in estimating sedimentation rates, especially over timeframes that include years before and after 1971 (the year of peak suspended sediment output).

The majority of research focuses on two sampling sites: (1) Station 6C (approximately 2 km northwest of the "Y" outfall along the 60-m isobath), which is a general representation of the conditions with the highest effluent-affected sediment deposition, and (2) Station 3C (approximately 5 km northwest of the "Y" outfall along the 60-m isobath), which is a general representation of a distal point near the edge of the effluent-affected sediments but still contains significant concentrations of contaminated sediments. A summary of historical sedimentation rates of the effluent-affected sediments is presented below, and includes spatial and temporal information, as appropriate.

- The rate of sedimentation on the outer shelf increased rapidly from pre-outfall (pre-1930s) rates of less than 0.2 cm/year to maximum sedimentation rates of nearly 2 cm/year at Station 6C and approximately 1 cm/year at Station 3C during the 1960s and early 1970s (Drake et al., 1994). Eganhouse and Pontolillo (2000) developed similar estimates independently. The heavily contaminated effluent-affected sediments also were principally produced in the 1960s and early 1970s.
- Rates slowed on the outer shelf (as sediment-reduction practices at the JWPCP plant were implemented through the late 1970s and 1980s) to about half that observed in the 1960s and 1970s (Drake et al., 1994), which would yield rates of approximately 1 cm/year and 0.5 cm/year around Stations 6C and 3C, respectively.

- Sediment accumulation rates between 1983 and 1991 were calculated from DDTs concentration profiles in cores collected biennially by LACSD (Lee, 1994). Average deposition rates of 0.7 cm/year (standard error ± 0.1 cm/year) and 0.4 cm/year (standard error ± 0.3 cm/year) were estimated for Stations 6C and 3C, respectively by Wheatcroft and Martin (1996) and Drake et al. (1994).
- During the 1980s and 1990s, sediments from the Portuguese Bend Landslide contributed to the sedimentation rate at Station 3C, and to a lesser degree at Station 6C. Likewise, reductions in sediment from the LACSD outfalls reduced the sedimentation rate at Station 6C, but had significantly less impact at Station 3C. Collectively, this led to a switch in the deposition rate between Stations 3C and 6C, with 3C having a higher deposition rate than 6C.
- Eganhouse and Pontolillo (2000) estimated sediment accumulation rates at Station 3C for the period from 1981 to 1992 between approximately 1.9 to 2.8 grams per square centimeter per year (g/cm^2/year) with the most likely range being about 2.4 to 2.7 g/cm^2/year. These sediment accumulation rate estimates were developed using three different methods: 1) molecular stratigraphy, 2) statistical core alignment, and 3) comparison of inventory distributions.
- Lee et al. (2002) listed burial velocities, associated with core profiles measured every 2 years from 1981 to 1997, which ranged from 0.22 to 1.55 cm/year for Station 3C, and 0.2 to 1.2 cm/year for Station 6C. Sherwood et al. (2002) reviewed this information and concluded the best estimate of burial velocity between 1981 and 1997 was 0.75 cm/year at Station 3C and 0.5 cm/year at Station 6C.

Sherwood et al. (2006) summarized sedimentation rates for the period of 1991 to 2005 (Figure 5-15) for LACSD monitoring Stations 1C through 10C. Sedimentation rates decreased from rates published for 1981 to 1997. Rates at Stations 3C and 6C for the period of 1991 to 2005 were 0.52 g/cm^2/year and 0.47 g/cm^2/year, respectively. Eganhouse (2007) determined a sediment accumulation rate of 0.36 g/cm^2/year for the period 1992 to 2003 at USGS Station 522 (near Station 3C).

Differences in the burial velocities presented by Drake et al. (1994) and Sherwood et al. (2002) may be partially the result of time span and sampling location. According to Drake et al. (1994), sedimentation rates shoreward of Station 3C were likely to be higher than the rate at Station 3C because of sediments from the Portuguese Bend Landslide (also Eganhouse and Pontolillo, 2000). The timeframe examined by Sherwood et al. (2002) was longer than that reviewed by Drake et al. (1994) and might have included additional sediment contributions from Portuguese Bend Landslide. Sherwood et al. (2002) described movement of the Portuguese Bend Landslide that had occurred post-1988 and especially after the heavy rains in January 1995.

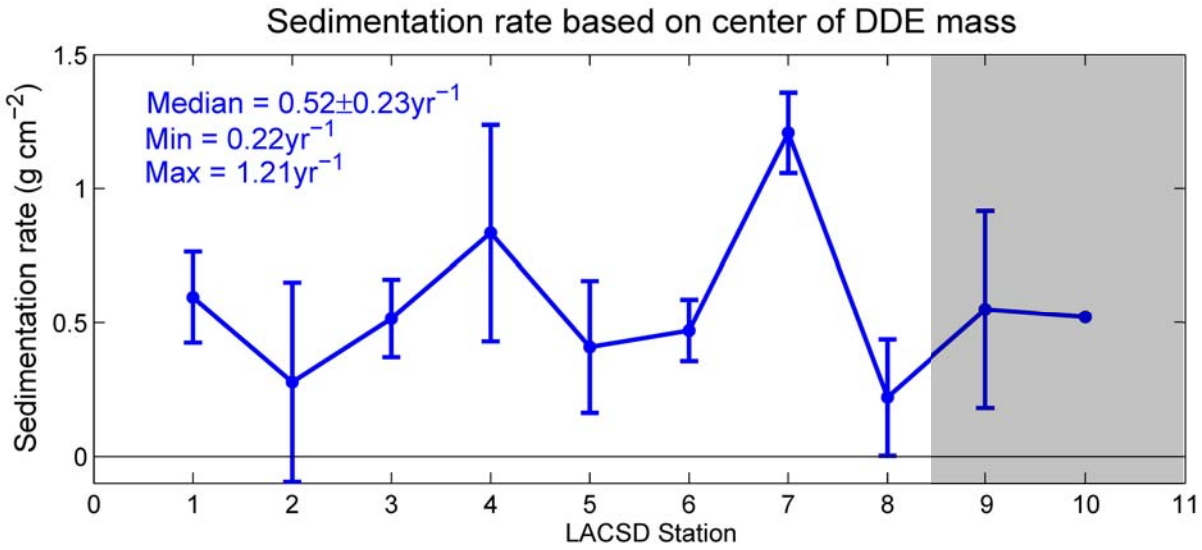
Evaluations of the concentration profiles of DDTs in cores from the slope suggested sedimentation rates of a few mm per year or less during the period 1983 to 1991 (Lee, 1994), although longer-term (from 1970 to 1992) averages were estimated at 0.1 cm/year (Drake et al., 1994). The maximum sedimentation rate through the 1990s was predicted to be 0.6 cm/year, and significantly dropped after 2002 when LACSD implemented full secondary treatment (Drake et al., 1994).

Other researchers have evaluated sedimentation rates of effluent-effected sediments for prolonged timeframes and provided average sedimentation rates. Paulsen et al. (1999) conducted modeling based on ^{210}Pb that included the rate of sedimentation near the LACSD diffuser. The authors described that sediment flux varied greatly over the past 60 years (late 1930s to 1990s) and that sedimentation rates were relatively high at 0.7 to 1.3 cm/year. Eganhouse and Pontolillo (2000) calculated 0.7 to 1.3 cm/year at Station 3C for the period of 1955 to 1981.

5.8.3 Future Sediment Deposition

Predicted future rates of sediment deposition could help model future conditions at the PV Shelf and serve as the basis for calculating changes in the depth and concentration of contaminants. If the deposit erodes, it will provide a continuing source of contaminants. Researchers predict that future rates of deposition will be lower than rates between the 1930s and 1990s, which can be attributed to reductions in sediment output from the LACSD outfalls and current and predicted future reductions in sediment from the Portuguese Bend Landslide (Kolpack, 1987; Drake et al., 1994; Lee et al., 2002; Sherwood et al., 2002). However, it is not known whether that rate will remain positive, neutral, or negative. Because the rate over the study area is not uniform, past, present, and future rates must be considered by geographic region within the study area. The rates indicated by the following authors represent the general range of predicted future sediment accumulation:

- The most recent estimates are from Sherwood et al. (2002), which estimated that future average deposition rates would be approximately 0.30 cm/year (range of 0.14 to 0.58 cm/year) at Station 6C and 0.43 cm/year (range 0.21 to 0.84) at Station 3C.
- Lee et al. (2002) concluded that the present-day background sedimentation rate, excluding the outfall and Portuguese Bend Landslide, is less than 0.2 cm/year (with 0.2 cm/year being the historic background rate) based on anthropogenic sediment source reductions in the rivers of the Los Angeles Basin and dredging of the Port of Los Angeles.
- Kolpack (1987) indicated that current (1980s) and future rates were predicted to be essentially zero.
- Drake et al. (1994) predicted that when full secondary treatment at the LACSD plant was implemented (which occurred in 2002), the average sedimentation rate would become quickly negative, -0.64 cm/year (0.35 to -1.62 cm/year); then around 2035, an equilibrium would be reached, attributed to sediment sorting and bed armoring, and burial velocities would be 0 cm/year over most of the area represented by Station 6C. However, the area represented by Station 3C would have a sedimentation rate of 0.22 cm/year (0.56 to -0.11 cm/year).



LACSD Station	1C	2C	3C	4C	5C	6C	7C	8C	9C	10C
Sedimentation rate ± std. dev. (g cm^{-2} y^{-1})	0.60 ±0.17	0.28 ±0.37	0.52 ±0.14	0.83 ±0.40	0.41 ±0.25	0.47 ±0.12	1.21 ±0.15	0.22 ±0.22	0.55 ±0.37	0.52 NA
r^2	0.80	0.22	0.72	0.52	0.35	0.74	0.96	0.20	0.42	NA
N	5	4	7	6	7	8	5	6	4	2

Note: Shaded area on plot indicates a line representing the approximate location of the LACSD outfalls. Error bars equal one standard deviation from the mean annual value.

Source: Sherwood et al., 2006.

FIGURE 5-15
Sedimentation Rates Along LACSD Monitoring Stations
Palos Verdes Shelf Study Area Remedial Investigation Report

6.0 Summary of Risk

Risk assessments are conducted during the RI/FS process to characterize current and potential threats to human health and the environment in the absence of remedial action. Risk assessments provide the basis for determining whether or not remedial action is necessary. In general, the objectives of a risk assessment may be achieved by identifying and characterizing the following:

- Toxicities and concentrations of hazardous substances in relevant media (e.g., air, groundwater, soil, surface water, sediment, and biota)
- Environmental fate and transport mechanisms within specific environmental media such as physical, chemical, and biological degradation processes, and hydrogeological conditions
- Potential human and environmental receptors
- Potential exposure routes and extent of actual or expected exposure
- Extent and magnitude of expected impact or threat and the likelihood of such impact or threat occurring (i.e., risk characterization)
- Level(s) of uncertainty associated with the above items

This section summarizes the results of the primary human health and ecological risk assessments conducted to date for the PV Shelf Study Area, as reported in the *Human Health Risk Evaluation for Palos Verdes Shelf* (SAIC, 1999) and the *Ecological Risk Assessment for the Palos Verdes Shelf* (CH2M HILL, 2003). This section also includes the following updates to these two documents: (1) the supplemental HHRE using 2002 ocean fish data, and (2) the updated food web exposure model.

6.1 Human Health Risk Evaluation

A streamlined HHRE was conducted for the PV Shelf Study Area in 1999, in accordance with the *Guidance on Conducting Non-Time-Critical Removal Actions under CERCLA* (EPA, 1993a). A streamlined HHRE is intermediate in scope between limited risk evaluation undertaken for emergency removal actions and the conventional baseline assessment. This section summarizes the 1999 HHRE for the PV Shelf Study Area and, subsequently, describes the supplemental HHRE. A memorandum providing further detail on the supplemental HHRE can be found in Appendix B.

6.1.1 Purpose and Scope of the 1999 Human Health Risk Evaluation

The purpose of the HHRE is to summarize, based on existing data, the human health risks posed by contaminated effluent-affected sediments on the PV Shelf. More specifically, the HHRE presents the human health risks posed by the presence of DDTs and PCBs in contaminated sediments on the PV Shelf, focusing on the consumption of contaminated fish as the primary exposure pathway. DDTs and PCBs are classified as probable human

carcinogens (SAIC, 1999). Potential risks to human health include the consumption of fish that have bioaccumulated contaminants from sediments and sediment-dwelling food items.

Single-point estimates of risks were calculated, and Monte Carlo simulation was employed to quantitatively evaluate uncertainty and variability in the risk estimates. More specifically, the scope of the evaluation included the quantitative assessment of the following:

- **Human health risks from the chemicals of greatest concern:** Although other contaminants are present in PV Shelf sediments and fish tissue, potential risks from exposure to or consumption of DDTs and PCBs are significantly higher and, therefore, the HHRE is focused on these compounds.
- **Human health risks from the most significant exposure route:** Although there could be other routes of exposure to DDTs and PCBs in sediment or fish, consumption of contaminated fish by recreational anglers is considered to be the most significant exposure pathway and, therefore, is evaluated quantitatively in the HHRE. The fish consumption rates, exposure duration, and receptors evaluated were based on those developed in the *Santa Monica Bay Seafood Consumption Study* (SMBRP, 1994), which is the largest study to date of California fishers. It is considered the most comprehensive study of noncommercial fish consumption in Southern California, and provides the most comprehensive database relevant to sport fishers.
- Although subsistence fishing in the PV Shelf area occurs, site-specific (e.g., Santa Monica Bay area) fish consumption data were available for recreational anglers only. A qualitative assessment of the potential risk to nursing infants was also conducted.
- **RME and CTE boat angler scenarios:** In accordance with EPA guidance (EPA, 1995a and 1995b), a high-end exposure scenario was evaluated to ensure the protection of human health. The consumption of contaminated fish by recreational boat anglers is considered to be the most significant exposure pathway. RME scenario is a high-end exposure scenario based on single-species fish consumption rates (i.e., consumption rates averaged over boat anglers who consume a particular species). An RME scenario is not a worst case, but an estimate of exposure in the upper range of the risk distribution (i.e., above the 90th percentile of the distribution of risks to recreational anglers). In addition, a CTE scenario was evaluated, using average and/or median values for exposure parameters. The CTE scenario assumes a mixed-species diet and uses median consumption rates averaged over all boat anglers. The CTE scenario reflects central estimates of exposure or dose, rather than a particular individual on the risk distribution (EPA, 1995a).
- **Variability and uncertainty in selected exposure parameters for the RME scenario using a Monte Carlo analysis:** Parameters assessed include fish ingestion rate, tissue concentrations of DDTs and PCBs, exposure duration, and body weight.

Because a streamlined approach was used to develop the HHRE, it is based on historical data from a variety of sources including the following:

- LACSD NPDES bioaccumulation monitoring reports (LACSD, various years) and other data collected by LACSD, which include fish tissue concentration data for white croaker, kelp bass, black surfperch, and California halibut

- Cal-EPA OEHHA *Study of Chemical Contamination of Marine Fish from Southern California* (Pollock et al., 1991), which reports tissue concentration data in 16 fish species from 24 sites in Southern California, including locations on the PV Shelf
- *Santa Monica Bay Seafood Consumption Study* (SMBRP, 1994), which describes fish consumption patterns and rates in areas including the PV Shelf

6.1.2 Exposure Assessment

The HHRE considered consumption of the 12 species of fish most commonly consumed by Santa Monica Bay boat anglers, based on information collected as part of the *Santa Monica Bay Seafood Consumption Study* (SMBRP, 1994). Fish tissue concentrations of DDTs and PCBs for these 12 species were based on data collected by the LACSD (white croaker, kelp bass, California halibut, surfperches) and for the OEHHA Comprehensive Study (barred sand bass, California scorpionfish, California sheephead, chub mackerel, halfmoon, Pacific barracuda, Pacific bonito, and rockfishes [Pollock et al., 1991]). LACSD analyzed fish tissue for DDTs (p,p'-DDT; o,p'-DDT; p,p'-DDD; o,p'-DDD; p,p'-DDE; and o,p'-DDE) and PCBs (Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260). Fish tissue in the OEHHA study were analyzed for DDTs (p,p'-DDT; o,p'-DDT; p,p'-DDD; o,p'-DDD; p,p'-DDE; and o,p'-DDE) and the PCBs (Aroclors 1254 and 1260).

Fish consumption rates were taken from the *Santa Monica Bay Seafood Consumption Study* in which 338 boat anglers reported consuming fish in the previous 4 weeks (28 days) (SMBRP, 1994). An RME scenario was evaluated for each of the 12 fish species included in the HHRE; consumption rates were based on consumers of a particular fish species. For example, 13 people reported eating white croaker during the previous 28 days. The average consumption rate (estimated using the 95 percent UCL on the mean) of white croaker by these 13 white croaker consumers (27.9 g/day) was used to quantify the RME scenario for consumers of this species. This represents about six 150-gram meals per month. The CTE scenario assumed that an angler would eat all 12 fish species, with consumption rates for each species calculated by multiplying the species diet fraction by the median fish consumption rate for all 338 boat anglers. For example, white croaker represents 2.2 percent, or 0.48 g/day, of the overall median fish consumption rate (21.4 g/day) for boat anglers, based on the results of the SMBRP (1994) study. This represents about one 150-gram meal of white croaker every year.

Exposure durations used to quantify human health risks were based on the reported fishing durations of boat anglers in the *Santa Monica Bay Seafood Consumption Study* (SMBRP, 1994). Reported fishing duration reflected only the length of time the surveyed individuals had been fishing up to the time of the survey. Because there was no information on how long these individuals will continue to fish in the future, the reported fishing duration is not the same as total exposure duration. The 90th percentile reported fishing duration of 30 years was used to quantify the RME scenario; the mean reported fishing duration of 13.8 years was used to quantify the CTE scenario.

Exposure point concentrations were assumed to remain constant for the selected exposure duration. Temporal trends in fish tissue concentrations are difficult to assess because of the variability in the data. It is expected that fish tissue concentrations of DDTs and PCBs will eventually decline. If these fish tissue concentrations decline significantly, the human health

risks calculated in the study could be an overestimation of actual risks. However, if tissue concentrations remain relatively constant, the assumption of a constant exposure point concentration would be appropriate.

6.1.3 Risk Characterization

Because of fundamental differences in the mechanisms through which carcinogenic and noncarcinogenic processes occur, risks are characterized separately for these two types of health effects. Cancer risks and noncancer hazard quotients (HQ) were calculated for the RME and CTE scenarios.

Potential health risks associated with carcinogens were estimated by calculating the increased probability of an individual developing cancer during his or her lifetime as a result of exposure to a carcinogenic compound. For example, a cancer risk of 2×10^{-6} means that for every 1 million people exposed to the carcinogen throughout their lifetimes, the average incidence of cancer might increase by two cases of cancer.

For noncancer effects, the likelihood that a receptor will develop an adverse effect was estimated by comparing the predicted level of exposure for a particular chemical with the highest level of exposure that is considered protective, or the RfD. When the estimated exposure exceeds the RfD (when the HQ for a chemical exceeds 1), there is a concern for potential noncancer health effects.

6.1.3.1 Reasonable Maximum Exposure Scenario

The RME scenario represents the potential risks to boat anglers who consume a particular species of fish collected from the PV Shelf, assuming mean tissue concentrations and consumption rates (as represented by the 95 percent UCL on the mean). RME cancer risks are presented in Table 6-1. Cancer risks exceed 1×10^{-4} for consumers of the following fish species: white croaker (2×10^{-3}) and surfperches (2×10^{-4}). Data indicate that DDTs contribute about two-thirds of the cancer risk for consumption of white croaker. Although cancer risks from PCBs exceed that for DDTs for most species evaluated, cancer risk is higher for DDTs for the two fish species with risks that exceeded 1×10^{-4}. Consumption of several species of fish resulted in a potential noncancer hazard for the RME scenario (Table 6-1). These species are white croaker (HQ for PCBs = 32, HQ for DDTs = 17), surfperches (HQ for PCBs = 5), barred sand bass (HQ for PCBs = 3), California halibut (HQ for PCBs = 3), California sheephead (HQ for PCBs = 2), and kelp bass (HQ for PCBs = 2).

This scenario reflects consumption of a single species of fish using a conservative estimate of the mean consumption rate (i.e., the 95 percent UCL) for that species. However, boat anglers generally do not consume only a single species of fish. For example, because the 95 percent UCL on the mean total fish consumption rate (i.e., all species) is 53.0 g/day, a consumer of white croaker (at the RME consumption rate of 27.9 g/day) might also be consuming other fish species. The contribution of DDTs and PCBs in these other fish species to human health risk is not reflected in the RME results.

TABLE 6-1
Summary of Point Estimate Risks, RME Scenario (Single-species Diet)

Fish Species	Cancer Risk DDTs	Cancer Risk PCBs	Cancer Risk Combined	Noncancer HQ DDTs	Noncancer HQ PCBs
Barred sand bass	9×10^{-6}	4×10^{-5}	5×10^{-5}	0.1	**3**
California halibut	9×10^{-5}	5×10^{-5}	1×10^{-4}	1	**3**
California scorpionfish	7×10^{-6}	1×10^{-5}	2×10^{-5}	0.1	0.6
California sheephead	3×10^{-5}	4×10^{-5}	7×10^{-5}	0.4	**2**
Chub mackerel	2×10^{-6}	1×10^{-5}	2×10^{-5}	0.03	0.7
Halfmoon	9×10^{-7}	7×10^{-6}	8×10^{-6}	0.01	0.4
Kelp bass	2×10^{-5}	3×10^{-5}	5×10^{-5}	0.3	**2**
Pacific barracuda	4×10^{-6}	1×10^{-5}	1×10^{-5}	0.05	0.6
Pacific bonito	2×10^{-6}	8×10^{-6}	1×10^{-5}	0.03	0.5
Rockfishes	8×10^{-6}	1×10^{-5}	2×10^{-5}	0.1	0.6
Surfperches	1×10^{-4}	8×10^{-5}	**2×10^{-4}**	1	**5**
White croaker	**1×10^{-3}**	**6×10^{-4}**	**2×10^{-3}**	**17**	**32**
Other species	1×10^{-5}	2×10^{-5}	3×10^{-5}	0.2	1

Note:
Species in bold have cancer risk greater than 1×10^{-4} or HQ greater than 1.
Source: SAIC, 1999

6.1.3.2 Central Tendency Exposure Scenario

The CTE scenario represents the potential risk to boat anglers who consume a mixed-species diet of fish collected from the PV Shelf, assuming arithmetic mean tissue concentrations and median consumption rates for all boat anglers (rather than for consumers of a particular species). The total cancer risk (DDTs and PCBs combined) for boat anglers (mixed-species diet) is 2×10^{-5}. The noncancer HQs are 0.3 and 0.9 for DDTs and PCBs, respectively. These HQs indicate that noncancer health hazards are not likely to occur. CTE point estimate cancer risks and noncancer hazard results are presented in Table 6-2.

TABLE 6-2
Summary of Point Estimate Risks, CTE Scenario (Mixed-species Diet)

Fish Species	Cancer Risk DDTs	Cancer Risk PCBs	Cancer Risk Combined	Noncancer HQ DDTs	Noncancer HQ PCBs
Barred sand bass	3×10^{-7}	1×10^{-6}	1×10^{-6}	0.008	0.1
California halibut	7×10^{-7}	8×10^{-7}	1×10^{-6}	0.02	0.1
California scorpionfish	9×10^{-8}	1×10^{-7}	2×10^{-7}	0.003	0.02
California sheephead	5×10^{-8}	6×10^{-8}	1×10^{-7}	0.002	0.008
Chub mackerel	4×10^{-8}	2×10^{-7}	2×10^{-7}	0.001	0.02
Halfmoon	8×10^{-9}	6×10^{-8}	7×10^{-8}	0.0002	0.008

TABLE 6-2
Summary of Point Estimate Risks, CTE Scenario (Mixed-species Diet)

Fish Species	Cancer Risk DDTs	Cancer Risk PCBs	Cancer Risk Combined	Noncancer HQ DDTs	Noncancer HQ PCBs
Kelp bass	9×10^{-7}	1×10^{-6}	2×10^{-6}	0.03	0.1
Pacific barracuda	5×10^{-8}	2×10^{-7}	3×10^{-7}	0.002	0.03
Pacific bonito	7×10^{-8}	2×10^{-7}	3×10^{-7}	0.002	0.03
Rockfishes	2×10^{-7}	2×10^{-7}	4×10^{-7}	0.005	0.03
Surfperches	7×10^{-8}	4×10^{-8}	1×10^{-7}	0.002	0.005
White croaker	6×10^{-6}	3×10^{-6}	9×10^{-6}	0.2	0.4
Other species	2×10^{-7}	2×10^{-7}	4×10^{-7}	0.005	0.03
Total	9×10^{-6}	7×10^{-6}	2×10^{-5}	0.3	0.9

Source: SAIC, 1999

6.1.3.3 Monte Carlo Simulation

In addition to the point estimate risk calculations, a Monte Carlo simulation was performed in the 1999 HHRE to evaluate uncertainty and variability in the consumption of white croaker by boat anglers (Table 6-3). Results of the Monte Carlo simulation, for DDTs and PCBs combined, indicated that the mean cancer risk is 3×10^{-4}, and the 95th percentile cancer risk is 1×10^{-3}. About 45 percent of simulation results, for DDTs and PCBs combined, were above 1×10^{-4}, which means the 55th percentile cancer risk is 1×10^{-4}. For DDTs, the mean and median noncancer HQs (7 and 3, respectively) are greater than 1, the level above which there could be a concern for potential noncancer health effects. The 95th percentile HQ is 26 for DDTs. About 75 percent of simulation results for DDTs exceeded an HQ of 1 (i.e., an HQ of 1 corresponds to a 25th percentile of the output distribution).

TABLE 6-3
Monte Carlo Simulation Results for Cancer Risk and Noncancer Hazard, White Croaker Consumption by Boat Anglers

	Cancer Risk – DDTs	Cancer Risk – PCBs	Cancer Risk – DDTs and PCBs Combined	HQ – DDTs	HQ – PCBs
Mean	2×10^{-4}	1×10^{-4}	3.4×10^{-4}	6.8	14
50th Percentile	5×10^{-5}	3×10^{-5}	8.0×10^{-5}	2.6	6.6
90th Percentile	5×10^{-4}	3×10^{-4}	8×10^{-4}	16	32
95th Percentile	9×10^{-4}	5×10^{-4}	1×10^{-3}	26	52
RME Point Estimate (white croaker)	1×10^{-3}	6×10^{-4}	2×10^{-3}	17	32
CTE Point Estimate (mixed-species diet)	9×10^{-6}	7×10^{-6}	2×10^{-5}	0.3	0.9

Source: SAIC, 1999

Sensitivity studies were performed to identify those input parameters that represent the greatest contributors to variance in the cancer risk and noncancer hazard for recreational boat anglers consuming white croaker. Exposure duration is the largest contributor to variance in the cancer risk results, followed by concentrations of DDTs and PCBs in white croaker tissue. Tissue concentrations of DDTs and PCBs are the largest contributors to variance in the noncancer hazard, followed by the white croaker consumption rate. These exposure factors reflect both uncertainty and natural variability in a population.

6.1.3.4 Risk to Nursing Infants

An assessment of the potential risk to nursing infants was also conducted in the 1999 HHRE. Breast milk consumption can be an important exposure route for nursing infants to contaminants like DDT and PCBs that biomagnify and become concentrated in breast milk fat. Infants are particularly vulnerable because they obtain most, if not all, of their dietary intake from breast milk. The equations used to quantify the breast milk pathway were obtained from Cal-EPA OEHHA Technical Support Document for Exposure Assessment and Stochastic Analysis (OEHHA, 1996). The exposure duration used in the analysis was one year; most American infants are weaned during the first year. The potential risks to nursing infants from consumption of DDTs and PCBs in breast milk were also evaluated in the 1999 HHRE. Results indicate that concentrations of DDTs and PCBs in breast milk, based on maternal consumption of one 150-gram meal of white croaker per month, could be as high as 0.8 mg/kg and 0.05 mg/kg, respectively. This corresponds to noncancer HQs of 220 and 370 for DDTs and PCBs, respectively. Based on maternal consumption of kelp bass, noncancer HQs to a nursing infant are 3 and 16 for DDTs and PCBs, respectively.

6.1.3.5 Results of the HHRE Compared with Previous Assessments

As shown in Table 6-4, point estimate results for cancer risk and noncancer hazard developed in the HHRE were compared with results of previous risk assessments conducted for fish consumption from the PV Shelf. For a single-species diet consisting of white croaker, cancer risk results are very similar, generally in the range of 1×10^{-3} to 2×10^{-3}. Potential risks from consumption of commercially sold white croaker are also comparable for whole fish, with slightly lower cancer risk calculated for fillets. Noncancer HQs for white croaker are consistent, ranging from 10 to 17 for DDTs and 17 to 32 for PCBs.

Point estimate cancer risk results for the mixed-species (or CTE) scenario in the HHRE are about an order of magnitude lower than in previous risk assessments; the difference is caused primarily by the significantly lower white croaker consumption rate assumed for the mixed-species diet in the current study. Noncancer HQs are similar. In summary, human health risk results of the HHRE are consistent with previous risk assessments conducted for fish consumption in the PV Shelf.

TABLE 6-4
Comparison of Risk Results with Previous Assessments

	Single-species Diet					Mixed-species Diet		
	1999 HHRE RME Scenario[1]	**Comprehensive Study[2]**	**SMBRP Risk Assessment[3]**	**Heal the Bay Study (whole fish)[4]**	**Heal the Bay Study (fish fillets)[4]**	**1999 HHRE CTE Scenario[5]**	**Comprehensive Study[6]**	**SMBRP Risk Assessment[7]**
Cancer Risk								
White croaker	2×10^{-3}	1×10^{-3} to 2×10^{-3}	2×10^{-3}	9×10^{-5} to 2×10^{-3}	6×10^{-5} to 9×10^{-4}	9×10^{-6}	NA	NA
All fish species	NA	NA	NA	NA	NA	2×10^{-5}	4×10^{-4}	2×10^{-4}
Noncancer HQ								
White croaker (DDTs)	17	NA	9.9	NA	NA	0.2	NA	NA
White croaker (PCBs)	32	NA	17	NA	NA	0.4	NA	NA
All fish species (DDTs)	NA	NA	NA	NA	NA	0.3	NA	0.5
All fish species (PCBs)	NA	NA	NA	NA	NA	0.9	NA	1.3

Notes:
[1]Assumes a white croaker ingestion rate of 28 g/day, 95 percent UCL tissue concentrations from PV Shelf, boaters only.
[2]Assumes a white croaker ingestion rate of 23 g/day, mean tissue concentration from PV Shelf; from Pollock et al. (1991).
[3]Assumes a white croaker ingestion rate of 30 g/day, mean tissue concentrations from PV Shelf, all fishing modes; from SMBRP (1997).
[4]Assumes a white croaker ingestion rate of 50 g/day, mean tissue concentrations of fish obtained from retail markets; from Gold et al. (1997).
[5]Assumes a total ingestion rate of 21.4 g/day, 2.2 percent of diet is white croaker (0.48 g/day), mean tissue concentrations from PV Shelf, boaters only.
[6]Assumes a total ingestion rate of 23 g/day, white croaker consumption of 4.6 g/day, mean tissue concentrations from Cabrillo Pier; from Pollock et al. 1991.
[7]Assumes a total ingestion rate of 21 g/day, 7 percent of diet is white croaker (1.5 g/day), mean tissue concentrations from PV Shelf, all fishing modes; from SMBRP (1997).
NA – Not available, or analysis not performed in the referenced study.
Source: SAIC, 1999

6.1.3.6 Uncertainty Analysis

An uncertainty analysis provides a qualitative and, where possible, semiquantitative evaluation of the assumptions and limitations inherent in each step of the risk assessment process and their effects on the risks calculated for the site, particularly those uncertainties not addressed as part of the Monte Carlo analysis. The HHRE describes the uncertainties associated with each step of the risk assessment process, including data evaluation, exposure assessment, toxicity assessment, and risk characterization. For each identified source of uncertainty, the direction and magnitude of the potential effect on the risk estimate and the steps taken to mitigate uncertainties are noted. In many cases, the only possible step to mitigate the uncertainties was the use of professional judgment and best available data. Uncertainties in risk assessment were addressed by using a conservative approach, which tends to overestimate risks. More information on the uncertainties in the HHRE can be found in Section 8 of the HHRE (SAIC, 1999).

6.1.4 1999 HHRE Conclusions

The results of the 1999 HHRE indicate that point estimate cancer risks for the RME scenario were above 1×10^{-4} for consumption of white croaker (2×10^{-3}) and surfperches (2×10^{-4}). RME noncancer hazards exceeded a HQ of 1 for white croaker, surfperches, barred sand bass, California halibut, kelp bass, and California sheephead. The HQs for white croaker were particularly high (17 and 32 for DDTs and PCBs, respectively). In general, DDTs in white croaker tissue is the most significant contributor to cancer risk; PCBs in white croaker tissue are the most significant contributor to noncancer health hazards. For the CTE scenario, the cancer risk was 2×10^{-5}. In addition, the CTE hazard quotients for both DDTs and PCBs were less than 1, indicating that noncancer health effects are unlikely to occur. The evaluation of risks to nursing infants from consumption of DDTs and PCBs in breast milk also indicated potential cancer and noncancer health effects. A comparison with other studies indicates that the results of this HHRE are consistent with previous risk assessments conducted for fish consumption in the PV Shelf Study Area.

6.1.5 Supplemental HHRE for the 2002-2004 Southern California Coastal Marine Fish Contaminants Survey

NOAA, on behalf of MSRP, and EPA initiated a comprehensive ocean fish sampling study in the fall of 2002 to assess more recent fish contamination levels on the PV Shelf and surrounding areas (EPA and NOAA, 2007). LACSD also conducted an ocean fish sampling study on the PV Shelf in 2002 (LACSD, 2003). Based on these data, a supplemental HHRE was performed to evaluate potential cancer and noncancer risks to people who consume fish caught from the PV Shelf. The supplemental HHRE is presented in a technical memorandum (TM) in Appendix B.

The purpose of the supplemental HHRE TM is to present the results of the analysis of human health risk using the *2002-2004 Southern California Coastal Marine Fish Contaminants Survey* (EPA and NOAA, 2007) and LACSD 2002 ocean fish data for PCBs and DDTs. The TM focuses on ocean fish data collected from the PV Shelf Study Area. The fish species used in the updated HHRE were selected because an adequate number of samples had been analyzed for each of these species to make the assessment statistically valid. The fish species evaluated represent a mix of water-column and bottom feeders, and pelagic and local dwelling species.

The evaluation of potential human cancer and noncancer risks is based on skin-off-fish-fillet results. The fish fillet scenario simulates fish consumption rates of all anglers as described in the *Santa Monica Bay Seafood Consumption Study* (SMBRP, 1994). To address the potential for high fish ingestion rates found in some Asian communities and other ethnic groups, high-end fish consumer scenarios were included in the evaluations. The risk scenario includes the RME and CTE scenarios based on all-angler and Asian-angler consumption rates.

6.1.5.1 Ocean Fish Sampling Studies

Data from two ocean fish sampling studies were used in the HHRE: (1) the EPA/MSRP 2002-2004 ocean fish sampling effort, and (2) the 2002 LACSD ocean fish sampling study.

2002-2004 Southern California Coastal Marine Fish Contaminants Survey

NOAA, on behalf of MSRP, and EPA initiated a comprehensive ocean fish sampling effort in the fall of 2002 to assess contamination levels in fish off the coast of Southern California. These fish were caught at designated locations from Ventura to Dana Point (Figure 2-2).

The fish species collected were pacific barracuda, pacific (chub) mackerel, pacific sardine, yellowtail, opaleye, sargo, kelp (calico) bass, surfperches, rockfishes, California sheephead, barred sandbass, top smelt, halfmoon, California scorpionfish (sculpin), white seabass, black croaker, white croaker, yellowfin croaker, jacksmelt, California corbina, California halibut, shovelnose guitarfish, and queenfish.

The following were primary goals of the *2002-2004 Southern California Coastal Marine Fish Contaminants Survey*:

- Update health advisories and commercial fishing bans.
- Determine restoration of lost fishing opportunities.
- Provide public information.
- Provide information for the RI/FS.

The HHRE uses data from six fish species caught from the PV Shelf from Point Fermin to Redondo Canyon (Segments 9, 12, 13/14, 15, and location EPA B). The following six fish species from the *2002-2004 Southern California Coastal Marine Fish Contaminants Survey* were evaluated for the HHRE:

- White croaker
- Kelp bass
- Rockfish
- Surfperches
- California scorpionfish
- Barred sandbass

The *2002-2004 Southern California Coastal Marine Fish Contaminants Survey* involved analyzing the fish tissue for DDTs (p,p'-DDT; o,p'-DDT; p,p'-DDD; o,p'-DDD; p,p'-DDE; and o,p'-DDE), PCBs (congeners 8, 18, 28, 31, 37, 44, 49, 52, 66, 70, 74, 77, 81, 87, 99, 101, 105, 110, 114, 118, 119, 123, 126, 128, 138, 149, 151, 153, 156, 157, 158, 167, 168, 169, 170, 177, 180, 183, 187, 189, 194, 195, 201, 203, and 206) and mercury.

LACSD Study

LACSD also conducted an ocean fish sampling study on the PV Shelf in 2002 (LACSD, 2003). Since 1971, LACSD has annually monitored the marine environment on the PV Shelf to assess the long-term ecological impacts from the effluent discharged from LACSD outfalls. Regional marine conditions in the area of the LACSD outfalls are monitored according to the requirements of the LACSD NPDES permit.

The current NPDES permit includes monitoring requirements for accumulation of DDTs and PCBs within tissues of various fish and invertebrate species. The purpose of the monitoring is to evaluate the temporal and spatial trends associated with bioaccumulation of DDTs and PCBs in biota collected within three zones across the PV Shelf: Zone 1, from White Point to Bunker Point; Zone 2, from Long Point to Point Vicente; and Zone 3, from Palos Verdes Point to Bluff Cove (Figure 2-2). The HHRE includes an evaluation of white croaker and kelp bass data collected from Zones 1, 2, and 3 as part of the LACSD sampling. LACSD analyzed fish tissue for DDTs (p,p'-DDT; o,p'-DDT; p,p'-DDD; o,p'-DDD; p,p'-DDE; and o,p'-DDE) and PCBs (Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260).

6.1.5.2 Summary of Data Used

Fish caught from MSRP Segments 9, 12, 13/14, 15, and location EPA B, from Point Fermin to Redondo Canyon in the *2002-2004 Southern California Coastal Marine Fish Contaminants Survey* and fish collected from Zones 1, 2, and 3 in the LACSD study were evaluated in the HHRE. Samples of fish fillet muscle from fish from the *2002-2004 Southern California Coastal Marine Fish Contaminants Survey* and the LACSD study were analyzed for DDTs and PCBs. The *2002-2004 Southern California Coastal Marine Fish Contaminants Survey* analyzed and reported PCBs as congeners and the LACSD study analyzed and reported PCBs as Aroclors. Combining the data can increase overall variation and effect point estimates in the risk and hazard results, but this effect is minimized by estimating risks using minimum, 95 percent UCL, and maximum concentrations of PCBs for each fish species evaluated.

6.1.5.3 Exposure Assessment

To address the potential for high fish ingestion rates found in some Asian communities and other ethnic groups, high-end fish consumer scenarios were evaluated. The high-end fish consumer is assumed to eat fish fillets at a rate substantially higher than the typical consumer. The high-end consumer scenario primarily provided a bounding estimate on risk.

Ingestion rates were obtained from the *Santa Monica Bay Seafood Consumption Study* (SMBRP, 1994). For all anglers of all ethnic groups and income levels, the upper 90 percent consumption rate is 107.1 g/day. The upper 90 percent consumption rate for Asian anglers is 115.7 g/day. The median (50 percent) consumption rate is 21.4 g/day for all anglers and for Asian anglers.

The fish fillet ingestion rates for RME and CTE scenarios for the high-end fish consumer scenario used in the HHRE are 107.1 and 21.4 g/day, respectively. The Asian-angler ingestion rates for RME and CTE cases are 115.7 and 21.4 g/day, respectively. These are the 90th percentile and mean consumption rates for all fish consumed based on the *Santa Monica Bay Seafood Consumption Study* (SMBRP, 1994).

6.1.5.4 Risk Characterization

Risk and hazard characterization results for the all-angler and Asian-angler high-end fish fillet RME and CTE consumers based on the *Santa Monica Bay Seafood Consumption Study* (SMBRP, 1994) fish ingestion rates, are presented below.

Fish Fillet Consumption by All Anglers

Under RME conditions (using 95 percent UCLs), excess lifetime cancer risks (ELCR) from ingestion of fish fillets range from 7×10^{-5} to 6×10^{-3} (Table 6-5). Of the six species tested, the highest risk was from white croaker fillets with a risk of 6×10^{-3}. White croaker fish could contain higher levels of DDTs and PCBs than other fish from the PV Shelf. This is primarily because the white croaker is a nonmigratory bottom fish that feeds off the ocean floor where these chemicals have settled. Both California scorpionfish and barred sandbass fillets have an ELCR of 3×10^{-4}. Kelp bass, rockfish, and surfperch fillets have ELCRs of 1×10^{-4}, 1×10^{-4}, and 7×10^{-5}, respectively. All six species have RME noncancer HI values of 2 to 183 from exposures to DDTs and PCBs. As with the HQ (which is for a single chemical), when the HI for exposures to multiple chemicals exceeds 1 (in this case DDTs and PCBs), there is a concern for potential noncancer health effects. White croaker fillets also have the highest HI values.

Under CTE conditions (using 95 percent UCLs), white croaker fillets have an ELCR of 6×10^{-4}. California scorpionfish and barred sandbass fillets have ELCRs of 3×10^{-5}, kelp bass and rockfish have ELCRs of 1×10^{-5}, and surfperches have an ELCR of 6×10^{-6}. White croaker, California scorpionfish, and barred sandbass have HI values of 2 to 37. Kelpfish, rockfish, and surfperches have HI values below 1.

Under the RME and CTE conditions (using 95 percent UCLs), DDTs contributed the most to the total cancer risk for five species, while PCBs contributed the most to cancer risk for one species (rockfish). Under the RME and CTE conditions, PCBs contributed most to HI values for all six species.

Fish Fillet Consumption by Asian Anglers

Under RME conditions (using 95 percent UCLs), ELCRs from ingestion of fish fillets range from 7×10^{-5} to 7×10^{-3} (Table 6-6). The highest risk of the six species tested is from white croaker with a risk of 7×10^{-3}. Barred sandbass and California scorpionfish fillets have ELCRs of 4×10^{-4} and 3×10^{-4}, respectively. Kelp bass, rockfish, and surfperch fillets have ELCRs of 1×10^{-4}, 1×10^{-4}, and 7×10^{-5}, respectively. All six species have RME HI values of 3 to 198. White croaker fillets also have the highest HI values.

Under CTE conditions (using 95 percent UCLs), ELCRs from ingestion of fish fillets range from 6×10^{-6} to 6×10^{-4}. The fish fillet ELCR for white croaker is 6×10^{-4}. Barred sandbass and California scorpionfish fillets both have ELCRs of 3×10^{-5}, while kelp bass and rockfish both have ELCRs of 1×10^{-5}. Fillets from surfperches have an ELCR of 6×10^{-6}. Three fish species (white croaker, California scorpionfish, and barred sandbass) have RME HI values of 2 to 37. Kelpfish, rockfish, and surfperches have HI values below 1.

TABLE 6-5
Summary of Risk and Hazard Estimates for All Angler Ingestion of Fish Fillet

	Reasonable Maximum Exposure			Central Tendency Exposure		
	Based on Minimum Conc.	**Based on 95% UCL Conc.**	**Based on Maximum Conc.**	**Based on Minimum Conc.**	**Based on 95% UCL Conc.**	**Based on Maximum Conc.**
Cancer Risks						
White Croaker	3×10^{-5}	6×10^{-3}	3×10^{-2}	3×10^{-6}	6×10^{-4}	2×10^{-3}
Kelp Bass	1×10^{-5}	1×10^{-4}	6×10^{-4}	1×10^{-6}	1×10^{-5}	6×10^{-5}
Rockfish	2×10^{-5}	1×10^{-4}	3×10^{-4}	2×10^{-6}	1×10^{-5}	3×10^{-5}
Surfperches (benthic feeding)	2×10^{-5}	7×10^{-5}	2×10^{-4}	2×10^{-6}	6×10^{-6}	2×10^{-5}
California Scorpionfish	1×10^{-5}	3×10^{-4}	9×10^{-4}	1×10^{-6}	3×10^{-5}	8×10^{-5}
Barred Sandbass	2×10^{-5}	3×10^{-4}	1×10^{-3}	2×10^{-6}	3×10^{-5}	1×10^{-4}
Noncancer HI						
White Croaker	2	183	738	0.4	37	148
Kelp Bass	0.4	5	23	0.1	0.9	5
Rockfish	1	5	11	0.2	0.9	2
Surfperches (benthic feeding)	0.7	2	6	0.1	0.5	1
California Scorpionfish	0.5	8	27	0.1	2	5
Barred Sandbass	0.6	10	36	0.1	2	7

TABLE 6-6
Summary of Risk and Hazard Estimates for Asian Angler Ingestion of Fish Fillet

	Reasonable Maximum Exposure			Central Tendency Exposure		
	Based on Minimum Conc.	**Based on 95% UCL Conc.**	**Based on Maximum Conc.**	**Based on Minimum Conc.**	**Based on 95% UCL Conc.**	**Based on Maximum Conc.**
Cancer Risks						
White Croaker	4×10^{-5}	7×10^{-3}	3×10^{-2}	3×10^{-6}	6×10^{-4}	2×10^{-3}
Kelp Bass	1×10^{-5}	1×10^{-4}	7×10^{-4}	1×10^{-6}	1×10^{-5}	6×10^{-5}
Rockfish	3×10^{-5}	1×10^{-4}	3×10^{-4}	2×10^{-6}	1×10^{-5}	3×10^{-5}
Surfperches	2×10^{-5}	7×10^{-5}	2×10^{-4}	2×10^{-6}	6×10^{-6}	2×10^{-5}
California Scorpionfish	1×10^{-5}	3×10^{-4}	1×10^{-3}	1×10^{-6}	3×10^{-5}	8×10^{-5}
Barred Sandbass	2×10^{-5}	4×10^{-4}	1×10^{-3}	2×10^{-6}	3×10^{-5}	1×10^{-4}
Noncancer HQ						
White Croaker	2	198	798	0.4	37	148
Kelp Bass	0.5	5	25	0.1	0.9	5
Rockfish	1	5	12	0.2	0.9	2
Surfperches	0.7	3	6	0.1	0.5	1
California Scorpionfish	0.5	8	29	0.1	2	5
Barred Sandbass	0.6	11	39	0.1	2	7

Under both RME and CTE conditions (using 95 percent UCLs), DDTs contributed the most to the total cancer risk for five fish species, while PCBs contributed the most for rockfish. PCBs contributed the most to hazards for all fish species under both RME and CTE conditions.

6.1.5.5 Uncertainties and Limitations

These risk calculations are quantitative estimates of current and future potential cancer risks and noncancer adverse health hazards. However, these numbers do not predict actual health outcomes. Using approaches and methodologies based on EPA guidance documents, the potential cancer risks and health hazards are estimated in a conservative, public health-protective manner. The risk and hazard estimates are calculated in a health-protective manner that tends to overestimate risks and, thus, any actual health impacts are likely to be lower than these estimates.

The use of toxicological data (noncancer reference doses and cancer slope factors) to estimate potential noncancer hazards and cancer risks, which are derived primarily from animal studies presents inherent uncertainties. General uncertainties associated with such data include extrapolation from high to low dose and from animals to humans. Within laboratory studies, potential sources of uncertainty can include: use of modeled animal species, gender differences, age, and strain differences in uptake, metabolism, organ distribution, and target site susceptibility. These uncertainties can be compounded when the data are used to assess risk and hazards to human populations, as a result of differences in diet, environment, activity patterns, and cultural factors. Toxicity values derived from human occupational studies are based on exposures to healthy worker populations and have the uncertainties inherent in epidemiologic data sets such as actual chemical exposures experienced by the worker population and exposure duration. The extrapolation of the data from relatively homogeneous occupational populations to residential and child populations consisting of individuals with a wide range of sensitivities is an uncertainty associated with the use of occupational studies to develop toxicity values used for risk assessment.

The estimation of exposure in this HHRE requires numerous assumptions to describe potential exposures to contaminated fish. There are a number of uncertainties regarding the likelihood of exposure, frequency of ingestion of contaminated fish, the concentration of contaminants in fish and the period of exposure. Assumptions used in this HHRE tend to simplify and conservatively approximate actual conditions, thereby serving to maximize confidence in decision-making during the HHRE.

For estimating chronic daily intake, there are uncertainties associated with standard exposure assumptions, such as body weight, period of time exposed, life expectancy, population characteristics, and lifestyle. Assumptions made for these exposure parameters might not be representative of any actual exposure situation and could result in either an over- or underestimation of the estimated risks. Another main assumption of the exposure assessment is that the period of constituent intake is assumed to be constant and representative of the exposed population.

The following uncertainties should be considered when interpreting the results for this HHRE:

- *Fish Sampling and Laboratory Analysis*. Uncertainty associated with fish sampling and laboratory tissue analysis includes representativeness of the fish samples collected, sampling errors, the variable nature of fish exposures to DDTs and PCBs from the PV Shelf, and the inherent variability (standard error) in the laboratory analyses.

- *DDTs and PCBs in Fish Fillet (Muscle)*. Human health risks were evaluated using DDTs and PCBs. Although other contaminants are present in PV Shelf sediments and fish tissue, potential risks from exposure to or consumption of DDTs and PCBs are of greatest concern. Therefore, the evaluation focused on these compounds. Exclusion of other chemicals detected in PV Shelf fish tissue could result in an significant underestimation of cumulative risk, but only in the event that the other chemicals bioaccumulated, were of high toxicity, were present in high enough concentrations in the fish fillet of fish typically caught by recreational and commercial fishers, and were typically eaten by fish consumers.

- *Method of Fish Preparation*. No attempt was made in the study to quantitatively evaluate the effects of fish preparation methods on human health risks, which could result in an overestimation of risk. Contaminant burdens in fish could decrease by 10 to 70 percent depending on how the fish is prepared and cooked (EPA, 1993b). Conversely, the risk analysis used only contaminant concentrations found in fish tissue (i.e., skin off fish fillets). DDT and PCBs concentrations in whole fish are 8 to 10 times higher. Therefore, the risk assessment underestimates risk to populations that consume whole fish.

- *Fish Consumption Rates*. The *Exposure Factors Handbook* (EPA, 2001b) provides a mean total fish consumption rate for the general population of 14.2 g/day for the Pacific region of the United States. This rate includes fish that are caught both recreationally and commercially, and meals that are eaten at home and away from home. The median consumption rate used in the evaluation, 21.4 g/day is based on 338 boat anglers who reported consuming fish in the previous 4 weeks (28 days) in the *Santa Monica Bay Seafood Consumption Study* (SMBRP, 1994). Based on the ingestion rates used for the HHRE, cancer risks and HI values might have been overestimated, and thus provide a health-protective RME estimate of risk.

6.1.5.6 Conclusions

The HHRE for 2002 ocean fish sampling evaluates potential cancer and noncancer risks to people who consume fish caught from the PV Shelf, based on data from the *2002-2004 Southern California Coastal Marine Fish Contaminants Survey* and LACSD fish studies. A range of ingestion rates for all-angler and Asian-angler high-end consumers for fish fillets, as described in the *Santa Monica Bay Seafood Consumption Study* (SMBRP, 1994), were considered to account for different exposure possibilities. The range of consumption rates include the potential for high fish ingestion rates found in some Asian communities and other ethnic groups.

For both all-angler and Asian-angler consumers under RME consumption of fish fillets, cancer risks from DDTs and PCBs for three species (white croaker, California scorpionfish, and barred sandbass) ranged from 3 $x10^{-4}$ to 7 x 10^{-3}, based on 95 percent UCL concentrations.

Risks from the other three species (kelp bass, rockfish, and surfperch) ranged from 7×10^{-5} to 1×10^{-4}. The HI values for all six species were 2 to 198.

For both all-angler and Asian-angler consumers under CTE conditions for consumption of fish fillets, cancer risks from DDTs and PCBs for one species (white croaker) was 6×10^{-4} based on 95 percent UCL concentrations. Risks from the other five species ranged from 6×10^{-6} to 3×10^{-5}. The HI values from three of the six species (white croaker, California scorpionfish, and barred sandbass) were 2 to 37. Kelpfish, rockfish, and surfperches have HI values below 1.

6.2 Ecological Risk Assessment

An ERA was conducted for the PV Shelf Study Area in 2003 (CH2M HILL, 2003). The ERA corresponds to the baseline ERA as described in EPA guidance, *Ecological Risk Assessment Guidance for Superfund Sites: Process for Designing and Conducting Ecological Risk Assessments* (EPA, 1997), and a validation assessment as described by the Department of Toxic Substances Control (DTSC) guidance, *Guidance for Ecological Risk Assessment at Hazardous Waste Sites and Permitted Facilities* (DTSC, 1996). This section summarizes the 2003 ERA for the PV Shelf Study Area and, subsequently, describes the 2006 revisions to the food web exposure model. A memorandum further describing the revisions to the food web model can be found in Appendix C.

6.2.1 Purpose and Scope of the ERA

The ERA is one component of the RI/FS designed to evaluate current levels of ecological risk by identifying and characterizing existing levels of contaminants at the site, and potentially completing exposure pathways to resident biota. More specifically, the ERA describes the risk from DDTs and PCBs to marine biota that inhabit or might use the PV Shelf Study Area and SCB. These biota include benthic invertebrates, benthic and water-column fish, brown pelicans, double-crested cormorants, bald eagles, peregrine falcons, and sea lions and their pups. This assemblage of receptors represents the marine food web from contaminated sediments up through invertebrate and vertebrate prey to wide-ranging, higher-order consumers. A geographic information system (GIS)-based food web exposure model was developed and presented in the ERA. In addition to evaluating existing risks, this food web exposure model can be adapted and used to estimate future risks as site conditions change as a result of remediation or under a no-action scenario.

The baseline ERA incorporates a comprehensive literature review and database summary that describe the physical, chemical, and ecological settings, and the methods for evaluating ecological risk. The resulting selection of contaminants of potential ecological concern, key ecological receptors, habitats, pathways, and selection of methods for describing and evaluating ecological risk are summarized in the conceptual site model. The model describes the contaminant sources and release mechanisms, evaluates potential exposure pathways, and identifies the representative species that were used to assess potential ecological risk to those and other similar species. The primary mechanisms for exposure are from the sediment to resident invertebrates and bottom-dwelling fish through ingestion or dermal or gill exposures. From there, bioaccumulated contaminants (DDTs and PCBs) continue through the food web to benthic and water-column invertebrates and water-

column fish and the fish-eating consumers (marine birds and sea lions). In addition, ecological receptors were assessed for exposure and risk through consumption of sea lion carcasses (bald eagles) and seabirds (bald eagles and peregrine falcons).

Algae, including kelp, were not targeted as an ecological receptor for measured tissue concentrations because plants typically do not demonstrate high levels of organochlorine contaminants uptake as compared with animals, and because the assessment of levels of fish tissue contamination acts as an integrative measure of site exposure and risk. However, the importance of kelp as a community and dietary input to animals suggests that future monitoring of kelp could help track spatial and temporal changes in DDT and PCB exposure at the PV Shelf Study Area. Kelp could be added to future monitoring to establish baseline contaminant concentrations and track changing levels of bioaccumulation over time. Although concentrations of DDTs and PCBs can be expected to be relatively low in kelp tissue concentrations, the use of kelp as a biomonitor has the advantage of sampling of a sedentary species for close tracking of spatial and temporal patterns of organochlorine bioaccumulation.

The PV Shelf Study Area, and to a lesser extent the entire SCB, have been the subject of intense investigations over a number of years. Those investigations have provided a comprehensive background for constructing the conceptual model and providing the data for the ERA. The ERA summarizes data collected throughout the SCB with an emphasis on the PV Shelf Study Area, from as many different sources as was practical, from 1990 to 2003 (data for birds are summarized for 1985 to 2000). Although numerous studies have shown that sediment and organism concentrations of DDTs and PCBs in the SCB are among the highest reported for any coastal marine ecosystem (EPA, 2000b), within the PV Shelf Study Area, concentrations of DDTs and PCBs in surface sediments and tissues of marine organisms have decreased since the 1970s and have generally leveled off since the mid-1980s. Results have been summarized in the ERA for DDTs and PCBs; however, primary data sources provided either varying sums of isomers and congeners or measures of individual, dominant isomers (e.g., DDE). Analytes for individual investigation are provided in Table 2-2 of the ERA (CH2M HILL, 2003).

Assessment endpoints for the ERA were developed based on known information on the contaminants present, study area, ecological management goals, and risk hypotheses. In addition, they represent properties of the system that can be measured. The following assessment endpoints were chosen for the PV Shelf ERA:

- **Community-level**: Marine infaunal and benthic invertebrate survival, abundance, and diversity (as assessed by sediment and estimated pore water concentrations [CH2M HILL, 2003] of DDTs and PCBs and effect levels, measures of community structure [from long-term LACSD monitoring], and toxicity tests)
- **Population-level**: Marine fish survival, reproduction, abundance, and diversity (as assessed by water-column concentrations of DDTs and PCBs [e.g., Zeng et al., 1999] and effect levels, and fish tissue concentrations)
- **Individual-level**: Special-status bird species and sea lion survival and reproduction (as assessed by dietary exposure levels and estimates of tissue concentrations)

6.2.2 Exposure Assessment

Exposure to DDTs and PCBs was evaluated in multiple ways, depending on the receptor and available data. Internal exposure, in the form of measured and estimated concentrations of DDTs and PCBs in tissues, was considered for invertebrates, fish, birds, and mammals. External exposure defined as contact with DDTs and PCBs in environmental media (sediment and water), was considered for biota, such as benthic invertebrates and fish, directly exposed to the media in which they live. In addition to measured and estimated internal and external exposures, a dietary exposure model for birds and marine mammals was developed and used to estimate the daily dosages of DDTs and PCBs from diet. The model required information on diet composition, ingestion rates, and foraging ranges as compared with the modeled geographic distribution of fish contamination. The bird and sea lion exposure model was based on the establishment of log-linear regression relationships between concentrations of DDT and PCBs in sediment and fish tissues at locations throughout the SCB. The sediment-to-fish regressions were then used to estimate potential concentrations of DDTs and PCBs in fish tissue for any SCB location. Overlapping concentrations in a mixed dietary fish assemblage within their foraging range yielded an estimated daily dosage of DDTs and PCBs for the bird and sea lion receptors. Peregrine falcon exposure estimates required the additional step of estimating tissue concentrations in the seabirds they consume (as derived from estimated fish concentrations in the diet of seabirds). Bald eagle exposure required a combination of exposure through dietary fish as well as sea lion carcasses and seabirds (with tissue concentrations in sea lions and seabirds, in turn, estimated from their fish diets). Sea lion pup exposures were estimated from maternal milk, as estimated from maternal dietary exposure and the use of literature-derived equations for transfer of contaminants to milk. DDTs were evaluated as summed isomers (DDTs) or as DDE, as available. PCBs were evaluated as summed PCBs either as congeners or Aroclors, as available.

6.2.3 Effects Assessment

A combination of literature-derived and site-specific effects data were used to develop effects levels for benthic macroinvertebrates, fish, birds, and sea lions. Effects data for benthic macroinvertebrates included site-specific sediment and literature-derived water quality benchmarks, as well as site-specific toxicity tests and benthic community assessments. For fish, literature-derived water quality and tissue residue-based benchmarks were used to determine risk from external and internal exposure, respectively. Both dietary exposure and target-organ-based internal tissue benchmarks (eggs for birds and blubber for sea lions) were developed from literature sources to assess external and internal risk to birds and mammals. In addition, site-specific studies outlining potential chronic effects from exposure to DDTs and PCBs (e.g., population declines, nest failures, juvenile mortality, impaired growth rates) were available and used, as appropriate, for birds and mammals.

6.2.4 Risk Characterization

Estimates of risk were determined by comparing measured and estimated chemical concentrations in a biotic media (measured sediment and surface water, and estimated sediment pore water), measured concentrations in biota (whole-body fish tissue, eggs for birds, and blubber for sea lions), and modeled bird and mammal exposures to site-specific and/or literature-based toxicity benchmarks. The HQ method used was a simple ratio of exposure (i.e., concentrations in media/tissue or daily dosage) over effect levels

(benchmarks). These quantitative risk estimates were evaluated along with the available site-specific field studies in a weight-of-evidence approach; these results are described by receptor. A description of the methods is discussed in the ERA (CH2M HILL, 2003) and in Appendix C.

6.2.4.1 Benthic Macroinvertebrates

The 2003 ERA indicated that shallow sediments at the PV Shelf Study Area exceeded sediment quality benchmarks (for bulk sediment concentrations) over 21.8 percent of the site for DDTs, but only 1.8 percent of the site for PCBs (MacDonald, 1997). Similarly, estimated pore water concentrations (using EqP) exceeded benchmarks over 79 percent of the area for DDTs, but only 0.2 percent of the area for PCBs. Recent work on sediment partitioning coefficients at one sampling station suggests that the EqP-based estimates of pore water concentrations might have been high for PV Shelf sediments as compared with sediments in other areas (Eganhouse, 2007). The magnitude of sediment benchmark exceedances for both DDTs and PCBs was relatively low at the PV Shelf Study Area (HQs less than 10), suggesting that risks are likely to be ecologically significant only for the most sensitive benthic invertebrate fauna. However, these risk estimates were supported by toxicity tests and benthic community assessments that demonstrated chronic toxicity and altered community structure (respectively) at the locations nearest the outfalls. All three lines of evidence support the conclusion that risk to infaunal and epibenthic invertebrates from exposure to sediment concentrations of DDTs and, to a lesser extent, PCBs is likely in the PV Shelf Study Area. This risk is greatest in areas nearest the outfalls (CH2M HILL, 2003).

6.2.4.2 Fish

Whole-body concentrations of DDTs and PCBs in individual fish collected near the PV Shelf exceeded literature-based no observed effects concentrations (NOEC) and lowest observed effects concentrations (LOEC), although the magnitude and extent of these exceedances varied by species (CH2M HILL, 2003). White croaker, a bottom-dwelling fish, had the highest percentage of tissue concentrations for individual fish exceeding benchmark values. Dover sole (another bottom-dwelling fish) and kelp bass (a water-column fish) had progressively fewer individuals that exceeded benchmark values for tissue concentrations. Most waterborne concentrations of DDTs at the site exceeded aquatic benchmark values, but fish did not appear to be at risk from water-column concentrations of PCBs. These quantitative results indicate that risks to fish from DDTs in the immediate vicinity of the PV Shelf Study Area are likely, but are generally limited to bottom-dwelling species. In contrast, no risks are expected for PV Shelf fish exposed to PCBs. Site-specific field and laboratory studies provide the same information. Although some researchers observed reproductive effects in the laboratory, others have found that DDTs- and PCBs-related anomalies (e.g., skin lesions and tumors) have decreased to background levels (Allen et al., 1997). Therefore, although risk to fish from exposure to DDTs cannot be eliminated, it is likely that this risk is greatest for bottom-dwelling fish and is localized in areas immediately adjacent to the outfalls. White croaker, sanddabs, and kelp bass were evaluated in the ERA because of the availability of co-collected sediment data, long-term records, and their suitability as surrogate species for various fish communities representative of dietary fish for birds and mammals. A number of other species are listed in the fish advisories as showing significant bioaccumulation of organochlorine contaminants (MSRP, 2005).

6.2.4.3 Birds and Mammals

Concentrations of DDTs in eggs exceeded toxicological benchmarks (Blus, 1984; Pearce et al., 1979; Weseloh et al., 1983; Koeman et al., 1972, 1973; Wiemeyer et al., 1993; Peakall et al., 1975) for brown pelicans at Anacapa Island and Santa Catalina Island; double-crested cormorants at Anacapa Island; bald eagles at Santa Catalina Island; and peregrine falcons on Anacapa, San Miguel, Santa Rosa, and Santa Cruz islands. Egg benchmarks (Tillitt et al., 1992; Wiemeyer et al., 1984) for PCBs were exceeded for pelicans and cormorants on Anacapa Island, peregrines on Santa Rosa Island, and bald eagles on Santa Catalina Island. Although not included in the ERA, an analysis of Santa Catalina bald eagle egg concentrations over time (1989 to 2004) showed no significant change in concentrations of DDE or PCBs and consistent exceedances of toxicity thresholds (MSRP, 2005). Although bald eagles exist on other channel islands, the assessment for ecological risk was limited to the Santa Catalina Island population because of the availability of data related to the birds and their prey.

Modeled dietary exposure distributions and risk for brown pelicans and double-crested cormorants were similar, with high percentages of the modeled exposures (100 percent for DDTs and 24 to 100 percent for PCBs) exceeding no observed adverse effect levels (NOAEL) in both the breeding and nonbreeding seasons (CH2M HILL, 2003). Exceedances of the lowest observed adverse effect levels (LOAEL) also occurred in the nonbreeding season, but were absent or significantly reduced during the breeding season. Modeled dietary exposures for bald eagles also exceeded NOAELs for DDTs and PCBs, though LOAELs were not exceeded. Bald eagles are mostly exposed to DDTs and PCBs from their seabird prey and sea lion carrion. Therefore, individuals are most at risk when feeding on seabirds or sea lions that forage within areas near the PV Shelf Study Area. For peregrine falcons, 100 percent of the modeled dietary exposures (depicted spatially as the foraging area of their seabird prey) for DDTs exceeded the NOAEL, and 16 percent exceeded the LOAEL. In general, percent exceedances of the benchmarks for PCBs were lower, with less than 1 percent exceeding a LOAEL. As with bald eagles, the risk to peregrine falcons from seabird prey is greatest when their prey are foraging in areas near the PV Shelf Study Area. Because their seabird prey generally have foraging ranges varying from 20 to 80 km, peregrine falcons nesting in the Northern Channel Islands would be exposed to lower dosages of DDTs and PCBs than those nesting near the PV Shelf Study Area (e.g., those in Los Angeles Harbor).

These quantitative risk estimates are supported by site-specific reproductive studies for the bird receptors. Increasing populations of pelicans and cormorants have been observed (Gress, 1994; Gress et al., 2003); however, current studies (Gress et al., 2003) indicate that chronic, low-level exposure to DDTs is likely depressing reproduction and some individuals still have egg concentrations above thresholds for reproductive failure. Within the SCB, some breeding pairs of peregrine falcons (Linthicum, 2003) and all breeding pairs of bald eagles on Santa Catalina Island (Sharpe, 2003) are unable to reproduce without intervention.

The weight of evidence indicates that there could be risk to brown pelicans and double-crested cormorants from exposure to DDTs and PCBs, but the risk from PCBs is expected to be lower than that from DDTs. For peregrine falcons and bald eagles, risks are likely to be present from both DDTs and PCBs, and adverse effects are probable for these species.

Blubber samples collected in 1970, 1972, and 1991 (DeLong et al., 1973; Gilmartin et al., 1976; and Costa and Bailey, 1994) from adult female sea lions were available for the comparison of tissue concentrations with toxicological benchmarks. Tissue samples from pups were not available. The 1970s values are included only for trend analysis and do not represent current conditions. The adult females were divided into two groups, premature parturient, and full-term parturient for comparison. None of the blubber samples collected in 1991 had concentrations of PCBs that exceeded the benchmark. However, the premature parturient females sampled in 1991 had DDE concentrations above the benchmark. This exceedance was an order of magnitude lower than in the 1970 and 1972 samples for this group.

Modeled risks to sea lions varied by season. Exposures to DDTs were highest near the PV Shelf during the fall, with exposures shifting more toward San Miguel, Anacapa, Santa Barbara, and Santa Cruz Islands during the summer breeding season. Exposures to PCBs were estimated to peak near the breeding areas on the islands. DDTs and PCBs could present risks to adult and pup sea lions as individuals, but effects on the population are less probable. Modeled exposure data have indicated that the immune systems of some pups could be compromised by exposure to DDTs and PCBs, though this effect on the population is unknown.

The weight of evidence indicates that DDTs and PCBs present risk to individual adult female and nursing pup California sea lions; however, population-level effects might not be occurring (i.e., sea lion populations are increasing). Despite population increases, the results of the risk assessment suggest that pups are likely experiencing adverse effects on their immune system that could result in high mortality when pups are exposed to increased environmental stress (e.g., diseases or adverse weather).

6.2.4.4 Uncertainties

Uncertainties are inherent in all aspects of an ERA. The nature and magnitude of uncertainties depend on the amount and quality of the data available, the degree of knowledge concerning site conditions, and the assumptions made to perform the risk assessment. The weight-of-evidence approach to characterization of risk is effective in reducing uncertainty when the number of risk indicators is not contradictory, particularly with respect to location and magnitude of risk. The rest of this subsection describes, in no particular order, several issues that were expected to contribute most to the uncertainty. Uncertainties in the ERA are further discussed in Section 4.3 of the ERA (CH2M HILL, 2003).

The PV Shelf Study Area and SCB benefit from a high degree of data collection over recent years. However, the adequacy of sediment, fish, bird, and mammal data in characterizing exposure is of concern. In particular, the food web exposure model depends on modeled relationships between measured fish and sediment concentrations and the extrapolation of those relationships to unmeasured areas. There is uncertainty in the broad application of the model. Results have been summarized in the ERA as DDTs and PCBs, yet primary data sources provided either varying sums of isomers and congeners or measures of individual, dominant isomers (e.g., DDE). The choice of receptors and physiological constants (such as ingestion rates) are also a source of uncertainty for characterizing risks over such a large area using surrogates to model risk for many different species.

The choice of toxicological benchmarks has been a source of uncertainty in the ERA process unless detailed site-specific information was available. Even the "best choice" of benchmarks might not be adequate to characterize site-specific effects. HQs rarely provide a precise quantification of risk, and only indicate that chosen benchmarks have been exceeded. Also, single-chemical risk estimates might be unrealistic in that natural, multichemical exposure could result in synergistic or additive effects.

6.2.5 Food Web Exposure Model Update

In 2006, the food web model used for the 2003 ERA was updated with sediment and fish data collected since 2003. An updated risk screening of benthic invertebrates for DDTs and PCBs was also conducted concurrent with the food web model update. A memorandum presenting the results of these updates is provided in Appendix C. The initial food web model incorporated data from 1990 to 2001; in the updated version, sediment and fish data from 2002 to 2005 were added to create a database inclusive of 1990 through 2005. New data sets incorporated since the publication of the initial ERA (CH2M HILL, 2003) include:

- LACSD sediment grab sample data: 2002, 2004
- LACSD fish tissue data: 2004, 2005
- *2002-2004 Southern California Coastal Marine Fish Contaminants Survey* fish tissue data

The updated food web model provides estimates of ecological risk associated with exposure to DDTs and PCBs attributable, in part, to the PV Shelf Study Area. Only the food web model and benthic invertebrate screening was updated, not the entire ERA. The food web model and benthic invertebrate screening results are considered two lines of evidence in the evaluation of ecological risk at the PV Shelf.

As part of the update, contour maps of concentrations of DDTs and PCBs in surface sediments for the PV Shelf were revised using an average of 2002 and 2004 LACSD surface grab sample data (Van Veen samples) and contouring routines incorporating the directional influence of predominant currents at the site (anisotropy). Updated maps of the HQs calculated for benthic invertebrates for DDTs and PCBs were prepared based on the new sediment concentration maps. The pattern of HQs greater than 1.0 is similar to that in the previous ERA. Shallow sediments at the PV Shelf Study Area exceeded sediment quality benchmarks over 25 percent of the site for DDTs and 9.0 percent of the site for PCBs. Revised HQ maps for DDTs and PCBs are provided in Appendix C.

Table 6-7 presents a comparison of risk screening exceedances for DDTs and PCBs from the initial and updated food web model, based on the 2002 and 2004 sediment concentrations of DDTs and PCBs, updated fish tissue data, and modeled dietary dosage exposures to bird and mammal receptors as expressed as percent of the PV Shelf and SCB areas showing risk exceedances. Risks from dietary dosages were compared with the NOAEL and the LOAEL values from the literature, as summarized in the ERA (CH2M HILL, 2003). Risk estimates for birds and mammals are based on modeled exposures using the updated sediment concentrations throughout the SCB, whereas risks to fish are based on measured fish tissue values from samples collected within the PV Shelf. Sanddab tissue data were only available from 1998 and, therefore, remained unchanged in the updated model. For kelp bass and white croaker, an updated data set was used, because new fish data have been collected since 2003.

TABLE 6-7
Comparisons of Risk Screening Exceedances for DDTs and PCBs from the Initial and Updated Food Web Model

Receptor	Percent of SCB Area Showing Exceedances of Screening Values for DDTs (NOAEL) Initial/Updated	Percent of SCB Area Showing Exceedances of Screening Values for DDTs (LOAEL) Initial/Updated	Percent of SCB Area Showing Exceedances of Screening Values for PCBs (NOAEL) Initial/Updated	Percent of SCB Area Showing Exceedances of Screening Values for PCBs (LOAEL) Initial/Updated
California Sea Lions (Winter/Spring)	1.6/37	No LOAEL available	0.5/8	0/0
Sea Lion Pups (Winter/Spring)	61/86	No LOAEL available	72/89	0/11
Bald Eagle	100/100	0/100	1/100	0/0
Brown Pelican (Breeding)	100/100	0/100	24/100	0/0
Peregrine Falcon	100/100	16.5/100	21/100	0/0
Double-Crested Cormorant (Breeding)	100/100	28/100	96/100	0/0
White Croaker fillets (as % of Total Number of Samples from PV Shelf)	89/70	15/3.1	0/0	0/0
Kelp Bass fillets (as % of Total Number of Samples from PV Shelf)	15/25	0/0	0/0	0/0

Note:
For fish, comparison with screening values is based on measured concentrations in muscle tissue. For bird and mammal tissue, comparison uses modeled values.

As shown in Table 6-7, the number of recent screening level exceedances increased for every receptor and chemical that showed exceedances in the initial 2003 model results. A review of the results of the food web model indicates that the changes in the biota-sediment accumulation factors (BSAF) caused by changes in concentrations in DDTs and PCBs in sediment and fish, had minimal effect on the estimates of risk (Appendix C). BSAF relationships in this risk assessment consisted of a series regression equations that predict fish concentrations based sediment concentrations of PCBs and DDTs. However, the tenfold increase in pelagic fish concentrations (and associated increase in modeled sea lion tissue and bird tissue concentrations) significantly increased the frequency of exceedance of screening values, as shown in Table 6-7. The significance differences between the initial and updated model risks were enhanced risks from PCBs to sea lions, pelicans, and eagles, and from DDTs to cormorants and falcons. Direct risks to fish did not change significantly; they continue to show a lack of exceedances for PCBs (Table 6-7). The *2002-2004 Southern California Coastal Marine Fish Contaminants Survey* targeted larger size ranges of pelagic species to better characterize human (versus ecological) risk, which might have produced a slight bias towards higher concentrations in those fish compared with the full-size ranges eaten by fish or mammals.

6.2.6 ERA Conclusions

Several lines of evidence, including sediment and pore water HQs, benthic community effects, toxicity tests, effects on fish, and modeling of food chain transfer to birds and mammals, were evaluated as part of the ERA. The results show the highest risks near the PV Shelf outfalls. Intermediate-risk areas are found generally to the south and southwest of the outfalls, and areas to the northwest off Point Vicente. Finally, low-risk areas occur at the far northeastern areas of the PV Shelf Study Area (near Redondo Canyon) and throughout the remainder of the SCB. Results for birds and mammals indicate some far-reaching risks, including out to the Channel Islands, driven by seasonal patterns and extent of foraging area. After many years of nesting failures, bald eagles have had some recent hatching successes on the Channel Islands.

The fish and benthic invertebrate risk estimates show a predictable spatial pattern of risk for the PV Shelf Study Area with a significant relationship between sediment concentrations and risks affecting the upper trophic-level consumers. Risks to fish and invertebrates were higher for DDTs than for PCBs and were higher in the immediate area of the outfalls.

The risk to birds and sea lions (as the representative marine mammal) from exposure to DDTs and PCBs in the PV Shelf and SCB was an important component of the ERA. Continuing risk is shown for birds throughout the SCB for both DDTs and PCBs. From the weight of evidence, it appears that DDTs (rather than PCBs) are associated with the greatest risk to birds.

Adult female sea lions show risk from exposure to the DDTs and PCBs from both external and internal exposure pathways. Risks are measurable but low near the PV Shelf Study Area and on the Channel Islands. Sea lion pups receive high exposure to DDTs and PCBs from maternal milk, and these exposures are related to the foraging range of the mother. The pups experience greater risk than the mothers; however, this increased risk from DDTs and PCBs would be expected only in combination with stressful events (e.g., diseases, food shortages). Population effects could occur from this type of synergistic interaction.

The ERA conclusions are based on a weight of evidence, including food web model results but combined with measured fish tissue, benthic invertebrate community measures, toxicity tests, sediment concentration exceedances, waterborne concentrations of contaminants, and various other direct measures pertaining to ecological risk. As a consequence, the changes in estimated risk from the updated food web model as compared with the earlier version do not solely constitute a change in overall risk as determined by a weight-of-evidence approach. The summary of risks from DDTs and PCBs remained unchanged compared with the previous ERA (CH2M HILL, 2003) and indicated risk for all receptors, with the greatest risk for DDTs than for PCBs.

In summary, the 2003 ERA, the revised benthic invertebrate screening, and food web model results indicate the following evidence of risk:

- **Benthic invertebrates at the PV Shelf:** Measured bulk sediment concentrations exceed SECs (MacDonald, 1997) for DDTs and PCBs resulting in HQs greater than 1.0. Exceedances of SECs for DDTs were slightly greater and over a larger area than for PCBs.

- **Fish at the PV Shelf (white croaker, kelp bass, and sanddabs):** Measured tissue levels exceed toxicity benchmarks for DDTs.
- **Birds (brown pelican, double-crested cormorant, bald eagle, peregrine falcon):** Modeled dietary exposures exceed screening values for DDTs and PCBs.
- **Mammals (sea lions and their pups):** Modeled dietary exposures exceed screening values for DDTs and PCBs.

7.0 Palos Verdes Shelf Study Area Conceptual Site Model

Information on the sources of contaminants, fate and transport mechanisms, exposure pathways and receptors is used to develop a conceptual understanding of a contaminated site. Figure 7-1 shows the CSM for the PV Shelf Study Area including past sources of contamination (outfall), existing sources of contamination (effluent-affected sediment), affected media (sediment and water), known and potential routes of migration (water), and known or potential human and environmental receptors (benthic organisms, fish, anglers).

The CSM evolves and becomes more defined as site-specific information is collected and verified. General science and professional judgment are used to develop an initial CSM. Site-specific information (such as physical, chemical, and biological sampling) is then used to supplement general site information to develop a more accurate and refined CSM. This section describes the key elements of the CSM for the PV Shelf Study Area by integrating pertinent information from earlier sections of this RI report including the environmental setting; source, nature and extent of the contamination; fate and transport processes; and exposure pathways and receptors.

7.1 Environmental Setting

7.1.1 Geography

The PV Shelf is about 1.5 to 4 km wide, up to 25 km long, and has a slope of 1 to 3 degrees (Figure 1-1). Kelp beds and rocky patches are found in shallower waters near shore; however, most of the shelf is covered in thick sediment. A shelf break occurs at water depths of 70 to 100 m. The continental slope drops seaward from the shelf, with a width of approximately 3 km and an average slope of 13 degrees, to a depth of approximately 800 m (Lee, 1994). The PV Shelf Study Area is defined as the area of the shelf and slope off the Palos Verdes Peninsula between Point Fermin and Redondo Canyon, from the shore to the 200-m isobath.

7.1.2 Waves

Waves from the open Pacific reach the PV Shelf Study Area. Although sheltering by islands partially protects the site, the waves are frequent and large enough to suspend sediment in shallow water (30 m) and can occasionally (during storms, which occur about 10 times per year) resuspend sediment across the PV Shelf Study Area. Pacific waves are largest in winter. Local wind-generated waves have minimal impact because wind waves are typically small due to the limited fetches, and the contaminants are in relatively deep water, so only long-period waves reach the bed.

7.1.3 Currents

Regional oceanography is not dominated by simple forces, such as tides or winds. General circulation in the ocean is mostly forced by meteorology and water properties over a region extending hundreds, even thousands, of kilometers from the site. Waves and currents at the site are not controlled by local winds. Tides are complicated by the regional topography. The PV Shelf is a narrow strip of shallow water adjacent to a deep basin, and water in the SCB is stratified by temperature and salinity gradients. In addition to currents forced by regional meteorology and tides, currents are caused by internal oscillations of the stratified waters. These include internal tides, internal waves, and solitons. Seasonal changes in water temperature influence the internal motions.

Flow on the PV Shelf has a long-term mean toward the northwest, but strength varies seasonally and sometimes reverses in surface waters in summer. The cumulative effect of tidal and low-frequency currents at the study area is the up-coast and down-coast dispersal of materials predominantly along isobaths, with tendency to disperse up-coast. Strength and variability of near-bottom currents is higher at both ends of the study area (on the San Pedro Shelf to the southeast and near Point Vicente to the northwest). Internal motions generate flows near the bottom, and the strength of these flows varies with location (and possibly with season).

7.1.4 Sediment Sources

The main sources of particulate materials or sediment are the LACSD outfalls and erosion of the toe of the Portuguese Bend Landslide. Other less significant sources of sediment include coastal erosion, river input, and local biological production in the water column. The sediment contribution from the Portuguese Bend Landslide has been estimated from its rate of movement by assuming that the toe erodes as quickly as it moves into the surf zone. Supply of sediment from the Portuguese Bend Landslide has fluctuated over time, and depends on rainfall and the efficacy of various engineering measures taken to stabilize the slide. More than half of the total sediment supplied to the PV Shelf since the outfalls were constructed has been estimated to come from the Portuguese Bend Landslide, and most of this sediment has been incorporated into the effluent-affected deposit. The toe of the Portuguese Bend Landslide is located in a few meters water depth about 5 km northwest of the outfalls. However, waves approaching from the west generate alongshore transport toward the southeast in the surf zone as some of the material is transported offshore.

7.1.5 Habitat

The PV Shelf region is characterized by (1) hard-bottom (rocky) habitat, including some kelp bed areas and associated invertebrate, fish, and algae communities, from shore to at least 20 m of water depth; (2) soft-bottom habitat, including invertebrate and fish communities, over most of the shelf and slope region to a water depth of at least 600 m; and (3) pelagic or water column zones, which are habitat for fish, invertebrates, birds, and mammals from near the sea floor to the water surface. The exception to this pattern is the hard-substrate, artificial reef habitat represented by the White Point outfall pipes that extend primarily over soft-bottom areas to a water depth of approximately 60 m, some hard-bottom areas scattered along the shelf, and more extensive hard-bottom areas paralleling the shelf break at 80 to 100 m.

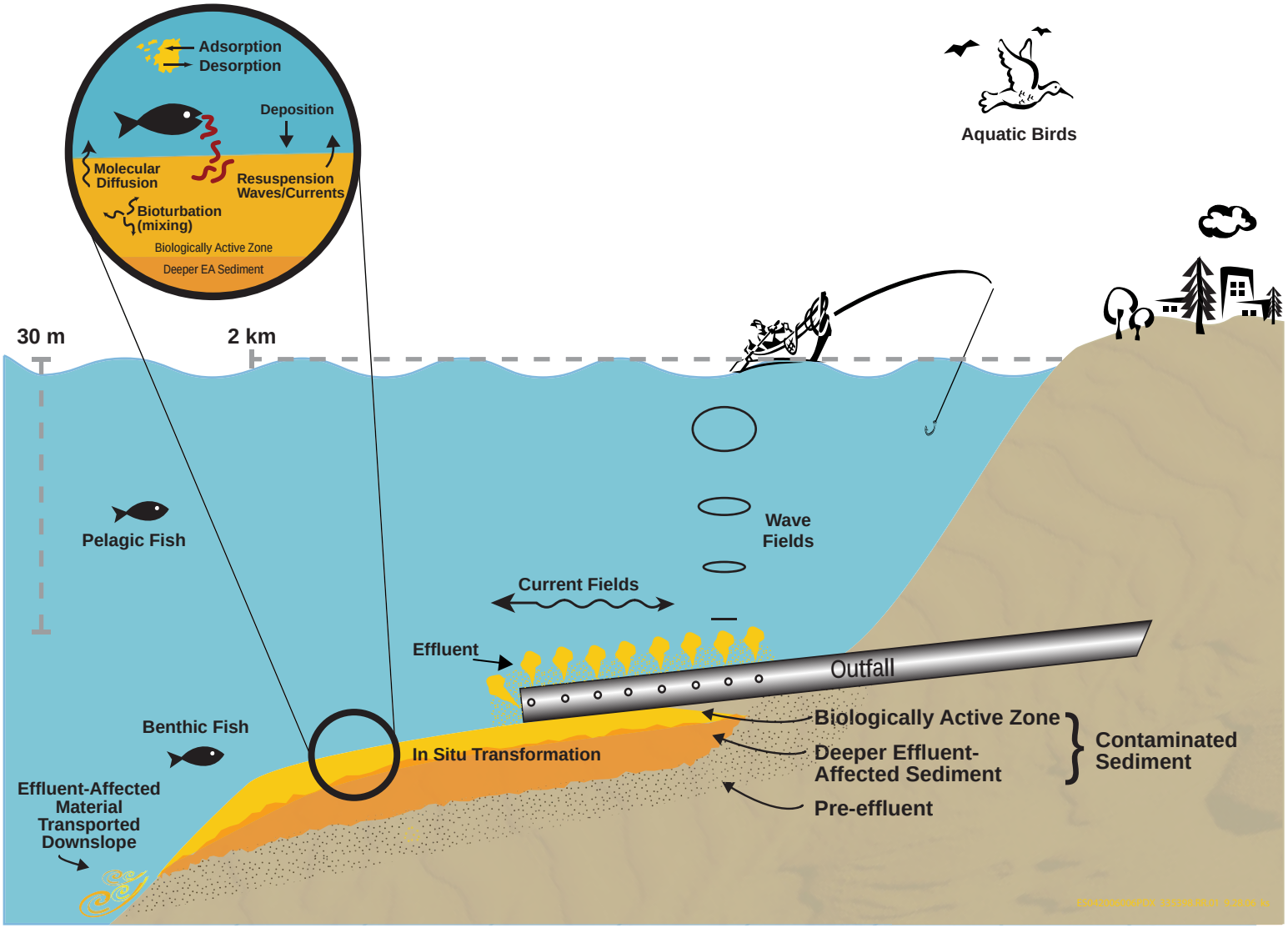


FIGURE 7-1
Conceptual Site Model
Palos Verdes Shelf Study Area
Remedial Investigation Report

7.2 Palos Verdes Shelf Study Area Contamination

7.2.1 Source of Contaminants

The primary historical source of chemical contaminants on the PV Shelf is effluent discharged through the LACSD outfalls, although some contaminants were introduced through runoff and other sources. Since 1937, LACSD has discharged treated sewage to PV Shelf approximately 2.5 km offshore of White Point. Wastewater contaminants in the discharge have included DDTs, PCBs, trace metals, and organic matter.

The primary source of DDTs was wastewater from Montrose, which manufactured DDT from 1947 to 1982; however, the discharge of wastewater from Montrose stopped in 1971. Sources of PCBs included various industries in the greater Los Angeles area. The peak annual mass emissions of effluent solids (167,000 metric tons), DDT (21.1 metric tons), and PCBs (5.2 metric tons) occurred in 1971 (EPA, 2000a). The primary component of DDTs delivered to the PV Shelf through the LACSD outfalls was p,p'-DDT, which was quickly transformed to p,p'-DDE. Approximately 1,800 metric tons of DDT was discharged before 1971. The effluent concentrations of DDTs have been near or below the detection limit since 1989 and have not been detected since 2002. PCBs have not been detected above the detection limit since 1985 (LACSD, 2006a). Therefore, there are no significant ongoing sources introducing DDTs or PCBs to the PV Shelf Study Area from the LACSD outfalls; the fate and transport of contaminants in the sediments will determine future concentrations and affected areas within the site.

7.2.2 Nature of Contaminants

DDTs and PCBs are hydrophobic organic compounds with relatively low water solubilities, high octanol-water partition coefficients (log K_{OW}), and organic carbon normalized sediment-water partition coefficient (log K_{OC}). These compounds were sorbed to organic-rich particulate or colloidal matter in the effluent (which was about 60 to 70 percent organic matter) and subsequently deposited on the seafloor at the PV Shelf. Most of the subsequent transport of these contaminants has occurred in the solid phase while sorbed onto organic particle or colloidal material. These compounds are generally very persistent in marine environments, but results from several studies on PV Shelf sediment indicate that, under appropriate conditions, DDE may be dechlorinated to form DDMU and possibly other compounds.

Data from the PV Shelf do not indicate the PCB transformation is occurring. PCB compositions in shelf sediments are uniform and no changes have been observed in the congener distribution profiles in PV Shelf sediment cores collected at the same location (near Station 3C) in different years (1992 and 2003). Therefore, the PCB concentrations or distributions at the PV Shelf do not appear to be changing through biotransformation of the PCBs.

7.2.3 Extent of the Contaminants

Releases from the outfalls have formed a thin deposit (less than 1 m thick) of cohesive, fine-grained, organic-rich, contaminated material that includes outfall effluents combined with natural sediment, most of which probably came from the eroding toe of the Portuguese

Bend Landslide. The effluent-affected deposit has been built on pre-effluent, native sediment that occupied the PV Shelf before the outfall construction. The native sediment is coarser, has less organic material, and is less cohesive. The native material was supplied by local rivers and erosion of the coastline, including the Portuguese Bend Landslide.

In shallow regions (water depth of less than 40 m) where bottom wave activity is higher, sediments are generally sandy, and there is no obvious accumulation of effluent-affected sediment on top of native sediment. Some effluent-affected material may be worked into surface sediment at these in-shore regions, and the deposit becomes apparent as surface sediments become finer with depth. The effluent-affected deposit is thickest at water depths of 60 m, which is the depth of the outfall diffusers. The deposit thins as depth increases across the shelf and, in 1992, was approximately 10 cm at the shelf break. The deposit is draped over the shelf break, but quickly thins and ceases to be a recognizable deposit only a short distance down the slope. The cross-shelf geometry is consistent with maximum deposition rates at 60 m, with decreasing deposition rates in the offshore direction because the material was more widely dispersed, and with decreasing deposition rates in the onshore direction because wave activity at the bottom increasingly prevented initial deposition or remobilized and dispersed deposited material.

The deposit is thickest (80 cm) near the 90-inch outfall, and thins rapidly toward the southwest, barely exceeding 15 cm a kilometer from the outfall. It tapers more gradually toward the northwest. About 12 km northwest from the outfalls, the effluent-affected deposit is 25 cm thick. This elliptical shape of the deposit is consistent with bi-directional dispersion from the outfall that has been skewed up-coast, in the direction of the long-term average current. On the northwest end, the increased thickness of the effluent-affected deposit and lower contaminant concentrations also suggest admixture of Portuguese Bend Landslide sediment.

The thickest part of the effluent-affected deposit has two distinct layers. The lower layer has the highest levels of contamination (about 80 to 200 mg/kg DDTs) and slightly higher water content, consistent with the more rapid deposition that occurred when large amounts of contaminated particulate matter was discharge from the outfalls. The upper sediment layer has generally lower levels of contamination (about 1 to 5 mg/kg DDTs) and is more uniform, indicating physical reworking by waves, currents, and benthic fauna. The thickness of these two layers varies across the deposit. The upper layer can include the top 10 to 30 cm; the lower layer represents another 30 cm, with peak concentrations at 35 to 45 cm below surface.

Surface sediment (0 to 2 cm) data indicate a significant drop in concentrations of DDTs from 1992 to 2002 and from 2002 to 2004 at the PV Shelf Study Area, with the exception of Station 8C. For PCBs, there was no significant decrease between 1992 and 2002, but a slight, measurable decrease between 2002 and 2004. In general, concentrations of DDE and PCBs southeast of the outfalls are highest in the shallow or surface sediment interval (0 to 15 cm). Northwest of the outfalls, the highest concentrations of DDE and PCBs occurred in the 16- to 30-cm or 31- to 45-cm intervals.

Contaminants sorbed to particulates and dissolved in seawater have been dispersed throughout the SCB from the PV Shelf. Some effluent solids never settled on the PV Shelf but remained in suspension (or dissolved) and were transported to deeper water or adjacent

regions by tidal currents and regional circulation patterns. Some of the effluent solids settled temporarily on the PV Shelf, but were subsequently remobilized and dispersed by the same currents. Through this process, the PV Shelf has acted as a source of contamination for the region long after the discharge of contamination was stopped, and this will continue as long as surface sediment on the PV Shelf remains relatively contaminated. Sources other than the PV Shelf, but much less significant, also contribute to the contamination of the SCB.

7.3 Processes Affecting Fate and Transport of DDTs and PCBs

Fate and transport of the contaminants is governed by physical, chemical, and biological processes, operating primarily in two environmental media: solids (e.g., suspended particles or bed sediment) and water (seawater or pore water). Physical processes are thought to be primary, while chemical and biological processes are significant, but secondary. However, chemical and biological processes significantly affect physical processes, such as in the case of bioturbation where biodiffusive mixing or nonlocal transport can cause physical transport of sediment from below the surface.

7.3.1 Physical Transport

Physical transport is the mechanical transport or mixing of fluids or solids containing DDTs and PCBs including the transport of other material (e.g., uncontaminated material) that ultimately influences the fate of contaminated material. Physical transport processes relevant to the PV Shelf Study Area include resuspension; transport and deposition with resulting net erosion or deposition of contaminated and uncontaminated sediment and associated contaminated pore water; solid-phase biological mixing or transport in the sediment with associated mixing of liquid-phase contaminants (pore water); and biological transport of liquid-phase contaminants (flushing or irrigation of pore water by benthic fauna). Physical transport or mixing of sediment on the PV Shelf is caused primarily by water motions, gravity, and benthic fauna. Some of these processes are discussed in more detail below.

Waves and Currents. Waves and currents resuspend and transport sediments along the PV Shelf. Depending on the location of resuspension, these transported sediments can consist of clean noncontaminated sediment (from local rivers, the Portuguese Bend Landslide, or other areas of the shelf) or contaminated sediments from the study area.

Waves were demonstrated to resuspend bottom sediments within the study area at depths where contaminated sediment has previously been deposited. Studies on sediment transport on the PV Shelf indicate that large storm-induced waves are the dominant mechanism for the resuspension of bottom sediments in the study area at depths greater than 40 m. Storm events sufficient to resuspend bottom sediments at a depth of 60 m occur about 10 times per year. Bottom sediments in water depths less than 30 m along the coast are frequently resuspended by waves; however, sediment in this area does not contain contaminants in concentrations of concern.

Sediments that are mobilized are from the upper 2 cm of the sediment-water interface. A storm-related scour depth of up to 2 cm can be significant when considering natural burial rates and biodiffusion rates. Fine-grained effluent-affected sediments along the near-shore edge will go into suspension and be moved by currents toward the northwest and offshore at a greater frequency than other areas. The lowest period of wave-induced sediment suspension is June through August.

Velocities and current speeds at the southern end of the shelf are greater than those at the northern end of the shelf. This inequity in current speed appears to be reflected in the sediment size distribution of bottom sediments between sites north and south of the LACSD outfalls. Drake and Cacchione (Drake et al., 1985; Drake and Cacchione, 1985 and 1986) indicated that the typical "low-frequency" currents (on the order of 10 to 30 cm/sec at 1 m above bottom) are not capable of eroding sandy silts on central and southern California shelves. LACSD data (SAIC, 2004b) indicated that bottom current velocities greater than 30 cm/sec occurred less than 0.2 percent of the time over the effluent-affected sediments and have average durations less than 1 hour.

The shape and location of the effluent-affected sediment layer and the relevant current meter studies indicate that net transport of sediment within the study area by bottom currents is to the northwest, with a subcomponent of the flow moving offshore and off-shelf to the west. Bottom currents from San Pedro Bay maintain a net northwesterly flow and significantly limit southeasterly movement of effluent-affected sediments. Similarly, current patterns in Santa Monica Bay, combined with the presence of the Redondo Canyon, could limit northern migration of effluent-affected sediments.

Contaminant Burial. Deposition rates before the 1930s were low, less than 0.2 cm/year. Rates rapidly increased with elevated output from the LACSD outfalls, and later, starting in the late 1950s, sediment from the Portuguese Bend Landslide. Maximum deposition occurred in the 1960s and 1970s and was approximately 2 cm/year around Station 6C (approximately 1.5 km northwest of the diffuser) and 1 cm/year around Station 3C (approximately 5 km northwest of the diffuser). Average deposition rates for the 1980s and 1990s range between 0.6 and 0.7 cm/year. Deposition rates will continue to drop at Station 6C with decreases in suspended sediment output from the LACSD outfalls. Rates at Station 3C could remain constant or increase for some time into the future based on the occurrence and significance of large storm events supplying sediments from the Portuguese Bend Landslide.

Bioturbation and Biodiffusion. Bioturbation represents a significant physical mechanism for mobilization and introduction of deeper effluent-affected sediments on the PV Shelf and associated pore water to surface layers (Niederoda et al., 1996). These processes continue to mobilize DDT compounds to the biologically active surface layer where transfer to epibenthic consumers of infauna, or planktonic particle feeders within the nepheloid layer, provides a means of bioaccumulation and transfer to higher trophic levels.

Biodiffusion homogenizes sediments and promotes transport of contaminants from regions of higher concentration to regions of lower concentration. Biodiffusion is most intense near and just below the sediment boundary, where sufficient oxygen is available in pore water to support aerobic metabolism of the fauna. In marine sediments, this surface layer is characterized by relatively high densities of infauna, primarily deposit-feeding polychaete

worms, pericarid crustaceans, and mollusks, usually numbering several thousand per m^2 in coastal zone sediments. The mean depth of the mixed layer from worldwide estimates of D_b (coefficient of diffusivity) in marine sediments using radionuclide techniques is about 10 cm (Boudreau, 1994).

Biological activity below the mixed layer declines rapidly. Organisms below the mixed layer are less abundant because of the reduced availability of labile organic matter for food and demands placed on organisms (tube building, irrigation) resulting from the hypoxic or anoxic state of surrounding interstitial water, which require animals to maintain connection with the surface. These subsurface organisms tend to be larger, significantly lower in population density, and often displace sediments by nonrandom advective transport, usually vertically, through such means as excavation of buried sediments to the surface layer for burrow maintenance, or ingestion of surface sediments with defecation into subsurface strata, or by directional reversal of this feeding mode (e.g., subsurface ingestion, surface defecation; head-down deposit feeding). These directional (advective) mechanisms of sediment transported by organisms are defined as nonlocal mixing. Nonlocal mixers can mobilize deep sediments to the surface layer. Sedimentation that buries particles in strata where biological mixing no longer occurs will eventually be several tens of centimeters below the surface. Continued presence of elevated contaminant concentrations in PV Shelf surface sediments indicates that various ongoing mechanisms mobilize and transport contaminant-laden sediments and solutes from deeper layers in the sediment column. Contaminant concentration peaks, 20 to 40 cm beneath the sediment-water interface, are below the mixed-layer zone of rapid biodiffusion; however, modeled estimates of Fickian biodiffusivity, while low, extend as deep as 25 cm.

7.3.2 Chemical Transformation of DDTs and PCBs

Chemical transformation consists of changes to the chemical structure of the contaminants (DDTs and PCBs). DDE can be transformed into DDMU, which, in turn, could transform into DDNU. These chemical changes might be caused by microbial activity while the rates of chemical transformation vary by location and depth in the core, which suggest that they are controlled by local sediment geochemistry or microfauna. The measured loss of DDE could be a result of these chemical transformations; however, there is no evidence that the transformation products (e.g., DDMU or DDNU) have significantly different chemical affinities or toxicity. These transformations affect measured estimates of contaminant levels, which are based mostly on DDE concentrations and do not include transformation products. There is no evidence that PCBs are undergoing significant transformations.

7.3.3 Molecular Diffusion

Molecular diffusion is the process by which dissolved solutes move from an area of higher concentration to an area of lower concentration. Molecular diffusion plays a role in the transport of DDTs and PCBs from below the surface to the sediment surface boundary. By motion of sediment particles, aqueous exchange between pore spaces is accelerated. This occurs by physical mixing resulting from animal activity; thus, bioturbation rates play a role in mediating the diffusion process.

Most molecules of DDTs and PCBs are bound to sediment particles. Sediment-water partition coefficients from various published sources typically exceed one million

(Karickhoff and Long, 1995; Pontolillo and Eganhouse, 2001); thus, relatively few molecules are transported as solutes compared with particulate transport. Nevertheless, wherever sediment DDT and PCB contamination exists, soluble material is present in pore water and is subject to biodiffusive transport from animal activities and by molecular diffusion within the sediment matrix and between sediments and the overlying water. There is not much focus on molecular diffusion in the PV Shelf Study Area except on microscopic scale when associated with adsorption/desorption.

7.3.4 Adsorption/Desorption

Adsorption is the process by which liquid or gaseous compounds bind to solid particles. Desorption is the process of changing from an adsorbed state on a solid surface back into a liquid or gaseous phase. DDTs and PCBs are hydrophobic, with very low solubility in water. They are strongly associated with particulate matter (primarily organic carbon) in the water column and bottom sediment of the PV Shelf Study Area. Their partitioning coefficients between adsorptive soil/sediment and water soluble states under various environmental conditions are on the order of one million or more (Pontolillo and Eganhouse, 2001), which means the log K_{OC} values tend to be about 6 or greater.

Desorption of PCBs and DDTs from sediment occurs when the particles and water surrounding them are not at equilibrium. Desorption can occur along concentration gradients in pore water, across biological interfaces (such as tubes and burrows), and when sediments are suspended at the boundary layer as a result of storm and wave action. These processes are all active in the sediment matrix and at the sediment-water interface of PV Shelf contaminated sediments.

Although dissolved contaminants are found at elevated concentrations over the PV Shelf (Zeng et al., 1999), it is likely that a significant portion of the desorbed compounds would be subsequently re-absorbed, partitioning onto relatively uncontaminated particles that are advected into the region, and become suspended in the nepheloid layer and near-bottom waters of the SCB.

Annual sediment monitoring by LACSD indicates a decrease of greater than 25 percent in sediment organic carbon concentration in PV Shelf Study Area sediments over the past decade (from an average 4.2 percent of sediment dry weight in the 1990s to 3.1 percent from 2000 to 2006). The results of these changes (lower contaminant concentration, using a site-specific higher partition coefficient, slightly lower TOC) have the effect of lowering equilibrium-based desorption rates to below 1 percent of the underlying contaminant mass per year.

Desorption from suspended sediments appears to be a relatively minor component of ongoing loss of contaminant mass from PV Shelf sediments. Other fate and transport mechanisms, such as chemical degradation and transport of particulate-bound contaminant compounds by currents are more significant at the PV Shelf Study Area.

7.4 Combinations of Processes Affecting Fate and Transport

The following combinations of the fate and transport processes affect the distribution of DDTs and PCBs at the PV Shelf Study Area:

Sediment Transport – Sediment transport on the PV Shelf is driven by near-bottom currents generated by surface waves, internal motions, tides, and regional circulation forced by large-scale meteorological and oceanographic conditions. Transport of contaminants occurs along with particulates, particularly finer and more organic particles. Low-frequency motions (those with periods in excess of 4 to 6 hours, including tidal currents, internal tides, and regional circulation) are not strong enough to cause sediment motion at most depths of interest. Current speeds in excess of approximately 20 cm/sec, measured 1 m above the bottom, are required to initiate motion in fine, non-cohesive sand, which is the most mobile sediment found on the PV Shelf. Mobilization of bottom sediments is caused mostly by wave-induced oscillatory currents, with some help by lower-frequency motions. Regional circulation and tidal currents are not strong enough to remobilize bottom sediments. Local winds and wind-generated waves have less significance, as are buoyancy effects associated with local river runoff. Surface currents are also relatively unimportant, because the contaminants were introduced in deep water (60 m). Shallow water processes are important only insofar as waves and near-shore transport move Portuguese Bend Landslide material alongshore and offshore.

Dispersal – A significant fraction of the material (especially slowly settling particles) resuspended from the effluent-affected deposit will be transported off the PV Shelf before it settles back to the bottom. Individual particles could frequently undergo resuspension, transport, and deposition and gradually disperse from the site, and settle in areas where they are resuspended less frequently. Thus, there is a tendency for finer material to be selectively winnowed from sediment in near-shore regions, and for shelf sediment to settle on the slope or in the deeper basins.

Non-deposition – Some areas have relatively energetic near-bottom waves or currents that effectively prevent fine contaminated material from accumulating on the bottom. For example, in the shallow near-shore regions, very little contamination has accumulated in depths less than 30 m because fine material is either never deposited or quickly winnowed from these regions. Parts of the San Pedro Shelf might be non-depositional because currents frequently mobilize most of the contaminated particles. As a result, effluent-affected material rarely accumulates in this area.

Deposition or Erosion – If sediment is more often transported into than out of an area, sediment will accumulate (deposition), and tend to bury existing contaminated sediment. The downward movement of the peak concentrations of DDT and PCBs, as seen in cores north of the outfalls, can be the result of sediment deposition. The opposite occurs if transport out of an area is higher than the rate of transport in, and buried contaminants can be exhumed (erosion). The area southeast of the outfalls appears to be erosive.

Dilution or Enrichment – The concentration of contaminants in the top layer of sediments can be decreased (or increased) by advection of cleaner (or more contaminated) material. If material transported into an area is less contaminated than material transported out of the area, contaminant concentrations will decrease, even without erosion or deposition.

The opposite can also occur and be responsible for maintaining elevated surface sediment contamination levels.

Physical Reworking – Even without net transport, material can be physically reworked by waves and currents. USGS model calculations indicate that only a thin layer (a few millimeters to a centimeter) are likely to be reworked during typical resuspension events, but in combination with uneven (small-scale, biogenic) bottom topography and some sediment transport, reworking depths could be slightly greater (up to 5 cm). In combination with bioturbation, this keeps the top few centimeters of sediment and pore water homogenous.

Compaction – Compaction influences fate and transport indirectly by decreasing the erodibility of the sediment. It also influences estimates of deposition and erosion based on profile changes. The effluent-affected sediment is thought to have compacted over time, resulting in 10 to 15 percent increases in bulk density, particularly in the upper layers.

Resuspension and Desorption – This combination of processes involves resuspension of contaminated sediment and subsequent desorption of DDTs or PCBs from the particles into seawater. Mixing and transport of the seawater widely dispersed the dissolved contaminant throughout the SCB; the sediment that settles back to the bottom is slightly less contaminated. This process also occurs during horizontal transport. USGS calculations suggest that the process of resuspension and desorption is responsible for the annual loss (transfer to overlying water column and rest of SCB) of about 10 percent of the DDE in the top 5 cm of sediment.

Sorption/Desorption in Bed Sediments – Contaminants can be desorbed from sediment particles to pore water, or sorbed from pore water onto sediment particles. Movement of pore water caused by irrigation or bioturbation can occur, with sorption back onto sediment particles through re-equilibration after the dissolved phase.

Bioturbation – Biodiffusion and non-local transport move contaminant in sediment and pore water. Current calculations concerning biodiffusion have indicated that contaminant transport is caused by random mixing in the presence of a concentration gradient. This process is thought to represent one of the two most important mechanisms for moving buried contaminants into surface-layer sediment (the other is erosion, which actually moves the sediment-water interface down, closer to the deeper sediment). However, non-local transport (directed movement of sediment during, for example, head-down deposit feeding) can contribute to transport of sediment.

Bioirrigation – The circulation of pore water by benthic activities helps transport dissolved contaminant within the sediment and into overlying water. Quantitatively, it is less significant than solid-phase transport because the majority of the contaminants remain sorbed to sediment.

7.5 Exposure Pathways and Receptors

Exposure pathways refer to the media and routes through which contaminants could reach ecological receptors. Exposure pathways might or might not be complete, depending on whether DDTs and PCBs have the potential to affect ecological receptors now or in the

future. Potential exposure pathways must meet specific criteria for an exposure to occur. A complete exposure pathway must satisfy the following elements:

- Contaminant source (e.g., chemicals in sediment)
- Mechanism for contaminant release and transport (e.g., erosion)
- Exposure point (e.g., sediment/water interface)
- Feasible route of exposure (e.g., ingestion)
- Receptor (e.g., bird, human)

Aquatic exposures and food web relationships are the major exposure pathways in the PV Shelf Study Area. DDTs and PCBs are strongly sorbed to organic matter and sediments and can result in direct exposure to contaminants in the sediment and sediment pore water. However, owing to the highly lipophilic nature of these contaminants and their propensity to biomagnify through the food web, indirect contact through the consumption of food items is considered the major pathway of exposure to organisms in the upper trophic levels. Sediment contaminants can also be released to the water column during resuspension of sediments and through diffusional flux to the water column from the sediment surface, which could be a secondary exposure pathway. The most important, measurable parameter is the level of contaminants in the biologically active top few centimeters of bottom sediment.

Primary trophic-level organisms form the basis of the food chain, and their exposures to contaminants occur in the sediments in the overlying water column. These organisms include polychaete worms, bivalves, crustaceans, zooplankton and phytoplankton. Secondary trophic-level organisms include several groups of animals, such as invertebrates, fish, and mammals that feed on the primary receptors. Tertiary trophic-level organisms include some fish species, fish-eating birds, and toothed marine mammals that feed on the secondary-level animals. The ERA indicates risks for all ecological receptors evaluated (benthic invertebrates, fish, birds, and mammals).

The most significant and complete human exposure pathway is consumption of fish caught on the PV Shelf. Humans can be exposed to DDTs and PCBs by consuming contaminated fish caught by recreational boat anglers, pier and jetty anglers, and commercial fishers. Contaminated fish could be consumed by many members of a household, including children and women of child-bearing age. Women who are nursing and have consumed contaminated fish could expose their infants to DDTs and PCBs through their breast milk. The recent HHRE has indicated cancer risk ranging from 7×10^{-3} to 6×10^{-6} for a range of fish consumption rates and several fish species, based on the 95 percent UCLs. The HI values are from below 1 to 198. Because human exposures to contaminated sediment or surface waters are minimal, these exposure pathways are not considered significant.

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Appendix A
Palos Verdes Shelf Sediment Data

Table A-1

Sediment Concentrations of DDTs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
101-B5 DDT-1 (0-2)	500	101-B5	0	2	34.16	-119.38	7/3/1992	05:24	11	Total_DDT	0.0152	mg/kg dry
101-B5 DDT-1 (0-2)	500	101-B5	0	2	34.16	-119.38	7/3/1992	05:24	11	Total_DDT	0.079	mg/kg dry
101-B5 DDT-1 (0-2)	500	101-B5	0	2	34.16	-119.38	7/3/1992	05:24	11	Total_DDT	0.0795	mg/kg dry
101-B5 DDT-1 (2-4)	500	101-B5	2	4	34.16	-119.38	7/3/1992	05:24	11	Total_DDT	0.0158	mg/kg dry
101-B5 DDT-1 (2-4)	500	101-B5	2	4	34.16	-119.38	7/3/1992	05:24	11	Total_DDT	0.018	mg/kg dry
101-B5 DDT-1 (4-6)	500	101-B5	4	6	34.16	-119.38	7/3/1992	05:24	11	Total_DDT	0.0231	mg/kg dry
101-B5 DDT-1 (6-8)	500	101-B5	6	8	34.16	-119.38	7/3/1992	05:24	11	Total_DDT	0.0284	mg/kg dry
102-B1 DDT-1 (0-2)	524	102-B1	0	2	33.72	-118.41	7/3/1992	14:03	72	Total_DDT	4.08	mg/kg dry
102-B1 DDT-1 (10-12)	524	102-B1	10	12	33.72	-118.41	7/3/1992	14:03	72	Total_DDT	0.797	mg/kg dry
102-B1 DDT-1 (12-14)	524	102-B1	12	14	33.72	-118.41	7/3/1992	14:03	72	Total_DDT	0.816	mg/kg dry
102-B1 DDT-1 (14-16)	524	102-B1	14	16	33.72	-118.41	7/3/1992	14:03	72	Total_DDT	0.977	mg/kg dry
102-B1 DDT-1 (2-4)	524	102-B1	2	4	33.72	-118.41	7/3/1992	14:03	72	Total_DDT	5.94	mg/kg dry
102-B1 DDT-1 (2-4)	524	102-B1	2	4	33.72	-118.41	7/3/1992	14:03	72	Total_DDT	6.92	mg/kg dry
102-B1 DDT-1 (4-6)	524	102-B1	4	6	33.72	-118.41	7/3/1992	14:03	72	Total_DDT	3.7	mg/kg dry
102-B1 DDT-1 (6-8)	524	102-B1	6	8	33.72	-118.41	7/3/1992	14:03	72	Total_DDT	4.39	mg/kg dry
102-B1 DDT-1 (8-10)	524	102-B1	8	10	33.72	-118.41	7/3/1992	14:03	72	Total_DDT	1.71	mg/kg dry
106-B1 DDT (0-4)	518	106-B1	0	4	33.73	-118.42	7/4/1992	05:31	28	Total_DDT	2.77	mg/kg dry
106-B1 DDT (4-8)	518	106-B1	4	8	33.73	-118.42	7/4/1992	05:31	28	Total_DDT	2.26	mg/kg dry
106-B1 DDT (8-12)	518	106-B1	8	12	33.73	-118.42	7/4/1992	05:31	28	Total_DDT	6.07	mg/kg dry
106-B1 DDT (8-12)	518	106-B1	8	12	33.73	-118.42	7/4/1992	05:31	28	Total_DDT	0.26	mg/kg dry
106-B1 DDT (8-12)	518	106-B1	8	12	33.73	-118.42	7/4/1992	05:31	28	Total_DDT	0.264	mg/kg dry
108-B2 DDT (0-2)	523	108-B2	0	2	33.72	-118.41	7/4/1992	12:21	43	Total_DDT	3.67	mg/kg dry
108-B2 DDT (10-12)	523	108-B2	10	12	33.72	-118.41	7/4/1992	12:21	43	Total_DDT	5.8	mg/kg dry
108-B2 DDT (12-14)	523	108-B2	12	14	33.72	-118.41	7/4/1992	12:21	43	Total_DDT	4.13	mg/kg dry
108-B2 DDT (14-16)	523	108-B2	14	16	33.72	-118.41	7/4/1992	12:21	43	Total_DDT	1.84	mg/kg dry
108-B2 DDT (16-18)	523	108-B2	16	18	33.72	-118.41	7/4/1992	12:21	43	Total_DDT	0.585	mg/kg dry
108-B2 DDT (2-4)	523	108-B2	2	4	33.72	-118.41	7/4/1992	12:21	43	Total_DDT	4	mg/kg dry
108-B2 DDT (4-6)	523	108-B2	4	6	33.72	-118.41	7/4/1992	12:21	43	Total_DDT	5.69	mg/kg dry
108-B2 DDT (6-8)	523	108-B2	6	8	33.72	-118.41	7/4/1992	12:21	43	Total_DDT	7.66	mg/kg dry
108-B2 DDT (8-10)	523	108-B2	8	10	33.72	-118.41	7/4/1992	12:21	43	Total_DDT	9.87	mg/kg dry
109-W1 DDT (0-2)	522	109-W1	0	2	33.73065	-118.4012	7/4/1992	15:12	18	Total_DDT	3.65	mg/kg dry
109-W1 DDT (2-4)	522	109-W1	2	4	33.73065	-118.4012	7/4/1992	15:12	18	Total_DDT	3.81	mg/kg dry
109-W1 DDT (2-4)	522	109-W1	2	4	33.73065	-118.4012	7/4/1992	15:12	18	Total_DDT	3.81	mg/kg dry
109-W1 DDT (4-6)	522	109-W1	4	6	33.73065	-118.4012	7/4/1992	15:12	18	Total_DDT	4.1	mg/kg dry
109-W1 DDT (6-8)	522	109-W1	6	8	33.73065	-118.4012	7/4/1992	15:12	18	Total_DDT	3.93	mg/kg dry
109-W1 DDT (8-10)	522	109-W1	8	10	33.73065	-118.4012	7/4/1992	15:12	18	Total_DDT	4.02	mg/kg dry
109-W1 DDT (10-12)	522	109-W1	10	12	33.73065	-118.4012	7/4/1992	15:12	18	Total_DDT	3.75	mg/kg dry
109-W1 DDT (12-14)	522	109-W1	12	14	33.73065	-118.4012	7/4/1992	15:12	18	Total_DDT	4.19	mg/kg dry
109-W1 DDT (14-16)	522	109-W1	14	16	33.73065	-118.4012	7/4/1992	15:12	18	Total_DDT	4.14	mg/kg dry
109-W1 DDT (16-18)	522	109-W1	16	18	33.73065	-118.4012	7/4/1992	15:12	18	Total_DDT	4.22	mg/kg dry

Table A-1

Sediment Concentrations of DDTs[1]

Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)

Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
109-W1 DDT (18-20)	522	109-W1	18	20	33.73065	-118.4012	7/4/1992	15:12	18	Total_DDT	4.53	mg/kg dry
109-W1 DDT (20-22)	522	109-W1	20	22	33.73065	-118.4012	7/4/1992	15:12	18	Total_DDT	4.28	mg/kg dry
109-W1 DDT (20-22)	522	109-W1	20	22	33.73065	-118.4012	7/4/1992	15:12	18	Total_DDT	0.309	mg/kg dry
109-W1 DDT (20-22)	522	109-W1	20	22	33.73065	-118.4012	7/4/1992	15:12	18	Total_DDT	0.447	mg/kg dry
109-W1 DDT (22-24)	522	109-W1	22	24	33.73065	-118.4012	7/4/1992	15:12	18	Total_DDT	4.05	mg/kg dry
109-W2 DDT (0-2)	522	109-W2	0	2	33.73	-118.40	7/5/1992	15:32	16	Total_DDT	3.14	mg/kg dry
109-W2 DDT (2-4)	522	109-W2	2	4	33.73	-118.40	7/5/1992	15:32	16	Total_DDT	2.96	mg/kg dry
109-W2 DDT (4-6)	522	109-W2	4	6	33.73	-118.40	7/5/1992	15:32	16	Total_DDT	3.78	mg/kg dry
109-W2 DDT (6-8)	522	109-W2	6	8	33.73	-118.40	7/5/1992	15:32	16	Total_DDT	3.98	mg/kg dry
109-W2 DDT (8-10)	522	109-W2	8	10	33.73	-118.40	7/5/1992	15:32	16	Total_DDT	3.63	mg/kg dry
109-W2 DDT (10-12)	522	109-W2	10	12	33.73	-118.40	7/5/1992	15:32	16	Total_DDT	3.64	mg/kg dry
109-W2 DDT (12-14)	522	109-W2	12	14	33.73	-118.40	7/5/1992	15:32	16	Total_DDT	4.2	mg/kg dry
109-W2 DDT (14-16)	522	109-W2	14	16	33.73	-118.40	7/5/1992	15:32	16	Total_DDT	3.86	mg/kg dry
109-W2 DDT (16-18)	522	109-W2	16	18	33.73	-118.40	7/5/1992	15:32	16	Total_DDT	3.77	mg/kg dry
109-W2 DDT (16-18)	522	109-W2	16	18	33.73	-118.40	7/5/1992	15:32	16	Total_DDT	3.52	mg/kg dry
109-W2 DDT (18-20)	522	109-W2	18	20	33.73	-118.40	7/5/1992	15:32	16	Total_DDT	2.93	mg/kg dry
109-W2 DDT (18-20)	522	109-W2	18	20	33.73	-118.40	7/5/1992	15:32	16	Total_DDT	0.051	mg/kg dry
109-W2 DDT (18-20)	522	109-W2	18	20	33.73	-118.40	7/5/1992	15:32	16	Total_DDT	0.126	mg/kg dry
111-B1 DDT (0-4)	539	111-B1	0	4	33.72	-118.37	7/5/1992	00:56	13	Total_DDT	4.06	mg/kg dry
111-B1 DDT (4-8)	539	111-B1	4	8	33.72	-118.37	7/5/1992	00:56	13	Total_DDT	3.17	mg/kg dry
111-B1 DDT (8-12)	539	111-B1	8	12	33.72	-118.37	7/5/1992	00:56	13	Total_DDT	3.12	mg/kg dry
111-B1 DDT (12-16)	539	111-B1	12	16	33.72	-118.37	7/5/1992	00:56	13	Total_DDT	2.34	mg/kg dry
111-B1 DDT (16-20)	539	111-B1	16	20	33.72	-118.37	7/5/1992	00:56	13	Total_DDT	3.6	mg/kg dry
111-B1 DDT (20-24)	539	111-B1	20	24	33.72	-118.37	7/5/1992	00:56	13	Total_DDT	4.23	mg/kg dry
111-B1 DDT (24-28)	539	111-B1	24	28	33.72	-118.37	7/5/1992	00:56	13	Total_DDT	4.1	mg/kg dry
111-B1 DDT (28-32)	539	111-B1	28	32	33.72	-118.37	7/5/1992	00:56	13	Total_DDT	3.6	mg/kg dry
111-B1 DDT (32-36)	539	111-B1	32	36	33.72	-118.37	7/5/1992	00:56	13	Total_DDT	4.82	mg/kg dry
111-B1 DDT (36-40)	539	111-B1	36	40	33.72	-118.37	7/5/1992	00:56	13	Total_DDT	4.55	mg/kg dry
111-B1 DDT (40-44)	539	111-B1	40	44	33.72	-118.37	7/5/1992	00:56	13	Total_DDT	4.61	mg/kg dry
111-B1 DDT (44-48)	539	111-B1	44	48	33.72	-118.37	7/5/1992	00:56	13	Total_DDT	1.94	mg/kg dry
111-B1 DDT (48-52)	539	111-B1	48	52	33.72	-118.37	7/5/1992	00:56	13	Total_DDT	5.59	mg/kg dry
111-B1 DDT (52-56)	539	111-B1	52	56	33.72	-118.37	7/5/1992	00:56	13	Total_DDT	16	mg/kg dry
111-B1 DDT (56-60)	539	111-B1	56	60	33.72	-118.37	7/5/1992	00:56	13	Total_DDT	16.2	mg/kg dry
113-B1 DDT (0-4)	542	113-B1	0	4	33.71	-118.39	7/5/1992	06:41	64	Total_DDT	1.88	mg/kg dry
113-B1 DDT (4-8)	542	113-B1	4	8	33.71	-118.39	7/5/1992	06:41	64	Total_DDT	0.855	mg/kg dry
113-B1 DDT (8-12)	542	113-B1	8	12	33.71	-118.39	7/5/1992	06:41	64	Total_DDT	0.377	mg/kg dry
113-B1 DDT (12-16)	542	113-B1	12	16	33.71	-118.39	7/5/1992	06:41	64	Total_DDT	0.167	mg/kg dry
113-B1 DDT (16-20)	542	113-B1	16	20	33.71	-118.39	7/5/1992	06:41	64	Total_DDT	NR	mg/kg dry
114-B1 DDT (0-4)	543	114-B1	0	4	33.70731	-118.3889	7/5/1992	09:35	122	Total_DDT	1.76	mg/kg dry
114-B1 DDT (4-8)	543	114-B1	4	8	33.70731	-118.3889	7/5/1992	09:35	122	Total_DDT	0.642	mg/kg dry

Table A-1

Sediment Concentrations of DDTs[1]

Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)

Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
114-B1 DDT (8-12)	543	114-B1	8	12	33.70731	-118.3889	7/5/1992	09:35	122	Total_DDT	0.199	mg/kg dry
114-B1 DDT (12-16)	543	114-B1	12	16	33.70731	-118.3889	7/5/1992	09:35	122	Total_DDT	0.206	mg/kg dry
115-B2 DDT (0-4)	544	115-B2	0	4	33.69831	-118.3919	7/5/1992	13:34	153	Total_DDT	3.87	mg/kg dry
115-B2 DDT (4-8)	544	115-B2	4	8	33.69831	-118.3919	7/5/1992	13:34	153	Total_DDT	9.8	mg/kg dry
117-B4 DDT (0-4)	571	117-B4	0	4	33.68	-118.32	7/6/1992	01:28	47	Total_DDT	14.6	mg/kg dry
117-B4 DDT (4-8)	571	117-B4	4	8	33.68	-118.32	7/6/1992	01:28	47	Total_DDT	33.8	mg/kg dry
117-B4 DDT (8-12)	571	117-B4	8	12	33.68	-118.32	7/6/1992	01:28	47	Total_DDT	19	mg/kg dry
117-B4 DDT (12-16)	571	117-B4	12	16	33.68	-118.32	7/6/1992	01:28	47	Total_DDT	6.23	mg/kg dry
117-B4 DDT (16-20)	571	117-B4	16	20	33.68	-118.32	7/6/1992	01:28	47	Total_DDT	1.13	mg/kg dry
120-B1 DDT (0-4)	577	120-B1	0	4	33.68	-118.31	7/6/1992	08:10	19	Total_DDT	3.4	mg/kg dry
120-B1 DDT (4-8)	577	120-B1	4	8	33.68	-118.31	7/6/1992	08:10	19	Total_DDT	1.05	mg/kg dry
120-B1 DDT (8-12)	577	120-B1	8	12	33.68	-118.31	7/6/1992	08:10	19	Total_DDT	9.84	mg/kg dry
120-B1 DDT (12-16)	577	120-B1	12	16	33.68	-118.31	7/6/1992	08:10	19	Total_DDT	9.92	mg/kg dry
120-B1 DDT (16-20)	577	120-B1	16	20	33.68	-118.31	7/6/1992	08:10	19	Total_DDT	2.26	mg/kg dry
120-B1 DDT (20-24)	577	120-B1	20	24	33.68	-118.31	7/6/1992	08:10	19	Total_DDT	0.732	mg/kg dry
120-B1 DDT (20-24)	577	120-B1	20	24	33.68	-118.31	7/6/1992	08:10	19	Total_DDT	0.0231	mg/kg dry
120-B1 DDT (20-24)	577	120-B1	20	24	33.68	-118.31	7/6/1992	08:10	19	Total_DDT	0.0929	mg/kg dry
120-B1 DDT (24-28)	577	120-B1	24	28	33.68	-118.31	7/6/1992	08:10	19	Total_DDT	1.15	mg/kg dry
120-B1 DDT (24-28)	577	120-B1	24	28	33.68	-118.31	7/6/1992	08:10	19	Total_DDT	1.13	mg/kg dry
121-B1 DDT (0-4)	570	121-B1	0	4	33.69	-118.32	7/6/1992	10:30	21	Total_DDT	3.58	mg/kg dry
121-B1 DDT (4-8)	570	121-B1	4	8	33.69	-118.32	7/6/1992	10:30	21	Total_DDT	4.13	mg/kg dry
121-B1 DDT (8-12)	570	121-B1	8	12	33.69	-118.32	7/6/1992	10:30	21	Total_DDT	8.88	mg/kg dry
121-B1 DDT (8-12)	570	121-B1	8	12	33.69	-118.32	7/6/1992	10:30	21	Total_DDT	0.0122	mg/kg dry
121-B1 DDT (8-12)	570	121-B1	8	12	33.69	-118.32	7/6/1992	10:30	21	Total_DDT	0.0184	mg/kg dry
121-B1 DDT (12-16)	570	121-B1	12	16	33.69	-118.32	7/6/1992	10:30	21	Total_DDT	19.1	mg/kg dry
121-B1 DDT (16-20)	570	121-B1	16	20	33.69	-118.32	7/6/1992	10:30	21	Total_DDT	18.1	mg/kg dry
121-B1 DDT (20-24)	570	121-B1	20	24	33.69	-118.32	7/6/1992	10:30	21	Total_DDT	11.7	mg/kg dry
121-B1 DDT (24-28)	570	121-B1	24	28	33.69	-118.32	7/6/1992	10:30	21	Total_DDT	8.7	mg/kg dry
121-B1 DDT (28-32)	570	121-B1	28	32	33.69	-118.32	7/6/1992	10:30	21	Total_DDT	1.66	mg/kg dry
121-B1 DDT (32-36)	570	121-B1	32	36	33.69	-118.32	7/6/1992	10:30	21	Total_DDT	0.32	mg/kg dry
122-B1 DDT (0-4)	566	122-B1	0	4	33.69	-118.34	7/6/1992	13:33	60	Total_DDT	5.89	mg/kg dry
122-B1 DDT (4-8)	566	122-B1	4	8	33.69	-118.34	7/6/1992	13:33	60	Total_DDT	16.1	mg/kg dry
122-B1 DDT (8-12)	566	122-B1	8	12	33.69	-118.34	7/6/1992	13:33	60	Total_DDT	2.74	mg/kg dry
122-B1 DDT (12-16)	566	122-B1	12	16	33.69	-118.34	7/6/1992	13:33	60	Total_DDT	1.01	mg/kg dry
122-B1 DDT (16-20)	566	122-B1	16	20	33.69	-118.34	7/6/1992	13:33	60	Total_DDT	0.243	mg/kg dry
122-B1 DDT (20-24)	566	122-B1	20	24	33.69	-118.34	7/6/1992	13:33	60	Total_DDT	0.0664	mg/kg dry
123-W2 DDT (0-2)	522	123-W2	0	2	33.73	-118.40	7/6/1992	16:50	16	Total_DDT	3.65	mg/kg dry
123-W2 DDT (2-4)	522	123-W2	2	4	33.73	-118.40	7/6/1992	16:50	16	Total_DDT	2.92	mg/kg dry
123-W2 DDT (4-6)	522	123-W2	4	6	33.73	-118.40	7/6/1992	16:50	16	Total_DDT	3.19	mg/kg dry
123-W2 DDT (6-8)	522	123-W2	6	8	33.73	-118.40	7/6/1992	16:50	16	Total_DDT	2	mg/kg dry

Table A-1

Sediment Concentrations of DDTs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
123-W2 DDT (8-10)	522	123-W2	8	10	33.73	-118.40	7/6/1992	16:50	16	Total_DDT	4.18	mg/kg dry
123-W2 DDT (10-12)	522	123-W2	10	12	33.73	-118.40	7/6/1992	16:50	16	Total_DDT	4.39	mg/kg dry
123-W2 DDT (12-14)	522	123-W2	12	14	33.73	-118.40	7/6/1992	16:50	16	Total_DDT	4.56	mg/kg dry
123-W2 DDT (14-16)	522	123-W2	14	16	33.73	-118.40	7/6/1992	16:50	16	Total_DDT	4.07	mg/kg dry
123-W2 DDT (16-18)	522	123-W2	16	18	33.73	-118.40	7/6/1992	16:50	16	Total_DDT	3.59	mg/kg dry
123-W2 DDT (18-20)	522	123-W2	18	20	33.73	-118.40	7/6/1992	16:50	16	Total_DDT	3.63	mg/kg dry
123-W2 DDT (20-22)	522	123-W2	20	22	33.73	-118.40	7/6/1992	16:50	16	Total_DDT	4.39	mg/kg dry
123-W2 DDT (22-24)	522	123-W2	22	24	33.73	-118.40	7/6/1992	16:50	16	Total_DDT	6.56	mg/kg dry
123-W2 DDT (24-26)	522	123-W2	24	26	33.73	-118.40	7/6/1992	16:50	16	Total_DDT	6.91	mg/kg dry
123-W2 DDT (26-28)	522	123-W2	26	28	33.73	-118.40	7/6/1992	16:50	16	Total_DDT	6.18	mg/kg dry
123-W2 DDT (26-28)	522	123-W2	26	28	33.73	-118.40	7/6/1992	16:50	16	Total_DDT	5.96	mg/kg dry
123-W2 DDT (28-30)	522	123-W2	28	30	33.73	-118.40	7/6/1992	16:50	16	Total_DDT	6.56	mg/kg dry
124-B1 DDT (0-2)	522	124-B1	0	2	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	4.93	mg/kg dry
124-B1 DDT (10-12)	522	124-B1	10	12	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	4.39	mg/kg dry
124-B1 DDT (12-14)	522	124-B1	12	14	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	4.07	mg/kg dry
124-B1 DDT (14-16)	522	124-B1	14	16	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	4.37	mg/kg dry
124-B1 DDT (16-18)	522	124-B1	16	18	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	2.79	mg/kg dry
124-B1 DDT (18-20)	522	124-B1	18	20	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	2.45	mg/kg dry
124-B1 DDT (2-4)	522	124-B1	2	4	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	4.69	mg/kg dry
124-B1 DDT (20-22)	522	124-B1	20	22	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	4.07	mg/kg dry
124-B1 DDT (22-24)	522	124-B1	22	24	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	5.15	mg/kg dry
124-B1 DDT (24-26)	522	124-B1	24	26	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	6.23	mg/kg dry
124-B1 DDT (26-28)	522	124-B1	26	28	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	6.69	mg/kg dry
124-B1 DDT (28-30)	522	124-B1	28	30	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	8.85	mg/kg dry
124-B1 DDT (30-32)	522	124-B1	30	32	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	22.3	mg/kg dry
124-B1 DDT (32-34)	522	124-B1	32	34	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	18.2	mg/kg dry
124-B1 DDT (34-36)	522	124-B1	34	36	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	11.9	mg/kg dry
124-B1 DDT (36-38)	522	124-B1	36	38	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	17.4	mg/kg dry
124-B1 DDT (38-40)	522	124-B1	38	40	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	8.79	mg/kg dry
124-B1 DDT (4-6)	522	124-B1	4	6	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	4.02	mg/kg dry
124-B1 DDT (40-42)	522	124-B1	40	42	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	3.26	mg/kg dry
124-B1 DDT (42-44)	522	124-B1	42	44	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	1.7	mg/kg dry
124-B1 DDT (44-46)	522	124-B1	44	46	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	1.49	mg/kg dry
124-B1 DDT (46-48)	522	124-B1	46	48	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	1.27	mg/kg dry
124-B1 DDT (6-8)	522	124-B1	6	8	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	3.42	mg/kg dry
124-B1 DDT (8-10)	522	124-B1	8	10	33.73	-118.40	7/6/1992	21:26	17	Total_DDT	5.5	mg/kg dry
125-B2 DDT (0-2)	554	125-B2	0	2	33.72	-118.35	7/7/1992	01:36	15	Total_DDT	0.856	mg/kg dry
125-B2 DDT (2-4)	554	125-B2	2	4	33.72	-118.35	7/7/1992	01:36	15	Total_DDT	0.854	mg/kg dry
125-B2 DDT (4-6)	554	125-B2	4	6	33.72	-118.35	7/7/1992	01:36	15	Total_DDT	1.19	mg/kg dry
125-B2 DDT (6-8)	554	125-B2	6	8	33.72	-118.35	7/7/1992	01:36	15	Total_DDT	1.02	mg/kg dry

Table A-1

Sediment Concentrations of DDTs[1]

Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)

Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
125-B2 DDT (8-10)	554	125-B2	8	10	33.72	-118.35	7/7/1992	01:36	15	Total_DDT	0.936	mg/kg dry
125-B2 DDT (20-24)	554	125-B2	20	24	33.72	-118.35	7/7/1992	01:36	15	Total_DDT	2.77	mg/kg dry
125-B2 DDT (24-28)	554	125-B2	24	28	33.72	-118.35	7/7/1992	01:36	15	Total_DDT	1.8	mg/kg dry
125-B2 DDT (28-32)	554	125-B2	28	32	33.72	-118.35	7/7/1992	01:36	15	Total_DDT	1.3	mg/kg dry
125-B2 DDT (32-36)	554	125-B2	32	36	33.72	-118.35	7/7/1992	01:36	15	Total_DDT	0.729	mg/kg dry
125-B2 DDT (36-39)	554	125-B2	36	39	33.72	-118.35	7/7/1992	01:36	15	Total_DDT	0.749	mg/kg dry
125-B2 DDT (10-13)	554	125-B2	10	13	33.72	-118.35	7/7/1992	01:36	15	Total_DDT	0.461	mg/kg dry
125-B2 DDT (13-16)	554	125-B2	13	16	33.72	-118.35	7/7/1992	01:36	15	Total_DDT	0.366	mg/kg dry
125-B2 DDT (16-20)	554	125-B2	16	20	33.72	-118.35	7/7/1992	01:36	15	Total_DDT	0.454	mg/kg dry
127-B1 DDT (0-2)	557	127-B1	0	2	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	12.2	mg/kg dry
127-B1 DDT (10-12)	557	127-B1	10	12	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	10.4	mg/kg dry
127-B1 DDT (12-14)	557	127-B1	12	14	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	18.5	mg/kg dry
127-B1 DDT (14-16)	557	127-B1	14	16	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	37.4	mg/kg dry
127-B1 DDT (16-18)	557	127-B1	16	18	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	41.9	mg/kg dry
127-B1 DDT (18-20)	557	127-B1	18	20	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	32	mg/kg dry
127-B1 DDT (2-4)	557	127-B1	2	4	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	10.4	mg/kg dry
127-B1 DDT (20-22)	557	127-B1	20	22	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	46.4	mg/kg dry
127-B1 DDT (22-24)	557	127-B1	22	24	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	108	mg/kg dry
127-B1 DDT (24-26)	557	127-B1	24	26	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	66.9	mg/kg dry
127-B1 DDT (26-28)	557	127-B1	26	28	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	78.5	mg/kg dry
127-B1 DDT (28-30)	557	127-B1	28	30	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	81.4	mg/kg dry
127-B1 DDT (30-32)	557	127-B1	30	32	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	29.8	mg/kg dry
127-B1 DDT (30-32)	557	127-B1	30	32	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	0.717	mg/kg dry
127-B1 DDT (30-32)	557	127-B1	30	32	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	0.815	mg/kg dry
127-B1 DDT (32-34)	557	127-B1	32	34	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	16.2	mg/kg dry
127-B1 DDT (4-6)	557	127-B1	4	6	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	7.71	mg/kg dry
127-B1 DDT (6-8)	557	127-B1	6	8	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	7.58	mg/kg dry
127-B1 DDT (8-10)	557	127-B1	8	10	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	9.21	mg/kg dry
127-B1 DDT (34-38)	557	127-B1	34	38	33.70	-118.35	7/7/1992	03:36	27	Total_DDT	2.13	mg/kg dry
128-B1 DDT (0-4)	563	128-B1	0	4	33.71	-118.34	7/7/1992	05:48	12	Total_DDT	0.655	mg/kg dry
128-B1 DDT (4-8)	563	128-B1	4	8	33.71	-118.34	7/7/1992	05:48	12	Total_DDT	0.603	mg/kg dry
128-B1 DDT (4-8)	563	128-B1	4	8	33.71	-118.34	7/7/1992	05:48	12	Total_DDT	0.281	mg/kg dry
128-B1 DDT (4-8)	563	128-B1	4	8	33.71	-118.34	7/7/1992	05:48	12	Total_DDT	0.288	mg/kg dry
128-B1 DDT (8-12)	563	128-B1	8	12	33.71	-118.34	7/7/1992	05:48	12	Total_DDT	0.286	mg/kg dry
128-B1 DDT (8-12)	563	128-B1	8	12	33.71	-118.34	7/7/1992	05:48	12	Total_DDT	0.293	mg/kg dry
128-B1 DDT (12-16)	563	128-B1	12	16	33.71	-118.34	7/7/1992	05:48	12	Total_DDT	0.348	mg/kg dry
128-B1 DDT (16-20)	563	128-B1	16	20	33.71	-118.34	7/7/1992	05:48	12	Total_DDT	0.548	mg/kg dry
128-B1 DDT (20-24)	563	128-B1	20	24	33.71	-118.34	7/7/1992	05:48	12	Total_DDT	0.268	mg/kg dry
128-B1 DDT (24-28)	563	128-B1	24	28	33.71	-118.34	7/7/1992	05:48	12	Total_DDT	0.659	mg/kg dry
128-B1 DDT (28-32)	563	128-B1	28	32	33.71	-118.34	7/7/1992	05:48	12	Total_DDT	0.478	mg/kg dry

Table A-1

Sediment Concentrations of DDTs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
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Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
130-B1 DDT (0-4)	553	130-B1	0	4	33.70081	-118.3790	7/7/1992	12:48	115	Total_DDT	5.08	mg/kg dry
130-B1 DDT (4-8)	553	130-B1	4	8	33.70081	-118.3790	7/7/1992	12:48	115	Total_DDT	4.09	mg/kg dry
130-B1 DDT (8-12)	553	130-B1	8	12	33.70081	-118.3790	7/7/1992	12:48	115	Total_DDT	1.58	mg/kg dry
130-B1 DDT (12-16)	553	130-B1	12	16	33.70081	-118.3790	7/7/1992	12:48	115	Total_DDT	1.45	mg/kg dry
131-W1 DDT (6-8)	556	131-W1	6	8	33.71	-118.35	7/7/1992	15:37	16	Total_DDT	35.6	mg/kg dry
131-W1 DDT (0-2)	556	131-W1	0	2	33.71	-118.35	7/7/1992	15:37	16	Total_DDT	9.63	mg/kg dry
131-W1 DDT (10-12)	556	131-W1	10	12	33.71	-118.35	7/7/1992	15:37	16	Total_DDT	17.2	mg/kg dry
131-W1 DDT (2-4)	556	131-W1	2	4	33.71	-118.35	7/7/1992	15:37	16	Total_DDT	9.7	mg/kg dry
131-W1 DDT (4-6)	556	131-W1	4	6	33.71	-118.35	7/7/1992	15:37	16	Total_DDT	17	mg/kg dry
131-W1 DDT (8-10)	556	131-W1	8	10	33.71	-118.35	7/7/1992	15:37	16	Total_DDT	9.77	mg/kg dry
131-W1 DDT (12-14)	556	131-W1	12	14	33.71	-118.35	7/7/1992	15:37	16	Total_DDT	14.7	mg/kg dry
131-W1 DDT (14-16)	556	131-W1	14	16	33.71	-118.35	7/7/1992	15:37	16	Total_DDT	14.1	mg/kg dry
131-W1 DDT (16-18)	556	131-W1	16	18	33.71	-118.35	7/7/1992	15:37	16	Total_DDT	9.7	mg/kg dry
131-W1 DDT (18-20)	556	131-W1	18	20	33.71	-118.35	7/7/1992	15:37	16	Total_DDT	15.1	mg/kg dry
131-W1 DDT (20-22)	556	131-W1	20	22	33.71	-118.35	7/7/1992	15:37	16	Total_DDT	10.9	mg/kg dry
131-W1 DDT (22-24)	556	131-W1	22	24	33.71	-118.35	7/7/1992	15:37	16	Total_DDT	21.7	mg/kg dry
131-W1 DDT (24-26)	556	131-W1	24	26	33.71	-118.35	7/7/1992	15:37	16	Total_DDT	26	mg/kg dry
132-B1 DDT (0-2)	555	132-B1	0	2	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	4.5	mg/kg dry
132-B1 DDT (10-12)	555	132-B1	10	12	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	1.68	mg/kg dry
132-B1 DDT (10-12)	555	132-B1	10	12	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	1.35	mg/kg dry
132-B1 DDT (12-14)	555	132-B1	12	14	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	2.37	mg/kg dry
132-B1 DDT (12-14)	555	132-B1	12	14	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	0.264	mg/kg dry
132-B1 DDT (12-14)	555	132-B1	12	14	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	0.0535	mg/kg dry
132-B1 DDT (14-16)	555	132-B1	14	16	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	2.65	mg/kg dry
132-B1 DDT (16-18)	555	132-B1	16	18	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	4.54	mg/kg dry
132-B1 DDT (18-20)	555	132-B1	18	20	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	3.28	mg/kg dry
132-B1 DDT (2-4)	555	132-B1	2	4	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	2.28	mg/kg dry
132-B1 DDT (20-22)	555	132-B1	20	22	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	4.81	mg/kg dry
132-B1 DDT (22-24)	555	132-B1	22	24	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	3.85	mg/kg dry
132-B1 DDT (24-26)	555	132-B1	24	26	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	3.93	mg/kg dry
132-B1 DDT (26-28)	555	132-B1	26	28	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	3.57	mg/kg dry
132-B1 DDT (28-30)	555	132-B1	28	30	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	4.25	mg/kg dry
132-B1 DDT (30-32)	555	132-B1	30	32	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	3.79	mg/kg dry
132-B1 DDT (32-34)	555	132-B1	32	34	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	3.64	mg/kg dry
132-B1 DDT (34-36)	555	132-B1	34	36	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	4.98	mg/kg dry
132-B1 DDT (36-38)	555	132-B1	36	38	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	4.66	mg/kg dry
132-B1 DDT (38-40)	555	132-B1	38	40	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	4.7	mg/kg dry
132-B1 DDT (4-6)	555	132-B1	4	6	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	2.38	mg/kg dry
132-B1 DDT (6-8)	555	132-B1	6	8	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	2.97	mg/kg dry
132-B1 DDT (8-10)	555	132-B1	8	10	33.71	-118.35	7/7/1992	20:00	12	Total_DDT	3.47	mg/kg dry

Table A-1

Sediment Concentrations of DDTs[1]

Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)

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Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
136-B1 DDT (0-2)	559	136-B1	0	2	33.70	-118.36	7/8/1992	02:11	122	Total_DDT	2.1	mg/kg dry
136-B1 DDT (10-12)	559	136-B1	10	12	33.70	-118.36	7/8/1992	02:11	122	Total_DDT	4.84	mg/kg dry
136-B1 DDT (12-14)	559	136-B1	12	14	33.70	-118.36	7/8/1992	02:11	122	Total_DDT	7.99	mg/kg dry
136-B1 DDT (14-16)	559	136-B1	14	16	33.70	-118.36	7/8/1992	02:11	122	Total_DDT	13.7	mg/kg dry
136-B1 DDT (16-18)	559	136-B1	16	18	33.70	-118.36	7/8/1992	02:11	122	Total_DDT	15.6	mg/kg dry
136-B1 DDT (18-20)	559	136-B1	18	20	33.70	-118.36	7/8/1992	02:11	122	Total_DDT	2.02	mg/kg dry
136-B1 DDT (2-4)	559	136-B1	2	4	33.70	-118.36	7/8/1992	02:11	122	Total_DDT	1.73	mg/kg dry
136-B1 DDT (4-6)	559	136-B1	4	6	33.70	-118.36	7/8/1992	02:11	122	Total_DDT	46.3	mg/kg dry
136-B1 DDT (6-8)	559	136-B1	6	8	33.70	-118.36	7/8/1992	02:11	122	Total_DDT	5.9	mg/kg dry
136-B1 DDT (8-10)	559	136-B1	8	10	33.70	-118.36	7/8/1992	02:11	122	Total_DDT	5.7	mg/kg dry
137-B1 DDT (0-2)	581	137-B1	0	2	33.69	-118.38	7/8/1992	04:33	141	Total_DDT	2	mg/kg dry
137-B1 DDT (10-12)	581	137-B1	10	12	33.69	-118.38	7/8/1992	04:33	141	Total_DDT	3.56	mg/kg dry
137-B1 DDT (12-14)	581	137-B1	12	14	33.69	-118.38	7/8/1992	04:33	141	Total_DDT	1.85	mg/kg dry
137-B1 DDT (14-16)	581	137-B1	14	16	33.69	-118.38	7/8/1992	04:33	141	Total_DDT	1	mg/kg dry
137-B1 DDT (16-18)	581	137-B1	16	18	33.69	-118.38	7/8/1992	04:33	141	Total_DDT	0.166	mg/kg dry
137-B1 DDT (2-4)	581	137-B1	2	4	33.69	-118.38	7/8/1992	04:33	141	Total_DDT	4.58	mg/kg dry
137-B1 DDT (4-6)	581	137-B1	4	6	33.69	-118.38	7/8/1992	04:33	141	Total_DDT	3.93	mg/kg dry
137-B1 DDT (6-8)	581	137-B1	6	8	33.69	-118.38	7/8/1992	04:33	141	Total_DDT	4.38	mg/kg dry
137-B1 DDT (8-10)	581	137-B1	8	10	33.69	-118.38	7/8/1992	04:33	141	Total_DDT	6.83	mg/kg dry
137-B1 DDT (8-10)	581	137-B1	8	10	33.69	-118.38	7/8/1992	04:33	141	Total_DDT	5.59	mg/kg dry
138-B2 DDT (0-4)	583	138-B2	0	4	33.67248	-118.3672	7/8/1992	08:18	215	Total_DDT	5.63	mg/kg dry
138-B2 DDT (4-8)	583	138-B2	4	8	33.67248	-118.3672	7/8/1992	08:18	215	Total_DDT	8.61	mg/kg dry
139-B2 DDT (0-4)	583	139-B2	0	4	33.66264	-118.3345	7/8/1992	11:58	186	Total_DDT	2.39	mg/kg dry
139-B2 DDT (4-8)	583	139-B2	4	8	33.66264	-118.3345	7/8/1992	11:58	186	Total_DDT	5.73	mg/kg dry
141-W1 DDT (0-2)	556	141-W1	0	2	33.71	-118.35	7/8/1992	15:46	15	Total_DDT	9.96	mg/kg dry
141-W1 DDT (10-12)	556	141-W1	10	12	33.71	-118.35	7/8/1992	15:46	15	Total_DDT	12.3	mg/kg dry
141-W1 DDT (2-4)	556	141-W1	2	4	33.71	-118.35	7/8/1992	15:46	15	Total_DDT	12.5	mg/kg dry
141-W1 DDT (4-6)	556	141-W1	4	6	33.71	-118.35	7/8/1992	15:46	15	Total_DDT	9.27	mg/kg dry
141-W1 DDT (6-8)	556	141-W1	6	8	33.71	-118.35	7/8/1992	15:46	15	Total_DDT	10.2	mg/kg dry
141-W1 DDT (8-10)	556	141-W1	8	10	33.71	-118.35	7/8/1992	15:46	15	Total_DDT	11.2	mg/kg dry
141-W1 DDT (12-14)	556	141-W1	12	14	33.71	-118.35	7/8/1992	15:46	15	Total_DDT	12.4	mg/kg dry
141-W1 DDT (12-14)	556	141-W1	12	14	33.71	-118.35	7/8/1992	15:46	15	Total_DDT	13.5	mg/kg dry
141-W1 DDT (14-16)	556	141-W1	14	16	33.71	-118.35	7/8/1992	15:46	15	Total_DDT	9.85	mg/kg dry
141-W1 DDT (16-18)	556	141-W1	16	18	33.71	-118.35	7/8/1992	15:46	15	Total_DDT	14.9	mg/kg dry
141-W1 DDT (16-18)	556	141-W1	16	18	33.71	-118.35	7/8/1992	15:46	15	Total_DDT	0.0139	mg/kg dry
141-W1 DDT (16-18)	556	141-W1	16	18	33.71	-118.35	7/8/1992	15:46	15	Total_DDT	0.00766	mg/kg dry
141-W1 DDT (18-20)	556	141-W1	18	20	33.71	-118.35	7/8/1992	15:46	15	Total_DDT	17.2	mg/kg dry
141-W1 DDT (20-22)	556	141-W1	20	22	33.71	-118.35	7/8/1992	15:46	15	Total_DDT	12.2	mg/kg dry
141-W1 DDT (22-24)	556	141-W1	22	24	33.71	-118.35	7/8/1992	15:46	15	Total_DDT	9.1	mg/kg dry
141-W1 DDT (26-28)	556	141-W1	26	28	33.71	-118.35	7/8/1992	15:46	15	Total_DDT	18.2	mg/kg dry

Table A-1

Sediment Concentrations of DDTs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
141-W1 DDT (28-30)	556	141-W1	28	30	33.71	-118.35	7/8/1992	15:46	15	Total_DDT	18.8	mg/kg dry
141-W1 DDT (30-32)	556	141-W1	30	32	33.71	-118.35	7/8/1992	15:46	15	Total_DDT	18.8	mg/kg dry
141-W1 DDT (32-34)	556	141-W1	32	34	33.71	-118.35	7/8/1992	15:46	15	Total_DDT	31.7	mg/kg dry
143-B1 DDT (0-4)	547	143-B1	0	4	33.72	-118.36	7/8/1992	20:31	5	Total_DDT	0.487	mg/kg dry
143-B1 DDT (4-8)	547	143-B1	4	8	33.72	-118.36	7/8/1992	20:31	5	Total_DDT	0.823	mg/kg dry
143-B1 DDT (8-12)	547	143-B1	8	12	33.72	-118.36	7/8/1992	20:31	5	Total_DDT	0.609	mg/kg dry
143-B1 DDT (12-16)	547	143-B1	12	16	33.72	-118.36	7/8/1992	20:31	5	Total_DDT	0.21	mg/kg dry
143-B1 DDT (16-20)	547	143-B1	16	20	33.72	-118.36	7/8/1992	20:31	5	Total_DDT	0.549	mg/kg dry
143-B1 DDT (20-24)	547	143-B1	20	24	33.72	-118.36	7/8/1992	20:31	5	Total_DDT	0.647	mg/kg dry
143-B1 DDT (24-28)	547	143-B1	24	28	33.72	-118.36	7/8/1992	20:31	5	Total_DDT	0.565	mg/kg dry
143-B1 DDT (28-32)	547	143-B1	28	32	33.72	-118.36	7/8/1992	20:31	5	Total_DDT	0.266	mg/kg dry
146-B1 DDT (0-4)	552	146-B1	0	4	33.71	-118.37	7/9/1992	03:36	55	Total_DDT	6.72	mg/kg dry
146-B1 DDT (4-8)	552	146-B1	4	8	33.71	-118.37	7/9/1992	03:36	55	Total_DDT	7.28	mg/kg dry
146-B1 DDT (8-12)	552	146-B1	8	12	33.71	-118.37	7/9/1992	03:36	55	Total_DDT	18.1	mg/kg dry
146-B1 DDT (12-16)	552	146-B1	12	16	33.71	-118.37	7/9/1992	03:36	55	Total_DDT	43.6	mg/kg dry
146-B1 DDT (16-20)	552	146-B1	16	20	33.71	-118.37	7/9/1992	03:36	55	Total_DDT	7.39	mg/kg dry
146-B1 DDT (20-24)	552	146-B1	20	24	33.71	-118.37	7/9/1992	03:36	55	Total_DDT	1.31	mg/kg dry
147-B3 DDT (0-2)	556	147-B3	0	2	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	16	mg/kg dry
147-B3 DDT (10-12)	556	147-B3	10	12	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	12.9	mg/kg dry
147-B3 DDT (12-14)	556	147-B3	12	14	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	17.9	mg/kg dry
147-B3 DDT (14-16)	556	147-B3	14	16	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	16	mg/kg dry
147-B3 DDT (16-18)	556	147-B3	16	18	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	17.3	mg/kg dry
147-B3 DDT (16-18)	556	147-B3	16	18	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	12.9	mg/kg dry
147-B3 DDT (18-20)	556	147-B3	18	20	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	12.4	mg/kg dry
147-B3 DDT (2-4)	556	147-B3	2	4	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	14.7	mg/kg dry
147-B3 DDT (20-22)	556	147-B3	20	22	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	13.5	mg/kg dry
147-B3 DDT (22-24)	556	147-B3	22	24	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	21.6	mg/kg dry
147-B3 DDT (24-26)	556	147-B3	24	26	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	29.8	mg/kg dry
147-B3 DDT (26-28)	556	147-B3	26	28	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	43.9	mg/kg dry
147-B3 DDT (28-30)	556	147-B3	28	30	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	28.3	mg/kg dry
147-B3 DDT (30-32)	556	147-B3	30	32	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	28.7	mg/kg dry
147-B3 DDT (32-34)	556	147-B3	32	34	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	38.8	mg/kg dry
147-B3 DDT (34-36)	556	147-B3	34	36	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	36.6	mg/kg dry
147-B3 DDT (36-38)	556	147-B3	36	38	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	77.8	mg/kg dry
147-B3 DDT (38-40)	556	147-B3	38	40	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	230	mg/kg dry
147-B3 DDT (4-6)	556	147-B3	4	6	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	9.42	mg/kg dry
147-B3 DDT (40-42)	556	147-B3	40	42	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	253	mg/kg dry
147-B3 DDT (40-42)	556	147-B3	40	42	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	6.62	mg/kg dry
147-B3 DDT (40-42)	556	147-B3	40	42	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	6.48	mg/kg dry
147-B3 DDT (42-44)	556	147-B3	42	44	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	201	mg/kg dry

Table A-1

Sediment Concentrations of DDTs[1]

Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)

Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
147-B3 DDT (6-8)	556	147-B3	6	8	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	11.4	mg/kg dry
147-B3 DDT (8-10)	556	147-B3	8	10	33.71	-118.35	7/9/1992	07:54	14	Total_DDT	12.3	mg/kg dry
148-B1 DDT (0-4)	532	148-B1	0	4	33.72	-118.40	7/9/1992	09:58	37	Total_DDT	6.66	mg/kg dry
148-B1 DDT (4-8)	532	148-B1	4	8	33.72	-118.40	7/9/1992	09:58	37	Total_DDT	7.48	mg/kg dry
148-B1 DDT (8-12)	532	148-B1	8	12	33.72	-118.40	7/9/1992	09:58	37	Total_DDT	8.87	mg/kg dry
148-B1 DDT (8-12)	532	148-B1	8	12	33.72	-118.40	7/9/1992	09:58	37	Total_DDT	8.83	mg/kg dry
148-B1 DDT (12-16)	532	148-B1	12	16	33.72	-118.40	7/9/1992	09:58	37	Total_DDT	8.1	mg/kg dry
148-B1 DDT (16-20)	532	148-B1	16	20	33.72	-118.40	7/9/1992	09:58	37	Total_DDT	24.3	mg/kg dry
148-B1 DDT (16-20)	532	148-B1	16	20	33.72	-118.40	7/9/1992	09:58	37	Total_DDT	0.0283	mg/kg dry
148-B1 DDT (16-20)	532	148-B1	16	20	33.72	-118.40	7/9/1992	09:58	37	Total_DDT	0.357	mg/kg dry
148-B1 DDT (20-24)	532	148-B1	20	24	33.72	-118.40	7/9/1992	09:58	37	Total_DDT	31.4	mg/kg dry
148-B1 DDT (24-28)	532	148-B1	24	28	33.72	-118.40	7/9/1992	09:58	37	Total_DDT	8.26	mg/kg dry
148-B1 DDT (28-32)	532	148-B1	28	32	33.72	-118.40	7/9/1992	09:58	37	Total_DDT	1.06	mg/kg dry
149-B1 DDT (0-4)	533	149-B1	0	4	33.72	-118.40	7/9/1992	11:46	46	Total_DDT	7.66	mg/kg dry
149-B1 DDT (4-8)	533	149-B1	4	8	33.72	-118.40	7/9/1992	11:46	46	Total_DDT	6.9	mg/kg dry
149-B1 DDT (8-12)	533	149-B1	8	12	33.72	-118.40	7/9/1992	11:46	46	Total_DDT	11.2	mg/kg dry
149-B1 DDT (12-16)	533	149-B1	12	16	33.72	-118.40	7/9/1992	11:46	46	Total_DDT	8.16	mg/kg dry
149-B1 DDT (16-20)	533	149-B1	16	20	33.72	-118.40	7/9/1992	11:46	46	Total_DDT	25.5	mg/kg dry
149-B1 DDT (20-24)	533	149-B1	20	24	33.72	-118.40	7/9/1992	11:46	46	Total_DDT	10.1	mg/kg dry
149-B1 DDT (24-28)	533	149-B1	24	28	33.72	-118.40	7/9/1992	11:46	46	Total_DDT	1.73	mg/kg dry
149-B1 DDT (28-32)	533	149-B1	28	32	33.72	-118.40	7/9/1992	11:46	46	Total_DDT	0.16	mg/kg dry
149-B1 DDT (32-36)	533	149-B1	32	36	33.72	-118.40	7/9/1992	11:46	46	Total_DDT	0.114	mg/kg dry
153-B1 DDT (0-4)	574	153-B1	0	4	33.69	-118.32	7/10/1992	06:14	13	Total_DDT	7.01	mg/kg dry
153-B1 DDT (4-8)	574	153-B1	4	8	33.69	-118.32	7/10/1992	06:14	13	Total_DDT	24.4	mg/kg dry
153-B1 DDT (8-12)	574	153-B1	8	12	33.69	-118.32	7/10/1992	06:14	13	Total_DDT	54.9	mg/kg dry
153-B1 DDT (8-12)	574	153-B1	8	12	33.69	-118.32	7/10/1992	06:14	13	Total_DDT	0.847	mg/kg dry
153-B1 DDT (12-16)	574	153-B1	12	16	33.69	-118.32	7/10/1992	06:14	13	Total_DDT	97.8	mg/kg dry
153-B1 DDT (12-16)	574	153-B1	12	16	33.69	-118.32	7/10/1992	06:14	13	Total_DDT	74.3	mg/kg dry
153-B1 DDT (16-20)	574	153-B1	16	20	33.69	-118.32	7/10/1992	06:14	13	Total_DDT	49.1	mg/kg dry
153-B1 DDT (16-20)	574	153-B1	16	20	33.69	-118.32	7/10/1992	06:14	13	Total_DDT	0.336	mg/kg dry
153-B1 DDT (16-20)	574	153-B1	16	20	33.69	-118.32	7/10/1992	06:14	13	Total_DDT	0.262	mg/kg dry
153-B1 DDT (20-24)	574	153-B1	20	24	33.69	-118.32	7/10/1992	06:14	13	Total_DDT	21.3	mg/kg dry
153-B1 DDT (20-24)	574	153-B1	20	24	33.69	-118.32	7/10/1992	06:14	13	Total_DDT	16.8	mg/kg dry
153-B1 DDT (24-28)	574	153-B1	24	28	33.69	-118.32	7/10/1992	06:14	13	Total_DDT	4.13	mg/kg dry
153-B1 DDT (28-32)	574	153-B1	28	32	33.69	-118.32	7/10/1992	06:14	13	Total_DDT	0.744	mg/kg dry
153-B1 DDT (32-36)	574	153-B1	32	36	33.69	-118.32	7/10/1992	06:14	13	Total_DDT	3.36	mg/kg dry
155-B2 DDT (0-4)	572	155-B2	0	4	33.67598	-118.3297	7/10/1992	10:41	110	Total_DDT	14.9	mg/kg dry
155-B2 DDT (4-8)	572	155-B2	4	8	33.67598	-118.3297	7/10/1992	10:41	110	Total_DDT	6.84	mg/kg dry
155-B2 DDT (8-12)	572	155-B2	8	12	33.67598	-118.3297	7/10/1992	10:41	110	Total_DDT	3.91	mg/kg dry
155-B2 DDT (12-16)	572	155-B2	12	16	33.67598	-118.3297	7/10/1992	10:41	110	Total_DDT	6.44	mg/kg dry

Table A-1

Sediment Concentrations of DDTs[1]

Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)

Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
155-B2 DDT (16-20)	572	155-B2	16	20	33.67598	-118.3297	7/10/1992	10:41	110	Total_DDT	15.6	mg/kg dry
155-B2 DDT (20-24)	572	155-B2	20	24	33.67598	-118.3297	7/10/1992	10:41	110	Total_DDT	15.2	mg/kg dry
155-B2 DDT (24-28)	572	155-B2	24	28	33.67598	-118.3297	7/10/1992	10:41	110	Total_DDT	4.93	mg/kg dry
155-B2 DDT (28-32)	572	155-B2	28	32	33.67598	-118.3297	7/10/1992	10:41	110	Total_DDT	8.02	mg/kg dry
155-B2 DDT (28-32)	572	155-B2	28	32	33.67598	-118.3297	7/10/1992	10:41	110	Total_DDT	0.121	mg/kg dry
155-B2 DDT (32-36)	572	155-B2	32	36	33.67598	-118.3297	7/10/1992	10:41	110	Total_DDT	0.301	mg/kg dry
155-B2 DDT (36-40)	572	155-B2	36	40	33.67598	-118.3297	7/10/1992	10:41	110	Total_DDT	0.0473	mg/kg dry
156-B1 DDT (2-4)	525	156-B1	2	4	33.71	-118.42	7/10/1992	13:16	185	Total_DDT	1.66	mg/kg dry
156-B1 DDT (0-2)	525	156-B1	0	2	33.71	-118.42	7/10/1992	13:16	185	Total_DDT	0.785	mg/kg dry
157-W1 DDT (0-2)	556	157-W1	0	2	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	8.25	mg/kg dry
157-W1 DDT (10-12)	556	157-W1	10	12	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	9.56	mg/kg dry
157-W1 DDT (2-4)	556	157-W1	2	4	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	11	mg/kg dry
157-W1 DDT (4-6)	556	157-W1	4	6	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	10.7	mg/kg dry
157-W1 DDT (4-6)	556	157-W1	4	6	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	11.8	mg/kg dry
157-W1 DDT (6-8)	556	157-W1	6	8	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	11.2	mg/kg dry
157-W1 DDT (8-10)	556	157-W1	8	10	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	6.96	mg/kg dry
157-W1 DDT (8-10)	556	157-W1	8	10	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	0.0177	mg/kg dry
157-W1 DDT (8-10)	556	157-W1	8	10	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	0.0213	mg/kg dry
157-W1 DDT (12-14)	556	157-W1	12	14	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	12.7	mg/kg dry
157-W1 DDT (14-16)	556	157-W1	14	16	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	11.1	mg/kg dry
157-W1 DDT (16-18)	556	157-W1	16	18	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	11.2	mg/kg dry
157-W1 DDT (18-20)	556	157-W1	18	20	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	11.9	mg/kg dry
157-W1 DDT (20-22)	556	157-W1	20	22	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	11.9	mg/kg dry
157-W1 DDT (22-24)	556	157-W1	22	24	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	14.4	mg/kg dry
157-W1 DDT (24-26)	556	157-W1	24	26	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	14.3	mg/kg dry
157-W1 DDT (26-28)	556	157-W1	26	28	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	13.8	mg/kg dry
157-W1 DDT (26-28)	556	157-W1	26	28	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	0.00774	mg/kg dry
157-W1 DDT (26-28)	556	157-W1	26	28	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	0.00898	mg/kg dry
157-W1 DDT (28-30)	556	157-W1	28	30	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	16.8	mg/kg dry
157-W1 DDT (30-32)	556	157-W1	30	32	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	25	mg/kg dry
157-W1 DDT (32-34)	556	157-W1	32	34	33.71	-118.35	7/10/1992	15:40	14	Total_DDT	25.9	mg/kg dry
159-B1 DDT (0-4)	519	159-B1	0	4	33.73331	-118.4319	7/10/1992	20:29	72	Total_DDT	3.04	mg/kg dry
159-B1 DDT (4-8)	519	159-B1	4	8	33.73331	-118.4319	7/10/1992	20:29	72	Total_DDT	3.83	mg/kg dry
159-B1 DDT (8-12)	519	159-B1	8	12	33.73331	-118.4319	7/10/1992	20:29	72	Total_DDT	2.15	mg/kg dry
159-B1 DDT (12-16)	519	159-B1	12	16	33.73331	-118.4319	7/10/1992	20:29	72	Total_DDT	2.63	mg/kg dry
160-B1 DDT (0-4)	514	160-B1	0	4	33.76	-118.44	7/10/1992	22:42	12	Total_DDT	4.05	mg/kg dry
160-B1 DDT (0-4)	514	160-B1	0	4	33.76	-118.44	7/10/1992	22:42	12	Total_DDT	0.151	mg/kg dry
160-B1 DDT (0-4)	514	160-B1	0	4	33.76	-118.44	7/10/1992	22:42	12	Total_DDT	0.239	mg/kg dry
160-B1 DDT (4-8)	514	160-B1	4	8	33.76	-118.44	7/10/1992	22:42	12	Total_DDT	4.42	mg/kg dry
160-B1 DDT (8-12)	514	160-B1	8	12	33.76	-118.44	7/10/1992	22:42	12	Total_DDT	4.41	mg/kg dry

Table A-1

Sediment Concentrations of DDTs[1]

Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)

Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
160-B1 DDT (12-16)	514	160-B1	12	16	33.76	-118.44	7/10/1992	22:42	12	Total_DDT	5.06	mg/kg dry
160-B1 DDT (12-16)	514	160-B1	12	16	33.76	-118.44	7/10/1992	22:42	12	Total_DDT	4.56	mg/kg dry
160-B1 DDT (16-20)	514	160-B1	16	20	33.76	-118.44	7/10/1992	22:42	12	Total_DDT	14.6	mg/kg dry
160-B1 DDT (20-24)	514	160-B1	20	24	33.76	-118.44	7/10/1992	22:42	12	Total_DDT	16.1	mg/kg dry
160-B1 DDT (24-28)	514	160-B1	24	28	33.76	-118.44	7/10/1992	22:42	12	Total_DDT	8.94	mg/kg dry
160-B1 DDT (28-32)	514	160-B1	28	32	33.76	-118.44	7/10/1992	22:42	12	Total_DDT	3.85	mg/kg dry
160-B1 DDT (32-36)	514	160-B1	32	36	33.76	-118.44	7/10/1992	22:42	12	Total_DDT	1.53	mg/kg dry
163-B1 DDT (0-4)	506	163-B1	0	4	33.79748	-118.5287	7/11/1992	04:05	175	Total_DDT	1.06	mg/kg dry
163-B1 DDT (4-8)	506	163-B1	4	8	33.79748	-118.5287	7/11/1992	04:05	175	Total_DDT	1.41	mg/kg dry
166-B1 DDT (0-4)	516	166-B1	0	4	33.73865	-118.4389	7/11/1992	13:07	110	Total_DDT	1.23	mg/kg dry
166-B1 DDT (4-8)	516	166-B1	4	8	33.73865	-118.4389	7/11/1992	13:07	110	Total_DDT	0.428	mg/kg dry
166-B1 DDT (8-12)	516	166-B1	8	12	33.73865	-118.4389	7/11/1992	13:07	110	Total_DDT	NR	mg/kg dry
169-B1 DDT (0-2)	550	169-B1	0	2	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	12.9	mg/kg dry
169-B1 DDT (10-12)	550	169-B1	10	12	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	13	mg/kg dry
169-B1 DDT (10-12)	550	169-B1	10	12	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	14.7	mg/kg dry
169-B1 DDT (12-14)	550	169-B1	12	14	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	6.19	mg/kg dry
169-B1 DDT (14-16)	550	169-B1	14	16	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	7.4	mg/kg dry
169-B1 DDT (14-16)	550	169-B1	14	16	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	9.46	mg/kg dry
169-B1 DDT (14-16)	550	169-B1	14	16	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	9.03	mg/kg dry
169-B1 DDT (16-18)	550	169-B1	16	18	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	17.5	mg/kg dry
169-B1 DDT (18-20)	550	169-B1	18	20	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	9.55	mg/kg dry
169-B1 DDT (2-4)	550	169-B1	2	4	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	9.58	mg/kg dry
169-B1 DDT (2-4)	550	169-B1	2	4	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	0.278	mg/kg dry
169-B1 DDT (2-4)	550	169-B1	2	4	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	0.108	mg/kg dry
169-B1 DDT (20-22)	550	169-B1	20	22	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	8.21	mg/kg dry
169-B1 DDT (20-22)	550	169-B1	20	22	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	9.68	mg/kg dry
169-B1 DDT (22-24)	550	169-B1	22	24	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	15.2	mg/kg dry
169-B1 DDT (24-26)	550	169-B1	24	26	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	3.06	mg/kg dry
169-B1 DDT (26-28)	550	169-B1	26	28	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	21.4	mg/kg dry
169-B1 DDT (28-30)	550	169-B1	28	30	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	35.3	mg/kg dry
169-B1 DDT (30-32)	550	169-B1	30	32	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	77.1	mg/kg dry
169-B1 DDT (30-32)	550	169-B1	30	32	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	4.15	mg/kg dry
169-B1 DDT (30-32)	550	169-B1	30	32	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	4.03	mg/kg dry
169-B1 DDT (32-34)	550	169-B1	32	34	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	148	mg/kg dry
169-B1 DDT (34-36)	550	169-B1	34	36	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	85.5	mg/kg dry
169-B1 DDT (36-38)	550	169-B1	36	38	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	72.2	mg/kg dry
169-B1 DDT (36-38)	550	169-B1	36	38	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	101	mg/kg dry
169-B1 DDT (38-40)	550	169-B1	38	40	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	48.3	mg/kg dry
169-B1 DDT (38-40)	550	169-B1	38	40	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	16.7	mg/kg dry
169-B1 DDT (38-40)	550	169-B1	38	40	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	20.1	mg/kg dry

Table A-1

Sediment Concentrations of DDTs[1]

Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)

Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
169-B1 DDT (4-6)	550	169-B1	4	6	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	10	mg/kg dry
169-B1 DDT (40-42)	550	169-B1	40	42	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	51.8	mg/kg dry
169-B1 DDT (42-44)	550	169-B1	42	44	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	45.3	mg/kg dry
169-B1 DDT (44-46)	550	169-B1	44	46	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	22.9	mg/kg dry
169-B1 DDT (6-8)	550	169-B1	6	8	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	9.61	mg/kg dry
169-B1 DDT (8-10)	550	169-B1	8	10	33.71	-118.36	7/11/1992	21:56	14	Total_DDT	9.2	mg/kg dry
171-B1 DDT (0-2)	564	171-B1	0	2	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	27.1	mg/kg dry
171-B1 DDT (10-12)	564	171-B1	10	12	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	12.2	mg/kg dry
171-B1 DDT (12-14)	564	171-B1	12	14	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	13.9	mg/kg dry
171-B1 DDT (0-46)	564	171-B1	0	46	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	14.3	mg/kg dry
171-B1 DDT (14-16)	564	171-B1	14	16	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	0.19	mg/kg dry
171-B1 DDT (14-16)	564	171-B1	14	16	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	0.17	mg/kg dry
171-B1 DDT (16-18)	564	171-B1	16	18	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	12.8	mg/kg dry
171-B1 DDT (18-20)	564	171-B1	18	20	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	14.1	mg/kg dry
171-B1 DDT (2-4)	564	171-B1	2	4	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	16.8	mg/kg dry
171-B1 DDT (20-22)	564	171-B1	20	22	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	20.4	mg/kg dry
171-B1 DDT (22-24)	564	171-B1	22	24	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	23.1	mg/kg dry
171-B1 DDT (24-26)	564	171-B1	24	26	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	26.3	mg/kg dry
171-B1 DDT (26-28)	564	171-B1	26	28	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	43.5	mg/kg dry
171-B1 DDT (28-30)	564	171-B1	28	30	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	50.3	mg/kg dry
171-B1 DDT (30-32)	564	171-B1	30	32	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	114	mg/kg dry
171-B1 DDT (32-34)	564	171-B1	32	34	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	164	mg/kg dry
171-B1 DDT (34-36)	564	171-B1	34	36	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	200	mg/kg dry
171-B1 DDT (36-38)	564	171-B1	36	38	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	181	mg/kg dry
171-B1 DDT (38-40)	564	171-B1	38	40	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	164	mg/kg dry
171-B1 DDT (4-6)	564	171-B1	4	6	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	16	mg/kg dry
171-B1 DDT (4-6)	564	171-B1	4	6	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	17.5	mg/kg dry
171-B1 DDT (6-8)	564	171-B1	6	8	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	22.4	mg/kg dry
171-B1 DDT (6-8)	564	171-B1	6	8	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	0.0383	mg/kg dry
171-B1 DDT (0-46)	564	171-B1	0	46	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	12.7	mg/kg dry
171-B1 DDT (0-46)	564	171-B1	0	46	33.70	-118.33	7/12/1992	09:49	13	Total_DDT	13.5	mg/kg dry
173-B1 DDT (0-4)	534	173-B1	0	4	33.73	-118.38	7/12/1992	12:52	9	Total_DDT	1.59	mg/kg dry
173-B1 DDT (4-8)	534	173-B1	4	8	33.73	-118.38	7/12/1992	12:52	9	Total_DDT	2.17	mg/kg dry
173-B1 DDT (8-12)	534	173-B1	8	12	33.73	-118.38	7/12/1992	12:52	9	Total_DDT	2.25	mg/kg dry
173-B1 DDT (12-16)	534	173-B1	12	16	33.73	-118.38	7/12/1992	12:52	9	Total_DDT	1.59	mg/kg dry
173-B1 DDT (16-20)	534	173-B1	16	20	33.73	-118.38	7/12/1992	12:52	9	Total_DDT	1.36	mg/kg dry
173-B1 DDT (20-24)	534	173-B1	20	24	33.73	-118.38	7/12/1992	12:52	9	Total_DDT	2.68	mg/kg dry
173-B1 DDT (24-28)	534	173-B1	24	28	33.73	-118.38	7/12/1992	12:52	9	Total_DDT	3.63	mg/kg dry
173-B1 DDT (28-32)	534	173-B1	28	32	33.73	-118.38	7/12/1992	12:52	9	Total_DDT	3.49	mg/kg dry
173-B1 DDT (32-36)	534	173-B1	32	36	33.73	-118.38	7/12/1992	12:52	9	Total_DDT	2.35	mg/kg dry

Table A-1

Sediment Concentrations of DDTs[1]

Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)

Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
173-B1 DDT (36-40)	534	173-B1	36	40	33.73	-118.38	7/12/1992	12:52	9	Total_DDT	2.66	mg/kg dry
173-B1 DDT (40-44)	534	173-B1	40	44	33.73	-118.38	7/12/1992	12:52	9	Total_DDT	6.12	mg/kg dry
173-B1 DDT (44-48)	534	173-B1	44	48	33.73	-118.38	7/12/1992	12:52	9	Total_DDT	3.59	mg/kg dry
173-B1 DDT (48-52)	534	173-B1	48	52	33.73	-118.38	7/12/1992	12:52	9	Total_DDT	0.917	mg/kg dry
174-B1 DDT (0-4)	536	174-B1	0	4	33.72	-118.39	7/12/1992	14:08	17	Total_DDT	5.15	mg/kg dry
174-B1 DDT (4-8)	536	174-B1	4	8	33.72	-118.39	7/12/1992	14:08	17	Total_DDT	5.54	mg/kg dry
174-B1 DDT (8-12)	536	174-B1	8	12	33.72	-118.39	7/12/1992	14:08	17	Total_DDT	8.51	mg/kg dry
174-B1 DDT (12-16)	536	174-B1	12	16	33.72	-118.39	7/12/1992	14:08	17	Total_DDT	3.04	mg/kg dry
174-B1 DDT (16-20)	536	174-B1	16	20	33.72	-118.39	7/12/1992	14:08	17	Total_DDT	11.7	mg/kg dry
174-B1 DDT (16-20)	536	174-B1	16	20	33.72	-118.39	7/12/1992	14:08	17	Total_DDT	0.192	mg/kg dry
174-B1 DDT (16-20)	536	174-B1	16	20	33.72	-118.39	7/12/1992	14:08	17	Total_DDT	0.257	mg/kg dry
174-B1 DDT (20-24)	536	174-B1	20	24	33.72	-118.39	7/12/1992	14:08	17	Total_DDT	24.4	mg/kg dry
174-B1 DDT (24-28)	536	174-B1	24	28	33.72	-118.39	7/12/1992	14:08	17	Total_DDT	65.4	mg/kg dry
174-B1 DDT (28-32)	536	174-B1	28	32	33.72	-118.39	7/12/1992	14:08	17	Total_DDT	10.3	mg/kg dry
174-B1 DDT (32-36)	536	174-B1	32	36	33.72	-118.39	7/12/1992	14:08	17	Total_DDT	50.1	mg/kg dry
174-B1 DDT (32-36)	536	174-B1	32	36	33.72	-118.39	7/12/1992	14:08	17	Total_DDT	55.6	mg/kg dry
174-B1 DDT (36-40)	536	174-B1	36	40	33.72	-118.39	7/12/1992	14:08	17	Total_DDT	4.16	mg/kg dry
174-B1 DDT (40-44)	536	174-B1	40	44	33.72	-118.39	7/12/1992	14:08	17	Total_DDT	0.628	mg/kg dry
177-G2 DDT (36-38)	550	177-G2	36	38	33.71	-118.36	7/13/1992	01:25	14	Total_DDT	54.9	mg/kg dry
177-G2 DDT (36-38)	550	177-G2	36	38	33.71	-118.36	7/13/1992	01:25	14	Total_DDT	0.0471	mg/kg dry
177-G2 DDT (36-38)	550	177-G2	36	38	33.71	-118.36	7/13/1992	01:25	14	Total_DDT	0.0458	mg/kg dry
177-G2 DDT (38-40)	550	177-G2	38	40	33.71	-118.36	7/13/1992	01:25	14	Total_DDT	18.4	mg/kg dry
177-G2 DDT (40-42)	550	177-G2	40	42	33.71	-118.36	7/13/1992	01:25	14	Total_DDT	2.76	mg/kg dry
177-G2 DDT (42-44)	550	177-G2	42	44	33.71	-118.36	7/13/1992	01:25	14	Total_DDT	1.3	mg/kg dry
177-G2 DDT (44-46)	550	177-G2	44	46	33.71	-118.36	7/13/1992	01:25	14	Total_DDT	1.07	mg/kg dry
179-G3 DDT (24-26)	556	179-G3	24	26	33.71	-118.35	7/13/1992	03:57	14	Total_DDT	117	mg/kg dry
179-G3 DDT (26-28)	556	179-G3	26	28	33.71	-118.35	7/13/1992	03:57	14	Total_DDT	118	mg/kg dry
179-G3 DDT (28-30)	556	179-G3	28	30	33.71	-118.35	7/13/1992	03:57	14	Total_DDT	65.6	mg/kg dry
179-G3 DDT (30-32)	556	179-G3	30	32	33.71	-118.35	7/13/1992	03:57	14	Total_DDT	22	mg/kg dry
179-G3 DDT (32-34)	556	179-G3	32	34	33.71	-118.35	7/13/1992	03:57	14	Total_DDT	10.2	mg/kg dry
179-G3 DDT (32-34)	556	179-G3	32	34	33.71	-118.35	7/13/1992	03:57	14	Total_DDT	0.00763	mg/kg dry
179-G3 DDT (32-34)	556	179-G3	32	34	33.71	-118.35	7/13/1992	03:57	14	Total_DDT	0.00711	mg/kg dry
179-G3 DDT (34-36)	556	179-G3	34	36	33.71	-118.35	7/13/1992	03:57	14	Total_DDT	4.02	mg/kg dry
179-G3 DDT (34-36)	556	179-G3	34	36	33.71	-118.35	7/13/1992	03:57	14	Total_DDT	3.65	mg/kg dry
181-G2 DDT (32-34)	564	181-G2	32	34	33.70	-118.33	7/13/1992	07:08	14	Total_DDT	20	mg/kg dry
181-G2 DDT (32-34)	564	181-G2	32	34	33.70	-118.33	7/13/1992	07:08	14	Total_DDT	0.777	mg/kg dry
181-G2 DDT (32-34)	564	181-G2	32	34	33.70	-118.33	7/13/1992	07:08	14	Total_DDT	0.742	mg/kg dry
181-G2 DDT (34-36)	564	181-G2	34	36	33.70	-118.33	7/13/1992	07:08	14	Total_DDT	11.1	mg/kg dry
181-G2 DDT (36-38)	564	181-G2	36	38	33.70	-118.33	7/13/1992	07:08	14	Total_DDT	4.01	mg/kg dry
181-G2 DDT (38-40)	564	181-G2	38	40	33.70	-118.33	7/13/1992	07:08	14	Total_DDT	2.42	mg/kg dry

Table A-1

Sediment Concentrations of DDTs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
181-G2 DDT (38-40)	564	181-G2	38	40	33.70	-118.33	7/13/1992	07:08	14	Total_DDT	4	mg/kg dry
181-G2 DDT (40-42)	564	181-G2	40	42	33.70	-118.33	7/13/1992	07:08	14	Total_DDT	0.0817	mg/kg dry
181-G2 DDT (42-44)	564	181-G2	42	44	33.70	-118.33	7/13/1992	07:08	14	Total_DDT	0.448	mg/kg dry
181-G2 DDT (44-46)	564	181-G2	44	46	33.70	-118.33	7/13/1992	07:08	14	Total_DDT	1.28	mg/kg dry
181-G2 DDT (46-48)	564	181-G2	46	48	33.70	-118.33	7/13/1992	07:08	14	Total_DDT	0.181	mg/kg dry
181-G2 DDT (48-50)	564	181-G2	48	50	33.70	-118.33	7/13/1992	07:08	14	Total_DDT	0.0937	mg/kg dry
181-G2 DDT (22-24)	564	181-G2	22	24	33.70	-118.33	7/13/1992	07:08	14	Total_DDT	305	mg/kg dry
181-G2 DDT (24-26)	564	181-G2	24	26	33.70	-118.33	7/13/1992	07:08	14	Total_DDT	287	mg/kg dry
181-G2 DDT (24-26)	564	181-G2	24	26	33.70	-118.33	7/13/1992	07:08	14	Total_DDT	255	mg/kg dry
181-G2 DDT (26-28)	564	181-G2	26	28	33.70	-118.33	7/13/1992	07:08	14	Total_DDT	216	mg/kg dry
181-G2 DDT (28-30)	564	181-G2	28	30	33.70	-118.33	7/13/1992	07:08	14	Total_DDT	35.5	mg/kg dry
181-G2 DDT (30-32)	564	181-G2	30	32	33.70	-118.33	7/13/1992	07:08	14	Total_DDT	86.7	mg/kg dry
187-B1 DDT-1 (0-2)	500	187-B1	0	2	34.16	-119.39	7/14/1992	05:29	11	Total_DDT	0.014	mg/kg dry
187-B1 DDT-1 (2-4)	500	187-B1	2	4	34.16	-119.39	7/14/1992	05:29	11	Total_DDT	0.0157	mg/kg dry
187-B1 DDT-1 (4-6)	500	187-B1	4	6	34.16	-119.39	7/14/1992	05:29	11	Total_DDT	0.0171	mg/kg dry
187-B1 DDT-1 (6-8)	500	187-B1	6	8	34.16	-119.39	7/14/1992	05:29	11	Total_DDT	0.0179	mg/kg dry

1 - DDTs consist of p,p'-DDE, o,p'-DDE, p,p'-DDD, o,p'-DDD, p,p'-DDT, and o,p'-DDT.

NR = Not Reported

Lee, 1994. *The Distribution and Character of Contaminated Effluent-Affected Sediment, Palos Verdes Margin, Southern California* (data from 1992)

Table A-2

Sediment Concentrations of PCBs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
101-B5 DDT-1 (0-2)	500	101-B5	0	2	34.16	-119.38	7/3/1992	05:24	11	Total_PCB	0.0087	mg/kg dry
101-B5 DDT-1 (0-2)	500	101-B5	0	2	34.16	-119.38	7/3/1992	05:24	11	Total_PCB	0.43	mg/kg dry
101-B5 DDT-1 (0-2)	500	101-B5	0	2	34.16	-119.38	7/3/1992	05:24	11	Total_PCB	0.434	mg/kg dry
101-B5 DDT-1 (2-4)	500	101-B5	2	4	34.16	-119.38	7/3/1992	05:24	11	Total_PCB	NR	mg/kg dry
101-B5 DDT-1 (2-4)	500	101-B5	2	4	34.16	-119.38	7/3/1992	05:24	11	Total_PCB	NR	mg/kg dry
101-B5 DDT-1 (4-6)	500	101-B5	4	6	34.16	-119.38	7/3/1992	05:24	11	Total_PCB	0.00897	mg/kg dry
101-B5 DDT-1 (6-8)	500	101-B5	6	8	34.16	-119.38	7/3/1992	05:24	11	Total_PCB	0.0099	mg/kg dry
102-B1 DDT-1 (0-2)	524	102-B1	0	2	33.72	-118.41	7/3/1992	14:03	72	Total_PCB	0.433	mg/kg dry
102-B1 DDT-1 (10-12)	524	102-B1	10	12	33.72	-118.41	7/3/1992	14:03	72	Total_PCB	0.122	mg/kg dry
102-B1 DDT-1 (12-14)	524	102-B1	12	14	33.72	-118.41	7/3/1992	14:03	72	Total_PCB	0.125	mg/kg dry
102-B1 DDT-1 (14-16)	524	102-B1	14	16	33.72	-118.41	7/3/1992	14:03	72	Total_PCB	0.0718	mg/kg dry
102-B1 DDT-1 (2-4)	524	102-B1	2	4	33.72	-118.41	7/3/1992	14:03	72	Total_PCB	0.624	mg/kg dry
102-B1 DDT-1 (2-4)	524	102-B1	2	4	33.72	-118.41	7/3/1992	14:03	72	Total_PCB	0.687	mg/kg dry
102-B1 DDT-1 (4-6)	524	102-B1	4	6	33.72	-118.41	7/3/1992	14:03	72	Total_PCB	0.523	mg/kg dry
102-B1 DDT-1 (6-8)	524	102-B1	6	8	33.72	-118.41	7/3/1992	14:03	72	Total_PCB	0.38	mg/kg dry
102-B1 DDT-1 (8-10)	524	102-B1	8	10	33.72	-118.41	7/3/1992	14:03	72	Total_PCB	0.192	mg/kg dry
106-B1 DDT (0-4)	518	106-B1	0	4	33.73	-118.42	7/4/1992	05:31	28	Total_PCB	0.331	mg/kg dry
106-B1 DDT (4-8)	518	106-B1	4	8	33.73	-118.42	7/4/1992	05:31	28	Total_PCB	0.336	mg/kg dry
106-B1 DDT (8-12)	518	106-B1	8	12	33.73	-118.42	7/4/1992	05:31	28	Total_PCB	0.851	mg/kg dry
106-B1 DDT (8-12)	518	106-B1	8	12	33.73	-118.42	7/4/1992	05:31	28	Total_PCB	1.05	mg/kg dry
106-B1 DDT (8-12)	518	106-B1	8	12	33.73	-118.42	7/4/1992	05:31	28	Total_PCB	0.99	mg/kg dry
108-B2 DDT (0-2)	523	108-B2	0	2	33.72	-118.41	7/4/1992	12:21	43	Total_PCB	0.444	mg/kg dry
108-B2 DDT (10-12)	523	108-B2	10	12	33.72	-118.41	7/4/1992	12:21	43	Total_PCB	0.921	mg/kg dry
108-B2 DDT (12-14)	523	108-B2	12	14	33.72	-118.41	7/4/1992	12:21	43	Total_PCB	0.435	mg/kg dry
108-B2 DDT (14-16)	523	108-B2	14	16	33.72	-118.41	7/4/1992	12:21	43	Total_PCB	0.199	mg/kg dry
108-B2 DDT (16-18)	523	108-B2	16	18	33.72	-118.41	7/4/1992	12:21	43	Total_PCB	0.1	mg/kg dry
108-B2 DDT (2-4)	523	108-B2	2	4	33.72	-118.41	7/4/1992	12:21	43	Total_PCB	0.484	mg/kg dry
108-B2 DDT (4-6)	523	108-B2	4	6	33.72	-118.41	7/4/1992	12:21	43	Total_PCB	0.59	mg/kg dry
108-B2 DDT (6-8)	523	108-B2	6	8	33.72	-118.41	7/4/1992	12:21	43	Total_PCB	0.773	mg/kg dry
108-B2 DDT (8-10)	523	108-B2	8	10	33.72	-118.41	7/4/1992	12:21	43	Total_PCB	1.3	mg/kg dry
109-W1 DDT (0-2)	522	109-W1	0	2	33.73065	-118.4012	7/4/1992	15:12	18	Total_PCB	0.409	mg/kg dry
109-W1 DDT (2-4)	522	109-W1	2	4	33.73065	-118.4012	7/4/1992	15:12	18	Total_PCB	0.41	mg/kg dry
109-W1 DDT (2-4)	522	109-W1	2	4	33.73065	-118.4012	7/4/1992	15:12	18	Total_PCB	0.443	mg/kg dry
109-W1 DDT (4-6)	522	109-W1	4	6	33.73065	-118.4012	7/4/1992	15:12	18	Total_PCB	0.478	mg/kg dry
109-W1 DDT (6-8)	522	109-W1	6	8	33.73065	-118.4012	7/4/1992	15:12	18	Total_PCB	0.515	mg/kg dry
109-W1 DDT (8-10)	522	109-W1	8	10	33.73065	-118.4012	7/4/1992	15:12	18	Total_PCB	0.494	mg/kg dry
109-W1 DDT (10-12)	522	109-W1	10	12	33.73065	-118.4012	7/4/1992	15:12	18	Total_PCB	0.451	mg/kg dry

Table A-2

Sediment Concentrations of PCBs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
109-W1 DDT (12-14)	522	109-W1	12	14	33.73065	-118.4012	7/4/1992	15:12	18	Total_PCB	0.479	mg/kg dry
109-W1 DDT (14-16)	522	109-W1	14	16	33.73065	-118.4012	7/4/1992	15:12	18	Total_PCB	0.501	mg/kg dry
109-W1 DDT (16-18)	522	109-W1	16	18	33.73065	-118.4012	7/4/1992	15:12	18	Total_PCB	0.533	mg/kg dry
109-W1 DDT (18-20)	522	109-W1	18	20	33.73065	-118.4012	7/4/1992	15:12	18	Total_PCB	0.659	mg/kg dry
109-W1 DDT (20-22)	522	109-W1	20	22	33.73065	-118.4012	7/4/1992	15:12	18	Total_PCB	0.575	mg/kg dry
109-W1 DDT (20-22)	522	109-W1	20	22	33.73065	-118.4012	7/4/1992	15:12	18	Total_PCB	0.649	mg/kg dry
109-W1 DDT (20-22)	522	109-W1	20	22	33.73065	-118.4012	7/4/1992	15:12	18	Total_PCB	0.851	mg/kg dry
109-W1 DDT (22-24)	522	109-W1	22	24	33.73065	-118.4012	7/4/1992	15:12	18	Total_PCB	0.532	mg/kg dry
109-W2 DDT (0-2)	522	109-W2	0	2	33.73	-118.40	7/5/1992	15:32	16	Total_PCB	0.375	mg/kg dry
109-W2 DDT (2-4)	522	109-W2	2	4	33.73	-118.40	7/5/1992	15:32	16	Total_PCB	0.372	mg/kg dry
109-W2 DDT (4-6)	522	109-W2	4	6	33.73	-118.40	7/5/1992	15:32	16	Total_PCB	0.47	mg/kg dry
109-W2 DDT (6-8)	522	109-W2	6	8	33.73	-118.40	7/5/1992	15:32	16	Total_PCB	0.495	mg/kg dry
109-W2 DDT (8-10)	522	109-W2	8	10	33.73	-118.40	7/5/1992	15:32	16	Total_PCB	0.437	mg/kg dry
109-W2 DDT (10-12)	522	109-W2	10	12	33.73	-118.40	7/5/1992	15:32	16	Total_PCB	0.447	mg/kg dry
109-W2 DDT (12-14)	522	109-W2	12	14	33.73	-118.40	7/5/1992	15:32	16	Total_PCB	0.486	mg/kg dry
109-W2 DDT (14-16)	522	109-W2	14	16	33.73	-118.40	7/5/1992	15:32	16	Total_PCB	0.441	mg/kg dry
109-W2 DDT (16-18)	522	109-W2	16	18	33.73	-118.40	7/5/1992	15:32	16	Total_PCB	0.438	mg/kg dry
109-W2 DDT (16-18)	522	109-W2	16	18	33.73	-118.40	7/5/1992	15:32	16	Total_PCB	0.399	mg/kg dry
109-W2 DDT (18-20)	522	109-W2	18	20	33.73	-118.40	7/5/1992	15:32	16	Total_PCB	0.329	mg/kg dry
109-W2 DDT (18-20)	522	109-W2	18	20	33.73	-118.40	7/5/1992	15:32	16	Total_PCB	0.16	mg/kg dry
109-W2 DDT (18-20)	522	109-W2	18	20	33.73	-118.40	7/5/1992	15:32	16	Total_PCB	0.721	mg/kg dry
111-B1 DDT (0-4)	539	111-B1	0	4	33.72	-118.37	7/5/1992	00:56	13	Total_PCB	0.419	mg/kg dry
111-B1 DDT (4-8)	539	111-B1	4	8	33.72	-118.37	7/5/1992	00:56	13	Total_PCB	0.346	mg/kg dry
111-B1 DDT (8-12)	539	111-B1	8	12	33.72	-118.37	7/5/1992	00:56	13	Total_PCB	0.355	mg/kg dry
111-B1 DDT (12-16)	539	111-B1	12	16	33.72	-118.37	7/5/1992	00:56	13	Total_PCB	0.323	mg/kg dry
111-B1 DDT (16-20)	539	111-B1	16	20	33.72	-118.37	7/5/1992	00:56	13	Total_PCB	0.367	mg/kg dry
111-B1 DDT (20-24)	539	111-B1	20	24	33.72	-118.37	7/5/1992	00:56	13	Total_PCB	0.51	mg/kg dry
111-B1 DDT (24-28)	539	111-B1	24	28	33.72	-118.37	7/5/1992	00:56	13	Total_PCB	0.492	mg/kg dry
111-B1 DDT (28-32)	539	111-B1	28	32	33.72	-118.37	7/5/1992	00:56	13	Total_PCB	0.484	mg/kg dry
111-B1 DDT (32-36)	539	111-B1	32	36	33.72	-118.37	7/5/1992	00:56	13	Total_PCB	0.553	mg/kg dry
111-B1 DDT (36-40)	539	111-B1	36	40	33.72	-118.37	7/5/1992	00:56	13	Total_PCB	0.53	mg/kg dry
111-B1 DDT (40-44)	539	111-B1	40	44	33.72	-118.37	7/5/1992	00:56	13	Total_PCB	0.511	mg/kg dry
111-B1 DDT (44-48)	539	111-B1	44	48	33.72	-118.37	7/5/1992	00:56	13	Total_PCB	0.283	mg/kg dry
111-B1 DDT (48-52)	539	111-B1	48	52	33.72	-118.37	7/5/1992	00:56	13	Total_PCB	0.828	mg/kg dry
111-B1 DDT (52-56)	539	111-B1	52	56	33.72	-118.37	7/5/1992	00:56	13	Total_PCB	2.27	mg/kg dry
111-B1 DDT (56-60)	539	111-B1	56	60	33.72	-118.37	7/5/1992	00:56	13	Total_PCB	2.07	mg/kg dry
113-B1 DDT (0-4)	542	113-B1	0	4	33.71	-118.39	7/5/1992	06:41	64	Total_PCB	0.163	mg/kg dry

Table A-2

Sediment Concentrations of PCBs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
113-B1 DDT (4-8)	542	113-B1	4	8	33.71	-118.39	7/5/1992	06:41	64	Total_PCB	0.09	mg/kg dry
113-B1 DDT (8-12)	542	113-B1	8	12	33.71	-118.39	7/5/1992	06:41	64	Total_PCB	0.0426	mg/kg dry
113-B1 DDT (12-16)	542	113-B1	12	16	33.71	-118.39	7/5/1992	06:41	64	Total_PCB	0.019	mg/kg dry
113-B1 DDT (16-20)	542	113-B1	16	20	33.71	-118.39	7/5/1992	06:41	64	Total_PCB	NR	mg/kg dry
114-B1 DDT (0-4)	543	114-B1	0	4	33.70731	-118.3889	7/5/1992	09:35	122	Total_PCB	0.189	mg/kg dry
114-B1 DDT (4-8)	543	114-B1	4	8	33.70731	-118.3889	7/5/1992	09:35	122	Total_PCB	0.067	mg/kg dry
114-B1 DDT (8-12)	543	114-B1	8	12	33.70731	-118.3889	7/5/1992	09:35	122	Total_PCB	0.0278	mg/kg dry
114-B1 DDT (12-16)	543	114-B1	12	16	33.70731	-118.3889	7/5/1992	09:35	122	Total_PCB	0.0232	mg/kg dry
115-B2 DDT (0-4)	544	115-B2	0	4	33.69831	-118.3919	7/5/1992	13:34	153	Total_PCB	0.335	mg/kg dry
115-B2 DDT (4-8)	544	115-B2	4	8	33.69831	-118.3919	7/5/1992	13:34	153	Total_PCB	0.503	mg/kg dry
117-B4 DDT (0-4)	571	117-B4	0	4	33.68	-118.32	7/6/1992	01:28	47	Total_PCB	1.16	mg/kg dry
117-B4 DDT (4-8)	571	117-B4	4	8	33.68	-118.32	7/6/1992	01:28	47	Total_PCB	2.89	mg/kg dry
117-B4 DDT (8-12)	571	117-B4	8	12	33.68	-118.32	7/6/1992	01:28	47	Total_PCB	1.42	mg/kg dry
117-B4 DDT (12-16)	571	117-B4	12	16	33.68	-118.32	7/6/1992	01:28	47	Total_PCB	0.415	mg/kg dry
117-B4 DDT (16-20)	571	117-B4	16	20	33.68	-118.32	7/6/1992	01:28	47	Total_PCB	0.111	mg/kg dry
120-B1 DDT (0-4)	577	120-B1	0	4	33.68	-118.31	7/6/1992	08:10	19	Total_PCB	0.317	mg/kg dry
120-B1 DDT (4-8)	577	120-B1	4	8	33.68	-118.31	7/6/1992	08:10	19	Total_PCB	0.17	mg/kg dry
120-B1 DDT (8-12)	577	120-B1	8	12	33.68	-118.31	7/6/1992	08:10	19	Total_PCB	1.47	mg/kg dry
120-B1 DDT (12-16)	577	120-B1	12	16	33.68	-118.31	7/6/1992	08:10	19	Total_PCB	1.29	mg/kg dry
120-B1 DDT (16-20)	577	120-B1	16	20	33.68	-118.31	7/6/1992	08:10	19	Total_PCB	0.257	mg/kg dry
120-B1 DDT (20-24)	577	120-B1	20	24	33.68	-118.31	7/6/1992	08:10	19	Total_PCB	0.104	mg/kg dry
120-B1 DDT (20-24)	577	120-B1	20	24	33.68	-118.31	7/6/1992	08:10	19	Total_PCB	0.3	mg/kg dry
120-B1 DDT (20-24)	577	120-B1	20	24	33.68	-118.31	7/6/1992	08:10	19	Total_PCB	0.297	mg/kg dry
120-B1 DDT (24-28)	577	120-B1	24	28	33.68	-118.31	7/6/1992	08:10	19	Total_PCB	0.114	mg/kg dry
120-B1 DDT (24-28)	577	120-B1	24	28	33.68	-118.31	7/6/1992	08:10	19	Total_PCB	0.112	mg/kg dry
121-B1 DDT (0-4)	570	121-B1	0	4	33.69	-118.32	7/6/1992	10:30	21	Total_PCB	0.422	mg/kg dry
121-B1 DDT (4-8)	570	121-B1	4	8	33.69	-118.32	7/6/1992	10:30	21	Total_PCB	0.542	mg/kg dry
121-B1 DDT (8-12)	570	121-B1	8	12	33.69	-118.32	7/6/1992	10:30	21	Total_PCB	1.13	mg/kg dry
121-B1 DDT (8-12)	570	121-B1	8	12	33.69	-118.32	7/6/1992	10:30	21	Total_PCB	1.32	mg/kg dry
121-B1 DDT (8-12)	570	121-B1	8	12	33.69	-118.32	7/6/1992	10:30	21	Total_PCB	1.34	mg/kg dry
121-B1 DDT (12-16)	570	121-B1	12	16	33.69	-118.32	7/6/1992	10:30	21	Total_PCB	3.68	mg/kg dry
121-B1 DDT (16-20)	570	121-B1	16	20	33.69	-118.32	7/6/1992	10:30	21	Total_PCB	3.34	mg/kg dry
121-B1 DDT (20-24)	570	121-B1	20	24	33.69	-118.32	7/6/1992	10:30	21	Total_PCB	1.76	mg/kg dry
121-B1 DDT (24-28)	570	121-B1	24	28	33.69	-118.32	7/6/1992	10:30	21	Total_PCB	0.981	mg/kg dry
121-B1 DDT (28-32)	570	121-B1	28	32	33.69	-118.32	7/6/1992	10:30	21	Total_PCB	0.204	mg/kg dry
121-B1 DDT (32-36)	570	121-B1	32	36	33.69	-118.32	7/6/1992	10:30	21	Total_PCB	0.0383	mg/kg dry
122-B1 DDT (0-4)	566	122-B1	0	4	33.69	-118.34	7/6/1992	13:33	60	Total_PCB	0.474	mg/kg dry

Table A-2

Sediment Concentrations of PCBs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
122-B1 DDT (4-8)	566	122-B1	4	8	33.69	-118.34	7/6/1992	13:33	60	Total_PCB	1.94	mg/kg dry
122-B1 DDT (8-12)	566	122-B1	8	12	33.69	-118.34	7/6/1992	13:33	60	Total_PCB	0.221	mg/kg dry
122-B1 DDT (12-16)	566	122-B1	12	16	33.69	-118.34	7/6/1992	13:33	60	Total_PCB	0.0857	mg/kg dry
122-B1 DDT (16-20)	566	122-B1	16	20	33.69	-118.34	7/6/1992	13:33	60	Total_PCB	0.0187	mg/kg dry
122-B1 DDT (20-24)	566	122-B1	20	24	33.69	-118.34	7/6/1992	13:33	60	Total_PCB	NR	mg/kg dry
123-W2 DDT (0-2)	522	123-W2	0	2	33.73	-118.40	7/6/1992	16:50	16	Total_PCB	0.406	mg/kg dry
123-W2 DDT (2-4)	522	123-W2	2	4	33.73	-118.40	7/6/1992	16:50	16	Total_PCB	0.333	mg/kg dry
123-W2 DDT (4-6)	522	123-W2	4	6	33.73	-118.40	7/6/1992	16:50	16	Total_PCB	0.374	mg/kg dry
123-W2 DDT (6-8)	522	123-W2	6	8	33.73	-118.40	7/6/1992	16:50	16	Total_PCB	0.268	mg/kg dry
123-W2 DDT (8-10)	522	123-W2	8	10	33.73	-118.40	7/6/1992	16:50	16	Total_PCB	0.493	mg/kg dry
123-W2 DDT (10-12)	522	123-W2	10	12	33.73	-118.40	7/6/1992	16:50	16	Total_PCB	0.508	mg/kg dry
123-W2 DDT (12-14)	522	123-W2	12	14	33.73	-118.40	7/6/1992	16:50	16	Total_PCB	0.505	mg/kg dry
123-W2 DDT (14-16)	522	123-W2	14	16	33.73	-118.40	7/6/1992	16:50	16	Total_PCB	0.425	mg/kg dry
123-W2 DDT (16-18)	522	123-W2	16	18	33.73	-118.40	7/6/1992	16:50	16	Total_PCB	0.396	mg/kg dry
123-W2 DDT (18-20)	522	123-W2	18	20	33.73	-118.40	7/6/1992	16:50	16	Total_PCB	0.438	mg/kg dry
123-W2 DDT (20-22)	522	123-W2	20	22	33.73	-118.40	7/6/1992	16:50	16	Total_PCB	0.533	mg/kg dry
123-W2 DDT (22-24)	522	123-W2	22	24	33.73	-118.40	7/6/1992	16:50	16	Total_PCB	0.749	mg/kg dry
123-W2 DDT (24-26)	522	123-W2	24	26	33.73	-118.40	7/6/1992	16:50	16	Total_PCB	0.841	mg/kg dry
123-W2 DDT (26-28)	522	123-W2	26	28	33.73	-118.40	7/6/1992	16:50	16	Total_PCB	0.724	mg/kg dry
123-W2 DDT (26-28)	522	123-W2	26	28	33.73	-118.40	7/6/1992	16:50	16	Total_PCB	0.699	mg/kg dry
123-W2 DDT (28-30)	522	123-W2	28	30	33.73	-118.40	7/6/1992	16:50	16	Total_PCB	0.797	mg/kg dry
124-B1 DDT (0-2)	522	124-B1	0	2	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	0.563	mg/kg dry
124-B1 DDT (10-12)	522	124-B1	10	12	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	0.582	mg/kg dry
124-B1 DDT (12-14)	522	124-B1	12	14	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	0.56	mg/kg dry
124-B1 DDT (14-16)	522	124-B1	14	16	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	0.577	mg/kg dry
124-B1 DDT (16-18)	522	124-B1	16	18	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	0.434	mg/kg dry
124-B1 DDT (18-20)	522	124-B1	18	20	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	0.212	mg/kg dry
124-B1 DDT (2-4)	522	124-B1	2	4	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	0.497	mg/kg dry
124-B1 DDT (20-22)	522	124-B1	20	22	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	0.388	mg/kg dry
124-B1 DDT (22-24)	522	124-B1	22	24	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	0.488	mg/kg dry
124-B1 DDT (24-26)	522	124-B1	24	26	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	0.692	mg/kg dry
124-B1 DDT (26-28)	522	124-B1	26	28	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	0.728	mg/kg dry
124-B1 DDT (28-30)	522	124-B1	28	30	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	1.23	mg/kg dry
124-B1 DDT (30-32)	522	124-B1	30	32	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	2.74	mg/kg dry
124-B1 DDT (32-34)	522	124-B1	32	34	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	1.82	mg/kg dry
124-B1 DDT (34-36)	522	124-B1	34	36	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	1.02	mg/kg dry
124-B1 DDT (36-38)	522	124-B1	36	38	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	1.08	mg/kg dry

Table A-2

Sediment Concentrations of PCBs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
124-B1 DDT (38-40)	522	124-B1	38	40	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	1.1	mg/kg dry
124-B1 DDT (4-6)	522	124-B1	4	6	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	0.443	mg/kg dry
124-B1 DDT (40-42)	522	124-B1	40	42	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	0.413	mg/kg dry
124-B1 DDT (42-44)	522	124-B1	42	44	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	0.174	mg/kg dry
124-B1 DDT (44-46)	522	124-B1	44	46	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	0.175	mg/kg dry
124-B1 DDT (46-48)	522	124-B1	46	48	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	0.183	mg/kg dry
124-B1 DDT (6-8)	522	124-B1	6	8	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	0.561	mg/kg dry
124-B1 DDT (8-10)	522	124-B1	8	10	33.73	-118.40	7/6/1992	21:26	17	Total_PCB	0.732	mg/kg dry
125-B2 DDT (0-2)	554	125-B2	0	2	33.72	-118.35	7/7/1992	01:36	15	Total_PCB	0.114	mg/kg dry
125-B2 DDT (2-4)	554	125-B2	2	4	33.72	-118.35	7/7/1992	01:36	15	Total_PCB	0.11	mg/kg dry
125-B2 DDT (4-6)	554	125-B2	4	6	33.72	-118.35	7/7/1992	01:36	15	Total_PCB	0.155	mg/kg dry
125-B2 DDT (6-8)	554	125-B2	6	8	33.72	-118.35	7/7/1992	01:36	15	Total_PCB	0.117	mg/kg dry
125-B2 DDT (8-10)	554	125-B2	8	10	33.72	-118.35	7/7/1992	01:36	15	Total_PCB	0.115	mg/kg dry
125-B2 DDT (20-24)	554	125-B2	20	24	33.72	-118.35	7/7/1992	01:36	15	Total_PCB	0.211	mg/kg dry
125-B2 DDT (24-28)	554	125-B2	24	28	33.72	-118.35	7/7/1992	01:36	15	Total_PCB	0.19	mg/kg dry
125-B2 DDT (28-32)	554	125-B2	28	32	33.72	-118.35	7/7/1992	01:36	15	Total_PCB	0.136	mg/kg dry
125-B2 DDT (32-36)	554	125-B2	32	36	33.72	-118.35	7/7/1992	01:36	15	Total_PCB	0.0731	mg/kg dry
125-B2 DDT (36-39)	554	125-B2	36	39	33.72	-118.35	7/7/1992	01:36	15	Total_PCB	0.0969	mg/kg dry
125-B2 DDT (10-13)	554	125-B2	10	13	33.72	-118.35	7/7/1992	01:36	15	Total_PCB	0.0568	mg/kg dry
125-B2 DDT (13-16)	554	125-B2	13	16	33.72	-118.35	7/7/1992	01:36	15	Total_PCB	0.0552	mg/kg dry
125-B2 DDT (16-20)	554	125-B2	16	20	33.72	-118.35	7/7/1992	01:36	15	Total_PCB	0.0907	mg/kg dry
127-B1 DDT (0-2)	557	127-B1	0	2	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	1.16	mg/kg dry
127-B1 DDT (10-12)	557	127-B1	10	12	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	1.37	mg/kg dry
127-B1 DDT (12-14)	557	127-B1	12	14	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	1.8	mg/kg dry
127-B1 DDT (14-16)	557	127-B1	14	16	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	3.94	mg/kg dry
127-B1 DDT (16-18)	557	127-B1	16	18	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	4.7	mg/kg dry
127-B1 DDT (18-20)	557	127-B1	18	20	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	6.98	mg/kg dry
127-B1 DDT (2-4)	557	127-B1	2	4	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	0.952	mg/kg dry
127-B1 DDT (20-22)	557	127-B1	20	22	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	9.82	mg/kg dry
127-B1 DDT (22-24)	557	127-B1	22	24	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	10.5	mg/kg dry
127-B1 DDT (24-26)	557	127-B1	24	26	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	12.6	mg/kg dry
127-B1 DDT (26-28)	557	127-B1	26	28	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	11.6	mg/kg dry
127-B1 DDT (28-30)	557	127-B1	28	30	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	6.59	mg/kg dry
127-B1 DDT (30-32)	557	127-B1	30	32	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	2.66	mg/kg dry
127-B1 DDT (30-32)	557	127-B1	30	32	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	4.15	mg/kg dry
127-B1 DDT (30-32)	557	127-B1	30	32	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	4.11	mg/kg dry
127-B1 DDT (32-34)	557	127-B1	32	34	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	2.18	mg/kg dry

Table A-2

Sediment Concentrations of PCBs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
127-B1 DDT (4-6)	557	127-B1	4	6	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	1.06	mg/kg dry
127-B1 DDT (6-8)	557	127-B1	6	8	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	1.09	mg/kg dry
127-B1 DDT (8-10)	557	127-B1	8	10	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	1.15	mg/kg dry
127-B1 DDT (34-38)	557	127-B1	34	38	33.70	-118.35	7/7/1992	03:36	27	Total_PCB	0.266	mg/kg dry
128-B1 DDT (0-4)	563	128-B1	0	4	33.71	-118.34	7/7/1992	05:48	12	Total_PCB	0.0501	mg/kg dry
128-B1 DDT (4-8)	563	128-B1	4	8	33.71	-118.34	7/7/1992	05:48	12	Total_PCB	0.0465	mg/kg dry
128-B1 DDT (4-8)	563	128-B1	4	8	33.71	-118.34	7/7/1992	05:48	12	Total_PCB	0.328	mg/kg dry
128-B1 DDT (4-8)	563	128-B1	4	8	33.71	-118.34	7/7/1992	05:48	12	Total_PCB	0.332	mg/kg dry
128-B1 DDT (8-12)	563	128-B1	8	12	33.71	-118.34	7/7/1992	05:48	12	Total_PCB	0.0266	mg/kg dry
128-B1 DDT (8-12)	563	128-B1	8	12	33.71	-118.34	7/7/1992	05:48	12	Total_PCB	0.0279	mg/kg dry
128-B1 DDT (12-16)	563	128-B1	12	16	33.71	-118.34	7/7/1992	05:48	12	Total_PCB	0.029	mg/kg dry
128-B1 DDT (16-20)	563	128-B1	16	20	33.71	-118.34	7/7/1992	05:48	12	Total_PCB	0.0477	mg/kg dry
128-B1 DDT (20-24)	563	128-B1	20	24	33.71	-118.34	7/7/1992	05:48	12	Total_PCB	0.0268	mg/kg dry
128-B1 DDT (24-28)	563	128-B1	24	28	33.71	-118.34	7/7/1992	05:48	12	Total_PCB	0.0549	mg/kg dry
128-B1 DDT (28-32)	563	128-B1	28	32	33.71	-118.34	7/7/1992	05:48	12	Total_PCB	0.0352	mg/kg dry
130-B1 DDT (0-4)	553	130-B1	0	4	33.70081	-118.3790	7/7/1992	12:48	115	Total_PCB	0.698	mg/kg dry
130-B1 DDT (4-8)	553	130-B1	4	8	33.70081	-118.3790	7/7/1992	12:48	115	Total_PCB	0.646	mg/kg dry
130-B1 DDT (8-12)	553	130-B1	8	12	33.70081	-118.3790	7/7/1992	12:48	115	Total_PCB	0.251	mg/kg dry
130-B1 DDT (12-16)	553	130-B1	12	16	33.70081	-118.3790	7/7/1992	12:48	115	Total_PCB	0.221	mg/kg dry
131-W1 DDT (6-8)	556	131-W1	6	8	33.71	-118.35	7/7/1992	15:37	16	Total_PCB	1.29	mg/kg dry
131-W1 DDT (0-2)	556	131-W1	0	2	33.71	-118.35	7/7/1992	15:37	16	Total_PCB	1.36	mg/kg dry
131-W1 DDT (10-12)	556	131-W1	10	12	33.71	-118.35	7/7/1992	15:37	16	Total_PCB	1.33	mg/kg dry
131-W1 DDT (2-4)	556	131-W1	2	4	33.71	-118.35	7/7/1992	15:37	16	Total_PCB	1.29	mg/kg dry
131-W1 DDT (4-6)	556	131-W1	4	6	33.71	-118.35	7/7/1992	15:37	16	Total_PCB	1.52	mg/kg dry
131-W1 DDT (8-10)	556	131-W1	8	10	33.71	-118.35	7/7/1992	15:37	16	Total_PCB	1.45	mg/kg dry
131-W1 DDT (12-14)	556	131-W1	12	14	33.71	-118.35	7/7/1992	15:37	16	Total_PCB	1.1	mg/kg dry
131-W1 DDT (14-16)	556	131-W1	14	16	33.71	-118.35	7/7/1992	15:37	16	Total_PCB	1.43	mg/kg dry
131-W1 DDT (16-18)	556	131-W1	16	18	33.71	-118.35	7/7/1992	15:37	16	Total_PCB	1.18	mg/kg dry
131-W1 DDT (18-20)	556	131-W1	18	20	33.71	-118.35	7/7/1992	15:37	16	Total_PCB	1.51	mg/kg dry
131-W1 DDT (20-22)	556	131-W1	20	22	33.71	-118.35	7/7/1992	15:37	16	Total_PCB	1.26	mg/kg dry
131-W1 DDT (22-24)	556	131-W1	22	24	33.71	-118.35	7/7/1992	15:37	16	Total_PCB	2.77	mg/kg dry
131-W1 DDT (24-26)	556	131-W1	24	26	33.71	-118.35	7/7/1992	15:37	16	Total_PCB	4.03	mg/kg dry
132-B1 DDT (0-2)	555	132-B1	0	2	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.278	mg/kg dry
132-B1 DDT (10-12)	555	132-B1	10	12	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.217	mg/kg dry
132-B1 DDT (10-12)	555	132-B1	10	12	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.199	mg/kg dry
132-B1 DDT (12-14)	555	132-B1	12	14	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.245	mg/kg dry
132-B1 DDT (12-14)	555	132-B1	12	14	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.533	mg/kg dry

Table A-2

Sediment Concentrations of PCBs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
132-B1 DDT (12-14)	555	132-B1	12	14	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.644	mg/kg dry
132-B1 DDT (14-16)	555	132-B1	14	16	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.306	mg/kg dry
132-B1 DDT (16-18)	555	132-B1	16	18	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.324	mg/kg dry
132-B1 DDT (18-20)	555	132-B1	18	20	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.357	mg/kg dry
132-B1 DDT (2-4)	555	132-B1	2	4	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.249	mg/kg dry
132-B1 DDT (20-22)	555	132-B1	20	22	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.348	mg/kg dry
132-B1 DDT (22-24)	555	132-B1	22	24	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.342	mg/kg dry
132-B1 DDT (24-26)	555	132-B1	24	26	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.366	mg/kg dry
132-B1 DDT (26-28)	555	132-B1	26	28	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.374	mg/kg dry
132-B1 DDT (28-30)	555	132-B1	28	30	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.42	mg/kg dry
132-B1 DDT (30-32)	555	132-B1	30	32	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.428	mg/kg dry
132-B1 DDT (32-34)	555	132-B1	32	34	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.443	mg/kg dry
132-B1 DDT (34-36)	555	132-B1	34	36	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.604	mg/kg dry
132-B1 DDT (36-38)	555	132-B1	36	38	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.564	mg/kg dry
132-B1 DDT (38-40)	555	132-B1	38	40	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.514	mg/kg dry
132-B1 DDT (4-6)	555	132-B1	4	6	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.253	mg/kg dry
132-B1 DDT (6-8)	555	132-B1	6	8	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.296	mg/kg dry
132-B1 DDT (8-10)	555	132-B1	8	10	33.71	-118.35	7/7/1992	20:00	12	Total_PCB	0.299	mg/kg dry
136-B1 DDT (0-2)	559	136-B1	0	2	33.70	-118.36	7/8/1992	02:11	122	Total_PCB	0.348	mg/kg dry
136-B1 DDT (10-12)	559	136-B1	10	12	33.70	-118.36	7/8/1992	02:11	122	Total_PCB	0.677	mg/kg dry
136-B1 DDT (12-14)	559	136-B1	12	14	33.70	-118.36	7/8/1992	02:11	122	Total_PCB	1.08	mg/kg dry
136-B1 DDT (14-16)	559	136-B1	14	16	33.70	-118.36	7/8/1992	02:11	122	Total_PCB	1.73	mg/kg dry
136-B1 DDT (16-18)	559	136-B1	16	18	33.70	-118.36	7/8/1992	02:11	122	Total_PCB	1.32	mg/kg dry
136-B1 DDT (18-20)	559	136-B1	18	20	33.70	-118.36	7/8/1992	02:11	122	Total_PCB	0.217	mg/kg dry
136-B1 DDT (2-4)	559	136-B1	2	4	33.70	-118.36	7/8/1992	02:11	122	Total_PCB	0.276	mg/kg dry
136-B1 DDT (4-6)	559	136-B1	4	6	33.70	-118.36	7/8/1992	02:11	122	Total_PCB	0.687	mg/kg dry
136-B1 DDT (6-8)	559	136-B1	6	8	33.70	-118.36	7/8/1992	02:11	122	Total_PCB	0.733	mg/kg dry
136-B1 DDT (8-10)	559	136-B1	8	10	33.70	-118.36	7/8/1992	02:11	122	Total_PCB	0.658	mg/kg dry
137-B1 DDT (0-2)	581	137-B1	0	2	33.69	-118.38	7/8/1992	04:33	141	Total_PCB	0.483	mg/kg dry
137-B1 DDT (10-12)	581	137-B1	10	12	33.69	-118.38	7/8/1992	04:33	141	Total_PCB	0.344	mg/kg dry
137-B1 DDT (12-14)	581	137-B1	12	14	33.69	-118.38	7/8/1992	04:33	141	Total_PCB	0.169	mg/kg dry
137-B1 DDT (14-16)	581	137-B1	14	16	33.69	-118.38	7/8/1992	04:33	141	Total_PCB	0.0848	mg/kg dry
137-B1 DDT (16-18)	581	137-B1	16	18	33.69	-118.38	7/8/1992	04:33	141	Total_PCB	NR	mg/kg dry
137-B1 DDT (2-4)	581	137-B1	2	4	33.69	-118.38	7/8/1992	04:33	141	Total_PCB	0.629	mg/kg dry
137-B1 DDT (4-6)	581	137-B1	4	6	33.69	-118.38	7/8/1992	04:33	141	Total_PCB	0.473	mg/kg dry
137-B1 DDT (6-8)	581	137-B1	6	8	33.69	-118.38	7/8/1992	04:33	141	Total_PCB	0.539	mg/kg dry
137-B1 DDT (8-10)	581	137-B1	8	10	33.69	-118.38	7/8/1992	04:33	141	Total_PCB	0.652	mg/kg dry

Table A-2

Sediment Concentrations of PCBs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
137-B1 DDT (8-10)	581	137-B1	8	10	33.69	-118.38	7/8/1992	04:33	141	Total_PCB	0.71	mg/kg dry
138-B2 DDT (0-4)	583	138-B2	0	4	33.67248	-118.3672	7/8/1992	08:18	215	Total_PCB	0.339	mg/kg dry
138-B2 DDT (4-8)	583	138-B2	4	8	33.67248	-118.3672	7/8/1992	08:18	215	Total_PCB	0.609	mg/kg dry
139-B2 DDT (0-4)	583	139-B2	0	4	33.66264	-118.3345	7/8/1992	11:58	186	Total_PCB	0.296	mg/kg dry
139-B2 DDT (4-8)	583	139-B2	4	8	33.66264	-118.3345	7/8/1992	11:58	186	Total_PCB	0.552	mg/kg dry
141-W1 DDT (0-2)	556	141-W1	0	2	33.71	-118.35	7/8/1992	15:46	15	Total_PCB	1.07	mg/kg dry
141-W1 DDT (10-12)	556	141-W1	10	12	33.71	-118.35	7/8/1992	15:46	15	Total_PCB	1.4	mg/kg dry
141-W1 DDT (2-4)	556	141-W1	2	4	33.71	-118.35	7/8/1992	15:46	15	Total_PCB	1.66	mg/kg dry
141-W1 DDT (4-6)	556	141-W1	4	6	33.71	-118.35	7/8/1992	15:46	15	Total_PCB	1.02	mg/kg dry
141-W1 DDT (6-8)	556	141-W1	6	8	33.71	-118.35	7/8/1992	15:46	15	Total_PCB	1.16	mg/kg dry
141-W1 DDT (8-10)	556	141-W1	8	10	33.71	-118.35	7/8/1992	15:46	15	Total_PCB	1.31	mg/kg dry
141-W1 DDT (12-14)	556	141-W1	12	14	33.71	-118.35	7/8/1992	15:46	15	Total_PCB	0.902	mg/kg dry
141-W1 DDT (12-14)	556	141-W1	12	14	33.71	-118.35	7/8/1992	15:46	15	Total_PCB	0.906	mg/kg dry
141-W1 DDT (14-16)	556	141-W1	14	16	33.71	-118.35	7/8/1992	15:46	15	Total_PCB	0.932	mg/kg dry
141-W1 DDT (16-18)	556	141-W1	16	18	33.71	-118.35	7/8/1992	15:46	15	Total_PCB	1.41	mg/kg dry
141-W1 DDT (16-18)	556	141-W1	16	18	33.71	-118.35	7/8/1992	15:46	15	Total_PCB	1.65	mg/kg dry
141-W1 DDT (16-18)	556	141-W1	16	18	33.71	-118.35	7/8/1992	15:46	15	Total_PCB	1.71	mg/kg dry
141-W1 DDT (18-20)	556	141-W1	18	20	33.71	-118.35	7/8/1992	15:46	15	Total_PCB	1.69	mg/kg dry
141-W1 DDT (20-22)	556	141-W1	20	22	33.71	-118.35	7/8/1992	15:46	15	Total_PCB	0.83	mg/kg dry
141-W1 DDT (22-24)	556	141-W1	22	24	33.71	-118.35	7/8/1992	15:46	15	Total_PCB	0.916	mg/kg dry
141-W1 DDT (26-28)	556	141-W1	26	28	33.71	-118.35	7/8/1992	15:46	15	Total_PCB	1.98	mg/kg dry
141-W1 DDT (28-30)	556	141-W1	28	30	33.71	-118.35	7/8/1992	15:46	15	Total_PCB	2.24	mg/kg dry
141-W1 DDT (30-32)	556	141-W1	30	32	33.71	-118.35	7/8/1992	15:46	15	Total_PCB	2.14	mg/kg dry
141-W1 DDT (32-34)	556	141-W1	32	34	33.71	-118.35	7/8/1992	15:46	15	Total_PCB	3.48	mg/kg dry
143-B1 DDT (0-4)	547	143-B1	0	4	33.72	-118.36	7/8/1992	20:31	5	Total_PCB	0.07	mg/kg dry
143-B1 DDT (4-8)	547	143-B1	4	8	33.72	-118.36	7/8/1992	20:31	5	Total_PCB	0.11	mg/kg dry
143-B1 DDT (8-12)	547	143-B1	8	12	33.72	-118.36	7/8/1992	20:31	5	Total_PCB	0.0938	mg/kg dry
143-B1 DDT (12-16)	547	143-B1	12	16	33.72	-118.36	7/8/1992	20:31	5	Total_PCB	0.0309	mg/kg dry
143-B1 DDT (16-20)	547	143-B1	16	20	33.72	-118.36	7/8/1992	20:31	5	Total_PCB	0.0854	mg/kg dry
143-B1 DDT (20-24)	547	143-B1	20	24	33.72	-118.36	7/8/1992	20:31	5	Total_PCB	0.0896	mg/kg dry
143-B1 DDT (24-28)	547	143-B1	24	28	33.72	-118.36	7/8/1992	20:31	5	Total_PCB	0.0822	mg/kg dry
143-B1 DDT (28-32)	547	143-B1	28	32	33.72	-118.36	7/8/1992	20:31	5	Total_PCB	0.0453	mg/kg dry
146-B1 DDT (0-4)	552	146-B1	0	4	33.71	-118.37	7/9/1992	03:36	55	Total_PCB	0.623	mg/kg dry
146-B1 DDT (4-8)	552	146-B1	4	8	33.71	-118.37	7/9/1992	03:36	55	Total_PCB	0.702	mg/kg dry
146-B1 DDT (8-12)	552	146-B1	8	12	33.71	-118.37	7/9/1992	03:36	55	Total_PCB	1.61	mg/kg dry
146-B1 DDT (12-16)	552	146-B1	12	16	33.71	-118.37	7/9/1992	03:36	55	Total_PCB	3.73	mg/kg dry
146-B1 DDT (16-20)	552	146-B1	16	20	33.71	-118.37	7/9/1992	03:36	55	Total_PCB	0.593	mg/kg dry

Table A-2

Sediment Concentrations of PCBs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
146-B1 DDT (20-24)	552	146-B1	20	24	33.71	-118.37	7/9/1992	03:36	55	Total_PCB	0.1	mg/kg dry
147-B3 DDT (0-2)	556	147-B3	0	2	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	1.55	mg/kg dry
147-B3 DDT (10-12)	556	147-B3	10	12	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	1.44	mg/kg dry
147-B3 DDT (12-14)	556	147-B3	12	14	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	1.61	mg/kg dry
147-B3 DDT (14-16)	556	147-B3	14	16	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	1.25	mg/kg dry
147-B3 DDT (16-18)	556	147-B3	16	18	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	1.14	mg/kg dry
147-B3 DDT (16-18)	556	147-B3	16	18	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	1.15	mg/kg dry
147-B3 DDT (18-20)	556	147-B3	18	20	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	0.866	mg/kg dry
147-B3 DDT (2-4)	556	147-B3	2	4	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	1.24	mg/kg dry
147-B3 DDT (20-22)	556	147-B3	20	22	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	1.45	mg/kg dry
147-B3 DDT (22-24)	556	147-B3	22	24	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	1.54	mg/kg dry
147-B3 DDT (24-26)	556	147-B3	24	26	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	2.01	mg/kg dry
147-B3 DDT (26-28)	556	147-B3	26	28	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	2.92	mg/kg dry
147-B3 DDT (28-30)	556	147-B3	28	30	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	4.85	mg/kg dry
147-B3 DDT (30-32)	556	147-B3	30	32	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	5.24	mg/kg dry
147-B3 DDT (32-34)	556	147-B3	32	34	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	7.6	mg/kg dry
147-B3 DDT (34-36)	556	147-B3	34	36	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	9.03	mg/kg dry
147-B3 DDT (36-38)	556	147-B3	36	38	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	14.7	mg/kg dry
147-B3 DDT (38-40)	556	147-B3	38	40	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	14.5	mg/kg dry
147-B3 DDT (4-6)	556	147-B3	4	6	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	1.29	mg/kg dry
147-B3 DDT (40-42)	556	147-B3	40	42	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	19.9	mg/kg dry
147-B3 DDT (40-42)	556	147-B3	40	42	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	15.6	mg/kg dry
147-B3 DDT (40-42)	556	147-B3	40	42	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	15.3	mg/kg dry
147-B3 DDT (42-44)	556	147-B3	42	44	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	10.8	mg/kg dry
147-B3 DDT (6-8)	556	147-B3	6	8	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	1.74	mg/kg dry
147-B3 DDT (8-10)	556	147-B3	8	10	33.71	-118.35	7/9/1992	07:54	14	Total_PCB	1.69	mg/kg dry
148-B1 DDT (0-4)	532	148-B1	0	4	33.72	-118.40	7/9/1992	09:58	37	Total_PCB	0.702	mg/kg dry
148-B1 DDT (4-8)	532	148-B1	4	8	33.72	-118.40	7/9/1992	09:58	37	Total_PCB	0.879	mg/kg dry
148-B1 DDT (8-12)	532	148-B1	8	12	33.72	-118.40	7/9/1992	09:58	37	Total_PCB	1.02	mg/kg dry
148-B1 DDT (8-12)	532	148-B1	8	12	33.72	-118.40	7/9/1992	09:58	37	Total_PCB	1.04	mg/kg dry
148-B1 DDT (12-16)	532	148-B1	12	16	33.72	-118.40	7/9/1992	09:58	37	Total_PCB	0.96	mg/kg dry
148-B1 DDT (16-20)	532	148-B1	16	20	33.72	-118.40	7/9/1992	09:58	37	Total_PCB	3.13	mg/kg dry
148-B1 DDT (16-20)	532	148-B1	16	20	33.72	-118.40	7/9/1992	09:58	37	Total_PCB	3.55	mg/kg dry
148-B1 DDT (16-20)	532	148-B1	16	20	33.72	-118.40	7/9/1992	09:58	37	Total_PCB	2.9	mg/kg dry
148-B1 DDT (20-24)	532	148-B1	20	24	33.72	-118.40	7/9/1992	09:58	37	Total_PCB	2.72	mg/kg dry
148-B1 DDT (24-28)	532	148-B1	24	28	33.72	-118.40	7/9/1992	09:58	37	Total_PCB	0.651	mg/kg dry
148-B1 DDT (28-32)	532	148-B1	28	32	33.72	-118.40	7/9/1992	09:58	37	Total_PCB	0.141	mg/kg dry

Table A-2

Sediment Concentrations of PCBs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
149-B1 DDT (0-4)	533	149-B1	0	4	33.72	-118.40	7/9/1992	11:46	46	Total_PCB	0.93	mg/kg dry
149-B1 DDT (4-8)	533	149-B1	4	8	33.72	-118.40	7/9/1992	11:46	46	Total_PCB	1.08	mg/kg dry
149-B1 DDT (8-12)	533	149-B1	8	12	33.72	-118.40	7/9/1992	11:46	46	Total_PCB	2.44	mg/kg dry
149-B1 DDT (12-16)	533	149-B1	12	16	33.72	-118.40	7/9/1992	11:46	46	Total_PCB	0.96	mg/kg dry
149-B1 DDT (16-20)	533	149-B1	16	20	33.72	-118.40	7/9/1992	11:46	46	Total_PCB	4.31	mg/kg dry
149-B1 DDT (20-24)	533	149-B1	20	24	33.72	-118.40	7/9/1992	11:46	46	Total_PCB	1.28	mg/kg dry
149-B1 DDT (24-28)	533	149-B1	24	28	33.72	-118.40	7/9/1992	11:46	46	Total_PCB	0.292	mg/kg dry
149-B1 DDT (28-32)	533	149-B1	28	32	33.72	-118.40	7/9/1992	11:46	46	Total_PCB	0.0161	mg/kg dry
149-B1 DDT (32-36)	533	149-B1	32	36	33.72	-118.40	7/9/1992	11:46	46	Total_PCB	0.0144	mg/kg dry
153-B1 DDT (0-4)	574	153-B1	0	4	33.69	-118.32	7/10/1992	06:14	13	Total_PCB	1.3	mg/kg dry
153-B1 DDT (4-8)	574	153-B1	4	8	33.69	-118.32	7/10/1992	06:14	13	Total_PCB	2.19	mg/kg dry
153-B1 DDT (8-12)	574	153-B1	8	12	33.69	-118.32	7/10/1992	06:14	13	Total_PCB	7.61	mg/kg dry
153-B1 DDT (8-12)	574	153-B1	8	12	33.69	-118.32	7/10/1992	06:14	13	Total_PCB	3.78	mg/kg dry
153-B1 DDT (8-12)	574	153-B1	8	12	33.69	-118.32	7/10/1992	06:14	13	Total_PCB	4.68	mg/kg dry
153-B1 DDT (12-16)	574	153-B1	12	16	33.69	-118.32	7/10/1992	06:14	13	Total_PCB	5.89	mg/kg dry
153-B1 DDT (12-16)	574	153-B1	12	16	33.69	-118.32	7/10/1992	06:14	13	Total_PCB	6.22	mg/kg dry
153-B1 DDT (16-20)	574	153-B1	16	20	33.69	-118.32	7/10/1992	06:14	13	Total_PCB	4.12	mg/kg dry
153-B1 DDT (16-20)	574	153-B1	16	20	33.69	-118.32	7/10/1992	06:14	13	Total_PCB	4.16	mg/kg dry
153-B1 DDT (16-20)	574	153-B1	16	20	33.69	-118.32	7/10/1992	06:14	13	Total_PCB	3.81	mg/kg dry
153-B1 DDT (20-24)	574	153-B1	20	24	33.69	-118.32	7/10/1992	06:14	13	Total_PCB	1.83	mg/kg dry
153-B1 DDT (20-24)	574	153-B1	20	24	33.69	-118.32	7/10/1992	06:14	13	Total_PCB	1.93	mg/kg dry
153-B1 DDT (24-28)	574	153-B1	24	28	33.69	-118.32	7/10/1992	06:14	13	Total_PCB	0.712	mg/kg dry
153-B1 DDT (28-32)	574	153-B1	28	32	33.69	-118.32	7/10/1992	06:14	13	Total_PCB	0.076	mg/kg dry
153-B1 DDT (32-36)	574	153-B1	32	36	33.69	-118.32	7/10/1992	06:14	13	Total_PCB	0.425	mg/kg dry
155-B2 DDT (0-4)	572	155-B2	0	4	33.67598	-118.3297	7/10/1992	10:41	110	Total_PCB	0.91	mg/kg dry
155-B2 DDT (4-8)	572	155-B2	4	8	33.67598	-118.3297	7/10/1992	10:41	110	Total_PCB	0.556	mg/kg dry
155-B2 DDT (8-12)	572	155-B2	8	12	33.67598	-118.3297	7/10/1992	10:41	110	Total_PCB	0.456	mg/kg dry
155-B2 DDT (12-16)	572	155-B2	12	16	33.67598	-118.3297	7/10/1992	10:41	110	Total_PCB	0.757	mg/kg dry
155-B2 DDT (16-20)	572	155-B2	16	20	33.67598	-118.3297	7/10/1992	10:41	110	Total_PCB	0.945	mg/kg dry
155-B2 DDT (20-24)	572	155-B2	20	24	33.67598	-118.3297	7/10/1992	10:41	110	Total_PCB	0.772	mg/kg dry
155-B2 DDT (24-28)	572	155-B2	24	28	33.67598	-118.3297	7/10/1992	10:41	110	Total_PCB	0.325	mg/kg dry
155-B2 DDT (28-32)	572	155-B2	28	32	33.67598	-118.3297	7/10/1992	10:41	110	Total_PCB	0.113	mg/kg dry
155-B2 DDT (28-32)	572	155-B2	28	32	33.67598	-118.3297	7/10/1992	10:41	110	Total_PCB	0.502	mg/kg dry
155-B2 DDT (28-32)	572	155-B2	28	32	33.67598	-118.3297	7/10/1992	10:41	110	Total_PCB	0.514	mg/kg dry
155-B2 DDT (32-36)	572	155-B2	32	36	33.67598	-118.3297	7/10/1992	10:41	110	Total_PCB	NR	mg/kg dry
155-B2 DDT (36-40)	572	155-B2	36	40	33.67598	-118.3297	7/10/1992	10:41	110	Total_PCB	NR	mg/kg dry
156-B1 DDT (2-4)	525	156-B1	2	4	33.71	-118.42	7/10/1992	13:16	185	Total_PCB	0.18	mg/kg dry

Table A-2

Sediment Concentrations of PCBs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
156-B1 DDT (0-2)	525	156-B1	0	2	33.71	-118.42	7/10/1992	13:16	185	Total_PCB	0.108	mg/kg dry
157-W1 DDT (0-2)	556	157-W1	0	2	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	0.972	mg/kg dry
157-W1 DDT (10-12)	556	157-W1	10	12	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	1.57	mg/kg dry
157-W1 DDT (2-4)	556	157-W1	2	4	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	1.38	mg/kg dry
157-W1 DDT (4-6)	556	157-W1	4	6	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	1.37	mg/kg dry
157-W1 DDT (4-6)	556	157-W1	4	6	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	1.42	mg/kg dry
157-W1 DDT (6-8)	556	157-W1	6	8	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	1.47	mg/kg dry
157-W1 DDT (8-10)	556	157-W1	8	10	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	1.16	mg/kg dry
157-W1 DDT (8-10)	556	157-W1	8	10	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	1.49	mg/kg dry
157-W1 DDT (8-10)	556	157-W1	8	10	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	1.8	mg/kg dry
157-W1 DDT (12-14)	556	157-W1	12	14	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	1.38	mg/kg dry
157-W1 DDT (14-16)	556	157-W1	14	16	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	1.32	mg/kg dry
157-W1 DDT (16-18)	556	157-W1	16	18	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	1.31	mg/kg dry
157-W1 DDT (18-20)	556	157-W1	18	20	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	1.23	mg/kg dry
157-W1 DDT (20-22)	556	157-W1	20	22	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	1.13	mg/kg dry
157-W1 DDT (22-24)	556	157-W1	22	24	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	1.55	mg/kg dry
157-W1 DDT (24-26)	556	157-W1	24	26	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	1.61	mg/kg dry
157-W1 DDT (26-28)	556	157-W1	26	28	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	1.64	mg/kg dry
157-W1 DDT (26-28)	556	157-W1	26	28	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	1.84	mg/kg dry
157-W1 DDT (26-28)	556	157-W1	26	28	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	1.86	mg/kg dry
157-W1 DDT (28-30)	556	157-W1	28	30	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	2.52	mg/kg dry
157-W1 DDT (30-32)	556	157-W1	30	32	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	2.91	mg/kg dry
157-W1 DDT (32-34)	556	157-W1	32	34	33.71	-118.35	7/10/1992	15:40	14	Total_PCB	3.4	mg/kg dry
159-B1 DDT (0-4)	519	159-B1	0	4	33.73331	-118.4319	7/10/1992	20:29	72	Total_PCB	2.79	mg/kg dry
159-B1 DDT (4-8)	519	159-B1	4	8	33.73331	-118.4319	7/10/1992	20:29	72	Total_PCB	0.49	mg/kg dry
159-B1 DDT (8-12)	519	159-B1	8	12	33.73331	-118.4319	7/10/1992	20:29	72	Total_PCB	0.249	mg/kg dry
159-B1 DDT (12-16)	519	159-B1	12	16	33.73331	-118.4319	7/10/1992	20:29	72	Total_PCB	0.246	mg/kg dry
160-B1 DDT (0-4)	514	160-B1	0	4	33.76	-118.44	7/10/1992	22:42	12	Total_PCB	0.356	mg/kg dry
160-B1 DDT (0-4)	514	160-B1	0	4	33.76	-118.44	7/10/1992	22:42	12	Total_PCB	0.447	mg/kg dry
160-B1 DDT (0-4)	514	160-B1	0	4	33.76	-118.44	7/10/1992	22:42	12	Total_PCB	0.465	mg/kg dry
160-B1 DDT (4-8)	514	160-B1	4	8	33.76	-118.44	7/10/1992	22:42	12	Total_PCB	0.35	mg/kg dry
160-B1 DDT (8-12)	514	160-B1	8	12	33.76	-118.44	7/10/1992	22:42	12	Total_PCB	0.381	mg/kg dry
160-B1 DDT (12-16)	514	160-B1	12	16	33.76	-118.44	7/10/1992	22:42	12	Total_PCB	0.489	mg/kg dry
160-B1 DDT (12-16)	514	160-B1	12	16	33.76	-118.44	7/10/1992	22:42	12	Total_PCB	0.467	mg/kg dry
160-B1 DDT (16-20)	514	160-B1	16	20	33.76	-118.44	7/10/1992	22:42	12	Total_PCB	0.78	mg/kg dry
160-B1 DDT (20-24)	514	160-B1	20	24	33.76	-118.44	7/10/1992	22:42	12	Total_PCB	0.691	mg/kg dry
160-B1 DDT (24-28)	514	160-B1	24	28	33.76	-118.44	7/10/1992	22:42	12	Total_PCB	0.427	mg/kg dry

Table A-2

Sediment Concentrations of PCBs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
160-B1 DDT (28-32)	514	160-B1	28	32	33.76	-118.44	7/10/1992	22:42	12	Total_PCB	0.277	mg/kg dry
160-B1 DDT (32-36)	514	160-B1	32	36	33.76	-118.44	7/10/1992	22:42	12	Total_PCB	0.115	mg/kg dry
163-B1 DDT (0-4)	506	163-B1	0	4	33.79748	-118.5287	7/11/1992	04:05	175	Total_PCB	0.125	mg/kg dry
163-B1 DDT (4-8)	506	163-B1	4	8	33.79748	-118.5287	7/11/1992	04:05	175	Total_PCB	0.169	mg/kg dry
166-B1 DDT (0-4)	516	166-B1	0	4	33.73865	-118.4389	7/11/1992	13:07	110	Total_PCB	0.102	mg/kg dry
166-B1 DDT (4-8)	516	166-B1	4	8	33.73865	-118.4389	7/11/1992	13:07	110	Total_PCB	0.0388	mg/kg dry
166-B1 DDT (8-12)	516	166-B1	8	12	33.73865	-118.4389	7/11/1992	13:07	110	Total_PCB	NR	mg/kg dry
169-B1 DDT (0-2)	550	169-B1	0	2	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	0.987	mg/kg dry
169-B1 DDT (10-12)	550	169-B1	10	12	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	0.782	mg/kg dry
169-B1 DDT (10-12)	550	169-B1	10	12	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	0.782	mg/kg dry
169-B1 DDT (12-14)	550	169-B1	12	14	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	0.716	mg/kg dry
169-B1 DDT (14-16)	550	169-B1	14	16	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	0.716	mg/kg dry
169-B1 DDT (14-16)	550	169-B1	14	16	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	3.66	mg/kg dry
169-B1 DDT (14-16)	550	169-B1	14	16	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	3.49	mg/kg dry
169-B1 DDT (16-18)	550	169-B1	16	18	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	0.707	mg/kg dry
169-B1 DDT (18-20)	550	169-B1	18	20	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	0.734	mg/kg dry
169-B1 DDT (2-4)	550	169-B1	2	4	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	0.776	mg/kg dry
169-B1 DDT (2-4)	550	169-B1	2	4	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	1.14	mg/kg dry
169-B1 DDT (2-4)	550	169-B1	2	4	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	1.2	mg/kg dry
169-B1 DDT (20-22)	550	169-B1	20	22	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	0.931	mg/kg dry
169-B1 DDT (20-22)	550	169-B1	20	22	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	1.1	mg/kg dry
169-B1 DDT (22-24)	550	169-B1	22	24	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	2.12	mg/kg dry
169-B1 DDT (24-26)	550	169-B1	24	26	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	2.39	mg/kg dry
169-B1 DDT (26-28)	550	169-B1	26	28	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	3.01	mg/kg dry
169-B1 DDT (28-30)	550	169-B1	28	30	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	4.44	mg/kg dry
169-B1 DDT (30-32)	550	169-B1	30	32	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	4.66	mg/kg dry
169-B1 DDT (30-32)	550	169-B1	30	32	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	11.8	mg/kg dry
169-B1 DDT (30-32)	550	169-B1	30	32	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	10.9	mg/kg dry
169-B1 DDT (32-34)	550	169-B1	32	34	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	18.4	mg/kg dry
169-B1 DDT (34-36)	550	169-B1	34	36	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	10.4	mg/kg dry
169-B1 DDT (36-38)	550	169-B1	36	38	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	8.1	mg/kg dry
169-B1 DDT (36-38)	550	169-B1	36	38	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	8.65	mg/kg dry
169-B1 DDT (38-40)	550	169-B1	38	40	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	6.54	mg/kg dry
169-B1 DDT (38-40)	550	169-B1	38	40	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	7.01	mg/kg dry
169-B1 DDT (38-40)	550	169-B1	38	40	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	7.47	mg/kg dry
169-B1 DDT (4-6)	550	169-B1	4	6	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	0.929	mg/kg dry
169-B1 DDT (40-42)	550	169-B1	40	42	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	5.76	mg/kg dry

Table A-2

Sediment Concentrations of PCBs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
169-B1 DDT (42-44)	550	169-B1	42	44	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	3.23	mg/kg dry
169-B1 DDT (44-46)	550	169-B1	44	46	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	2.22	mg/kg dry
169-B1 DDT (6-8)	550	169-B1	6	8	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	0.883	mg/kg dry
169-B1 DDT (8-10)	550	169-B1	8	10	33.71	-118.36	7/11/1992	21:56	14	Total_PCB	0.998	mg/kg dry
171-B1 DDT (0-2)	564	171-B1	0	2	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	1.8	mg/kg dry
171-B1 DDT (10-12)	564	171-B1	10	12	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	1.3	mg/kg dry
171-B1 DDT (12-14)	564	171-B1	12	14	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	1.29	mg/kg dry
171-B1 DDT (0-46)	564	171-B1	0	46	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	1.49	mg/kg dry
171-B1 DDT (14-16)	564	171-B1	14	16	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	1.92	mg/kg dry
171-B1 DDT (14-16)	564	171-B1	14	16	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	2.05	mg/kg dry
171-B1 DDT (16-18)	564	171-B1	16	18	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	1.36	mg/kg dry
171-B1 DDT (18-20)	564	171-B1	18	20	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	1.87	mg/kg dry
171-B1 DDT (2-4)	564	171-B1	2	4	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	1.35	mg/kg dry
171-B1 DDT (20-22)	564	171-B1	20	22	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	2.94	mg/kg dry
171-B1 DDT (22-24)	564	171-B1	22	24	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	3.42	mg/kg dry
171-B1 DDT (24-26)	564	171-B1	24	26	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	3.89	mg/kg dry
171-B1 DDT (26-28)	564	171-B1	26	28	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	4.88	mg/kg dry
171-B1 DDT (28-30)	564	171-B1	28	30	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	9.25	mg/kg dry
171-B1 DDT (30-32)	564	171-B1	30	32	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	17.4	mg/kg dry
171-B1 DDT (32-34)	564	171-B1	32	34	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	20.6	mg/kg dry
171-B1 DDT (34-36)	564	171-B1	34	36	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	20.3	mg/kg dry
171-B1 DDT (36-38)	564	171-B1	36	38	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	18.4	mg/kg dry
171-B1 DDT (38-40)	564	171-B1	38	40	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	13.1	mg/kg dry
171-B1 DDT (4-6)	564	171-B1	4	6	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	1.86	mg/kg dry
171-B1 DDT (4-6)	564	171-B1	4	6	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	1.58	mg/kg dry
171-B1 DDT (6-8)	564	171-B1	6	8	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	1.68	mg/kg dry
171-B1 DDT (6-8)	564	171-B1	6	8	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	2.73	mg/kg dry
171-B1 DDT (0-46)	564	171-B1	0	46	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	1.34	mg/kg dry
171-B1 DDT (0-46)	564	171-B1	0	46	33.70	-118.33	7/12/1992	09:49	13	Total_PCB	1.27	mg/kg dry
173-B1 DDT (0-4)	534	173-B1	0	4	33.73	-118.38	7/12/1992	12:52	9	Total_PCB	0.246	mg/kg dry
173-B1 DDT (4-8)	534	173-B1	4	8	33.73	-118.38	7/12/1992	12:52	9	Total_PCB	0.308	mg/kg dry
173-B1 DDT (8-12)	534	173-B1	8	12	33.73	-118.38	7/12/1992	12:52	9	Total_PCB	0.323	mg/kg dry
173-B1 DDT (12-16)	534	173-B1	12	16	33.73	-118.38	7/12/1992	12:52	9	Total_PCB	0.184	mg/kg dry
173-B1 DDT (16-20)	534	173-B1	16	20	33.73	-118.38	7/12/1992	12:52	9	Total_PCB	0.232	mg/kg dry
173-B1 DDT (20-24)	534	173-B1	20	24	33.73	-118.38	7/12/1992	12:52	9	Total_PCB	0.326	mg/kg dry
173-B1 DDT (24-28)	534	173-B1	24	28	33.73	-118.38	7/12/1992	12:52	9	Total_PCB	0.492	mg/kg dry
173-B1 DDT (28-32)	534	173-B1	28	32	33.73	-118.38	7/12/1992	12:52	9	Total_PCB	0.436	mg/kg dry

Table A-2

Sediment Concentrations of PCBs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
173-B1 DDT (32-36)	534	173-B1	32	36	33.73	-118.38	7/12/1992	12:52	9	Total_PCB	0.322	mg/kg dry
173-B1 DDT (36-40)	534	173-B1	36	40	33.73	-118.38	7/12/1992	12:52	9	Total_PCB	0.414	mg/kg dry
173-B1 DDT (40-44)	534	173-B1	40	44	33.73	-118.38	7/12/1992	12:52	9	Total_PCB	0.818	mg/kg dry
173-B1 DDT (44-48)	534	173-B1	44	48	33.73	-118.38	7/12/1992	12:52	9	Total_PCB	0.435	mg/kg dry
173-B1 DDT (48-52)	534	173-B1	48	52	33.73	-118.38	7/12/1992	12:52	9	Total_PCB	0.122	mg/kg dry
174-B1 DDT (0-4)	536	174-B1	0	4	33.72	-118.39	7/12/1992	14:08	17	Total_PCB	0.511	mg/kg dry
174-B1 DDT (4-8)	536	174-B1	4	8	33.72	-118.39	7/12/1992	14:08	17	Total_PCB	0.585	mg/kg dry
174-B1 DDT (8-12)	536	174-B1	8	12	33.72	-118.39	7/12/1992	14:08	17	Total_PCB	0.943	mg/kg dry
174-B1 DDT (12-16)	536	174-B1	12	16	33.72	-118.39	7/12/1992	14:08	17	Total_PCB	0.3	mg/kg dry
174-B1 DDT (16-20)	536	174-B1	16	20	33.72	-118.39	7/12/1992	14:08	17	Total_PCB	1.44	mg/kg dry
174-B1 DDT (16-20)	536	174-B1	16	20	33.72	-118.39	7/12/1992	14:08	17	Total_PCB	1.53	mg/kg dry
174-B1 DDT (16-20)	536	174-B1	16	20	33.72	-118.39	7/12/1992	14:08	17	Total_PCB	1.56	mg/kg dry
174-B1 DDT (20-24)	536	174-B1	20	24	33.72	-118.39	7/12/1992	14:08	17	Total_PCB	2.46	mg/kg dry
174-B1 DDT (24-28)	536	174-B1	24	28	33.72	-118.39	7/12/1992	14:08	17	Total_PCB	4.97	mg/kg dry
174-B1 DDT (28-32)	536	174-B1	28	32	33.72	-118.39	7/12/1992	14:08	17	Total_PCB	1.05	mg/kg dry
174-B1 DDT (32-36)	536	174-B1	32	36	33.72	-118.39	7/12/1992	14:08	17	Total_PCB	5.04	mg/kg dry
174-B1 DDT (32-36)	536	174-B1	32	36	33.72	-118.39	7/12/1992	14:08	17	Total_PCB	5.29	mg/kg dry
174-B1 DDT (36-40)	536	174-B1	36	40	33.72	-118.39	7/12/1992	14:08	17	Total_PCB	0.466	mg/kg dry
174-B1 DDT (40-44)	536	174-B1	40	44	33.72	-118.39	7/12/1992	14:08	17	Total_PCB	0.0548	mg/kg dry
177-G2 DDT (36-38)	550	177-G2	36	38	33.71	-118.36	7/13/1992	01:25	14	Total_PCB	3.77	mg/kg dry
177-G2 DDT (36-38)	550	177-G2	36	38	33.71	-118.36	7/13/1992	01:25	14	Total_PCB	4.72	mg/kg dry
177-G2 DDT (36-38)	550	177-G2	36	38	33.71	-118.36	7/13/1992	01:25	14	Total_PCB	4.74	mg/kg dry
177-G2 DDT (38-40)	550	177-G2	38	40	33.71	-118.36	7/13/1992	01:25	14	Total_PCB	1.48	mg/kg dry
177-G2 DDT (40-42)	550	177-G2	40	42	33.71	-118.36	7/13/1992	01:25	14	Total_PCB	0.348	mg/kg dry
177-G2 DDT (42-44)	550	177-G2	42	44	33.71	-118.36	7/13/1992	01:25	14	Total_PCB	0.139	mg/kg dry
177-G2 DDT (44-46)	550	177-G2	44	46	33.71	-118.36	7/13/1992	01:25	14	Total_PCB	0.102	mg/kg dry
179-G3 DDT (24-26)	556	179-G3	24	26	33.71	-118.35	7/13/1992	03:57	14	Total_PCB	7.01	mg/kg dry
179-G3 DDT (26-28)	556	179-G3	26	28	33.71	-118.35	7/13/1992	03:57	14	Total_PCB	6.26	mg/kg dry
179-G3 DDT (28-30)	556	179-G3	28	30	33.71	-118.35	7/13/1992	03:57	14	Total_PCB	4.29	mg/kg dry
179-G3 DDT (30-32)	556	179-G3	30	32	33.71	-118.35	7/13/1992	03:57	14	Total_PCB	3.01	mg/kg dry
179-G3 DDT (32-34)	556	179-G3	32	34	33.71	-118.35	7/13/1992	03:57	14	Total_PCB	0.662	mg/kg dry
179-G3 DDT (32-34)	556	179-G3	32	34	33.71	-118.35	7/13/1992	03:57	14	Total_PCB	2.03	mg/kg dry
179-G3 DDT (32-34)	556	179-G3	32	34	33.71	-118.35	7/13/1992	03:57	14	Total_PCB	1.5	mg/kg dry
179-G3 DDT (34-36)	556	179-G3	34	36	33.71	-118.35	7/13/1992	03:57	14	Total_PCB	0.38	mg/kg dry
179-G3 DDT (34-36)	556	179-G3	34	36	33.71	-118.35	7/13/1992	03:57	14	Total_PCB	0.375	mg/kg dry
181-G2 DDT (32-34)	564	181-G2	32	34	33.70	-118.33	7/13/1992	07:08	14	Total_PCB	1.18	mg/kg dry
181-G2 DDT (32-34)	564	181-G2	32	34	33.70	-118.33	7/13/1992	07:08	14	Total_PCB	1.6	mg/kg dry

Table A-2

Sediment Concentrations of PCBs[1]
Natural Resources Damage Assessment (USGS) 1992 Data (Lee et al., 1994)
Palos Verdes Shelf Remedial Investigation Report

Sample ID	Station	Core	Top of Sample (cm)	Bottom of Sample (cm)	Latitude	Longitude	Sample Date	Sample Time	Water Depth (m)	Analyte	Value	Units
181-G2 DDT (32-34)	564	181-G2	32	34	33.70	-118.33	7/13/1992	07:08	14	Total_PCB	1.52	mg/kg dry
181-G2 DDT (34-36)	564	181-G2	34	36	33.70	-118.33	7/13/1992	07:08	14	Total_PCB	0.681	mg/kg dry
181-G2 DDT (36-38)	564	181-G2	36	38	33.70	-118.33	7/13/1992	07:08	14	Total_PCB	0.281	mg/kg dry
181-G2 DDT (38-40)	564	181-G2	38	40	33.70	-118.33	7/13/1992	07:08	14	Total_PCB	0.186	mg/kg dry
181-G2 DDT (38-40)	564	181-G2	38	40	33.70	-118.33	7/13/1992	07:08	14	Total_PCB	0.186	mg/kg dry
181-G2 DDT (40-42)	564	181-G2	40	42	33.70	-118.33	7/13/1992	07:08	14	Total_PCB	0.0104	mg/kg dry
181-G2 DDT (42-44)	564	181-G2	42	44	33.70	-118.33	7/13/1992	07:08	14	Total_PCB	0.0388	mg/kg dry
181-G2 DDT (44-46)	564	181-G2	44	46	33.70	-118.33	7/13/1992	07:08	14	Total_PCB	0.0996	mg/kg dry
181-G2 DDT (46-48)	564	181-G2	46	48	33.70	-118.33	7/13/1992	07:08	14	Total_PCB	0.0123	mg/kg dry
181-G2 DDT (48-50)	564	181-G2	48	50	33.70	-118.33	7/13/1992	07:08	14	Total_PCB	0.00745	mg/kg dry
181-G2 DDT (22-24)	564	181-G2	22	24	33.70	-118.33	7/13/1992	07:08	14	Total_PCB	13.9	mg/kg dry
181-G2 DDT (24-26)	564	181-G2	24	26	33.70	-118.33	7/13/1992	07:08	14	Total_PCB	11.9	mg/kg dry
181-G2 DDT (24-26)	564	181-G2	24	26	33.70	-118.33	7/13/1992	07:08	14	Total_PCB	10.9	mg/kg dry
181-G2 DDT (26-28)	564	181-G2	26	28	33.70	-118.33	7/13/1992	07:08	14	Total_PCB	7.98	mg/kg dry
181-G2 DDT (28-30)	564	181-G2	28	30	33.70	-118.33	7/13/1992	07:08	14	Total_PCB	2.11	mg/kg dry
181-G2 DDT (30-32)	564	181-G2	30	32	33.70	-118.33	7/13/1992	07:08	14	Total_PCB	3.89	mg/kg dry
187-B1 DDT-1 (0-2)	500	187-B1	0	2	34.16	-119.39	7/14/1992	05:29	11	Total_PCB	NR	mg/kg dry
187-B1 DDT-1 (2-4)	500	187-B1	2	4	34.16	-119.39	7/14/1992	05:29	11	Total_PCB	NR	mg/kg dry
187-B1 DDT-1 (4-6)	500	187-B1	4	6	34.16	-119.39	7/14/1992	05:29	11	Total_PCB	NR	mg/kg dry
187-B1 DDT-1 (6-8)	500	187-B1	6	8	34.16	-119.39	7/14/1992	05:29	11	Total_PCB	NR	mg/kg dry

1 - PCBs consist of PCB congeners 8, 18, 28, 44, 52, 66, 101, 105, 118, 128, 138, 153, 170, 180, 187, 195, 206, and 209.

NR = Not Reported

Lee, 1994. *The Distribution and Character of Contaminated Effluent-Affected Sediment, Palos Verdes Margin, Southern California* (data from 1992)

Table A-3
Station 1C
Sediment Concentrations of DDE (mg/kg) from LACSD Core Samples
Palos Verdes Shelf Remedial Investigation Report

Depth (cm)	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005
1	--	--	--	4.11	2.6933	2.8	3.5	1.9	1.52	--	1.14	--	--
3	--	--	--	4.09	2.43	3.265	4	2.5	2.136	--	1.25	--	--
5	--	--	--	3.37	2.89	4.36	5.1	2.9	2.856	--	1.705	--	--
7	--	--	--	2.99	4.7767	3.905	4.2	3.7	3.125	--	2.22	--	--
9	--	--	--	3.51	4.28	5.29	5.7	4.1	3.406	--	2.38	--	--
11	--	--	--	5.09	4.75	4.865	6.4	4.7	4.052	--	3.13	--	--
13	--	--	--	11.3	8.7967	13.63	7.2	6.1	5.426	--	3.16	--	--
15	--	--	--	19.6	7.1667	12.95	19	14	10.09	--	2.88	--	--
17	--	--	--	13.9	10.3	9.1	15	18	9.433	--	8.46	--	--
19	--	--	--	4.57	19.767	12.35	7.1	8.7	3.964	--	8.41	--	--
21	--	--	--	--	14.413	4.455	4.5	4.6	3.598	--	7.51	--	--
23	--	--	--	--	2.41	2.215	0.64	3	1.692	--	3.19	--	--
25	--	--	--	--	2.15	1.53	0.77	3	1.366	--	1.11	--	--
27	--	--	--	--	2.38	1.315	0.52	0.98	0.99989	--	0.841	--	--
29	--	--	--	--	1.32	0.905	0.58	0.91	0.31	--	0.384	--	--
31	--	--	--	--	1.74	0.81	--	1.6	0.28	--	0.27	--	--
33	--	--	--	--	1.09	0.25	--	0.8	0.077	--	0.813	--	--
35	--	--	--	--	2.11	0.022	--	0.42	0.72	--	0.329	--	--
37	--	--	--	--	1.78	0.009	--	0.44	--	--	0.972	--	--
39	--	--	--	--	0.888	--	--	--	--	--	1.12	--	--
41	--	--	--	--	1.38	--	--	--	--	--	0.162	--	--
43	--	--	--	--	0.226	--	--	--	--	--	0.184	--	--
45	--	--	--	--	--	--	--	--	--	--	0.276	--	--
47	--	--	--	--	--	--	--	--	--	--	0.022	--	--
49	--	--	--	--	--	--	--	--	--	--	0.028	--	--

-- = No data collected
Note: Some values are "average" profiles computed from 2 or 3 replicate profiles.

Table A-4
Station 2C
Sediment Concentrations of DDE (mg/kg) from LACSD Core Samples
Palos Verdes Shelf Remedial Investigation Report

Depth (cm)	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005
1	--	--	--	--	8.4	3.6	2.2	1.9	1.52	--	0.868	--	--
3	--	--	--	--	4.13	3.4	3.4	2.5	2.136	--	1.01	--	--
5	--	--	--	--	4.31	2.7	4.1	2.9	2.856	--	1.33	--	--
7	--	--	--	--	3.82	4	4.2	3.7	3.125	--	1.69	--	--
9	--	--	--	--	2.82	3.6	4.6	4.1	3.406	--	2.52	--	--
11	--	--	--	--	3.4	2.6	4.2	4.7	4.052	--	2.39	--	--
13	--	--	--	--	4.46	3.6	3.8	6.1	5.426	--	2.72	--	--
15	--	--	--	--	6.04	9.3	4.5	14	10.09	--	2.68	--	--
17	--	--	--	--	16.6	20	7.4	18	9.433	--	3.11	--	--
19	--	--	--	--	26.8	21	14	8.7	3.964	--	4.58	--	--
21	--	--	--	--	25.2	18	17	4.6	3.598	--	6.95	--	--
23	--	--	--	--	10.8	14	6.7	3	1.692	--	7.1	--	--
25	--	--	--	--	6.58	8	5.9	3	1.366	--	9.07	--	--
27	--	--	--	--	2.26	3.1	5.3	0.98	0.99989	--	3.27	--	--
29	--	--	--	--	2	1.6	2.1	0.91	0.31	--	1.61	--	--
31	--	--	--	--	1.12	7.7	0.95	1.6	0.28	--	1.39	--	--
33	--	--	--	--	0.372	1.9	1.3	0.8	0.077	--	1.37	--	--
35	--	--	--	--	0.438	3.2	1	0.42	0.72	--	0.833	--	--
37	--	--	--	--	0.212	0.63	0.38	0.44	--	--	1.1	--	--
39	--	--	--	--	0.958	0.78	0.24	--	--	--	0.457	--	--
41	--	--	--	--	0.115	1.6	0.14	--	--	--	0.142	--	--
43	--	--	--	--	0.00654	--	--	--	--	--	0.433	--	--
45	--	--	--	--	--	--	--	--	--	--	0.097	--	--
47	--	--	--	--	--	--	--	--	--	--	0.197	--	--
49	--	--	--	--	--	--	--	--	--	--	0.184	--	--
51	--	--	--	--	--	--	--	--	--	--	0.092	--	--
53	--	--	--	--	--	--	--	--	--	--	0.015	--	--
55	--	--	--	--	--	--	--	--	--	--	0.09	--	--

-- = No data collected
Note: Some values are "average" profiles computed from 2 or 3 replicate profiles.

Table A-5
Station 3C
Sediment Concentrations of DDE (mg/kg) from LACSD Core Samples
Palos Verdes Shelf Remedial Investigation Report

Depth (cm)	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005
1	4.66	3.18	3.18	6.4	4.7933	4.4267	3.8133	2.9333	2.104	1.819	1.365	--	1.2667
3	15.48	5.64	7.18	2.8	4.1433	4.6433	4.5567	3.3	2.6273	1.751	1.325	--	1.46
5	26.02	7.7	4.99	3.8	3.9833	4.8333	4.1603	3.8	2.9113	2.154	1.925	--	1.7933
7	39.25	21.3	7.51	5.05	3.3167	5.2733	6.77	4.1333	3.3093	2.449	2.275	--	2.0567
9	60.27	42.3	12.3	8.2	4.8867	5.1533	6.6933	5.7333	3.9773	3.022	2.87	--	2.2067
11	84.04	52.6	30.3	14.5	6.0433	5.42	5.37	5.9667	3.791	3.892	2.605	--	2.3167
13	105.76	73.9	52.8	25	6.8067	5.8267	4.9767	5.9333	4.186	4.843	3.135	--	2.46
15	74.09	70	48.7	49	17.12	5.8733	5.1067	4.9333	3.9393	4.138	3.49	--	2.8367
17	45.39	60.6	72.6	98	25.333	10.217	6.9	4.5333	3.937	4.02	3.65	--	2.6833
19	33.44	49.15	43.2	71	39.2	15	10.093	6.9	5.0163	2.832	4.19	--	2.7533
21	15.34	37.7	31.4	51	32.933	21.233	15.67	9.8333	7.0313	3.244	7.405	--	3.8
23	8.93	9.2	3.22	27	18.667	30.133	23.867	13.3	7.246	6.401	11.15	--	6.28
25	1.91	3.22	4.57	16	6.71	11.733	18.633	10.7	14.798	9.664	12.078	--	8.18
27	--	1.14	0.9	4.8	2.068	7.93	26.9	7.8667	18.677	14.82	17.95	--	14.007
29	--	1.14	0.191	2.7	0.68867	4.7733	31.933	6	14.287	12.74	11.305	--	12.7
31	--	--	1.14	10	1.0697	2.2867	30.54	10.633	6.9533	4.38	10.77	--	8.72
33	--	--	0.256	2.2	1.3147	1.95	19.66	4.9	6.272	3.987	3.63	--	3.0933
35	--	--	0.154	0.75	1.314	0.84667	16.54	2.0733	3.378	5.072	2.395	--	1.3297
37	--	--	--	0.21	0.31433	2	8.9	2.3667	1.6393	1.824	1.83	--	1.191
39	--	--	--	0.05	0.4842	1.1873	4.1233	1.6	1.3305	1.766	1.0965	--	0.74967
41	--	--	--	--	0.306	1.3	2.94	1.9533	1.5492	0.97859	1.448	--	0.53933
43	--	--	--	--	--	1.68	2.971	1.93	1.4306	0.842	0.903	--	0.64067
45	--	--	--	--	--	0.675	2.3683	1.6233	1.1933	0.87639	0.7495	--	0.378
47	--	--	--	--	--	1.1133	1.4945	0.55667	0.7908	0.3677	0.4885	--	0.488
49	--	--	--	--	--	0.28133	1.2645	0.79333	0.62356	0.35359	0.601	--	0.643
51	--	--	--	--	--	0.29767	0.719	0.80667	0.42697	1.601	0.6065	--	0.602
53	--	--	--	--	--	0.1495	4.24	0.47867	0.53173	0.2524	0.771	--	0.32933
55	--	--	--	--	--	--	0.804	0.535	1.208	0.63829	0.561	--	0.47867
57	--	--	--	--	--	--	0.88	0.025	0.2151	0.5102	0.65	--	0.2284
59	--	--	--	--	--	--	--	0.032	--	0.2082	0.748	--	0.25273
61	--	--	--	--	--	--	--	0.25	--	0.38489	0.5825	--	0.127

Table A-5
Station 3C
Sediment Concentrations of DDE (mg/kg) from LACSD Core Samples
Palos Verdes Shelf Remedial Investigation Report

Depth (cm)	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005
63	--	--	--	--	--	--	--	--	--	0.06436	0.3625	--	0.439
65	--	--	--	--	--	--	--	--	--	0.0336	0.13865	--	0.153
67	--	--	--	--	--	--	--	--	--	0.0239	0.34745	--	0.0895
69	--	--	--	--	--	--	--	--	--	0.0069	0.066	--	--
71	--	--	--	--	--	--	--	--	--	--	0.0069	--	--

-- = No data collected
Note: Some values are "average" profiles computed from 2 or 3 replicate profiles.

Table A-6
Station 4C
Sediment Concentrations of DDE (mg/kg) from LACSD Core Samples
Palos Verdes Shelf Remedial Investigation Report

Depth (cm)	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005
1	--	--	--	--	3.7	7.3	3.541	3.8	4.48	2.082	1.69	--	--
3	--	--	--	--	3.82	6.1	5	5.1	3.2	1.856	1.98	--	--
5	--	--	--	--	4.56	5.7	4.8	5.8	3.788	2.594	2.17	--	--
7	--	--	--	--	18.7	5.2	7	5.9	5.027	4.036	2.18	--	--
9	--	--	--	--	23.6	6.1	7.8	6.6	6.474	5.034	3.09	--	--
11	--	--	--	--	34.4	5.3	7.3	7.4	6.38	5.304	3.64	--	--
13	--	--	--	--	56.8	7.5	7.1	8.2	6.858	5.064	2.97	--	--
15	--	--	--	--	21.6	17	6.5	5.5	7.574	5.092	4.24	--	--
17	--	--	--	--	53.9	20	6.76	5.2	6.553	6.797	5.24	--	--
19	--	--	--	--	54.9	29	5.75	6.4	5.082	8.237	4.8	--	--
21	--	--	--	--	106	32	6.85	4.9	10.27	5.848	5.33	--	--
23	--	--	--	--	82.8	52	6.13	6.7	13.18	4.951	4.59	--	--
25	--	--	--	--	25.8	71	18.5	11	24.24	12.48	6.76	--	--
27	--	--	--	--	21.3	28	7.54	21	28.12	20.4	7.04	--	--
29	--	--	--	--	9.32	10	20.2	24	44.06	42.02	19.2	--	--
31	--	--	--	--	3.61	2.1	22.8	28	38.72	72.61	20	--	--
33	--	--	--	--	0.9	1.4	31.5	84	23.6	96.81	28.4	--	--
35	--	--	--	--	1.74	1.6	56.2	47	14.78	50.22	34.4	--	--
37	--	--	--	--	1.34	0.19	3.42	46	4.579	14.99	36.3	--	--
39	--	--	--	--	0.188	1.1	9.35	24	2.575	4.208	6.78	--	--
41	--	--	--	--	0.133	0.25	11.6	8.8	1.897	1.462	10.5	--	--
43	--	--	--	--	0.0808	1.8	23.2	5.9	0.7577	3.36	1.92	--	--
45	--	--	--	--	--	0.73	2.2	3.6	1.622	1.676	1.76	--	--
47	--	--	--	--	--	0.26	1.94	2.5	0.708	0.80439	1.34	--	--
49	--	--	--	--	--	0.047	0.862	6.1	--	0.8222	1.33	--	--
51	--	--	--	--	--	--	0.787	4.3	--	0.764	0.318	--	--
53	--	--	--	--	--	--	0.525	0.3	--	0.56789	1.1	--	--
55	--	--	--	--	--	--	0.77	0.083	--	1.504	0.045	--	--
57	--	--	--	--	--	--	0.1	0.05	--	0.09382	1.7	--	--
59	--	--	--	--	--	--	0.72	0.33	--	0.1626	0.122	--	--
61	--	--	--	--	--	--	0.74	0.21	--	0.1182	0.669	--	--

Table A-6
Station 4C
Sediment Concentrations of DDE (mg/kg) from LACSD Core Samples
Palos Verdes Shelf Remedial Investigation Report

Depth (cm)	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005
63	--	--	--	--	--	--	0.48	0.099	--	0.1402	0.268	--	--
65	--	--	--	--	--	--	0.027	--	--	0.221	0.024	--	--
67	--	--	--	--	--	--	--	--	--	0.1623	0.054	--	--
69	--	--	--	--	--	--	--	--	--	0.36759	--	--	--
71	--	--	--	--	--	--	--	--	--	0.04176	--	--	--

-- = No data collected
Note: Some values are "average" profiles computed from 2 or 3 replicate profiles.

Table A-7
Station 5C
Sediment Concentrations of DDE (mg/kg) from LACSD Core Samples
Palos Verdes Shelf Remedial Investigation Report

Depth (cm)	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005
1	--	--	--	--	5.74	10.6	9.7	4.1	3.502	3.228	2.17	--	1.5467
3	--	--	--	--	5.5	10.4	8.1	5.6	4.328	4.397	2.85	--	2.16
5	--	--	--	--	9.41	7.46	8.1	8.1	4.844	4.91	2.31	--	2.7
7	--	--	--	--	6.76	8.54	7.6	10	7.994	4.134	4.27	--	3.1733
9	--	--	--	--	7.11	6.78	9.3	7.3	5.624	6.99	4.34	--	4.4
11	--	--	--	--	5.14	5.92	8.5	5.3	6.301	6.691	4.89	--	4.7133
13	--	--	--	--	6.99	5.58	8.9	5.5	4.764	6.244	4.44	--	4.58
15	--	--	--	--	9.08	6.62	7.4	5.7	6.574	4.925	4.4	--	4.9067
17	--	--	--	--	10.1	8.49	7.7	6.7	12.26	6.954	4.5	--	5.1367
19	--	--	--	--	11.5	14	16	7.8	18.18	6.148	5.44	--	4.9633
21	--	--	--	--	21.9	22.3	9.2	8.8	25.86	9.076	5.91	--	6.0167
23	--	--	--	--	23.8	27.5	7.8	11	44.16	11.92	5.23	--	7.46
25	--	--	--	--	32.6	38.9	8	17	90.3	14.98	13.2	--	16.333
27	--	--	--	--	32.1	61.2	13	22	97.12	30.56	15.8	--	19.867
29	--	--	--	--	63.3	136	23	42	50.39	28.92	20	--	26.5
31	--	--	--	--	63.2	116	27	70	81.12	39.02	20.3	--	55.233
33	--	--	--	--	85	126	64	110	100.8	48.06	38.7	--	89.4
35	--	--	--	--	75	120	27	140	77.4	23.51	50.5	--	75.333
37	--	--	--	--	116	83	61	110	68.92	40.74	22.5	--	87.4
39	--	--	--	--	60.4	69.5	91	86	30.14	98.46	49.9	--	88.633
41	--	--	--	--	76.8	21.6	100	70	19.58	58.12	74.3	--	81.133
43	--	--	--	--	29.6	22.2	130	38	17.48	66.79	16.1	--	54.267
45	--	--	--	--	9.44	10.5	77	7.6	2.265	35.83	44.9	--	23.133
47	--	--	--	--	3.4	6.59	6.8	6.4	0.70639	8.857	39.4	--	7.4467
49	--	--	--	--	1.51	1.63	20	2.1	1.512	9.735	10.5	--	2.8933
51	--	--	--	--	0.37	0.254	56	0.39	0.4322	4.257	2.95	--	1.4543
53	--	--	--	--	0.343	1.36	1	0.3	0.638	1.624	3.69	--	0.44633
55	--	--	--	--	0.25	0.367	0.57	0.48	5.087	0.28539	2.75	--	0.79933
57	--	--	--	--	0.216	0.314	0.32	0.13	2.54	1.573	1.15	--	0.35297
59	--	--	--	--	1.68	--	0.84	0.15	1.914	2.145	2.63	--	0.38433
61	--	--	--	--	0.164	--	0.4	0.077	0.1208	2.019	1.53	--	0.48167

Table A-7
Station 5C
Sediment Concentrations of DDE (mg/kg) from LACSD Core Samples
Palos Verdes Shelf Remedial Investigation Report

Depth (cm)	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005
63	--	--	--	--	0.0956	--	0.31	0.051	0.088	0.08338	1.27	--	0.279
65	--	--	--	--	0.039	--	0.16	0.069	0.04698	0.04004	1.8	--	0.25497
67	--	--	--	--	0.148	--	0.152	0.033	0.06492	0.314	0.53	--	0.21685
69	--	--	--	--	--	--	0.569	0.017	0.04682	0.0589	0.85	--	0.02795
71	--	--	--	--	--	--	0.465	0.065	0.52479	0.329	0.322	--	0.02065
73	--	--	--	--	--	--	--	--	0.02854	0.03926	0.309	--	0.02382
75	--	--	--	--	--	--	--	--	0.2256	0.1346	0.098	--	0.0793
77	--	--	--	--	--	--	--	--	0.01018	0.06338	0.368	--	--
79	--	--	--	--	--	--	--	--	0.02222	0.1254	0.286	--	--
81	--	--	--	--	--	--	--	--	0.1114	--	0.184	--	--
83	--	--	--	--	--	--	--	--	0.08269	--	--	--	--
85	--	--	--	--	--	--	--	--	0.65329	--	--	--	--

-- = No data collected
Note: Some values are "average" profiles computed from 2 or 3 replicate profiles.

Table A-8
Station 6C
Sediment Concentrations of DDE (mg/kg) from LACSD Core Samples
Palos Verdes Shelf Remedial Investigation Report

Depth (cm)	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005
1	6.03	6.28	8.14	9.2	8.1667	12.25	8.0933	10.3	8.9403	4.0565	3.0967	2.5467	0.91893
3	7.72	8.89	7.97	6.4	9.6033	12.425	11.733	11.167	8.477	4.3595	3.4367	2.99	2.1467
5	9.41	9.54	12.1	8.1	10.637	10.245	10.707	13.667	9.702	5.55	3.0033	4.8517	3.36
7	18.855	14.1	9.91	8.8	11.8	13.175	12.803	12.667	9.8227	6.0105	4.55	6.31	5
9	28.3	9.58	12.1	12.4	10.2	10.915	9.6933	11.333	12.253	6.403	6.5033	8.2767	6.64
11	37.9	10.6	19.5	11.2	10.097	11.175	10.12	11.233	10.57	6.5625	7.11	9.3633	7.2767
13	47.5	13.7	24.1	14.2	9.1133	12.725	10.033	11.633	10.46	8.033	8.13	9.2433	7.66
15	146	24.2	29.2	18.9	11.9	12.95	10.917	11.667	10.49	12.71	8.92	8.82	8.0033
17	162	42.2	32.2	19	17.833	14.485	12.233	14	11.217	12.12	7.6967	7.6133	8.18
19	189	55	92.1	35.6	25.467	18.775	17.6	13	13.85	15.545	9.7333	9.0383	10.053
21	141.85	67	89.9	87.3	32.433	27.725	23.867	22	18.403	23.08	11.437	11.27	11.1
23	94.7	140	217	112.6	61.467	34.1	28.033	25.667	28.117	34.85	16.803	14.8	15.633
25	54.45	161	251	214	97.4	52.35	40.233	32	42.933	72.37	15.947	18.467	18.2
27	14.2	251	270	228.5	114.07	103	72.067	52.667	51.517	54.015	22.86	27.967	26
29	27.4	132	169	229	177	132	125.93	96.333	91.507	30.685	40.467	35.067	40.633
31	40.6	196	107	171	189	214	128	116.33	117.58	50.39	49.993	52.4	59.833
33	23.19	165	164	139	152.67	127	120.53	134	119.27	90.19	91.32	159.33	83.733
35	5.78	82.1	124	66	100.27	119	102.23	143.33	138.97	60.109	155.17	114.47	119.93
37	--	92.2	30.3	58	100.3	107	117.23	109.67	161.47	64.062	121.3	126.33	100.97
39	--	39.2	11.6	11.7	67.967	108	99.033	116.67	128.37	61.378	64.743	72.567	111.07
41	--	15.8	8.67	9.5	51.2	73.725	85.3	106.33	99.88	85.325	102.25	75.8	88.233
43	--	5.89	6.86	19	20.933	52.75	38.2	54.333	81.007	55.372	92.8	69.333	79.533
45	--	--	10.9	1	10.14	22.925	18.167	35.333	40.823	31.99	100.58	50.083	64.567
47	--	--	8.5	0.38	3.9333	20.725	9.6333	24.667	25.09	14.465	52.273	24.763	26.917
49	--	--	1.19	0.24	2.8933	5.81	5.3367	10.733	13.993	5.9035	42.427	10.333	8.9167
51	--	--	0.78	0.2	1.61	4.42	3	3.8	5.5303	4.8783	23.073	3.93	6.99
53	--	--	0.16	0.51	0.632	1.79	1.72	1.4633	3.3361	2.8302	10.857	5.4233	1.8077
55	--	--	0.073	0.012	1.689	1.74	0.84633	2	1.2652	1.3058	3.08	2.7087	1.0007
57	--	--	0.123	--	0.4185	0.22667	1.5393	0.99667	0.86443	0.94065	2.1867	1.1307	0.464
59	--	--	--	--	0.09665	0.25	1.0003	1.6433	1.0744	1.2228	2.1127	0.56333	0.8386
61	--	--	--	--	0.12	0.0985	0.82567	0.61667	3.157	0.5251	2.508	0.45933	0.60767

Table A-8
Station 6C
Sediment Concentrations of DDE (mg/kg) from LACSD Core Samples
Palos Verdes Shelf Remedial Investigation Report

Depth (cm)	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005
63	--	--	--	--	0.218	0.48	1.12	0.36	0.36259	4.143	1.3093	1.228	0.45333
65	--	--	--	--	0.13	0.2	1.02	0.395	0.1904	0.1802	0.555	3.0643	0.38667
67	--	--	--	--	--	--	0.728	0.8	0.1091	0.1234	0.93767	0.4746	0.38923
69	--	--	--	--	--	--	0.398	5.9	0.01341	0.0688	0.26067	1.2211	0.14393
71	--	--	--	--	--	--	--	0.67	--	0.1392	0.33333	0.8577	0.041467
73	--	--	--	--	--	--	--	0.58	--	0.0439	0.21133	0.97967	0.23873
75	--	--	--	--	--	--	--	0.15	--	0.4012	0.64733	1.15	0.213
77	--	--	--	--	--	--	--	--	--	--	0.36637	--	--
79	--	--	--	--	--	--	--	--	--	--	0.115	--	--

-- = No data collected
Note: Some values are "average" profiles computed from 2 or 3 replicate profiles.

Table A-9
Station 7C
Sediment Concentrations of DDE (mg/kg) from LACSD Core Samples
Palos Verdes Shelf Remedial Investigation Report

Depth (cm)	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005
1	--	--	--	19.5	8.08	9.59	14.8	11	10	13.88	1.8067	--	--
3	--	--	--	12.6	8.28	10	11.4	11	10	7.832	0.65767	--	--
5	--	--	--	12.2	10.1	10.4	13	13	11	8.416	0.162	--	--
7	--	--	--	11.8	11.2	9.23	17	14	11	9.177	0.257	--	--
9	--	--	--	16.3	11.6	11.7	13.2	15	10	6.978	1.537	--	--
11	--	--	--	21.8	10.4	11	13.2	13	11	11.22	6.4033	--	--
13	--	--	--	79.2	16	13.5	14.7	13	9.7	12.85	29.833	--	--
15	--	--	--	71.9	14	19	11.2	15	11	15.18	45.867	--	--
17	--	--	--	97	23.2	23.4	16.4	18	15	14.08	87.21	--	--
19	--	--	--	116	27	38.9	21.6	26	17	13.69	101.97	--	--
21	--	--	--	191	32.5	49	28.2	21	19	11.02	103.73	--	--
23	--	--	--	214	80.4	81.5	34.8	29	24	13.74	76.1	--	--
25	--	--	--	195	92.6	201	51.4	39	35	15.44	63.033	--	--
27	--	--	--	234	150	201	101	46	42	27	76.157	--	--
29	--	--	--	147	216	236	60	69	48	29.56	103.39	--	--
31	--	--	--	146	293	218	120	116	100	47.85	77.132	--	--
33	--	--	--	110	256	142	230	140	130	16.56	56.955	--	--
35	--	--	--	121	165	157	200	150	130	65.55	48.367	--	--
37	--	--	--	174	80	102	310	150	160	88.78	32.999	--	--
39	--	--	--	96.4	108	88.7	160	150	110	234.6	21.349	--	--
41	--	--	--	19.2	96.7	37.4	79	140	130	271.8	8.084	--	--
43	--	--	--	7.86	80.2	15.3	120	150	58.72	162	4.4163	--	--
45	--	--	--	5.4	30.4	6.65	130	140	120	89.72	1.9767	--	--
47	--	--	--	1.61	6.66	8.07	88	87	23	102.6	0.929	--	--
49	--	--	--	0.5	4.41	1.91	46	51	80	154.3	0.54	--	--
51	--	--	--	0.47	5.28	3.51	19.1	15	12	92.95	0.08	--	--
53	--	--	--	0.37	0.618	1.79	12.2	13	22	91.5	0.6255	--	--
55	--	--	--	0.08	4.22	0.17	14.4	9.2	0.98	50.02	0.162	--	--
57	--	--	--	0.09	0.75	0.41	3.68	14	2.7	29.41	0.038	--	--
59	--	--	--	0.05	0.176	0.2	9.08	1.3	0.76	10.32	0.339	--	--
61	--	--	--	0.18	43.6	0.92	7.73	0.22	1.8	5.683	--	--	--

Table A-9
Station 7C
Sediment Concentrations of DDE (mg/kg) from LACSD Core Samples
Palos Verdes Shelf Remedial Investigation Report

Depth (cm)	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005
63	--	--	--	0.41	--	0.21	1.38	0.25	3.3	2.092	--	--	--
65	--	--	--	--	--	--	3.39	0.072	1.4	0.7072	--	--	--
67	--	--	--	--	--	--	0.0826	--	0.58039	1.924	--	--	--
69	--	--	--	--	--	--	0.316	--	2.696	0.576	--	--	--
71	--	--	--	--	--	--	0.286	--	0.41639	0.1722	--	--	--
73	--	--	--	--	--	--	--	--	0.0455	1.636	--	--	--
75	--	--	--	--	--	--	--	--	0.0139	0.312	--	--	--
77	--	--	--	--	--	--	--	--	--	0.89559	--	--	--
79	--	--	--	--	--	--	--	--	--	0.358	--	--	--

-- = No data collected
Note : Some values are "average" profiles computed from 2 or 3 replicate profiles.

Table A-10
Station 8C
Sediment Concentrations of DDE (mg/kg) from LACSD Core Samples
Palos Verdes Shelf Remedial Investigation Report

Depth (cm)	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005
1	54.9	--	8.09	11.4	11.8	14	11.6	6.3	14.89	8.94	30.7	--	--
3	107.95	--	13.4	3.9	15.148	31	12.9	8.5	44.09	32.866	20.9	--	--
5	161	--	21.4	13.5	22.153	41	22	9.4	78.04	24.217	29.4	--	--
7	310.33	--	33.4	16.4	28	110	30.9	12	137.3	53.48	26.9	--	--
9	459.67	--	80.8	19.9	40.3	100	69.3	19	190.4	40.96	122	--	--
11	609	--	202	55.8	38.725	230	71.3	27	192.6	173.43	106	--	--
13	488.33	--	220	111	78.105	160	72	36	398	116.26	198	--	--
15	367.67	--	135	102	92.948	190	109	57	313.7	111.77	176	--	--
17	247	--	110	145	102.31	250	114	92	351.8	148.28	193	--	--
19	231.33	--	170	179	170.92	300	177	91	273	196.58	158	--	--
21	215.67	--	185	212	169.75	340	216	88	564.6	127.64	126	--	--
23	200	--	125	238	152.44	420	389	140	299.8	156.58	102	--	--
25	161.67	--	95.4	194	169.47	280	335	340	360.1	109.68	238	--	--
27	123.33	--	99.6	310	127.36	240	420	220	329.5	135.44	107	--	--
29	85	--	128	268	153	210	408	230	249.6	115.03	127	--	--
31	75.7	--	85	335	141.67	170	266	290	154.1	65.554	96.8	--	--
33	66.4	--	35.7	204	116.13	140	203	140	181.2	72.839	109	--	--
35	57.1	--	17.6	210	94.667	110	318	200	180.5	125.84	143	--	--
37	39.38	--	17.8	168	102.17	100	152	140	154.2	68.156	88	--	--
39	21.65	--	6.56	131	85.207	140	157	160	178.2	43.756	88.8	--	--
41	3.93	--	0.779	136	101.38	140	246	180	181.7	94.149	92.5	--	--
43	--	--	0.801	217	55.815	130	237	160	95.2	76.122	108	--	--
45	--	--	0.115	139	25.219	91	272	97	85.38	36.211	94.4	--	--
47	--	--	0.099	73	16.995	64	164	60	110.1	32.63	75.8	--	--
49	--	--	0.271	97	8.4721	53	81.1	26	77.25	56.632	73.5	--	--
51	--	--	0.057	101	11.653	100	85.9	20	60.42	120.1	53.5	--	--
53	--	--	0.012	57.3	5.4449	39	84.4	18	71.36	57.86	51.4	--	--
55	--	--	--	28.7	5.0276	32	65	0.87	48.96	55.74	44.1	--	--
57	--	--	--	10.2	2.9	8.2	28.9	0.53	8.115	69.68	36.75	--	--
59	--	--	--	4.72	1.69	4	18.8	0.1	4.136	24.7	12	--	--
61	--	--	--	0.89	1.16	2.6	16.2	--	2.978	5.348	3.87	--	--

Table A-10
Station 8C
Sediment Concentrations of DDE (mg/kg) from LACSD Core Samples
Palos Verdes Shelf Remedial Investigation Report

Depth (cm)	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005
63	--	--	--	0.13	--	0.52	8.73	--	3.098	3.182	0.905	--	--
65	--	--	--	0.09	--	1.7	0.74	--	0.08731	4.524	0.804	--	--
67	--	--	--	0.12	--	--	1.64	--	0.4857	1.816	1.39	--	--
69	--	--	--	0.11	--	--	0.201	--	--	0.06955	1.13	--	--
71	--	--	--	0.05	--	--	0.353	--	--	0.07754	1.07	--	--
73	--	--	--	--	--	--	--	--	--	0.07892	0.467	--	--
75	--	--	--	--	--	--	--	--	--	0.189	0.6	--	--
77	--	--	--	--	--	--	--	--	--	0.03786	0.096	--	--
79	--	--	--	--	--	--	--	--	--	0.075	0.205	--	--
81	--	--	--	--	--	--	--	--	--	2.2	0.308	--	--
83	--	--	--	--	--	--	--	--	--	--	0.038	--	--
85	--	--	--	--	--	--	--	--	--	--	0.047	--	--
87	--	--	--	--	--	--	--	--	--	--	0.018	--	--

-- = No data collected
Note : Some values are "average" profiles computed from 2 or 3 replicate profiles.

Table A-11
Station 9C
Sediment Concentrations of DDE (mg/kg) from LACSD Core Samples
Palos Verdes Shelf Remedial Investigation Report

Depth (cm)	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005
1	--	--	--	3.25	1.45	1.155	1.6	5.5	1.52	0.864	0.61467	--	--
3	--	--	--	2.48	3.06	2.915	0.76	9.2	2.136	4.372	0.65633	--	--
5	--	--	--	5.32	0.496	2.78	0.26	17	2.856	8.201	2.423	--	--
7	--	--	--	14.3	0.748	1.375	0.78	23	3.125	24.41	6.6873	--	--
9	--	--	--	21	2.08	1.105	0.14	23	3.406	19.18	6.7467	--	--
11	--	--	--	21.9	0.0974	0.19	0.22	17	4.052	8.354	9.082	--	--
13	--	--	--	14.9	--	0.41	0.18	9.2	5.426	1.471	3.679	--	--
15	--	--	--	5.92	--	0.1555	0.11	13	10.09	0.79339	2.1727	--	--
17	--	--	--	1	--	0.295	0.11	34	9.433	1.081	1.2011	--	--
19	--	--	--	0.68	--	0.325	--	28	3.964	0.70379	0.66367	--	--
21	--	--	--	0.45	--	0.145	--	3.6	3.598	1.356	0.571	--	--
23	--	--	--	--	--	0.035	--	1.2	1.692	1.498	0.42767	--	--
25	--	--	--	--	--	0.015	--	0.4	1.366	0.72479	0.74467	--	--
27	--	--	--	--	--	--	--	0.19	0.99989	0.99359	0.39367	--	--
29	--	--	--	--	--	--	--	0.47	0.31	0.95539	0.80633	--	--
31	--	--	--	--	--	--	--	--	0.28	1.33	0.5267	--	--
33	--	--	--	--	--	--	--	--	0.077	0.72179	0.12933	--	--
35	--	--	--	--	--	--	--	--	0.72	0.2206	0.17467	--	--
37	--	--	--	--	--	--	--	--	--	0.0693	0.2364	--	--
39	--	--	--	--	--	--	--	--	--	0.01424	1.0455	--	--
41	--	--	--	--	--	--	--	--	--	0.05915	0.0731	--	--
43	--	--	--	--	--	--	--	--	--	0.107	--	--	--

-- = No data collected
Note: Some values are "average" profiles computed from 2 or 3 replicate profiles.

Table A-12
Station 10C
Sediment Concentrations of DDE (mg/kg) from LACSD Core Samples
Palos Verdes Shelf Remedial Investigation Report

Depth (cm)	1981	1983	1985	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005
1	--	--	--	0.96	0.578	0.62	0.5	--	--	--	--	--	--
3	--	--	--	0.77	0.812	1.1	1.4	--	--	--	--	--	--
5	--	--	--	1.1	1.5	1	1.3	--	--	--	--	--	--
7	--	--	--	1.8	0.775	0.6	1.1	--	--	--	--	--	--
9	--	--	--	0.38	0.72	0.35	0.538	--	--	--	--	--	--
11	--	--	--	0.09	0.63	0.064	0.0358	--	--	--	--	--	--
13	--	--	--	1.04	0.0524	0.027	0.22	--	--	--	--	--	--
15	--	--	--	--	0.0253	0.059	0.0162	--	--	--	--	--	--
17	--	--	--	--	0.0105	--	0.0603	--	--	--	--	--	--
19	--	--	--	--	0.0422	--	0.00961	--	--	--	--	--	--
21	--	--	--	--	0.0367	--	0.00302	--	--	--	--	--	--
23	--	--	--	--	0.0393	--	0.0041	--	--	--	--	--	--

-- = No data collected
Note : Some values are "average" profiles computed from 2 or 3 replicate profiles.

Appendix B
Human Health Risk Evaluation Memorandum

Palos Verdes Shelf Superfund Site: Human Health Risk Evaluation, 2002 Ocean Fish Sampling Data

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1. Background and Purpose

The Palos Verdes Shelf Superfund Site is located off the coast of Los Angeles, California, near the Palos Verdes Peninsula. The marine sediments at the site are contaminated with dichlorodiphenyltrichloroethane (DDT) and its metabolites (hereafter referred to collectively as tDDT or total DDT), and polychlorinated biphenyls (PCBs; also referred to as tPCBs or total PCBs). This contamination is a result of wastewater from the Montrose Chemical Company and other industrial sources that flowed through the Joint Water Pollution Control Plant operated by Los Angeles County Sanitation Districts (LACSD), and was discharged to the ocean waters of the Palos Verdes Shelf through LACSD outfalls.

Historically, the waters of the Palos Verdes Shelf have been used extensively by both sport and commercial fishermen. Sport fishermen angle from party boats, private boats, rocky intertidal areas, and sandy beaches. Currently, high levels of tDDT and tPCBs are found in the active biologic zone of the Palos Verdes Shelf sediments and fish from the Palos Verdes Shelf are contaminated with tDDT and tPCBs. Generally speaking, contaminant levels are highest in bottom-feeding fish, such as the white croaker, and are significantly lower in fish that live higher in the water column. This contamination poses a potential health risk to humans if they consume fish contaminated with tDDT and tPCBs. A Human Health Risk Evaluation (HHRE) conducted in 1999 found significant cancer and noncancer health risks from the consumption of fish caught from the Palos Verdes Shelf site (Science Applications International Corporation [SAIC], 1999).

The National Oceanic and Atmospheric Administration (NOAA), on behalf of the Montrose Settlements Restoration Program (MSRP), and the United States Environmental Protection Agency (EPA) conducted a comprehensive ocean fish sampling study (referred to as the MSRP/EPA study) in the fall of 2002 to assess more recent fish contamination levels on the Palos Verdes Shelf and surrounding areas (EPA and NOAA, 2007). LACSD also conducted an ocean fish sampling study on the Palos Verdes Shelf in 2002 (LACSD, 2002).

The purpose of this HHRE Technical Memorandum is to present the results of the analysis of human health risk using the MSRP/EPA 2002 and LACSD 2002 ocean fish data for PCBs and DDT. This technical memorandum focuses on ocean fish data collected from the Palos Verdes Shelf Superfund Site. The fish species used in this updated HHRE were selected because an adequate number of samples from each species had been analyzed to make the assessment statistically valid. The fish species evaluated represent a mix of water column and bottom feeders, and pelagic and local dwelling species.

The evaluation of potential human cancer risks and noncancer hazards is based on skin-off-fish-fillet results. The fish fillet scenario simulates fish consumption rates of all anglers as described in the Santa Monica Bay Seafood Consumption Study (Santa Monica Bay Restoration Program [SMBRP], 1994). To address the potential for high fish ingestion rates found in some Asian communities and other ethnic groups, high-end fish consumer scenarios are also included in the evaluations. The risk scenario includes the Reasonable Maximum Exposure (RME) and Central Tendency Exposure (CTE) scenarios based on all-angler and Asian-angler consumption rates.

2. Ocean Fish Sampling Studies

Data from two ocean fish sampling studies were used in this HHRE: the MSRP/EPA 2002 ocean fish sampling effort and the 2002 LACSD ocean fish sampling study. Details of these two studies are provided below.

2.1 MSRP/EPA Study

The MSRP and the EPA initiated a comprehensive ocean fish sampling effort in the fall of 2002 to assess contamination levels in fish off the coast of Southern California. These fish were caught at designated locations from Ventura to Dana Point.

The collected fish species were pacific barracuda, pacific (chub) mackerel, pacific sardine, yellowtail, opaleye, sargo, kelp (calico) bass, surfperches, rockfishes, California sheephead, barred sandbass, top smelt, halfmoon, California scorpionfish (sculpin), white seabass, black croaker, white croaker, yellowfin croaker, jacksmelt, California corbina, California halibut, shovelnose guitarfish, and queenfish.

The primary goals of the MSRP/EPA study were to:

- Update health advisories and commercial fishing bans.
- Determine restoration of lost fishing opportunities.
- Provide public information.
- Provide information for the remedial investigation/feasibility study (RI/FS).

This HHRE uses data from six fish species caught from the Palos Verdes Shelf Superfund Site from the Point Fermin area to Redondo Canyon (MSRP Segments 9, 12, 13/14, 15, and location EPA B). The six fish species from the MSRP/EPA study evaluated for this HHRE include:

- White croaker
- Kelp bass
- Rockfish

- Surfperches
- California scorpionfish
- Barred sandbass

The MSRP/EPA study analyzed the fish tissue for tDDT (metabolites), tPCB (congeners), and mercury.

2.2 LACSD Study

LACSD also conducted an ocean fish sampling study on the Palos Verdes Shelf in 2002 (LACSD, 2002). Since 1971, LACSD has performed annual monitoring of the marine environment on the Palos Verdes Shelf to assess the long-term ecological impacts from the effluent discharged from LACSD outfalls. Regional marine conditions in the area of the LACSD outfalls are monitored according to the requirements of the LACSD National Pollutant Discharge Elimination System (NPDES) permit.

The current NPDES permit includes monitoring requirements for accumulation of tDDT and tPCBs within tissues of various fish and invertebrate species. The purpose of the monitoring is to evaluate the temporal and spatial trends associated with bioaccumulation of tDDT and tPCBs in biota collected within three zones across the Palos Verdes Shelf: Zone 1, from White Point to Bunker Point; Zone 2, from Long Point to Point Vicente; and Zone 3, from Palos Verdes Point to Bluff Cove. This HHRE includes an evaluation of white croaker and kelp bass data collected from Zones 1, 2, and 3 as part of the LACSD sampling. LACSD analyzed fish tissue for tDDT and tPCBs (Aroclors).

2.3 Summary of Data Used

Fish caught from MSRP Segments 9, 12, 13/14, 15, and the location EPA B, from the Point Fermin area to Redondo Canyon in the MSRP/EPA study and fish collected from Zones 1, 2, and 3 in the LACSD study are evaluated in this HHRE. The EPA, MSRP, and LACSD 2002 fish sampling locations are shown in Figure 1. Samples of fish fillet muscle from fish from the MSRP/EPA and LACSD studies were analyzed for total DDT and total PCBs. The fish fillet concentrations are summarized in Table 1. The raw data are provided in Appendix A, Tables A-1 through A-6. The results of the statistical analysis of the raw data are provided in Appendix B.

3. Exposure Assessment

The exposure assessment identifies human populations that may be exposed to total DDT and total PCBs in fish fillets, and the magnitude, frequency, and duration of potential exposures. The estimation of exposure to total DDT and total PCBs from consumption of fish requires several assumptions to describe potential exposure scenarios.

To address the potential for high fish ingestion rates found in some Asian communities and other ethnic groups, high-end fish consumer scenarios are evaluated. The high-end fish consumer is assumed to eat fish fillets at a rate substantially higher than the typical consumer. The high-end consumer case is primarily evaluated to provide a bounding estimate on risk.

Ingestion rates were obtained from the Santa Monica Bay Seafood Consumption Study (Table 12 in SMBRP, 1994). For all anglers of all ethnic groups and income levels, the upper 90 percent consumption rate is 107.1 grams per day (grams/day). The upper 90 percent consumption rate for Asian anglers is 115.7 grams/day. The median (50 percent) consumption rate is 21.4 grams/day for all anglers and for Asian anglers. The exposure assumptions for the high-end fillet consumer are provided in Table 2.

The fish fillet ingestion rates for RME and CTE cases for the high-end fish consumer scenario used in the HHRE are 107.1 and 21.4 grams/day, respectively. The Asian-angler ingestion rates for RME and CTE cases are 115.7 and 21.4 grams/day, respectively. These are the 90th percentile and mean consumption rates for all fish consumed, identified from the Santa Monica Bay Seafood Consumption Study (Table 12 in SMBRP, 1994).

3.1 Calculation of Chemical Intake

The following equation was used to calculate intake associated with the ingestion of carcinogenic and noncarcinogenic constituents in fish:

$$Intake = \frac{C_{fish} \times IR_{fish} \times EF \times ED}{BW \times AT}$$

Where:

Intake	=	Constituent daily intake (milligrams per kilogram [mg/kg] body weight/day)
C_{fish}	=	Chemical concentration in fish (mg/kg) (DDT and PCBs reported as micrograms per kilogram [µg/kg] were converted to units of mg/kg [µg/kg x mg/1,000 µg = mg/kg] for Exposure Point Concentration [EPC])
IR_{fish}	=	Fish ingestion rate (kilograms per day [kg/day])
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kilograms [kg])
AT	=	Average time (days)

For the six species of fish evaluated, the potential exposures and human health risks and hazards posed by total DDT and total PCBs were estimated using the minimum, 95 percent upper confidence limit (UCL) on the mean, and maximum concentrations of total DDT and total PCBs. For PCB data from the LACSD study, results reported as nondetect were evaluated at one-half the detection limit. The detection limit was 10 µg/kg; therefore, a proxy value of 5 µg/kg was used.

4. Toxicity Assessment

The regulatory agency sources consulted to obtain toxicity criteria (i.e., noncarcinogenic reference doses and cancer slope factors) for total DDT and total PCBs in order of priority were:

- EPA Integrated Risk Information System (IRIS) (EPA, 2006)
- EPA Health Effects Assessment Summary Tables (HEAST) (EPA, 1997)

- California Environmental Protection Agency (Cal-EPA) Office of Environmental Health Hazard Assessment, Toxicity Criteria Database (Cal-EPA, 2006)

The use of EPA and Cal-EPA toxicity values is in accordance with Office of Solid Waste and Emergency Response (OSWER) Directive 9285.7-53 (December 5, 2003), which defines the EPA hierarchy of human health toxicity values for use in human health risk assessments (HHRAs) and assures the use of high-quality toxicity criteria for the estimation of risks and hazards during the HHRA process. Carcinogenic and noncarcinogenic toxicity values used in this evaluation are summarized in Tables 3 and 4, and discussed below.

- *Carcinogenic Effects of DDT*: Studies in animals have shown that oral exposure to DDT can result in an increased occurrence of liver tumors. An oral slope factor of 0.34 $(mg/kg\text{-}day)^{-1}$ has been derived for DDT and dichlorodiphenyldichloroethene (DDE); and an oral slope factor of 0.24 $(mg/kg\text{-}day)^{-1}$ has been derived for dichlorodiphenyldichloroethane (DDD). All are based on liver tumors in rats and mice exposed via diet (EPA, 2006). A slope factor of 0.34 $(mg/kg\text{-}day)^{-1}$ is used to evaluate carcinogenic risks for DDT and its metabolites, as recommended by EPA (1994).

- *Carcinogenic Effects of PCBs*: Occupational studies show some increase in cancer mortality in workers exposed to PCBs. A cancer slope factor of 2.0 $(mg/kg\text{-}day)^{-1}$, appropriate for food chain exposure, was used.

- *Noncancer Toxicity of DDT*: The major adverse health effects of DDT involve the nervous system, the liver, and reproduction and development of offspring. The reference dose used in the risk calculations is 5×10^{-4} mg/kg-day, which is the current oral reference dose (RfD) listed in the IRIS (EPA) database.

- *Noncancer Toxicity of PCBs*: Liver effects and skin irritations characterized by acne-like lesions and rashes are the only significant adverse health effects reported in workers exposed to PCBs. An oral RfD of 2×10^{-5} mg/kg-day was derived for Aroclor 1254 from monkey clinical immunological studies. Because RfDs are not available for Aroclors 1242 and 1260, the oral RfD for Aroclor 1254 was applied to total PCBs.

5. Risk Characterization

In the risk characterization step, quantification of risk is accomplished by combining the results of the exposure assessment (estimated chemical intakes) with the results of the dose-response assessment (toxicity values identified in the toxicity assessment) to provide numerical estimates of potential health effects. The quantification approach differs for potential cancer and noncancer effects, as described below.

The potential for cancer effects are evaluated by estimating the excess lifetime cancer risk (ELCR), which is the incremental increase in the probability of developing cancer during one's lifetime in addition to the background probability of developing cancer (that is, if no exposure to Site chemicals occurs). For example, a 2×10^{-6} ELCR means that for every 1 million people exposed to the carcinogen throughout their lifetimes, the average incidence of cancer might increase by two cases of cancer. Cancer slope factors developed by the EPA represent upper-bound estimates; therefore, any cancer risks generated in this assessment should be regarded as an upper bound on the potential cancer risks rather than

representations of true cancer risk. The actual cancer risk is likely to be less than that predicted (EPA, 1989). ELCRs will be estimated by using the following formula:

$$ELCR = CSF \times Intake$$

Where:

ELCR	=	Excess lifetime cancer risk
CSF	=	Cancer slope factor (risk per mg/kg-day) or $(mg/kg\text{-}day)^{-1}$
Intake	=	Chronic daily intake averaged over a lifetime (mg/kg-day)

Although synergistic or antagonistic interactions might occur between cancer-causing chemicals and other chemicals, information is generally lacking in the toxicological literature to predict quantitatively the effects of these potential interactions. Therefore, cancer risks will be treated as additive within an exposure route in this assessment. This is consistent with the EPA guidelines on chemical mixtures (EPA, 1989). For estimating the cancer risks from exposure to multiple carcinogens from a single exposure route, the following equation is used to sum risks:

$$Risk_T = \sum_1^N Risk_i$$

Where:

$Risk_T$	=	Total cancer risk from route of exposure
$Risk_i$	=	Cancer risk for the i^{th} chemical
N	=	Number of chemicals

For noncancer effects, the likelihood that a receptor will develop an adverse effect will be estimated by comparing the predicted level of exposure for a particular chemical with the highest level of exposure that is considered protective, or the RfD. The following ratio of the chronic daily intake divided by RfD is termed the hazard quotient (HQ):

$$HQ = \frac{Intake}{RfD}$$

Where:

HQ	=	Hazard quotient
RfD	=	Reference dose (mg/kg-day)
Intake	=	Chronic daily intake (mg/kg-day)

When the HQ for a chemical exceeds 1 (when the exposure exceeds the RfD), there is a concern for potential noncancer health effects. To assess the potential for noncancer effects posed by exposure to multiple chemicals, a hazard index (HI) approach will be used according to EPA guidance (EPA, 1989). This approach assumes that the noncancer hazard associated with exposure to more than one chemical is additive; therefore, synergistic or antagonistic interactions between chemicals are not accounted for. The HI may exceed 1 even if all the individual HQ values are less than 1. In this case, the chemicals may be segregated by similar mechanisms of toxicity and toxicological effects. Separate HIs may then be derived based on mechanism and effect. The HI is calculated as follows:

$$HI = \sum_{1}^{N} Intake_i \Big/ RfD_i$$

Where:

HI	=	Hazard index
$Intake_i$	=	Daily intake of the i^{th} chemical (mg/kg-day)
RfD_i	=	Reference dose of the i^{th} chemical (mg/kg-day)
N	=	Number of chemicals

Because both DDT and PCBs exert toxic effects on the liver, these constituents are considered additively in this HHRE.

5.1 Risk Characterization Results

Risk and hazard characterization results for the all-angler and Asian-angler high-end fish fillet RME and CTE consumers based on the Santa Monica Bay Seafood Consumption Study fish ingestion rates, are presented below.

5.1.1 Fish Fillet Consumption by All Anglers

Tables 5 through 16 present chemical-specific risk calculations for carcinogenic and noncarcinogenic effects for fish fillets from each of the evaluated species, under RME and CTE conditions, using the Santa Monica Bay Seafood Consumption Study exposure assumptions for all anglers for minimum, 95 percent UCL, and maximum total DDT and total PCB concentrations. A summary of the cumulative ELCRs and HIs under RME and CTE conditions for each species is presented in Table 17.

Under RME conditions (using 95 percent UCLs), ELCRs from ingestion of fish fillets range from 7×10^{-5} to 6×10^{-3} (Table 17). The highest risk of the six species tested was from white croaker fillets with a risk of 6×10^{-3}. White croaker fish may generally contain higher levels of DDT and PCBs than other fish from the Palos Verdes Shelf area. This is primarily because the white croaker is a nonmigratory bottom fish that feeds off the ocean floor where these chemicals have settled. Both California scorpionfish and barred sandbass fillets have an ELCR of 3×10^{-4}. Kelp bass, rockfish, and surfperch fillets have ELCRs of 1×10^{-4}, 1×10^{-4}, and 7×10^{-5}, respectively. All six species have RME HI values ranging from 2 to 183. White croaker fillets also have the highest HI values.

Under CTE conditions (using 95 percent UCLs), white croaker fillets have an ELCR of 6×10^{-4}. California scorpionfish and barred sandbass fillets have ELCRs of 3×10^{-5}, kelp bass and rockfish have ELCRs of 1×10^{-5}, and surfperches have an ELCR of 6×10^{-6}. White croaker, California scorpionfish, and barred sandbass have HI values ranging from 2 to 37. Kelpfish, rockfish, and surfperches have HI values below 1.

Under the RME and CTE conditions (using 95 percent UCLs), total DDT contributed the most to the total cancer risk for five species, while total PCBs contributed the most to cancer risk for one species (rockfish). PCBs contributed most to HI values for all six species under the RME and CTE conditions.

5.1.2 Fish Fillet Consumption by Asian Anglers

Tables 18 through 29 present chemical-specific risk calculations for carcinogenic and noncarcinogenic effects for fish fillet concentrations estimated for each species, under RME and CTE conditions, using the Santa Monica Bay Seafood Consumption Study exposure assumptions for the Asian angler for minimum, 95 percent UCL, and maximum total DDT and total PCB concentrations. A summary of the cumulative ELCRs and HIs under RME and CTE conditions for each species is presented in Table 30.

Under RME conditions (using 95 percent UCLs), ELCRs from ingestion of fish fillets range from 7×10^{-5} to 7×10^{-3} (Table 30). The highest risk of the six species tested is from white croaker with a risk of 7×10^{-3}. Barred sandbass and California scorpionfish fillets have ELCRs of 4×10^{-4} and 3×10^{-4}, respectively. Kelp bass, rockfish, and surfperch fillets have ELCRs of 1×10^{-4}, 1×10^{-4}, and 7×10^{-5}, respectively. All six species have RME HI values ranging from 3 to 198. White croaker fillets also have the highest HI values.

Under CTE conditions (using 95 percent UCLs), ELCRs from ingestion of fish fillets range from 6×10^{-6} to 6×10^{-4}. The fish fillet ELCR for white croaker is 6×10^{-4}. Barred sandbass and California scorpionfish fillets both have ELCRs of 3×10^{-5}, while kelp bass and rockfish both have ELCRs of 1×10^{-5}. Fillets from surfperches have an ELCR of 6×10^{-6}. Three fish species (white croaker, California scorpionfish, and barred sandbass) have RME HI values ranging from 2 to 37. Kelpfish, rockfish, and surfperches have HI values below 1.

Under both RME and CTE conditions (using 95 percent UCLs), DDT contributed the most to the total cancer risk for five fish species, while PCBs contributed the most for rockfish. Total PCBs contributed the most to hazards for all fish species under both RME and CTE conditions.

6. Uncertainties and Limitations

These risk calculations present quantitative estimates of current and future potential cancer risks and noncancer adverse health hazards. However, it is important to note that these numbers do not predict actual health outcomes. Using approaches and methodologies based on EPA guidance documents, the potential cancer risks and health hazards are estimated in a conservative, public health-protective manner. The risk and hazard estimates are calculated in a health protective manner, that tends to overestimate risks, and thus any actual health impacts are likely to be lower than these estimates.

The use of toxicological data (noncancer reference doses and cancer slope factors) to estimate potential noncancer hazards and cancer risks, which are derived primarily from animal studies presents inherent uncertainties. General uncertainties associated with such data include extrapolation from high to low dose and from animals to humans. Within laboratory studies, potential sources of uncertainty can include: use of modeled animal species, gender differences, age, and strain differences in uptake, metabolism, organ distribution, and target site susceptibility. These uncertainties can be compounded when the data are used to assess risk and hazards to human populations, as a result of differences in diet, environment, activity patterns, and cultural factors. Toxicity values derived from human occupational studies are based on exposures to healthy worker populations and have the uncertainties inherent in epidemiologic data sets such as actual chemical exposures

experienced by the worker population and exposure duration. The extrapolation of the data from relatively homogeneous occupational populations to residential and child populations consisting of individuals with a wide range of sensitivities is an uncertainty associated with the use of occupational studies to develop toxicity values used for risk assessment.

The estimation of exposure in this HHRE requires numerous assumptions to describe potential exposures to contaminated fish. There are a number of uncertainties regarding the likelihood of exposure, frequency of ingestion of contaminated fish, the concentration of contaminants in fish and the period of exposure. Assumptions used in this HHRA tend to simplify and conservatively approximate actual conditions, thereby serving to maximize confidence in decision-making during the HHRA.

For estimating chronic daily intake, there are uncertainties associated with standard exposure assumptions, such as body weight, period of time exposed, life expectancy, population characteristics, and lifestyle. Assumptions made for these exposure parameters might not be representative of any actual exposure situation and could result in either an over- or underestimation of the estimated risks. Another main assumption of the exposure assessment is that the period of constituent intake is assumed to be constant and representative of the exposed population.

Specific uncertainties that should be considered when interpreting the results for this HHRE include:

- *Fish Sampling and Laboratory Analysis*. Uncertainty associated with fish sampling and laboratory tissue analysis includes representativeness of the fish samples collected, sampling errors, the variable nature of fish exposures to DDTs and PCBs from the PV Shelf, and the inherent variability (standard error) in the laboratory analyses.

- *DDT and PCBs in Fish Fillet (Muscle)*. Human health risks were evaluated using chemicals of greatest concern. Although other contaminants are present in Palos Verdes Shelf sediments and fish tissue, potential risks due to total DDT and total PCBs are significantly higher. Therefore, this evaluation focused on these compounds. Exclusion of other chemicals detected in Palos Verdes Shelf fish tissue could result in an underestimation of cumulative risk.

- *Method of Fish Preparation*. No attempt was made in this study to quantitatively evaluate the effects of fish preparation methods on human health risks; this may result in an overestimate of risk. Contaminant burdens in fish may decrease by 10 to 70 percent depending on how the fish is prepared and cooked (EPA, 1993).

- *Fish Consumption Rates*. The Exposure Factors Handbook (EPA, 2001) provides a mean total fish consumption rate for the general population of 14.2 grams/day for the Pacific Region of the United States. This rate includes fish that are caught both recreationally and commercially, and meals that are eaten at home and away from home. The median consumption rate used in this evaluation, 21.4 grams/day, is based on 338 boat anglers who reported consuming fish in the previous 4 weeks (28 days) in the Santa Monica Bay Seafood Consumption Study. Based on the ingestion rates used for the HHRE, cancer risks and HI values may be overestimated, and thus provide a health-protective, RME estimate of risk.

7. Conclusions

This HHRE evaluates potential cancer and noncancer risks to people that consume fish caught from the Palos Verdes Shelf, based on data from the 2002 MSRP/EPA and LACSD fish studies. A range of ingestion rates for all-angler and Asian-angler high-end consumers for fish fillets, as described in the Santa Monica Bay Seafood Consumption Study, were considered to provide a range of potential exposure possibilities. The range of consumption rates include the potential for high fish ingestion rates found in some Asian communities and other ethnic groups.

For both all-angler and Asian-angler consumers under RME consumption of fish fillets, cancer risks from tDDT and tPCBs for three species, white croaker, California scorpionfish, and barred sandbass, ranged from 3 $x10^{-4}$ to 7 x 10^{-3}, based on 95 percent UCL concentrations. Risks from the other three species, kelp bass, rockfish, and surfperch, ranged from 7 x 10^{-5} to 1 x 10^{-4}. The HI values for all six species ranged from 2 to 198.

For both all-angler and Asian-angler consumers under CTE conditions for consumption of fish fillets, cancer risks from tDDT and tPCBs for one species (white croaker) was 6 x 10^{-4} based on 95 percent UCL concentrations. Risks from the other five species ranged from 6 x 10^{-6} to 3 x 10^{-5}. The HI values from three of the six species (white croaker, California scorpionfish, and barred sandbass) ranged from 2 to 37. Kelp bass, rockfish, and surfperches have HI values below 1.

8. References

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Figure

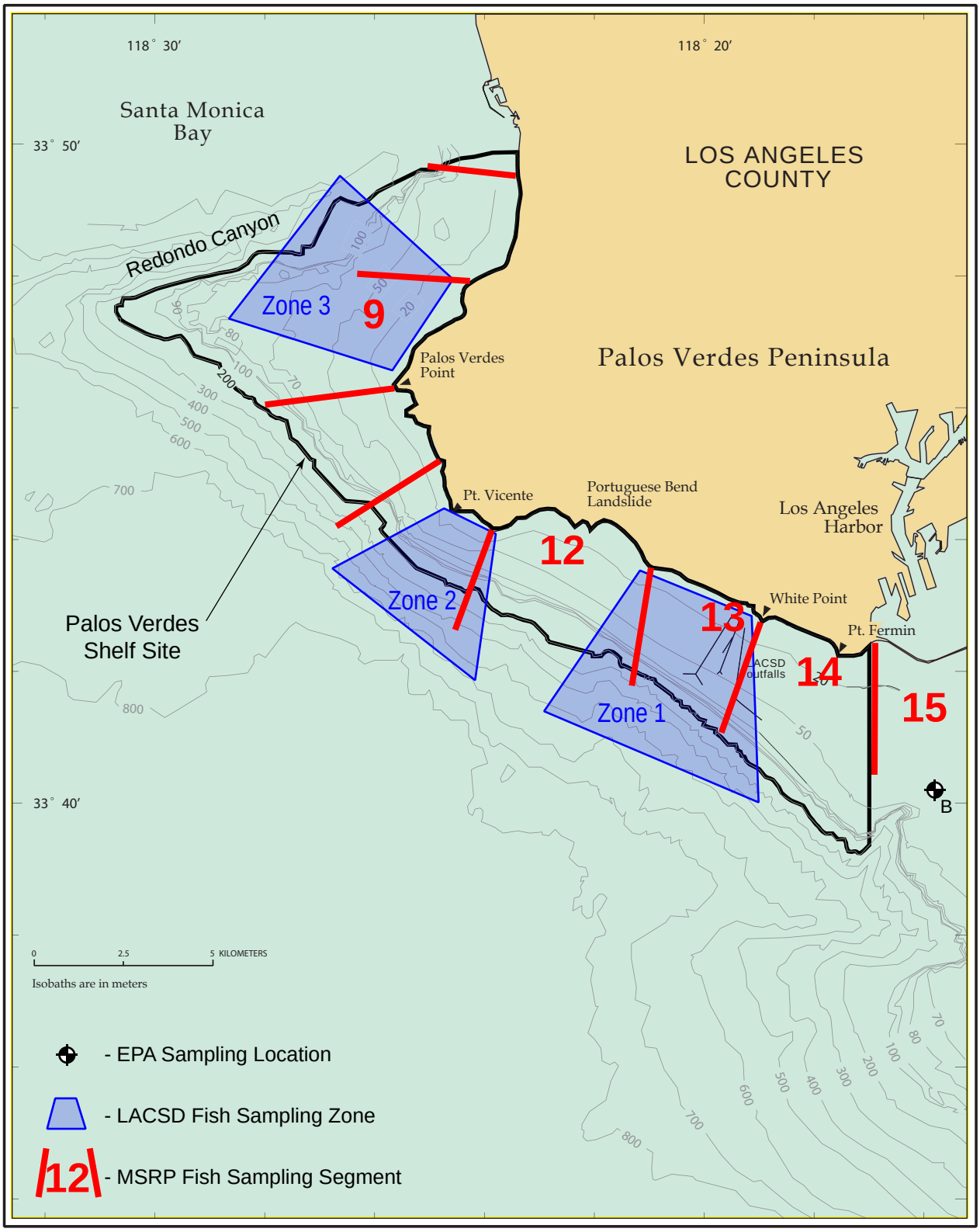

FIGURE 1
EPA, MSRP, and LACSD 2002
Fish Sampling Locations
Palos Verdes Shelf

Tables

List of Tables

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Table 1
Fish Data Summary
Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Fish Species	Number of Samples	Total DDT (μg/kg)			Total PCBs (μg/kg)		
		Min	Max	95% UCL	Min	Max	95% UCL
White Croaker	65	5.49	78800	19189	24.8	6500	1624
Kelp Bass	51	20	1420	346	5	250	45.4
Rockfish	23	34.7	567	270	12.3	124	51.2
Surfperches (benthic feeding)	20	36.8	430	169	7.59	60.0	24.1
California Scorpionfish	28	21.6	2630	830	5.68	243	68.0
Barred Sandbass	28	46.2	4318	897	5.47	294	100

Notes:
DDT = p,p'-Dichlorodiphenyltrichloroethane
PCBs = Polychlorinated Biphenyls
Min = Minimum Detected Concentration
Max = Maximum Detected Concentration
Total DDT and Total PCB concentrations used in exposure calculations were in units of mg/kg (μg/kg x mg/1000 μg = mg/kg)
Total DDT = Sum of DDT metabolites
Total PCBs = Sum of PCB congeners (EPA/MSRP 2002) and PCB Aroclors (LACSD 2002)
95% UCL = 95% upper confidence limit on the mean

Table 2
Exposure Assumptions - Santa Monica Bay Anglers
Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Parameter		Reasonable Maximum Exposure (RME)		Central Tendancy Exposure (CTE)	
			Source		Source
Fish Fillet Ingestion Rate, All Anglers (kg/day)	IR_{all}	0.1071	SMBSCS, 1994	0.0214	SMBSCS, 1994
Fish Fillet Ingestion Rate, Asian Anglers (kg/day)	IR_{Asian}	0.1157	SMBSCS, 1994	0.0214	SMBSCS, 1994
Exposure Frequency (days/year)	EF	365	site-specific	365	site-specific
Exposure Duration (years)	ED	30	HHRE PVS, 1999	13.8	HHRE PVS, 1999
Body Weight (kg)	BW	70	EPA, 1989	70	EPA, 1989
Averaging Time for noncarcinogens (days)	ATnc	10950	HHRE PVS, 1999	5037	HHRE PVS, 1999
Averaging Time for carcinogens (days)	ATc	25550	EPA, 1989	25550	EPA, 1989

Notes:
HHRE PVS, 1999 = Human Health Risk Evaluation for Palos Verdes Shelf (SAIC, 1999).
SMBSCS, 1994 = Santa Monica Bay Seafood Consumption Study (S. Cal. Coastal Water Research Project and MBC Applied Environmental Sciences, 1994).

Table 3
Carcinogenic Toxicity Values
Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Constituent	Carcinogenic Classification	Oral Carcinogenic Slope Factor $[mg/kg/day]^{-1}$	Oral SF Source
Total DDT	Probable human carcinogen	3.40E-01	IRIS
Total PCBs	Probable human carcinogen	2.00E+00	IRIS

Note:
IRIS: Integrated Risk Information System (EPA, 2006).

Table 4
Noncarcinogenic Toxicity Values
Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Chemical	Chronic/ Subchronic	Oral Reference Dose [mg/kg/day]	Primary Target Organ	Oral RfD Source
Total DDT	Chronic	5.00E-04	liver	IRIS
Total PCBs	Chronic	2.00E-05	skin, liver, stomach, thyroid gland	IRIS

Note:
IRIS: Integrated Risk Information System (EPA, 2006).

Table 5

Risk Calculation Worksheet - Carcinogenic Effects - All Angler Ingestion of White Croaker Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information	Exposure Scenario:	RME/CTE
	Fish Species:	White Croaker
	Receptor Population:	All Anglers
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1071
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
Averaging Time for carcinogens, 70 year lifetime (days)	ATc	25,550

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Cancer Slope Factor, SF $[mg/kg/day]^{-1}$**	**Cancer Risk**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	5.49E-03	3.60E-06	3.40E-01	1.22E-06
	Total PCBs	2.48E-02	1.62E-05	2.00E+00	3.25E-05
	Cumulative Risk				3.37E-05
	95% UCL				
	Total DDT	1.92E+01	1.26E-02	3.40E-01	4.28E-03
	Total PCBs	1.62E+00	1.06E-03	2.00E+00	2.13E-03
	Cumulative Risk				6.41E-03
	Maximum Concentrations				
	Total DDT	7.88E+01	5.17E-02	3.40E-01	1.76E-02
	Total PCBs	6.50E+00	4.26E-03	2.00E+00	8.52E-03
	Cumulative Risk				2.61E-02
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	5.49E-03	3.31E-07	3.40E-01	1.12E-07
	Total PCBs	2.48E-02	1.49E-06	2.00E+00	2.98E-06
	Cumulative Risk				3.10E-06
	95% UCL				
	Total DDT	1.92E+01	1.16E-03	3.40E-01	3.93E-04
	Total PCBs	1.62E+00	9.78E-05	2.00E+00	1.96E-04
	Cumulative Risk				5.89E-04
	Maximum Concentrations				
	Total DDT	7.88E+01	4.75E-03	3.40E-01	1.61E-03
	Total PCBs	6.50E+00	3.92E-04	2.00E+00	7.84E-04
	Cumulative Risk				2.40E-03

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 6

Risk Calculation Worksheet - Noncarcinogenic Effects - All Angler Ingestion of White Croaker Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information	Exposure Scenario:	RME/CTE
	Fish Species:	White Croaker
	Receptor Population:	All Anglers
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1071
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
RME Averging Time for noncarcinogens, (days)	$ATnc_{RME}$	10,950
CTE Averaging Time for noncarcinogens, (days)	$ATnc_{CTE}$	5,037

Risk Calculations

Route	**Chemical**	**EPC Value [mg/kg]**	**Concentration [mg/kg/day]**	**Reference Dose [mg/kg/day]**	**NonCancer HQ/HI**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	5.49E-03	8.40E-06	5.00E-04	1.68E-02
	Total PCBs	2.48E-02	3.79E-05	2.00E-05	1.89E+00
	Hazard Index				1.91E+00
	95% UCL				
	Total DDT	1.92E+01	2.94E-02	5.00E-04	5.87E+01
	Total PCBs	1.62E+00	2.48E-03	2.00E-05	1.24E+02
	Hazard Index				1.83E+02
	Maximum Concentrations				
	Total DDT	7.88E+01	1.21E-01	5.00E-04	2.41E+02
	Total PCBs	6.50E+00	9.95E-03	2.00E-05	4.97E+02
	Hazard Index				7.38E+02
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	5.49E-03	1.68E-06	5.00E-04	3.36E-03
	Total PCBs	2.48E-02	7.57E-06	2.00E-05	3.78E-01
	Hazard Index				3.82E-01
	95% UCL				
	Total DDT	1.92E+01	5.87E-03	5.00E-04	1.17E+01
	Total PCBs	1.62E+00	4.96E-04	2.00E-05	2.48E+01
	Hazard Index				3.65E+01
	Maximum Concentrations				
	Total DDT	7.88E+01	2.41E-02	5.00E-04	4.82E+01
	Total PCBs	6.50E+00	1.99E-03	2.00E-05	9.94E+01
	Hazard Index				1.48E+02

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 7

Risk Calculation Worksheet - Carcinogenic Effects - All Angler Ingestion of Kelp Bass Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data

Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information		
	Exposure Scenario:	RME/CTE
	Fish Species:	Kelp Bass
	Receptor Population:	All Anglers
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1071
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
Averaging Time for carcinogens, 70 year lifetime (days)	ATc	25,550

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Cancer Slope Factor, SF $[mg/kg/day]^{-1}$**	**Cancer Risk**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	2.00E-02	1.31E-05	3.40E-01	4.46E-06
	Total PCBs	5.00E-03	3.28E-06	2.00E+00	6.56E-06
	Cumulative Risk				1.10E-05
	95% UCL				
	Total DDT	3.46E-01	2.27E-04	3.40E-01	7.71E-05
	Total PCBs	4.54E-02	2.98E-05	2.00E+00	5.95E-05
	Cumulative Risk				1.37E-04
	Maximum Concentrations				
	Total DDT	1.42E+00	9.31E-04	3.40E-01	3.17E-04
	Total PCBs	2.50E-01	1.64E-04	2.00E+00	3.28E-04
	Cumulative Risk				6.44E-04
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	2.00E-02	1.21E-06	3.40E-01	4.10E-07
	Total PCBs	5.00E-03	3.01E-07	2.00E+00	6.03E-07
	Cumulative Risk				1.01E-06
	95% UCL				
	Total DDT	3.46E-01	2.08E-05	3.40E-01	7.08E-06
	Total PCBs	4.54E-02	2.74E-06	2.00E+00	5.47E-06
	Cumulative Risk				1.26E-05
	Maximum Concentrations				
	Total DDT	1.42E+00	8.56E-05	3.40E-01	2.91E-05
	Total PCBs	2.50E-01	1.51E-05	2.00E+00	3.01E-05
	Cumulative Risk				5.92E-05

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 8

Risk Calculation Worksheet - Noncarcinogenic Effects - All Angler Ingestion of Kelp Bass Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information	Exposure Scenario:	RME/CTE
	Fish Species:	Kelp Bass
	Receptor Population:	All Anglers
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1071
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
RME Averging Time for noncarcinogens, (days)	$ATnc_{RME}$	10,950
CTE Averaging Time for noncarcinogens, (days)	$ATnc_{CTE}$	5,037

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Reference Dose [mg/kg/day]**	**NonCancer HQ/HI**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	2.00E-02	3.06E-05	5.00E-04	6.12E-02
	Total PCBs	5.00E-03	7.65E-06	2.00E-05	3.83E-01
	Hazard Index				4.44E-01
	95% UCL				
	Total DDT	3.46E-01	5.29E-04	5.00E-04	1.06E+00
	Total PCBs	4.54E-02	6.95E-05	2.00E-05	3.47E+00
	Hazard Index				4.53E+00
	Maximum Concentrations				
	Total DDT	1.42E+00	2.17E-03	5.00E-04	4.35E+00
	Total PCBs	2.50E-01	3.83E-04	2.00E-05	1.91E+01
	Hazard Index				2.35E+01
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	2.00E-02	6.11E-06	5.00E-04	1.22E-02
	Total PCBs	5.00E-03	1.53E-06	2.00E-05	7.64E-02
	Hazard Index				8.87E-02
	95% UCL				
	Total DDT	3.46E-01	1.06E-04	5.00E-04	2.11E-01
	Total PCBs	4.54E-02	1.39E-05	2.00E-05	6.94E-01
	Hazard Index				9.05E-01
	Maximum Concentrations				
	Total DDT	1.42E+00	4.34E-04	5.00E-04	8.68E-01
	Total PCBs	2.50E-01	7.64E-05	2.00E-05	3.82E+00
	Hazard Index				4.69E+00

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 9

Risk Calculation Worksheet - Carcinogenic Effects - All Angler Ingestion of Rockfish Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data

Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information		
	Exposure Scenario:	RME/CTE
	Fish Species:	Rockfish
	Receptor Population:	All Anglers
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1071
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
Averaging Time for carcinogens, 70 year lifetime (days)	ATc	25,550

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Cancer Slope Factor, SF $[mg/kg/day]^{-1}$**	**Cancer Risk**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	3.47E-02	2.28E-05	3.40E-01	7.74E-06
	Total PCBs	1.23E-02	8.08E-06	2.00E+00	1.62E-05
	Cumulative Risk				2.39E-05
	95% UCL				
	Total DDT	2.70E-01	1.77E-04	3.40E-01	6.03E-05
	Total PCBs	5.12E-02	3.36E-05	2.00E+00	6.71E-05
	Cumulative Risk				1.27E-04
	Maximum Concentrations				
	Total DDT	5.67E-01	3.72E-04	3.40E-01	1.26E-04
	Total PCBs	1.24E-01	8.13E-05	2.00E+00	1.63E-04
	Cumulative Risk				2.89E-04
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	3.47E-02	2.09E-06	3.40E-01	7.11E-07
	Total PCBs	1.23E-02	7.43E-07	2.00E+00	1.49E-06
	Cumulative Risk				2.20E-06
	95% UCL				
	Total DDT	2.70E-01	1.63E-05	3.40E-01	5.54E-06
	Total PCBs	5.12E-02	3.08E-06	2.00E+00	6.17E-06
	Cumulative Risk				1.17E-05
	Maximum Concentrations				
	Total DDT	5.67E-01	3.42E-05	3.40E-01	1.16E-05
	Total PCBs	1.24E-01	7.48E-06	2.00E+00	1.50E-05
	Cumulative Risk				2.66E-05

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 10

Risk Calculation Worksheet - Noncarcinogenic Effects - All Angler Ingestion of Rockfish Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information	Exposure Scenario:	RME/CTE
	Exposure Medium:	Rockfish
	Receptor Population:	All Anglers
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1071
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
RME Averging Time for noncarcinogens, (days)	$ATnc_{RME}$	10,950
CTE Averaging Time for noncarcinogens, (days)	$ATnc_{CTE}$	5,037

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Reference Dose [mg/kg/day]**	**NonCancer HQ/HI**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	3.47E-02	5.31E-05	5.00E-04	1.06E-01
	Total PCBs	1.23E-02	1.88E-05	2.00E-05	9.42E-01
	Hazard Index				1.05E+00
	95% UCL				
	Total DDT	2.70E-01	4.14E-04	5.00E-04	8.27E-01
	Total PCBs	5.12E-02	7.83E-05	2.00E-05	3.92E+00
	Hazard Index				4.74E+00
	Maximum Concentrations				
	Total DDT	5.67E-01	8.68E-04	5.00E-04	1.74E+00
	Total PCBs	1.24E-01	1.90E-04	2.00E-05	9.49E+00
	Hazard Index				1.12E+01
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	3.47E-02	1.06E-05	5.00E-04	2.12E-02
	Total PCBs	1.23E-02	3.77E-06	2.00E-05	1.88E-01
	Hazard Index				2.10E-01
	95% UCL				
	Total DDT	2.70E-01	8.27E-05	5.00E-04	1.65E-01
	Total PCBs	5.12E-02	1.56E-05	2.00E-05	7.82E-01
	Hazard Index				9.48E-01
	Maximum Concentrations				
	Total DDT	5.67E-01	1.73E-04	5.00E-04	3.47E-01
	Total PCBs	1.24E-01	3.79E-05	2.00E-05	1.90E+00
	Hazard Index				2.24E+00

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 11

Risk Calculation Worksheet - Carcinogenic Effects - All Angler Ingestion of Surfperches Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data

Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information		
	Exposure Scenario:	RME/CTE
	Fish Species:	Surfperches
	Receptor Population:	All Anglers
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1071
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
Averaging Time for carcinogens, 70 year lifetime (days)	ATc	25,550

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Cancer Slope Factor, SF $[mg/kg/day]^{-1}$**	**Cancer Risk**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	3.68E-02	2.42E-05	3.40E-01	8.21E-06
	Total PCBs	7.59E-03	4.98E-06	2.00E+00	9.95E-06
	Cumulative Risk				1.82E-05
	95% UCL				
	Total DDT	1.69E-01	1.11E-04	3.40E-01	3.77E-05
	Total PCBs	2.41E-02	1.58E-05	2.00E+00	3.16E-05
	Cumulative Risk				6.94E-05
	Maximum Concentrations				
	Total DDT	4.30E-01	2.82E-04	3.40E-01	9.59E-05
	Total PCBs	6.00E-02	3.93E-05	2.00E+00	7.86E-05
	Cumulative Risk				1.74E-04
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	3.68E-02	2.22E-06	3.40E-01	7.55E-07
	Total PCBs	7.59E-03	4.57E-07	2.00E+00	9.15E-07
	Cumulative Risk				1.67E-06
	95% UCL				
	Total DDT	1.69E-01	1.02E-05	3.40E-01	3.47E-06
	Total PCBs	2.41E-02	1.45E-06	2.00E+00	2.91E-06
	Cumulative Risk				6.38E-06
	Maximum Concentrations				
	Total DDT	4.30E-01	2.59E-05	3.40E-01	8.81E-06
	Total PCBs	6.00E-02	3.61E-06	2.00E+00	7.23E-06
	Cumulative Risk				1.60E-05

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 12

Risk Calculation Worksheet - Noncarcinogenic Effects - All Angler Ingestion of Surfperches Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information	Exposure Scenario:	RME/CTE
	Fish Species:	Surfperches
	Receptor Population:	All Anglers
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1071
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
RME Averging Time for noncarcinogens, (days)	$ATnc_{RME}$	10,950
CTE Averaging Time for noncarcinogens, (days)	$ATnc_{CTE}$	5,037

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Reference Dose [mg/kg/day]**	**NonCancer HQ/HI**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	3.68E-02	5.64E-05	5.00E-04	1.13E-01
	Total PCBs	7.59E-03	1.16E-05	2.00E-05	5.81E-01
	Hazard Index				6.93E-01
	95% UCL				
	Total DDT	1.69E-01	2.59E-04	5.00E-04	5.18E-01
	Total PCBs	2.41E-02	3.69E-05	2.00E-05	1.84E+00
	Hazard Index				2.36E+00
	Maximum Concentrations				
	Total DDT	4.30E-01	6.58E-04	5.00E-04	1.32E+00
	Total PCBs	6.00E-02	9.17E-05	2.00E-05	4.59E+00
	Hazard Index				5.90E+00
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	3.68E-02	1.13E-05	5.00E-04	2.25E-02
	Total PCBs	7.59E-03	2.32E-06	2.00E-05	1.16E-01
	Hazard Index				1.39E-01
	95% UCL				
	Total DDT	1.69E-01	5.18E-05	5.00E-04	1.04E-01
	Total PCBs	2.41E-02	7.37E-06	2.00E-05	3.69E-01
	Hazard Index				4.72E-01
	Maximum Concentrations				
	Total DDT	4.30E-01	1.31E-04	5.00E-04	2.63E-01
	Total PCBs	6.00E-02	1.83E-05	2.00E-05	9.16E-01
	Hazard Index				1.18E+00

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 13

Risk Calculation Worksheet - Carcinogenic Effects - All Angler Ingestion of California Scorpionfish Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information	Exposure Scenario:	RME/CTE
	Fish Species:	California Scorpionfish
	Receptor Population:	All Anglers
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1071
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
Averaging Time for carcinogens, 70 year lifetime (days)	ATc	25,550

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Cancer Slope Factor, SF $[mg/kg/day]^{-1}$**	**Cancer Risk**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	2.16E-02	1.42E-05	3.40E-01	4.82E-06
	Total PCBs	5.68E-03	3.72E-06	2.00E+00	7.45E-06
	Cumulative Risk				1.23E-05
	95% UCL				
	Total DDT	8.30E-01	5.44E-04	3.40E-01	1.85E-04
	Total PCBs	6.80E-02	4.46E-05	2.00E+00	8.92E-05
	Cumulative Risk				2.74E-04
	Maximum Concentrations				
	Total DDT	2.63E+00	1.72E-03	3.40E-01	5.86E-04
	Total PCBs	2.43E-01	1.59E-04	2.00E+00	3.19E-04
	Cumulative Risk				9.05E-04
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	2.16E-02	1.30E-06	3.40E-01	4.43E-07
	Total PCBs	5.68E-03	3.42E-07	2.00E+00	6.85E-07
	Cumulative Risk				1.13E-06
	95% UCL				
	Total DDT	8.30E-01	5.00E-05	3.40E-01	1.70E-05
	Total PCBs	6.80E-02	4.10E-06	2.00E+00	8.20E-06
	Cumulative Risk				2.52E-05
	Maximum Concentrations				
	Total DDT	2.63E+00	1.59E-04	3.40E-01	5.39E-05
	Total PCBs	2.43E-01	1.46E-05	2.00E+00	2.93E-05
	Cumulative Risk				8.32E-05

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 14

Risk Calculation Worksheet - Noncarcinogenic Effects - All Angler Ingestion of California Scorpionfish Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information		
	Exposure Scenario:	RME/CTE
	Fish Species:	California Scorpionfish
	Receptor Population:	All Anglers
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1071
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
RME Averging Time for noncarcinogens, (days)	$ATnc_{RME}$	10,950
CTE Averaging Time for noncarcinogens, (days)	$ATnc_{CTE}$	5,037

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Reference Dose [mg/kg/day]**	**NonCancer HQ/HI**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	2.16E-02	3.31E-05	5.00E-04	6.62E-02
	Total PCBs	5.68E-03	8.69E-06	2.00E-05	4.35E-01
	Hazard Index				5.01E-01
	95% UCL				
	Total DDT	8.30E-01	1.27E-03	5.00E-04	2.54E+00
	Total PCBs	6.80E-02	1.04E-04	2.00E-05	5.20E+00
	Hazard Index				7.74E+00
	Maximum Concentrations				
	Total DDT	2.63E+00	4.02E-03	5.00E-04	8.05E+00
	Total PCBs	2.43E-01	3.72E-04	2.00E-05	1.86E+01
	Hazard Index				2.66E+01
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	2.16E-02	6.61E-06	5.00E-04	1.32E-02
	Total PCBs	5.68E-03	1.74E-06	2.00E-05	8.68E-02
	Hazard Index				1.00E-01
	95% UCL				
	Total DDT	8.30E-01	2.54E-04	5.00E-04	5.07E-01
	Total PCBs	6.80E-02	2.08E-05	2.00E-05	1.04E+00
	Hazard Index				1.55E+00
	Maximum Concentrations				
	Total DDT	2.63E+00	8.04E-04	5.00E-04	1.61E+00
	Total PCBs	2.43E-01	7.43E-05	2.00E-05	3.71E+00
	Hazard Index				5.32E+00

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 15

Risk Calculation Worksheet - Carcinogenic Effects - All Angler Ingestion of Barred Sandbass Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information		
	Exposure Scenario:	RME/CTE
	Fish Species:	Barred Sandbass
	Receptor Population:	All Anglers
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1071
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
Averaging Time for carcinogens, 70 year lifetime (days)	ATc	25,550

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Cancer Slope Factor, SF $[mg/kg/day]^{-1}$**	**Cancer Risk**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	4.62E-02	3.03E-05	3.40E-01	1.03E-05
	Total PCBs	5.47E-03	3.59E-06	2.00E+00	7.17E-06
	Cumulative Risk				1.75E-05
	95% UCL				
	Total DDT	8.97E-01	5.88E-04	3.40E-01	2.00E-04
	Total PCBs	9.98E-02	6.55E-05	2.00E+00	1.31E-04
	Cumulative Risk				3.31E-04
	Maximum Concentrations				
	Total DDT	4.32E+00	2.83E-03	3.40E-01	9.63E-04
	Total PCBs	2.94E-01	1.93E-04	2.00E+00	3.86E-04
	Cumulative Risk				1.35E-03
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	4.62E-02	2.79E-06	3.40E-01	9.48E-07
	Total PCBs	5.47E-03	3.30E-07	2.00E+00	6.59E-07
	Cumulative Risk				1.61E-06
	95% UCL				
	Total DDT	8.97E-01	5.41E-05	3.40E-01	1.84E-05
	Total PCBs	9.98E-02	6.02E-06	2.00E+00	1.20E-05
	Cumulative Risk				3.04E-05
	Maximum Concentrations				
	Total DDT	4.32E+00	2.60E-04	3.40E-01	8.85E-05
	Total PCBs	2.94E-01	1.77E-05	2.00E+00	3.55E-05
	Cumulative Risk				1.24E-04

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 16

Risk Calculation Worksheet - Noncarcinogenic Effects - All Angler Ingestion of Barred Sandbass Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information		
	Exposure Scenario:	RME/CTE
	Fish Species:	Barred Sandbass
	Receptor Population:	All Anglers
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1071
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
RME Averging Time for noncarcinogens, (days)	$ATnc_{RME}$	10,950
CTE Averaging Time for noncarcinogens, (days)	$ATnc_{CTE}$	5,037

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Reference Dose [mg/kg/day]**	**NonCancer HQ/HI**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	4.62E-02	7.07E-05	5.00E-04	1.41E-01
	Total PCBs	5.47E-03	8.37E-06	2.00E-05	4.18E-01
	Hazard Index				5.60E-01
	95% UCL				
	Total DDT	8.97E-01	1.37E-03	5.00E-04	2.75E+00
	Total PCBs	9.98E-02	1.53E-04	2.00E-05	7.64E+00
	Hazard Index				1.04E+01
	Maximum Concentrations				
	Total DDT	4.32E+00	6.61E-03	5.00E-04	1.32E+01
	Total PCBs	2.94E-01	4.50E-04	2.00E-05	2.25E+01
	Hazard Index				3.57E+01
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	4.62E-02	1.41E-05	5.00E-04	2.83E-02
	Total PCBs	5.47E-03	1.67E-06	2.00E-05	8.36E-02
	Hazard Index				1.12E-01
	95% UCL				
	Total DDT	8.97E-01	2.74E-04	5.00E-04	5.49E-01
	Total PCBs	9.98E-02	3.05E-05	2.00E-05	1.53E+00
	Hazard Index				2.07E+00
	Maximum Concentrations				
	Total DDT	4.32E+00	1.32E-03	5.00E-04	2.64E+00
	Total PCBs	2.94E-01	8.99E-05	2.00E-05	4.50E+00
	Hazard Index				7.14E+00

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 17
Summary of Risk and Hazard Estimates for All Angler Ingestion of Fish Fillet
Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Excess Lifetime Cancer Risks						
	Reasonable Maximum Exposure			**Central Tendency Exposure**		
Fish Species	**Cancer Risk Based on Minimum Conc.**	**Cancer Risk Based on 95% UCL Conc.**	**Cancer Risk Based on Maximum Conc.**	**Cancer Risk Based on Minimum Conc.**	**Cancer Risk Based on 95% UCL Conc.**	**Cancer Risk Based on Maximum Conc.**
White Croaker	3E-05	6E-03	3E-02	3E-06	6E-04	2E-03
Kelp Bass	1E-05	1E-04	6E-04	1E-06	1E-05	6E-05
Rockfish	2E-05	1E-04	3E-04	2E-06	1E-05	3E-05
Surfperches (benthic feeding)	2E-05	7E-05	2E-04	2E-06	6E-06	2E-05
California Scorpionfish	1E-05	3E-04	9E-04	1E-06	3E-05	8E-05
Barred Sandbass	2E-05	3E-04	1E-03	2E-06	3E-05	1E-04

Noncancer Health Hazards						
	Reasonable Maximum Exposure			**Central Tendency Exposure**		
Fish Species	**Hazard Index Based on Minimum Conc.**	**Hazard Index Based on 95% UCL Conc.**	**Hazard Index Based on Maximum Conc.**	**Hazard Index Based on Minimum Conc.**	**Hazard Index Based on 95% UCL Conc.**	**Hazard Index Based on Maximum Conc.**
White Croaker	2	183	738	0.4	37	148
Kelp Bass	0.4	5	23	0.1	0.9	5
Rockfish	1	5	11	0.2	0.9	2
Surfperches (benthic feeding)	0.7	2	6	0.1	0.5	1
California Scorpionfish	0.5	8	27	0.1	2	5
Barred Sandbass	0.6	10	36	0.1	2	7

Table 18

Risk Calculation Worksheet - Carcinogenic Effects - Asian Santa Monica Bay Angler Ingestion of White Croaker Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information	Exposure Scenario:	RME/CTE
	Fish Species:	White Croaker
	Receptor Population:	Asian Angler
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1157
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
Averaging Time for carcinogens, 70 year lifetime (days)	ATc	25,550

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Cancer Slope Factor, SF $[mg/kg/day]^{-1}$**	**Cancer Risk**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	5.49E-03	3.89E-06	3.40E-01	1.32E-06
	Total PCBs	2.48E-02	1.75E-05	2.00E+00	3.51E-05
	Cumulative Risk				3.64E-05
	95% UCL				
	Total DDT	1.92E+01	1.36E-02	3.40E-01	4.62E-03
	Total PCBs	1.62E+00	1.15E-03	2.00E+00	2.30E-03
	Cumulative Risk				6.92E-03
	Maximum Concentrations				
	Total DDT	7.88E+01	5.58E-02	3.40E-01	1.90E-02
	Total PCBs	6.50E+00	4.60E-03	2.00E+00	9.21E-03
	Cumulative Risk				2.82E-02
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	5.49E-03	3.31E-07	3.40E-01	1.12E-07
	Total PCBs	2.48E-02	1.49E-06	2.00E+00	2.98E-06
	Cumulative Risk				3.10E-06
	95% UCL				
	Total DDT	1.92E+01	1.16E-03	3.40E-01	3.93E-04
	Total PCBs	1.62E+00	9.78E-05	2.00E+00	1.96E-04
	Cumulative Risk				5.89E-04
	Maximum Concentrations				
	Total DDT	7.88E+01	4.75E-03	3.40E-01	1.61E-03
	Total PCBs	6.50E+00	3.92E-04	2.00E+00	7.84E-04
	Cumulative Risk				2.40E-03

Notes:
95% UCL = 95% Upper Confidence Limit on the Mean.
Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 19

Risk Calculation Worksheet - Noncarcinogenic Effects - Asian Santa Monica Bay Angler Ingestion of White Croaker Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information		
	Exposure Scenario:	RME/CTE
	Fish Species:	White Croaker
	Receptor Population:	Asian Angler
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1157
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
RME Averging Time for noncarcinogens, (days)	$ATnc_{RME}$	10,950
CTE Averaging Time for noncarcinogens, (days)	$ATnc_{CTE}$	5,037

Risk Calculations

Route	**Chemical**	**EPC Value [mg/kg]**	**Concentration [mg/kg/day]**	**Reference Dose [mg/kg/day]**	**NonCancer HQ/HI**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	5.49E-03	9.07E-06	5.00E-04	1.81E-02
	Total PCBs	2.48E-02	4.09E-05	2.00E-05	2.05E+00
	Hazard Index				2.06E+00
	95% UCL				
	Total DDT	1.92E+01	3.17E-02	5.00E-04	6.34E+01
	Total PCBs	1.62E+00	2.68E-03	2.00E-05	1.34E+02
	Hazard Index				1.98E+02
	Maximum Concentrations				
	Total DDT	7.88E+01	1.30E-01	5.00E-04	2.60E+02
	Total PCBs	6.50E+00	1.07E-02	2.00E-05	5.37E+02
	Hazard Index				7.98E+02
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	5.49E-03	1.68E-06	5.00E-04	3.36E-03
	Total PCBs	2.48E-02	7.57E-06	2.00E-05	3.78E-01
	Hazard Index				3.82E-01
	95% UCL				
	Total DDT	1.92E+01	5.87E-03	5.00E-04	1.17E+01
	Total PCBs	1.62E+00	4.96E-04	2.00E-05	2.48E+01
	Hazard Index				3.65E+01
	Maximum Concentrations				
	Total DDT	7.88E+01	2.41E-02	5.00E-04	4.82E+01
	Total PCBs	6.50E+00	1.99E-03	2.00E-05	9.94E+01
	Hazard Index				1.48E+02

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 20

Risk Calculation Worksheet - Carcinogenic Effects - Asian Santa Monica Bay Angler Ingestion of Kelp Bass Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information	Exposure Scenario:	RME/CTE
	Fish Species:	Kelp Bass
	Receptor Population:	Asian Angler
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1157
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
Averaging Time for carcinogens, 70 year lifetime (days)	ATc	25,550

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Cancer Slope Factor, SF $[mg/kg/day]^{-1}$**	**Cancer Risk**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	2.00E-02	1.42E-05	3.40E-01	4.82E-06
	Total PCBs	5.00E-03	3.54E-06	2.00E+00	7.08E-06
	Cumulative Risk				1.19E-05
	95% UCL				
	Total DDT	3.46E-01	2.45E-04	3.40E-01	8.32E-05
	Total PCBs	4.54E-02	3.22E-05	2.00E+00	6.43E-05
	Cumulative Risk				1.48E-04
	Maximum Concentrations				
	Total DDT	1.42E+00	1.01E-03	3.40E-01	3.42E-04
	Total PCBs	2.50E-01	1.77E-04	2.00E+00	3.54E-04
	Cumulative Risk				6.96E-04
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	2.00E-02	1.21E-06	3.40E-01	4.10E-07
	Total PCBs	5.00E-03	3.01E-07	2.00E+00	6.03E-07
	Cumulative Risk				1.01E-06
	95% UCL				
	Total DDT	3.46E-01	2.08E-05	3.40E-01	7.08E-06
	Total PCBs	4.54E-02	2.74E-06	2.00E+00	5.47E-06
	Cumulative Risk				1.26E-05
	Maximum Concentrations				
	Total DDT	1.42E+00	8.56E-05	3.40E-01	2.91E-05
	Total PCBs	2.50E-01	1.51E-05	2.00E+00	3.01E-05
	Cumulative Risk				5.92E-05

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 21

Risk Calculation Worksheet - Noncarcinogenic Effects - Asian Santa Monica Bay Angler Ingestion of Kelp Bass Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information		
	Exposure Scenario:	RME/CTE
	Fish Species:	Kelp Bass
	Receptor Population:	Asian Anglers
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1157
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
RME Averging Time for noncarcinogens, (days)	$ATnc_{RME}$	10,950
CTE Averaging Time for noncarcinogens, (days)	$ATnc_{CTE}$	5,037

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Reference Dose [mg/kg/day]**	**NonCancer HQ/HI**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	2.00E-02	3.31E-05	5.00E-04	6.61E-02
	Total PCBs	5.00E-03	8.26E-06	2.00E-05	4.13E-01
	Hazard Index				4.79E-01
	95% UCL				
	Total DDT	3.46E-01	5.71E-04	5.00E-04	1.14E+00
	Total PCBs	4.54E-02	7.50E-05	2.00E-05	3.75E+00
	Hazard Index				4.89E+00
	Maximum Concentrations				
	Total DDT	1.42E+00	2.35E-03	5.00E-04	4.69E+00
	Total PCBs	2.50E-01	4.13E-04	2.00E-05	2.07E+01
	Hazard Index				2.54E+01
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	2.00E-02	6.11E-06	5.00E-04	1.22E-02
	Total PCBs	5.00E-03	1.53E-06	2.00E-05	7.64E-02
	Hazard Index				8.87E-02
	95% UCL				
	Total DDT	3.46E-01	1.06E-04	5.00E-04	2.11E-01
	Total PCBs	4.54E-02	1.39E-05	2.00E-05	6.94E-01
	Hazard Index				9.05E-01
	Maximum Concentrations				
	Total DDT	1.42E+00	4.34E-04	5.00E-04	8.68E-01
	Total PCBs	2.50E-01	7.64E-05	2.00E-05	3.82E+00
	Hazard Index				4.69E+00

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 22

Risk Calculation Worksheet - Carcinogenic Effects - Asian Santa Monica Bay Angler Ingestion of Rockfish Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information	Exposure Scenario:	RME/CTE
	Fish Species:	Rockfish
	Receptor Population:	Asian Angler
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1157
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
Averaging Time for carcinogens, 70 year lifetime (days)	ATc	25,550

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Cancer Slope Factor, SF $[mg/kg/day]^{-1}$**	**Cancer Risk**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	3.47E-02	2.46E-05	3.40E-01	8.36E-06
	Total PCBs	1.23E-02	8.73E-06	2.00E+00	1.75E-05
	Cumulative Risk				2.58E-05
	95% UCL				
	Total DDT	2.70E-01	1.92E-04	3.40E-01	6.51E-05
	Total PCBs	5.12E-02	3.63E-05	2.00E+00	7.25E-05
	Cumulative Risk				1.38E-04
	Maximum Concentrations				
	Total DDT	5.67E-01	4.02E-04	3.40E-01	1.37E-04
	Total PCBs	1.24E-01	8.79E-05	2.00E+00	1.76E-04
	Cumulative Risk				3.12E-04
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	3.47E-02	2.09E-06	3.40E-01	7.11E-07
	Total PCBs	1.23E-02	7.43E-07	2.00E+00	1.49E-06
	Cumulative Risk				2.20E-06
	95% UCL				
	Total DDT	2.70E-01	1.63E-05	3.40E-01	5.54E-06
	Total PCBs	5.12E-02	3.08E-06	2.00E+00	6.17E-06
	Cumulative Risk				1.17E-05
	Maximum Concentrations				
	Total DDT	5.67E-01	3.42E-05	3.40E-01	1.16E-05
	Total PCBs	1.24E-01	7.48E-06	2.00E+00	1.50E-05
	Cumulative Risk				2.66E-05

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 23

Risk Calculation Worksheet - Noncarcinogenic Effects - Asian Santa Monica Bay Angler Ingestion of Rockfish Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information		
	Exposure Scenario:	RME/CTE
	Exposure Medium:	Rockfish
	Receptor Population:	Asian Angler
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1157
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
RME Averging Time for noncarcinogens, (days)	$ATnc_{RME}$	10,950
CTE Averaging Time for noncarcinogens, (days)	$ATnc_{CTE}$	5,037

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Reference Dose [mg/kg/day]**	**NonCancer HQ/HI**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	3.47E-02	5.74E-05	5.00E-04	1.15E-01
	Total PCBs	1.23E-02	2.04E-05	2.00E-05	1.02E+00
	Hazard Index				1.13E+00
	95% UCL				
	Total DDT	2.70E-01	4.47E-04	5.00E-04	8.94E-01
	Total PCBs	5.12E-02	8.46E-05	2.00E-05	4.23E+00
	Hazard Index				5.12E+00
	Maximum Concentrations				
	Total DDT	5.67E-01	9.37E-04	5.00E-04	1.87E+00
	Total PCBs	1.24E-01	2.05E-04	2.00E-05	1.03E+01
	Hazard Index				1.21E+01
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	3.47E-02	1.06E-05	5.00E-04	2.12E-02
	Total PCBs	1.23E-02	3.77E-06	2.00E-05	1.88E-01
	Hazard Index				2.10E-01
	95% UCL				
	Total DDT	2.70E-01	8.27E-05	5.00E-04	1.65E-01
	Total PCBs	5.12E-02	1.56E-05	2.00E-05	7.82E-01
	Hazard Index				9.48E-01
	Maximum Concentrations				
	Total DDT	5.67E-01	1.73E-04	5.00E-04	3.47E-01
	Total PCBs	1.24E-01	3.79E-05	2.00E-05	1.90E+00
	Hazard Index				2.24E+00

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 24

Risk Calculation Worksheet - Carcinogenic Effects - Asian Santa Monica Bay Angler Ingestion of Surfperches Fish Fillets

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information	Exposure Scenario:	RME/CTE
	Fish Species:	Surfperches
	Receptor Population:	Asian Angler
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1157
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
Averaging Time for carcinogens, 70 year lifetime (days)	ATc	25,550

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Cancer Slope Factor, SF $[mg/kg/day]^{-1}$**	**Cancer Risk**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	3.68E-02	2.61E-05	3.40E-01	8.87E-06
	Total PCBs	7.59E-03	5.38E-06	2.00E+00	1.08E-05
	Cumulative Risk				1.96E-05
	95% UCL				
	Total DDT	1.69E-01	1.20E-04	3.40E-01	4.08E-05
	Total PCBs	2.41E-02	1.71E-05	2.00E+00	3.42E-05
	Cumulative Risk				7.49E-05
	Maximum Concentrations				
	Total DDT	4.30E-01	3.05E-04	3.40E-01	1.04E-04
	Total PCBs	6.00E-02	4.25E-05	2.00E+00	8.49E-05
	Cumulative Risk				1.88E-04
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	3.68E-02	2.22E-06	3.40E-01	7.55E-07
	Total PCBs	7.59E-03	4.57E-07	2.00E+00	9.15E-07
	Cumulative Risk				1.67E-06
	95% UCL				
	Total DDT	1.69E-01	1.02E-05	3.40E-01	3.47E-06
	Total PCBs	2.41E-02	1.45E-06	2.00E+00	2.91E-06
	Cumulative Risk				6.38E-06
	Maximum Concentrations				
	Total DDT	4.30E-01	2.59E-05	3.40E-01	8.81E-06
	Total PCBs	6.00E-02	3.61E-06	2.00E+00	7.23E-06
	Cumulative Risk				1.60E-05

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 25

Risk Calculation Worksheet - Noncarcinogenic Effects - Asian Santa Monica Bay Angler Ingestion of Surfperches Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information	Exposure Scenario:	RME/CTE
	Fish Species:	Surfperches
	Receptor Population:	Asian Angler
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1157
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
RME Averging Time for noncarcinogens, (days)	$ATnc_{RME}$	10,950
CTE Averaging Time for noncarcinogens, (days)	$ATnc_{CTE}$	5,037

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Reference Dose [mg/kg/day]**	**NonCancer HQ/HI**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	3.68E-02	6.09E-05	5.00E-04	1.22E-01
	Total PCBs	7.59E-03	1.25E-05	2.00E-05	6.27E-01
	Hazard Index				7.49E-01
	95% UCL				
	Total DDT	1.69E-01	2.80E-04	5.00E-04	5.60E-01
	Total PCBs	2.41E-02	3.99E-05	2.00E-05	1.99E+00
	Hazard Index				2.55E+00
	Maximum Concentrations				
	Total DDT	4.30E-01	7.11E-04	5.00E-04	1.42E+00
	Total PCBs	6.00E-02	9.91E-05	2.00E-05	4.95E+00
	Hazard Index				6.38E+00
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	3.68E-02	1.13E-05	5.00E-04	2.25E-02
	Total PCBs	7.59E-03	2.32E-06	2.00E-05	1.16E-01
	Hazard Index				1.39E-01
	95% UCL				
	Total DDT	1.69E-01	5.18E-05	5.00E-04	1.04E-01
	Total PCBs	2.41E-02	7.37E-06	2.00E-05	3.69E-01
	Hazard Index				4.72E-01
	Maximum Concentrations				
	Total DDT	4.30E-01	1.31E-04	5.00E-04	2.63E-01
	Total PCBs	6.00E-02	1.83E-05	2.00E-05	9.16E-01
	Hazard Index				1.18E+00

Notes:
95% UCL = 95% Upper Confidence Limit on the Mean.
Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 26

Risk Calculation Worksheet - Carcinogenic Effects - Asian Santa Monica Bay Angler Ingestion of California Scorpionfish Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information	Exposure Scenario:	RME/CTE
	Fish Species:	California Scorpionfish
	Receptor Population:	Asian Angler
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1157
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
Averaging Time for carcinogens, 70 year lifetime (days)	ATc	25,550

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Cancer Slope Factor, SF $[mg/kg/day]^{-1}$**	**Cancer Risk**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	2.16E-02	1.53E-05	3.40E-01	5.21E-06
	Total PCBs	5.68E-03	4.02E-06	2.00E+00	8.05E-06
	Cumulative Risk				1.33E-05
	95% UCL				
	Total DDT	8.30E-01	5.88E-04	3.40E-01	2.00E-04
	Total PCBs	6.80E-02	4.82E-05	2.00E+00	9.64E-05
	Cumulative Risk				2.96E-04
	Maximum Concentrations				
	Total DDT	2.63E+00	1.86E-03	3.40E-01	6.33E-04
	Total PCBs	2.43E-01	1.72E-04	2.00E+00	3.44E-04
	Cumulative Risk				9.78E-04
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	2.16E-02	1.30E-06	3.40E-01	4.43E-07
	Total PCBs	5.68E-03	3.42E-07	2.00E+00	6.85E-07
	Cumulative Risk				1.13E-06
	95% UCL				
	Total DDT	8.30E-01	5.00E-05	3.40E-01	1.70E-05
	Total PCBs	6.80E-02	4.10E-06	2.00E+00	8.20E-06
	Cumulative Risk				2.52E-05
	Maximum Concentrations				
	Total DDT	2.63E+00	1.59E-04	3.40E-01	5.39E-05
	Total PCBs	2.43E-01	1.46E-05	2.00E+00	2.93E-05
	Cumulative Risk				8.32E-05

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 27

Risk Calculation Worksheet - Noncarcinogenic Effects - Asian Santa Monica Bay Angler Ingestion of California Scorpionfish Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information		
	Exposure Scenario:	RME/CTE
	Fish Species:	California Scorpionfish
	Receptor Population:	Asian Angler
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1157
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
RME Averging Time for noncarcinogens, (days)	$ATnc_{RME}$	10,950
CTE Averaging Time for noncarcinogens, (days)	$ATnc_{CTE}$	5,037

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Reference Dose [mg/kg/day]**	**NonCancer HQ/HI**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	2.16E-02	3.58E-05	5.00E-04	7.15E-02
	Total PCBs	5.68E-03	9.39E-06	2.00E-05	4.69E-01
	Hazard Index				5.41E-01
	95% UCL				
	Total DDT	8.30E-01	1.37E-03	5.00E-04	2.74E+00
	Total PCBs	6.80E-02	1.12E-04	2.00E-05	5.62E+00
	Hazard Index				8.36E+00
	Maximum Concentrations				
	Total DDT	2.63E+00	4.35E-03	5.00E-04	8.69E+00
	Total PCBs	2.43E-01	4.02E-04	2.00E-05	2.01E+01
	Hazard Index				2.88E+01
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	2.16E-02	6.61E-06	5.00E-04	1.32E-02
	Total PCBs	5.68E-03	1.74E-06	2.00E-05	8.68E-02
	Hazard Index				1.00E-01
	95% UCL				
	Total DDT	8.30E-01	2.54E-04	5.00E-04	5.07E-01
	Total PCBs	6.80E-02	2.08E-05	2.00E-05	1.04E+00
	Hazard Index				1.55E+00
	Maximum Concentrations				
	Total DDT	2.63E+00	8.04E-04	5.00E-04	1.61E+00
	Total PCBs	2.43E-01	7.43E-05	2.00E-05	3.71E+00
	Hazard Index				5.32E+00

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 28

Risk Calculation Worksheet - Carcinogenic Effects - Asian Santa Monica Bay Angler Ingestion of Barred Sandbass Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information		
	Exposure Scenario:	RME/CTE
	Fish Species:	Barred Sandbass
	Receptor Population:	Asian Angler
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1157
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
Averaging Time for carcinogens, 70 year lifetime (days)	ATc	25,550

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Cancer Slope Factor, SF $[mg/kg/day]^{-1}$**	**Cancer Risk**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	4.62E-02	3.28E-05	3.40E-01	1.11E-05
	Total PCBs	5.47E-03	3.87E-06	2.00E+00	7.75E-06
	Cumulative Risk				1.89E-05
	95% UCL				
	Total DDT	8.97E-01	6.36E-04	3.40E-01	2.16E-04
	Total PCBs	9.98E-02	7.07E-05	2.00E+00	1.41E-04
	Cumulative Risk				3.58E-04
	Maximum Concentrations				
	Total DDT	4.32E+00	3.06E-03	3.40E-01	1.04E-03
	Total PCBs	2.94E-01	2.08E-04	2.00E+00	4.17E-04
	Cumulative Risk				1.46E-03
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	4.62E-02	2.79E-06	3.40E-01	9.48E-07
	Total PCBs	5.47E-03	3.30E-07	2.00E+00	6.59E-07
	Cumulative Risk				1.61E-06
	95% UCL				
	Total DDT	8.97E-01	5.41E-05	3.40E-01	1.84E-05
	Total PCBs	9.98E-02	6.02E-06	2.00E+00	1.20E-05
	Cumulative Risk				3.04E-05
	Maximum Concentrations				
	Total DDT	4.32E+00	2.60E-04	3.40E-01	8.85E-05
	Total PCBs	2.94E-01	1.77E-05	2.00E+00	3.55E-05
	Cumulative Risk				1.24E-04

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 29

Risk Calculation Worksheet - Noncarcinogenic Effects - Asian Santa Monica Bay Angler Ingestion of Barred Sandbass Fish Fillet

Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Exposure Scenario Information	Exposure Scenario:	RME/CTE
	Fish Species:	Barred Sandbass
	Receptor Population:	Asian Angler
	Receptor Age:	Adult

Exposure Parameter (units)	**Variable**	**Value**
RME Fish Ingestion Rate (kg/day)	IR_{RME}	0.1157
CTE Fish Ingestion Rate (kg/day)	IR_{CTE}	0.0214
Exposure Frequency (days/year)	EF	365
RME Exposure Duration (years)	ED_{RME}	30
CTE Exposure Duration (years)	ED_{CTE}	13.8
Body Weight (kg)	BW	70
RME Averging Time for noncarcinogens, (days)	$ATnc_{RME}$	10,950
CTE Averaging Time for noncarcinogens, (days)	$ATnc_{CTE}$	5,037

Risk Calculations

Exposure Route	**Chemical**	**EPC Value [mg/kg]**	**Chronic Exposure Concentration [mg/kg/day]**	**Reference Dose [mg/kg/day]**	**NonCancer HQ/HI**
Fish Ingestion RME	***Minimum Concentrations***				
	Total DDT	4.62E-02	7.64E-05	5.00E-04	1.53E-01
	Total PCBs	5.47E-03	9.04E-06	2.00E-05	4.52E-01
	Hazard Index				6.05E-01
	95% UCL				
	Total DDT	8.97E-01	1.48E-03	5.00E-04	2.97E+00
	Total PCBs	9.98E-02	1.65E-04	2.00E-05	8.25E+00
	Hazard Index				1.12E+01
	Maximum Concentrations				
	Total DDT	4.32E+00	7.14E-03	5.00E-04	1.43E+01
	Total PCBs	2.94E-01	4.86E-04	2.00E-05	2.43E+01
	Hazard Index				3.86E+01
Fish Ingestion CTE	***Minimum Concentrations***				
	Total DDT	4.62E-02	1.41E-05	5.00E-04	2.83E-02
	Total PCBs	5.47E-03	1.67E-06	2.00E-05	8.36E-02
	Hazard Index				1.12E-01
	95% UCL				
	Total DDT	8.97E-01	2.74E-04	5.00E-04	5.49E-01
	Total PCBs	9.98E-02	3.05E-05	2.00E-05	1.53E+00
	Hazard Index				2.07E+00
	Maximum Concentrations				
	Total DDT	4.32E+00	1.32E-03	5.00E-04	2.64E+00
	Total PCBs	2.94E-01	8.99E-05	2.00E-05	4.50E+00
	Hazard Index				7.14E+00

Notes:

95% UCL = 95% Upper Confidence Limit on the Mean.

Minimum Concentration (or Maximum) = Minimum or maximum fish concentration.

Table 30
Summary of Risk and Hazard Estimates for Asian Angler Ingestion of Fish Fillet
Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Excess Lifetime Cancer Risks						
	Reasonable Maximum Exposure			Central Tendency Exposure		
Fish Species	Cancer Risk Based on Minimum Conc.	Cancer Risk Based on 95% UCL Conc.	Cancer Risk Based on Maximum Conc.	Cancer Risk Based on Minimum Conc.	Cancer Risk Based on 95% UCL Conc.	Cancer Risk Based on Maximum Conc.
White Croaker	4E-05	7E-03	3E-02	3E-06	6E-04	2E-03
Kelp Bass	1E-05	1E-04	7E-04	1E-06	1E-05	6E-05
Rockfish	3E-05	1E-04	3E-04	2E-06	1E-05	3E-05
Surfperches	2E-05	7E-05	2E-04	2E-06	6E-06	2E-05
California Scorpionfish	1E-05	3E-04	1E-03	1E-06	3E-05	8E-05
Barred Sandbass	2E-05	4E-04	1E-03	2E-06	3E-05	1E-04

Noncancer Health Hazards						
	Reasonable Maximum Exposure			Central Tendency Exposure		
Fish Species	Hazard Index Based on Minimum Conc.	Hazard Index Based on 95% UCL Conc.	Hazard Index Based on Maximum Conc.	Hazard Index Based on Minimum Conc.	Hazard Index Based on 95% UCL Conc.	Hazard Index Based on Maximum Conc.
White Croaker	2	198	798	0.4	37	148
Kelp Bass	0.5	5	25	0.1	0.9	5
Rockfish	1	5	12	0.2	0.9	2
Surfperches	0.7	3	6	0.1	0.5	1
California Scorpionfish	0.5	8	29	0.1	2	5
Barred Sandbass	0.6	11	39	0.1	2	7

Appendix A
MSRP/EPA 2002 and LACSD 2002 Ocean Fish Sampling Data

Table A-1
Data Set for Segment 9 - Flat Rock Point to Palos Verdes Point
Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Species	Sample ID	Total DDT	Total PCBs
Barred Sandbass	BS017	586.24	80.388
	BS018	405.75	55.979
	BS019	380.45	33.381
	BS020	81.822	12.057
Average		363.57	45.45

Note:
Units in μg/kg wet weight (surrogate corrected values)

Table A-2
Data Set for Segment 12 - Long Pt. to Bunker Pt.
Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Species	Sample ID	Total DDT	Total PCBs
California Scorpionfish	SC094	113	20.28
	SC095	154	21.43
	SC096	430	68.03
	SC097	111	19.42
	SC098	456	54.77
	SC099	901	108.29
	SC100	127	26.41
	SC101	277	37.61
Average		321.13	44.53
White Croaker	WC332	6770	618.99
	WC334	1870	197.85
	WC342	841	97.92
	WC343	589	72.28
	WC352	701	78.99
	WC354	1130	130.96
	WC356	1510	210.25
	WC357	609	83.74
	WC358	2430	309.22
Average		1827.78	200.02
Barred Seabass	BS003	438.04	56.34
	BS076	823.75	104.36
	BS077	529.37	64.01
	BS070	46.24	5.47
	BS073	1537.32	156.52
	BS074	114.86	29.43
	BS075	285.77	42.88
	BS078	618.81	79.93
	BS079	327.56	59.52
	BS080	145.29	17.37
Average		486.70	61.58
Rockfish	RF001	333.08	31.083
	RF029	228.53	29.521
	RF030	292.574	35.475
Average		284.73	32.03

Note:
Units in μg/kg wet weight (surrogate corrected values)

Table A-3
Data Set for Segment 13/14 - Bunker Point to Point Fermin Including White Point
Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Species	Sample ID	Total DDT	Total PCBs
Surfperches (benthic feeding)	BF127	124	15.61
	BF129	226	28.54
	BF130	80.2	9.32
	BF131	140	14.13
	BF133	98.4	10.42
	BF135	72.7	7.59
	BF136	79.5	8.71
	BF139	324	44.88
	BF140	430	59.95
	BF141	152	17.57
Average		172.68	21.67
Rockfish	RF020	107	13.4
	RF021	360	41.11
	RF022	160	25.99
	RF023	116	16.08
	RF024	77.2	12.77
	RF025	90.8	19.13
	RF027	332	48.53
	RF031	121	20.59
	RF034	283	33.47
	RF035	427	46.62
Average		207.4	27.769
California Scorpionfish	SC089	1920	179.6
	SC090	1730	167.19
	SC091	657	76.41
	SC105	617	66.48
	SC106	171	25.85
	SC107	191	27.45
	SC108	61.3	10.7
	SC109	314	39.96
	SC111	38.1	8.9
	SC112	2630	242.99
Average		832.94	84.55
White Croaker	WC361	186	24.76
	WC369	251	29.88
	WC373	1070	115.73
	WC374	698	99.45
	WC376	1400	161
	WC383	769	97.35
	WC384	822	106.97
Average		742.29	90.73

Table A-3
Data Set for Segment 13/14 - Bunker Point to Point Fermin Including White Point
Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Species	Sample ID	Total DDT	Total PCBs
Kelp Bass	KB046	296	55.61
	KB048	248	36.8
	KB053	210	36.38
	KB054	66.6	17.57
	KB055	269	46.73
	KB057	124	26.4
	KB058	399	61.66
	KB059	206	35.49
	KB061	65.9	15.05
	KB063	605	71.5
Average		248.95	40.32
Barred Seabass	BS067	261.68	56.43
	BS068	1838.25	138.24
	BS069	985.218	129.287
	BS072	345.519	208.941
	BS084	1496.82	119.111
	BS085	4317.78	294.139
Average		1540.88	157.69

Note:
Units in μg/kg wet weight (surrogate corrected values)

Table A-4
Data Set for LACSD 2002
Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Species/Zone	Total DDT	Total PCBs
White Croaker	78800	6500
ZONE 1	13700	1300
	28060	3410
	29480	3130
	14450	1130
	23320	1270
	27100	2900
	18540	1940
	47400	3280
	46500	3500
Average	32735	2836
ZONE 2	2440	290
	11270	1400
	6460	580
	3810	620
	20230	1960
	6380	590
	4850	370
	16440	1730
	4090	320
	10080	940
Average	8605	880
ZONE 3	1600	640
	2350	310
	1910	370
	1310	190
	320	80
	1290	640
	960	200
	1050	160
	1270	90
	2640	430
Average	1470	311
Kelp Bass	840	80
ZONE 1	570	70
	20	ND
	370	30
	200	30
	420	30
	1100	90
	60	ND
	150	ND
	400	30
Average	413	51.43

Table A-4
Data Set for LACSD 2002
Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Species/Zone	Total DDT	Total PCBs
ZONE 2	200	30
	150	20
	220	30
	190	20
	340	50
	1410	100
	60	ND
	50	ND
	170	20
	1420	250
Average	421	65
ZONE 3	190	30
	310	90
	70	ND
	140	ND
	60	ND
	130	ND
	120	ND
	240	30
	330	50
	130	10
Average	172	42

Notes:
Units in μg/kg wet weight (surrogate corrected values)
Total PCBs are sum of Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260

Table A-5
Data Set for Segment 15 - Cabrillo/LA Breakwater: Ocean Side
Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Species	Sample ID	Total DDT	Total PCBs
Rockfish	RF010	567	124.06
	RF011	432	118.14
	RF012	101	28.16
	RF013	116	39.84
	RF014	106	38.75
	RF015	111	40.4
	RF016	145	59
	RF017	34.7	12.32
	RF019	121	37.8
	RF032	193	59.66
Average		192.67	55.813
Surfperch (benthic feeding)	BF124	108	15.89
	BF110	89.4	13.48
	BF111	101.08	19.69
	BF112	169.02	27.62
	BF117	36.84	14
	BF118	61.19	15.07
	BF119	70.12	12.67
	BF120	119.89	21.18
	BF121	51.15	11.04
	BF125	99.18	17.36
Average		90.587	16.8
White Croaker	WC393	5.49	41.48
	WC401	11087	1116.272
	WC402	4543.9	490.222
	WC405	384.01	65.277
	WC406	713.84	85.395
	WC411	6665.9	719.499
	WC412	3733.3	394.196
	WC417	640.72	80.614
	WC420	806.97	122.904
Average		3175.68	346.21
Barred Sandbass	BS083	90.564	18.031
	BS096	158.417	19.936
	BS097	68.907	19.049
	BS098	138.23	27.1
	BS099	398.55	47.716
	BS100	481.122	129.157
	BS101	303.122	44.748
	BS105	436.04	48.019
Average		259.37	44.22

Table A-5
Data Set for Segment 15 - Cabrillo/LA Breakwater: Ocean Side
Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Species	Sample ID	Total DDT	Total PCBs
Kelp Bass	KB041	29.81	10.13
	KB042	37.87	11.2
	KB043	70.31	18.4
	KB044	41.04	12.63
	KB064	53.4	18.77
	KB100	358.62	60.686
	KB101	118.766	19.777
	KB102	327.375	66.519
	KB103	185.231	34.424
	KB104	172.937	29.29
	KB105	132.402	28.021
Average		138.89	28.17
California Scorpionfish	SC071	54.88	8.19
	SC073	21.63	5.68
	SC074	35.78	6.24
	SC077	75.15	12.07
	SC079	69.78	10.33
	SC082	54.35	7.33
	SC083	46.04	10.29
	SC086	279.53	39.48
	SC087	92.68	12.26
	SC102	74.92	13.2
Average		80.47	12.51

Note:
Units in μg/kg wet weight (surrogate corrected values)

Table A-6
Data Set for Segment B - Approx. 2 Miles Offshore of Segment 15
Evaluation of Human Health Risks for Palos Verdes Shelf, EPA/MSRP 2002 and LACSD 2002 Fish Data
Palos Verdes Shelf Remedial Investigation Report

Species	Sample ID	Total DDT	Total PCBs
White Croaker	Nov-02		
	WC631	931	107.41
	WC635	2618.46	362.668
	WC637	1286.82	120.412
	WC640	464.57	56.262
	WC643	907.31	103.06
	WC644	2180.83	304.231
	WC645	6445.74	663
	WC649	125.13	45
	WC652	147.455	73
	WC653	99.91	38
Average		1520.72	187.30

Note:
Units in μg/kg wet weight (surrogate corrected values)

Appendix B
Statistical Analysis (proUCL Output Files)

Data File

Variable: White Croaker - DDT

Raw Statistics	
Number of Valid Samples	65
Number of Unique Samples	65
Minimum	5.49
Maximum	78800
Mean	7592.836
Median	1870
Standard Deviation	13664.07
Variance	1.87E+08
Coefficient of Variation	1.7996
Skewness	3.200135

Gamma Statistics	
k hat	0.509773
k star (bias corrected)	0.496502
Theta hat	14894.53
Theta star	15292.67
nu hat	66.27053
nu star	64.54523
Approx.Chi Square Value (.05)	47.0575
Adjusted Level of Significance	0.046308
Adjusted Chi Square Value	46.71922

Log-transformed Statistics	
Minimum of log data	1.702928
Maximum of log data	11.27467
Mean of log data	7.69268
Standard Deviation of log data	1.731815
Variance of log data	2.999182

RECOMMENDATION

Data are lognormal (0.05)

Use H-UCL

Normal Distribution Test	
Lilliefors Test Statisitic	0.29324
Lilliefors 5% Critical Value	0.109895
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	10421.51

Gamma Distribution Test	
A-D Test Statistic	2.107725
A-D 5% Critical Value	0.81542
K-S Test Statistic	0.174997
K-S 5% Critical Value	0.116891
Data do not follow gamma distribution at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	10414.52
Adjusted Gamma UCL	10489.93

Lognormal Distribution Test	
Lilliefors Test Statisitic	0.085498
Lilliefors 5% Critical Value	0.109895
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	19189.24
95% Chebyshev (MVUE) UCL	21749.18
97.5% Chebyshev (MVUE) UCL	27135.25
99% Chebyshev (MVUE) UCL	37715.16

95% Non-parametric UCLs	
CLT UCL	10380.57
Adj-CLT UCL (Adjusted for skewness)	11099.38
Mod-t UCL (Adjusted for skewness)	10533.63
Jackknife UCL	10421.51
Standard Bootstrap UCL	10339.49
Bootstrap-t UCL	11611.6
Hall's Bootstrap UCL	12009.85
Percentile Bootstrap UCL	10550.56
BCA Bootstrap UCL	11319.41
95% Chebyshev (Mean, Sd) UCL	14980.38
97.5% Chebyshev (Mean, Sd) UCL	18176.98
99% Chebyshev (Mean, Sd) UCL	24456.07

Data File

Variable: White Croaker - PCBs

Raw Statistics	
Number of Valid Samples	65
Number of Unique Samples	63
Minimum	24.76
Maximum	6500
Mean	733.7576
Median	304.231
Standard Deviation	1148.709
Variance	1319532
Coefficient of Variation	1.565516
Skewness	2.863687

Gamma Statistics	
k hat	0.66931
k star (bias corrected)	0.648675
Theta hat	1096.289
Theta star	1131.163
nu hat	87.01033
nu star	84.32781
Approx.Chi Square Value (.05)	64.15855
Adjusted Level of Significance	0.046308
Adjusted Chi Square Value	63.76039

Log-transformed Statistics	
Minimum of log data	3.209229
Maximum of log data	8.779557
Mean of log data	5.689526
Standard Deviation of log data	1.359913
Variance of log data	1.849363

RECOMMENDATION

Data are Non-parametric (0.05)

Use 97.5% Chebyshev (Mean, Sd) UCL

Normal Distribution Test	
Lilliefors Test Statisitic	0.278405
Lilliefors 5% Critical Value	0.109895
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	971.5582

Gamma Distribution Test	
A-D Test Statistic	2.213592
A-D 5% Critical Value	0.800083
K-S Test Statistic	0.13689
K-S 5% Critical Value	0.115602
Data do not follow gamma distribution at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	964.4259
Adjusted Gamma UCL	970.4484

Lognormal Distribution Test	
Lilliefors Test Statisitic	0.11004
Lilliefors 5% Critical Value	0.109895
Data not lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	1169.515
95% Chebyshev (MVUE) UCL	1423.541
97.5% Chebyshev (MVUE) UCL	1725.274
99% Chebyshev (MVUE) UCL	2317.969

95% Non-parametric UCLs	
CLT UCL	968.116
Adj-CLT UCL (Adjusted for skewness)	1022.192
Mod-t UCL (Adjusted for skewness)	979.9929
Jackknife UCL	971.5582
Standard Bootstrap UCL	969.77
Bootstrap-t UCL	1062.333
Hall's Bootstrap UCL	1074.638
Percentile Bootstrap UCL	979.9132
BCA Bootstrap UCL	1028.004
95% Chebyshev (Mean, Sd) UCL	1354.813
97.5% Chebyshev (Mean, Sd) UCL	1623.544
99% Chebyshev (Mean, Sd) UCL	2151.414

Data File

Variable: Kelp Bass - DDT

Raw Statistics	
Number of Valid Samples	51
Number of Unique Samples	45
Minimum	20
Maximum	1420
Mean	276.0247
Median	190
Standard Deviation	308.9519
Variance	95451.27
Coefficient of Variation	1.119291
Skewness	2.529832

Gamma Statistics	
k hat	1.251117
k star (bias corrected)	1.190594
Theta hat	220.6227
Theta star	231.8379
nu hat	127.6139
nu star	121.4405
Approx.Chi Square Value (.05)	96.98762
Adjusted Level of Significance	0.045294
Adjusted Chi Square Value	96.35289

Log-transformed Statistics	
Minimum of log data	2.995732
Maximum of log data	7.258412
Mean of log data	5.170337
Standard Deviation of log data	0.960669
Variance of log data	0.922884

RECOMMENDATION

Assuming gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test	
Lilliefors Test Statisitic	0.206853
Lilliefors 5% Critical Value	0.124065
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	348.5276

Gamma Distribution Test	
A-D Test Statistic	0.882976
A-D 5% Critical Value	0.77361
K-S Test Statistic	0.102847
K-S 5% Critical Value	0.127127
Data follow approximate gamma distibution at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	345.6173
Adjusted Gamma UCL	347.894

Lognormal Distribution Test	
Lilliefors Test Statisitic	0.086266
Lilliefors 5% Critical Value	0.124065
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	379.7941
95% Chebyshev (MVUE) UCL	463.9185
97.5% Chebyshev (MVUE) UCL	545.4125
99% Chebyshev (MVUE) UCL	705.4915

95% Non-parametric UCLs	
CLT UCL	347.1842
Adj-CLT UCL (Adjusted for skewness)	363.5597
Mod-t UCL (Adjusted for skewness)	351.0818
Jackknife UCL	348.5276
Standard Bootstrap UCL	346.7716
Bootstrap-t UCL	377.2303
Hall's Bootstrap UCL	376.0438
Percentile Bootstrap UCL	349.4882
BCA Bootstrap UCL	369.2706
95% Chebyshev (Mean, Sd) UCL	464.5991
97.5% Chebyshev (Mean, Sd) UCL	546.1953
99% Chebyshev (Mean, Sd) UCL	706.4754

Data File

Variable: Kelp Bass -PCB

Raw Statistics	
Number of Valid Samples	51
Number of Unique Samples	31
Minimum	5
Maximum	250
Mean	36.33406
Median	30
Standard Deviation	39.54408
Variance	1563.734
Coefficient of Variation	1.088347
Skewness	3.412167

Gamma Statistics	
k hat	1.27249
k star (bias corrected)	1.21071
Theta hat	28.5535
Theta star	30.01054
nu hat	129.794
nu star	123.4924
Approx.Chi Square Value (.05)	98.82338
Adjusted Level of Significance	0.045294
Adjusted Chi Square Value	98.18243

Log-transformed Statistics	
Minimum of log data	1.609438
Maximum of log data	5.521461
Mean of log data	3.150924
Standard Deviation of log data	0.985817
Variance of log data	0.971835

RECOMMENDATION

Assuming gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test	
Lilliefors Test Statisitic	0.22079
Lilliefors 5% Critical Value	0.124065
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	45.61401

Gamma Distribution Test	
A-D Test Statistic	0.781708
A-D 5% Critical Value	0.773076
K-S Test Statistic	0.109948
K-S 5% Critical Value	0.127067
Data follow approximate gamma distibution at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	45.40404
Adjusted Gamma UCL	45.70044

Lognormal Distribution Test	
Lilliefors Test Statisitic	0.13713
Lilliefors 5% Critical Value	0.124065
Data not lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	52.26386
95% Chebyshev (MVUE) UCL	63.88284
97.5% Chebyshev (MVUE) UCL	75.31967
99% Chebyshev (MVUE) UCL	97.78511

95% Non-parametric UCLs	
CLT UCL	45.44207
Adj-CLT UCL (Adjusted for skewness)	48.26905
Mod-t UCL (Adjusted for skewness)	46.05496
Jackknife UCL	45.61401
Standard Bootstrap UCL	45.31432
Bootstrap-t UCL	50.51959
Hall's Bootstrap UCL	85.09702
Percentile Bootstrap UCL	46.1139
BCA Bootstrap UCL	48.92202
95% Chebyshev (Mean, Sd) UCL	60.4705
97.5% Chebyshev (Mean, Sd) UCL	70.91435
99% Chebyshev (Mean, Sd) UCL	91.42928

Data File

Variable: Rockfish - DDT

Raw Statistics	
Number of Valid Samples	23
Number of Unique Samples	21
Minimum	34.7
Maximum	567
Mean	211.0819
Median	145
Standard Deviation	140.6201
Variance	19774.01
Coefficient of Variation	0.666187
Skewness	1.000446

Gamma Statistics	
k hat	2.498807
k star (bias corrected)	2.201861
Theta hat	84.47309
Theta star	95.86524
nu hat	114.9451
nu star	101.2856
Approx.Chi Square Value (.05)	79.06138
Adjusted Level of Significance	0.0389
Adjusted Chi Square Value	77.63868

Log-transformed Statistics	
Minimum of log data	3.54674
Maximum of log data	6.340359
Mean of log data	5.139004
Standard Deviation of log data	0.683388
Variance of log data	0.467019

RECOMMENDATION

Assuming gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.87701
Shapiro-Wilk 5% Critical Value	0.914
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	261.4308

Gamma Distribution Test	
A-D Test Statistic	0.715433
A-D 5% Critical Value	0.75254
K-S Test Statistic	0.198785
K-S 5% Critical Value	0.183266
Data follow approximate gamma distibution at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	270.4172
Adjusted Gamma UCL	275.3725

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.949456
Shapiro-Wilk 5% Critical Value	0.914
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	294.8738
95% Chebyshev (MVUE) UCL	354.1633
97.5% Chebyshev (MVUE) UCL	415.3335
99% Chebyshev (MVUE) UCL	535.4906

95% Non-parametric UCLs	
CLT UCL	259.3112
Adj-CLT UCL (Adjusted for skewness)	265.8469
Mod-t UCL (Adjusted for skewness)	262.4503
Jackknife UCL	261.4308
Standard Bootstrap UCL	258.2664
Bootstrap-t UCL	270.8555
Hall's Bootstrap UCL	265.9384
Percentile Bootstrap UCL	260.4306
BCA Bootstrap UCL	264.8903
95% Chebyshev (Mean, Sd) UCL	338.8906
97.5% Chebyshev (Mean, Sd) UCL	394.1935
99% Chebyshev (Mean, Sd) UCL	502.8253

Data File

Variable: Rockfish - PCB

Raw Statistics	
Number of Valid Samples	23
Number of Unique Samples	23
Minimum	12.32
Maximum	124.06
Mean	40.51735
Median	35.475
Standard Deviation	28.78312
Variance	828.4682
Coefficient of Variation	0.71039
Skewness	2.006725

Gamma Statistics	
k hat	2.791102
k star (bias corrected)	2.456031
Theta hat	14.51661
Theta star	16.49709
nu hat	128.3907
nu star	112.9774
Approx.Chi Square Value (.05)	89.4358
Adjusted Level of Significance	0.0389
Adjusted Chi Square Value	87.91833

Log-transformed Statistics	
Minimum of log data	2.511224
Maximum of log data	4.820765
Mean of log data	3.512022
Standard Deviation of log data	0.615138
Variance of log data	0.378394

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.763572
Shapiro-Wilk 5% Critical Value	0.914
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	50.82313

Gamma Distribution Test	
A-D Test Statistic	0.579921
A-D 5% Critical Value	0.751263
K-S Test Statistic	0.150111
K-S 5% Critical Value	0.182942
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	51.18247
Adjusted Gamma UCL	52.06588

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.952151
Shapiro-Wilk 5% Critical Value	0.914
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	53.232
95% Chebyshev (MVUE) UCL	63.83133
97.5% Chebyshev (MVUE) UCL	74.09508
99% Chebyshev (MVUE) UCL	94.25624

95% Non-parametric UCLs	
CLT UCL	50.38926
Adj-CLT UCL (Adjusted for skewness)	53.07262
Mod-t UCL (Adjusted for skewness)	51.24167
Jackknife UCL	50.82313
Standard Bootstrap UCL	50.08467
Bootstrap-t UCL	58.27108
Hall's Bootstrap UCL	107.7392
Percentile Bootstrap UCL	50.98952
BCA Bootstrap UCL	53.27783
95% Chebyshev (Mean, Sd) UCL	66.67813
97.5% Chebyshev (Mean, Sd) UCL	77.99793
99% Chebyshev (Mean, Sd) UCL	100.2335

Data File

Variable: Surfperches - DDT

Raw Statistics	
Number of Valid Samples	20
Number of Unique Samples	20
Minimum	36.84
Maximum	430
Mean	131.6335
Median	100.13
Standard Deviation	96.10594
Variance	9236.352
Coefficient of Variation	0.730102
Skewness	2.1051

Gamma Statistics	
k hat	2.855771
k star (bias corrected)	2.460739
Theta hat	46.09386
Theta star	53.49349
nu hat	114.2308
nu star	98.42954
Approx.Chi Square Value (.05)	76.53858
Adjusted Level of Significance	0.038
Adjusted Chi Square Value	75.01367

Log-transformed Statistics	
Minimum of log data	3.606584
Maximum of log data	6.063785
Mean of log data	4.694838
Standard Deviation of log data	0.593495
Variance of log data	0.352236

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.759597
Shapiro-Wilk 5% Critical Value	0.905
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	168.7925

Gamma Distribution Test	
A-D Test Statistic	0.670101
A-D 5% Critical Value	0.748234
K-S Test Statistic	0.160335
K-S 5% Critical Value	0.195186
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	169.2823
Adjusted Gamma UCL	172.7235

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.966735
Shapiro-Wilk 5% Critical Value	0.905
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	173.486
95% Chebyshev (MVUE) UCL	207.5789
97.5% Chebyshev (MVUE) UCL	241.5226
99% Chebyshev (MVUE) UCL	308.1983

95% Non-parametric UCLs	
CLT UCL	166.9813
Adj-CLT UCL (Adjusted for skewness)	177.79
Mod-t UCL (Adjusted for skewness)	170.4784
Jackknife UCL	168.7925
Standard Bootstrap UCL	166.3893
Bootstrap-t UCL	197.6665
Hall's Bootstrap UCL	334.9945
Percentile Bootstrap UCL	168.5355
BCA Bootstrap UCL	177.418
95% Chebyshev (Mean, Sd) UCL	225.306
97.5% Chebyshev (Mean, Sd) UCL	265.8381
99% Chebyshev (Mean, Sd) UCL	345.4557

Data File

Variable: Surfperches - PCB

Raw Statistics	
Number of Valid Samples	20
Number of Unique Samples	20
Minimum	7.59
Maximum	59.95
Mean	19.236
Median	15.34
Standard Deviation	12.86255
Variance	165.4453
Coefficient of Variation	0.668671
Skewness	2.195106

Gamma Statistics	
k hat	3.500183
k star (bias corrected)	3.008489
Theta hat	5.495713
Theta star	6.393908
nu hat	140.0073
nu star	120.3396
Approx.Chi Square Value (.05)	96.00333
Adjusted Level of Significance	0.038
Adjusted Chi Square Value	94.28653

Log-transformed Statistics	
Minimum of log data	2.026832
Maximum of log data	4.093511
Mean of log data	2.807185
Standard Deviation of log data	0.523942
Variance of log data	0.274515

RECOMMENDATION

Assuming gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.7421
Shapiro-Wilk 5% Critical Value	0.905
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	24.20925

Gamma Distribution Test	
A-D Test Statistic	0.841996
A-D 5% Critical Value	0.74653
K-S Test Statistic	0.194602
K-S 5% Critical Value	0.194835
Data follow approximate gamma distibution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	24.1122
Adjusted Gamma UCL	24.55124

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.937568
Shapiro-Wilk 5% Critical Value	0.905
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	24.23543
95% Chebyshev (MVUE) UCL	28.869
97.5% Chebyshev (MVUE) UCL	33.20203
99% Chebyshev (MVUE) UCL	41.71343

95% Non-parametric UCLs	
CLT UCL	23.96685
Adj-CLT UCL (Adjusted for skewness)	25.47531
Mod-t UCL (Adjusted for skewness)	24.44454
Jackknife UCL	24.20925
Standard Bootstrap UCL	23.86031
Bootstrap-t UCL	28.82849
Hall's Bootstrap UCL	47.64991
Percentile Bootstrap UCL	24.1335
BCA Bootstrap UCL	25.6155
95% Chebyshev (Mean, Sd) UCL	31.77287
97.5% Chebyshev (Mean, Sd) UCL	37.19758
99% Chebyshev (Mean, Sd) UCL	47.85337

Data File

Variable: California Scorpionfish - DDT

Raw Statistics	
Number of Valid Samples	28
Number of Unique Samples	28
Minimum	21.63
Maximum	2630
Mean	417.9693
Median	140.5
Standard Deviation	642.4923
Variance	412796.4
Coefficient of Variation	1.537176
Skewness	2.398502

Gamma Statistics	
k hat	0.708807
k star (bias corrected)	0.656673
Theta hat	589.6803
Theta star	636.4957
nu hat	39.69317
nu star	36.77366
Approx.Chi Square Value (.05)	23.89
Adjusted Level of Significance	0.0404
Adjusted Chi Square Value	23.24728

Log-transformed Statistics	
Minimum of log data	3.074081
Maximum of log data	7.874739
Mean of log data	5.184269
Standard Deviation of log data	1.288994
Variance of log data	1.661505

RECOMMENDATION

Data are lognormal (0.05)

Use H-UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.632087
Shapiro-Wilk 5% Critical Value	0.924
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	624.7819

Gamma Distribution Test	
A-D Test Statistic	1.281812
A-D 5% Critical Value	0.78888
K-S Test Statistic	0.173184
K-S 5% Critical Value	0.172376
Data do not follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	643.3763
Adjusted Gamma UCL	661.1638

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.954798
Shapiro-Wilk 5% Critical Value	0.924
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	829.7263
95% Chebyshev (MVUE) UCL	889.1541
97.5% Chebyshev (MVUE) UCL	1105.396
99% Chebyshev (MVUE) UCL	1530.161

95% Non-parametric UCLs	
CLT UCL	617.6868
Adj-CLT UCL (Adjusted for skewness)	676.494
Mod-t UCL (Adjusted for skewness)	633.9547
Jackknife UCL	624.7819
Standard Bootstrap UCL	614.2452
Bootstrap-t UCL	759.2534
Hall's Bootstrap UCL	662.5376
Percentile Bootstrap UCL	624.2468
BCA Bootstrap UCL	688.5596
95% Chebyshev (Mean, Sd) UCL	947.2252
97.5% Chebyshev (Mean, Sd) UCL	1176.235
99% Chebyshev (Mean, Sd) UCL	1626.079

Data File

Variable: California Scorpionfish - PCB

Raw Statistics	
Number of Valid Samples	28
Number of Unique Samples	28
Minimum	5.68
Maximum	242.99
Mean	47.38714
Median	23.64
Standard Deviation	59.31575
Variance	3518.358
Coefficient of Variation	1.251727
Skewness	2.119604

Gamma Statistics	
k hat	0.983935
k star (bias corrected)	0.902323
Theta hat	48.16086
Theta star	52.51685
nu hat	55.10035
nu star	50.53007
Approx.Chi Square Value (.05)	35.20421
Adjusted Level of Significance	0.0404
Adjusted Chi Square Value	34.41264

Log-transformed Statistics	
Minimum of log data	1.736951
Maximum of log data	5.49302
Mean of log data	3.27059
Standard Deviation of log data	1.071198
Variance of log data	1.147465

RECOMMENDATION

Assuming gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.698754
Shapiro-Wilk 5% Critical Value	0.924
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	66.48036

Gamma Distribution Test	
A-D Test Statistic	1.060736
A-D 5% Critical Value	0.774479
K-S Test Statistic	0.164749
K-S 5% Critical Value	0.170317
Data follow approximate gamma distibution at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	68.01675
Adjusted Gamma UCL	69.58129

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.944711
Shapiro-Wilk 5% Critical Value	0.924
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	79.11124
95% Chebyshev (MVUE) UCL	91.72546
97.5% Chebyshev (MVUE) UCL	111.8051
99% Chebyshev (MVUE) UCL	151.2477

95% Non-parametric UCLs	
CLT UCL	65.82533
Adj-CLT UCL (Adjusted for skewness)	70.62319
Mod-t UCL (Adjusted for skewness)	67.22873
Jackknife UCL	66.48036
Standard Bootstrap UCL	65.30032
Bootstrap-t UCL	75.37783
Hall's Bootstrap UCL	70.74003
Percentile Bootstrap UCL	66.79607
BCA Bootstrap UCL	71.02143
95% Chebyshev (Mean, Sd) UCL	96.24876
97.5% Chebyshev (Mean, Sd) UCL	117.3912
99% Chebyshev (Mean, Sd) UCL	158.9215

Data File

Variable: Barred Sandbass - DDT

Raw Statistics	
Number of Valid Samples	28
Number of Unique Samples	28
Minimum	46.24
Maximum	4317.78
Mean	630.0533
Median	389.5
Standard Deviation	856.7355
Variance	733995.7
Coefficient of Variation	1.359783
Skewness	3.295578

Gamma Statistics	
k hat	1.024649
k star (bias corrected)	0.938675
Theta hat	614.8967
Theta star	671.2158
nu hat	57.38034
nu star	52.56578
Approx.Chi Square Value (.05)	36.90863
Adjusted Level of Significance	0.0404
Adjusted Chi Square Value	36.09684

Log-transformed Statistics	
Minimum of log data	3.833845
Maximum of log data	8.370497
Mean of log data	5.88407
Standard Deviation of log data	1.062714
Variance of log data	1.129361

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.613671
Shapiro-Wilk 5% Critical Value	0.924
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	905.8289

Gamma Distribution Test	
A-D Test Statistic	0.733797
A-D 5% Critical Value	0.773231
K-S Test Statistic	0.161858
K-S 5% Critical Value	0.170119
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	897.3305
Adjusted Gamma UCL	917.5109

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.980686
Shapiro-Wilk 5% Critical Value	0.924
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	1063.063
95% Chebyshev (MVUE) UCL	1235.23
97.5% Chebyshev (MVUE) UCL	1504.352
99% Chebyshev (MVUE) UCL	2032.989

95% Non-parametric UCLs	
CLT UCL	896.3679
Adj-CLT UCL (Adjusted for skewness)	1004.114
Mod-t UCL (Adjusted for skewness)	922.635
Jackknife UCL	905.8289
Standard Bootstrap UCL	892.8503
Bootstrap-t UCL	1178.183
Hall's Bootstrap UCL	1919.918
Percentile Bootstrap UCL	914.8995
BCA Bootstrap UCL	1034.806
95% Chebyshev (Mean, Sd) UCL	1335.793
97.5% Chebyshev (Mean, Sd) UCL	1641.167
99% Chebyshev (Mean, Sd) UCL	2241.015

Data File

Variable: Barred Sandbass -PCB

Raw Statistics	
Number of Valid Samples	28
Number of Unique Samples	28
Minimum	5.47
Maximum	294.139
Mean	74.91211
Median	56.1595
Standard Deviation	66.05583
Variance	4363.372
Coefficient of Variation	0.881778
Skewness	1.726518

Gamma Statistics	
k hat	1.513125
k star (bias corrected)	1.374814
Theta hat	49.50822
Theta star	54.48892
nu hat	84.73498
nu star	76.98956
Approx.Chi Square Value (.05)	57.77376
Adjusted Level of Significance	0.0404
Adjusted Chi Square Value	56.74433

Log-transformed Statistics	
Minimum of log data	1.699279
Maximum of log data	5.684052
Mean of log data	3.950827
Standard Deviation of log data	0.920331
Variance of log data	0.84701

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.832653
Shapiro-Wilk 5% Critical Value	0.924
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	96.1749

Gamma Distribution Test	
A-D Test Statistic	0.243383
A-D 5% Critical Value	0.762527
K-S Test Statistic	0.107609
K-S 5% Critical Value	0.168339
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	99.82821
Adjusted Gamma UCL	101.6392

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.982916
Shapiro-Wilk 5% Critical Value	0.924
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	120.8017
95% Chebyshev (MVUE) UCL	144.17
97.5% Chebyshev (MVUE) UCL	172.9049
99% Chebyshev (MVUE) UCL	229.3491

95% Non-parametric UCLs	
CLT UCL	95.44544
Adj-CLT UCL (Adjusted for skewness)	99.79759
Mod-t UCL (Adjusted for skewness)	96.85374
Jackknife UCL	96.1749
Standard Bootstrap UCL	95.16476
Bootstrap-t UCL	102.8938
Hall's Bootstrap UCL	106.036
Percentile Bootstrap UCL	95.81461
BCA Bootstrap UCL	99.92596
95% Chebyshev (Mean, Sd) UCL	129.3259
97.5% Chebyshev (Mean, Sd) UCL	152.8708
99% Chebyshev (Mean, Sd) UCL	199.1201

Appendix C
Updated Food Web Exposure Model Memorandum

Updated Food Web Model for the Palos Verdes Shelf Ecological Risk Assessment

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COPIES: Peter Torrey/CH2M HILL

DATE: November 30, 2006

1. Introduction

In 2003, a food web exposure model was developed for the Palos Verdes Shelf (PV Shelf) Ecological Risk Assessment (ERA) to evaluate the effects of sediment contamination at Palos Verdes and throughout the Southern California Bight (SCB) on ecological receptors (Environmental Protection Agency [EPA], 2003). A number of fish, bird, and mammal receptors were chosen for the model based on their ecological importance to the SCB aquatic ecosystem, for their known exposure to and bioaccumulation of dichlorodiphenyltrichloroethane (DDT) and polychlorinated biphenyls (PCBs) (the primary contaminants of the PV Shelf), and because their foraging area or dietary items coincide with the PV Shelf study area. The model was designed to characterize exposure to birds and marine mammals, for which ecological risk was described as a function of the concentrations of DDT and PCBs in sediments. In addition to characterizing existing conditions, the model can be used to predict changing exposure and ecological risk to the selected fish, birds, and marine mammals due to changes in the distribution of or exposure to DDT and PCBs in SCB sediments.

2. Scope

The purpose of this technical memorandum (TM) is to describe the changes made to update the 2003 ERA food web model with sediment and fish data collected since 2002, and to present full model results for the species evaluated in the initial ERA. The initial food web model incorporated data for the period of 1990 to 2001; in the latest version, sediment and fish data from 2002 to 2005 were added to create a database inclusive of 1990 through 2005. New datasets incorporated since the publication of the initial ERA (EPA, 2003) include:

- Los Angeles County Sanitation District (LACSD) sediment grab sample data: 2002, 2004 (LACSD, 2003, 2005)
- LACSD fish tissue data: 2004, 2005 (LACSD, 2005, 2006)
- The 2002-2004 Southern California Marine Fish Contaminants Survey (EPA and NOAA, 2007)

The updated food web model provides estimates of ecological risk associated with exposure to DDT and PCB compounds attributable, in part, to the PV Shelf site. However, this TM does not attempt to update all aspects of the earlier ERA. As mentioned in the ERA, the food web model results are considered one line of evidence in the evaluation of ecological risk at the PV Shelf. The updated assumptions and data of the new version of the food web model as compared to the earlier version can be summarized as follows:

- More recent data have been used to update the surface sediment concentration contours for DDT and PCBs at the PV Shelf site. The initial food web model used sediment concentrations of DDT and PCBs from 1990 to 2001. The revised food web model uses an average of surface sediment concentrations of DDT and PCBs from 2002 and 2004. The new sediment contours were used to establish new areas of potential toxicological exceedances for exposure to benthic invertebrates living on or in the sediment.
- New values for fish tissue concentrations of DDT and PCBs are used for the PV Shelf site and surrounding areas of the Southern California Bight. The initial food web model used fish tissue data from 1990 to 2001. The revised food web model uses DDT and PCB concentrations from fish tissue samples collected between 2002 and 2005.
- New regression relationships were established between the concentrations of DDT and PCBs in benthic fish and the surface sediments (as a result of the update to both datasets). The new relationships were established for DDT and PCBs for both white croaker and kelp bass.
- New data were used to convert fish fillet chemistry data (white croaker and kelp bass) to estimates of whole-body fish tissue concentrations for DDT and PCBs. The data are now specific for the species used in the food web model.
- The new sediment concentrations of DDT and PCBs and benthic fish/sediment relationships were used along with new average concentrations of DDT and PCBs for whole-body tissue in pelagic fish to create new estimates of oral dosage exposure for marine mammals and birds in the food web model.

As discussed above, data used in this evaluation were collected between 1990 and 2005 for the Southern California Bight, and between 2002 and 2005 for the PV Shelf. The updated data for PV Shelf replaced older data; the new fish data for the SCB adds to earlier data. This relatively wide timeframe was needed to retain the spatial coverage of tissue and sediment values only available from inclusion of the earliest datasets. The food web model depends on a continuous grid of sediment concentrations of DDT and PCBs for the entire SCB shelf area. For those sites where samples have been collected more than once, only the most recent data have been used in the updated food web model. This is in contrast to the database of the initial food web model, which used averages of sediment concentrations of DDT and PCBs at sites with multiple years of data (EPA, 2003). Sediment sampling conducted at the PV Shelf over the last several years has indicated that gradual changes in contaminant concentrations have occurred at some sites. For that reason, the most recent sediment concentration data have been chosen as most representative of baseline conditions and are used in the updated model. The first task of this update was to recreate the summary of concentrations of tDDT and tPCBs in surface sediment for the PV Shelf using an average of the 2002 and 2004 LACSD surface grab samples.

In addition to providing results on the updated food web model, this TM also presents an updated risk screening (calculation of hazard quotients) for benthic invertebrates for total DDT (tDDT) and total PCBs (tPCBs) that logically result from any update to the mapped depiction of tDDT and tPCBs in surface sediments. This benthic risk screening is updated in this memorandum because it was part of the initial ERA.

The updated model results are based on 2002 and 2004 PV Shelf sediment concentrations of DDT and PCBs. Changes in bioaccumulation due to broad-scale degradation, loss, or burial of contaminants over time or as a result of sediment remediation techniques (such as capping) may be estimated using the model. For example, new contaminant concentrations may be assigned to the surface sediments of discrete areas, and the resulting changes to ecological risk at the PV Shelf can then be predicted as part of the new, projected conditions. Therefore, a revised food web model could be a valuable tool in evaluating future remedial alternatives in the feasibility study. However, the intent of this update is not to prepare the food web model for evaluating remedial alternatives, as additional adjustments of the model may be necessary. Rather, this Technical Memorandum is limited to the update of the sediment and fish databases, benthic community exposure estimates, and updates to the food web model and outputs.

It is important to note that the weight of evidence approach is used to evaluate risks in the ERA and the food web model. This memorandum will conclude by addressing differences in overall risk using the weight of evidence approach and comparing the initial and updated food web model results.

3. Food Web Model Methods and Assumptions

The basic concept of the model is to take advantage of the relatively high sample density for surface sediment concentrations of DDT and PCBs at the PV Shelf to create a sediment contour map that can be used to predict bioaccumulated tDDT and PCBs in fish. It is recognized that sediment, water, and biota tissue concentrations vary continuously on differing time scales. However, the model is constructed to describe a snapshot of risk for the PV Shelf area to represent "current conditions." No component of changes over time are accommodated in the model. Instead, if the spatial distribution of sediment DDT and PCB concentrations are changed, the model outputs of estimated risk to ecological receptors will change, correspondingly. The surface sediment concentrations of DDT and PCBs used in the food web model update consist of an average of the 2002 and 2004 surface sediment data collected by LACSD at 44 sampling locations.

3.1 Biota-Sediment Accumulation Factors

It is assumed that DDT and PCB levels in benthic species of fish (white croaker, sanddab species) and mid water-column kelp bass are causally related to contaminant concentrations in the co-located sediment. This general, positive relationship has already been shown statistically for PCBs and DDT in sanddabs (Allen et al., 2002) and demonstrated graphically for the other species, including white croaker and kelp bass (EPA, 2003; MSRP, 2002). The numerical relationships between sediment and fish tissue constitute biota-sediment accumulation factors (BSAFs), which were expressed as species-specific log-linear regression relationships between fish tissue associated with underlying sediment concentrations (EPA, 2003). The main assumption of the sediment to fish BSAF relationship is that the

combined effects of diet and home range of the fish can be causally related to the chemical contamination of any given area of bottom sediment. It is recognized that the relationships between co-located sediment and fish tissue concentrations are highly variable. However, the statistically significant slope is of most importance; the trend is that fish from areas of more contaminated sediments tend to have significantly higher tissue concentrations than fish from cleaner areas. The BSAF regression relationships are based on fish sampled from throughout the SCB, including the PV Shelf, and therefore encompass the full range of expected sediment concentrations to be found within SCB environments, from background values to highly contaminated levels found only at the PV Shelf.

Statistically significant regression relationships between fish tissue DDT and PCB concentrations and the concentrations in underlying, co-located sediment were established for kelp bass and white croaker fillets from the data sets from 2002, 2004, and 2005 (LACSD, 2005, 2006; EPA and NOAA, 2007). The relationships for these two species represent an update to the earlier ERA food web model. The similar, previously established relationship between sanddab tissue and sediment was used from the Bight '98 dataset (*Southern California Coastal Water Research Project* [SCCWRP], 1998) and remains unchanged from the earlier ERA. None of the regression relationships for these fish species benefited from lipid normalization of DDT or PCB concentrations. The best relationships (highest r^2 values) were established from comparing tissue to sediment concentrations without tissue normalizations to lipid content or sediment normalizations to organic carbon (except for sanddabs, which were normalized to total organic carbon [TOC] in the sediment). Tissue concentrations for fillets were then converted to whole body concentrations as shown below for white croaker and kelp bass. This is an additional update to the previous model that used a whole body conversion based on various freshwater fish (EPA, 2003).

The predicted DDT and PCB concentrations in fish were then used in the model at the same 50-meter (m)-square spatial grid as the underlying sediment. The modeled fish then serve as primary dietary components for estimated exposure to marine birds and mammals. Dietary exposure from fish (and squid) is the basis for modeled ecological risk to higher order consumers (taking into account their home range, dietary composition, and consumption rates). Risks vary to the degree that diet is linked to the underlying sediment concentrations (see Pelagic Fish section, below). The basic conceptual model and model equations were provided in Appendix C of the ERA (EPA, 2003). Based on the revised food web model, Appendix C has been revised and is included with this TM (Attachment 1).

The tDDT was estimated as the sum of all six DDT, dichlorodiphenyldichloroethene (DDE), and dichlorodiphenyldichloroethane (DDD) isomers. Because PCB analyses varied by study, PCBs are estimated as the sum of either all congeners or all homologs detected. The detailed data on the six DDT isomers from USGS samples (Lee, 1994) were used as a means of establishing a strongly positive relationship between tDDT and DDE concentrations in the PV Shelf sediment. That regression was used to predict tDDT values from the p, p' DDE concentrations as measured by LACSD ($r^2 = 0.993$, $P < 0.001$, $n = 405$) and allowed the use of LACSD data as converted to tDDT.

3.2 Pelagic Fish

It is assumed that other common dietary items of birds and marine mammals are more wide-ranging throughout the SCB and that their tissue concentrations are not spatially tied

to underlying sediments (EPA, 2003; MSRP, 2002). These are referred to in the model as "pelagic fish," and they constitute a significant part of the diet of the important PV Shelf ecological receptors. Those dietary fish species (e.g., mackerel, sardines, topsmelt) are part of a plankton-based, midwater food web rather than a food web directly linked to sediments and sediment-dwelling invertebrates. Their concentrations were entered into the food web model as constant values rather than as estimated from underlying sediment concentrations, because their tissue concentrations are not causally linked to underlying sediments. The most recent pelagic fish data were used in the food web model update because these values are part of the most current, comprehensive Southern-California-wide dataset from which the new white croaker and kelp bass values for the model were taken (EPA and NOAA, 2007).

3.3 Diet

Dietary items for the initial and updated food web model were assumed as follows:

- Brown pelicans: 100 percent fish
- Double-crested cormorants: 100 percent fish
- Bald eagles: 81 percent fish, 13 percent mixed seabirds, and 6 percent sea lion carcasses
- Peregrine falcons: 32 percent land birds (resident and migratory) and 68 percent mixed seabirds
- Adult female California sea lions: 100 percent fish
- Nursing California sea lion pups: 100 percent milk

Dietary information for all receptors and the proportions of prey in surrogate diets are summarized in Appendixes B and C of the ERA (EPA, 2003) and Attachment 1 of this TM.

3.4 Evaluation Area

Risks to marine birds and mammals were evaluated through characterization of sediment concentrations of DDT and PCBs and predicted fish concentrations of DDT and PCBs in coastal zones of the SCB to a total depth of 200 m. The evaluation area was limited to those water depths, as representative of sea lion foraging depths up to 200 m (Bureau of Land Management [BLM], 1981). The water depth for modeling of brown pelican exposure was limited to 150 m (to account for fish originating from that depth of water and a certain distance from shore); and the water depth for modeling of double-crested cormorant exposure was limited to 22 m, the foraging depth for cormorants (Zeiner et al., 1990).

3.5 Exposure Calculations

Exposures for birds and sea lions were estimated as the geographic distribution of the receptor (as percentage of time at a certain location) times the estimated tissue concentration of DDT and PCBs in the prey species in that location times the daily dietary intake. Resulting exposure values were expressed in standard dosage units, as milligrams (mg) of contaminant per kilogram (kg) of body weight consumed per day. Species ranges, dietary intakes, exposure values, and calculating equations are presented in Attachment 1.

3.6 Spatially-averaged Exposure Area

The home ranges of the benthic species are unknown (Allen, 2002) but it must be assumed that fish average contaminant exposures over time over some wide-ranging (but unknown) area of the sediment. It was assumed that regression analyses of tissue concentrations versus spatially averaged sediment concentrations could be used to determine exposure over an area of sediment surface that would be more representative of long-term exposure than a simple point exposure for the point of fish capture. In the original ERA (EPA, 2003) various sediment averaging areas were tested against fish tissue concentrations with the assumption that as the area over which spatial averaging was conducted approached the actual (but unknown) exposure area, the r-square (r^2) value from the regression would increase to a maximum value. Species tested for regression relationships to sediment (white croaker and kelp bass) were initially assigned potential home ranges ranging from 1 to 2.5 kilometer (km) in radius. However, the differences in r^2 values with changing exposure areas were not great (although r^2 values were always greater testing against an exposure area instead of a point). For that reason, a 1-km-radius area of sediment was chosen as a representative exposure area for bioaccumulation in all fish. White croaker and kelp bass tissue concentrations were compared to surface sediment concentrations averaged over a 1-km-radius exposure area. Both species (white croaker and kelp bass) yielded significant, positive linear regressions between 1-km-radius average sediment concentrations of DDT and PCBs and the corresponding fish tissue values from the center of the assumed exposure area. All regression relationships were established using $\log_{10}$-transformed values to improve normality.

3.7 Prediction of Fish Tissue Concentrations

The usefulness of standard data normalization techniques varied in the development of the revised food web model. Tissue lipid normalization of fish tissue contaminant concentrations (mg/kg WW [wet weight]/ percent lipid) did not improve the strength of the regression predictions from sediment concentrations. This finding was consistent with similar regression models established for whole-body sanddabs versus sediment contamination (normalized for TOC (total organic carbon) [mg/kg DW {dry weight}/ percent TOC]) in the Bight '98 report (Allen et al., 2002). The regression analysis results for predicting fish tissue from averaged underlying sediment concentrations are given in Table 1. Note that the two sanddab relationships required TOC normalization of sediment values to improve the fit. All predicted values were back-transformed to yield geometric mean tissue concentrations for given sediment values. All regression relationships, except for sanddabs, were changed from those used in the initial food web model (EPA, 2003). The new regression relationships (Table 1) are based only on the most recent, uniformly collected and analyzed tissue (skin-off fillet) and sediment data, collected and analyzed from 2004 and 2005 (fish) and 2002 and 2004 (sediment).

TABLE 1
Linear Regression Relationships for Predicting Dietary Concentrations for the Updated Food Web Model: Fish Fillet Concentrations as Predicted from Surface Sediment Concentrations as Averaged over a 1-km-radius Exposure Area

Analyte	Fish Species	Regression Equation[a], [b]	r^2, n
DDT	White croaker	logDDT(F)=2.636 + 0.412(logSedDDT)	0.387, 178
DDT	Kelp bass	logDDT(F)=2.201 + 0.306(logSedDDT)	0.168, 62
DDT	Sanddab guild	logDDT(WB)=3.416+1.02(log(SedDDT/TOC))	0.641, 76 [c]
DDT	Composite pelagic species	253(WB)	Constant value [c]
PCBs	White croaker	logPCB(F)=2.4 + 0.268(logSedPCB)	0.231,177
PCBs	Kelp bass	logPCB(F)=2.148 + 0.316* (logSedPCB)	0.137, 62
PCBs	Sanddab guild	logPCB(WB)=2.905 + 0.706* (log(SedPCB/TOC))	0.505, 34 [c]
PCBs	Composite pelagic species	121(WB)	Constant value[c]

Notes:
[a] All regressions are statistically significant, P < 0.05. Log transformations are all log10.
[b] F = fillet concentrations, µg/kg, wet-weight basis; WB = whole body concentrations, µg/kg, wet-weight basis; Sed = sediment concentrations; TOC = total organic carbon as percent dry weight.
[c] No exposure area estimated for sanddab guild species or pelagic fish. The point estimate equations used for sanddabs were used as presented in the Bight '98 report (SCCWRP, 2000).

Pelagic fish were assumed to average their exposure over a wide area and to be of constant tissue concentrations throughout the SCB. Pelagic species tissue concentrations were computed as the geometric mean value for combined whole-body concentrations in mackerel and sardines from the SCB (EPA and NOAA, 2007). Note that these are updated from those in the initial food web model and have increased in concentration for both contaminants approximately 10-fold. The initial food web model used average pelagic fish values for mackerel, bonito, and barracuda; the updated model is based on an average of mackerel and sardines. The updated assemblage is much more recent and a more reasonable choice for potential dietary items. The California sea lion has a varied diet, of which 10 percent consists of market squid. The updated model uses the original squid tissue concentrations (EPA, 2003).

The regression predictions for two fish (white croaker and kelp bass) from sediment were based on fillet concentrations. Whole-body to fillet contaminant concentration relationships are lacking for SCB species, but were developed for the purposes of this food web model based on fillet and fish remainder analyses from EPA and NOAA (2007). In general, whole-body concentrations of organochlorine contaminants in white croaker and kelp bass were greater than those in muscle tissue, given the higher lipid content of the whole body and the strong lipid affinity of the bioaccumulated compounds within certain tissues. The simple regression models were based on log-log transformed data and were all statistically significant. The equations for converting fillet to whole-body concentrations are as follows:

White croaker; DDT (WB) = 10^((Log (F)*1.137 + 0.583)), r^2 = 0.79, n = 14

White croaker; PCB (WB) = 10^((Log (F)*0.671 + 1.438)), r^2 = 0.53, n = 14

Kelp bass; DDT (WB) = 10^((Log (F)*0.816 + 1.411)), r^2 = 0.83, n = 12

Kelp bass; PCB (WB) =10^((Log (F)*0.676 + 1.436)), r^2 = 0.66, n = 12

Where:

F = fillet

WB = whole-body tissue contaminant concentrations (both as mg/kg WW)

The whole body reconstructions (WB) used in these relationships were based on multiplying the concentrations times the weight of each body part (i.e., viscera, fillet, remainders, etc.), adding the products, and dividing by the sum of the weights (total fish weight). The resulting value was the estimated "whole body" (WB) concentration that was compared to the skin-off fillet (F) concentration from the same fish.

The exposure areas of marine birds and mammals were established through a search of recent literature and conversations with local SCB-area researchers (as discussed in Attachment 1). Differing distributions, based on season or breeding condition of the birds or mammals, were incorporated wherever possible.

3.8 Benthic Invertebrate Risk Screening Values

The concentrations of tDDT and tPCBs in sediment samples collected in 2002 and 2004 (averaged) were also compared to benthic invertebrate toxicity risk screening values as an update to the initial screening in the ERA (EPA, 2003). PV Shelf-specific toxicity screening values for benthic invertebrates, the Sediment Effects Concentrations (SECs) developed by MacDonald (1997), were compared to sediment concentrations of DDT or PCBs normalized for sediment TOC concentrations, and a hazard quotient was calculated. A plot of the hazard quotients provides an updated proportion of the current PV Shelf area exceeding benthic invertebrate screening values and is meant to depict areas of sediment with concentrations of DDT or PCBs that may produce some risk to benthic invertebrate communities.

3.9 Methods Used to Produce Gridded Data Representing Contaminant Distributions in Sediment

To process the data electronically, it was necessary to interpolate the measured concentrations of DDT and PCBs in shallow sediment onto a regularly spaced grid. This process of interpolation is referred to as *gridding*. The grid spacing used was 100 m over most of the SCB but narrowed at the PV Shelf to 50-m grids to improve detail. The resulting grids contain an array of values, each representing the average, interpolated concentration over a 10,000- or 2,500-square-meter (m^2) area. The details of the geographic information system (GIS) techniques used for the model are presented in Attachment 1.

4. Results and Conclusions

The updated sediment contour maps with average 2002/2004 concentrations for surface grab samples (Van Veen samples) for the PV Shelf site are presented in Figures 1 and 2 for DDT and PCBs, respectively. There was little change in the overall pattern of contamination compared to the dataset presented in the initial food web model. Earlier depictions as smoothed contours of surface sediment concentrations (EPA, 2003) were based on a combination of average values over the top 15 centimeters (cm) of cores and/or surface grab samples sampled over a 10-year interval. The current contour values for surface sediment concentrations at the PV Shelf are based on surface grab samples, only, as an average of 2002 and 2004 values (Figures 1 and 2).

Figures 3 and 4 present updated maps of the hazard quotients for bulk sediment calculated for benthic invertebrates for DDT and PCBs, respectively; hazard quotients greater than 1.0 indicate that the SEC screening level concentrations were exceeded. The pattern of hazard quotients greater than 1.0 is similar to that portrayed in the original ERA. In general, the updated maps show a more spatially spread and slightly greater risk from DDT to benthic invertebrates than from PCBs at the PV Shelf. They also indicate that the greatest potential risk to benthic invertebrates can be found near the outfalls. The hazard quotients for benthic invertebrates indicate one line of evidence for potential for risk due to the tDDT and PCBs.

Table 2 presents a comparison of risk screening exceedances for tDDT and tPCBs from the initial and updated food web model, based on the 2002 and 2004 DDT concentrations in sediment, updated fish tissue data, and modeled oral dosage exposures to bird and mammal receptors. Please note that the table does not necessarily refer to changes over time, but rather to several differences between older model results and the current configuration. Differences are due to changed sediment concentrations, changed sediment to fish relationships, and updated fish data, including much higher concentrations of organochlorine compounds in pelagic fish tissue than had been used in the earlier version. Oral dosages were compared to the No Observed Adverse Effect Level (NOAEL) and the Lowest Observed Adverse Effect Level (LOAEL) values from the literature, as summarized in the ERA for secondary oral benchmarks (see Table 4-11 in EPA, 2003). Note that risk estimates for birds and mammals are based on modeled exposures using the updated sediment concentrations throughout the SCB, whereas risks to fish are based on measured fish tissue values from samples collected within the PV Shelf (Table 3). Sanddab tissue data were only available from 1998 and, therefore, remained unchanged as part of the newly updated model. For kelp bass and white croaker, an updated dataset was used, because new fish data have been collected since 2002.

TABLE 2
Comparisons of Risk Screening Exceedances for tDDT and tPCBs from the Initial and Updated Food Web Model

Receptor	Percent of SCB Area Showing Exceedances of DDT Screening Values (NOAEL) Initial/Updated	Percent of SCB Area Showing Exceedances of DDT Screening Values (LOAEL) Initial/Updated	Percent of SCB Area Showing Exceedances of PCB Screening Values (NOAEL) Initial/Updated	Percent of SCB Area Showing Exceedances of PCB Screening Values (LOAEL) Initial/Updated
California Sea Lions (Winter/Spring)	1.6/37	no LOAEL available	0.5/8	0/0
Sea Lion Pups (Winter/Spring)	61/86	no LOAEL available	72/89	0/11
Bald Eagle	100/100	0/100	1/100	0/0
Brown Pelican (Breeding)	100/100	0/100	24/100	0/0
Peregrine Falcon	100/100	16.5/100	21/100	0/0
Double-Crested Cormorant (Breeding)	100/100	28/100	96/100	0/0

As shown in Table 2, the number of screening level exceedances increased for every receptor and chemical that showed exceedances in the initial model results. A review of the results of the food web model indicates that the changes in the fish BSAFs and PV Shelf concentrations of DDT in sediment had little effect on the estimates of risk. However, the increase in pelagic fish concentrations (and associated increased sea lion tissue and bird tissue) significantly increased the frequency of exceedance of screening values for mammal and bird receptors. The greatest changes between the initial and updated model risks were enhanced risks from PCBs for sea lions, pelicans, and eagles, and for DDT for cormorants and falcons.

TABLE 3
Comparisons of Geometric means, 95% UCLs, and Risk Screening Exceedances for tDDT and tPCBs for Measured Fish from the Initial (1990-2001) and Updated Database (2002-2005) for PV Shelf (as fillet concentrations).

Fish/Contaminant	Geometric Mean (mg/kg WW)	95% UCL (mg/kg WW)	Maximum (mg/kg WW)	Percent of Fish Exceeding NOAEL (whole body)	Percent of Fish Exceeding LOAEL (whole body)
White Croaker/DDT	6.83/1.25	13.35/3.82	86.7/15.3	89/70	15/3.1
White Croaker/PCBs	1.09/0.21	1.56/0.415	8.64/1.73	0/0	0/0
Kelp Bass/DDT	0.56/0.144	1.31/0.273	15.2/1.02	15/23	0/0
Kelp Bass/PCBs	0.20/0.071	0.66/0.093	4.14/0.24	0/0	0/0

Direct, general risks to fish did not change significantly but almost all summary measures of concentrations went up as compared to the previous dataset (Table 3). The only evidence for a change in dietary risk (changing from an original 0 or near-0 exceedance) is the newly-estimated modeled risk to adult sea lions, and bald eagles from PCBs (Table 2). The change in modeled dietary risk stems from the updated pelagic fish concentrations of PCBs, rather than a change in sediment concentrations. All other receptor/contaminant combinations were unchanged from showing either some or no evidence of risk. The updated fish concentrations did not show evidence of a significant change in risk as compared to earlier estimates (Table 3).

It is important to note that the conclusions in the ERA are based on a weight of evidence from food web model results combined with measured fish, bird, and mammal tissues, benthic invertebrate community measures, toxicity tests, sediment concentration exceedances, waterborne concentrations of contaminants, and various other direct measures pertaining to ecological risk. As a consequence, the small changes in estimated risk from the updated food web model as compared to the earlier version do not constitute a change in overall risk as determined by the weight of evidence approach. Summary risks from DDT and PCBs remained unchanged from the original ERA (EPA, 2003) and those cumulative lines of evidence indicated risk for all receptors, with the greatest risk from DDT as compared to PCBs. Therefore, an update of the entire ERA is not recommended at this time.

In summary, the revised sediment concentrations, fish concentrations, and food web model results (e.g., Figures 3 and 4 and Tables 2 and 3) indicate the following evidence of risk:

- Benthic invertebrates at the PV Shelf: Measured sediment concentrations exceed DDT and PCB toxicity benchmarks resulting in hazard quotients greater than 1.0 (Figures 3 and 4).
- Fish at the PV Shelf (white croaker, kelp bass, sanddabs): Measured tissue levels exceed toxicity benchmarks for DDT and at a lower level for PCBs.
- Birds (brown pelican, double-crested cormorant, bald eagle, peregrine falcon): Modeled dietary exposure exceed DDT and PCB screening values.
- Mammals (sea lions and their pups): Modeled dietary exposure exceeds DDT and PCB screening values.

The updated food web model provides a new estimate of food web exposure and associated baseline risks from DDT and PCBs to a wide variety of receptors throughout the SCB. As part of future feasibility study activities at the PV Shelf, it may be possible to refine the model further, to focus on a subset of species with high site-fidelity at PV Shelf, and develop remedial action objectives. Using the same basic food web model approach, these fish and/or mammal or bird receptors could be evaluated for effects limited to the PV Shelf study area. It is likely that benthic fish (white croaker, sanddabs) and fish-eating birds (cormorants) would be the best candidates for a future feasibility study (FS) version of the food web model. Whatever receptors are most appropriate, pelagic fish will have to be either eliminated as food items in the FS model or modeled as being responsive to sediment chemistry (as they may be in nature, but are not, in the current version of the food web model). Currently, the relatively elevated pelagic fish tissue concentrations drive the evidence for dietary risk; they are entered into the model as constant values, unlinked to underlying sediment concentrations.

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Figures

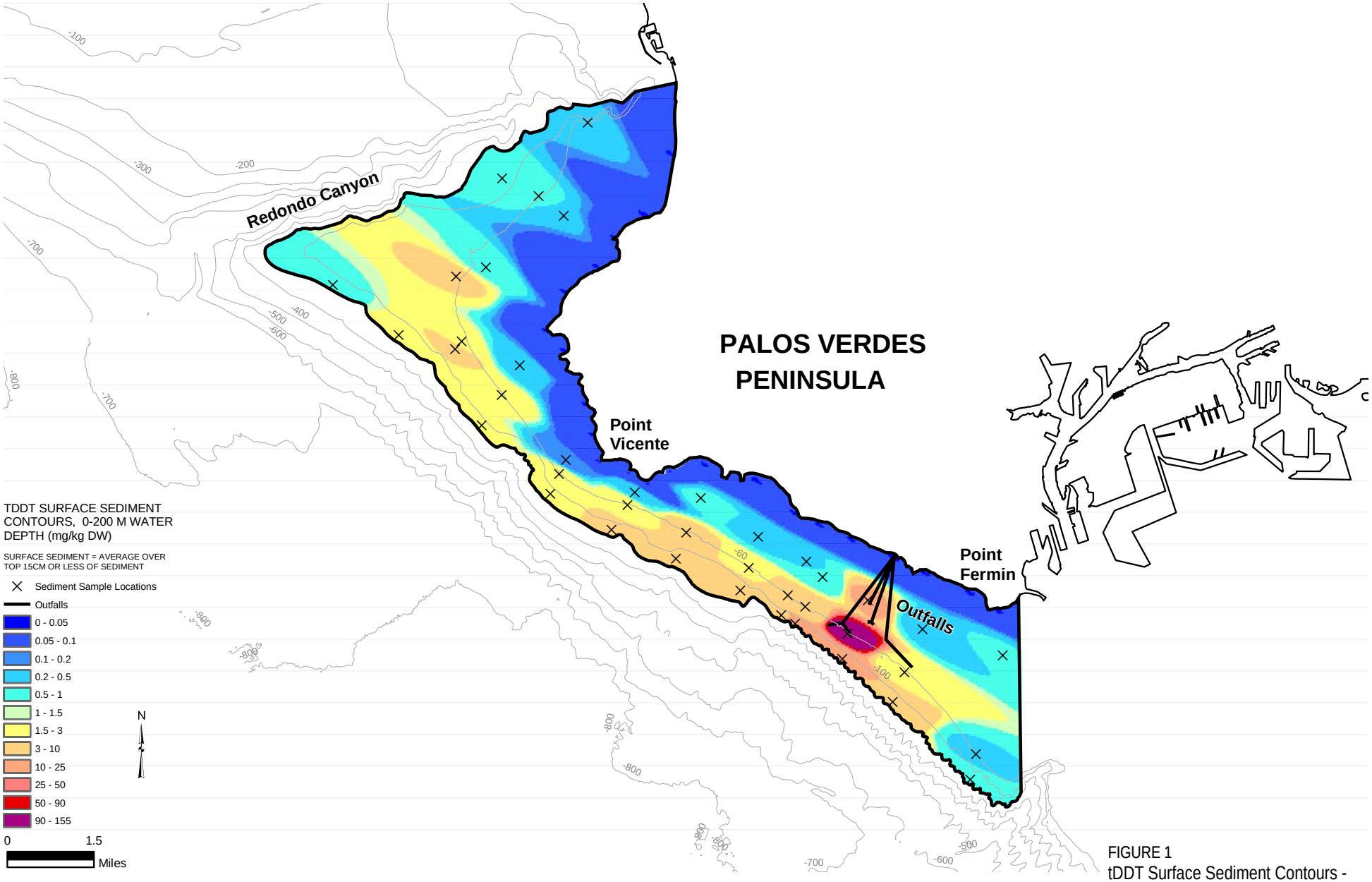

FIGURE 1
tDDT Surface Sediment Contours - 2002/2004 Average
Palos Verdes Shelf
Remedial Investigation Report

Note: In addition to the 2002/2004 LACSD data, this figure uses four Bight '94 samples, one 1993 LACSD sample, and two 1992 NOAA samples to provide actual tDDT concentrations between the 0 and 1 transects and north of the 0 transect. Shoreline concentrations set at 0.05 mg/kg for contouring.

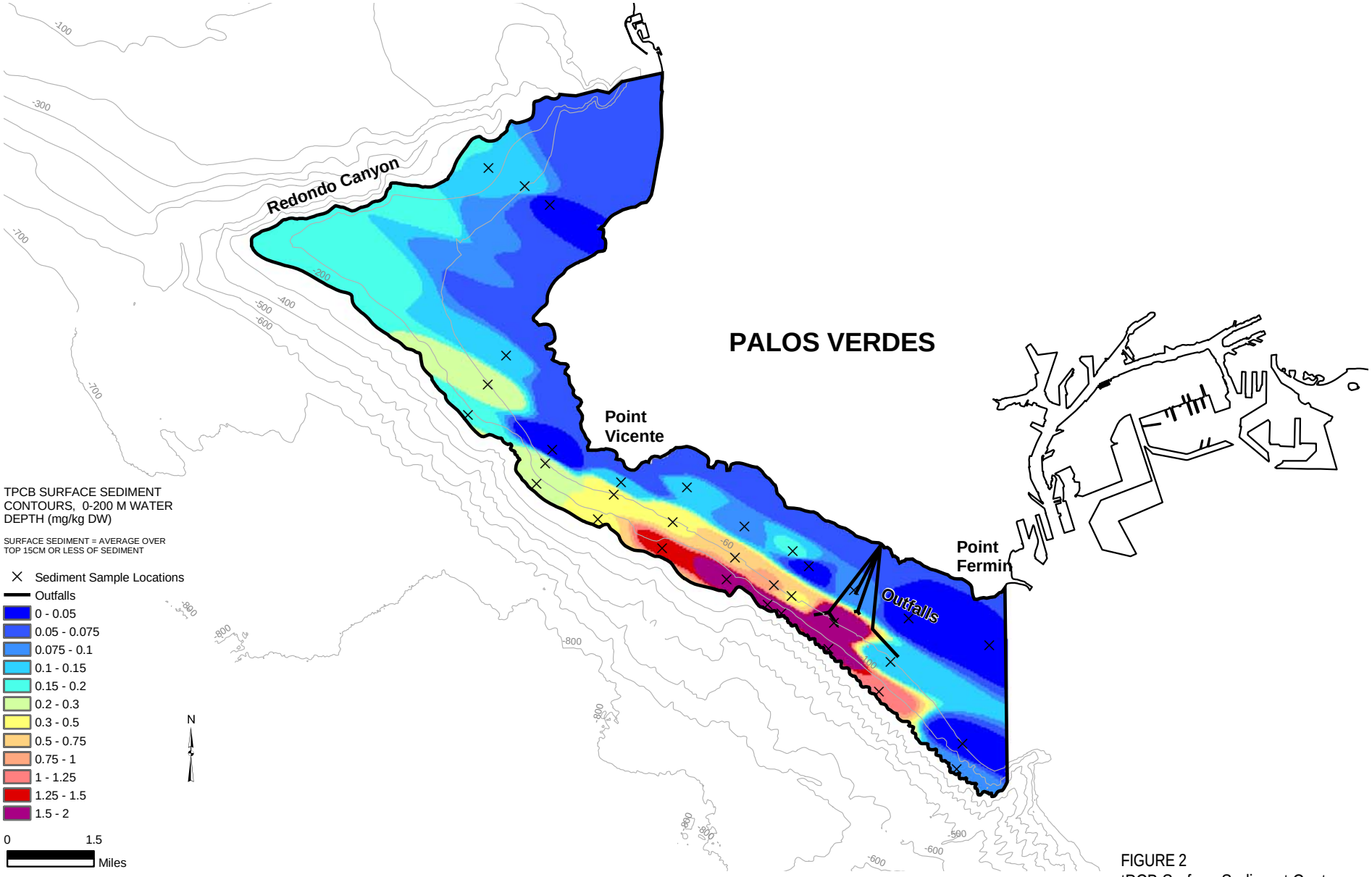

FIGURE 2
tPCB Surface Sediment Contours - 2002/2004 Average
Palos Verdes Shelf
Remedial Investigation Report

Note: In addition to the 2002/2004 LACSD data, two simulated transects were inserted between the 0 and 1 transects to approximate sediment concentrations where no data exist. The simulated transects were set as an average of the 0 and 1 transect concentrations. Shoreline concentrations have been set at 0.05 mg/kg for contouring.

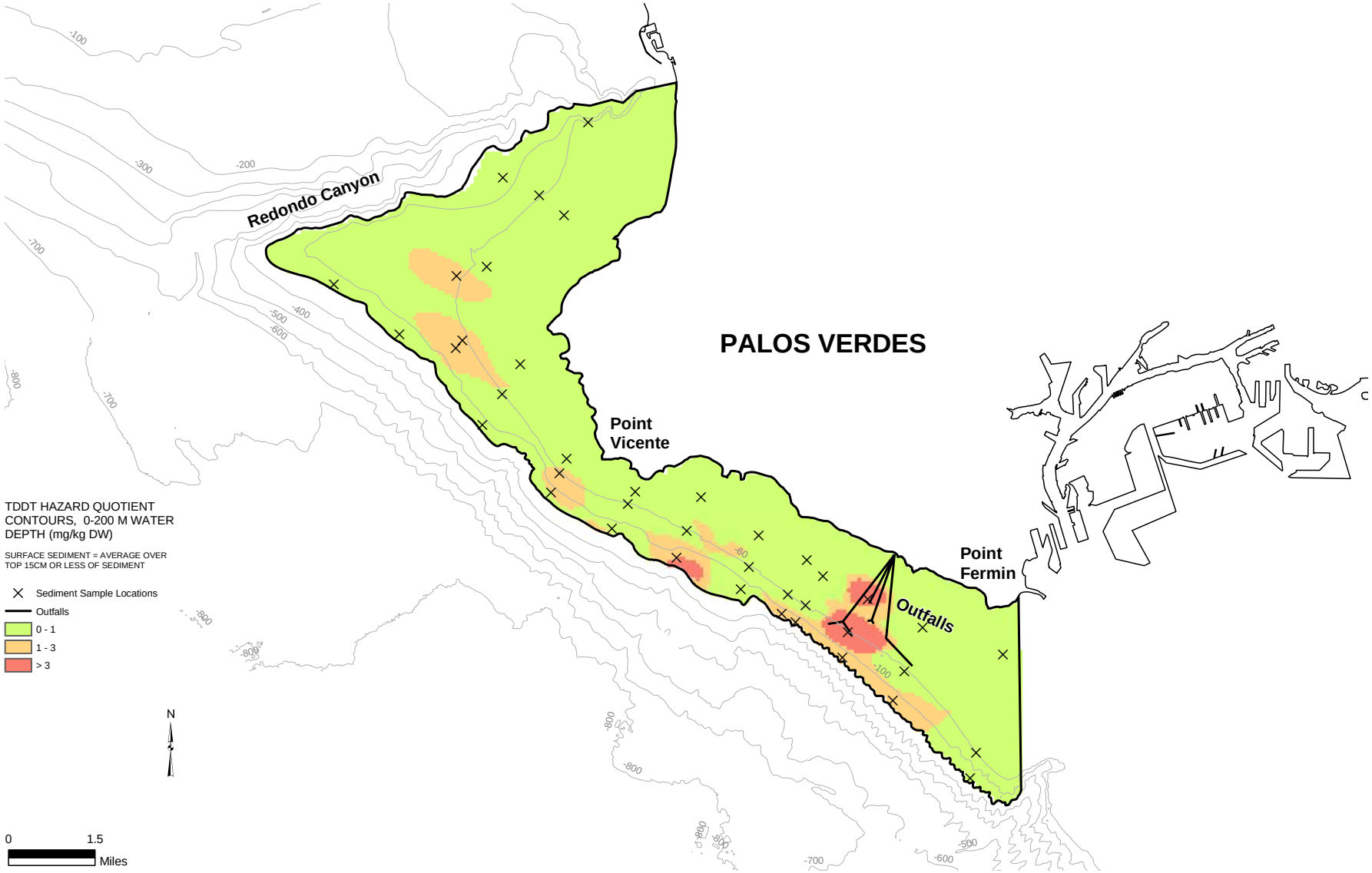

FIGURE 3
tDDT 2002/2004 Bulk Sediment Hazard Quotients
Palos Verdes Shelf Study Area

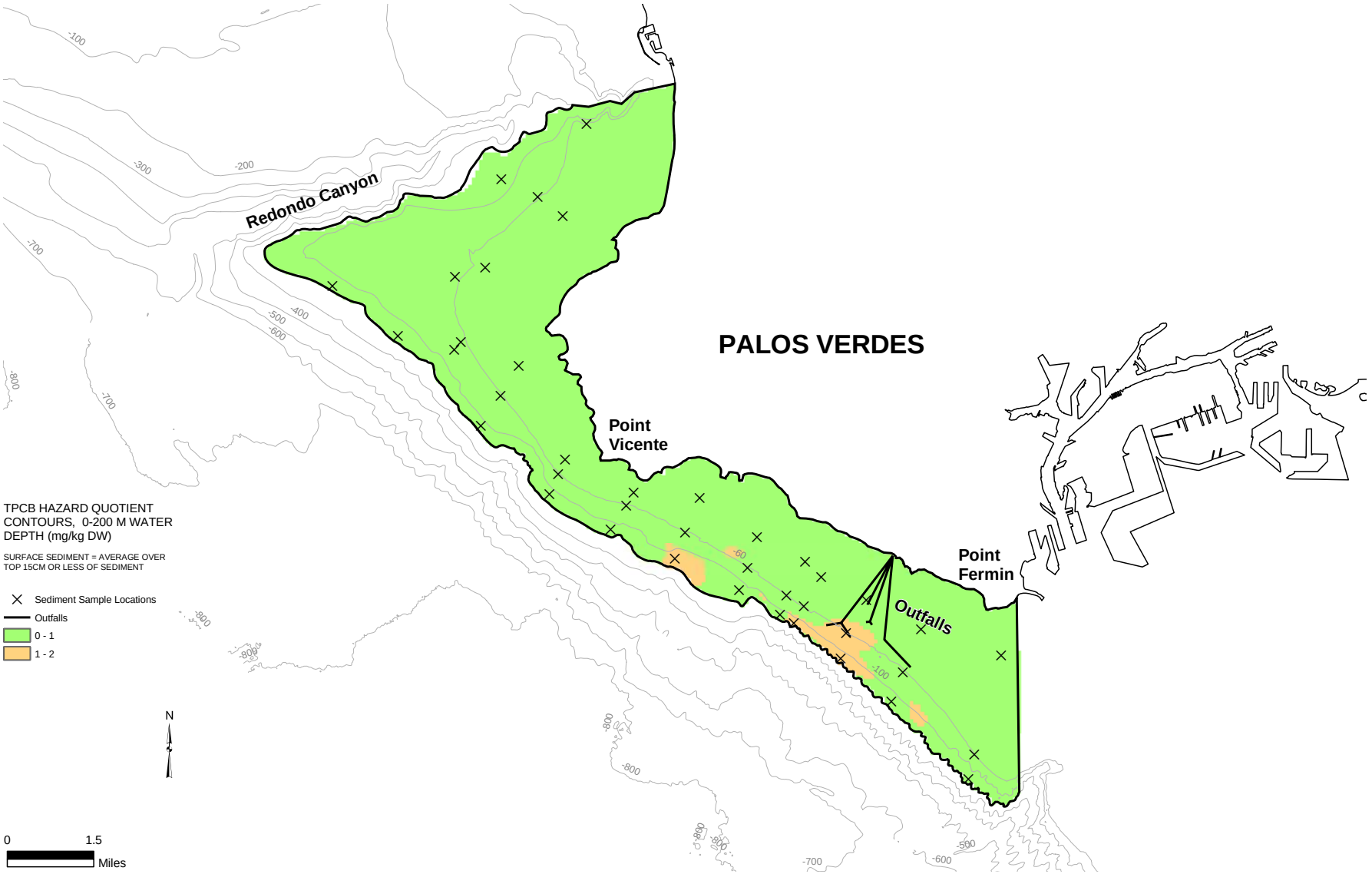

FIGURE 4
tPCB 2002/2004 Bulk Sediment Hazard Quotients
Palos Verdes Shelf Study Area

Attachment 1
Food Web Exposure Model

Attachment 1 – Food Web Exposure Model

1. Introduction and Background

The food web exposure model described in this attachment was constructed to evaluate sediment contamination effects throughout the Southern California Bight (SCB). The model is an integral part of the effects and exposure characterization of the Ecological Risk Assessment (ERA). In particular, the model is designed to characterize exposure to wide-ranging species of birds and marine mammals, for which ecological risk is associated with the contaminant concentrations of the surface sediments. The model does not replace the measured tissue concentrations in the risk assessment but rather, supplies an additional line of evidence in an overall weight of evidence that links sediment contamination to the potential for bioaccumulated contaminants. The purpose of this attachment is to present a full description of the food web model, input parameters, and calculation methods.

2. Rationale

The results of the model may be used for studies involving the prediction of ecological risk. First, an analysis designed to predict the effects of sediment concentrations of DDT and PCBs on the ecological risk to selected receptors has provided input into the Baseline ERA for the Palos Verdes Shelf (PV Shelf) and the SCB. The results of the model yielded estimated whole-body tissue concentrations for various fish species and estimated average dietary concentrations for birds and mammals. The dietary concentrations served as exposure-point concentrations (EPCs) in the exposure and risk characterization sections of the ERA.

Second, an abbreviated, future form of the model may serve as a tool for investigations into the effects of changing sediment concentrations of DDT and PCBs in the PV Shelf and SCB study areas as part of the ongoing RI/FS. Model results are based on knowledge of current, sediment concentrations of DDT and PCBs. The effects of broad-scale degradation, loss, or burial of contaminants over time or as a result of sediment remediation techniques (such as capping) could be estimated using the model. New contaminant concentrations may be assigned to discrete sediment areas, and the resulting changes to PV Shelf and SCB-wide ecological risk could then be predicted as part of new average conditions. It is recognized that water, sediment, and biota tissue chemistry change on very different time scales and no element of change over time is incorporated into the food web model. Instead it is meant to mimic conditions based on the snapshot of current sediment concentration of DDT and PCBs.

3. Methods

The basic concept of the model is to take advantage of the relatively high sample density for surface-sediment concentrations of tDDT and tPCBs in the PV Shelf and SCB continental shelf to create an SCB-wide sediment concentration dataset that can be used to predict bioaccumulated tDDT and tPCBs in fish. The fish serve as primary dietary components for

marine birds and mammals. Average dietary exposure from fish (and squid) is the basis for modeled ecological risk to higher-order consumers (taking into account their exposure area, dietary composition, and consumption rates). Risks will vary by modeled or assigned changes to underlying sediment concentrations. The basic, conceptual model structure is shown in Figure 1. Specific model inputs and outputs are shown in Figure 2.

3.1 Assumptions

The underlying assumption of the model is that SCB-wide sediment and fish tissue quality can be characterized by media-specific concentrations of DDT, PCBs, and total organic carbon (TOC) as analyzed from samples collected from 1990 through 2005 by a variety of agencies and institutions (summarized below). Further, it is assumed that DDT and PCB levels in benthic species of fish (white croaker and sanddab species) and kelp bass are significantly correlated to contaminant concentrations in the co-located sediment. This general relationship has already been shown statistically for PCBs and DDT in sanddabs (Allen et al., 2002) and demonstrated graphically for the other species, including kelp bass (MSRP, 2002). In contrast, it is assumed that such common bird and marine mammal dietary items as pelagic fish species are wide-ranging throughout the SCB and that their tissue concentrations are not tied to underlying sediments.

Whole-body fish tissue concentrations of PCBs and DDT are necessary to predict dietary risk to higher-order consumers. Most of the existing database for DDT and PCBs in SCB fish is derived from human health risk-related sampling and is, therefore, composed of concentration values from fillets. Predictions of tissue concentrations for white croaker and kelp bass were converted from skin-off fillets to whole-body concentrations to facilitate the evaluation of ecological risk. In contrast, whole-body tissue concentration estimates are available for mixed sanddab species (Allen et al., 2002) as well for various pelagic species (EPA and NOAA, 2007).

Risks to marine birds are characterized by exposure estimates for brown pelicans and double-crested cormorants. Risks to raptors are assessed by exposure estimates for bald eagles and peregrine falcons. Risks to marine mammals are characterized by exposure estimates for adult female California sea lions and nursing California sea lion pups. Dietary items are assumed as follows:

- Brown pelicans: fish
- Double-crested cormorants: fish
- Bald eagles: fish, mixed seabirds, and sea lion carcasses
- Peregrine falcons: land birds (resident and migratory) and mixed seabirds
- Adult female California sea lions: fish
- Nursing California sea lion pups: milk

Life histories and dietary information for all receptors and the proportions of prey in surrogate diets are summarized in the Ecological Risk Assessment (EPA, 2003).

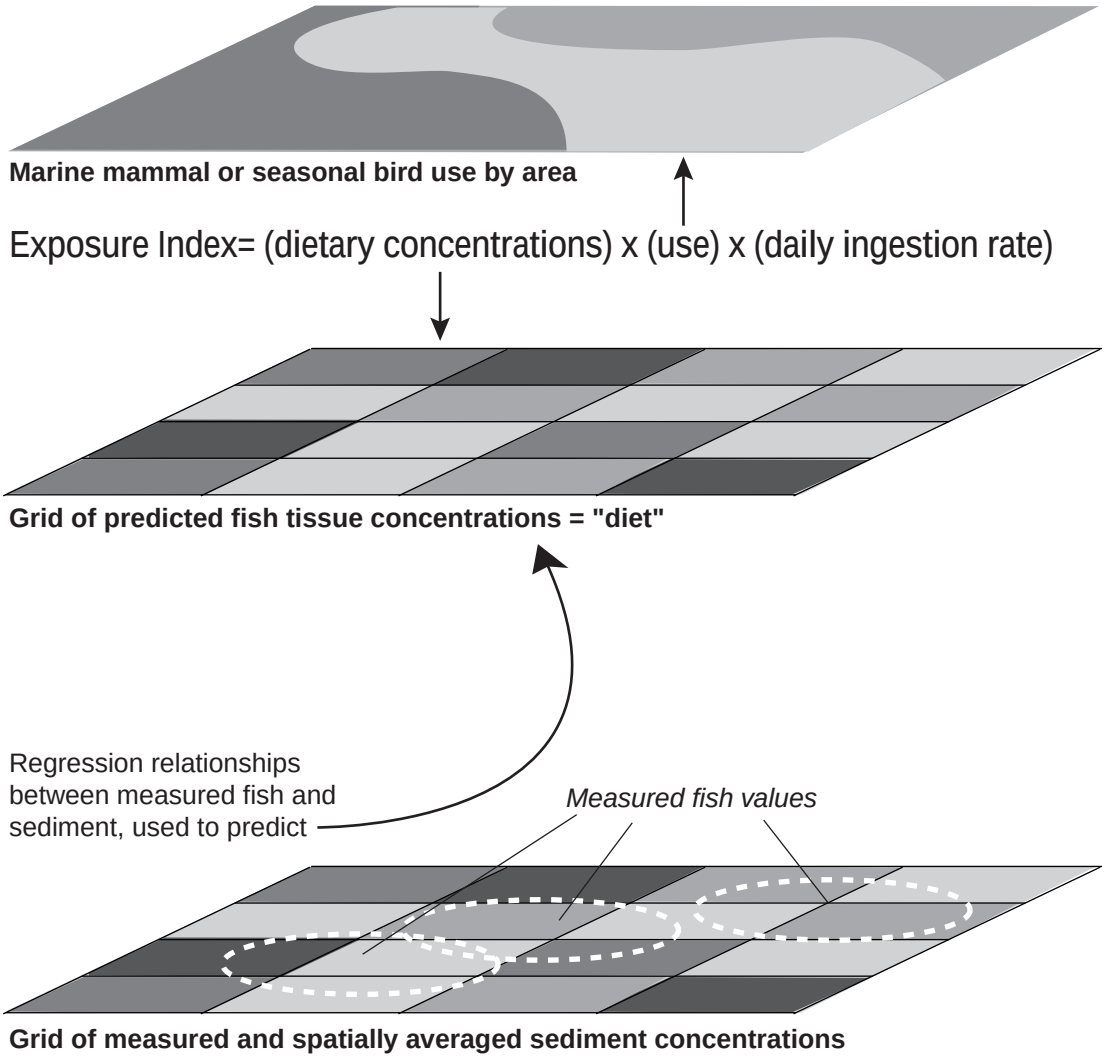

Figure 1
Conceptual Structure Of
Food Web Exposure Model
Palos Verdes Shelf Ecological Risk Assessment

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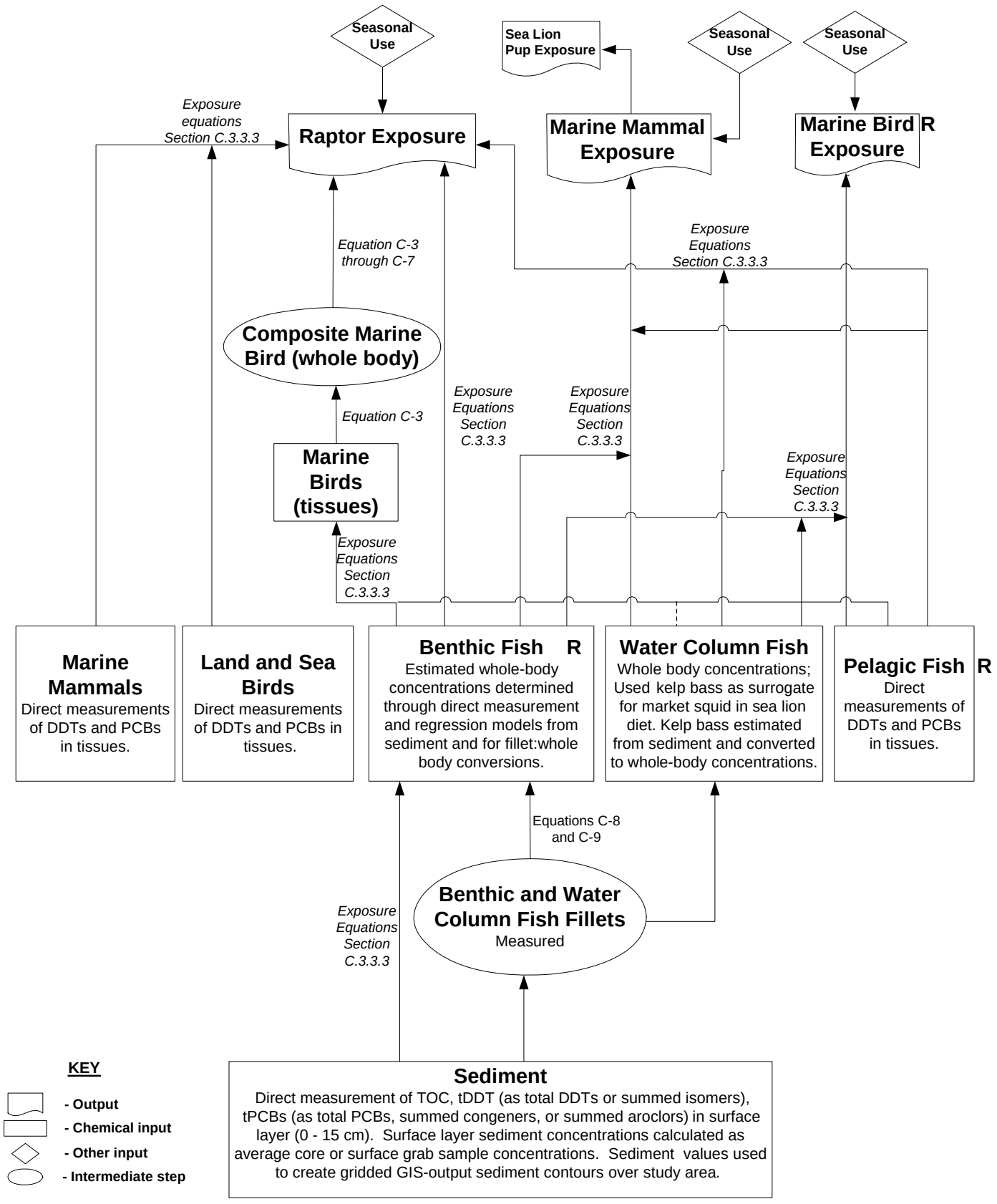

Figure 2
Conceptual Design of Food Web/Pathways Exposure Model
Palos Verdes Shelf Ecological Risk Assessment

R = Subset of model used as RI/FS assessment tool.

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Risks to marine birds and mammals were evaluated through characterization of sediment concentrations of DDT and PCBs in coastal zones of the SCB to a total depth of 200 meters (m). The evaluation area was limited to those locations, as representative of sea lion foraging depths to 200 m (BLM, 1981). The water depth for modeling of brown pelican and double-crested cormorant exposure was limited to 150 m and 22 m, respectively (Zeiner et al., 1990). These depths of water define the areal extent of the coastal zones for foraging for these species (distance out from shore) rather than any assumptions related to the diving depths of the birds (e.g., pelicans are shallow divers).

3.2 Estimating Methods

Exposures for birds and sea lions were estimated as the geographic distribution of the receptor (as percentage of time at a certain location) times the estimated tissue concentration of DDT or PCBs in the prey species in that location times the daily dietary intake. Resulting exposure values were expressed in standard dosage units, as mg of contaminant/kg body weight consumed per day.

The exposure model for peregrine falcons and bald eagles required that whole-body seabird concentrations be estimated from fish. This was accomplished using the western gull as a representative seabird to develop a "composite seabird" that varies relative to western gull tDDT and tPCB concentrations. This provides a more realistic estimate of the tDDT and tPCB concentrations in the bird component of the peregrine and bald eagle diet.

To estimate tDDT and tPCB body burdens in the western gull, the transfer of these contaminants from sediment to fish to western gull (whole-body, mg/kg) was modeled. The sediment-to-fish model components were the same as those developed for the other receptors and are described later in this section. Western gulls were assumed to eat a diet of 100 percent fish with proportions of prey in the surrogate diet of 50 percent pelagic fish, 5 percent white croaker, 10 percent kelp bass, and 25 percent mixed species of sanddabs. To estimate uptake from prey to western gull whole-body tissue, models developed in HydroQual, Inc. (1997) were used as described below.

The body burden of the adult western gull can be described by the following toxicokinetic model (HydroQual, Inc. 1997):

$$\frac{dv}{dt} = \alpha\ C\ u_{prey} - (k + G)\ v \qquad \text{[Equation 1]}$$

Where

$\frac{dv}{dt}$ = change of concentration of tDDT or tPCB over time (mg/kg-d)

α = assimilation efficiency (unitless)

C = consumption rate of the western gull (kg food/kg fresh body weight-day)

u_{prey} = concentration of contaminant in prey (mg/kg)

k = rate of elimination (1/d)

G = growth rate of the western gull (1/d)

v = concentration of tDDT or tPCB in the western gull (mg/kg fresh body weight)

The integral form of the model is:

$$v(t) = \frac{\alpha\ C\ u_{prey}}{k+G}\left[1 - e^{-(k+G)t}\right] \qquad \text{[Equation 2]}$$

Where

$v(t)$ = concentration of tDDT or tPCB in the western gull at time t (mg/kg fresh body weight)

α = assimilation efficiency (unit less)

C = consumption rate of the western gull (kg food/kg fresh body weight-day)

u_{prey} = concentration of contaminant in prey (mg/kg)

k = rate of elimination (1/d)

G = growth rate of western gull (kg fresh body weight/kg fresh body weight-day)

v = concentration of tDDT or tPCB in the western gull (mg/kg fresh body weight)

Equation 2 indicates that as the exposure time increases, the body burden of the western gull will attain equilibrium, and the concentration of tDDT or tPCBs in the western gull would then be:

$$v_{ss} = \frac{\alpha\ C\ u_{prey}}{k+G} \qquad \text{[Equation 3]}$$

Where

v_{ss} = concentration of tDDT or tPCB in the western gull (mg/kg fresh body weight)

α = assimilation efficiency (unit less)

C = consumption rate of the western gull (kg food/kg fresh body weight-day)

u_{prey} = concentration of contaminant in prey (mg/kg)

k = rate of elimination (1/day)

G = growth rate of western gull (kg fresh body weight/kg fresh body weight-day)

v = concentration of tDDT or tPCB in the western gull (mg/kg fresh body weight)

Once it becomes an adult, the incremental change in body weight typically would remain unchanged, other than temporary seasonal variations. The increase in the incremental growth rate would increase the volume and body mass, which would dilute the tissue concentration of contaminants; on the other hand, a decrease in incremental growth rate would decrease the body mass, which in turn would increase the concentration of contaminant in the body (assuming no change in the amount of contaminant in the body). For the purpose of modeling the body burden of contaminants in the adult western gull, the incremental growth rate is assumed to be negligible (i.e., equal to zero).

Parameter values used in the models, including those specific for tDDT and tPCBs, are outlined in Table 1.

TABLE 1
Input Parameters Used for Estimating tDDT and tPCB Concentrations in Western Gulls

Parameter	Value	Unit	Source
α	tDDT = 0.75 tPCB = 1.0	Unit less	HydroQual, Inc. (1997)
C	0.257	kg/kg-day	Table 3-3 (Section 3.1.4.1 of Ecological Risk Assessment)
u_{prey}	Modeled concentrations of the western gull prey (i.e., fish)	mg/kg	Modeled
k	tDDT = 0.00219[a] tPCB = 0.00438	1/day	HydroQual, Inc. (1997)
G	0[b]	1/day	None

[a] Based on the allometric equation presented in HydroQual, Inc. (1997) using an average adult body weight of 875 grams.

[b] The growth rate is assumed to be zero because the incremental growth rate for the western gull is negligible once it reaches adulthood (Pierotti and Annett, 1995).

For determining peregrine falcon exposure, whole-body western gull concentrations were estimated throughout the major foraging areas of the western gull within the SCB (Figure 3). Unlike peregrines which breed at several locations within the SCB, bald eagles currently only breed on Santa Catalina Island (Garcelon, 2000). Therefore, bald eagles are most likely to prey on western gulls breeding and/or resting on Santa Catalina Island. Western gulls generally forage within 80 km of the colony, with distances within 20 km being common (Pierotti and Annett, 1995). Ultimately, the foraging distance depends on availability of reliable food sources and preferences of individual birds. To account for these possible differences, whole-body concentrations of western gulls for use in the bald eagle exposure model were estimated in a 50-km (midpoint between 20 and 80 km) radius of Santa Catalina Island.

A "composite seabird" was constructed that integrates whole-body concentrations of dichlorodiphenyldichloroethylene (DDE) and PCBs from several prey species, normalized to the western gull whole-body concentration. This composite seabird model made it possible to calculate peregrine exposure and partial bald eagle exposure relative to western gull whole-body concentrations as mg/kg wet weight (WW). This is important because future

monitoring efforts of peregrine and bald eagle dietary exposure could focus on collection of western gulls to reflect ingestion of a wide variety of seabirds and other waterbirds.

To estimate dietary exposure for tPCBs and tDDT from avian prey to peregrine falcons and bald eagles, when whole-body concentrations and dietary proportions are known for all prey items, exposure is calculated as:

$$\text{Exposure (mg/kg WW)} = \left(\frac{\sum_{i=1}^{n} (C_i P_i)}{\sum_{i=1}^{n} (P_i)} \right) \qquad \text{[Equation 4]}$$

Where

n = number of prey items (bird species)

C_i = concentration in prey item i (mg/kg WW)

P_i = proportion of diet for prey item i (unit less)

To construct the "composite seabird," the fraction of mean whole-body DDT or PCB concentrations of various prey species, relative to the western gull whole-body concentration, was calculated as $F_i = (S_i/W)$.

Rearranging this equation gives:

$$S_i = (F_i)(W) \qquad \text{[Equation 5]}$$

Where

W = western gull whole-body concentration (mg/kg WW)

S_i = whole-body concentration of species i (mg/kg WW)

F_i = proportion of whole-body concentration of species S_i to the western gull

Rearranging and substituting F_iW in Equation 5 for C_i in Equation 4 yields:

$$C_s = \left(\frac{\sum_{i=1}^{n} (F_i P_i)}{\sum_{i=1}^{n} (P_i)} \right) \qquad \text{[Equation 6]}$$

Where

C_s = whole-body concentration (tDDT or tPCB) in the composite seabird (mg/kg WW).

N

0 35
Miles

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FIGURE 3
MAJOR FORAGING AREAS FOR THE WESTERN GULL

PALOS VERDES SHELF ECOLOGICAL RISK ASSESSMENT

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The following composite seabird equations were developed for peregrines and bald eagles using the seabird and waterbird dietary proportions and contaminant concentrations detailed in HydroQual, Inc. (1997) and presented in Tables 2 and 3. See HydroQual, Inc. (1997) for methods and assumptions associated with mean 4,4'-DDE and PCB concentrations in seabirds and waterbirds:

$$tDDT\ C_{s\ (peregrine\ falcon)} = 0.563*(W) \quad \text{[Equation 7]}$$

$$tPCB\ C_{s\ (peregrine\ falcon)} = 0.486*(W) \quad \text{[Equation 8]}$$

$$tDDT\ C_{s\ (bald\ eagle)} = 0.458*(W) \quad \text{[Equation 9]}$$

$$tPCB\ C_{s\ (bald\ eagle)} = 0.477*(W) \quad \text{[Equation 10]}$$

These equations are considered to be accurate, if the same prey species are used as those used to develop the constants in Equations 7 through 10. If other prey species are used, it is likely the exposure model will be neither accurate nor precise.

TABLE 2
Dietary Proportions and Whole-Body 4,4'-DDE and PCB Concentrations in Seabird and Other Waterbird Prey of Peregrine Falcons

Prey	Proportion of Diet (energy basis)	Contaminant Levels (mg/kg wet weight)	
		4,4'-DDE	PCB
Western gull	0.096	4.0	0.90
California gull	0.094	2.9	0.90
Heermann's gull	0.022	2.9	0.90
Bonaparte's gull	0.022	2.9	0.90
Cassin's auklet	0.18	2.2	0.42
Other waterbirds[a]	0.26	1.2	0.39

Source: Reproduced from Table 5-3 in HydroQual, Inc. (1997).
[a] Species include grebes, shearwaters, waterfowl, shorebirds, and phalaropes.

TABLE 3
Dietary Proportions and Whole-Body 4,4'-DDE and PCB Concentrations in Seabird and Other Waterbird Prey of Bald Eagles

Prey	Proportion of Diet (energy basis)	Contaminant Levels (mg/kg wet weight)	
		4,4'-DDE	PCB
Western gull	0.033	8.3	2.3
Other gulls[a]	0.013	5.4	1.3
Other waterbirds[b]	0.085	1.7	0.6

Source: Reproduced from Table 5-7 in HydroQual, Inc. (1997).
[a] Heermann's and California gulls.
[b] Species include western grebes, sooty shearwaters, Brandt's cormorant, Cassin's auklet, and Xantus' murrelet.

Once the whole body concentration of tDDT or tPCBs in the "composite seabird" is obtained, exposure to the peregrine falcon or bald eagle from the seabird prey source is estimated by calculating the dose from the concentration of tDDT or tPCBs in the "composite seabird" and the ingestion rate of the peregrine or bald eagle.

Seabirds make up 68 percent of the peregrine diet and migratory (13 percent) and land (19 percent) birds make up the remaining 32 percent. The full distribution of modeled seabird concentrations is included in the peregrine exposure model and the other birds are represented as constants. Therefore, peregrine exposure is depicted across the foraging range of the western gull.

For the bald eagle, seabirds make up only 13 percent of the diet, with fish (81 percent) and marine mammals (6 percent) making up the remaining portion of the diet.

Bald eagles forage within 5 km of their nesting site (Garcelon, 1994a and 1994b) and therefore, feed on fish in this localized area surrounding Santa Catalina Island. In contrast, the eagle seabird and sea lion prey forage over large areas, which exposes bald eagles to contaminants from areas across the foraging range of the prey species. As described, seabird body burdens were estimated for a 50-km radius around Santa Catalina Island. For sea lions, it was assumed that bald eagles were most likely to prey on sea lion carcasses from animals using the island as a resting/loafing area. Therefore, body burdens in sea lions (methods described below) were estimated within a 54-km radius of Santa Catalina Island based on the foraging distance of female sea lions during the breeding season. This is a conservative estimate because adult and juvenile males are generally observed on and near the island (Le Boeuf, 2002) and males likely forage across further distances (particularly in winter) than breeding females. Because the individual species in the three components of the bald eagle diet represent three different foraging areas, the 95 percent upper confidence limit (UCL) of the geometric mean was calculated from the body burden distributions modeled for seabirds and sea lions and was used in the bald eagle exposure model as a constant. The fish component was modeled over the 5 km foraging area of the bald eagle.

Sea lion diets are assumed to be composed of 50 percent mixed pelagic species, 20 percent kelp bass, 5 percent white croaker, and 25 percent mixed species of sanddabs.

To estimate the effect of food chain transfer of tDDT and tPCBs, a mass-balance model was used to propagate the concentration of tDDT and tPCBs from fish to the adult female sea lion, which ultimately exposes sea lion pups to tDDT and tPCBs through milk. For exposure to the bald eagle, a mass-balance model was used to estimate adult male body burdens of tDDT and tPCBs from the fish diet. The body burden of the adult female and male sea lion can be described by the following toxicokinetic model (HydroQual, Inc. 1997):

$$\frac{dv}{dt} = \alpha \; C \; u_{prey} - (k + G) \; v \qquad \text{[Equation 11]}$$

Where

$\frac{dv}{dt}$ = change of concentration of tDDT or tPCB over time (mg/kg-d)

α = assimilation efficiency (unit less)

C = consumption rate of the adult sea lion (kg food/kg fresh body weight-day)

u_{prey} = concentration of contaminant in prey (mg/kg)

k = rate of elimination (1/d)

G = growth rate of the sea lion (1/d)

v = concentration of tDDT or tPCB in the sea lion (mg/kg fresh body weight)

The integral form of the model is:

$$v(t) = \frac{\alpha\ C\ u_{prey}}{k + G}\left[1 - e^{-(k+G)t}\right] \qquad \text{[Equation 12]}$$

Where

$v(t)$ = concentration of tDDT or tPCB in the sea lion at time t (mg/kg fresh body weight)

α = assimilation efficiency (unit less)

C = consumption rate of the adult sea lion (kg food/kg fresh body weight-day)

u_{prey} = concentration of contaminant in prey (mg/kg)

k = rate of elimination (1/d)

G = growth rate of the sea lion (kg fresh body weight/kg fresh body weight-day)

v = concentration of tDDT or tPCB in the sea lion (mg/kg fresh body weight)

Equation 12 indicates that as the exposure time increases, the body burden of the sea lion will reach equilibrium, and the concentration of tDDT in the adult female sea lion would then be:

$$v_{ss} = \frac{\alpha\ C\ u_{prey}}{k + G} \qquad \text{[Equation 13]}$$

Where

v_{ss} = concentration of tDDT or tPCB in the sea lion at (mg/kg fresh body weight)

α = assimilation efficiency (unit less)

C = consumption rate of the adult sea lion (kg food/kg fresh body weight-day)

u_{prey} = concentration of contaminant in prey (mg/kg)

k = rate of elimination (1/day)

G = growth rate of the sea lion (kg fresh body weight/kg fresh body weight-day)

v = concentration of tDDT or tPCB in the sea lion (mg/kg fresh body weight)

Once a sea lion becomes an adult, the incremental change in body weight typically would remain unchanged (HydroQual, Inc., 1997), other than temporarily seasonal variations. An increase in incremental growth rate would increase the volume and body mass, which would dilute the tissue concentration of contaminants; on the other hand, a decrease in incremental growth rate would decrease the body mass, which in turn would increase the concentration of contaminant in the body (assuming no change in the amount of contaminant in the body). For the purpose of modeling the body burden of contaminants in the adult sea lion, the incremental growth rate is assumed to be negligible (i.e., equal to zero).

The final result of Equation 13 is a wet weight body concentration of tDDT or tPCBs for adult male or female sea lions (depending on excretion rate used). The modeled adult male whole-body concentrations (WB) were used in the bald eagle exposure model as described above. Once the whole-body concentration of tDDT or tPCBs in the adult female sea lion is obtained, the concentration of tDDT or tPCBs in the milk of lactating female sea lions can be estimated using the relationship presented in HydroQual, Inc. (1997):

$$v_{milk} = \left[\frac{1 + K_{MLA} x_{L_m}}{1 + K_{LA} x_L} \right] v_{ss} \qquad \text{[Equation 14]}$$

Where

v_{milk} = concentration of tDDT or tPCB in female sea lion's milk (mg/kg)

K_{MLA} = the equilibrium partition coefficient between the milk lipids and the whole body non-lipid fraction (unit less)

X_{LM} = the lipid fraction of the milk

K_{LA} = the equilibrium partition coefficient of tDDT or tPCB between the lipid and the aqueous phase of the sea lion (unit less)

X_L = the lipid fraction of the sea lion

v_{ss} = concentration of tDDT or tPCB in the sea lion (mg/kg fresh body weight)

Finally, exposure of tDDT or tPCBs to sea lion pups is estimated by calculating the dose from the concentration of tDDT or tPCBs in milk and the milk ingestion rate of the pup. A weighted average of the milk ingestion rate over the first 7 months of the sea lion pup's life was derived from published data on sea lion pup body weights and milk intake rates for months 1, 2, 3, and 7 postpartum (Table 4). Body weights and milk intake rates for months 4, 5, and 7 postpartum were interpolated from the available data. From these, milk ingestion rates were calculated as grams of milk ingested per gram of body weight per day. The average milk ingestion rate for male and female pups over the 7-month period (0.0488 kg/kg BW/d) was used in the model.

TABLE 4
Average Milk Intake Rate by Sea Lion Pups [a]

Month Postpartum	Body Weight (kg)		Milk Intake Rate (g/d)		Normalized Milk Intake Rate[b] (g/g-d)	
	Male	Female	Male	Female	Male	female
1st	8.79	7.76	773 [c, d]	631 [c, d]	0.088	0.081
2nd	10.32	9.12	681 [c, d]	600 [c, d]	0.066	0.066
3rd	22.7	15	768 [e]	772 [e]	0.034	0.051
4th	22 [f]	18 [f]	845 [g]	801 [g]	0.0388	0.0456
5th	26 [f]	21 [f]	891 [g]	868 [g]	0.0344	0.0412
6th	30 [f]	25 [f]	938 [g]	935 [g]	0.0313	0.0381
7th [h]	33	28	1000 [i]	1000 [i]	0.0303	0.0357
Average	21.8	17.6	845	801	0.0462	0.0513
Average of male and female pups					0.0488	

[a] Source: Oftedal et al. (1987); values taken from this reference are those reported for 1982; 1984 values were not included because those were collected during an El Niño year.
[b] Calculated by dividing the milk intake rate by the body weight
[c] Values reported in Oftedal et al. (1987); developed using age-specific data for the sea lion pups one month and two month postpartum
[d] No statistically significant difference was found between the age groups (Oftedal et al., 1987)
[e] Estimated using the equation presented in Oftedal et al. (1987)
[f] Estimated by linear extrapolation using the body weight data from the first, second, third, and the seventh month postpartum for males and females, respectively
[g] Estimated by linear extrapolation using the milk ingestion data from the first, second, third, and the seventh month postpartum for males and females, respectively
[h] Pups older than the first 200 days may begin to ingest solid food (Boness et al., 1991); thus, milk ingestion rate is not estimated beyond the seventh month postpartum
[i] Value reported in HydroQual, Inc. (1997)

Parameter values used in the exposure models, including those specific for tDDT and tPCBs and those specific for adult males and females, are presented in Table 5.

TABLE 5
Input Parameters Used for Estimating tDDT and tPCB Concentrations in Sea Lion Pups

Parameter	Value	Unit	Source
α	tDDT = 0.75	unit less	HydroQual, Inc. (1997)
	tPCB = 1.0		
C	0.116	kg/kg-day	Table 3-3 (Section 3.1.4.1 of Ecological Risk Assessment)
u_{prey}	Modeled concentrations of the sea lion prey (i.e., fish)	mg/kg	Modeled in the current Ecological Risk Assessment
k	0.00045 for males	1/day	HydroQual, Inc. (1997)
	0.01 for lactating females		
G	0[a]	1/day	None
K_{MLA}	DDT = $1x10^6$	unit less	HydroQual, Inc. (1997)
	PCBs = $1x10^7$		

TABLE 5
Input Parameters Used for Estimating tDDT and tPCB Concentrations in Sea Lion Pups

Parameter	Value	Unit	Source
X_{LM}	0.4057[b]	unit less	
K_{LA}	DDT = $1x10^6$	unit less	HydroQual, Inc. (1997)
	PCBs = $1x10^7$		
X_L	0.30	unit less	HydroQual, Inc. (1997)

[a] Growth is assumed to be zero because the growth curve presented in HydroQual, Inc. (1997) for lactating female adult sea lions indicates that the incremental growth of adult sea lions is negligible.

[b] Based on the weighted average lipid fraction of sea lion milk over the first 7 months postpartum (32 percent for months one and two and 44 percent for months three through seven; HydroQual, Inc., 1997).

The brown pelican, double-crested cormorant, and sea lion diets are composed wholly of fish, as are portions of the bald eagle diet. Additionally, seabird and marine mammal prey of bald eagles and seabird prey of peregrines have diets composed wholly of fish. Therefore, measured fish and sediment data were used to develop site-specific bioaccumulation models describing sediment-to-fish transfer of tDDT and tPCBs.

Chemical concentration data used as the basis for the model consist of spatially distributed sediment and fish tissue values as summarized from 1990 to 2006. Data sources are listed in Table 6. Surface sediment data (grab samples or 0-15 cm core sections) were plotted by location and spatially averaged for concentration in the coastal areas within the SCB bounded by dry land and the 200-m depth bathymetric contour. GIS-based techniques for spatial averaging (kriging) are discussed in the GIS section below. Summaries of sediment sample values, post-kriging, from the PV Shelf Study Area are shown in Table 7.

It was necessary to establish predictive relationships between sediment and benthic fish tissue concentrations to create the model. Pelagic fish are wide-ranging and assumed not to be significantly linked to underlying sediment concentrations of DDT and PCBs. Because the home ranges of the benthic species was unknown (Allen, 2002), several possible exposure areas were assigned to each fish sampling location in the original ERA (EPA, 2003). Spatially averaged sediment concentrations corresponding to the areas under several exposure areas (centered on the fish sample location) were compared to the associated fish concentrations using simple linear regressions with log-transformed data. For the 2006 update of the earlier model, a uniform exposure area of 1-km radius around the sampling point was assumed to represent the best area for sediment averaging. In every case, a 1-km-radius average produced a better regression relationship to fish tissue concentrations than the simple point concentration of sediment at the point of fish capture. All species tested showed significant, positive linear regressions between 1-km-radius averaged sediment concentrations of tPCBs or tDDT and corresponding fish tissue. All regression relationships were established using log-transformed values to improve normality. In the case of sanddabs, the best relationships required sediment normalization to TOC. However, no regressions were improved by fish tissue concentrations normalized to lipid content. The regression equations used to predict fish tissue concentrations from the concentrations in underlying sediments are shown in Table 8. All predicted values were back-transformed from log values to yield geometric mean fillet concentrations for given sediment values.

Sanddabs were evaluated from point source sediment samples as was presented in Bight 98 reports (Allen et al., 2002). Sanddab guild values consist of cumulative results based on longfin sanddab, Pacific sanddab, speckled sanddab, California halibut, and slender sole (Allen et al., 2002).

Pelagic fish and market squid were assumed to be uniformly constant throughout the SCB. Pelagic species tissue concentrations were computed as the geometric mean value for combined whole-body concentrations in mackerel and Pacific sardines from the SCB (EPA/MSRP, 2002/2004). SCB-wide average values of 0.253 mg/kg WB for tDDT and 0.121 mg/kg WB for tPCBs were used for pelagic fish and squid. The whole body concentration for mackerel was estimated from fillet concentrations based on the whole-body from fillet conversion developed for white croaker, as shown below.

The California sea lion has a varied diet, of which 10 percent consists of market squid. To assess dietary exposure to the California sea lion, it was necessary to have measured or estimated contaminant levels in its various diet items. Recent body burden data were not available for market squid in the SCB. The most recent data, from 1981, consisted of only three samples (Mearns et al., 1991; Table 9). Because of these extremely limited data, pelagic fish were used as a surrogate for the market squid portion of the sea lion diet.

TABLE 6
Site-Specific Sediment and Fish Data Sources

Source	No. Sediment Samples				No. Fish Tissue Samples			
	Year(s)	tDDT	tPCBs	Total	Year(s)	tDDT	tPCBs	Total
Anderson et al., 1998	1992; 1996-97	24 [a]	24 [b]	48	1992; 1997	4 [a]	4 [d]	8
Connolly and Glaser, 1994	--	--	--	--	1990-91	105 [a]	104 [c]	209
Costa et al., 1994	--	--	--	--	1994	131 [d]	131 [d]	262
Fredette et al., 2002	2000	2[a]	2[c]	4	--	--	--	--
Hansen and Associates, 2000	--	--	--	--	1999	104 [d]	104 [d]	208
LACSD, 2002-2005	2002-2004	88 [e]	88	176	2004-2005	30[d]	50 [d]	80
Lee, 1994	1992	40 [a]	40 [b]	80	--	--	--	--
NOAA, 1994	1990-91	20 [a]	20 [b]	40	--	--	--	--
NOAA, unpubl.	1992	45 [a]	44 [b]	89	--	--	--	--
Noblet et al., 2002	1998	132 [a]	75 [b]	207	1998	198 [a]	114 [d]	312
OEHHA, 2001	--	--	--	--	1999-2000	36 [a]	36 [c]	72
SAIC, 2002	2002	2[e]	--	2	--	--	--	--
SCCWRP, 1999-2000	1997	25 [a]	25 [b]	50	--	--	--	--
Schiff and Gossett, 1997 (Bight 94)	1994-95	167 [a]	--	167	--	--	--	--
SMBRP, 1992	--	--	--	--	1990	59 [a]	60 [c]	119

TABLE 6
Site-Specific Sediment and Fish Data Sources

Source	No. Sediment Samples				No. Fish Tissue Samples			
	Year(s)	tDDT	tPCBs	Total	Year(s)	tDDT	tPCBs	Total
USACE, 2000	2000	6[d]	--	6	--	--	--	--
EPA and NOAA, 2007	--				2003	32	32	64
Total	**1990-2003**	**551**	**318**	**869**	**1990-2005**	**699**	**635**	**1334**

[a] Reported as the sum of DDE, DDD, and DDT isomers
[b] Reported as the sum of PCB congeners
[c] Reported as the sum of Aroclors
[d] Reported as total
[e] Reported as 4,4'-DDE

TABLE 7
Sediment Summary Statistics from Gridded GIS Output for the PV Shelf Study Area (less than 200 m in water depth)

Sediment Layer	Analyte	Geometric Mean (mg/kg DW)	Standard Deviation	Minimum	Median	Maximum
0-15 cm	tDDT	0.585	12	0.05	0.653	141
0-15 cm	tPCB	0.116	0.471	0.0307	0.0917	3.14

Note:
Mean and standard deviation are calculated from ln-transformed data.

TABLE 8
Linear Regression Relationships for Predicting Dietary Concentrations: Fish Fillet Concentrations as Predicted from Surface Sediment Concentrations (as developed from SCB-wide fish and sediment concentrations).
Palos Verdes Shelf Ecological Risk Assessment

Analyte	Fish Species	Regression Equation[a, b]	r^2; n
DDT	White croaker	logDDT(F) = 2.636 + 0.412(logSedDDT)	0.387; 178
DDT	Kelp bass	logDDT(F) = 2.201 + 0.306(logSedDDT)	0.168; 62
DDT	Sanddab guild	logDDT(WB) = 3.416+1.02(log(SedDDT/TOC))	0.641; 76[c]
PCBs	White croaker	logPCB(F) = 2.4 + 0.268(logSedPCB)	0.231; 177
PCBs	Kelp bass	logPCB(F) = 2.148 + 0.316* (logSedPCB)	0.137; 62
PCBs	Sanddab guild	logPCB(WB) = 2.905 + 0.706* (log(SedPCB/TOC))	0.505; 34

[a] All regressions are statistically significant, $P < 0.05$. Log transformations are all log10.
[b] F = fillet concentrations, mg/kg, wet-weight basis; WB = whole body concentrations, mg/kg, wet-weight basis; Sed = sediment concentrations, mg/kg, dry-weight basis; TOC = total organic carbon concentrations as percent dry weight.
[c] No exposure area estimated for sanddab guild species or pelagic fish. The point estimate equations used for sanddabs were used as presented in the Bight '98 report (SCCWRP, 2000).

These fish were selected as surrogate species because both the market squid and pelagic fish are water column feeders. Additionally, their diets are similar. Both species feed on crustaceans, such as the pelagic red crab, and on small fishes like anchovies, sardines, surfperch, and queenfish. Pelagic fish and market squid are both water column feeders that forage over wide ranges, though market squid are short-lived and concentrated along the continental shelf (PFMC, 1998).

TABLE 9
Tissue Sample Data from the SCB
Palos Verdes Shelf Ecological Risk Assessment

Species	Analyte	Year	Number of Samples	Mean Tissue Concentration (mg/kg WW)	Range
Market Squid	DDT	1980-1981	3	0.01	0.006 – 0.031
	PCB	1980-1981	3	0.01	0.003 – 0.24

Source: Mearns et al. (1991)

Four of the regression predictions for fish from sediment were based on databases of fillet concentrations. Whole-body to fillet contaminant concentration relationships were established based on skin-off fillet and remainder samples of kelp bass and white croaker collected in 2003 (EPA/MSRP, 2002/2004).

The equations for converting fillet to whole-body concentrations are as follows:

White croaker; DDT (WB) = 10^((Log (F)*1.137 + 0.583)), $r^2 = 0.79$, n = 14 [Equation 15]

White croaker; PCB (WB) = 10^((Log (F)*0.671 + 1.438)), $r^2 = 0.53$, n = 14 [Equation 16]

Kelp bass; DDT (WB) = 10^((Log (F)*0.816 + 1.411)), $r^2 = 0.83$, n = 12 [Equation 17]

Kelp bass; PCB (WB) =10^((Log (F)*0.676 + 1.436)), $r^2 = 0.66$, n = 12 [Equation 18]

Where

F = fillet (mg/kg WW)

WB = whole-body tissue contaminant concentrations (mg/kg WW)

The whole body reconstructions (WB) used in these relationships were based on multiplying the concentrations times the weight of each body part (i.e., viscera, fillet, remainders, etc.), adding the products, and dividing by the sum of the weights (total fish weight). The resulting value was the "whole body" (WB) concentration that was compared to the skin-off fillet (F) concentration from the same fish.

The foraging ranges of marine birds and mammals were established through a search of recent literature and conversations with local SCB-area researchers. Differing distributions based on season or breeding condition of the birds or mammals were incorporated wherever possible. The ranges used to overlap with predicted food quality (as predicted from sediment concentrations of DDT and PCBs) are shown in Figures 3, 4, and 5.

Modeling the Spatial Distribution of Bird and Mammal Exposure

GIS macros and layers were developed to model the spatial distribution of tDDT and tPCB exposure for birds and mammals using ESRI's GRID module and grid mathematics.

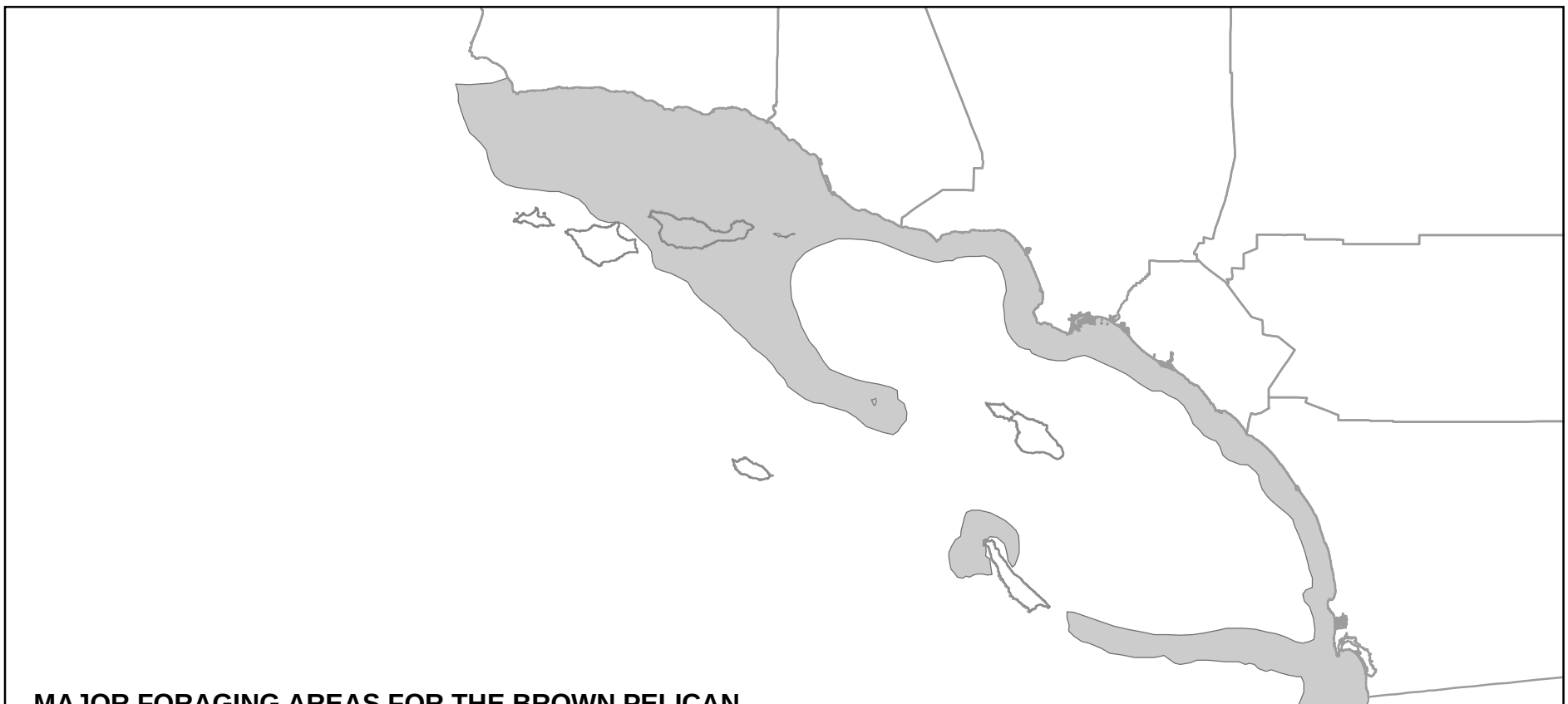
Information on percentage use areas for sea lions were used at three periods throughout the year: December through May, June through August, and September through November (Figure 5). For birds, pelican, cormorant, western gull, and bald eagle foraging areas were developed (Figures 3 and 4). Breeding areas for pelicans and cormorants were also developed.

Using the sediment concentration/fish concentration modeling results, a spatial distribution of DDT and PCB fish concentrations was developed based on the GIS layers in the sediment for three fish species. The following six equations assume that the sediment TOC layer is as a percentage (e.g., 1% TOC expressed as 1.0), sediment DDT and PCB layers are as parts per million (ppm) (mg/kg DW) and the resultant fish values are as whole body concentrations in parts per billion (ppb) (µg/kg [micrograms per kilograms] WW).

- White Croaker DDT Concentration = 10^(((2.636 + 0.412 * Log10(Sediment DDT Layer)))*1.137 + 0.583)
- White Croaker PCB Concentration = 10^(((2.4 + 0.268 * Log10(Sediment PCB Layer)))*0.671 + 1.438)
- Kelp Bass DDT Concentration = 10^(((2.201 + 0.306 * log10(Sediment DDT Layer)))*0.816 + 1.411)
- Kelp Bass PCB Concentration = 10^(((2.148 + 0.316* log10(Sediment PCB Layer)))*0.676 + 1.436)
- Sanddab DDT Concentration = 10^(3.416 + 1.02 * log10(Sediment DDT Layer/ Sediment TOC Layer))
- Sanddab PCB Concentration = 10^(2.905 + 0.706 * log10(Sediment PCB Layer / Sediment TOC Layer))

For birds and mammals, diet GIS layers were produced based on the percentage of each fish species consumed:

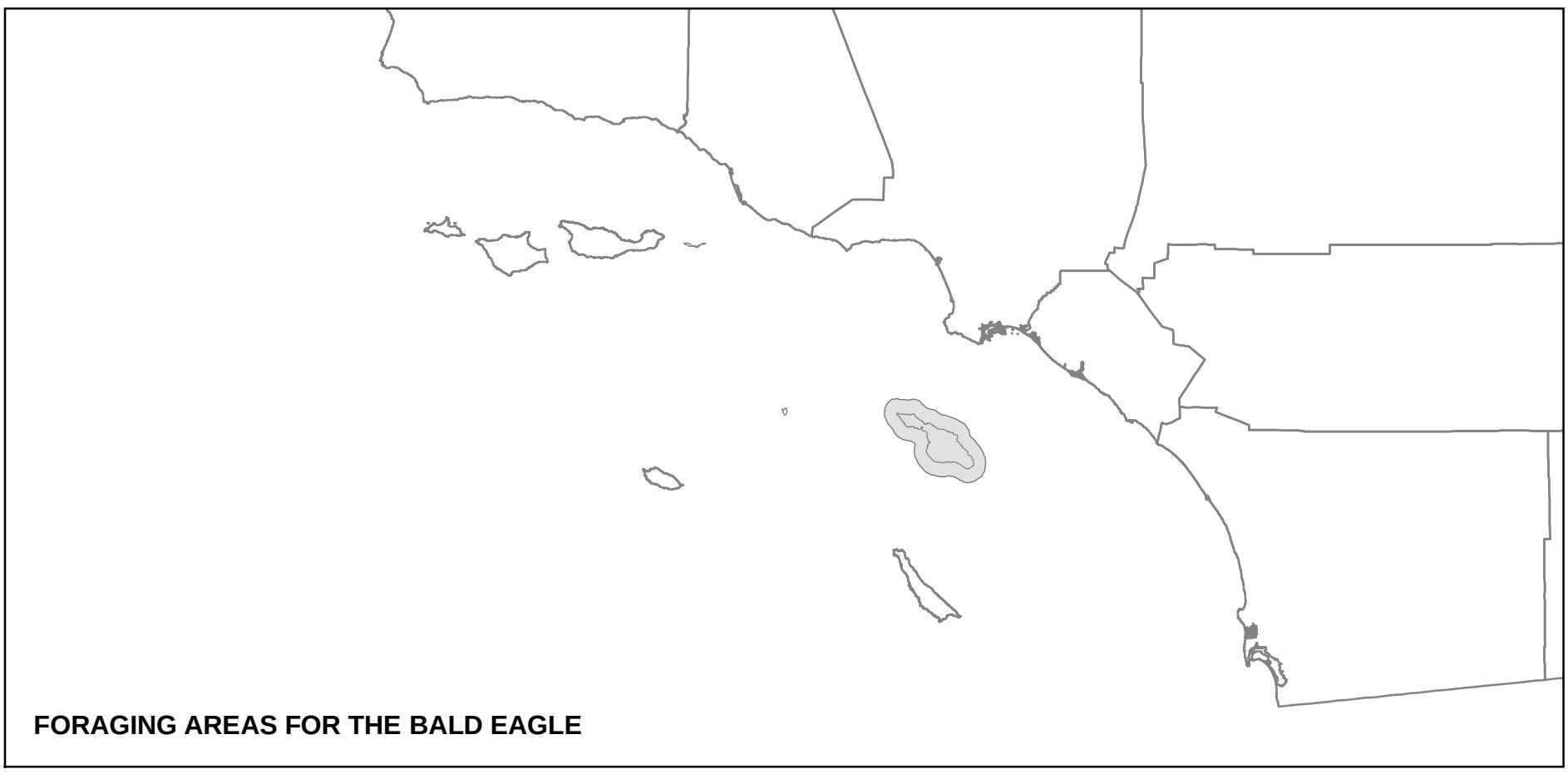
- Pelican DDT Diet = (0.20 * Kelp Bass DDT Concentration) + (0.80 * Pelagic fish Concentration)
- Pelican PCB Diet = (0.20 * Kelp Bass PCB Concentration) + (0.80 * Pelagic fish Concentration)
- Cormorant DDT Diet = (0.05 * White Croaker DDT Concentration) + (0.3 * Kelp Bass DDT Concentration) + (0.15 * Sanddab DDT Concentration) + (0.5 * Pelagic fish Concentration)
- Cormorant PCB Diet = (0.05 * White Croaker PCB Concentration) + (0.3 * Kelp Bass PCB Concentration) + (0.15 0.10* Sanddab PCB Concentration) + (0.5 * Pelagic fish Concentration)
- Bald Eagle DDT Diet = (0.50 * Kelp Bass DDT Concentration) + (0.10 * Sanddab DDT Concentration) + (0.21 * Pelagic fish Concentration) + (0.06 * 49.9) + (0.13 * 13.1*0.458)
- Bald Eagle PCB Diet = (0.05 * Dover Sole PCB Concentration) + (0.50 * Kelp Bass PCB Concentration) + (0.05 * Sanddab PCB Concentration) + (0.21 * Pelagic fish Concentration) + (0.06 * 31.24) + (0.13 * 5.37*0.477)



MAJOR FORAGING AREAS FOR THE BROWN PELICAN

SOURCE: BAIRD 1993

FORAGING AREAS FOR THE DOUBLE-CRESTED CORMORANT



FORAGING AREAS FOR THE BALD EAGLE

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FIGURE 4
AVIAN FORAGING AREAS

PALOS VERDES SHELF ECOLOGICAL RISK ASSESSMENT

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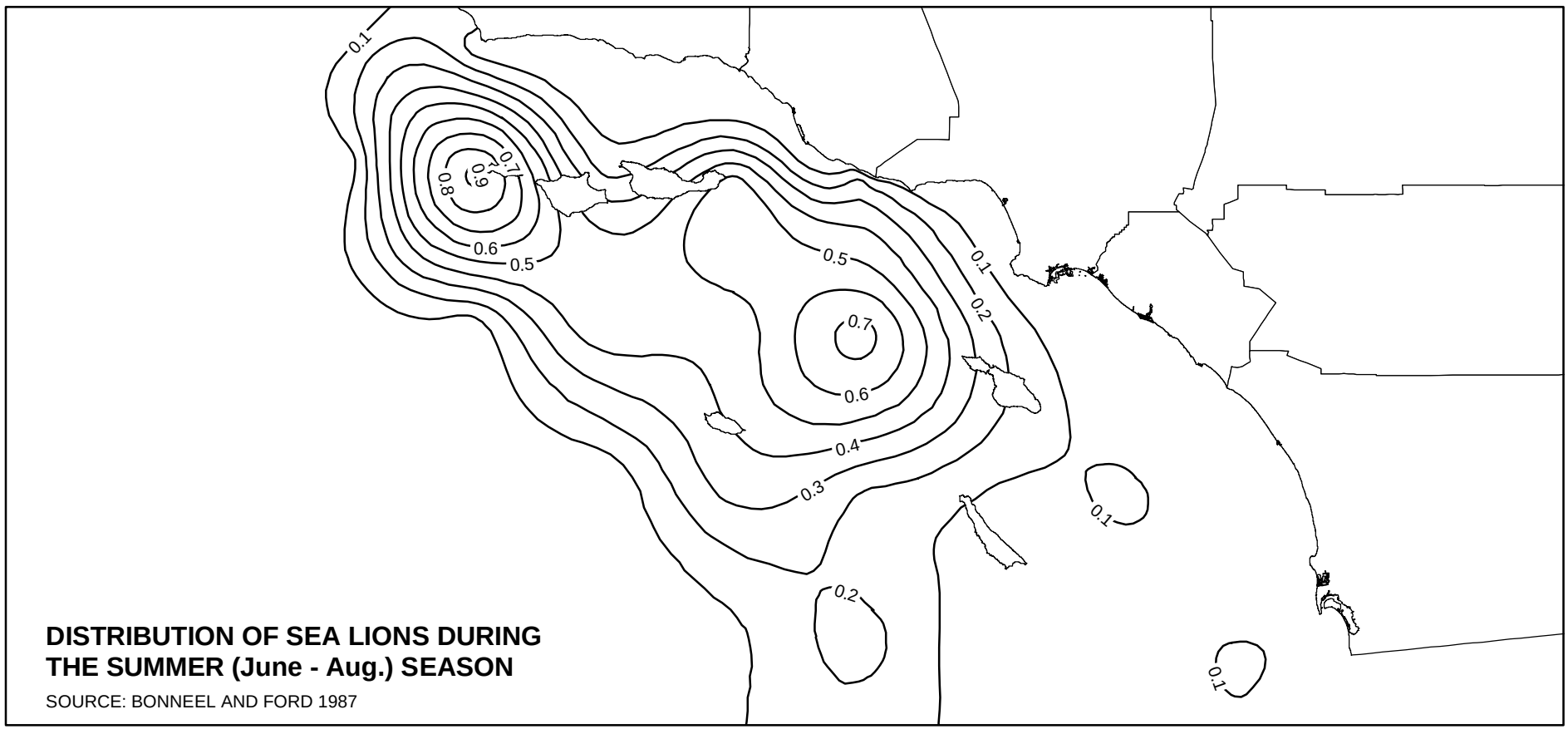
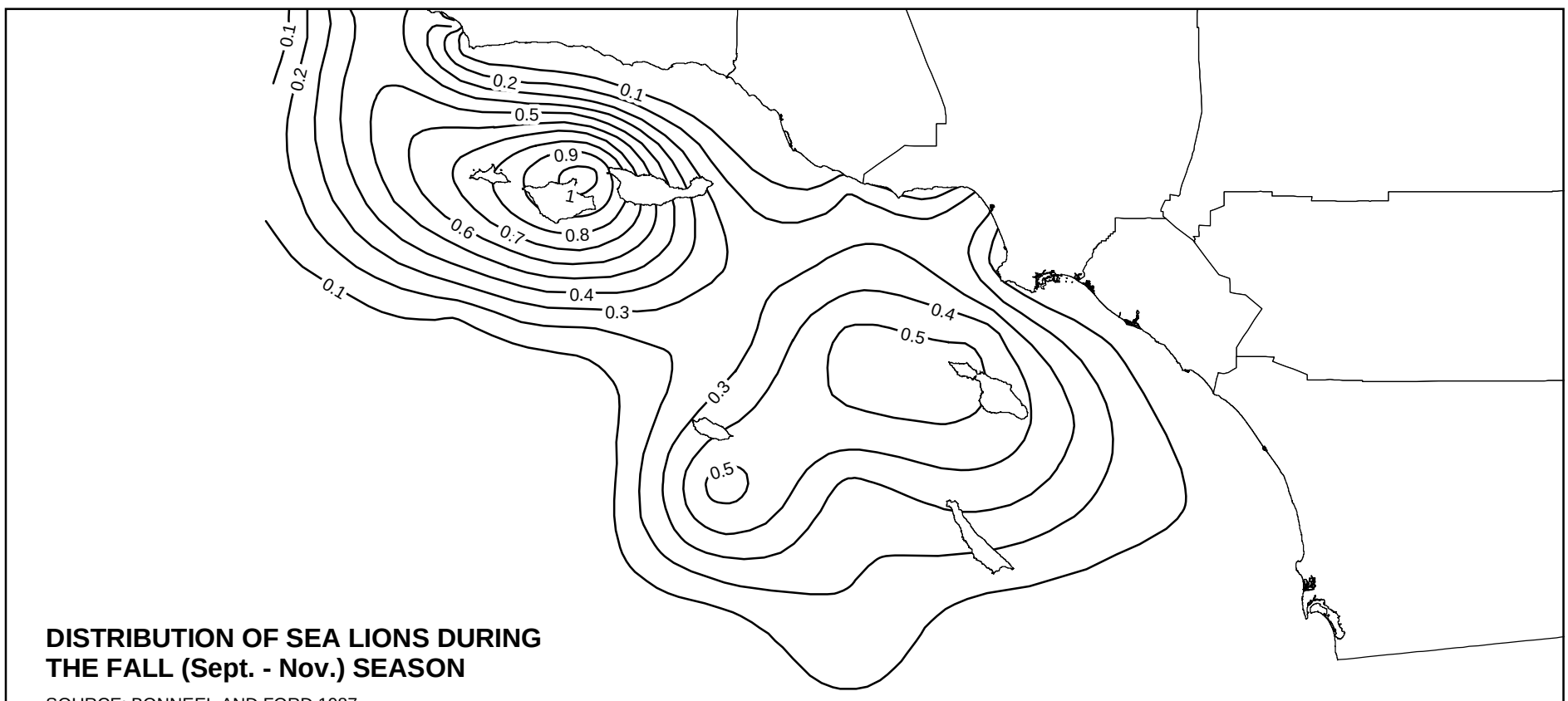


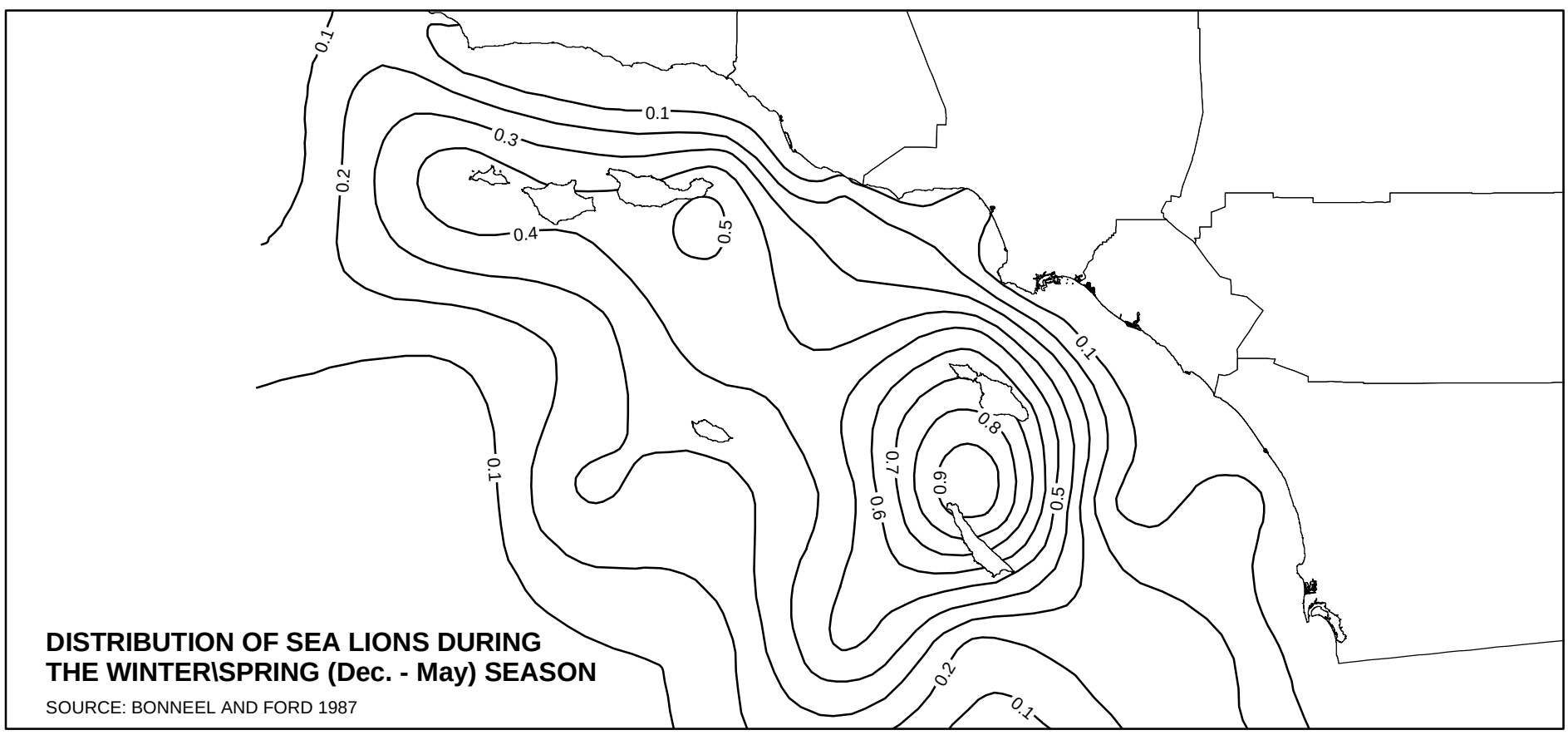
DISTRIBUTION OF SEA LIONS DURING THE SUMMER (June - Aug.) SEASON

SOURCE: BONNEEL AND FORD 1987



DISTRIBUTION OF SEA LIONS DURING THE FALL (Sept. - Nov.) SEASON

SOURCE: BONNEEL AND FORD 1987



DISTRIBUTION OF SEA LIONS DURING THE WINTER\SPRING (Dec. - May) SEASON

SOURCE: BONNEEL AND FORD 1987

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FIGURE 5
SEASONAL DISTRIBUTION OF SEA LIONS

PALOS VERDES ECOLOGICAL RISK ASSESSMENT

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Western Gull DDT Diet = (0.05 * White Croaker DDT Concentration) + (0.1 * Kelp Bass DDT Concentration) + (0.15 * Sanddab DDT Concentration) + (0.7 * Pelagic fish Concentration)

- Western Gull PCB Diet = (0.05 * White Croaker PCB Concentration) + (0.1 * Kelp Bass PCB Concentration) + (0.15 * Sanddab PCB Concentration) + (0.7 Pelagic fish Concentration)
- Sea Lion DDT Diet = (0.05 * White Croaker DDT Concentration) + (0.2 * Kelp Bass DDT Concentration) + (0.25 * Sanddab DDT Concentration) + (0.5 * Pelagic fish Concentration)
- Sea Lion PCB Diet = (0.05 * White Croaker PCB Concentration) + (0.2 * Kelp Bass PCB Concentration) + (0.25 * Sanddab PCB Concentration) + (0.5 * Pelagic fish Concentration)

Sea lion exposure GIS layers were produced by multiplying the sea lion diet layer by the percent use layer by the amount of fish ingested per day:

- Sea Lion DDT Exposure Sep – Nov = (Sea Lion DDT Diet * Sea Lion Use Sep. - Nov) * 0.116
- Sea Lion PCB Exposure Sep – Nov = (Sea Lion PCB Diet * Sea Lion Use Sep. - Nov) * 0.116

These calculations were repeated for the other two sea lion use area layers that represented the varying times of the year:

- Sea Lion DDT Exposure Jun - Aug = (Sea Lion DDT Diet * Sea Lion Use Jun - Aug) * 0.116
- Sea Lion PCB Exposure Jun - Aug = (Sea Lion PCB Diet * Sea Lion Use Jun - Aug) * 0.116
- Sea Lion DDT Exposure Dec - May = (Sea Lion DDT Diet * Sea Lion Use Dec. - May) * 0.116
- Sea Lion PCB Exposure Dec - May = (Sea Lion PCB Diet * Sea Lion Use Dec. - May) * 0.116

Sea lion pup exposure GIS layers were produced by multiplying the adult sea lion exposure layer by the uptake to adult tissue, the transfer factor from adult tissue to milk, and the amount of milk ingested per day by the pups.

- Sea Lion Pup DDT Exposure Jun - Aug = [Sea Lion DDT Exposure Jun - Aug] * (0.75/0.01) * 1.35233 * 0.0488
- Sea Lion Pup DDT Exposure Sep - Nov = [Sea Lion DDT Exposure Sep. – Nov] * (0.75/0.01) * 1.35233 * 0.0488
- Sea Lion Pup DDT Exposure Dec - May = [Sea Lion DDT Exposure Dec. - May] * (0.75/0.01) * 1.35233 * 0.0488
- Sea Lion Pup PCB Exposure Jun - Aug = [Sea Lion PCB Exposure Jun - Aug] * (1/0.01) * 1.35233 * 0.0488
- Sea Lion Pup PCB Exposure Sep - Nov = [Sea Lion PCB Exposure Sep. – Nov] * (1/0.01) * 1.35233 * 0.0488
- Sea Lion Pup PCB Exposure Dec - May = [Sea Lion PCB Exposure Dec. - May] * (1/0.01) * 1.35233 * 0.0488

Pelican and cormorant exposure values for tDDT and tPCB were calculated for both foraging and breeding areas:

- Pelican DDT Exposure = (Pelican DDT Diet * 0.15)
- Pelican PCB Exposure = (Pelican PCB Diet * 0.15)

- Cormorant DDT Exposure = (Cormorant DDT Diet * 0.18)
- Cormorant PCB Exposure = (Cormorant PCB Diet * 0.18)

Western gull body burden layers were produced for the foraging areas by multiplying the diet by the amount of fish ingested per day and by the uptake of tDDT or tPCBs from the diet.

- Western Gull DDT Body Burden = (Western Gull DDT Diet * 0.257) * (0.75/0.00219)
- Western Gull PCB Body Burden = (Western Gull PCB Diet * 0.257) * (1/0.00438)

Peregrine exposure layer produced by multiplying the western gull body burden by the composite bird ratio and by the amount of bird prey ingested per day.

- Peregrine DDT Exposure = [(0.68* Western Gull DDT Body Burden * 0.563) +(0.19*0) + (0.13*0.33)] * 0.193
- Peregrine PCB Exposure = [(0.68* Western Gull PCB Body Burden * 0.486) +(0.19*0) + (0.13*0.26)] * 0.193

For bald eagles, it was necessary to estimate tDDT and tPCB concentrations for the seabird and marine mammal portions of the diet. The western gull (body burden equations provided above) and sea lions (body burden equations provided below) were used as surrogates for these portions of exposure. Sea lion body burdens were calculated for the foraging areas around Santa Catalina Island by multiplying the diet by the amount of fish ingested per day and by the uptake of tDDT or tPCBs from the diet. Western gull body burden values were calculated within a 50-km radius of Santa Catalina Island and sea lion body burden values were calculated within a 54-km radius. The 95 percent UCLs from these body burden distributions were used in the bald eagle diet equations (above).

- Sea Lion DDT Body Burden = (Sea Lion DDT Diet * 0.116) * (0.75/0.00045)
- Sea Lion PCB Body Burden = (Sea Lion PCB Diet * 0.116) * (1/0.00045)

The bald eagle foraging area layer was used to develop the bald eagle exposure values:

- Bald Eagle DDT Exposure = (Bald Eagle DDT Diet * 0.13)
- Bald Eagle PCB Exposure = (Bald Eagle PCB Diet * 0.13)

3.3 Calibration and Statistical Error

The simple linear regressions forming the basis of the model include documented errors in predictive ability. They are given as the r^2 values in Table 8. The gridding function in GIS, key assumptions, use of weighting factors, and the need for multiple datasets are described above.

Measured PV Shelf study area fish tissue concentrations can be compared to predicted values for fish as a means of checking the model's accuracy. Table 10 shows maximum and average for both datasets. The comparison indicates that, for white croaker, highly contaminated individual fish (maximum values) were not reproduced well in the model. However, that is an expected characteristic, common to all such models. Differences between average values showed the model slightly underestimated mean tDDT in white croaker, but was very close to measured values for mean tDDT and tPCBs in all other cases (Table 10). The predicted fish, in this case, were estimated derived from sediment concentrations for the 1 km circle at the central point of the trawl sample, with no knowledge of the fish's true historical home range.

TABLE 10
Comparisons Between Measured and Predicted Fish Whole Body Concentrations at PV Shelf in mg/kg

Analyte	Species	Geometric mean		Maximum	
		Sampled	Modeled	Sampled	Modeled
tDDT	White croaker	3.05	4.98	11.3	84.9
tDDT	Kelp bass	4.88	5.33	7.55	26.2
tPCB	White croaker	9.56	8.59	39.6	12.7
tPCB	Kelp bass	4.56	4.18	10.4	4.64

Note: Sampled data were converted from fillet to whole-body concentrations using a fillet-to-whole body ratio as described above.

The most recent measured fish data were used. Kelp bass data is from 2002 MSRP/EPA and 2004 LACSD (Zones 1, 2 and 3) data sets; white croaker were taken from 2002 MSRP/EPA, 2004 LACSD (Zones 2 and 3), and 2005 LACSD (Zone 1) data sets.

Measured SCB tDDT and tPCB concentrations in western gulls and adult sea lions can be compared to predicted western gull and adult sea lion values as a means of checking the model's accuracy (Table 11). To verify our model, we converted our tDDT and tPCB concentrations in sea lions from whole-body concentrations to blubber (shown in parentheses in Table 11) concentrations, assuming all tDDT and tPCB accumulates in the blubber [a reasonable assumption given that the log K_{ow} of DDT is 6.0 and that for PCBs is 7.0 (HydroQual, Inc., 1997)]. A lipid content of 30 percent for sea lions was used for this conversion. Table 11 shows mean, and maximum values for both datasets. Both sea lion and western gull concentrations were overestimated in their respective models, although mean values were within factors of 3 to 7.

TABLE 11
Comparisons Between Measured and Predicted Western Gull and Sea Lion Concentrations from Bight-Wide Measurements

Analyte	Species	Geometric Mean		Maximum	
		Sampled WW (LW)	Modeled WW (LW)	Sampled WW (LW)	Modeled WW (LW)
DDT	Sea lion	(37.7)	(198)	(1589)	(23,000)
DDT	Western gull	7.34	21.97	19.3	1950
PCB	Sea lion	(12.3)	(119)	(227)	(450)
PCB	Western gull	1.54	8.67	3.2	21.9

Notes:
Sea lion data represent lipid weight concentrations measured in tissue samples from carcasses collected on Santa Catalina Island in 1992-93 and 2000 (Costa et al,. 1994 and Le Boeuf, 2002). Western gull data represent whole-body wet weight concentrations from gulls collected on Santa Catalina Island in 1992-93 (Costa et al., 1994).

WW = wet weight
LW = lipid weight

4. Discussion and Conclusions

The model appears to be a useful tool for evaluating ecological risk to fish, birds, and marine mammals that are potentially affected by sediment contaminants in the SCB. The high density of underlying sediment samples accurately depicts current conditions. The assumed small exposure areas of resident fish aid in establishing predictive relationships between surficial sediment and tissue concentrations in co-located samples. The result is an ability to tie sediment contamination by tDDT and tPCBs throughout the SCB to contamination in the dietary items of birds and marine mammals. Any changes in the spatial distribution and degree of contamination of surface sediments can logically be predicted to affect the dietary exposures of higher-order consumers of the SCB. The model provides one line of evidence for ecological risk by estimating oral exposure to marine mammals and birds. The model predicts measured geometric mean fish tissue concentrations within a factor of 2 and measured geometric mean marine mammal and bird tissues within factors of 3 to 9.

Selected subsets of the ecological risk food web model can be adapted as a tool to evaluate sediment concentrations of DDT and PCBs at the PV Shelf by focusing the model output on the PV Shelf area, for receptors with high site-fidelity.

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Appendix D
Primer on Waves, Currents, and Bottom Stress

The following is a primer on waves, currents, and bottom stress to assist the reader in understanding some of the oceanographic terms and processes that are discussed in the remedial investigation report. Movement of seafloor sediment is related to the amount of force exerted on the bottom by waves or currents. Because sediment is always subjected to a huge exerted by the weight of the overlying water, it is the varying force tangential to the seafloor that is important for initiating movement. This force is called shear stress, and is measured as force per unit area, in Newtons per square meter (N/m^2 = kg-m/s^2), also called Pascals (Pa), which are the same units used to measure pressure.

In a steady current, the shear stress (τ; Pa) exerted on the bottom is proportional to the square of the current speed (U; m/s), according to the equation

$$\tau = \rho C_d U |U| \quad (1)$$

where ρ is the density of water (approximately 1,030 kg/m^3) and C_d is the drag coefficient (dimensionless). Both τ and U are vectors (i.e., have a direction associated with them). That is why the equation is often written with $U|U|$ instead of U^2; where $|U|$ represents the absolute value or magnitude of the current. The resulting stress has the same direction as U. The drag coefficient is not a constant, but rather depends on several things, the two most important of which are (1) the height above the bottom at which the current is measured, and (2) the hydraulic roughness of the seafloor. Typically, drag coefficients are expressed for currents measured 1 meter (m) above the bottom, and adjustments must be made if the measurements are made at a different elevation.

Current speed varies with elevation above the bottom, from zero at the bed to U at the measurement elevation (z). This variation is called the velocity profile, and it usually has a distinctive shape, referred to as the "log profile," described by this equation

$$U = \frac{u_*}{\kappa} \ln\left(\frac{z}{z_0}\right) \quad (2)$$

where u_* is the friction velocity (m/s), κ is von Karman's constant (approximately 0.4), z is the elevation of the current (m), and z_0 is the roughness length (m, a measure of the hydraulic roughness of the seabed). The friction velocity is an alternative measure of shear stress. Shear stress and friction velocity are related according to:

$$\tau = \rho u_* |u_*| \quad (3)$$

The log-profile equation (Equation 2) generates profiles that have a characteristic shape, increasing rapidly with distance from the bed in the boundary layer (Figure 1, left panel). These profiles are linear when plotted with a logarithmic elevation axis (Figure 1, right panel). In this example, U at 1 m above the bottom is 0.24 m/s, τ = 0.1 Pa, so u_* is about 0.01 meter per second (m/s), C_d is 0.003, and z_0 is 0.00058 m. The current velocity at 3 m is 0.27 m/s.

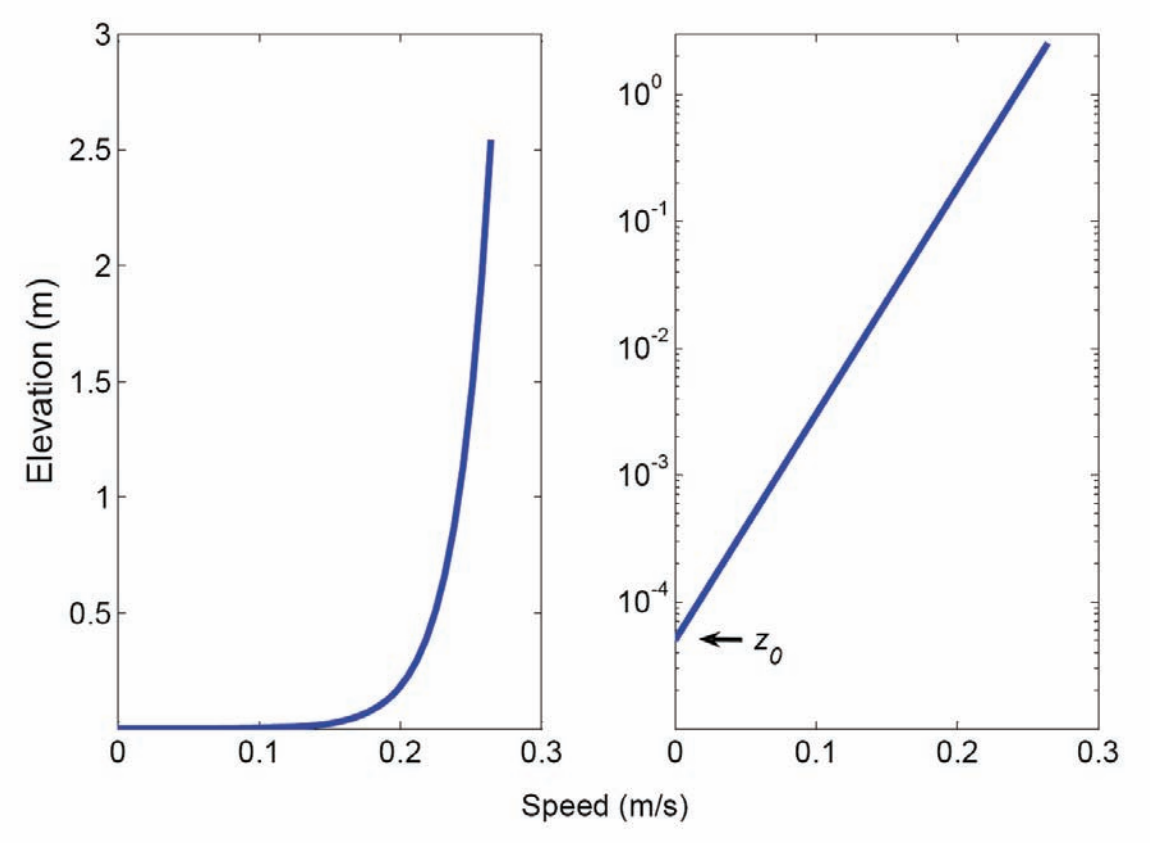

FIGURE 1
Plots of Current Speed versus Elevation above Seabed (both panels represent the same velocity profile but, in the right panel, the y-axis is logarithm of the elevation)

If velocity U is known at elevation z, and shear stress t is known, then Equation 1 can be used to calculate drag coefficient. Also, Equation 3 can be used to convert shear stress to friction velocity (u_*), and then Equation 2 can be used to estimate roughness length z_0.

$$C_d = \left(\frac{\kappa}{\ln(z / z_0)} \right)^2 \tag{4}$$

In fact, substitution of Equation 2 for U in Equation 1 and re-arranging yields shows how the drag coefficient depends on the measurement elevation z for any given roughness length z_0. The expression for z_0 in terms of C_d is

$$z_0 = \frac{z}{\exp(\kappa / \sqrt{C_d})} \tag{5}$$

Typical values of C_d in the ocean are around 0.003, which (for currents measured 1 m above the bottom) corresponds to z_0 of about 0.0006 m. Coarse sediments, ripples, and wave motions can increase the drag and roughness length. These equations allow conversion between currents specified at some height, friction velocity, and shear stress.

The amount of shear stress required to cause sand grains to start moving along the bottom or to rip small particles of cohesive mud from the bottom is called the critical shear stress. Critical shear stress varies according to the nature of the particles. For sand, it depends mostly on grain size, but for finer sediment, it depends on how cohesive the sediment is. The critical shear stress at the PV Shelf Study Area is 0.08 to 0.1 Pa. Figure 1 indicates that a current of 0.24 m/s at 1 meters above bottom (mab) (or 0.27 m/s at 3 mab) would be required to initiate motion in this material.

Waves complicate these calculations. Wave motions at the seabed vary with wave height, period, and water depth, and because they oscillate at the wave period (typically 10 to 20 seconds at 60 m deep on the PV Shelf), they never develop a thick boundary layer, so the velocity profile changes rapidly from zero to full speed in just a few cm above the seabed. Therefore, wave motions impart more shear stress to the bed (for any given velocity). That stress varies over the wave period reversing and has a mean of nearly zero (except in the surf zone). Although waves can initiate motion, waves alone are not very effective at causing net transport. However, there are almost always some currents available to transport any material suspended by waves, so the timing and amplitude of wave-induced resuspension plays an important role in sediment transport calculations on the PV Shelf Study Area.