FINAL

REMEDIAL INVESTIGATION REPORT
SKEET RANGE
ALAMEDA POINT, CALIFORNIA

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EXECUTIVE SUMMARY

This report was prepared for the Southwest Division Naval Facilities Engineering Command (SWDIV) to present the findings from the 2001 field investigation at the Alameda Point Skeet Range (Installation Restoration [IR] Site 29) and identify potential areas requiring further evaluation in the Feasibility Study (FS). The primary objectives of this Remedial Investigation (RI) report was to evaluate the offshore sediment quality at the Skeet Range, identify areas of unacceptable risk based on the human health and ecological risk assessments, and delineate the areas requiring evaluation in the Feasibility Study (FS) based on the data collected from the recent field effort implemented in 2001.

The Skeet Range was historically developed offshore as two active shooting ranges (northern and southern) for approximately 30 to 40 years until its closure in 1993. A majority of the lead shot located in the Skeet Range sediment occurs at approximately 5 to 10 ft below mean low water. Petroleum pitch binding agents were used in the manufacture of clay targets and are the suspected source of poly-chlorinated aromatic hydrocarbons (PAHs) found in sediment. Based on the historical practices that occurred at the Skeet Range, lead shot and PAHs appear to be the primary contaminants attributable to historical Skeet Range activities.

Data collected from the recent 2001 field investigation were used in the ecological risk assessment and human health conceptual site model (CSM) to determine potential adverse health effects associated with exposure to lead shot and PAHs found in sediment. Two additional studies were conducted as part of the 2001 investigation to determine if the source of PAHs is related to the dissolution of clay target fragments and to determine sediment accretion rates at the Skeet Range. PAH fingerprinting techniques were employed to characterize the unique signature of PAH constituents within the clay target fragments in comparisons to measured levels of PAHs in sediment. The chemical composition of sediment and fragment samples were then evaluated using a Principal Component Analysis (PCA), which groups chemical similarities or differences, without any preclassification as to their nature/source(s). The PCA revealed that nearly all of the sediment samples were chemically distinct from the chemical composition of clay target fragments, which led to the conclusion that the organic binder in clay fragments was not the source of PAHs in the sediment. A further ancillary investigation to determine the source of PAHs indicated that the Skeet Range sediments are likely a mixture of San Francisco Bay background sediment and trace levels of tar from a former manufactured gas plant.

The sediment dynamics study focused on analysis of radioisotopes Pb-210 and Cs-137 in three cores to estimate sediment accumulation rates. The objective of the study was to determine the amount of Pb-210 formed by the radioactive decay of its gaseous parent, Rn-222, by using a half-life of Pb-210 of 22.3 years. Based on the core data, the net sediment accumulation rate was estimated to be between 0.65 and 1.0 cm/yr. The horizontal and vertical distribution of shot supports the hypothesis that lead shot has not been transported significant distances and that gradual burial is occurring.

To evaluate potential risks to ecological receptors, a tiered process was used that encompasses the eight steps consistent with the U.S. EPA and Navy guidelines. In the first tier, a screening-level ecological risk assessment (SLERA) was conducted which included a development of the CSM, identification of chemicals of potential ecological concern (COPECs), and screening-level dose assessment using conservative assumptions. Lead shot and PAHs from clay targets are preliminary COPECs, and direct exposure to these compounds is considered the primary release mechanism and exposure route. Benthic-feeding birds (e.g., scaups and scoters) were identified as the receptors of concern at the Skeet Range because their life histories suggest that, during foraging, these receptors may ingest lead shot from sediment within the grit size range either inadvertently or intentionally selected for use as grit. In order to evaluate potential effects associated with exposure to lead shot, a conservative toxicity reference value

(TRV) for lead shot was proposed in the SLERA; no TRVs were developed for PAHs due to lack of toxicity and effects data for avian species.

To assess the potential for exposure to lead shot, the probability that a bird may ingest a lead shot within the grit size range while foraging for grit was estimated. A site-specific probability model was developed using a binomial probability expansion formula that estimates the likelihood that a bird may ingest either grit or lead shot within the grit size range at every attempt. Using field collected data to estimate the abundance of lead shot by area and conservative values for site use factor (SUF), amount of grit ingested, and grit/shot retention time, the model was run to estimate the probability that an individual bird will ingest the TRV daily dose of lead shot at the Skeet Range. Use of conservative exposure parameters, including a SUF of 1, generated risk probabilities for lead shot that exceeded the population risk level threshold of 10^{-3} at approximately half of the stations. Because of the conservatism inherent in the SLERA, a finding of unacceptable risk indicates that additional evaluation is necessary to refine the risk estimates based on site-specific conditions to more accurately characterize potential risks to diving ducks at the site. These refined estimates were generated in the BERA.

The goal of the BERA is to use protective assumptions to refine the modeling. To address the (1) uncertainty associated with the exposure and effects parameters used to estimate risk in the SLERA, and (2) the conservatism in the SLERA that resulted in a worst-case estimate of risk that has a negligible chance of occurring, a refinement to these parameters was conducted in the BERA. To aid in this refinement, a Monte Carlo analysis was conducted to evaluate the effects of uncertainty in input variable values for the binomial probability risk model and the sensitivity of the predictive capability of the model to the input variables. In Monte Carlo analyses, a larger number of scenarios can be evaluated based upon a range of continuous input values for each model parameter. Input values are randomly drawn from each input variable's distribution to generate a value for the model output variable. This process is then repeated multiple times to derive a distribution of values for the output variable.

Distributions were developed for the input parameters to the binomial probability model, including the lead shot NOAEL. A site-wide estimate of the probability of an individual bird encountering lead shot also was generated to account for spatial variation of lead shot found throughout the site using a 95 percent upper confidence limit (95UCL) on the mean of sample location probabilities.

Monte Carlo analysis methods were used to evaluate the remaining uncertainty and natural variability in model exposure parameters and characterize the potential for risk to diving ducks at Alameda Point. Based on this refined, yet still conservative assessment, there is very limited potential for unacceptable risk from exposure to lead shot posed to the avian community that may use the site. The results of the analysis showed that, approximately 96 percent of the time, less than 1 in 1,000 birds foraging at the site would potentially be at risk. Exposure of diving ducks to lead shot may even be more limited given the thick mats of *Ampelisca* tubes found on the surface of all the samples collected from the Skeet Range.

Although exposure to PAHs were not quantitatively evaluated, any potential risks associated with exposure to these compounds should not be significantly different from prevailing conditions throughout much of San Francisco Bay Area, given that a majority of the stations had PAH concentrations within ambient concentrations. Additionally, it is unlikely that clay targets are the source of the PAHs measured in the sediment at the site.

The human health CSM identifies the conditions of exposure and likely scenarios in which human receptors may come in contact with impacted sediment at the Skeet Range. Due to the offshore location of lead shot and clay targets, direct human exposures are limited because access to the site is restricted. Under a future land use scenario when the site is developed into an open space and/or recreational park, the riprap along the shoreline will deter access to the beach areas and minimize potential direct exposures to recreational users. Indirect exposures via fishing may occur on the property; however, there is no evidence that PAHs biomagnify in aquatic food webs or bioaccumulate in vertebrate species. It also is unlikely that any fish species will ingest lead shot from the surface of the sediment because the thick mat of *Ampelisca* tubes reduces bioavailability of these contaminants through the food chain. Therefore, risks to human receptors from exposures to PAHs and lead shot are considered *de minimis*.

Based on all these considerations, *de minimis* risks are associated with exposure to this site based on the ecological and human health assessments. Because the PAH levels are indicative of background levels and majority of the lead shot is gradually buried, exposures to sediment do not pose a health threat to current or future human receptors and the environment. Consequently, a no further action determination is recommended for this site.

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ABBREVIATIONS AND ACRONYMS

AE	assessment endpoint
ALAD	δ-aminolevulinic acid dehydratase
ARRA	Alameda Reuse and Redevelopment Authority
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	ambient water quality criteria
BDO	Battelle Duxbury Operations (laboratory)
BERA	baseline ecological risk assessment
BPTCP	Bay Protection and Toxic Hot Spot Cleanup Program
BTAG	Biological Technical Assistance Group
CDFG	California Department of Fish and Game
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CNO	Chief of Naval Operations
COPEC	contaminant of potential ecological concern
CSM	conceptual site model
DO	dissolved oxygen
DON	United States Department of the Navy
DQO	data quality objective
DUP	field duplicate
ERA	Ecological Risk Assessment
ER-L	effects range-low
ER-M	effects range-median
FMGP	former manufactured gas plant
FS	Feasibility Study
HPAH	high-molecular-weight PAH
ID	identification
IR	Installation Restoration
LPAH	low-molecular-weight PAH
ME	measurement endpoint
MLLW	mean lower low water
NA	not applicable
NAD	North American Datum
NAS	Naval Air Station
NEESA	Naval Energy and Environmental Support Activity
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observed adverse effects level
NR	not recorded
OU	Operable Unit

PAH	polycyclic aromatic hydrocarbon
PCA	principal components analysis
PCB	polychlorinated biphenyl
PRC	PRC Environmental Management, Inc.
RMP	Regional Monitoring Program
RI	Remedial Investigation
RWQCB	Regional Water Quality Control Board
SD	standard deviation
SFEI	San Francisco Estuary Institute
SLERA	screening-level ecological risk assessment
STL	Severn Trent Laboratory
SUF	site use factor
SVOC	semivolatile organic compound
SWAT	Solid Waste Assessment Test
SWDIV	Southwest Division Naval Facilities Engineering Command
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TPH-DRO	total petroleum hydrocarbons-diesel range organics
TRV	toxicity reference value
TtEMI	Tetra Tech EM, Inc.
USACE	United States Army Corps of Engineers
U.S. EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UTL	upper tolerance limit
VOC	volatile organic compound
VS	Validation Study
95UCL	95 percent upper confidence limit on the mean
p-95UCL	95UCL probability

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1.0 INTRODUCTION

This report was prepared for the Southwest Division Naval Facilities Engineering Command (SWDIV) under Contract No. GS-10F-0275K to present the findings from the 2001 field investigation at the Alameda Point Skeet Range (Installation Restoration [IR] Site 29), and provides a recommendation in this Remedial Investigation (RI) for the offshore sediment based on interpretation of these results. The RI is being performed under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to support the transfer and reuse of the property by the Alameda Reuse and Redevelopment Authority (ARRA).

1.1 Site Background

A description of the site history and physical setting is presented below followed by a brief description of the previous site investigations performed at the Skeet Range.

1.1.1 Site Description and Physical Setting

The Skeet Range is located on the northwestern corner of former Naval Air Station (NAS) Alameda (now referred to as Alameda Point). The Skeet Range extends approximately 800 ft offshore into the San Francisco Bay with dimensions of about 1,300 ft by 800 ft (see Figure 1-1). The area is exposed to wind

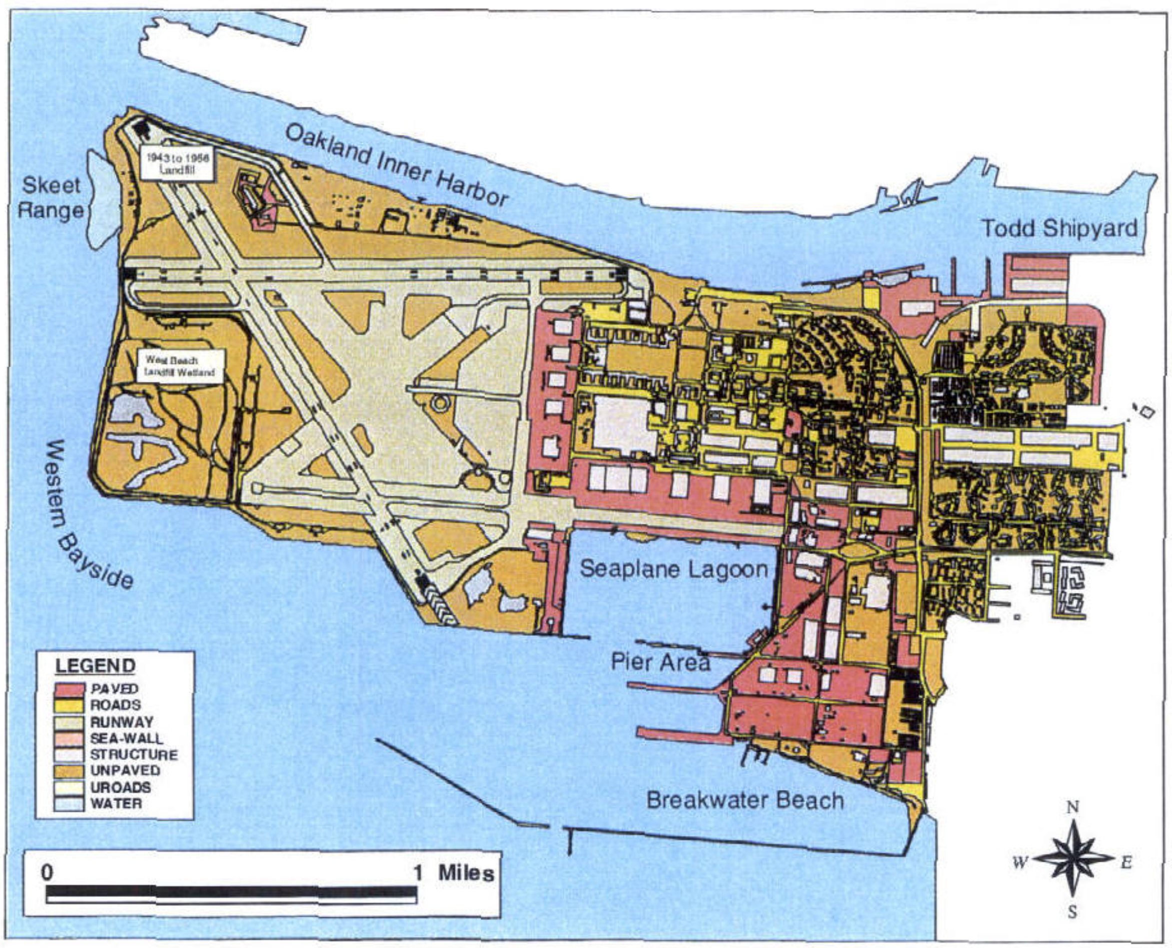

Figure 1-1. Site Map of Alameda Point

and wave action from San Francisco Bay (TtEMI, 2000). Based on a current bathymetry map of Skeet Range from 2001 acoustic imaging (Figure 1-2), the bottom of the range is a broadly uniform, gentle slope with water depths ranging from <5 ft (<1.5 m) to about 12 ft (3.7 m). The majority of the Skeet Range fall zone is between 1.5 to 3 m deep. The adjacent onshore area consists of fill material dredged from San Francisco Bay coastal mudflats, marshlands, and sloughs in the 1930s and 1940s. The onshore area has relatively flat topography and most of the shoreline is lined with riprap and former concrete ramp. No significant streams, rivers or other surface water bodies discharge into the bay in the vicinity of Skeet Range.

Table 1-1 presents the grain size data for surface sediment samples collected at the Skeet Range from historical investigations. Percent fines (i.e., percent silt-plus clay-sized particles) increases with increasing distance from the shore, from fine to medium sand in the near-shore area to clayey silt further offshore. Although this gradient is not completely uniform across the entire study area, the overall trend shows an increase in percent fines with increasing distance from shore. For example, the five stations with the percent fines <50% (SKB004, SKB011, SR001, SR003, SR004) are all near-shore stations located at a depth of 5-10 feet below water surface (Figure 1-3). The stations with the next highest percent-fines (56.5% at SR002 and 67.6% at SKB003) are also near-shore stations. Conversely, stations with percent fines >90% (SKB010, SR011 and SR012) are the farthest offshore stations and are located at a depth of 10-15 feet below water surface. Some beach area is exposed near the Skeet Range during low tide; however, the access to the onshore portion of Skeet Range and IR Site 1 is restricted to authorized Navy personnel.

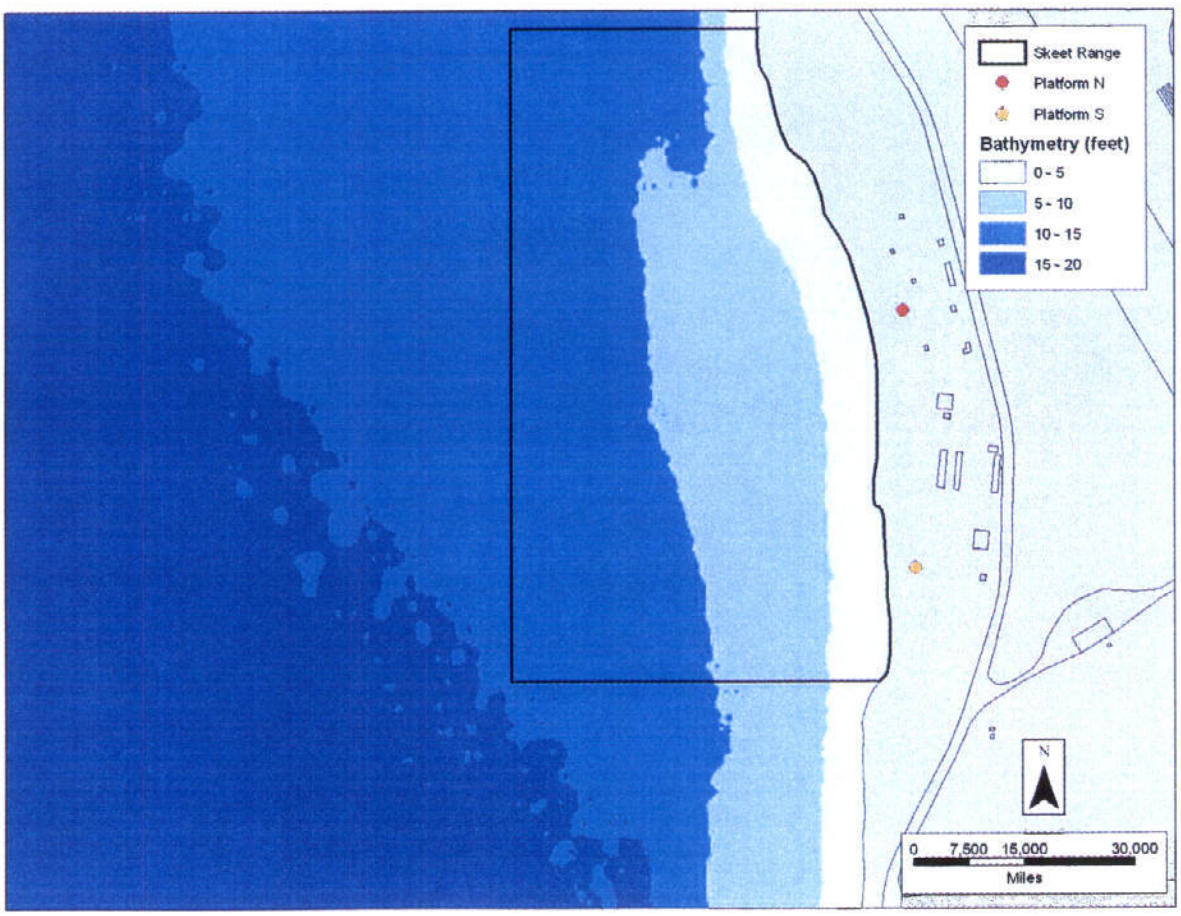

Figure 1-2. Skeet Range Bathymetry Map

Table 1-1. Surface Sediment Grain Size Data from Previous Investigations

Station	Sample Interval (ft)	% Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Silt	% Clay	% Fines[(a)]	Sediment Type
SKB001	0 - 1.5	0	0	0.2	19.7	47.9	32.2	80.1	clayey sandy silt
SKB002	0 - 1.3	0	0	0.2	20.8	44.0	35.0	79.0	clayey sandy silt
SKB003	0 - 1.3	0	0	0.3	32.1	43.9	23.7	67.6	sandy clayey silt
SKB004	0 - 1.5	0	0	2.9	56.3	25.0	15.8	40.8	silty clayey sand
SKB005	0 - 1.3	0	0	0.3	20.8	58.4	20.5	78.9	sandy clayey silt
SKB006	0 - 1.3	0	0	0.0	19.9	47.9	32.2	80.1	clayey sandy silt
SKB007	0 - 1.3	0	0	0.2	23.4	44.8	31.6	76.4	clayey sandy silt
SKB008	0 - 1.3	0	0	0.0	16.6	46.1	37.3	83.4	clayey sandy silt
SKB009	0 - 1.3	0	0	0.3	13.5	50.1	36.1	86.2	clayey sandy silt
SKB010	0 - 1.4	0	0	0.0	4.9	62.0	33.1	95.1	clayey silt
SKB011	0 - 1.3	0	0	11.9	55.7	20.8	11.6	32.4	silty clayey sand
SKB012	0 - 1.3	0	0	0.9	16.5	56.1	26.5	82.6	clayey sandy silt
SR001	0 - 1.3	0	0	1.3	58.5	14.5	25.7	40.2	clayey silty sand
SR002	0 - 1.4	0	0	1.0	42.5	34.6	21.9	56.5	silty clayey sand
SR003	0 - 1.3	0	0	1.5	51.2	13.2	34.1	47.3	clayey silty sand
SR004	0 - 1.4	0	0	0.9	52.3	30.0	16.8	46.8	silty clayey sand
SR005	0 - 1.4	0	0	0.8	26.6	49.6	23.0	72.6	sandy clayey silt
SR006	0 - 1.4	0	0	0.2	13.1	60.8	25.9	86.7	clayey sandy silt
SR007	0 - 1.4	0	0	0.6	17.2	50.6	31.6	82.2	clayey sandy silt
SR008	0 - 1.3	0	0	0.8	16.1	49.6	33.5	83.1	clayey sandy silt
SR009	0 - 1.4	0	0	2.0	17.2	44.0	36.8	80.8	clayey sandy silt
SR010	0 - 1.4	0	0	0.1	18.9	46.5	34.5	81.0	clayey sandy silt
SR011	0 - 1.4	0	0	0.2	9.8	45.4	44.6	90.0	clayey silt
SR012	0 - 1.4	0	0	1.4	8.0	47.6	43.0	90.6	clayey silt

(a) % fines = % silt + % clay.

Historically, the IR Site 1 disposal/landfill area located east of the range was part of the open bay until fill materials were deposited from the early 1940s to 1956 (PRC, 1996). The area subsequently was filled with dredge spoils to form its present topography. The landfill reportedly received all waste generated at Alameda Point except for wastewater which was discharged directly to Seaplane Lagoon via the storm sewer system. It is estimated that 15,000 to 200,000 tons of solid waste were disposed of in the landfill including old aircraft engines, cables, scrap metals, waste oil, paint waste, solvents, cleaning compounds, construction debris, ashes from incinerator located in former Building 68 (demolished in 1961) near IR Site 7, and low-level radioactive material from the Naval Air Rework Facility (NEESA, 1983). The Navy Public Works Department employed open burning as the primary waste disposal method starting in the early 1950s.

Burn residue was pushed into San Francisco Bay with a bulldozer that extended the shoreline westward. Logs for borings drilled during the Solid Waste Assessment Test (SWAT) program indicate that the shoreline was filled with burned and unburned refuse and a thin covering of sand. Chemicals detected in surface soil (0 to 2 feet below ground surface) include metals, polycyclic biphenyls (PCBs), pesticides, polycyclic aromatic hydrocarbons (PAHs), and volatile organic compounds (VOCs). To detect if potential offsite migration may be occurring, groundwater monitoring wells were installed on the western perimeter of the site in 2002. Chemicals detected during the quarterly sampling from these wells include metals, PAHs, and VOCs. A Feasibility Study is currently being developed for IR Site 1 that will consider alternatives to address potential migration of contaminants from the landfill.

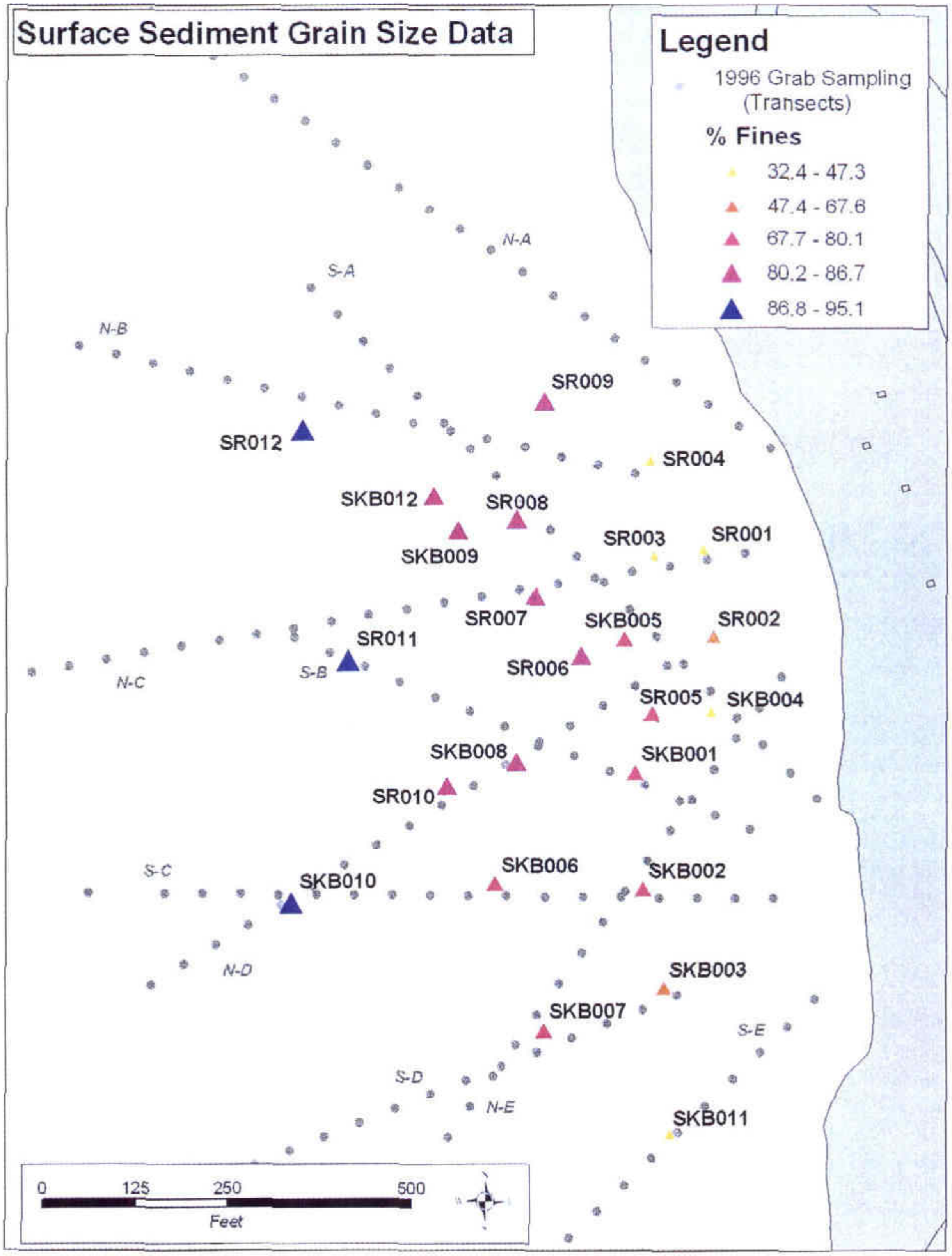

Figure 1-3. Surface Sediment Grain Size Distribution

The Skeet Range was developed offshore as an active shooting range for approximately 30 to 40 years until it ceased operations in 1993. The Skeet Range consisted of two shooting ranges (northern and southern) located roughly 1,500 ft south of the mouth of the Oakland Inner Harbor. During shooting activities, lead shot was discharged at clay targets in a westward direction towards San Francisco Bay. Most of the lead shot located in Skeet Range sediments occurs at approximately 5-10 ft below mean low water (TtEMI, 2000). Petroleum pitch binding agents were used in the manufacture of clay targets and are the suspected source of PAHs found in sediment. Based on the historical practices that occurred at the Skeet Range, lead shot and PAHs appear to be the two primary contaminants attributable to Skeet Range activities.

Proposed future land use of the onshore areas adjacent to the Skeet Range consist of recreation and open space including a Bay Trail, shoreline park, and Point Alameda Regional Park (ARRA, 1996). The Bay Trail is the main feature planned to run the length of Oakland Alameda Estuary to allow full public access to the shoreline, whereas the tip of Alameda Point will be preserved as a regional park for fishing and other recreational uses. South of the point, the open areas will be used for recreational sports including potential construction of soccer and baseball fields and a golf course.

1.1.2 Hydrodynamic Setting

Circulation offshore of the Skeet Range is driven primarily by tidal currents and winds. The tidal cycle consists of two high and two low tides per day of unequal amplitude. The tides in the vicinity of the Skeet Range vary from approximately –0.5 m mean lower low water (MLLW) to +2.4 m during extreme spring tides. Site-specific tidal current measurements are not available; however, tidal current data for the entrance to Oakland Inner Harbor indicate that ebb currents are stronger than flood currents, with peak ebb tidal currents ranging from approximately 0.3 to 1.2 m/s and peak flood tidal currents ranging from about 0.3 to 0.7 m/s (NOAA, 2004). Field measurements of current speeds at the Oakland Inner Harbor entrance indicated velocities between approximately 0.25 to 0.50 m/s with peaks up to 1.07 m/sec (USACE and Port of Oakland, 1998). Currents along the western shore of Alameda Point flow to the south during flood tides and to the north during ebb tides.

The western shore of Alameda Point is exposed to wind-generated waves, particularly from the west-northwest (the prevailing wind direction). Summer winds in the bay area tend to show a strong diurnal variation, with strong afternoon sea breezes from the west-northwest. The summer mean wind speed was approximately 5-6 m/s and the maximum wind speeds were measured at about 15 m/s. Winter in the bay area is characterized by variable winds and periodic storms. Winds are typically from the south and southeast during a storm and shift to the northwest after its passage. The mean wind speed for winter was approximately 6 m/s and the maximum wind speeds were approximately 18 m/s.

1.1.3 Previous Investigation

The Skeet Range was identified as a specific area of concern based on the results of sediment sampling conducted as part of the 1994 Ecological Assessment for former NAS Alameda. One of five study areas evaluated in the Ecological Assessment was Western Bayside, a region of open bay water adjacent to the northern and western edges of former NAS Alameda. Of the 13 Western Bayside sample stations, two were located within the Skeet Range study area (i.e., Stations B03 and B04) (see Figure 1-4). Due to the presence of lead shot and PAHs measured at these stations, additional sampling and analysis was conducted in 1996 as a follow-on to the draft Operable Unit (OU) 4 ERA (PRC, 1996) and in 1998 as a part of the *Ecological Assessment of the Alameda Point Skeet Range Area* (TtEMI, 2000). The results from these investigations led to the designation of the Skeet Range as an Installation Restoration site (IR Site 29) in August 2000 during the development of the Site Management Plan for the Federal Facilities Agreement. Details regarding each of the historical investigations and their findings are presented in the following subsections.

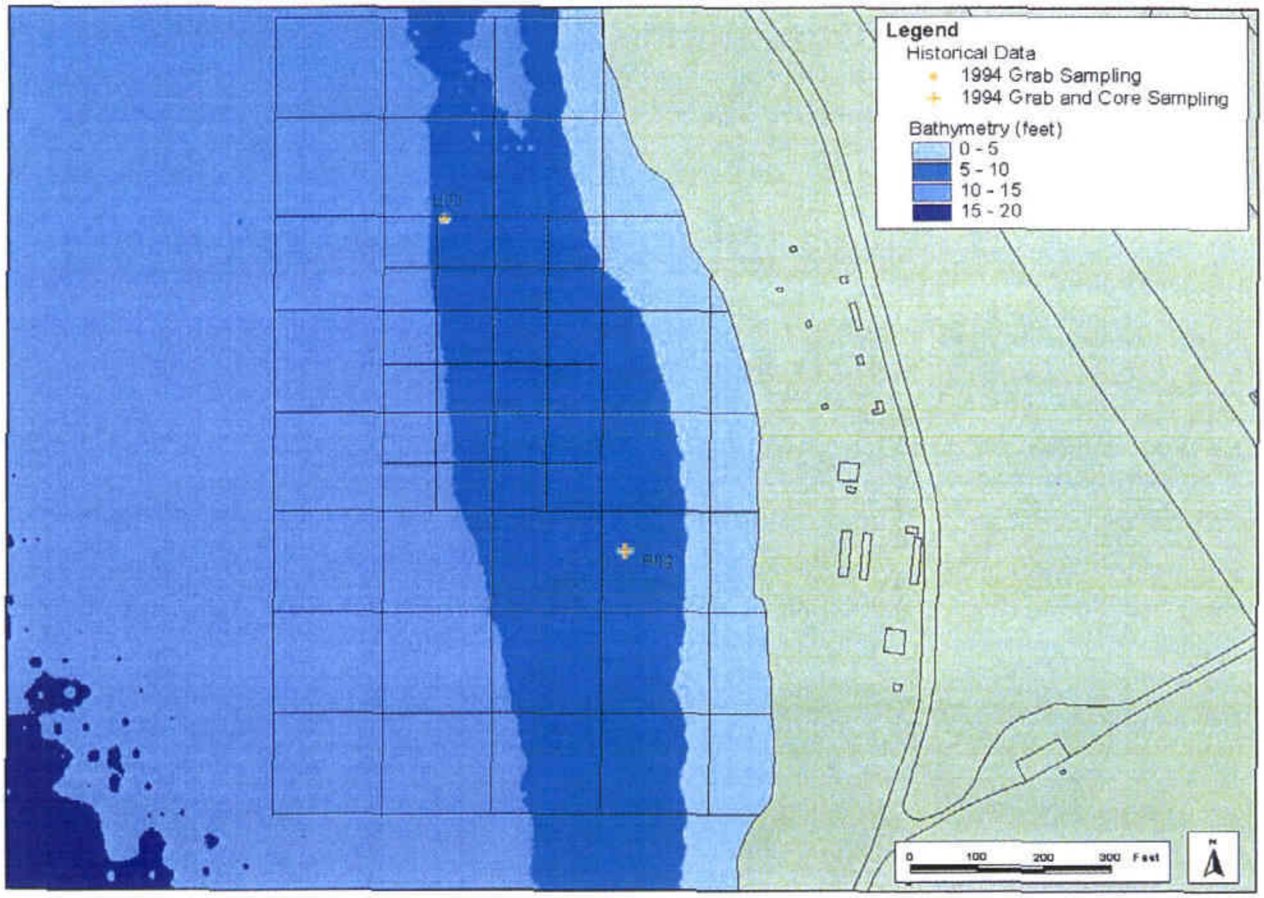

Figure 1-4. Sampling Stations from Collection Efforts in 1994

1.1.3.1 1996 OU 4 Ecological Assessment

Based on the results presented in the 1994 Ecological Assessment, PRC (subsequently called TtEMI) performed additional sampling and analysis as follow-on to the draft *OU 4 Ecological Risk Assessment* (PRC, 1996). Initially, a full reconnaissance of the site was performed where grab samples were collected every 45 ft along five transects (A through E) covering an angle of 90 degrees outward from each of the two (northern and southern) shooting ranges (Figure 1-5). The transects from each range were labeled A through E in a north to south direction from their point of origin (N-A through N-E in the northern shooting range, S-A through S-E in the southern shooting range). The approximate origin of each transect corresponded to the shooting stand of each range, and extended out to a distance of roughly 1,000 ft. Grab samples were sieved and weighted for lead shot and used to determine the approximate spatial distribution (i.e., fall zone) of lead shot over the site. Using the distributions, a series of arcs representing contaminant distribution were established for the northern and southern halves of the Skeet Range, which were used to develop the sampling plan. These arcs represented:

- The region of the Skeet Range at which shot density was greatest (middle arc)
- The inshore boundary of the Skeet Range at which shot density decreases (inner arc)
- The offshore boundary at which shot density decreases (outer arc).

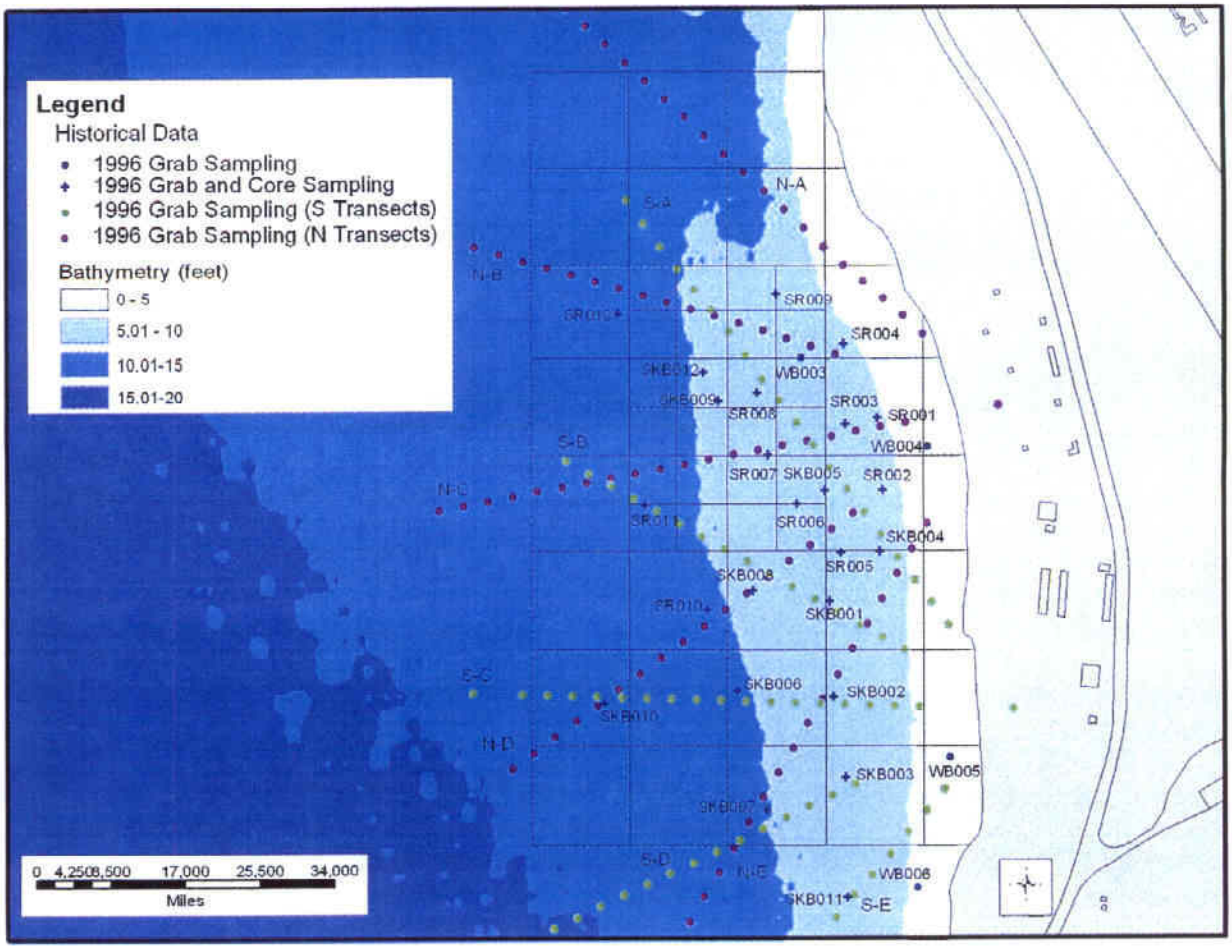

Figure 1-5. Sampling Stations from Collection Efforts in 1996

In addition to lead shot data, additional surface sediment samples were collected from the northern range (Stations SR001-SR012) and southern range (Stations SKB001-SKB012). The surface sediment samples were analyzed for metals (24 samples: Stations SKB001-SKB012 and SR001-SR012), PAH compounds (24 samples: Stations SKB001-SKB012 and SR001-SR012), and semivolatile organic compounds (SVOCs) (6 samples: Stations SKB001-SKB006). Additional grab samples were analyzed for total petroleum hydrocarbons (TPH) (2 samples: Stations WB003 and WB007) and pesticides and PCBs (7 samples: Stations WB001-WB007) at locations corresponding with porewater samples. Physico-chemical parameters (total organic carbon [TOC], ammonia [NH_3], dissolved oxygen [DO], sulfide, percent moisture, and percent fines) were tested in 33 of the samples collected (all were sampled from Stations SR001-SR012).

Based on the results of the field reconnaissance, 12 sediment core locations were sampled from select stations in the northern and southern ranges. At each range, five 3-ft core samples (4-inch diameter) were taken at locations along the middle arc (maximum density), and three core samples were taken at locations along the inner and outer arcs. One additional core was taken near the shore. The sample locations from the northern range were labeled SR001-SR012, and the sample locations from the southern range were labeled SKB001-SKB012. Each of the twenty-four, 3-ft Vibracore samples was divided into two 1.5-ft sections (from 0 ft to 1.5 ft and 1.5 to 3 ft below the sediment-water interface). The samples were analyzed for lead and PAHs to characterize the vertical extent of contamination. Samples were sieved to remove the lead shot prior to chemical analyses. Samples SKB001-SKB006 also were tested for semi-volatile organic compounds at each sampling depth.

Eight of the 24 core sampling locations were randomly selected for porewater analyses. These samples were collected using a Van Veen bottom grab sampler at 0 to 6 inches below the sediment-water interface. The sediment samples were centrifuged and the supernatant was used for porewater analysis of lead and PAHs. In addition, six of the porewater samples were tested for pesticides and PCBs (Stations WB001-WB006), and five were tested for TPH (Stations WB001-WB006, except WB003). Physico-chemical parameters were tested at Stations SR004, SR006, SR009, and SR010. The data collected from these samples are presented in the *Chemical Data Summary Report for Offshore Sediment* (TtEMI, 1998).

The 1996 study results were integrated with the 1998 investigation and presented in the *Ecological Assessment* (TtEMI, 2000). Based on the 1996 investigation, density of lead shot was highest in the area that overlaps the two shooting ranges. The study also included an investigation of the degree of dissolution of lead in sediment and porewater from lead pellets to determine if lead is biologically available. After sediments were sieved to remove lead shot, lead concentrations were analyzed in the sediment cores. The mean total lead concentration of surface sediment samples (less than 1.5 ft deep) was 31.2 mg/kg, which is below the California Regional Water Quality Control Board (RWQCB) San Francisco ambient value of 43.2 mg/kg, based on an 85th percentile of sediments with 40 to 100 percent fines (RWQCB, 1998). The average (31.2 mg/kg), minimum (14.6 mg/kg), and maximum (46.1 mg/kg) values of lead in surface sediment were below the effects range-low (ER-L) (46.7 mg/kg), indicating that lead exposure to benthic invertebrates is not significant. This led to the conclusion that the dissolved lead concentrations in sediment represent ambient conditions and lead dissolution into sediment appears to be an insignificant transport mechanism. Similar findings were found for dissolution of lead into porewater where the lead concentrations from Stations SKB004, SR004, SKB006, SR006, SKB009, SR009, SKB010, and SR010 were below detection limits based on the chronic ambient water quality criteria (AWQC) for protection of marine life. Data indicated that the lead is not dissolving in quantities that would be considered to be biologically of concern based on AWQC and is not present at concentrations that could cause adverse ecological effects (TtEMI, 2000).

PAH concentrations from sediment and porewater were compared against San Francisco Bay reference stations and ER-Ls. The data show that the concentrations of total PAHs found in the Skeet Range are comparable to concentrations measured from ambient locations. Concentrations within the Skeet Range either are relatively uniform with depth or (in several locations) increase with depth. Maximum concentrations of PAHs in some samples were found at depths greater than lead shot, suggesting that clay targets or Skeet Range activities are not responsible for the PAHs found in sediment.

1.1.3.2 1998 Supplemental Sampling

In 1998, additional sediment core samples were collected at the Skeet Range to further delineate the distribution of lead shot found at depth (TtEMI, 2000). Based on the 1996 investigation, the area of maximum lead shot density was located in the vicinity of sampling location SKB009 with decreasing density extending 10 acres from the shooting ranges. Ten sediment core samples were randomly collected from this area of highest lead shot density (see Figure 1-6). Only lead and PAHs were identified as constituents of concern based on the historical activities at the site. All ten sediment core sampling locations (Stations 1-1 to 1-5, and Stations 2-1 to 2-5) were collected using a push-coring device extending between 25 and 50 cm below the sediment surface. The top 10-cm section of each core was separated into 2-cm sections; below 10 cm, the cores were separated into 5-cm sections.

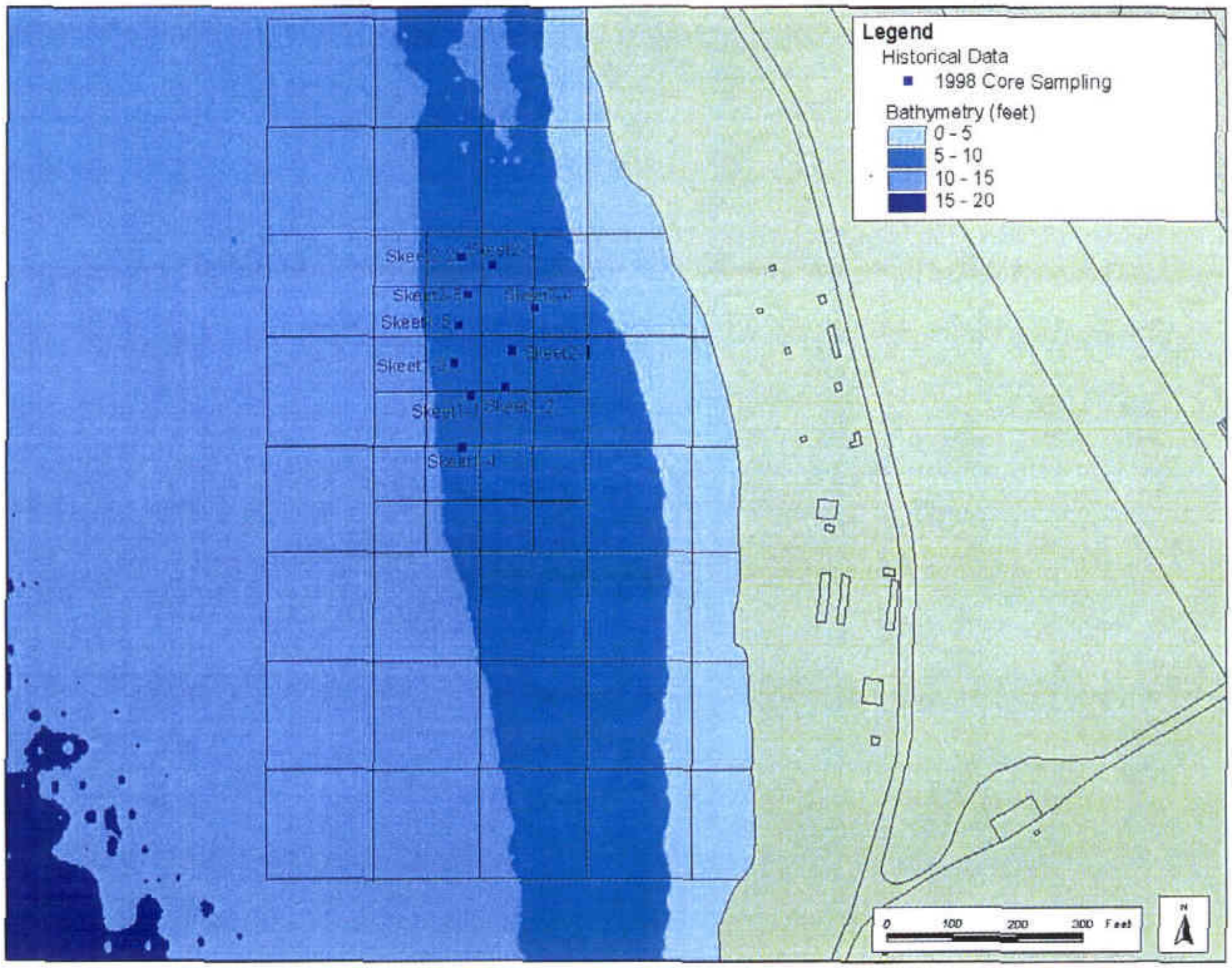

Figure 1-6. Sampling Stations from Collection Efforts in 1998

Results of the lead shot depth distribution analysis showed that the concentration of lead shot generally increases with depth to about 20 cm, with maximum concentration occurring between 4 and 20 cm. Lead shot was not detected in the 40- to 45-cm depth interval, indicating that the shot only occurs in the top 0.5 m of sediment. Lead shot was not typically found in the top 4 cm of sediment, suggesting that settling and sedimentation are leading to shot burial.

Incorporating the results from both the 1996 and 1998 investigation, the *Ecological Assessment* (TtEMI, 2000) concluded that the bulk and dissolved concentrations of lead and PAHs reflect ambient concentrations and are below AWQC. In addition, the lead shot depth distribution suggests that sediment accretion is burying the lead shot and unavailable for diving birds; and that PAH distribution may not be attributable to historical site operation.

On February 20, 2000, the *Ecological Assessment* was submitted to the RWQCB (TtEMI, 2000). The RWQCB identified several significant concerns regarding the conclusions of the report. The RWQCB disagreed with the finding that levels of lead and PAHs in sediments were within the range of ambient concentrations. The RWQCB also expressed concern about the relevance of applying results from the USACE sediment accretion studies to the Skeet Range. Finally, the RWQCB disagreed with the low significance of exposure and risks to diving birds from ingestion of shot as stated in the ERA. To address these concerns, the Sediment Work Group (i.e., Battelle, ENTRIX, and Neptune & Co.) conducted a field investigation in November 2001 to further characterize the spatial extent of lead shot distribution, determine the source of the PAH contamination, and develop sediment depositional rates. Results from this study are presented in Section 2.0.

1.2 RI Objectives

The primary objectives of this RI report are to evaluate the sediment quality at the Skeet Range, identify areas of unacceptable risk, and delineate the areas requiring evaluation in a Feasibility Study (FS) of remedial alternatives using the data collected from the recent field effort implemented in 2001. The specific objectives are as follows:

- Describe the physical site conditions and ecological setting;
- Describe the distribution of lead shot and grit measured in the surface and subsurface sediment;
- Present the findings of the PAH fingerprinting analysis and sediment dynamics study;
- Present the methods and results of the Ecological Risk Assessment (ERA);
- Present the conceptual site model (CSM) to identify potential human health exposures;
- Delineate the areas that pose unacceptable risks to human health and the environment and require evaluation in a FS of remedial alternatives; and,
- Propose preliminary acceptable lead shot levels in sediment that are health protective of human and ecological receptors.

1.3 Document Organization

The Draft RI Report is organized as follows:

Section 1.0: Introduction.

Section 2.0: 2001 Skeet Range Site Evaluation. This section describes the sample design, collection and analysis, and processing of the grab and cores collected in 2001 field study. This section also includes a description of the lead shot and grit count processing and how the clay fragments were composited for chemical analysis.

Section 3.0: Extent of Contamination. This section describes the distribution of lead shot and clay fragments found at the site and also presents the findings from the PAH fingerprinting analysis and sediment dynamics study.

Section 4.0: Ecological Risk Assessment. This section presents the results of the ERA for Skeet Range.

Section 5.0: Human Health Conceptual Site Model. This section presents the conceptual site model for human health exposures.

Section 6.0: Uncertainty Analysis. This section discusses the uncertainties associated with the analytical data, ecological assessment, and human health conceptual site model.

Section 7.0: Summary and Conclusions. This section presents the summary and conclusions of the draft RI report.

Section 8.0: References.

Summary of the 2001 field investigation and supporting white papers are presented in Appendices A through D:

Appendix A: Field Data
Appendix B: Draft PAH Fingerprinting Report
Appendix C: Skeet Range Sediment Dynamics Evaluation
Appendix D: Probability Model Issue Paper

Supporting documentation for the ERA data analysis is presented in Appendix E; responses to agency comments are presented in Appendix F.

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2.0 2001 SKEET RANGE SITE EVALUATION

Data collected from the previous field investigations in 1996 and 1998 were integrated into the *Ecological Assessment* (TtEMI, 2000) submitted to the RWQCB. In response to comments received from the RWQCB, the Sediment Work Group collected additional sediment grabs and cores in 2001 for analysis of lead shot and clay targets to further characterize the nature and extent of contamination and evaluate potential risks to upper trophic level species associated with sediment exposures as outlined in the *Skeet Range (IR Site 29) Evaluation Work Plan* (Battelle et al., 2001a). Details on the sampling method and sample processing are presented in the *Skeet Range Survey Report* (Battelle et al., 2001b). Excerpts from these reports describing the approach and methods used for conducting the 2001 Skeet Range Evaluation is presented below.

2.1 Objectives

The primary objectives of the 2001 evaluation were to define the extent of sediments that pose an unacceptable risk to ecological receptors as a result of former Skeet Range activities and to address the data gaps identified by RWQCB's review of the *Ecological Assessment* (TtEMI, 2000). Specific tasks to achieve these objectives were identified as follows:

- Characterize the potential for erosion or burial of lead shot and clay target fragments by determining the extent and depth of lead shot and clay target fragments present in sediment in order to identify if any contaminants are biologically available to ecological receptors;
- Determine if contaminant of potential ecological concern (COPEC) PAHs are present in the sediments at the site and if they are associated with clay target fragments or other sources (e.g., runoff, petroleum releases, fires, car exhaust) resulting from regional impacts; and,
- Obtain measurements of the site-specific, sediment accumulation rate to evaluate the degree of vertical mixing and the relative sediment dynamics in the area.

To meet each of these objectives, data quality objectives (DQOs; see Table 2-1) were developed in accordance with the United States Environmental Protection Agency's seven-step DQO process (U.S. EPA, 2000) to identify each type of data to be collected.

2.2 Sample Design

The sampling design followed in the Work Plan was developed to augment previous sampling efforts and address any identified data gaps. Based on the 1996 reconnaissance survey, the fall zone for the Skeet Range encompasses 19.5 acres offshore of the northwest edge of Alameda Point with a high impact zone of lead shot confined to a smaller, 3.6-acre area within the fall zone. Using the previous sampling data, sampling locations were selected following a judgmental sampling design using a fine grid (0.15-acre squares) on the high impact zone and coarse grid (0.6-acre squares) on the fall zone to ensure spatial representation of the Skeet Range (see Figure 2-1). An attempt was made to collect a grab sample from each of the grids. A total of 28 grab samples were collected from within the fall zone and 12 grabs were centered within the 3.6-acre high impact area. At each sampling location, the top 5 cm of material from the sediment grab were sieved and lead shot or grit particles found between 0.5 mm and 4 mm were collected. The presence or absence of prey animals and clay targets in sieve samples were noted on the sample collection form. Clay target fragments were hand-collected from the top sieve during the sieving process for fingerprinting analysis. A description of the sieving and counting processes of the lead shot is provided in Sections 2.3 and 2.4. Section 2.5 presents the compositing scheme for the clay target fragments collected during this field exercise.

In addition to the sediment grabs, two co-located sediment cores were collected at 25 specified locations. Co-located push cores of 20 cm length were collected at 22 locations for lead shot and PAH analysis including 11 from the 3.6-acre high-impact area, and 14 from the larger fall zone area. Five cores from the 1996 sampling and five cores from the 1998 sampling were re-evaluated during this sampling effort. Four of the 22 cores were collected from grid locations bordering the shoreline to determine whether PAH concentrations are a result of land-based activities. Two reference cores were collected, one to the north and one to the south of the fall zone, in order to provide ambient PAH concentrations. The findings from the PAH fingerprinting analysis are discussed in Section 3.2.

In addition, 100-cm-long co-located push cores were collected at three locations for lead shot, PAH, and radioisotope analysis. These cores were collected from the most northern, southern, and western sampling stations where lead shot is absent to obtain an undisturbed sediment profile. The results from these samples were used in the sediment dynamics study to determine accretion rates of sediments at the Skeet Range.

2.3 Sample Preparation

Sample preparation procedures for surface grab samples, sediment short core samples, and sediment long core samples are described in Sections 2.3.1, 2.3.2, and 2.3.3, respectively. Sample processing for lead and grit count is discussed in Section 2.4, and clay fragment compositing and analysis are discussed in Section 2.5.

2.3.1 Sediment Grabs

Sediment grab samples were collected at 40 stations using a 0.1-m^2 Van Veen grab sampler. Duplicate samples were collected at four stations (i.e., SK-26, SK-42, SK-45, and SK-65) and processed in the same manner as the original sample for field quality control. Grab sample collection information is provided in Table 2-2; sampling stations are shown on Figure 2-1. For each acceptable grab sample, the top 5 cm of sediment was collected using a stainless steel scoop and processed through three nested sieves: a U.S. Standard sieve #5, which retains material greater than 4.0 mm; a U.S. Standard sieve #10, which retains material greater than 2.0 mm; and a U.S. Standard sieve #35, which retains material greater than 0.5 mm. Sea water pumped from the barge through a hose was gently applied to the sieve to force smaller material to the lower sieves. Materials retained in each sieve are described the *Field Survey Report* (Battelle et al., 2001b). The retained materials (including lead shot and grit particles) then were placed in labeled zip-lock bags and transported to the Battelle Duxbury Operations laboratory (BDO) for enumeration. Section 2.4 presents the counting procedures followed by the laboratory.

2.3.2 Sediment Short Cores

Duplicate short cores designated Core A and Core B were collected from 24 stations (Stations SK-4 through SK-25, and reference stations SK-66 and SK-67) using a double 2.5-inch gravity corer. Core sampling information is provided in Table 2-3. Duplicate samples were collected at Stations SK-7, SK-19, and SK-25 as field quality controls. The samples were collected using a double gravity corer with two-core barrel fitted with a 49-cm length of steam-cleaned 2.5-inch inner diameter polycarbonate core liner attached to a weighted coring head consisting of a check valve for each core barrel. The coring head with double 2.5-inch core barrels was lowered to the sediment surface and allowed to slowly penetrate the sediment with its own weight to minimize disturbance or compaction of the sediment. Depth of penetration was estimated at 45 to 50 cm so that a minimum of 20 cm of sediment was retained in each barrel. The core liners then were removed from the barrels and capped. Each core was labeled and then processed depending on the analysis to be performed.

Core A was processed and analyzed for clay target fragments, lead shot and grit abundance. Core A samples were placed upright in the plunger of a 2.5-inch core extruder and gently extruded upward 5 cm at a time. A spatula was used to cut the core into 5-cm increments to a depth of 20 cm. Each 5-cm increment of sediment was sieved through 4-mm, 2-mm, and 0.5-mm sieves following the same procedure as for the grab samples (described in Section 2.3.1). Fresh water supplied on shore was used to wash the sediment through the nested sieves. Materials retained in each of the sieve are described in the *Field Survey Report* (Battelle et al., 2001b). Clay fragments retained in the 4-mm sieve were collected and placed in labeled, certified-clean glass jars with Teflon™-lined lids, and placed in a cooler with ice (see Section 2.5 for description of clay fragment compositing). All other materials retained in the 4-mm sieve were discarded. As with the grab sample procedure, lead shot and any other material retained in the 0.5 and 2-mm screens were placed in labeled zip-lock bags and shipped to the laboratory for placed in a cooler with ice. These samples later were sent to BDO for enumeration.

Core B was extruded for organic compound analysis. Following the procedures described for Core A, the samples were cut into 5-cm increments from the surface to a depth of 20 cm using a clean spatula and placed into a certified clean glass jar with Teflon™-lined lid. Half of the sediment from each 5-cm increment was sent to BDO for PAH analysis, and the other half was sent to Severn Trent Laboratory (STL) in Santa Ana, CA for total petroleum hydrocarbons-diesel range organics (TPH-DRO) analysis. Each sample was homogenized and sample aliquots collected in the laboratory using clean, solvent-rinsed stainless steel spoons for the chemical analyses. Core B processing data are provided in Table 2-4. Core A processing data are provided in Table 2-5.

2.3.3 Sediment Long Cores

Duplicate long cores designated as Core A and B were collected from three stations (SK-1, SK-2, and SK-3) using a single gravity corer lined with a 3.5-inch inner diameter butyrate liner. The longer gravity cores also were collected by allowing the sampler to penetrate the sediment under its own weight to approximately 150 cm so that a minimum of 102 cm of sediment was retained in each core. The cores then were brought to shore for processing. Long core collection information is provided in Tables 2-4 and 2-5.

Each long Core A was processed following the same procedure as the short Core A samples. The top 20 cm were split into 5-cm increments, each of which was sieved through the stack of 4-mm, 2-mm, and 0.5-mm sieves and sampled for clay target fragments, lead shot, and grit particles as described in Section 2.3.2.

Each long Core B was subsampled for organic compounds and radioisotope analysis. The core was placed on Teflon™-lined table and cut longitudinally using an electric Kett Power Shear model 442 saw. One half (Side 1) was used to collect samples for organic compound analysis, and the other half (Side 2) was used for radioisotope analysis. Side 1 of the long Core B was partitioned into 5-cm increments from 0 to 25 cm. Three additional organics samples were collected from 45-50 cm, 70-75 cm, and 95-100 cm increments. Half of the sediment from each 5-cm increment of Side 1 was collected for PAH analysis, the other half was collected for TPH-DRO analysis. Sediment was scooped out of each measured segment using a clean stainless steel spatula and placed in labeled, certified-clean glass jars with Teflon™-lined lids. Samples then were sent to BDO and STL for PAH and TPH-DRO analyses, respectively. A detailed physical description of Side 2 of long Core B, including color, sediment type, structure, odor, and particle size, was recorded in the core logs (see Appendix A). Side 2 then was partitioned into eleven 2-cm sections: 0-2, 10-12, 20-22, 30-32, 40-42, 50-52, 60-62, 70-72, 80-82, 90-92, and 100-102 cm. Sediment from each 2-cm horizon was placed into a labeled, tared polystyrene container using a small wooden spatula. The samples were shipped to Battelle Marine Sciences Laboratory in Sequim, WA, for radioisotope analysis. Core B processing data is provided in Table 2-4.

2.4 Lead Shot and Grit Count Processing

Grab samples and Core A samples from both the long and short cores were sent to BDO for enumeration of lead shot and grit particles. Initially, the samples were visually inspected to identify any inconsistencies in particle size. Samples that appeared to contain larger-sized particles were resieved through the 0.5-mm sieve. Following this step, each sample was emptied into a glass bowl, and placed on a light box so that the contents could be examined under a magnifying lamp.

The lead shot and grit particles then were individually counted for each sample. For this analysis, the term "grit" was defined as any solid object, other than lead shot, with a diameter greater than 0.5 mm. This included rock, sand, brick, bone, wood, clay target fragments, and pieces of shell. Organic matter including worms, worm-tubes, algae, and pellets of mud were not counted.

The lead and grit counts from the cores were processed with minimal of difficulty; however, this was not the case for the grab samples. Because the grab samples consisted of a larger volume of sediment, the top few centimeters of the samples contained a thick matte of *Ampelisca abdita* tubes that could not be removed in the field. The top 5 cm of sediment at the majority of the Skeet Range sample stations consisted almost entirely of *Ampelisca* tubes (Figure 2-2). In most cases, the tubes were very densely packed and extended approximately 2-3 cm into the overlying water. Numerous polychaetes up to 12 cm long also were observed in many of the grab samples. Consequently, approximately 200 of the samples arrived in the laboratory with the tubes, lead shot, and grit particles coalesced with the sediment which made it impossible to separate the lead shot and grit following the procedures used for the core samples.

To resolve this problem, several attempts were made to oven dry the samples. The first attempt was at a relatively low temperature (approximately 25°C), which required one week for adequate drying. The temperature therefore was raised to 50°C, but at this higher temperature the samples became quite hard. Pieces were broken off from the dried sample and resieved through the 0.5 mm screen, but the original problem resurfaced with much of the organic material remaining intact. The samples then were rehydrated and oven-dried again with the same results. Other trials included drying the samples to approximately 90°C, which formed very hard pellets that were not easily broken up by hand.

Through trial and error, the best method to separate the grit from the tubes was through decomposition. After the samples were allowed to decompose at room temperature for one week, they were placed in 4-L beakers and slowly flushed with large quantities of tap water while gently agitating the mixture by hand. As much worm matter as possible was decanted while retaining 100% of the grit. The mixture then was resieved through both the 2 mm and 0.5 mm sieves. The remaining mixture in the sieves then were placed on aluminum weighing pans and dried in the oven at 50°C for a minimum of 2 days for final decomposition of the remaining worm matter.

Of the 200 samples impacted, 111 of these samples were discarded due to the absence of lead shot. The remaining 89 samples were processed to remove the worm tubes as described above. For samples containing less than 200 grit pieces, the counted was conducted by hand. For samples consisting of more than 200 pieces, the total grit count was estimated as follows:

1. The dried sample after decomposition was spread evenly in a dissection bowl.
2. The sample was subdivided evenly maintaining a representative subsample in each fraction until a fraction was developed that contained approximately 100 grit pieces.
3. This fraction (the aliquot) was counted exactly by hand.

4. The aliquot was weighed in a labeled and tared weighing pan.

5. The remainder of the sample then was added to the aliquot in the weighing dish to determine total weight.

6. The total grit count of the sample was estimated using the following equation:

$$(\text{aliquot count})(\text{total weight}) \big/ (\text{aliquot weight}) = \text{total count}$$

Deviations encountered during the lead shot and grit count processing are described in detail in Appendix A. Two grit samples (i.e., AAE-527-A and AAE-551-A) from Stations SK-39 and SK-56 were lost while processing as a result of an accident in which sample SK-39 was spilled during processing and SK-56 was accidentally discarded before the grit count was performed. Consequently, no grit count was conducted on samples SK-39 and SK-56, although lead shot was found in these samples.

2.5 Clay Fragment Composite

During the sampling effort, clay target fragments retained in the 4-mm sieve were collected and placed in labeled, certified-clean glass jars with Teflon™-lined lids, and all other materials were discarded. Solid materials believed to be clay targets were observed in 30 of the 131 sediment samples processed, and majority of these samples were too small to confidently process alone for chemical analysis. Upon arrival in the BDO laboratory, visual inspection suggested that all but five of these fragment samples were too small to process individually for chemical fingerprinting. As a result, the remaining 25 fragment samples were composited into six samples as indicated in Table 2-6 (see Figure 2-3). The strategy for compositing small fragment samples was primarily driven by the locations (i.e., an effort was made to group samples from the same vicinity until enough masses of fragments were available to confidently analyze). This resulted in 11 samples (six composites and five individual samples) that were considered representative of the clay fragment population contained in the sediments collected.

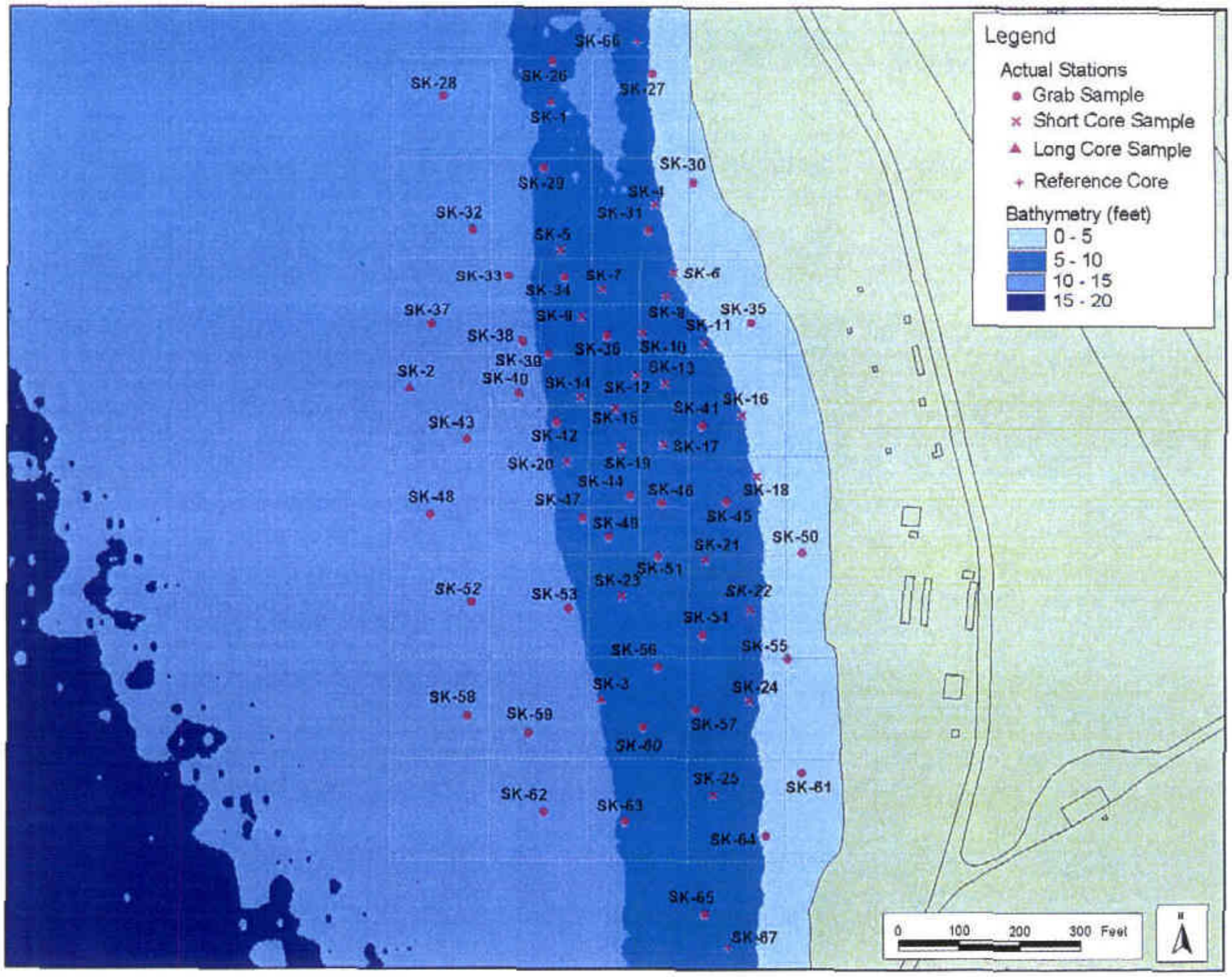

Figure 2-1. Sediment Grab and Core Sampling Locations from 2001 Investigation

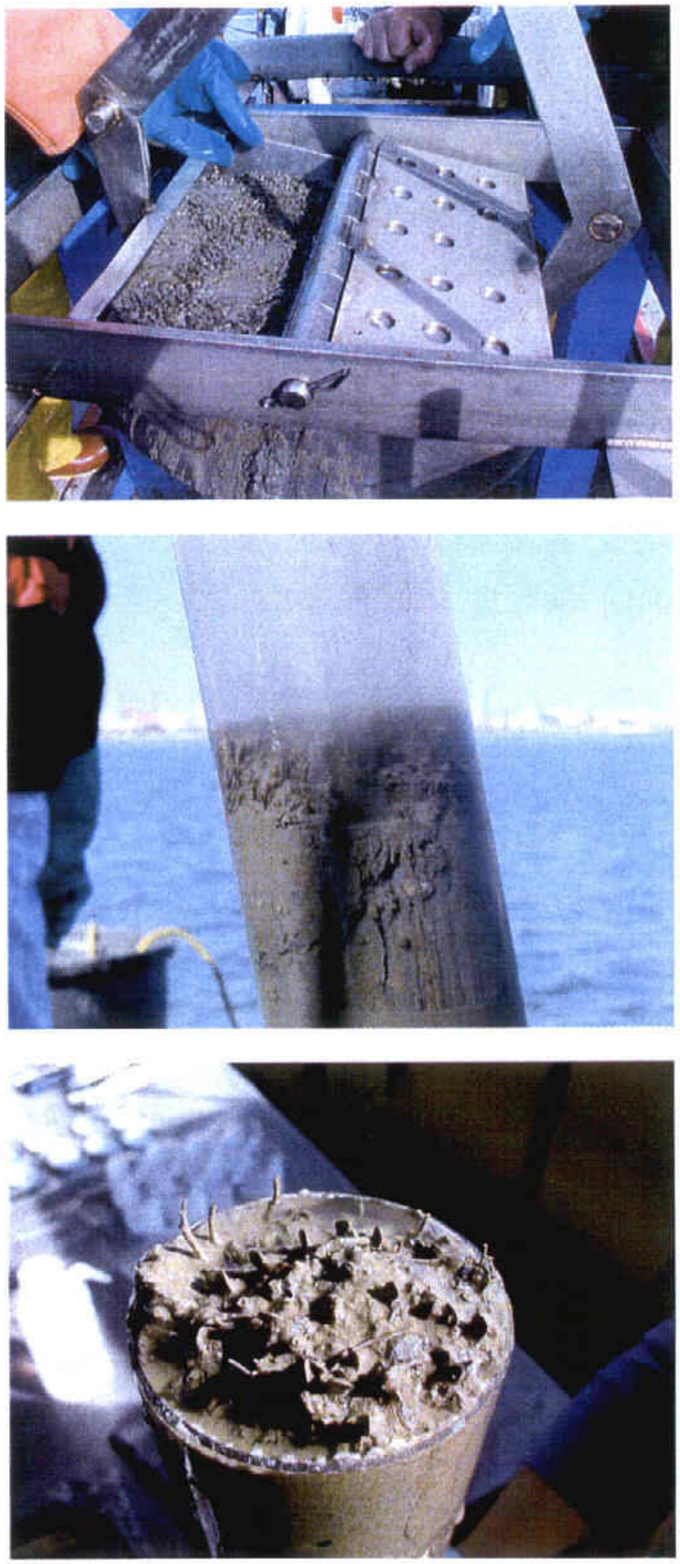

Figure 2-2. Photos of *Ampelisca* (Amphipod) Mats from Skeet Range Sampling Event (November 2001)

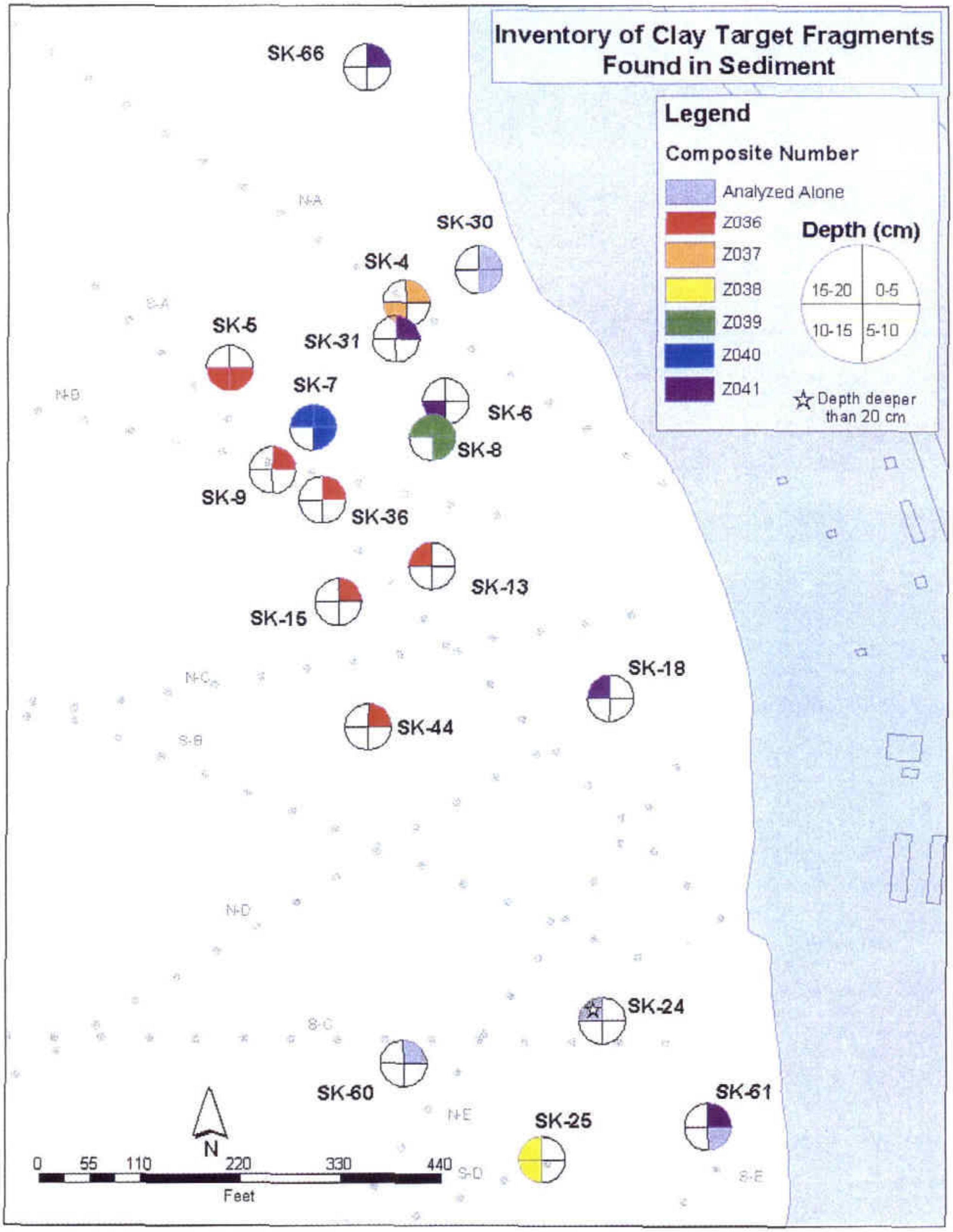

Figure 2-3. Inventory of Clay Fragments Found in Sediment

Table 2-1. Data Quality Objectives for Skeet Range Sampling Plan

STEP 1: State the Problem Existing data indicate that lead shot and fragments of clay pigeons are present in sediments offshore of Alameda Point in the vicinity of the former Skeet Range. There is concern about the potential ecological risk associated with the lead shot, and PAHs released from clay pigeons. In particular, the potential exposure of lead shot to diving birds is of concern. The question being posed is whether natural sediment dynamics are burying the shot to the extent that they are no longer available for ingestion, or whether these dynamics are acting in such a way as to maintain or enhance availability of the shot. Data are needed to fill gaps in the historical evaluations to assess lead shot abundance and location (including depth), to assess sediment dynamics, and to support the assessment of ecological risk associated with the shot and PAHs that are related to the clay pigeons.
STEP 2: Identify the Decision 1. Is lead shot available to diving birds in the surface sediment at the Alameda Point Skeet Range, and if so, does it pose an unacceptable risk to diving birds? 2. Are PAHs detected in the sediment associated with the clay pigeon fragments or other sources and whether the PAH concentrations pose an unacceptable risk?
STEP 3: Identify Inputs to the Decision 1. Number of lead shot per unit volume of sediment in 0-5 cm (grab samples) to characterize the potential exposure to most diving birds. 2. Number of lead shot per unit volume of sediment and PAH concentrations in 0-5 cm, 5-10 cm, 10-15 cm, and 15-20 cm depths (push cores) to characterize the worst-case scenario for diving birds, and also to determine the fate of lead shot and clay targets in the environment. 3. Abundance of lead shot and other grit size particles per unit volume of sediment between 0.5 mm and 4.0 mm (#5 and #35 sieve sizes). 4. Total volume of sediment in each grab and core sample (upper 5 cm and upper 10 cm) in the area where historically elevated lead was observed. 5. Field observations of the type and general abundance of benthic organisms and pieces of clay target taken in shot samples (qualitative field notes to determine if this area is a potential feeding area, and if clay target material is present). 6. Modeled predictions of the probability of lead shot ingestion and associated risk to diving birds to establish a biologically relevant risk-based criterion for lead shot. 7. PAH concentrations in Skeet Range sediments (0-5, 5-10, 10-15, 15-20, 20-25, 45-50, 70-75, and 95-100 cm depth intervals) with resolution sufficient to fingerprint PAHs associated with clay pigeon versus other potential PAH sources at Alameda Point. 8. Radioisotope analyses at 10 depth intervals in three core samples (assuming 1 cm/yr accretion and desire to represent 100 years) to determine long-term sedimentation rates. 9. Results of existing hydrodynamic data analysis to predict erosion and burial of lead shot. 10. Bathymetric survey of the Skeet Range area to assist in sampling design and determination of potential scouring areas.
STEP 4: Define the Study Boundaries The area potentially affected by the former Skeet Range encompasses sediments to the west/northwest of the Alameda Point Skeet Range. The 5 cm depth represents the extent of potential exposure to most diving birds with 10 cm representing a worst case. Lead shot buried below 10 cm are not considered biologically available for the avian species being evaluated. No specific temporal boundaries are of concern for the surficial sediment studies. To assist in understanding sediment accumulation rates, radioisotope analysis will be conducted on sediments representing the past 100 years of accumulation. Based on area-wide accretion studies, the top 100 cm of sediment is assumed to represent this time frame.
STEP 5: Develop a Decision Rule If data indicate that natural sediment processes are acting to prevent unacceptable exposure to lead shot, and are not expected to result in scouring or otherwise re-expose the shot, no action will be required to protect birds from the shot. If data indicate that shot continue to be available, and the risk is considered unacceptable, consider potential remedial actions to protect the ecosystem. If PAHs in Skeet Range sediments are fingerprinted as being associated with clay pigeons, ecological risks associated with exposure from these compounds will be evaluated based on exposure and toxicity information from the literature. If unacceptable risks to ecological receptors are determined for PAHs correlated to the clay pigeons, the potential leachability of PAHs from clay targets will be determined based on studies performed at similar shooting ranges.
STEP 6: Evaluate Decision Errors Data from the lead shot and PAH investigations could over- or underestimate toxicity and potential risks to ecological receptors. In general, if ecological risk is overestimated (false positive) based on a higher density or depth of lead shot, a possible consequence is unnecessary remedial work that may itself have detrimental impacts to the existing environment. If ecological risk is underestimated, a possible consequence is to fail to conclude that remedial action is required and biological systems may continue to be detrimentally impacted.
STEP 7: Optimize the Design for Obtaining Data Sampling locations were devised using a gridded sampling design based on historic information and best professional judgment to ensure spatial representation of the Skeet Range. In order to optimize the sampling design, a course and fine grid patterns were overlayed on the 20-acre outfall area. The fine sampling grid consisted of 0.15-acre grid squares over a target area of 3.6 acres where the highest lead shot concentrations were previously detected. Target grab sample locations were assigned based on the delineated surface shot distribution from the 1996 data and are co-located with several previously sampled stations. A larger course grid pattern (0.6 acre grid size) over the entire area spans the original outfall area. Approximately, one sample was selected in each of the gridded areas in order to ensure that the entire outfall area was represented. Cores for PAH analysis were located further inshore as the potential dispersion distance of the clay targets is shorter than that of the shot.

Table 2-2. Grab Sample Coordinates

Station	Date Collected	Time Collected	Location (Lat Long, NAD83)		Uncorrected Water Depth (ft)	Corrected Water Depth (-ft MLLW) [(a)]
			Latitude (N)	Longitude (W)		
SK-26	11/10/01	1027	37º 47.7428'	122º 19.9650'	15.2	10.6
SK-26 DUP	11/10/01	1050	37º 47.7428'	122º 19.9650'	15.2	10.9
SK-27	11/10/01	0901	37º 47.7399'	122º 19.9319'	11.0	4.9
SK-28	11/10/01	1107	37º 47.7326'	122º 20.0028'	16.2	12.2
SK-29	11/10/01	1137	37º 47.7145'	122º 19.9674'	13.7	10.3
SK-30	11/10/01	1004	37º 47.7113'	122º 19.9168'	6.9	1.7
SK-31	11/10/01	1229	37º 47.6985'	122º 19.9316'	11.4	8.9
SK-32	11/10/01	1244	37º 47.6974'	122º 19.9916'	14.8	12.4
SK-33	11/10/01	1255	37º 47.6852'	122º 19.9781'	14.2	11.9
SK-34	11/10/01	1335	37º 47.6850'	122º 19.9596'	12.0	10.0
SK-35	11/11/01	0902	37º 47.6731'	122º 19.8950'	10.1	3.5
SK-36	11/10/01	1349	37º 47.6694'	122º 19.9440'	11.1	9.2
SK-37	11/10/01	1310	37º 47.6711'	122º 20.0045'	14.7	12.6
SK-38	11/10/01	1321	37º 47.6674'	122º 19.9735'	13.3	11.3
SK-39	11/11/01	0936	37º 47.6641'	122º 19.9647'	17.8	11.4
SK-40	11/11/01	0951	37º 47.6530'	122º 19.9743'	18.8	12.5
SK-41	11/11/01	0916	37º 47.6462'	122º 19.9111'	15.5	8.9
SK-42	11/11/01	1019	37º 47.6460'	122º 19.9618'	17.1	11.2
SK-42 DUP	11/11/01	1029	37º 47.6462'	122º 19.9629'	17.1	11.4
SK-43	11/11/01	1006	37º 47.6413'	122º 19.9914'	19.3	13.2
SK-44	11/11/01	1058	37º 47.6270'	122º 19.0352'	13.8	8.7
SK-45	11/11/01	0834	37º 47.6260'	122º 19.9020'	15.6	9.1
SK-45 DUP	11/11/01	0843	37º 47.6252'	122º 19.9006'	15.6	9.0
SK-46	11/11/01	1041	37º 47.6252'	122º 19.9247'	14.4	9.0
SK-47	11/13/01	0851	37º 47.621'	122º 19.951'	15.1	8.8
SK-48	11/13/01	1132	37º 47.621'	122º 20.003'	19.4	13.0
SK-49	11/13/01	1117	37º 47.616'	122º 19.942'	16.0	9.3
SK-50	11/11/01	0853	37º 47.6133'	122º 19.8766'	9.1	2.5
SK-51	11/13/01	1208	37º 47.611'	122º 19.925'	14.6	9.1
SK-52	11/13/01	1146	37º 47.598'	122º 19.988'	19.5	13.5
SK-53	11/13/01	1157	37º 47.597'	122º 19.955'	16.6	10.8
SK-54	11/13/01	1222	37º 47.591'	122º 19.909'	13.5	8.3
SK-55	11/13/01	0914	37º 47.585'	122º 19.880'	9.2	2.4
SK-56	11/13/01	1236	37º 47.582'	122º 19.924'	13.7	9.0
SK-57	11/13/01	1254	37º 47.571'	122º 19.911'	12.8	8.4
SK-58	11/14/01	0822	37º 47.5688'	122º 19.9892'	19.7	14.4
SK-59	11/14/01	0837	37º 47.5643'	122º 19.9687'	18.8	13.4
SK-60	11/14/01	0847	37º 47.5664'	122º 19.9291'	15.2	9.5
SK-61	11/13/01	0936	37º 47.555'	122º 19.874'	6.8	-0.2
SK-62	11/14/01	0858	37º 47.5435'	122º 19.9621'	20.1	14.2
SK-63	11/14/01	0906	37º 47.5412'	122º 19.9340'	16.0	9.8
SK-64	11/13/01	0957	37º 47.538'	122º 19.886'	11.9	4.8
SK-65	11/13/01	1049	37º 47.517'	122º 19.906'	14.3	7.2
SK-65 DUP	11/13/01	1056	37º 47.517'	122º 19.904'	14.3	7.4

(a) Water depth correction to mean lower low water (MLLW) calculated using the predicted tidal height at Alameda Station.
rep: replicate sample.

Table 2-3. Core Sample Coordinates

Station	Date Collected	Time Collected	Location (Lat Long, NAD83)		Uncorrected Water Depth (ft)	Corrected Water Depth (-ft MLLW)[a]	Core A (Physical)		Core B (Chemical)	
			Latitude (N)	Longitude (W)			Core Retained	Sample ID	Core Retained	Sample ID
SK-1	11/05/01	1344	37º 47.732'	122º 19.965'	16.9	10.6	113	AAE-002	110	AAE-001
SK-2	11/05/01	1435	37º 47.655'	122º 20.011'	19.0	12.4	110	AAE-004	110	AAE-003
SK-3	11/06/01	0956	37º 47.574'	122º 19.943'	14.0	10.3	30	AAE-006	141	AAE-005
SK-4	11/08/01	1249	37º 47.7054'	122º 19.9298'	12.4	9.0	40	AAE-045	38	AAE-046
SK-5	11/08/01	1053	37º 47.6930'	122º 19.9617'	12.8	9.3	35	AAE-049	38	AAE-050
SK-6	11/09/01	1005	37º 47.6876'	122º 19.9227'	11.7	7.2	47	AAE-055	42	AAE-056
SK-7	11/08/01	0842	37º 47.6826'	122º 19.9464'	14.1	9.3	44	AAE-033	48	AAE-034
SK-7 DUP	11/08/01	0852	37º 47.6826'	122º 19.9464'	14.1	9.3	44	AAE-035	35	AAE-036
SK-8	11/08/01	0928	37º 47.6806'	122º 19.9241'	12.6	8.3	47	AAE-039	47	AAE-040
SK-9	11/08/01	0952	37º 47.6741'	122º 19.9532'	12.5	8.5	40	AAE-037	32	AAE-038
SK-10	11/06/01	1142	37º 47.670'	122º 19.932'	13.5	8.9	43	AAE-007	30	AAE-008
SK-11	11/06/01	1402	37º 47.668'	122º 19.911'	12.1	6.1	38	AAE-017	46	AAE-018
SK-12	11/06/01	1250	37º 47.659'	122º 19.934'	14.0	8.9	28	AAE-009	48	AAE-010
SK-13	11/06/01	1320	37º 47.657'	122º 19.924'	14.2	8.5	37	AAE-019	41	AAE-020
SK-14	11/07/01	1045	37º 47.6530'	122º 19.9533'	12.8	9.2	42	AAE-027	32	AAE-028
SK-15	11/07/01	0921	37º 47.6502'	122º 19.9417'	12.2	8.4	42	AAE-015	49	AAE-016
SK-16	11/07/01	1256	37º 47.6492'	122º 19.8982'	10.1	5.6	39	AAE-023	34	AAE-024
SK-17	11/08/01	1350	37º 47.6419'	122º 19.9245'	12.2	8.3	39	AAE-043	43	AAE-044
SK-18	11/09/01	1045	37º 47.6338'	122º 19.8924'	9.9	6.1	44	AAE-057	44	AAE-058
SK-19	11/07/01	0942	37º 47.6406'	122º 19.9384'	12.0	8.3	39	AAE-011	44	AAE-012
SK-19 DUP	11/07/01	0959	37º 47.6406'	122º 19.9384'	12.0	8.3	26	AAE-029	22	AAE-030
SK-20	11/07/01	1211	37º 47.6368'	122º 19.9576'	13.2	9.1	32	AAE-025	34	AAE-026
SK-21	11/08/01	1435	37º 47.6117'	122º 19.9098'	12.1	7.7	45	AAE-041	39	AAE-042
SK-22	11/09/01	1124	37º 47.5983'	122º 19.8933'	10.3	6.9	36	AAE-059	42	AAE-060
SK-23	11/08/01	1505	37º 47.6012'	122º 19.9370'	13.9	9.2	40	AAE-051	39	AAE-052
SK-24	11/09/01	1225	37º 47.574'	122º 19.893'	8.3	5.5	22	AAE-061	37	AAE-062
SK-25	11/07/01	1357	37º 47.5494'	122º 19.9048'	14.0	8.9	47	AAE-021	30	AAE-022
SK-25 DUP	11/07/01	1412	37º 47.5494'	122º 19.9048'	14.0	8.9	36	AAE-031	46	AAE-032
SK-66	11/08/01	1122	37º 47.7480'	122º 19.9365'	12.5	9.2	29	AAE-047	28	AAE-048
SK-67	11/08/01	1550	37º 47.5095'	122º 19.8989'	11.2	6.1	38	AAE-053	>20 (NR)	AAE-054

(a) Water depth correction to mean lower low water (MLLW) calculated using the predicted tidal height at Alameda Station.
NR = not recorded.
DUP = field duplicate.

Table 2-4. Summary of Results from Collection of Core B Samples

Station	Field Sample ID	Processing Date	Processing Time	Depth Interval (cm)		Chemistry Sample ID[a] –Side 1	Chemistry Sample ID[b] – Side 2
SK-1	AAE-001	11/05/01	1618	0	5	AAE-102-B	NA
			1618			AAE-102-C	NA
			1618	5	10	AAE-103-B	NA
			1619			AAE-103-C	NA
			1619	10	15	AAE-104-B	NA
			1620			AAE-104-C	NA
			1621	15	20	AAE-105-B	NA
			1621			AAE-105-C	NA
			1622	20	25	AAE-106-B	NA
			1622			AAE-106-C	NA
			1624	45	50	AAE-107-B	NA
			1624			AAE-107-C	NA
			1625	70	75	AAE-108-B	NA
			1626			AAE-108-C	NA
			1626	95	100	AAE-109-B	NA
			1627			AAE-109-C	NA
			1651	0	2	NA	AAE-83-D
			1653	10	12	NA	AAE-84-D
			1655	20	22	NA	AAE-91-D
			1657	30	32	NA	AAE-89-D
			1656	40	42	NA	AAE-87-D
			1657	50	52	NA	AAE-90-D
			1657	60	62	NA	AAE-92-D
			1659	70	72	NA	AAE-93-D
			1702	80	82	NA	AAE-94-D
			1656	90	92	NA	AAE-86-D
			1655	100	102	NA	AAE-88-D
SK-2	AAE-003	11/05/01	1708	0	5	AAE-110-B	NA
						AAE-110-C	NA
			1710	5	10	AAE-111-B	NA
						AAE-111-C	NA
			1712	10	15	AAE-112-B	NA
						AAE-112-C	NA
			1714	15	20	AAE-113-B	NA
						AAE-113-C	NA
			1714	20	25	AAE-114-B	NA
						AAE-114-C	NA
			1716	45	50	AAE-115-B	NA
						AAE-115-C	NA
			1718	70	75	AAE-116-B	NA
						AAE-116-C	NA
			1720	95	100	AAE-117-B	NA
						AAE-117-C	NA
			1732	0	2	NA	AAE-99-D
			1748	10	12	NA	AAE-74-D
			1718	20	22	NA	AAE-80-D
			1725	30	32	NA	AAE-79-D
			1741	40	42	NA	AAE-76-D
			1722	50	52	NA	AAE-82-D
			1748	60	62	NA	AAE-77-D
			1733	70	72	NA	AAE-85-D

Table 2-4. Summary of Results from Collection of Core B Samples (page 2 of 6)

Station	Field Sample ID	Processing Date	Processing Time	Depth Interval (cm)		Chemistry Sample ID[a] –Side 1	Chemistry Sample ID[b] – Side 2
SK-2	AAE-003	11/05/01	1745	80	82	NA	AAE-75-D
			1752	90	92	NA	AAE-78-D
			1754	100	102	NA	AAE-81-D
SK-3	AAE-005	11/06/01	1100	0	5	AAE-119-B	NA
						AAE-119-C	NA
			1105	5	10	AAE-120-B	NA
						AAE-120-C	NA
			1109	10	15	AAE-121-B	NA
						AAE-121-C	NA
			1117	15	20	AAE-122-B	NA
						AAE-122-C	NA
			1120	20	25	AAE-123-B	NA
						AAE-123-C	NA
			1125	45	50	AAE-124-B	NA
						AAE-124-C	NA
			1133	70	75	AAE-125-B	NA
						AAE-125-C	NA
			1137	95	100	AAE-126-B	NA
						AAE-126-C	NA
			1205	0	2	NA	AAE-95-D
			1210	10	12	NA	AAE-572-B/C
			1213	20	22	NA	AAE-96-D
			1215	30	32	NA	AAE-72-D
			1218	40	42	NA	AAE-97-D
			1220	50	52	NA	AAE-98-D
			1222	60	62	NA	AAE-573-B/C
			1225	70	72	NA	AAE-100-D
			1228	80	82	NA	AAE-571-B/C
			1230	90	92	NA	AAE-71-D
			1233	100	102	NA	AAE-73-D
SK-4	AAE-046	11/08/01	1415	0	5	AAE-198-B	NA
						AAE-198-C	NA
				5	10	AAE-199-B	NA
						AAE-199-C	NA
				10	15	AAE-200-B	NA
						AAE-200-C	NA
				15	20	AAE-201-B	NA
						AAE-201-C	NA
SK-5	AAE-050	11/08/01	1350	0	5	AAE-194-B	NA
						AAE-194-C	NA
				5	10	AAE-195-B	NA
						AAE-195-C	NA
				10	15	AAE-196-B	NA
						AAE-196-C	NA
				15	20	AAE-197-B	NA
						AAE-197-C	NA
SK-6	AAE-056	11/09/01	1435	0	5	AAE-222-B	NA
						AAE-222-C	NA
				5	10	AAE-223-B	NA
						AAE-223-C	NA

Table 2-4. Summary of Results from Collection of Core B Samples (page 3 of 6)

Station	Field Sample ID	Processing Date	Processing Time	Depth Interval (cm)		Chemistry Sample ID[(a)] –Side 1	Chemistry Sample ID[(b)] – Side 2
SK-6	AAE-056	11/09/01	1435	10	15	AAE-224-B	NA
						AAE-224-C	NA
				15	20	AAE-225-B	NA
						AAE-225-C	NA
SK-7	AAE-034	11/08/01	1030	0	5	AAE-174-B	NA
						AAE-174-C	NA
				5	10	AAE-175-B	NA
						AAE-175-C	NA
				10	15	AAE-176-B	NA
						AAE-176-C	NA
				15	20	AAE-177-B	NA
						AAE-177-C	NA
SK-7 DUP	AAE-036	11/08/01	1155	0	5	AAE-186-B	NA
						AAE-186-C	NA
			1200	5	10	AAE-187-B	NA
						AAE-187-C	NA
			1205	10	15	AAE-188-B	NA
						AAE-188-C	NA
			1210	15	20	AAE-189-B	NA
						AAE-189-C	NA
SK-8	AAE-040	11/08/01	1100	0	5	AAE-178-B	NA
						AAE-178-C	NA
				5	10	AAE-179-B	NA
						AAE-179-C	NA
				10	15	AAE-180-B	NA
						AAE-180-C	NA
				15	20	AAE-181-B	NA
						AAE-181-C	NA
SK-9	AAE-038	11/08/01	1130	0	5	AAE-182-B	NA
						AAE-182-C	NA
			1130	5	10	AAE-183-B	NA
						AAE-183-C	NA
			1135	10	15	AAE-184-B	NA
						AAE-184-C	NA
			1142	15	20	AAE-185-B	NA
						AAE-185-C	NA
SK-10	AAE-008	11/06/01	1610	0	5	AAE-131-B	NA
						AAE-131-C	NA
				5	10	AAE-132-B	NA
						AAE-132-C	NA
				10	15	AAE-133-B	NA
						AAE-133-C	NA
				15	20	AAE-134-B	NA
						AAE-134-C	NA
SK-11	AAE-018	11/06/01	1640	0	5	AAE-139-B	NA
						AAE-139-C	NA
				5	10	AAE-140-B	NA
						AAE-140-C	NA
				10	15	AAE-141-B	NA
						AAE-141-C	NA

Table 2-4. Summary of Results from Collection of Core B Samples (page 4 of 6)

Station	Field Sample ID	Processing Date	Processing Time	Depth Interval (cm)		Chemistry Sample ID[a] –Side 1	Chemistry Sample ID[b] – Side 2
SK-11	AAE-018	11/06/01	1640	15	20	AAE-142-B	NA
						AAE-142-C	NA
SK-12	AAE-010	11/06/01	1620	0	5	AAE-135-B	NA
						AAE-135-C	NA
				5	10	AAE-136-B	NA
						AAE-136-C	NA
				10	15	AAE-137-B	NA
						AAE-137-C	NA
				15	20	AAE-138-B	NA
						AAE-138-C	NA
SK-13	AAE-020	11/06/01	1600	0	5	AAE-127-B	NA
						AAE-127-C	NA
				5	10	AAE-128-B	NA
						AAE-128-C	NA
				10	15	AAE-129-B	NA
						AAE-129-C	NA
				15	20	AAE-130-B	NA
						AAE-130-C	NA
SK-14	AAE-028	11/07/01	1315	0	5	AAE-118-B	NA
						AAE-118-C	NA
				5	10	AAE-143-B	NA
						AAE-143-C	NA
				10	15	AAE-144-B	NA
						AAE-144-C	NA
				15	20	AAE-145-B	NA
						AAE-145-C	NA
SK-15	AAE-016	11/07/01	1325	0	5	AAE-146-B	NA
						AAE-146-C	NA
				5	10	AAE-147-B	NA
						AAE-147-C	NA
				10	15	AAE-148-B	NA
						AAE-148-C	NA
				15	20	AAE-149-B	NA
						AAE-149-C	NA
SK-16	AAE-024	11/07/01	1615	0	5	AAE-170-B	NA
						AAE-170-C	NA
				5	10	AAE-171-B	NA
						AAE-171-C	NA
				10	15	AAE-172-B	NA
						AAE-172-C	NA
				15	20	AAE-173-B	NA
						AAE-173-C	NA
SK-17	AAE-044	11/08/01	1640	0	5	AAE-206-B	NA
						AAE-206-C	NA
				5	10	AAE-207-B	NA
						AAE-207-C	NA
				10	15	AAE-208-B	NA
						AAE-208-C	NA
				15	20	AAE-209-B	NA
						AAE-209-C	NA

Table 2-4. Summary of Results from Collection of Core B Samples (page 5 of 6)

Station	Field Sample ID	Processing Date	Processing Time	Depth Interval (cm)		Chemistry Sample ID[a] –Side 1	Chemistry Sample ID[b] – Side 2
SK-18	AAE-058	11/09/01	1510	0	5	AAE-230-B	NA
						AAE-230-C	NA
				5	10	AAE-231-B	NA
						AAE-231-C	NA
				10	15	AAE-232-B	NA
						AAE-232-C	NA
				15	20	AAE-233-B	NA
						AAE-233-C	NA
SK-19 rep 2	AAE-030	11/07/01	1410	0	5	AAE-150-B	NA
						AAE-150-C	NA
				5	10	AAE-151-B	NA
						AAE-151-C	NA
				10	15	AAE-152-B	NA
						AAE-152-C	NA
				15	20	AAE-153-B	NA
						AAE-153-C	NA
SK-19	AAE-012	11/07/01	1430	0	5	AAE-154-B	NA
						AAE-154-C	NA
				5	10	AAE-155-B	NA
						AAE-155-C	NA
				10	15	AAE-156-B	NA
						AAE-156-C	NA
				15	20	AAE-157-B	NA
						AAE-157-C	NA
SK-20	AAE-026	11/07/01	1600	0	5	AAE-166-B	NA
						AAE-166-C	NA
				5	10	AAE-167-B	NA
						AAE-167-C	NA
				10	15	AAE-168-B	NA
						AAE-168-C	NA
				15	20	AAE-169-B	NA
						AAE-169-C	NA
SK-21	AAE-042	11/08/01	1705	0	5	AAE-214-B	NA
						AAE-214-C	NA
				5	10	AAE-215-B	NA
						AAE-215-C	NA
				10	15	AAE-216-B	NA
						AAE-216-C	NA
				15	20	AAE-217-B	NA
						AAE-217-C	NA
SK-22	AAE-060	11/09/01	1425	0	5	AAE-226-B	NA
						AAE-226-C	NA
				5	10	AAE-227-B	NA
						AAE-227-C	NA
				10	15	AAE-228-B	NA
						AAE-228-C	NA
				15	20	AAE-229-B	NA
						AAE-229-C	NA

Table 2-4. Summary of Results from Collection of Core B Samples (page 6 of 6)

Station	Field Sample ID	Processing Date	Processing Time	Depth Interval (cm)		Chemistry Sample ID[(a)] –Side 1	Chemistry Sample ID[(b)] – Side 2
SK-23	AAE-052	11/08/01	1625	0	5	AAE-202-B	NA
						AAE-202-C	NA
				5	10	AAE-203-B	NA
						AAE-203-C	NA
				10	15	AAE-204-B	NA
						AAE-204-C	NA
				15	20	AAE-205-B	NA
						AAE-205-C	NA
SK-24	AAE-062	11/09/01	1455	0	5	AAE-218-B	NA
						AAE-218-C	NA
				5	10	AAE-219-B	NA
						AAE-219-C	NA
				10	15	AAE-220-B	NA
						AAE-220-C	NA
				15	20	AAE-221-B	NA
						AAE-221-C	NA
SK-25 DUP	AAE-032	11/07/01	1510	0	5	AAE-158-B	NA
						AAE-158-C	NA
				5	10	AAE-159-B	NA
						AAE-159-C	NA
				10	15	AAE-160-B	NA
						AAE-160-C	NA
				15	20	AAE-161-B	NA
						AAE-161-C	NA
SK-25	AAE-022	11/07/01	1540	0	5	AAE-162-B	NA
						AAE-162-C	NA
				5	10	AAE-163-B	NA
						AAE-163-C	NA
				10	15	AAE-164-B	NA
						AAE-164-C	NA
				15	20	AAE-165-B	NA
						AAE-165-C	NA
SK-66	AAE-048	11/08/01	1330	0	5	AAE-190-B	NA
						AAE-190-C	NA
				5	10	AAE-191-B	NA
						AAE-191-C	NA
				10	15	AAE-192-B	NA
						AAE-192-C	NA
				15	20	AAE-193-B	NA
						AAE-193-C	NA
SK-67	AAE-054	11/08/01	1650	0	5	AAE-210-B	NA
						AAE-210-C	NA
				5	10	AAE-211-B	NA
						AAE-211-C	NA
				10	15	AAE-212-B	NA
						AAE-212-C	NA
				15	20	AAE-213-B	NA
						AAE-213-C	NA

(a) Samples labeled -B and -C are for PAH and TPH-DRO analysis, respectively.
(b) Samples labeled -D and -B/C are for radioisotope analysis.
NA = not applicable.
rep = replicate sample.

Table 2-5. Summary of Results from Collection of Core A Samples

Station	Field Sample ID	Processing Date	Processing Time	Depth Interval (cm) Top	Bottom	Sample Particle Size (mm)	Lead Shot and Grit Sample ID	Comments
SK-1	AAE-002	11/05/01	NA	0	5	>4	NA	worm tubes
			0900			2-4	AAE-246-A	worms
			0905			0.5-2	AAE-248-A	worms
			NA	5	10	>4	NA	small worm tubes
			0845			2-4	AAE-242-A	lots of worms
			0852			0.5-2	AAE-244-A	shells
			NA	10	15	>4	NA	
			NA			2-4	NA	no sample material
			0817			0.5-2	AAE-241-A	small shells
			NA	15	20	>4	NA	
			0828			2-4	AAE-243-A	small shells, sticks
			0831			0.5-2	AAE-245-A	
SK-2	AAE-004	11/06/01	NA	0	5	>4	NA	lots of worms
			0930			2-4	AAE-247-A	worms
			0935			0.5-2	AAE-249-A	
			NA	5	10	>4	NA	worm tubes
			0945			2-4	AAE-250-A	worms
			0947			0.5-2	AAE-251-A	
			NA	10	15	>4	NA	worms
			1000			2-4	AAE-252-A	worms, little grit
			1005			0.5-2	AAE-253-A	grit
			NA	15	20	>4	NA	one worm, one bivalve
			NA			2-4	NA	no sample material
			1015			0.5-2	AAE-254-A	
SK-3	AAE-006	11/06/01	NA	0	5	>4	NA	lots of worms, one bivalve
			NA			2-4	NA	no grit, a few small worms
			1310			0.5-2	AAE-255-A	small tubes
			NA	5	10	>4	NA	
			1320			2-4	AAE-257-A	shot in sample
			1321			0.5-2	AAE-256-A	
			NA	10	15	>4	NA	bivalves and worms
			1330			2-4	AAE-258-A	shot in sample
			1332			0.5-2	AAE-259-A	shot in sample
			NA	15	20	>4	NA	bivalves and worm tubes
			1340			2-4	AAE-260-A	shot in sample, shells
			1345			0.5-2	AAE-261-A	
SK-4	AAE-045	11/08/01	NA	0	5	>4	NA	worm tubes, clay target fragment[(a)]
			1405			2-4	AAE-361-A	grit, shells, clay target fragments[(a)]
			1510			0.5-2	AAE-362-A	grit, organic matter
			NA	5	10	>4	NA	worm tubes
			1520			2-4	AAE-363-A	grit, shells
			1520			0.5-2	AAE-364-A	grit, shells, organic matter
			NA	10	15	>4	NA	bivalve, worms, clay target fragments[(a)]
			1534			2-4	AAE-365-A	wood, shells
			1534			0.5-2	AAE-366-A	grit, organic matter
			NA	15	20	>4	NA	worm tube
			1537			2-4	AAE-367-A	shot, shells, grit
			1538			0.5-2	AAE-368-A	shells, rocks

Table 2-5. Summary of Results from Collection of Core A Samples (page 2 of 9)

Station	Field Sample ID	Processing Date	Processing Time	Depth Interval (cm) Top	Depth Interval (cm) Bottom	Sample Particle Size (mm)	Lead Shot and Grit Sample ID	Comments
SK-5	AAE-049	11/09/01	NA	0	5	>4	NA	worm tubes
			0940			2-4	AAE-401-A	shot, worm tubes, grit
			0940			0.5-2	AAE-402-A	worm tubes, grit
			NA	5	10	>4	NA	worm tubes, one clay target fragment[(a)]
			0950			2-4	AAE-403-A	grit
			0950			0.5-2	AAE-404-A	grit
			NA	10	15	>4	NA	worm tubes, shells, clay target fragments[(a)]
			0940			2-4	AAE-405-A	shells, organic matter
			0940			0.5-2	AAE-406-A	
			NA	15	20	>4	NA	shell fragments and wood pieces
			0950			2-4	AAE-407-A	shot, shells, organic material
			0950			0.5-2	AAE-408-A	grit, shell fragments, organic matter
SK-6	AAE-055	11/09/01	NA	0	5	>4	NA	worm tubes
			1455			2-4	AAE-457-A	worm tubes, shells
			1455			0.5-2	AAE-458-A	shells, organic debris
			NA	5	10	>4	NA	worm tubes
			1510			2-4	AAE-459-A	worms, grit
			1510			0.5-2	AAE-460-A	grit
			NA	10	15	>4	NA	clay target fragment[(a)]
			1455			2-4	AAE-461-A	worm, grit
			1455			0.5-2	AAE-462-A	grit
			NA	15	20	>4	NA	shell fragments
			1520			2-4	AAE-463-A	grit
			1520			0.5-2	AAE-464-A	grit
SK-7	AAE-033	11/09/01	NA	0	5	>4	NA	worm tubes, clay target fragments[(a)]
			0805			2-4	AAE-377-A	worm tubes, shell fragments, shot
			0805			0.5-2	AAE-378-A	worm tubes, shell fragments, grit
			NA	5	10	>4	NA	worm tube, clay target fragments[(a)]
			0820			2-4	AAE-379-A	shot, organic matter
			0820			0.5-2	AAE-380-A	shell fragments, grit, shot
			NA	10	15	>4	NA	worm tubes
			0805			2-4	AAE-381-A	shot and grit
			0805			0.5-2	AAE-382-A	grit
			NA	15	20	>4	NA	
			0815			2-4	AAE-383-A	shot, grit
			0815			0.5-2	AAE-384-A	shells, organic matter

Table 2-5. Summary of Results from Collection of Core A Samples (page 3 of 9)

Station	Field Sample ID	Processing Date	Processing Time	Depth Interval (cm) Top	Depth Interval (cm) Bottom	Sample Particle Size (mm)	Lead Shot and Grit Sample ID	Comments
SK-7 DUP	AAE-035	11/09/01	NA	0	5	>4	NA	many worm tubes
			0910			2-4	AAE-393-A	worm tubes, shell fragments
			0910			0.5-2	AAE-394-A	organic matter, grit
			NA	5	10	>4	NA	worm tubes, clay target fragments[a]
			0920			2-4	AAE-395-A	shot, shell fragments
			0920			0.5-2	AAE-396-A	shot and grit
			NA	10	15	>4	NA	shell fragments
			0910			2-4	AAE-397-A	shot, shell fragments
			0910			0.5-2	AAE-398-A	shell fragments, grit, organic matter
			NA	15	20	>4	NA	clay target fragment[a]
			0920			2-4	AAE-399-A	shot, organic matter
			0920			0.5-2	AAE-400-A	grit and organic matter
SK-8	AAE-039	11/09/01	NA	0	5	>4	NA	worm tubes, shells, clay target fragment[a]
			1150			2-4	AAE-433-A	shell fragments, worms
			1150			0.5-2	AAE-434-A	worm tubes, grit
			NA	5	10	>4	NA	shells, worm tubes, clay target fragment[a]
			1200			2-4	AAE-435-A	rocks, shot, shells
			1200			0.5-2	AAE-436-A	grit, shells
			NA	10	15	>4	NA	wood and shells
			1200			2-4	AAE-437-A	shot, shells
			1200			0.5-2	AAE-438-A	grit
			NA	15	20	>4	NA	shell fragments, clay target fragments[a]
			1150			2-4	AAE-439-A	shot, organic matter
			1150			0.5-2	AAE-440-A	grit, shell fragments
SK-9	AAE-037	11/09/01	NA	0	5	>4	NA	worm tubes, shells, clay target fragment[a]
			1010			2-4	AAE-409-A	shot, worm tubes, many shells
			1010			0.5-2	AAE-410-A	worm tubes, grit, shell fragments
			NA	5	10	>4	NA	shells, worm tubes
			1010			2-4	AAE-411-A	shot, shells, grit
			1010			0.5-2	AAE-412-A	grit, organic material
			NA	10	15	>4	NA	worm tubes, shell fragments
			1020			2-4	AAE-413-A	shot, organic matter
			1020			0.5-2	AAE-414-A	grit, shell fragments
			NA	15	20	>4	NA	shell fragments
			1020			2-4	AAE-415-A	shell fragments, shot
			1020			0.5-2	AAE-416-A	grit
SK-10	AAE-007	11/07/01	NA	0	5	>4	NA	few shells
			0930			2-4	AAE-270-A	shot/grit
			0930			0.5-2	AAE-271-A	grit/shells
			NA	5	10	>4	NA	shell/wood
			0945			2-4	AAE-274-A	shot/wood
			0947			0.5-2	AAE-275-A	wood and shells
			NA	10	15	>4	NA	few shells, wood
			0935			2-4	AAE-272-A	shot, shells, grit
			0935			0.5-2	AAE-273-A	shot, shell fragments, grit
			NA	15	20	>4	NA	2 pieces organic debris
			0955			2-4	AAE-276-A	lead shot, shell frags, debris
			0955			0.5-2	AAE-277-A	grit and shells

Table 2-5. Summary of Results from Collection of Core A Samples (page 4 of 9)

Station	Field Sample ID	Processing Date	Processing Time	Depth Interval (cm) Top	Depth Interval (cm) Bottom	Sample Particle Size (mm)	Lead Shot and Grit Sample ID	Comments
SK-11	AAE-017	11/07/01	NA	0	5	>4	NA	worm tubes, wood
			1115			2-4	AAE-288-A	worm tubes
			1115			0.5-2	AAE-289-A	shell fragments, organic matter
			NA	5	10	>4	NA	worm tube
			1130			2-4	AAE-292-A	wood and shells
			1130			0.5-2	AAE-293-A	wood parts and shells
			NA	10	15	>4	NA	shell fragments
			1120			2-4	AAE-290-A	black grit
			1120			0.5-2	AAE-291-A	organic debris
			NA	15	20	>4	NA	2 worm tubes
			1118			2-4	AAE-284-A	wood, shells, shot
			1118			0.5-2	AAE-287-A	small wood and shells
SK-12	AAE-009	11/07/01	NA	0	5	>4	NA	no material
			0828			2-4	AAE-262-A	a few shot
			0828			0.5-2	AAE-263-A	small grit
			NA	5	10	>4	NA	3 small clam shells
			0840			2-4	AAE-264-A	shot, some twigs
			0840			0.5-2	AAE-265-A	shell frags and grit
			NA	10	15	>4	NA	
			0845			2-4	AAE-266-A	shot and grit
			0845			0.5-2	AAE-267-A	small shells and grit
			NA	15	20	>4	NA	
			0905			2-4	AAE-268-A	shot; some twigs
			0905			0.5-2	AAE-269-A	grit, organic material, shell fragments
SK-13	AAE-0019	11/07/01	NA	0	5	>4	NA	worms
			1030			2-4	AAE-278-A	shot, worms
			1030			0.5-2	AAE-279-A	grit, biota
			NA	5	10	>4	NA	3 shell fragments, wood
			1045			2-4	AAE-282-A	shot, wood, shells
			1045			0.5-2	AAE-283-A	shells, grit
			NA	10	15	>4	NA	shell frags, wood
			1035			2-4	AAE-280-A	shot, shells, wood
			1035			0.5-2	AAE-281-A	shells, organic particles
			NA	15	20	>4	NA	shells, worm tubes, clay target fragments[(a)]
			1045			2-4	AAE-285-A	shot, biota
			1045			0.5-2	AAE-286-A	biota, grit

Table 2-5. Summary of Results from Collection of Core A Samples (page 5 of 9)

Station	Field Sample ID	Processing Date	Processing Time	Depth Interval (cm) Top	Depth Interval (cm) Bottom	Sample Particle Size (mm)	Lead Shot and Grit Sample ID	Comments
SK-14	AAE-027	11/07/01	NA	0	5	>4	NA	worms
			1340			2-4	AAE-303-A	shot
			1340			0.5-2	AAE-304-A	worm material, shells
			NA	5	10	>4	NA	worm tubes
			1340			2-4	AAE-305-A	shot
			1340			0.5-2	AAE-306-A	wood, shells, worms
			NA	10	15	>4	NA	rocks
			1340			2-4	AAE-307-A	shot, wood, shells
			1340			0.5-2	AAE-308-A	shells, wood
			NA	15	20	>4	NA	worm tube
			1340			2-4	AAE-309-A	shot
			1340			0.5-2	AAE-310-A	shell fragments, wood
SK-15	AAE-015	11/07/01	NA	0	5	>4	NA	worm tubes, molluscs, clay target fragments[(a)]
			1215			2-4	AAE-294-A	shot, grit, shrimp
			1215			0.5-2	AAE-295-A	worm material
			NA	5	10	>4	AAE-302-A	one musket ball
			1245			2-4	AAE-300-A	shot, rocks
			1245			0.5-2	AAE-301-A	shells, wood, worm parts
			NA	10	15	>4	NA	one worm tube
			1230			2-4	AAE-296-A	shot, rocks
			1230			0.5-2	AAE-297-A	shell fragments, wood
			NA	15	20	>4	NA	shells, molluscs
			1245			2-4	AAE-298-A	shot
			1245			0.5-2	AAE-299-A	wood and shells
SK-16	AAE-023	11/08/01	NA	0	5	>4	NA	worm tubes
			0805			2-4	AAE-327-A	worms/worm tubes, shells
			0805			0.5-2	AAE-328-A	organic matter, worms, worm tubes
			NA	5	10	>4	NA	5 worm tubes
			0820			2-4	AAE-330-A	black grit
			0820			0.5-2	AAE-329-A	grit, organic matter
			NA	10	15	>4	NA	5 worm tubes
			0835			2-4	AAE-331-A	shells, organic matter
			0835			0.5-2	AAE-332-A	grit, organic matter
			NA	15	20	>4	NA	4 worm tubes
			0845			2-4	AAE-333-A	shell, grit
			0845			0.5-2	AAE-334-A	grit, organic matter

Table 2-5. Summary of Results from Collection of Core A Samples (page 6 of 9)

Station	Field Sample ID	Processing Date	Processing Time	Depth Interval (cm) Top	Depth Interval (cm) Bottom	Sample Particle Size (mm)	Lead Shot and Grit Sample ID	Comments
SK-17	AAE-043	11/09/01	NA	0	5	>4	NA	worm tubes, shell fragments
			1120			2-4	AAE-425-A	worm tubes, shells
			1120			0.5-2	AAE-426-A	worm tubes, worms, grit
			NA	5	10	>4	NA	2 worm tubes
			1130			2-4	AAE-427-A	shot, organic matter
			1130			0.5-2	AAE-428-A	grit, shells
			NA	10	15	>4	NA	one worm tube
			1120			2-4	AAE-429-A	shot, grit
			1120			0.5-2	AAE-430-A	grit, worms
			NA	15	20	>4	NA	worm tube
			1130			2-4	AAE-431-A	shot, wood pieces
			1130			0.5-2	AAE-432-A	grit
SK-18	AAE-057	11/09/01	NA	0	5	>4	NA	one worm
			1555			2-4	NA	no sample material
			1555			0.5-2	AAE-474-A	organic debris, grit
			NA	5	10	>4	NA	one worm
			1600			2-4	NA	one worm, no sample material
			1600			0.5-2	AAE-476-A	grit
			NA	10	15	>4	NA	shell fragments
			1605			2-4	AAE-477-A	shell fragments, wood
			1605			0.5-2	AAE-478-A	organic debris, grit
			NA	15	20	>4	NA	one clay target fragment[(a)]
			1605			2-4	AAE-479-A	shell fragments, grit
			1605			0.5-2	AAE-480-A	shell fragments, grit
SK-19	AAE-011	11/07/01	NA	0	5	>4	NA	worm tube
			1430			2-4	AAE-311-A	shot and worms
			1430			0.5-2	AAE-312-A	worms, wood, shells
			NA	5	10	>4	NA	worm tube
			1430			2-4	AAE-313-A	shot
			1430			0.5-2	AAE-314-A	wood, shells, worms
			NA	10	15	>4	NA	worms
			1430			2-4	AAE-315-A	shot, wood
			1430			0.5-2	AAE-316-A	wood and shells
			NA	15	20	>4	NA	worm tubes
			1430			2-4	AAE-317-A	shot, wood
			1430			0.5-2	AAE-318-A	wood, shells
SK-19 DUP	AAE-029	11/07/01	NA	0	5	>4	NA	lots of worm tubes and worms
			1515			2-4	AAE-319-A	shot, shells
			1515			0.5-2	AAE-320-A	wood and shells
			NA	5	10	>4	NA	few worm tubes
			1515			2-4	AAE-321-A	shot
			1515			0.5-2	AAE-322-A	wood and shells
			NA	10	15	>4	NA	one worm
			1515			2-4	AAE-323-A	shot
			1515			0.5-2	AAE-324-A	shells and wood
			NA	15	20	>4	NA	rocks
			1515			2-4	AAE-325-A	shot
			1515			0.5-2	AAE-326-A	wood and shells

Table 2-5. Summary of Results from Collection of Core A Samples (page 7 of 9)

Station	Field Sample ID	Processing Date	Processing Time	Depth Interval (cm) Top	Depth Interval (cm) Bottom	Sample Particle Size (mm)	Lead Shot and Grit Sample ID	Comments
SK-20	AAE-025	11/08/01	NA	0	5	>4	NA	lots of worm tubes, shells
			1220			2-4	AAE-345-A	shot
			1220			0.5-2	AAE-346-A	worm tubes
			NA	5	10	>4	NA	worm tubes
			1230			2-4	AAE-347-A	shot
			1230			0.5-2	AAE-348-A	grit, organic matter
			NA	10	15	>4	NA	worm tubes
			1255			2-4	AAE-349-A	shot
			1255			0.5-2	AAE-350-A	grit, woody debris
			NA	15	20	>4	NA	worm tubes
			1300			2-4	AAE-351-A	one piece of shell
			1300			0.5-2	AAE-352-A	grit
SK-21	AAE-041	11/09/01	NA	0	5	>4	NA	worm tubes
			1050			2-4	NA	worm tubes
			1050			0.5-2	AAE-418-A	worm tubes, shell fragments
			NA	5	10	>4	NA	
			1100			2-4	AAE-419-A	shot, shell fragments
			1100			0.5-2	AAE-420-A	shell fragments, worm
			NA	10	15	>4	NA	
			1100			2-4	AAE-421-A	organic debris, grit
			1100			0.5-2	AAE-422-A	organic debris, grit
			NA	15	20	>4	NA	
			1045			2-4	AAE-423-A	shot, shell fragments, organic debris
			1045			0.5-2	AAE-424-A	organic debris, grit
SK-22	AAE-059	11/09/01	NA	0	5	>4	NA	worm tubes
			1420			2-4	AAE-449-A	worm tubes, grit
			1420			0.5-2	AAE-450-A	worm tubes, grit
			NA	5	10	>4	NA	worm tubes, shells
			1435			2-4	AAE-451-A	shell and wood fragments
			1435			0.5-2	AAE-452-A	grit
			NA	10	15	>4	NA	worm tubes, wood debris
			1420			2-4	AAE-453-A	shell fragments, shot
			1420			0.5-2	AAE-454-A	organic debris, shells
			NA	15	20	>4	NA	shells and fragments, one worm
			1435			2-4	AAE-455-A	shot, shells, wood
			1435			0.5-2	AAE-456-A	shells, organic debris, grit, shot
SK-23	AAE-051	11/09/01	NA	0	5	>4	NA	worm tubes, shells
			1225			2-4	AAE-441-A	worm tubes, shot
			1225			0.5-2	AAE-442-A	worm tubes, worms, grit
			NA	5	10	>4	NA	worm tubes
			1240			2-4	AAE-443-A	shot, worms
			1240			0.5-2	AAE-444-A	grit
			NA	10	15	>4	NA	shell fragments
			1225			2-4	AAE-445-A	shot, grit, worms
			1225			0.5-2	AAE-446-A	grit, organic debris
			NA	15	20	>4	NA	worm tubes, fragments
			1240			2-4	NA	no sample material
			1240			0.5-2	AAE-448-A	grit

Table 2-5. Summary of Results from Collection of Core A Samples (page 8 of 9)

Station	Field Sample ID	Processing Date	Processing Time	Depth Interval (cm) Top	Depth Interval (cm) Bottom	Sample Particle Size (mm)	Lead Shot and Grit Sample ID	Comments
SK-24	AAE-061	11/09/01	NA	0	5	>4	NA	nothing
			1525			2-4	NA	no sample material
			1525			0.5-2	AAE-466-A	grit
			NA	5	10	>4	NA	nothing
			1540			2-4	AAE-467-A	grit
			1540			0.5-2	AAE-468-A	grit
			NA	10	15	>4	NA	nothing
			1540			2-4	AAE-469-A	shot, shell frags
			1540			0.5-2	AAE-470-A	shell frags, organic debris, grit
			NA	15	20	>4	NA	nothing
			1545			2-4	AAE-471-A	grit
			1545			0.5-2	AAE-472-A	grit
SK-25 DUP	AAE-031	11/08/01	NA	0	5	>4	NA	seaweed, worm tubes
			0945			2-4	AAE-337-A	worm tubes
			0945			0.5-2	AAE-338-A	organic matter
			NA	5	10	>4	NA	one shell, one worm tube
			0945			2-4	AAE-339-A	one shell, some seaweed
			0945			0.5-2	AAE-340-A	organic particles, grit
			NA	10	15	>4	NA	10 tiny shells
			0945			2-4	AAE-341-A	shells, grit, clay target fragments[(a)]
			0945			0.5-2	AAE-342-A	shells, grit, organic matter
			NA	15	20	>4	NA	lots of shells
			0930			2-4	AAE-335-A	shot
			0930			0.5-2	AAE-336-A	grit
SK-25	AAE-021	11/08/01	NA	0	5	>4	NA	lots of worm tubes
			1313			2-4	AAE-353-A	worm tubes and grit
			1313			0.5-2	AAE-354-A	worms, grit
			NA	5	10	>4	NA	worm tube
			1316			2-4	AAE-355-A	clam shell, grit
			1316			0.5-2	AAE-356-A	grit, organic matter
			NA	10	15	>4	NA	
			1323			2-4	AAE-357-A	grit, worm tubes
			1323			0.5-2	AAE-358-A	grit
			NA	15	20	>4	NA	shells, clay target fragment[(a)]
			1330			2-4	AAE-359-A	shot and shells
			1330			0.5-2	AAE-360-A	organic matter, grit
SK-66	AAE-047	11/08/01	NA	0	5	>4	NA	worm tubes, shells
			1600			2-4	AAE-369-A	shells, grit, clay target fragment[(a)]
			1600			0.5-2	AAE-370-A	shells, grit, organic matter
			NA	5	10	>4	NA	worm tubes
			1655			2-4	AAE-371-A	grit and shells
			1655			0.5-2	AAE-372-A	grit and shells
			NA	10	15	>4	NA	worm tubes, shells
			1705			2-4	AAE-373-A	grit and shells
			1705			0.5-2	AAE-374-A	grit and shells
			NA	15	20	>4	NA	many shells
			1710			2-4	AAE-375-A	grit and shells
			1710			0.5-2	AAE-376-A	grit and shells

Table 2-5. Summary of Results from Collection of Core A Samples (page 9 of 9)

Station	Field Sample ID	Processing Date	Processing Time	Depth Interval (cm)		Sample Particle Size (mm)	Lead Shot and Grit Sample ID	Comments
				Top	Bottom			
SK-67	AAE-053	11/09/01	NA	0	5	>4	NA	worm tubes
			0840			2-4	AAE-385-A	worm tubes, grit
			0840			0.5-2	AAE-386-A	organic matter, shell fragments, grit
			NA	5	10	>4	NA	worm tube
			0850			2-4	AAE-387-A	shells, worm tubes
			0850			0.5-2	AAE-388-A	organic matter, grit
			NA	10	15	>4	NA	worm tubes
			0850			2-4	AAE-389-A	shell fragments
			0850			0.5-2	AAE-390-A	grit and shell fragments
			NA	15	20	>4	NA	
			0840			2-4	AAE-391-A	shot, grit, shells
			0840			0.5-2	AAE-392-A	sand, grit, shot

(a) See Table 2-6 for clay target fragment collection data.
NA = not applicable.

Table 2-6. Inventory of Fragment Samples Isolated and Composited from Sediments

Locations	Top Depth (cm)	Bottom Depth (cm)	Chemistry Field ID	Analyzed Alone	Composited[a]
SK-13	15	20	AAE-574-B/C	no	1
SK-15	0	5	AAE-575-B/C	no	1
SK-5	10	15	AAE-587-B/C	no	1
SK-5	5	10	AAE-588-B/C	no	1
SK-9	0	5	AAE-589-B/C	no	1
SK-36	0	5	AAE-600-B/C	no	1
SK-44	0	5	AAE-601-B/C	no	1
SK-4 [b]	0	5	AAE-579-B/C	no	2
SK-4	0	5	AAE-580-B/C	no	2
SK-4	10	15	AAE-581-B/C	no	2
SK-25 DUP	10	15	AAE-576-B/C	no	3
SK-25	15	20	AAE-577-B/C	no	3
SK-25 [b]	15	20	AAE-578-B/C	no	3
SK-8	0	5	AAE-590-B/C	no	4
SK-8	15	20	AAE-591-B/C	no	4
SK-8	5	10	AAE-592-B/C	no	4
SK-7	0	5	AAE-583-B/C	no	5
SK-7	5	10	AAE-584-B/C	no	5
SK-7 DUP	5	10	AAE-585-B/C	no	5
SK-7 DUP	15	20	AAE-586-B/C	no	5
SK-66	0	5	AAE-582-B/C	no	6
SK-6	10	15	AAE-593-B/C	no	6
SK-18	15	20	AAE-595-B/C	no	6
SK-31	0	5	AAE-599-B/C	no	6
SK-61	0	5	AAE-603-B/C	no	6
SK-24	20	25	AAE-594-B/C	yes	--
SK-30	0	5	AAE-596-B/C	yes	--
SK-30	5	10	AAE-597-B/C	yes	--
SK-61	7	8	AAE-602-B/C	yes	--
SK-60	0	5	AAE-604-B/C	yes	--

(a) Composite Key: 1 = Z036Comp; 2 = Z037Comp; 3 = Z038Comp; 4 = Z039Comp; 5 = Z040Comp; 6 = Z041Comp.
(b) Fragments 2.0-4.0 mm; all others > 4.0-mm.

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3.0 EXTENT OF CONTAMINATION

This section describes the spatial distribution of PAHs and TPH in sediment and the presence of lead shot and clay target fragments in relation with the historical Navy activities at the Skeet Range. To further understand the source of PAHs at the Skeet Range, fingerprinting techniques were used to differentiate the contribution of PAHs associated with clay target versus those from other sources. A sediment dynamics study was performed to estimate accretion rates and evaluate whether lead shot was available for uptake by diving birds.

3.1 Distribution of Contamination

The following section describes the spatial distribution of PAH, TPH, lead shot, and clay fragments found in the Skeet Range based on the 2001 field investigation.

3.1.1 Sediment Chemistry

Analytical results based on PAH and TPH data from the 2001 field investigation were prepared for analysis following these guidelines:

- All chemical concentrations which were not detected were set to one-half the reporting limit.
- Field duplicates were collected at three stations as field quality controls and were excluded from the analysis. The primary field sample result was used for all three samples.
- Individual PAH compounds were evaluated in addition to summed totals representing concentrations for total high-molecular-weight PAHs (HPAHs) and total low-molecular-weight PAHs (LPAHs). Only detected concentrations were summed; otherwise, nondetects were set equal to zero in the total calculation. Chemicals included in the summed groups were as follows:

Total LPAHs (sum of 7 constituents)

Acenaphthene	Naphthalene
Acenaphthylene	2-Methylnaphthalene
Anthracene	Phenanthrene
Fluorene	

Total HPAHs (sum of 10 constituents)

Benzo(a)anthracene	Chrysene
Benzo(a)pyrene	Dibenzo(a,h)anthracene
Benzo(b)fluoranthene	Fluoranthene
Benzo(g,h,i)perylene	Indeno(1,2,3-cd)pyrene
Benzo(k)fluoranthene	Pyrene

The PAH concentrations in sediments were compared against risk-based sediment screening benchmarks, i.e., effects range-low (ER-Ls) and effects range-median (ER-Ms) (Long et al., 1995); and to San Francisco Bay ambient upper tolerance limits (UTLs) for sediments of <100% fines (RWQCB, 1998). Based on the comparisons, only three stations had concentrations of HPAHs (Figure 3-1) and/or LPAHs (Figure 3-2) above ER-Ms in the surface sediment and all are located along the northern edge of the Skeet Range. Specifically, chemical concentrations at station SK-66 (5-10 cm depth interval) exceed ER-Ms for HPAHs and LPAHs, and the concentration of HPAH exceed the ER-M at SK-04 (5-10 cm depth interval).

Both these stations are located in the northern half of the skeet range along the eastern edge of the sampling area. In addition, concentrations of both LPAHs and HPAHs exceed the ER-Ms at station SK-01 at the deepest (70-75 cm and 95-100 cm) depth intervals. It is likely that PAH concentrations at these sites represent a source other than skeet range activities. This assertion is supported by the PAH fingerprinting presented in Appendix B of this report, which shows that the sediment PAH composition is dissimilar from the PAH composition of the clay pigeon fragments evaluated.

Twenty-six (26) samples contained LPAH concentrations between the LPAH ER-L and ER-M. Fifty (50) samples had concentrations of HPAH between the ER-M and ER-L benchmarks; however, only 12 of these samples were above the ambient UTL. It also was observed through this analysis that PAHs are distributed relatively uniformly throughout the sediment depth (particularly within the upper 20 cm), which suggests that there was a consistent source(s) of PAH to the sediments during their deposition. The highest concentrations of PAH occurred in the deeper portions of the SK-1 core.

Table 3-1 presents a list of the individual PAH compounds that had concentrations exceeding the screening benchmarks (i.e., ER-Ls or ambient UTL) in the top 5 cm of sediment. Stations SK-04, SK-06, and SK-11 consistently have the highest concentrations of individual PAH analytes; an observation consistent with the finding that these same stations have the highest concentrations of total PAHs in the surface interval. Individual box plots of each PAH constituent are presented in Appendix A.

The 131 sediment samples contained between 16 and 310 mg/kg of TPH. The median and mean concentrations of TPH were 53 mg/kg and 69 mg/kg, respectively. No comparisons were performed for TPH because benchmarks and ambient UTLs are not available. Ninety percent of the sediments studied contained less than 120 mg/kg of TPH. Only four sediment samples contained more than 200 mg/kg TPH and each of these occurred at the SK-1 (0-5 and 70-75 cm) and SK-66 (0-5 and 10-15 cm) locations. Both of these locations are at the northernmost extent of the study area (i.e., closest to the Oakland Inner Harbor), which could indicate that some influence (source) of TPH may exist from the harbor.

3.1.2 Lead Shot

As stated in Section 2.5, the number of lead shot pellets were numerated by hand for every sample collected at the Skeet Range. Because both core and grab samples were collected, the density of the lead pellets was estimated by dividing the total number of lead shot pellets in the sample by the volume of the sampling device. The nominal volumes of the 5-cm grab and the 5-cm cores were estimated as 4,645 cm^3 and 405.4 cm^3, respectively. Figures 3-3 through 3-6 present the lead shot density by depth starting from 0-5 cm, 5-10 cm, 10-15 cm, and 15-20 cm, respectively collected as part of the 2001 investigation.

Approximately 52% of the sampling locations (36 stations of the 67 sampled) had no lead pellets in the top 0-5 cm of sediment. A majority of these stations were located on the outer perimeter of the fallout zone originally identified by TtEMI. Another 22% of the stations (15 stations) contained less than 10 lead pellets per liter of sediment in the top 5 cm. The highest density of lead shot appears to be clustered in the middle of the Skeet Range along the intersection of the trajectories leading from the northern and southern shooting ranges. These five stations (i.e., SK-15, SK-19, SK-44, SK-49, and SK-51) have the highest lead shot density ranging from 51 to 115 lead shot pellets per liter of sediment. Lower density of lead shot (11 to 50 pellets/liter) was found in stations surrounding the high impact area with two distinct areas of moderate impact in the north and south of the fallout zone.

Twenty-seven long and short cores were collected in the deeper depths from 5-20 cm. From the 5 to 10 cm depth, twelve perimeter stations along the shoreline had no lead pellets, whereas the highest density of lead was isolated to three distinct locations: (1) SK-23 in the south; (2) SK-14 and SK-15 in the middle of the range; and (3) SK-7 in the north. Surrounding these areas were stations that had moderate to low lead density. For the 10-15 cm depth, the pattern is slightly different with several of the southern shoreline sampling stations containing low density of lead pellets (<10 lead pellets per liter). A majority of the highest impact stations are located in the northern section surrounding SK-15, whereas only SK-3 in the southern section contained moderate levels of lead shot (31 to 50 pellets per liter). In the deeper core (15 to 20 cm), a similar pattern continues with the majority of the shoreline samples containing moderate to low density of lead pellets. The highest impact station remains SK-15 with a second fallout zone at Station SK-3.

Because subsurface samples were not collected for all surface stations, it is difficult to determine a clear pattern as to whether the lead shot is being buried or resuspended. Using the stations in which core data were collected from the entire 0-20 cm length, it appears that, although several of the samples had lead shot in the surface, lead shot density for a majority of the samples was greater at depth (i.e., >5 cm). Specifically, in 14 of 18 samples in which shot were present and data are available for the surface and at least two subsurface intervals, lead shot density was greater in the 5-10cm, 10-15 cm and/or 15-20 cm interval than in the 0-5 cm interval (Table 3-2).

Overall, these results support the finding from the sediment dynamics study that gradual sedimentation was occurring at most site locations. This is particularly the case for SK-3 and several of the shoreline stations (SK-4, SK-21, SK-22, SK-24, SK-25, and SK-67). Several trajectories also appear to be favored by the sportsman, which may explain the consistently high lead shot density at SK-15 at every depth. Two exceptions to the general pattern of sedimentation at stations where subsurface shot densities are greater than surface density are SK-10 and SK-15. At these stations, a pattern of sedimentation is more equivocal as shot density is relatively consistent throughout the core and the increase with depth is minor. Two locations (SK-14 and SK-23) had the highest impact in the 5-10 cm, with low density of lead in the surface. It is likely that gradual sedimentation resulted in the highest density of lead in the subsurface, but periodic resuspension may have resurfaced some of the lead pellets (see Section 3.3.3).

For depths greater than 20 cm, a cluster of 10 cores were collected by TtEMI as part of the 1998 investigation. Because the samples were collected on a grams per liter basis, it is difficult to compare the results between the separate investigations. Based on the review of the historical data, it appears that the highest lead concentrations were found at depths ranging from 4 to 20 cm. Past 20 cm, the lead concentration dramatically declined with depth. In sample Skeet 1-5, no detectable lead concentration was measured past 30 cm, whereas a definite decrease in concentration is clearly evident at depth in the remaining samples.

3.1.3 Clay Fragments

Clay targets for general skeet shooting are saucer shaped with a diameter between 100-110 mm and a height between 20-25 mm. They have a grooved upper surface to provide for steady flight when shot from a skeet launcher. Clay fragments meeting this criteria were only found in 30 of the 131 sediment samples processed with few being encountered in the >4-mm or >2-mm sieves (see Figure 2-3). Fragments of clay pigeon were found in about a quarter (18 of 67) of the stations sampled. The five largest pieces that were not composited were found near shore throughout the upper 20 cm sediments (see Figure 3-7). A majority (13 of 30) of the fragments were encountered in the upper 5 cm of sediments with visible erosion as evidence by the rounded edges. At only one location (SK-24) were fragments found below 20 cm with sharp edges, indicating that the fragments were not significantly transported and eroded prior to burial.

Based on these observations, it appears that clay fragments are not uniformly distributed in sediments within the study area. In fact, the bulk of the locations where fragments were encountered tended to form two "clusters," a more aerially extensive, "northerly" cluster (including Stations SK-4, SK-5, SK-6, SK-7, SK-8, SK-9, SK-13, SK-30, SK-31, and SK-36) and a smaller "southerly" cluster (at Stations SK-24, SK-25, and SK-61). Pieces recovered from SK-60 were excluded from this analysis because it was later determined that these pieces were not clay pigeon fragments (see PAH fingerprinting paper in Appendix B). These two "clusters" are consistent with past skeet shooting practices, as seen in Figure 2-3. The northerly cluster represents the trajectory overlaps from both shooting ranges, whereas the southern cluster is likely associated with the shooting activities at the southern range. Clay target fragments that were encountered at locations beyond the two main "clusters" were reported from SK-18, SK-44, and SK-66. Stations SK-18 and SK-44 are located along the shooting trajectories developed from the northern range. It is suspected that fragments found in reference Station SK-66 may be due to sediment transport from the northern border of the Skeet Range.

3.2 PAH Fingerprinting Analysis

One of the objectives of the 2001 investigation was to collect appropriate data to determine if PAHs measured in sediment are associated with clay targets or other sources (e.g., runoff, petroleum releases, fires, car exhaust) resulting from regional impacts. Appendix B presents the PAH "fingerprinting" analysis white paper in its entirety; excerpts from this white paper are presented in this section.

As described in Section 2.2, a total of 25 core stations were sampled and analyzed for TPH-DRO and PAHs. At each station, the 20-cm-long cores were subsampled in 5-cm increments for PAH fingerprinting to better describe the source of PAHs in the sediment. Additional chemical compounds (non-COPEC PAHs and TPH) also were evaluated for fingerprinting purposes based on an inventory of 43 nonalkylated and alkylated PAHs (see Table 3-3) that constituted the basis for the forensic investigation (e.g., Stout et al., 2001).

In addition to the cores, clay target fragments were hand-collected to establish the PAH signature unique to targets. Clay targets are comprised of approximately two-thirds limestone ($CaCO_3$) and one-third an organic binder. The organic binder is traditionally comprised of either coal-derived materials (coal tar pitch) or petroleum-derived residues (bitumen, tar, or asphalt) (see Figure 3-8). The general composition of PAHs derived from each type of binder is fairly well established. The coal tar binder material exhibits characteristic "pyrogenic" features, such as the predominance of nonalkylated (parent) PAHs and decreasing abundance of alkyl-homologues with increasing degree of alkylation (Stout et al., 2002). This pyrogenic pattern is dominated by fluoranthene/pyrenes flanked by approximately equal amounts of phenanthrenes/anthracenes and benz(a)anthrancenes/chrysenes.

However, these pyrogenic features contrast with the more "petrogenic" PAH distribution in clay targets manufactured using a petroleum-derived bitumen binder. Petrogenic patterns are dominated by fluoranthene, benzo(b)fluoranthene, and indeno(1,2,3-cd)pyrene. The PAHs in a Winchester clay target purchased from a local sporting goods store exhibit characteristic petrogenic features that include a predominance of C_2-C_3 alkyl-homologues (see Figure 3-8), which can be readily distinguished from coal-derived binders.

PAHs from urban sediments typically show a pyrogenic PAH signature, dominated by nonalkylated PAH attributed to urban runoff/fallout, because (1) the PAHs in stormwater runoff often have a pyrogenic PAH signature to begin with, and (2) the 2- and 3-ring PAHs are more water soluble and degradable than higher-ring PAHs. These runoff PAH signatures can be readily distinguished from PAH signatures originating from the organic binder materials used in clay targets.

3.2.1 Principal Component Analysis

The chemical compositions of sediment and fragment samples were evaluated using principal components analysis (PCA) in order to help classify PAHs in sediments and clay target fragments according to their chemical similarities or differences, without any preclassification as to their nature/source(s). PCA is a factor analysis method that generates new independent variables (i.e., factors) that are linear combinations of the original input variables (e.g., PAH concentrations or ratios; Johnson et al., 2002). Data used in the analysis include concentrations from all 43 PAH analytes for all sediment and fragment samples collected.

As shown on Figure 3-9, the PCA indicated that PAH distributions observed in sediment samples (designated with the prefix "SK-") appear quite uniform in composition based on their clustering. As also shown on Figure 3-9, the PCA revealed the presence of three distinct types of fragments that are chemically different based on their PAH compositions. Also, each type of clay fragment (designated with the prefix "F-") was distinct from the PAH distributions observed in sediment samples. The three types of fragments are:

- An "asphalt-like" material exemplified by the atypical fragments obtained from SK-60 (0-5 cm) sample. The sample results are plotted in the upper right corner of the plot under F-SK-60-0. Inspection of the accompanying factor loadings plots (Figure 3-9C) reveals that this material contains relatively high concentrations of HPAHs (4- to 6-ring) with a petrogenic signature similar to asphalt. This sample also had excessively high TPH concentrations and unique PAH distributions.

- Clay target fragments containing a "pitch-type" of coal-derived organic binder as exemplified by three of the larger clay fragments obtained from SK-30 (5-10 cm), SK-61 (5-10 cm), and SK-24 (20-25 cm). All of these samples were plotted in the lower right corner of the figure. All of these samples appear to contain relatively high concentrations of HPAHs (4- to 6-ring) with an overwhelmingly pyrogenic signature similar to coal tar pitch.

- Clay target fragments containing a petroleum-derived organic binder as exemplified by the fragments from SK-30 (0-5 cm) sample. The sample plotted in the right corner of the figure indicated that the sample contained relatively high concentrations of intermediate weight (3- to 5-ring) PAH with a petrogenic signature observed in petroleum-derived organic binder.

The composited clay fragment pieces appear to plot between the fragment types and the sediments. The mixed signature likely is due to the compositing of fragment pieces manufactured using coal-derived and petroleum-derived organic binders. However, the figure clearly indicates that three types of fragments were encountered at the Skeet Range. The question then becomes whether evidence for the presence of PAHs in sediment mirrors those PAHs found in the clay fragments.

Figure 3-9A reveals that samples enriched in alkylated PAHs (i.e., petrogenic PAHs) plot near the top of the figure, whereas samples with high concentrations of nonalkylated (i.e., parent or pyrogenic PAHs) plot on the right side of the figure. Samples plotted in the lower left corner of the figure contain lower concentrations of lighter (lower molecular weight) pyrogenic PAHs. All of the sediment samples "clustered" tightly in the lower left corner of the plot and were clearly chemically distinct from the three types of clay fragments described above. Some sediment samples are "pulled" out of the main cluster of sediments toward fragment samples, suggesting that some sediments may contain PAHs associated with the fragments. However, the clear and distinct separation between all of the sediments and the fragment samples indicate that the sediments contain different chemical compositions from any of the fragments.

In fact, no obvious combination of any of the fragments or weathering process would generate a PAH distribution typical of the sediments. The source of the PAHs appears to be distinct from the fragments.

To more fully differentiate the relationship between pyrogenic PAHs in clay targets and sediment, a second PCA was conducted to determine the specific compositional differences between the pyrogenic fragments and sediments using diagnostic source and weathering ratios appropriate for the 3- to 6-ring PAHs detected in sediment. Results of the PCA performed on PAH ratios indicated that a similar PAH signature was found among all of the sediment samples; these results are similar to those from the first PCA. The sediment samples from different locations, background areas, depths, and lead shot density closely overlap within the boxed area of Figure 3-10. These samples are clearly different from fragment samples that were relatively enriched in parent and 5-carbon-ring-containing PAHs [fluoranthene, benzo(b)fluoranthene, and indeno(1,2,3-cd)pyrene] attributed to the extreme thermal conditions used during manufacturing. The composited fragment sample from SK-36 was relatively unique due to its high relative abundances of fluoranthene, pyrene, and the alkylated fluoranthenes and pyrenes. The deeper samples (70-100 cm) from SK01 resembled the sediment samples in a more weathered state as indicated by the depletion of 2- and 3-ring PAH relative to 4-, 5-, and 6-ring PAH. Finally, sample SK-17 from 15 cm-20 cm was statistically independent from the other sediments due to the presence of petroleum and diagenic material as indicated by the enriched organic sulfur and perylene, respectively.

3.2.2 PCA Conclusions

It was concluded based on multiple lines of evidence that it is unlikely that PAHs leached from clay targets into sediment at the Skeet Range. This is supported by numerous findings that include:

- Nearly all of the sediment samples were chemically distinct from the chemical composition of clay target fragments.
- The total extractable hydrocarbon and PAH "fingerprints" in the clay target fragments were not detected in the sediment samples from which they were most closely associated. This result suggests that the abrasions or leaching of any organic binder from the clay fragments was not the source of hydrocarbons, including PAHs, in the sediments.
- Approximately 90% of the sediment samples containing less than 10,000 μg/kg (dry) total PAHs were distributed uniformly both laterally and with depth, including areas beyond the expected fall zone of clay targets.
- The influence of the Skeet Range activities on the PAHs in the sediments was unrecognized except for the isolated fragments of clay targets recovered from areas around SK-7 (north cluster) and SK-25 (south cluster). However, the chemical differences between these fragments and the sediments around them, along with the virtual absence of soluble PAHs in both fresh and weathered clay target fragments, suggest that the PAHs bound within these fragments were not leached to sediments.

3.3 Sediment Dynamics Study

The objectives of the sediment dynamics evaluation of the Skeet Range offshore area were to (1) predict sediment mobility based on a qualitative evaluation of hydrodynamic conditions and sediment characteristics; (2) estimate sediment accumulation rates based on radioisotope data from sediment cores collected in November 2001; and (3) evaluate the potential for the erosion or burial of lead shot based on the prevailing hydrodynamic conditions and estimated sediment accumulation rates. This section presents excerpts from the entire sediment dynamics study, which is presented in Appendix C.

3.3.1 Radioisotope Analysis

In November 2001, three sediment cores (SK-1, SK-2, and SK-3) were collected and analyzed for the radioisotopes Pb-210 and Cs-137 to estimate sediment accumulation rates. The core samples were collected in water depths ranging from 3.1 to 3.8 m MLLW at stations shown in Figure 2-1. As stated in Section 2.3.3, the samples were collected for radioisotope analysis in 2-cm increments at 10-cm intervals to a depth of 102 cm. Macroscopic examination of the sediment cores indicated that the sediment type and structure were uniform and homogeneous with increasing depth at all three locations. The sediment consisted of dark gray to very dark gray clayey silt with no obvious lamination or stratification. The fine-grained, uniform sediment texture indicates that the sediment was deposited in a uniform, relatively low energy depositional environment.

The use of radioisotope profiling to support the characterization of sediment dynamics is described in Appendix C. Briefly, Pb-210 forms by the radioactive decay of its gaseous parent, Rn-222. Unsupported Pb-210 (i.e., concentration exceeding background or "supported" levels) is removed from the atmosphere by precipitation, and is rapidly adsorbed to and deposited with sediment particles. Using a half-life of the Pb-210 of 22.3 years, the accretion rate can be estimated by determining decrease of Pb-210 activity with depth until it reaches the supported Pb-210 level. However, mixing or disturbance of the sediment column by organisms and other processes will disrupt the smooth profile and reduce the accuracy of the estimated dates and sediment accumulation rates. Three key assumptions associated with the use of radioisotopes to estimate sediment age dates are that (1) the sediment accumulation rate is constant (i.e., sedimentation processes are uniform and continuous), (2) the grain size of the deposited sediment is uniform, and (3) there is no postdepositional redistribution of sediments or Pb-210. If grain size data are not available, the percent dry weight data are used as a proxy for grain size. Ideally, percent dry weight will be constant throughout the sediment column, with lower percent dry weight reflecting finer-grained sediment (silt and clay) and higher percent dry weight reflecting sandier sediment.

Data for the radioisotope Cs-137 can be used to confirm dates estimated from the Pb-210 data. Cs-137 was present in the fallout from atmospheric nuclear tests, and first appeared in sediment cores around 1952-1955 with maximum deposition occurring in 1963-1964. In an undisturbed sediment core, Cs-137 activity levels will mirror the production of Cs-137 with an initial appearance in the 1950s, a peak in the early 1960s, and a decrease in the early 1970s after atmospheric testing was halted. This profile may be difficult to observe in cores that are not continuously subsampled.

Pb-210 and Cs-137 results and percent dry weight data for the three cores are provided in Table 3-4. Figure 3-11 shows the percent dry weight, and Figures 3-12 through 3-14 show Pb-210 and Cs-137 activity with increasing depth. None of the three cores were ideal for application of the Pb-210 dating method. The variable radioisotope profiles may be due to grain size changes that are not visible on a macroscopic scale and postdepositional sediment mixing and disturbance.

Using the data collected from Core SK-1, the average sediment accumulation rate was estimated at 0.9 cm/yr. The Cs-137 profiles in Cores SK-1 and SK-3 indicated an average sediment accumulation rate between 0.65 and 1.0 cm/yr based on the depth of the first appearance of Cs-137. The presence of Cs-137 to a depth of >1 m in Core SK-2 implies a sediment accumulation rate of >2 cm/yr; however, this could not be verified with Pb-210 due to the increased activity of Pb-210 with depth in Core SK-2.

USACE compared bathymetric differences in San Francisco Bay from 1955-1990 in order to identify areas of net sediment accretion and erosion (USACE and Port of Oakland, 1998). The Skeet Range was shown as an area of net accretion, with approximately 0.9-1.8 m of sediment accumulation in 35 years. This corresponds to an average sediment accumulation rate of 2.6-5.2 cm/yr. These estimates are broadly consistent with the radioisotope data collected for the Skeet Range RI. The major source of sediment to the area is most likely suspended sediment that is deposited when tidal velocities decrease. Some of this suspended material may originate from dredging operations at the Ports of Oakland and Alameda. As previously noted, no significant surface water bodies enter San Francisco Bay in the vicinity of the Skeet Range, and little material is likely to erode from the low-lying, armored shoreline.

3.3.2 *Ampelisca* Tubes

Tubes built by the amphipod *Ampelisca abdita* were noted in the surface sediments from Cores SK-1 and SK-2 and in most of the surface sediment grab samples collected across the Skeet Range. *Ampelisca abdita* is one of the dominant benthic invertebrate species found in intertidal and shallow subtidal areas of San Francisco Bay, and is abundant nearly everywhere in the bay (Nichols and Pamatmat, 1988; Weston, 1996). As described in Section 2.4, the top 5 cm of sediment at the majority of the Skeet Range sample stations were densely packed with *Ampelisca* tubes approximately 2-3 cm in length (Figure 2-2). Numerous polychaetes up to 12 cm long also were observed in many of the grab samples.

Ampelisca are sedentary, bottom-dwelling detritus feeders that build their tubes from grandular secretions and sand grains. They colonize in depositional areas where the density of other species is low (Mills, 1967). The tubes trap the sediment and detritus upon which the amphipods feed. The glandular secretions that form the tubes appear to increase the cohesiveness and stability of the sediment surface, although the tubes are susceptible to damage or destruction by storms (Mills, 1967). The tubes rarely persist for longer than one life cycle, which ranges from 40-100 days. The colonized areas eventually become unstable and wash out, and newly hatched juveniles will build new tubes on uncolonized sediment (Mills, 1967). In San Francisco Bay, *Ampelisca* tend to produce two generations per year, with peak abundance occurring in October (Nichols and Thompson, 1985b). The decline in abundance in South San Francisco Bay after October may be related to disturbance associated with winter runoff, although the factors most responsible for the decline are not clear (e.g. decreased salinity, decreased temperature, increased currents, or increased sediment resuspension and transport) (Nichols and Thompson, 1985b).

The presence of *Ampelisca* in the Skeet Range offshore area indicates that it is a depositional environment followed by occurrences of episodic resuspension. These amphipods prefer areas that lack a well established and diverse benthic community, and have a short life cycle that allows them to reproduce before the area can be colonized by competing species. This opportunistic lifestyle is compatible with episodic habitat disturbance, an association that appears to be characteristic of San Francisco Bay (Nichols and Thompson, 1985a and 1985b).

3.3.3 Potential for Erosion or Burial of Lead Shot

Information on site characteristics and estimated sediment accumulation rates was used to qualitatively evaluate the potential for erosion and exposure of lead shot at the Skeet Range. The Skeet Range operated from about 1953 to 1993, and the estimated net sediment accumulation rate is estimated to be between 0.65 and 1.0 cm/yr. If the depositional environment was relatively quiescent and undisturbed, then lead shot would not be found in the upper 5-8 cm of sediment or below 31-48 cm. Lead shot distribution maps (Figures 3-3 through 3-6) show that lead shot was found in a number of surface sediment samples (0-5 cm) in 2001, particularly in the central part of the Skeet Range fall zone. Lead shot concentrations are greatest between 4-20 cm below the surface, and shot was not found below 40 cm in previous investigations (TtEMI, 2000).

Although the Skeet Range has been inactive for almost 10 years and is an area of sediment accumulation, lead shot is still found at sediment surface. An investigation of lead shot transport phenomena in an offshore environment indicated that lead shot is more dense than sediment particles and behaves hydraulically like medium gravel (Madsen, 1997). If lead shot at the Skeet Range was being transported and redistributed by currents and waves, then it should co-occur with coarse-grained sediments. However, the majority of lead shot at the Skeet Range is found in clayey silt (>80% fines) within the fall zone, which suggests that little post-depositional transport has taken place.

It appears that the fine-grained sediment surrounding the lead shot is periodically eroded and resuspended, exposing some of the lead shot. Several lines of evidence indicate that periodic sediment resuspension and disturbance occur in the Skeet Range offshore area:

- Given the relatively shallow depth and exposed location of the fall zone, surface sediment is likely to be resuspended in periods of high winds;
- Radioisotope profiles deviate from the ideal profile for an undisturbed, uniform depositional environment.

The horizontal and vertical distribution of shot supports the hypothesis that lead shot has not been transported significant distances and that gradual burial is occurring. The fine-grained, uniform sediment texture indicates that the Skeet Range is generally a low-energy, depositional environment. Hydrodynamic forces appear to be sufficient to cause episodic resuspension of surface sediments, but are insufficient to transport the lead shot any significant distance.

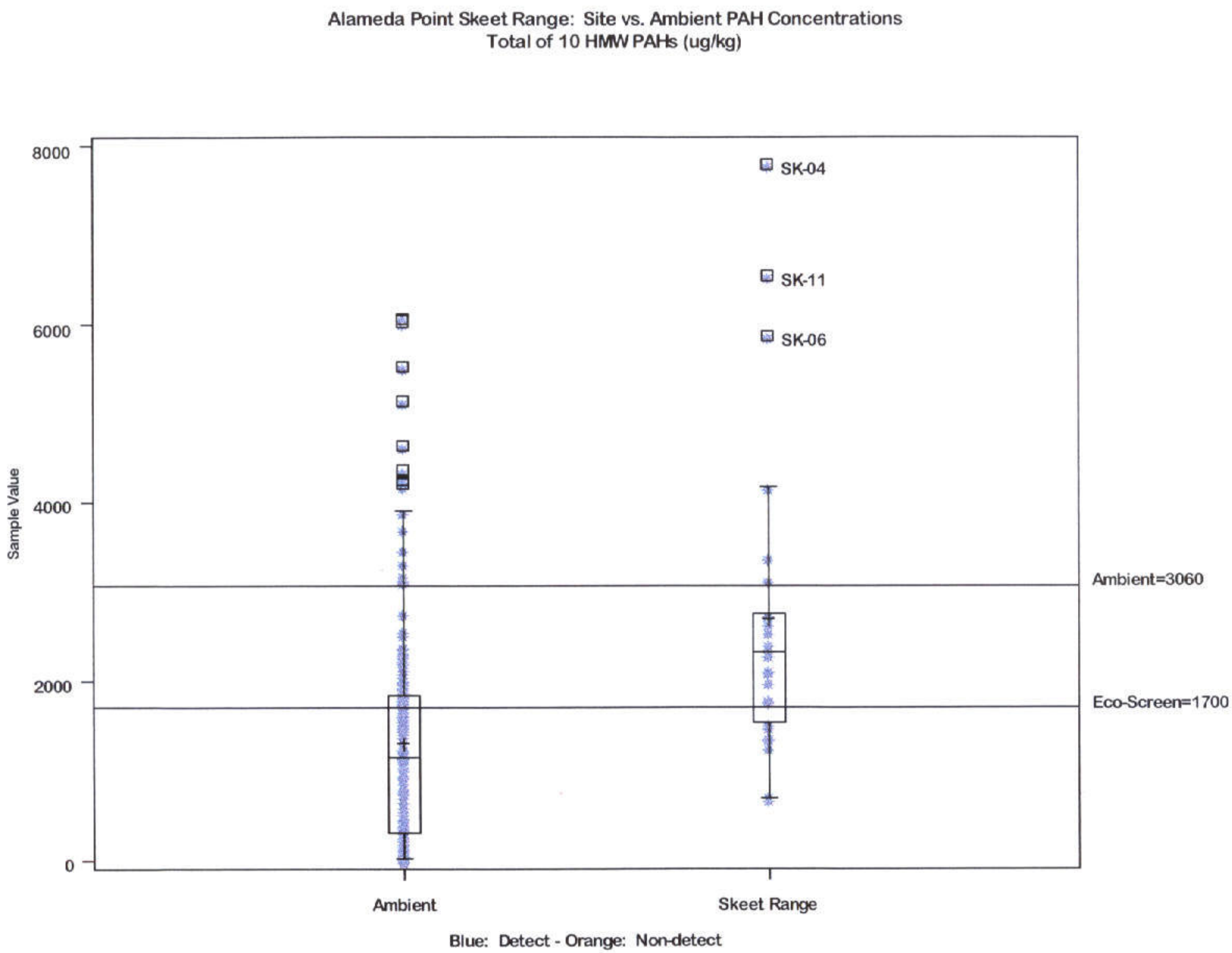

Figure 3-1. Box Plot of HPAHs in Surface Sediment (0-5 cm) at the Skeet Range

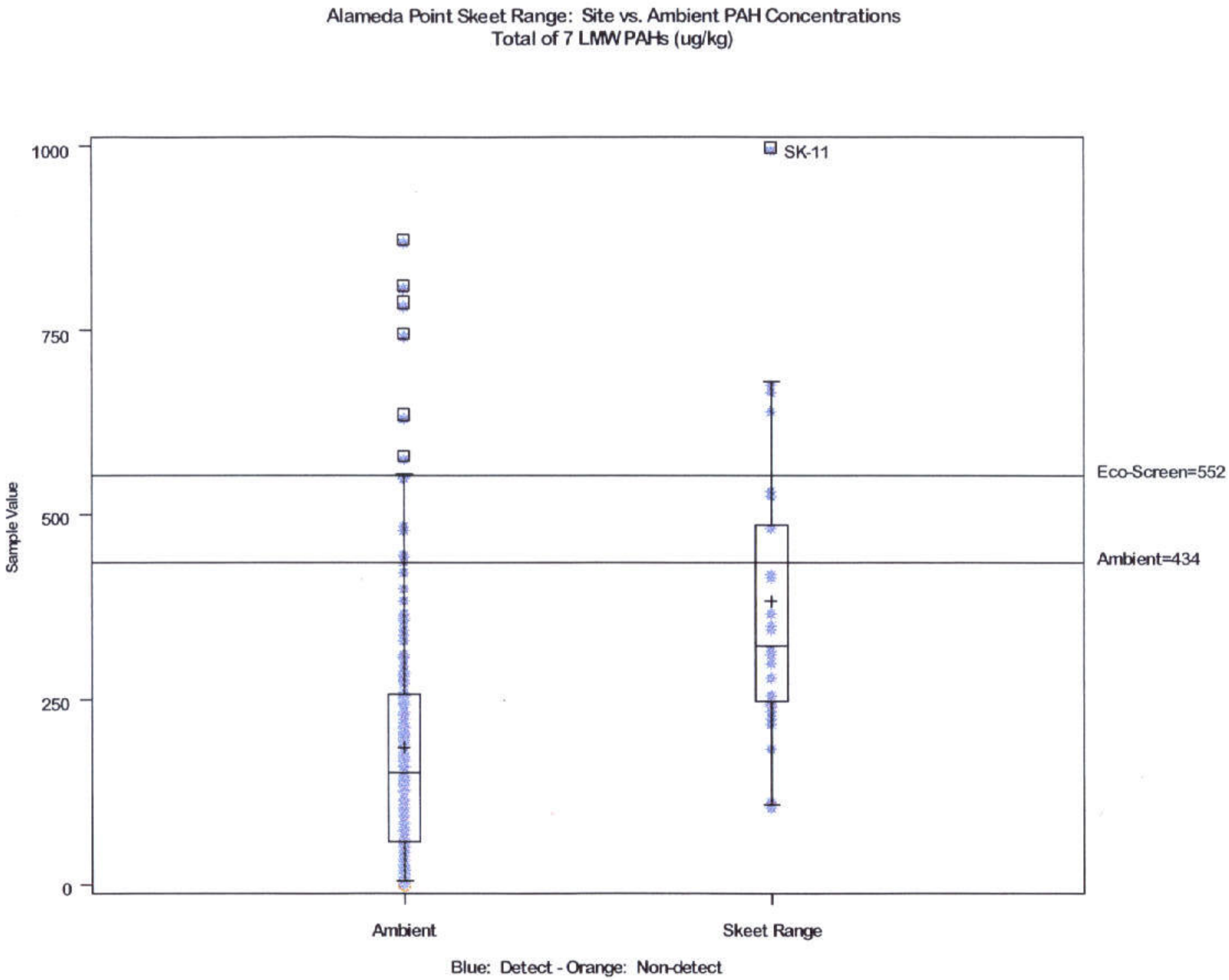

Figure 3-2. Box Plot of LPAHs in Surface Sediment (0-5 cm) at the Skeet Range

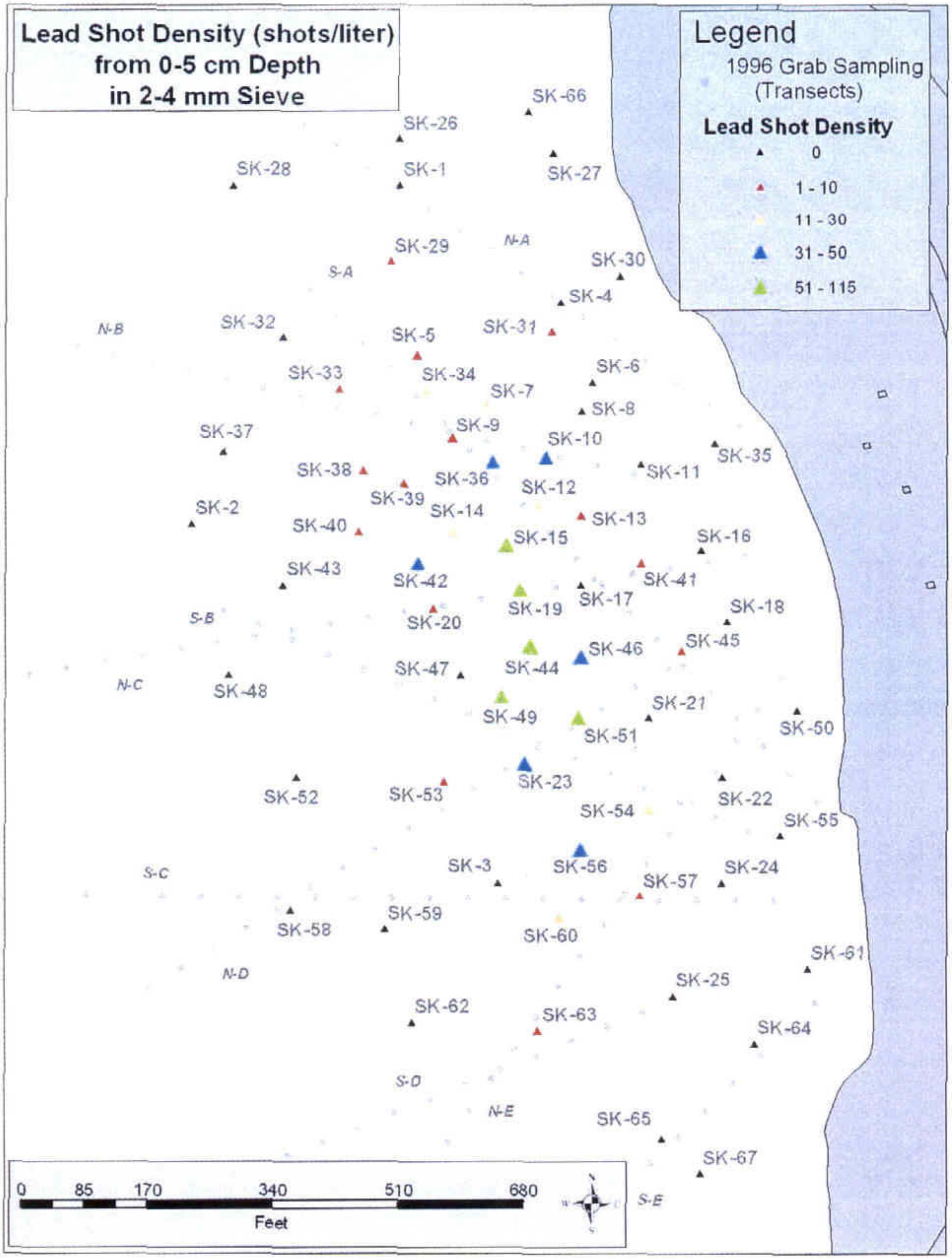

Figure 3-3. Lead Shot Density from 0-5 cm Depth in 2-4 mm Sieve

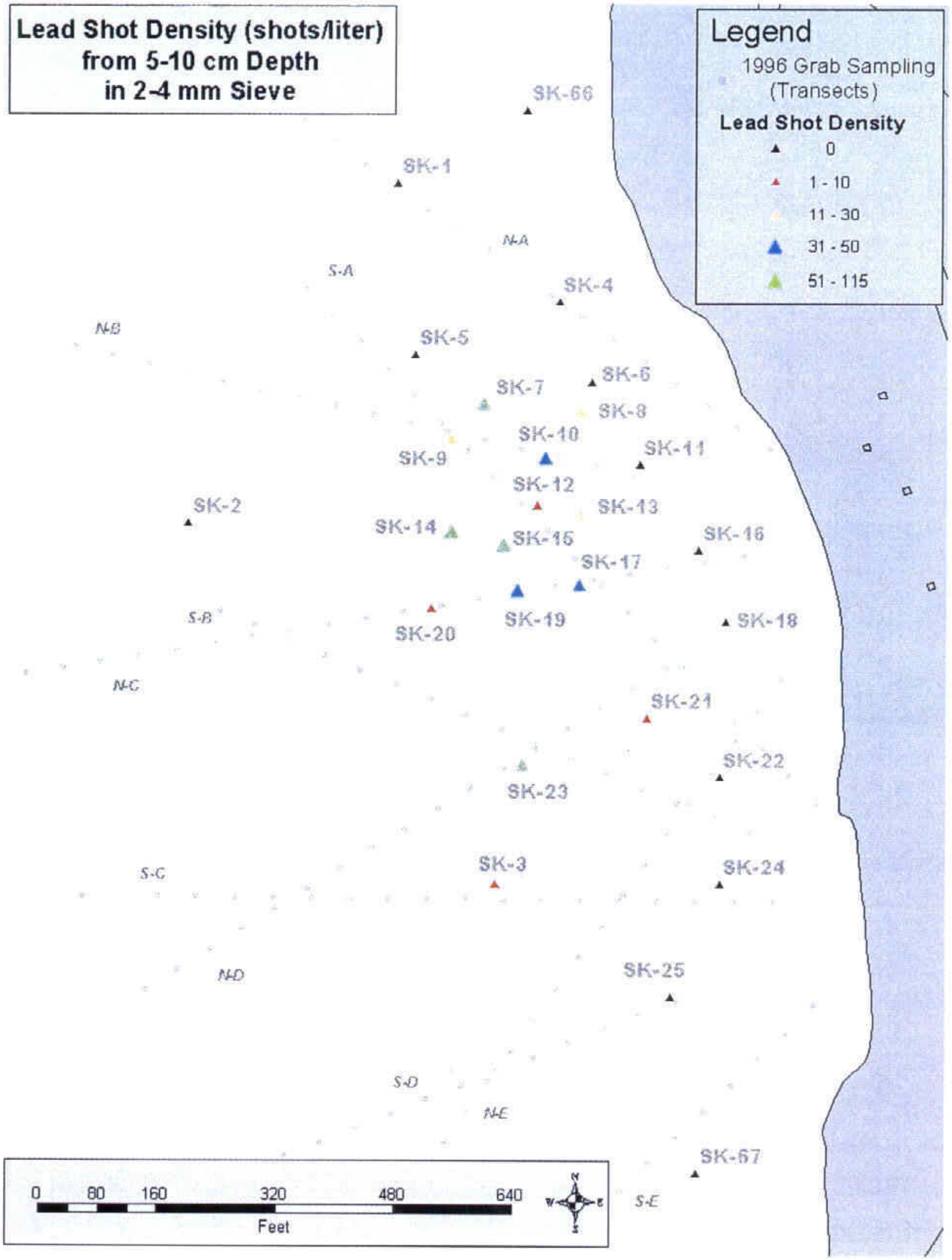

Figure 3-4. Lead Shot Density from 5-10 cm Depth in 2-4 mm Sieve

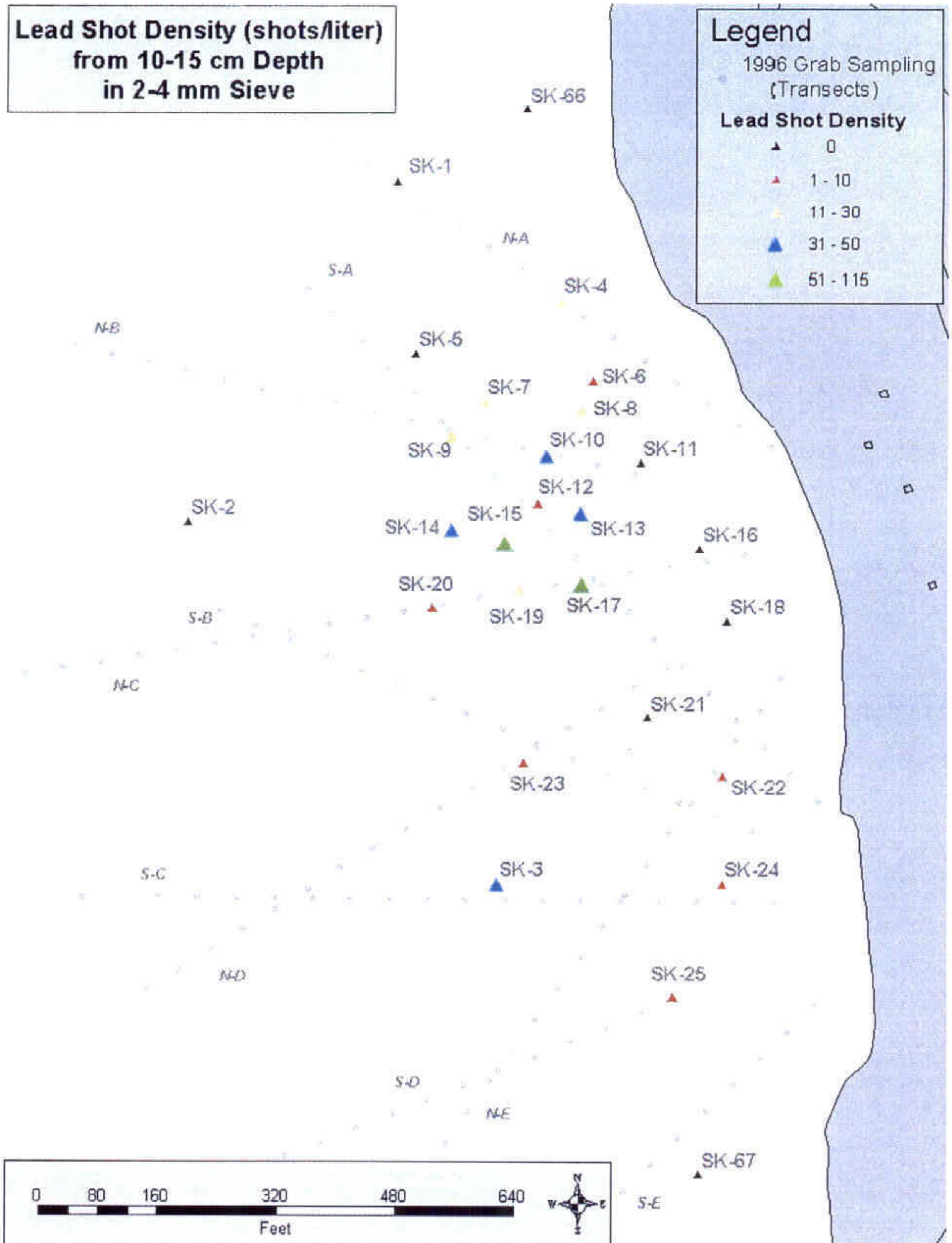

Figure 3-5. Lead Shot Density from 10-15 cm Depth in 2-4 mm Sieve

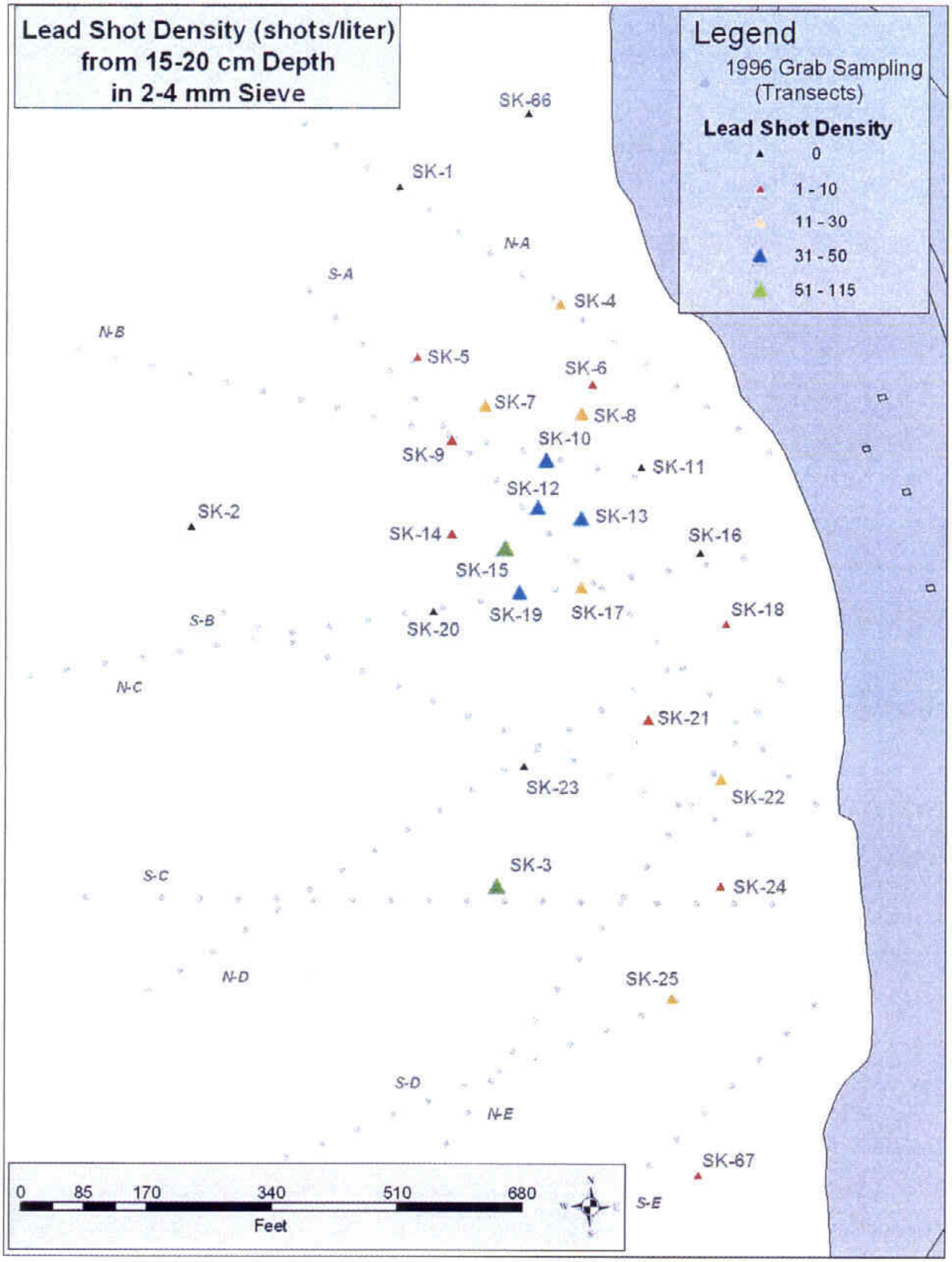

Figure 3-6. Lead Shot Density from 15-20 cm Depth in 2-4 mm Sieve

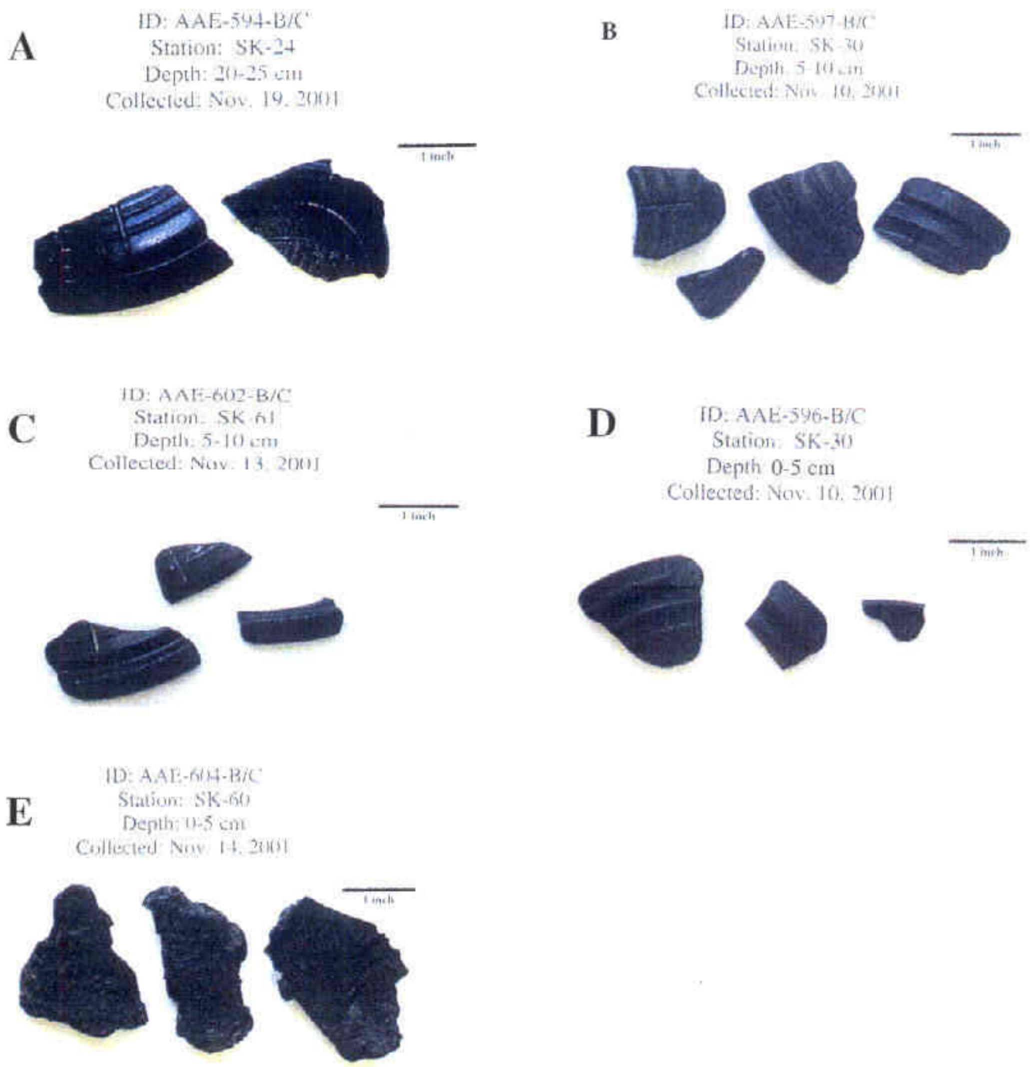

Figure 3-7. Photographs of the Larger Hand-Picked Fragments Encountered in Sediment Samples from Alameda Point Skeet Range Study. (A-D) represent typical clay target fragments; (E) is atypical and appears more like asphalt fragments.

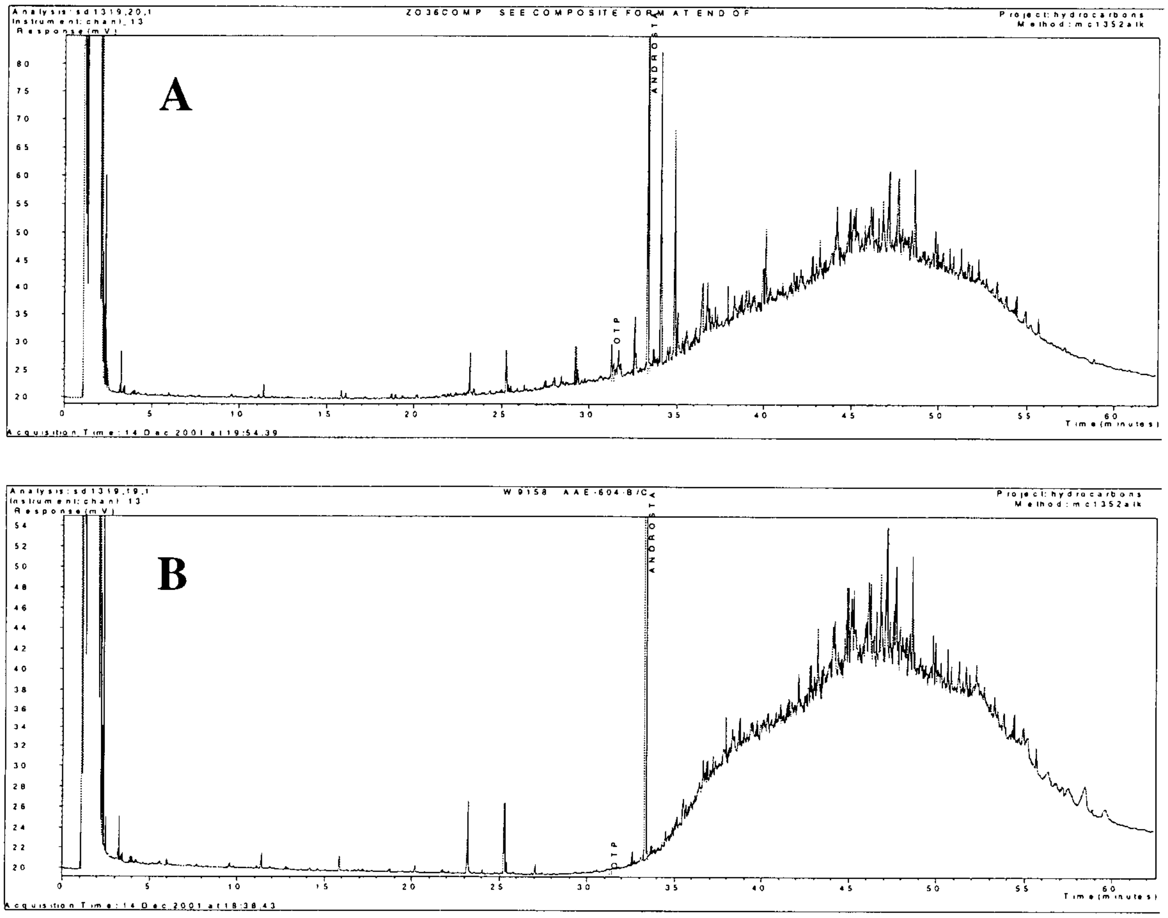

Figure 3-8. GC/FID Chromatograms of (A) Composite of Fragments Isolated from Sediments, and (B) Fragment Containing an "Asphalt-Like" Material Unrelated to Clay Targets

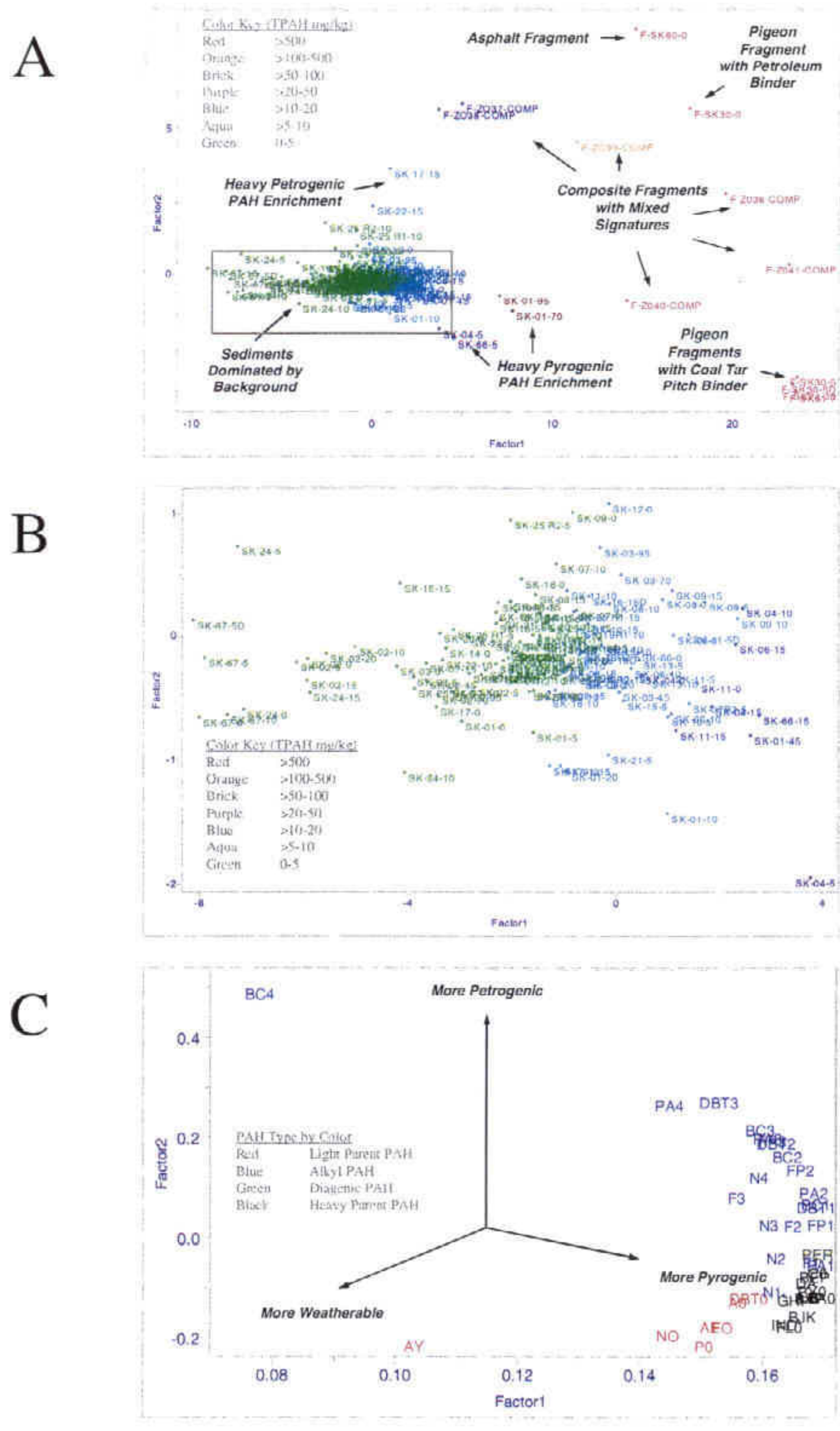

Figure 3-9. Results of the Principal Components Analysis (PCA) for PAH Analyte Concentrations. The factor score plot (a) presents the distribution of samples by sample type (fragments designated "F-"), station number (SK##), replicate (R#), and top depth of sampling interval (-##). A magnified view (b) of the boxed area in (a) is presented for improved resolution. The factor loading plot (c) presents the directional influence of each PAH analyte. Factors 1 and 2 accounted for 88% and 5.4% of the variability, respectively.

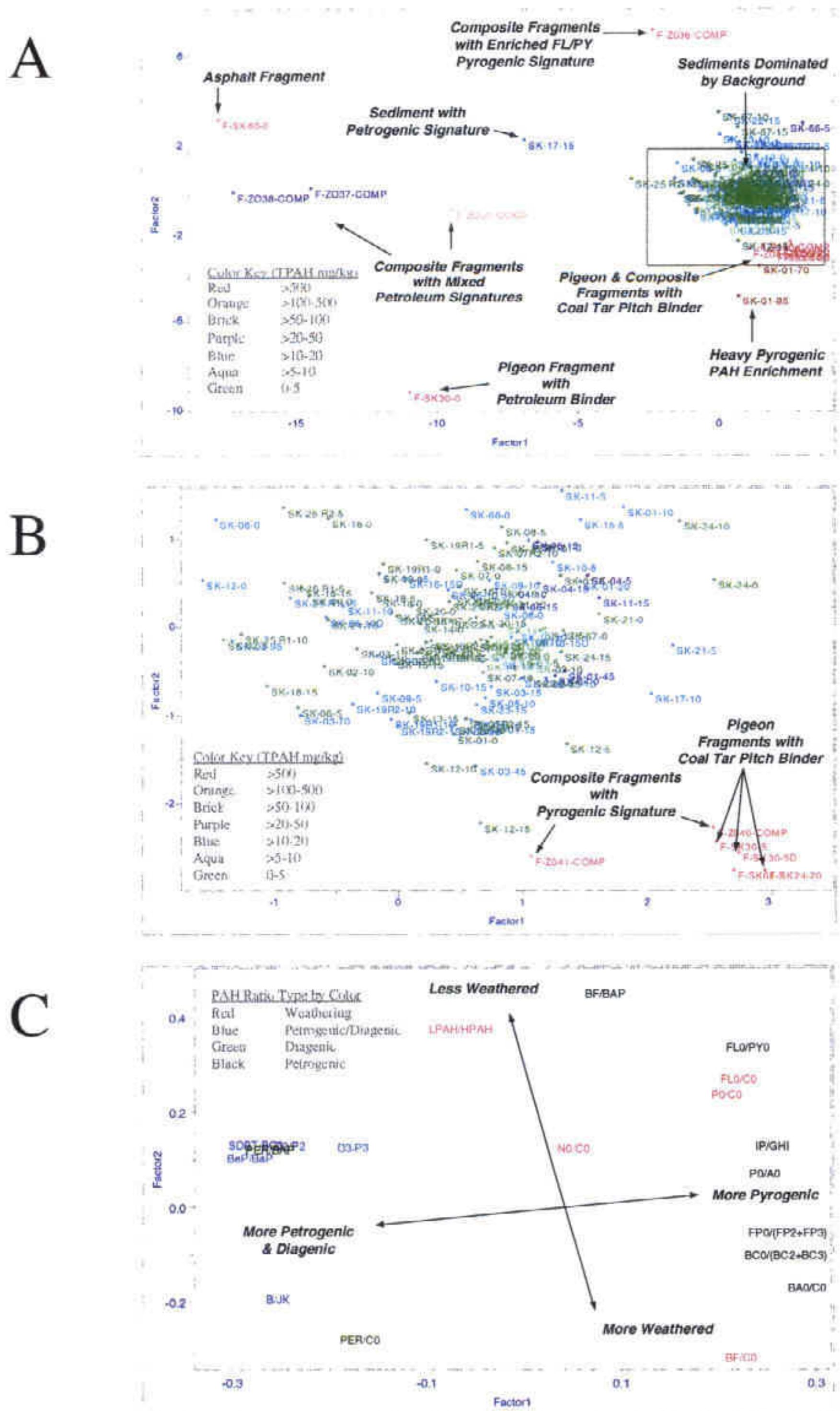

Figure 3-10. Results of the Principal Components Analysis (PCA) for Selected PAH Source and Weathering Ratios. The factor score plot (a) presents the distribution of samples by sample type (fragments designated "F-"), station number (SK##), replicate (R#), and top depth of sampling interval (-##). A magnified view (b) of the boxed area in (a) is presented for improved resolution. The factor loading plot (c) presents the directional influence of each PAH analyte. Factors 1 and 2 accounted for 44% and 13% of the variability, respectively.

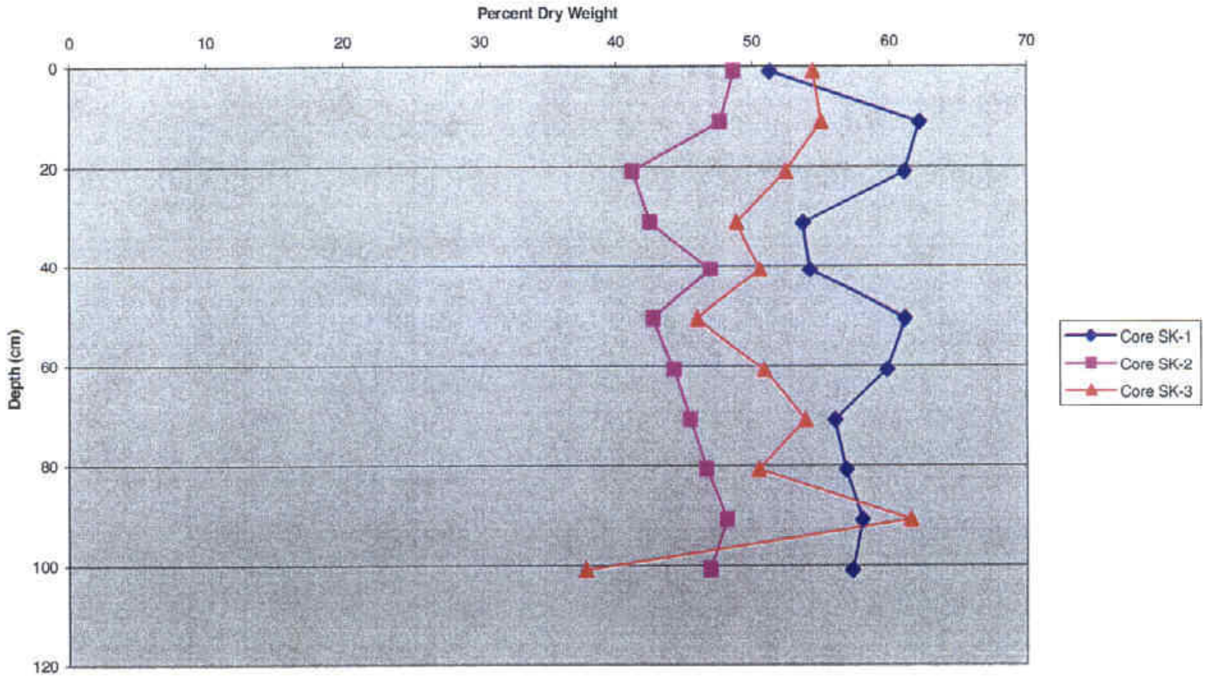

Figure 3-11. Percent Dry Weight in Cores SK-1, SK-2, and SK-3

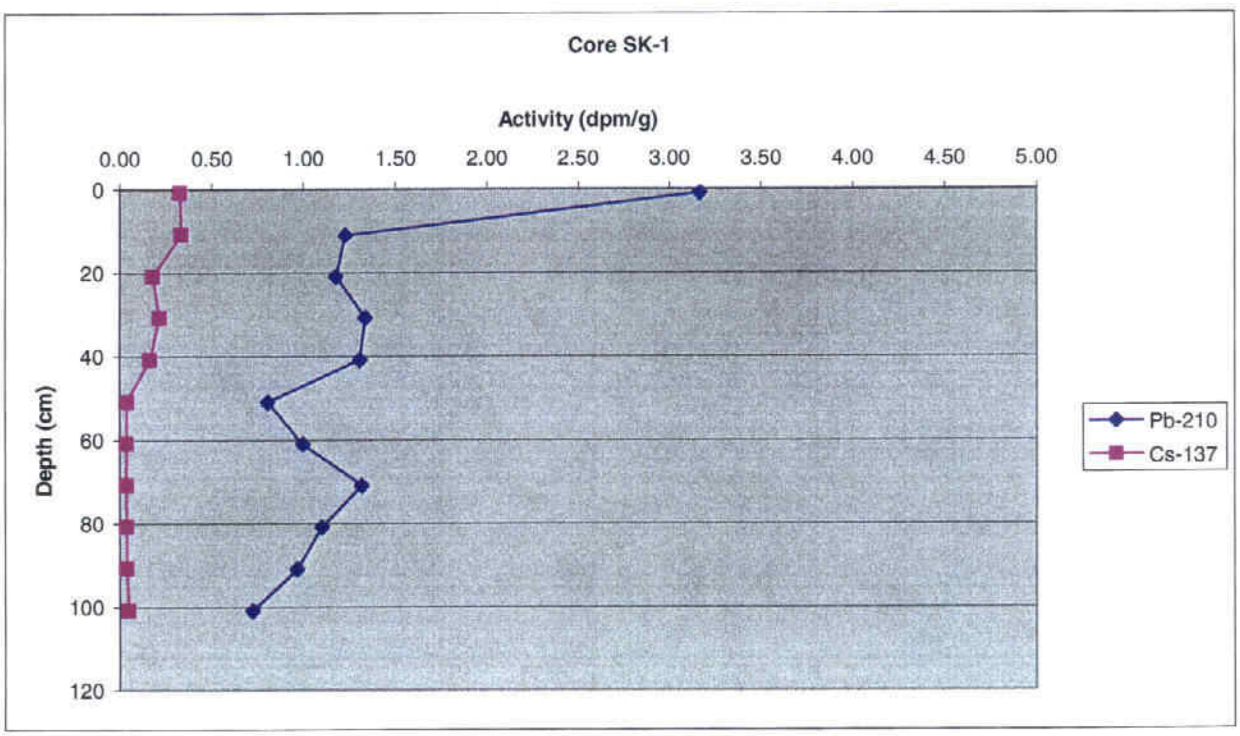

Figure 3-12. Pb-210 and Cs-137 Profiles in Core SK-1

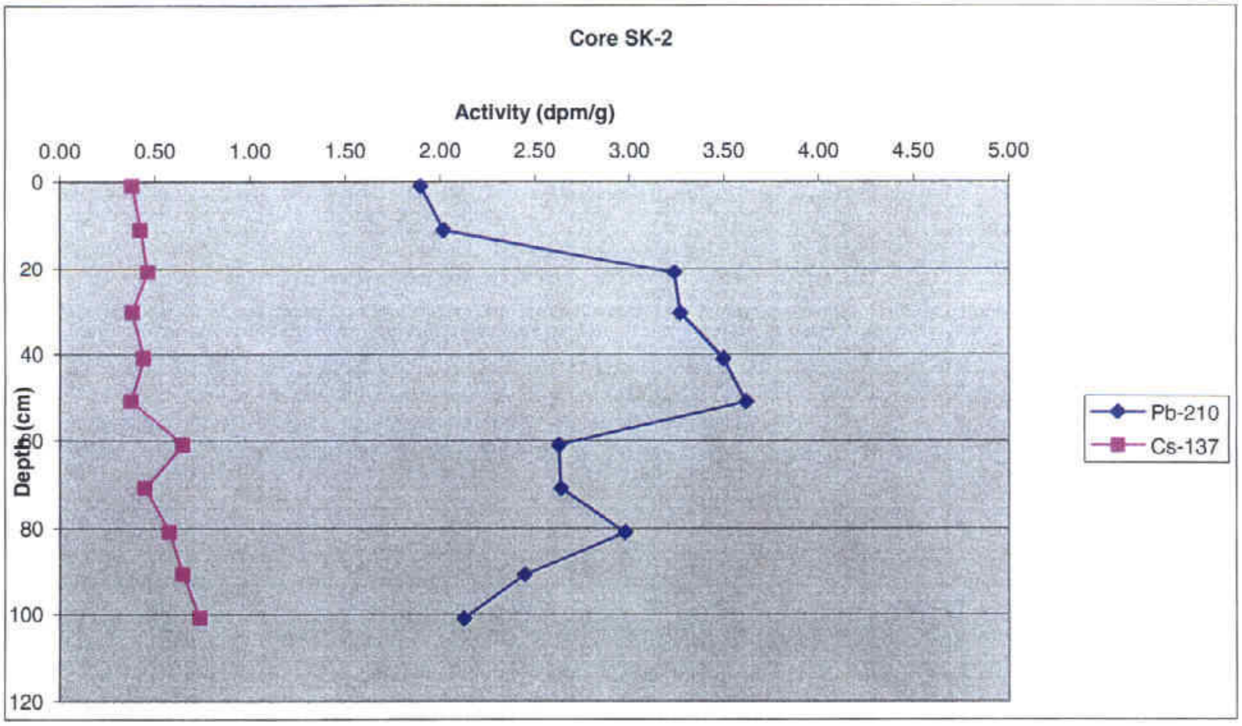

Figure 3-13. Pb-210 and Cs-137 Profiles in Core SK-2

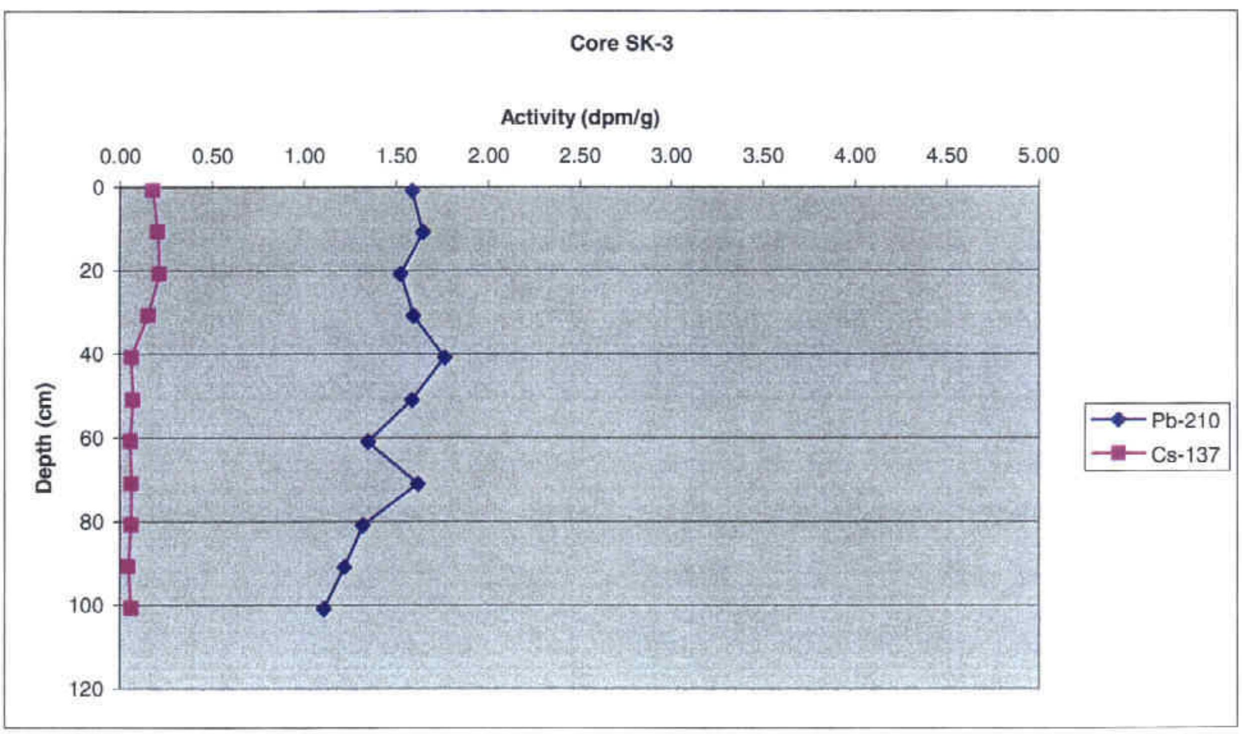

Figure 3-14. Pb-210 and Cs-137 Profiles in Core SK-3

Table 3-1. Identification of Stations Exceeding PAH Screening Benchmarks

Analyte	Benchmark (µg/kg) [(a)]	Stations Exceeding Benchmark (in order of decreasing concentration)
2-methylnaphthalene	170 (ER-L)	No exceedances
Acenaphthene	26.6 (Ambient UTL)	SK-04, SK-06, SK-08, SK-11, SK-66
Acenaphthylene	44 (ER-L)	SK-66, SK-08, SK-11, SK-13
Anthracene	88 (Ambient UTL)	SK-11, SK-66, SK-08, SK-07, SK-04, SK-06, SK-13, SK-10
Benzo(a)anthracene	261 (ER-L)	SK-04, SK-11, SK-06, SK-66, SK-08, SK-13
Benzo(a)pyrene	430 (ER-L)	SK-04, SK-11, SK-06, SK-12, SK-66
Benzo(b)fluoranthene	371 (Ambient UTL)	SK-04, SK-11, SK-06, SK-08
Benzo(g,h,i)perylene	310 (Ambient UTL)	SK-04, SK-06, SK-11, SK-12, SK-15, SK-23, SK-05, SK-19
Benzo(k)fluoranthene	258 (Ambient UTL)	SK-04, SK-11, SK-06, SK-08, SK-66, SK-12, SK-13
Chrysene	384 (ER-L)	SK-04, SK-11, SK-06, SK-08
Dibenz(a,h)anthracene	63.4 (ER-L)	SK-04, SK-11, SK-06, SK-66
Fluoranthene	600 (ER-L)	SK-04, SK-11, SK-06
Fluorene	25.3 (Ambient UTL)	SK-11, SK-66, SK-13, SK-04, SK-06, SK-08
Indeno(1,2,3-cd)pyrene	382 (Ambient UTL)	SK-04, SK-11, SK-06
Naphthalene	160 (ER-L)	No exceedances
Phenanthrene	240 (ER-L)	SK-11, SK-04, SK-66, SK-06, SK-08, SK-07, SK-13
Pyrene	665 (ER-L)	SK-04, SK-08, SK-06, SK-11

(a) The greater of the ER-L and ambient UTL.

Table 3-2. Vertical Distribution of Lead Shot in Sediment Cores

Station ID	Field QC Code	Density 0-5 cm (shot/L)	Density 5-10 cm (shot/L)	Density 10-15 cm (shot/L)	Density 15-20 cm (shot/L)
SK-1	SA	0.0	0.0	NA	0.0
SK-2	SA	0.0	0.0	0.0	NA
SK-3	SA	NA	4.9	39.5	86.3
SK-4	SA	0.0	0.0	14.8	12.3
SK-5	SA	7.4	0.0	0.0	2.5
SK-6	SA	0.0	0.0	2.5	4.9
SK-7	DU	34.5	27.1	24.7	0.0
SK-7	SA	12.3	69.1	22.2	19.7
SK-8	SA	0.0	24.7	17.3	22.2
SK-9	SA	9.9	22.2	24.7	9.9
SK-10	SA	37.0	44.4	39.5	37.0
SK-11	SA	0.0	0.0	0.0	0.0
SK-12	SA	19.7	2.5	2.5	34.5
SK-13	SA	2.5	14.8	44.4	34.5
SK-14	SA	27.1	76.5	39.5	7.4
SK-15	SA	88.8	83.9	69.1	96.2
SK-16	SA	0.0	0.0	0.0	0.0
SK-17	SA	0.0	34.5	49.3	19.7
SK-18	SA	NA	NA	0.0	2.5
SK-19	DU	59.2	27.1	49.3	9.9
SK-19	SA	51.8	44.4	17.3	34.5
SK-20	SA	2.5	4.9	7.4	0.0
SK-21	SA	NA	2.5	0.0	9.9
SK-22	SA	NA	0.0	2.5	14.8
SK-23	SA	39.5	64.1	2.5	NA
SK-24	SA	NA	0.0	2.5	4.9
SK-25	DU	0.0	0.0	4.9	17.3
SK-25	SA	0.0	NA	2.5	7.4
SK-66	SA	0.0	0.0	0.0	NA
SK-67	SA	0.0	0.0	0.0	2.5

DU = duplicate sample.
NA = not applicable.
SA = sample.

Table 3-3. Inventory of 43 PAH Analytes and Abbreviations Used in the 2001 Investigation

Analyte/Analyte Group	Abbr.	Analyte/Analyte Group	Abbr.
Naphthalene	N0	C3-dibenzothiophenes	D3
C1-naphthalenes	N1	C4-dibenzothiophenes	D4
C2-naphthalenes	N2	**Fluoranthene**	FL
C3-naphthalenes	N3	**Pyrene**	PY
C4-naphthalenes	N4	C1-fluoranthenes/pyrenes	FP1
Biphenyl	Bph	C2-fluoranthenes/pyrenes	FP2
Acenaphthylene	Acl	C3-fluoranthenes/pyrenes	FP3
Acenaphthene	Ace	**Benz(a)anthracene**	BaA
Dibenzofuran	DbF	**Chrysene**	C0
Fluorene	F0	C1-chrysenes	C1
C1-fluorenes	F1	C2-chrysenes	C2
C2-fluorenes	F2	C3-chrysenes	C3
C3-fluorenes	F3	C4-chrysenes	C4
Anthracene	AN	**Benzo(b)fluoranthene**	BbF
Phenanthrene	P0	**Benzo(j,k)fluoranthene**	BkF
C1-phenanthrenes/anthracenes	P1	Benzo(e)pyrene	BeP
C2-phenanthrenes/anthracenes	P2	**Benzo(a)pyrene**	BaP
C3-phenanthrenes/anthracenes	P3	Perylene	Per
C4-phenanthrenes/anthracenes	P4	**Indeno(1,2,3-c,d)pyrene**	ID
Dibenzothiophene	D0	**Dibenzo(a,h)anthracene**	DA
C1-dibenzothiophenes	D1	**Benzo(g,h,i)perylene**	BgP
C2-dibenzothiophenes	D2		

bold - 16 Priority Pollutant PAHs.

Table 3-4. Percent Dry Weight, Pb-210, and Cs-137 Results

Core	Depth (cm)	Percent Dry Weight	Activity Pb-210 (dpm/g)	Activity Cs-137 (dpm/g)
SK-1	0-2	51.3	3.17	0.330
SK-1	10-12	62.2	1.23	0.338
SK-1	20-22	61.1	1.18	0.183
SK-1	30-32	53.7	1.34	0.220
SK-1	40-42	54.2	1.31	0.169
SK-1	50-52	61.1	0.809	0.085 U
SK-1	60-62	59.8	1.00	0.081 U
SK-1	70-72	56.0	1.32	0.076 U
SK-1	80-82	56.8	1.10	0.079 U
SK-1	90-92	58.0	0.966	0.079 U
SK-1	100-102	57.3	0.722	0.101 U
SK-2	0-2	48.6	1.90	0.382
SK-2	10-12	47.6	2.02	0.427
SK-2	20-22	41.2	3.24	0.465
SK-2	30-32	42.5	3.27	0.384
SK-2	40-42	46.9	3.50	0.444
SK-2	50-52	42.7	3.62	0.377
SK-2	60-62	44.2	2.63	0.651
SK-2	70-72	45.4	2.64	0.450
SK-2	80-82	46.6	2.98	0.579
SK-2	90-92	48.1	2.45	0.651
SK-2	100-102	46.9	2.13	0.741
SK-3	0-2	54.4	1.59	0.181
SK-3	10-12	55.0	1.65	0.208
SK-3	20-22	52.4	1.53	0.218
SK-3	30-32	48.8	1.60	0.157
SK-3	40-42	50.5	1.77	0.132 U
SK-3	50-52	45.9	1.59	0.149 U
SK-3	60-62	50.8	1.35	0.120 U
SK-3	70-72	53.8	1.62	0.129 U
SK-3	80-82	50.4	1.32	0.125 U
SK-3	90-92	61.5	1.22	0.096 U
SK-3	100-102	37.8	1.11	0.125 U

U = not detected at or above the given detection limit.

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4.0 ECOLOGICAL RISK ASSESSMENT

The objective of the ERA is to evaluate the potential for adverse effects to the environment through exposure to sediment contaminants at the Skeet Range. To evaluate these potential risks, guidance from U.S. EPA (1992, 1997) and the Navy (CNO, 1999) was followed. As outlined in the guidance, a tiered process that encompasses 8 steps was followed (see Figure 4-1). In the first tier, a screening-level ecological risk assessment (SLERA) is conducted (encompassing Steps 1 and 2 of the U.S. EPA guidance) consisting of a preliminary conceptual site model (CSM), identification of COPECs, and a screening-level dose assessment using conservative assumptions. The second tier, or baseline ecological risk assessment (BERA) (Steps 3 through 7 of the U.S. EPA process), uses the output from the SLERA to refine the problem formulation stage and further evaluate the COPECs that may cause an adverse effect to receptors of concern. Exposure and effects were assessed for all endpoints defined in the problem formulation step and used to characterize risks to ecological receptors. The following sections describe in more detail the results of the tiered ERA process conducted for the Skeet Range.

4.1 Screening Level ERA

The primary goals of the SLERA are to identify appropriate ecological receptors and the constituents (i.e., COPECs) to which they might be exposed. As discussed above, the SLERA consisted of a preliminary problem formulation step with the development of a CSM, identification of COPECs, and a screening-level dose assessment. The output of the SLERA then was used to focus further evaluation in the BERA. In this section the preliminary CSM, Tier 1 COPEC screen, and the screening-level dose assessment will be discussed.

4.1.1 Problem Formulation

One of the first steps of the ERA process is the development of the problem formulation, which establishes the goals and the focus of the ERA. The problem formulation includes (1) the ecological setting, including the habitat and receptors potentially at risk; (2) selection of COPECs; (3) development of a CSM and exposure pathway analysis; and (4) selection of assessment and measurement endpoints. A preliminary problem formulation for the Skeet Range is presented in the following sections.

4.1.1.1 Ecological Setting

A complete habitat evaluation has not been conducted for the Skeet Range. However, an ecological assessment for Alameda Point (PRC, 1996) and field survey assessments conducted for other nearby areas, including Oakland Inner Harbor (ENTRIX, 1997) provide limited data and information describing the composition of the biotic community in and around Alameda Point.

Biota

The Skeet Range, like other areas of Alameda Point, supports a multi-trophic level ecosystem that includes a diversity of aquatic and terrestrial organisms. Previous investigations of the Skeet Range and proximate areas have reported the presence of diverse populations of benthic invertebrate, fish, and bird species (PRC, 1994 and 1996; ENTRIX, Inc., 1997; TtEMI, 2000).

The waters and benthos around Alameda Point support an abundance of prey items such as planktonic organisms (e.g., phytoplankton and zooplankton) and benthic organisms (e.g., polychaete worms, mollusks and crustaceans) (PRC, 1996; ENTRIX, 1997; TtEMI, 2000). The subtidal areas in the vicinity of Skeet Range are dominated by crustaceans, annelids, and molluscs.

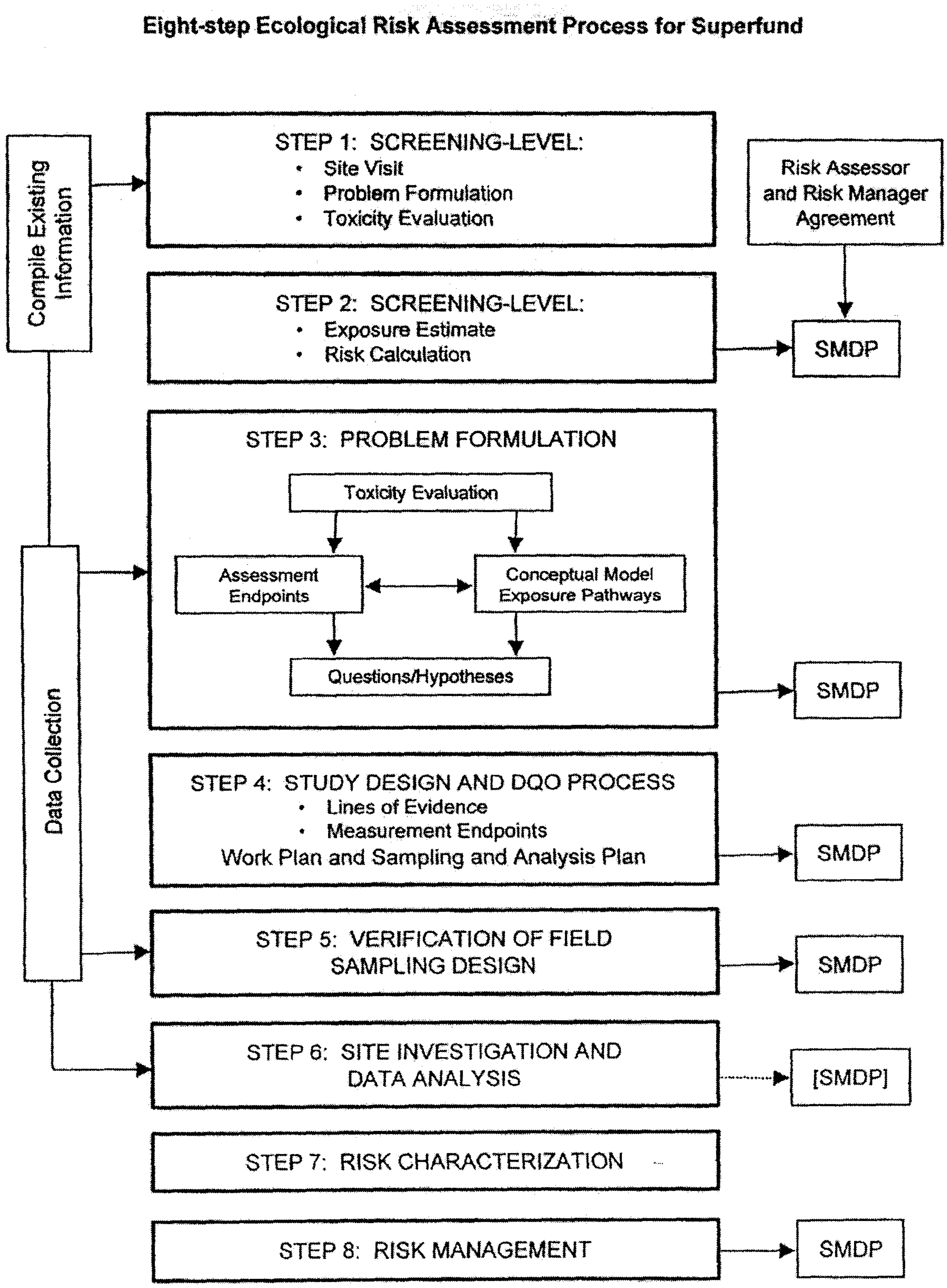


Figure 4-1. Overview of Eight-Step U.S. EPA Ecological Risk Assessment Process (from U.S. EPA, 1997)

The most abundant species present include black shrimp (*Crangnon nigricauda*), sand shrimp (*Crangnon franciscorum*), and dungeness crab (*Cancer magister*). Several species of polychaete worms and bivalves (e.g., *Mytilus edulis*) also are abundant (PRC, 1996; TtEMI, 2000). In sediment samples collected from the vicinity of the Skeet Range, Chapman et al. (1987) reported an abundance of crustacean species (*Ampelisca abdita, Photis californica,* and *Leptochelia* sp.), as well as the presence of polychaetes (*Euchone analis*) and phoronidae (tube worms; *Phoronis* sp.).

As discussed in Sections 2.4 and 3.3.2, sediment sampling in November 2001 confirmed the presence of tube worms in the top 5 cm of sediment at the majority of the Skeet Range sample stations. Samples consisted almost entirely of tubes built by amphipods *Ampelisca* (spp.) (Figure 2-2). In most cases, the tubes were very densely packed, and extended approximately 2-3 cm into the overlying water. *Ampelisca* are sedentary, bottom-dwelling detritus feeders that colonize in depositional areas where the density of other species is low (Mills, 1967). The tubes rarely persist for longer than 40 to 100 days, which is the typical life cycle. These and other benthic species represent a food source for predators such as fish and benthic-feeding birds.

The nearshore environment in the vicinity of the Skeet Range supports a diverse fish community (ENTRIX, 1997), including estuarine, marine, and anadromous fishes. Among them are various flatfish, surfperch, gobies, sculpin, silversides, pipefish, sharks, and rays. Several species of both pelagic and benthic fish are anticipated to be present at the Skeet Range, including shiner perch (*Cymatogaster aggregata*), bay pipefish (*Syngnathus leptorhynchus*), walleye surfperch (*Hyperprosopon urgenteum*), and redtail surfperch (*Amphistichus rhodoterus*).

Field surveys of bird communities in the vicinity of the Port of Oakland and Alameda Point were conducted by ENTRIX and the Biological Field Service in the winter (January – April) and summer (June – July) of 1997 (ENTRIX, 1997). Two of the survey areas were located off of the western end of Alameda Point and include the area encompassing the Skeet Range. The following discussion will focus on the species that feed in open water or along the shoreline. A wide range of species was observed in these surveys including grebes, gulls, diving ducks, cormorants, and terns. Although a number of aquatic bird species (e.g., gulls) are year-round residents of San Francisco Bay, many other species (e.g., grebes) are temporary residents, using the bay as wintering grounds during their seasonal migrations. This temporal variability in species composition and numbers is reflected in the results of the winter and summer field surveys conducted in the vicinity of Alameda Point.

In the winter surveys, more than 3,000 birds were observed in the vicinity of the Skeet Range, representing approximately 40 bird species. Birds in the Skeet Range area were observed over open water, along the shoreline and in proximate upland areas (ENTRIX, 1997). Daily numbers of each species varied from a single bird to hundreds of individuals. The most abundant and frequently observed species were American coots (*Fulica americana*), gulls (*Larus* sp.), grebes (*Aechmorphorus* sp.), and surf scoter (*Melanitta perspicillata*). The most common benthic-feeding species observed in the Skeet Range area included multiple species of grebes, surf scoters, and scaups (*Aythya* sp.). Species foraging at the tidal edge/shoreline included coots, sandpiper, heron, and mallards. California least terns (*Sterna antillarum browni*) were not seen in the winter surveys, which ended in April before this migratory species is seen in San Francisco Bay (ENTRIX, 1997). The avian species observed in the vicinity of the Skeet Range during the winter survey are listed in Table 4-1.

Table 4-1. Summary of Bird Survey Data Collected in the Vicinity of the Skeet Range (ENTRIX, 1997)

Common Name	Scientific Name	Present In Winter	Present in Summer	Total Observed (Winter + Summer)	Primary Feeding Habitat	Observed Feeding at Skeet Range?
Pacific loon	*Gavia pacifica*	3		3	Water column	Y
Common loon	*Gavia immer*	18		18	Water column	Y
Pied-billed grebe	*Podilymbus podiceps*	10		10	Benthos	Y
Horned grebe	*Podiceps auritus*	36		36	Benthos	Y
Western grebe	*Aechmophorus occidentalis*	43		43	Benthos	Y
Clark's grebe	*Aechmophorus clarkii*	15		15	Benthos	Y
Unspecified grebe species	*Aechmophorus* sp.	311		311	Benthos	Y
Brown pelican	*Pelecanus occidentalis*	1	3	4	Water column	N
Double-crested cormorant	*Phalacrocorax auritus*	41	71	112	Water column	Y
Pelagic cormorant	*Phalacrocorax pelagicus*	4	1	5	Water column	Y
Great blue heron	*Ardea herodias*	1		1	Shoreline	Y
Snowy egret	*Egretta thula*		16	16	Shoreline	NR
Mallard	*Anas platyrhynchos*	13	1	14	Shoreline	Y
American wigeon	*Anas americana*	18		18	Shoreline	Y
Greater scaup	*Aythya marila*	37		37	Water column/benthos	Y
Unspecified scaup species	*Aythya* sp.	12		12	Water column/benthos	Y
Surf scoter	*Melanitta perspicillata*	92		92	Water column/benthos	Y
Common goldeneye	*Bucephala clangula*	3		3	Water column/benthos	Y
Bufflehead	*Bucephala albeola*	3		3	Water column/benthos	Y
Red-breasted merganser	*Mergus serrator*	6		6	Water column	Y
American coot	*Fulica americana*	1201		1201	Shoreline/shallow benthos	Y
Willet	*Catoptrophorus semipalmatus*	48	4	52	Tidal edge	Y
Western sandpiper	*Calidris mauri*		68	68	Tidal edge	NR
Least sandpiper	*Calidris minutilla*	36		36	Tidal edge	Y
Forster's tern	*Sterna forsteri*	18	8	26	Water column	Y
California least tern	*Sterna antillarum browni*		22	22	Water column	NR
Caspian Tern	*Sterna caspia*	4	18	22	Water column	NR

NR = Behavioral descriptions were not included in summer surveys.

In summer surveys, both the number of species (26) and overall abundance (total of 550 birds) observed were reduced in comparison to the winter surveys. Western gulls (*Larus occidentalis*), western sandpiper (*Calidris mauri*), double-crested cormorant (*Phalacrocorax auritus*), doves (*Columba livia* and *Zenaida macroura*), California least terns, and snowy egret (*Egretta thula*) were the most abundant species overall (ENTRIX, 1997). The avian species observed in the vicinity of the Skeet Range during the summer survey are listed in Table 4-1.

Previous investigations (PRC, 1994 and 1996) at Alameda Point and a review of the literature indicate that numerous additional species could be present at the site. A detailed list of species potentially present at the site is provided in Appendix E.

Special Status Species

Several species with special conservation status may be present in the area surrounding Alameda Point. Special conservation status is defined as (1) species officially listed as threatened or endangered under the California state or federal Endangered Species Act; (2) state or federal candidate species for possible listing; and (3) California Department of Fish and Game (CDFG) Species of Special Concern.

Several species of birds warranting special conservation status may forage, roost and/or nest in the vicinity of Alameda Point. The former NAS Alameda has been the primary nesting site in Northern California for least terns, which are listed as endangered both federally and by the state of California, since 1977, excluding 1983 (Feeney and Collins, 1993). The largest breeding colony of Caspian terns (a CDFG Species of Special Concern) on the Pacific coast of North America is just south of the Skeet Range, in the West Beach Landfill Wetland (Bailey, 1994). However, recent communication with the Audubon Society indicates that this colony may no longer use the West Beach Landfill Wetland as a breeding location (Feinstein, 2004). California brown pelicans, which are endangered federally and are a State of California Fully Protected Species, use the breakwater island for day and night roosting, mainly from May to November each year (Bailey, 1985). The western snowy plover is a federally threatened species and CDFG Species of Special Concern. Plovers breed in the vicinity of the former NAS Alameda during the summer, nesting in uplands but foraging along the shoreline. Two pairs of American peregrine falcons, which are federally and state listed as an endangered species, have been observed nesting on the Bay Bridge (Bell et al., 1996), but the time spent foraging near the Skeet Range and Alameda Point is unknown. Double-crested cormorants are permanent bay area residents that have been observed perching in the vicinity of the former NAS Alameda and feeding in the open bay, channels, and protected lagoons. The double-crested cormorant is a CDFG Species of Special Concern. Other avian species of special concern that may be present in the vicinity of the Skeet Range are listed in Appendix E.

The Steller and California sea lions and harbor seals, protected under the Federal Marine Mammal Protection Act of 1972, may be present in the vicinity of the Skeet Range. The Steller sea lion also is listed federally as a threatened species, and one has been observed offshore of the former NAS Alameda during avian surveys (Feeney and Collins, 1993). Harbor seals also may use areas near Alameda Point, such as the breakwater gap area, for feeding (Kopec, 1994). Additionally, Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) and harbor porpoises (*Phocaena phocaena*) may be observed infrequently in the area.

4.1.1.2 Selection of Contaminants of Potential Ecological Concern

A central part of the problem formulation is to identify those constituents requiring further evaluation. COPECs were identified by evaluating the site history, specifically, the historical operation as a skeet range including the discharge of lead shot and PAH-containing clay targets into the Skeet Range offshore habitat. Consequently, lead shot and PAHs from clay targets are the preliminary constituents identified for the Skeet Range.

The COPEC screen was conducting following a two-step process: the first step was conducted in the SLERA, and the second step in the BERA. In the initial screen, constituents requiring further evaluation were identified. First the maximum detected value or the maximum reporting limit (maximum replicate value at stations with multiple replicates) for each constituent was compared to conservative screening benchmark values. A number of sediment guidelines have been developed for evaluating potential risk to benthic organisms exposed to chemical constituents in marine and freshwater sediments. For this COPEC screen, ER-L values were selected as the preferred sediment screening benchmarks. ER-Ls were derived from a compilation of datasets characterized as toxic by the original investigators. An ER-L is calculated as the lower 10th percentile concentration of the available sediment toxicity data. Therefore, these values represent the low end of a range of levels at which effects were observed in compiled studies and represent values at which toxicity may begin to be observed in sensitive species (Long and Morgan, 1991; Long et al., 1995).

All analytes for which the maximum detected value or the maximum reported detection limit exceeded the ER-L were retained. All detected analytes are reasonably linked to Navy operations, and for which there are no benchmarks, also were retained. All detected constituents that are on the U.S. EPA Region 9 bioaccumulator list were retained regardless of whether the detected value exceeded the ER-L.

Because the data sets were judged to have a sufficient number of samples (>100 samples), all retained constituents were evaluated based on the frequency of exceedance above the benchmark, and magnitude of exceedance above the benchmark. If less than 5% of the samples exceeded the benchmark, the magnitude of the exceedance was evaluated. If the maximum observed value exceeded an ER-M or other 50th percentile effects level, the constituent was retained; otherwise, the constituent was eliminated.

For inorganic compounds, the focus of further evaluation is primarily on lead shot because it clearly is related to the historical operations at the Skeet Range. However, lead sorbed to sediments was not carried through as a COPEC. Lead may dissolve from the shot into porewater and then sorb onto sediment, but the potential for partitioning into sediment, porewater, and biota is expected to be very low. The dissolved lead concentrations in sediment represent ambient conditions, and lead dissolution into sediment appears to be an insignificant transport mechanism. Studies of the potential for mobilization of lead from shot at other skeet ranges have found that, although lead did dissolve from shot into porewater, the vast majority of lead at the site was still in the form of lead shot (Battelle, 1987; Bair et al., 1995). The results of these studies are supported by sediment and porewater data collected from the Skeet Range by TtEMI (2000). TtEMI (2000) found that the average lead concentrations (when shot was removed) from sediments collected at the Skeet Range were within ambient levels for San Francisco Bay and lead concentrations in porewater were below detection limits and AWQC. Thus, lead sorbed to sediments was not identified as a COPEC, and the main focus of the ERA is on lead shot.

For organics, the constituents of interest are PAHs that may have dissolved from the clay targets into porewater and then sorbed onto sediment; however, as with lead shot, the potential for partitioning into sediment and porewater is expected to be very low. PAHs are tightly bound in the petroleum pitch and limestone matrix of the targets and are unlikely to be readily available in the environment (Battelle, 1987; Bair et al., 1995). This is supported by the data collected in this investigation where fingerprinting analyses demonstrated that the source of the PAHs detected in sediments from the Skeet Range is unlikely to be from dissolution of clay target fragments. Although the presence of PAHs at the site is unlikely to be due to skeet range practices, PAHs were still evaluated through the COPEC screening process to identify whether current conditions exceeded screening benchmarks. The results of the PAH COPEC screen are listed in Table 4-2.

4.1.1.3 Conceptual Site Model and Exposure Pathway Analysis

The CSM is a framework for relating ecological receptors to contaminated media and determining the degree of completion and significance of exposure pathways. In general, an exposure pathway describes the route(s) a chemical takes from its source to a receptor of concern. An exposure pathway analysis links the source, location, and type of environmental release with population location and activity patterns to determine the primary means of potential exposure. If potentially complete and significant exposure pathways exist between contaminants (i.e., COPECs) and receptors, an assessment of potential effects and exposure is conducted. Only those potentially complete exposure pathways likely to contribute significantly to the total exposure will be quantitatively evaluated. All other potentially complete exposure pathways that result in minor exposures or for which there are no exposure models or insufficient toxicity data will not be quantitatively evaluated in this assessment.

An exposure pathway is considered complete if all four of the following elements are present:

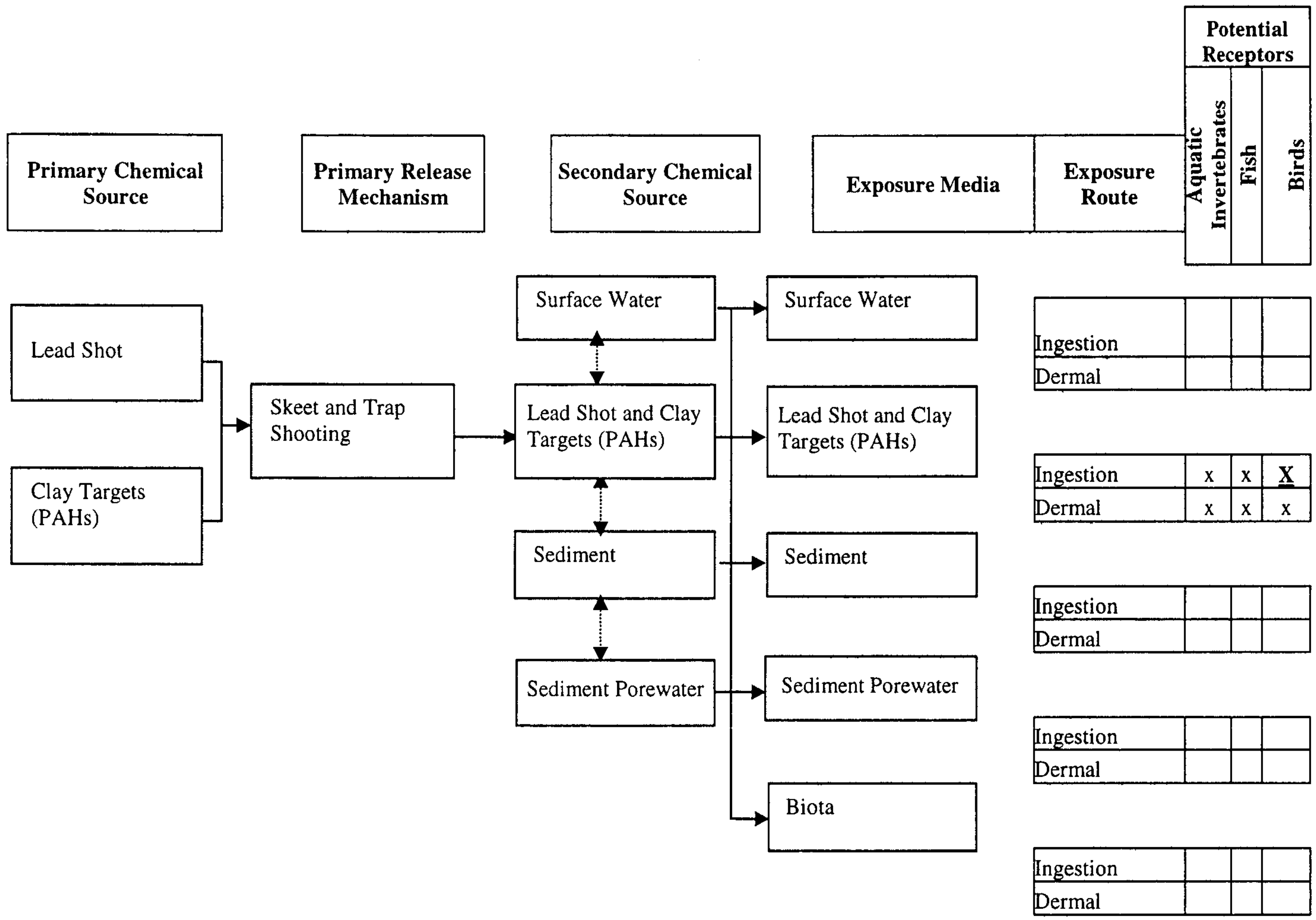
- A source and mechanism of chemical release to the environment;
- An environmental retention or transport medium (e.g., water or sediment) for the released chemical;
- A point of potential physical contact of a receptor with the contaminated medium (exposure point); and,
- An exposure route (e.g., ingestion of contaminated prey, incidental ingestion of sediment).

Figure 4-2 graphically represents the CSM for the Skeet Range. As discussed in greater detail below, lead shot and clay target fragments present in sediments are the primary contaminants to which ecological receptors may be potentially exposed. Due to the firing arc of the skeet range, sediments containing lead shot and clay target fragments are located offshore at water depths of up to 15 ft (Battelle, 2001 and 2002a). Previous investigations at the Skeet Range indicated that the majority of lead shot is found in sediments lying in 10 or more feet of water and at sediment depths of approximately 4 cm or greater below sediment surface (TtEMI, 2000). Recent sampling events confirmed that the majority of lead shot was found in sediments lying in more than 10 ft of water. However, lead shot was found in all sediment depths evaluated (i.e., up to 20 cm), and in approximately 50% of the samples collected from 0-5 cm (Battelle, 2001 and 2002a).

The two primary release mechanisms for COPECs in lead shot and the clay targets are dissolution and direct contact. First, lead and PAHs may dissolve from the shot and clay targets into porewater and then sorb onto sediment. From there they may be taken up into the tissues of biota. However, the potential for partitioning into sediment, porewater, and biota is expected to be very low. Studies conducted at other skeet ranges found that (1) although lead did dissolve from shot into porewater, the vast majority of lead at the site was still in the form of lead shot (Battelle, 1987); and (2) PAHs are tightly bound in the petroleum pitch and limestone matrix of the targets and are unlikely to be readily available in the environment (Battelle, 1990; Bair et al., 1995). Sediment and porewater data collected from the Alameda Point

Table 4-2. PAH Tier 1 COPEC Screen

Analyte	No. of Detects	No. of Samples	Detects (%)	Step 1		Step 2	Step 3	Carry Forward?	Reason to Carry Forward/Not Carry Forward
				Maximum Detected Value µg/kg	Screening Value µg/kg	Bioaccumulator?	Samples Greater than Screening Value (%)		
Benzo(a)anthracene	25	25	100	600.42	261	Yes	20	**Yes**	>5% of results>threshold value and/or maximum result>ER-L
Benzo(a)pyrene	25	25	100	1047.17	430	Yes	16	**Yes**	>5% of results>threshold value and/or maximum result>ER-L
Benzo(b)fluoranthene	25	25	100	757.54	–	Yes	–	**Yes**	No threshold value. >5% of results are detects
Benzo(g,h,i)perylene	25	25	100	771.48	290	Yes	28	**Yes**	Maximum result>threshold value. Analyte does not have ER-L
Benzo(k)fluoranthene	25	25	100	766.26	24	Yes	100	**Yes**	Maximum result>threshold value. Analyte does not have ER-L
Chrysene	25	25	100	731.35	384	Yes	16	**Yes**	>5% of results>threshold value and/or maximum result>ER-L
Dibenzo(a,h)anthracene	25	25	100	164.68	63.4	Yes	12	**Yes**	>5% of results>threshold value and/or maximum result>ER-L
Fluoranthene	25	25	100	946.04	600	Yes	12	**Yes**	>5% of results>threshold value and/or maximum result>ER-L
Indeno(1,2,3-cd)pyrene	25	25	100	784.05	78	Yes	96	**Yes**	Maximum result>threshold value. Analyte does not have ER-L
Pyrene	25	25	100	1238.15	665	Yes	16	**Yes**	>5% of results>threshold value and/or maximum result>ER-L
Total HPAH	25	25	100	4727.81	1700	Yes	24	**Yes**	>5% of results>threshold value and/or maximum result>ER-L
2-Methylnaphthalene	23	25	92	39.68	70	No	0	No	<=5% of results>threshold value and maximum result<=ER-L. Not bioaccumulator.
Acenaphthene	25	25	100	65.99	16	No	48	**Yes**	>5% of results>threshold value and/or maximum result>ER-L
Acenaphthylene	25	25	100	87.69	44	No	12	**Yes**	>5% of results>threshold value and/or maximum result>ER-L
Anthracene	25	25	100	209.54	85.3	Yes	28	**Yes**	>5% of results>threshold value and/or maximum result>ER-L
Fluorene	25	25	100	51.55	19	No	32	**Yes**	>5% of results>threshold value and/or maximum result>ER-L
Naphthalene	24	25	96	147.19	160	No	0	No	<=5% of results>threshold value and maximum result<=ER-L. Not bioaccumulator.
Phenanthrene	25	25	100	516.5	240	Yes	24	**Yes**	>5% of results>threshold value and/or maximum result>ER-L
Total LPAH	25	25	100	999.75	552	Yes	16	**Yes**	>5% of results>threshold value and/or maximum result>ER-L



x = Complete exposure pathway of limited significance.
<u>X</u> = Complete exposure pathway of primary significance.
Blank squares indicate incomplete exposure pathways.

Figure 4-2. Ecological Site Conceptual Exposure Model

Skeet Range support these findings. For example, the average lead concentrations from Skeet Range sediments with shot removed were within ambient levels for San Francisco Bay sediments (TtEMI, 2000). PAHs also were evaluated via fingerprinting techniques and were not found to be associated with clay targets (see Section 3.2).

The second release mechanism and primary exposure route for the Skeet Range is direct exposure to lead shot and PAHs. Benthic invertebrate species may be exposed to Skeet Range COPECs through dermal contact with sediment porewater or surface water, or through ingestion of sediments. However, the size of the lead shot makes it unlikely that benthic invertebrates would feed on lead shot or target fragments, and incidental ingestion of these items is expected to be *de minimis*. Benthic organisms in sediment pore-water (e.g., invertebrates) and organisms foraging primarily on water column prey (e.g., piscivorous birds and fish) are unlikely to be exposed to lead shot or clay target constituents because the lead in the shot matrix and the PAHs in the clay matrix have limited bioavailability.

The present benthic community at the Skeet Range, compromised primarily of *Ampelisca*, is an indication of the low impact that lead shot and PAHs have on the environment. The San Francisco Estuary Institute (SFEI) has proposed using the growth rate of *Ampelisca abdita* as another potential measure of sediment toxicity, as *Ampelisca* is already a species recommended for 10-day mortality test. It is believed that the chronic growth rate test could be a more sensitive indicator of pollution than acute mortality and provide a higher degree of environmental protection. Due to the high abundance of *Ampelisca* tubes observed during the field effort, it is clear that the benthic community is relatively unimpacted by the current levels of contaminants measured at the Skeet Range.

Fish species may be exposed to COPECs at the Skeet Range through dermal contact with surface water, or through ingestion of sediments, sediment porewater, surface water, or biota. Because of the low bio-availability of the lead shot and clay target, fish species inhabiting and foraging within the water column are unlikely to come into direct contact with lead and PAHs in the water column (i.e., an incomplete exposure pathway). Similarly, benthic-feeding fish species also are unlikely to be significantly exposed to Skeet Range COPECs, as they are unlikely to feed on lead shot or target fragments. Furthermore, incidental ingestion of these items is likely to be *de minimis*, due to the dense *Ampelisca* mat. Therefore, although benthic-feeding fishes may potentially coming into direct contact with shot and target fragments, these organisms are not considered receptors of concern because they are unlikely to have significant exposure to Skeet Range COPECs.

Because of the location of sediments containing lead shot and clay target fragments, upland-foraging organisms (e.g., terrestrial birds and gulls) and near-shore/shoreline foraging organisms (e.g., wading birds and coots) are unlikely to be exposed to lead shot or clay target fragments. However, some benthic-feeding avian species forage at depths and in a manner that makes possible a direct exposure to lead shot and clay target fragments at the Skeet Range. However, once again, the dense *Ampelisca* mats at the site are likely to limit potential exposure. Benthic-feeding avian species, specifically diving ducks, possess the greatest potential for significant exposure to Skeet Range COPECs. Although these species could conceivably be exposed to site COPECs through ingestion of surface water, sediment porewater or biota, or through dermal contact with sediment, sediment porewater or surface water, the highest potential for exposure is through incidental ingestion of sediment-borne lead shot or PAH-containing clay target fragments as grit. Therefore, the primary complete and potentially significant exposure pathway that will be evaluated in the SLERA is the exposure of diving ducks to lead shot and PAHs in clay target fragments at the Skeet Range.

4.1.1.4 Assessment and Measurement Endpoints

The CSM also serves as the basis for identification of risk assessment endpoints (AEs). Once the AEs are identified, appropriate measurement endpoints (MEs) are selected. Selection of AEs must consider the ecosystem, communities, and species relevant to a particular site. The selection of AEs depends on:

- The chemicals present and their concentration;
- Mechanisms of toxicity of the chemicals to different groups of organisms;
- Ecologically relevant receptor groups that are potentially sensitive or highly exposed to the chemicals; and
- Potentially complete exposure pathways.

As defined by the U.S. EPA (1997), AEs are formal expressions of the actual environmental values that are to be protected at a site. AEs are defined based on technical considerations including the significance of exposure pathways, the presence of receptors, and a COPEC's biotic transfer pathway.

The AEs selected for quantitative evaluation in this assessment are based on protection of the most sensitive environmental resources identified at the site (i.e., protection of the benthic-feeding avian communities that may use the site) and the primary potentially complete exposure pathway. Although receptors in other feeding guilds (e.g., sediment-dwelling organisms, fish) and special status species may potentially come into direct contact with shot and target fragments (i.e., a complete exposure pathway exists), these organisms are not considered receptors of concern because they are unlikely to have significant exposure to Skeet Range COPECs. The avian benthic-feeding guild is considered to have the highest potential for exposure to site-related compounds potentially found in sediment, and therefore, it should provide an upper bound risk estimate that is protective of the lesser-exposed guilds. As a result, the selected AE presents a conservative approach for estimating risk.

AE-1: Protection of the benthic-feeding avian community at the former Skeet Range

ME-1: Estimated probabilities of a benthic-feeding bird foraging at the site ingesting a sufficient dose of lead shot to exceed levels in the literature that produce toxic effects.

ME-2: Comparison of risk probabilities of benthic feeding birds to a risk-based population threshold indicating effects observed at a population level.

ME-3: Evaluation of the likelihood of exposure by benthic-feeding birds to PAHs at levels that elicit toxic effects.

Benthic-feeding birds (e.g., scaups and scoters) were identified as receptors of concern at the Skeet Range because their life histories suggest that, during foraging, these receptors may ingest lead shot within the grit size range either inadvertently or intentionally selected for use as grit (Trost, 1981).

Benthic feeding birds with the greatest potential exposure to lead shot or target fragments are those species that forage in water depths greater than 10 ft, and forage in a manner that includes mucking or straining of subsurface sediments. Species such as the grebe that forage at water depths of greater than 10 ft, but feed on fish or pluck prey items from the sediment surface or benthic structures (e.g., submerged rocks), are not likely to have a high potential for direct exposure to lead shot or target fragments. Terns, cormorants, and pelicans have been observed foraging at the Skeet Range, but none of these special status piscivorous species is expected to feed extensively on benthic prey. Likewise, although egrets and herons were observed at Skeet Range, the foraging strategy of these benthic feeders limits their foraging activities to the near-shore environment.

Based on the foraging habits of the avian species identified at the Skeet Range, the greater scaup (*Aythya marila*) and surf scoter (*Melanitta perspicillata*) are the species likely to have the highest potential for exposure to lead shot and clay target fragments. Both greater scaup (USGS, 2001) and scoters (Savard et al., 1998) have been observed foraging in water depths up to 10 m (approx. 35 ft), indicating that both species can readily access the Skeet Range sediments, although the feeding modes of scaups and scoters differ.

Observations of scoter foraging behavior have described the scoter as grasping a mussel in its bill while underwater and, by paddling vigorously with their feet, tearing the mussel loose (Brown and Frederickson, 1997). Goodman and Fisher (1962) concluded that powerful adduction and retraction of the jaws is required because scoters eat such large quantities of mussels. This foraging behavior is necessary due to the type of prey scoters primarily eat in their wintering habitat, which include molluscs and especially bivalves (Savard et al., 1998). In San Francisco Bay, barnacles and mussels have been found in the stomachs of scoters (Ohlendorf et al., 1986). Straining behavior (as found in scaups) has not been reported for scoters (Goodman and Fisher, 1962).

The lesser scaup (*Aythya affinis*), a close relative to the greater scaup, feeds by inserting its bill into sediment substrate at a 35-45 degree angle and rapidly opening and closing its mandibles while swimming forward and moving its head in short, lateral arcs (Tome and Wrubleski, 1988; Austin et al., 1998). Goodman and Fisher (1962) have categorized scaups as "strainers" that feed by rapidly opening and closing their jaws to strain water away from food items. Similar straining behavior, however, was not reported for scoters (Goodman and Fisher, 1962). Furthermore, the limited amount of scoter foraging information available suggests that this species frequently forages in the water column (i.e., feeding on fish) or by removing mussels from submerged rock surfaces (USGS, 2001; Brown and Frederickson, 1997).

Therefore, based on their mode of feeding, scaups are more likely than scoters to come into contact with lead shot and clay target fragments present in the sediments at the Skeet Range. Scaups feed through a straining action up to a depth of about 5 cm, whereas scoters forage by plucking objects off of the substrate. Based on this feeding behavior, the depth of sediment most likely to be accessed by diving ducks (such as scaups and scoters) is 5 cm. However, a conservative estimate of the depth of sediment that might be accessed by a scaup or scoter might be as deep as 10 cm (Takekawa, 2001).

4.1.2 Effects and Exposure Assessment

Because potentially complete exposure pathways and COPECs were identified at the Skeet Range, potential risks to upper trophic level receptors were evaluated in the SLERA. The assessment of effects and exposure are discussed in detail in the following sections.

4.1.2.1 Effects Assessment

For the purpose of evaluating the potential effects associated with the doses calculated in the exposure assessment, chemical- and receptor-specific toxicity reference values (TRVs) were compared to the calculated doses. In general, a TRV is defined as a dose level at which a particular biological effect may occur in an organism, based on laboratory toxicological investigations.

The Navy, in consultation with the U.S. EPA Region 9 Biological Technical Assistance Group (BTAG), has developed effects-based TRVs. Each of these values represents a critical exposure level from a toxicological study and is supported by a published dataset of toxicological exposures and effects (DON, 1998). TRVs for lead shot and PAHs were not available for birds from the Navy/BTAG effort. Therefore, an effort was conducted to develop TRVs for lead shot and PAHs. For PAHs, insufficient data were found to develop TRVs for birds; thus, toxicity associated with exposure to PAHs is discussed in the Uncertainty Analysis (Section 6.0). Sufficient toxicity data were found for lead shot in order to derive a TRV. The information discussed herein was presented to the regulatory agencies in the form of a white paper on July 30, 2002, and is presented in its entirety in Appendix D.

Lead poisoning in ducks consists of either acute or chronic toxicity and both can result in death. Ducks that die from acute lead toxicity show no outward symptoms of toxicity; however, large numbers of shot have been found in their gizzards. Birds with chronic toxicity from lead poisoning exhibit weight loss, green watery feces, and drooping wings. These symptoms are generally the result of fewer lead shot retained in the gizzard over a longer length of time (Sanderson and Bellrose, 1986; Friend, 1989). Lead affects the central and peripheral nervous system, the kidneys, and the circulatory systems of the birds. However, many factors influence the potential toxicity associated with exposure to lead shot, including species-specific differences in lead sensitivity, diet, the volume of food consumed and its rate of passage through the gastrointestinal tract, the volume of grit ingested and its rate of passage through the gastrointestinal tract, and the size of the lead shot ingested (Godin, 1967; Sanderson and Bellrose, 1986). The dosing regime (e.g., single dosing versus multiple dosing) also may influence potential toxicity.

A literature review has been conducted to identify relevant studies to assist in developing a no observed adverse effects level (NOAEL) for lead shot. Preference was given to studies that assessed scaups (*Aythya* spp.), scoters (*Melanitta perspicillata*), or related species; shot in the size found at the Alameda Point Skeet Range (No. 7½, 8, and 9); and diets similar to those eaten by scaups and scoters. No papers were found that specifically addressed lead shot ingestion by scoters or scaups. One study (Mautino and Bell, 1986) evaluated effects of lead shot ingestion on ring-necked ducks (*Aythya collaris*), which are closely related to scaups. Only one study was found that used No. 7½ lead shot, and none were found that used No. 8 or No. 9 shot. The papers that were reviewed included review papers, field studies, and laboratory studies that evaluate the effects of lead toxicity on waterfowl. The studies included in this review are described below, and discussed in detail as appropriate.

Overview of Lead Toxicity

The toxic effects of lead and the incidence of lead poisoning of waterfowl has been reviewed and summarized by several authors (Sanderson and Bellrose, 1986; Scheuhammer and Norris, 1995; Pain, 1996). Death may occur from chronic poisoning from ingestion of a few pellets or, less often, from acute poisoning after ingestion of a large number of shot (Sanderson and Bellrose, 1986). Overt symptoms of lead poisoning due to chronic exposure include weight loss, severe wasting of the breast muscles, green-stained vents, loss of muscle coordination (ataxia) that may lead to an inability to swim or fly, and drooping wings. Necropsy of chronically lead-poisoned birds may reveal reduced amounts of: (1) visceral fat; (2) impactions of the esophagus, proventriculus, or gizzard; (3) a distended gallbladder filled with bile; (4) green staining of the normally yellow gizzard lining; and (5) the presence of lead shot pellets or small particles of lead in the proventriculus and gizzard contents. Many of these signs and lesions are absent in birds that die from acute lead poisoning (Friend, 1989).

Reports vary on the effects of lead poisoning on the appetites of waterfowl. Studies from the 1930s and 1940s indicate that there is no loss of appetite in lead-poisoned birds. Other studies have found that a decreased appetite and intake of food is one of the earliest external signs of lead poisoning in birds (Sanderson and Bellrose, 1986). The varied effects may be due to differing proportions of protein in the diets of different species. Diets higher in protein and calcium reduce the effects of lead poisoning and may reduce weight loss resulting from lead poisoning (Sanderson and Bellrose, 1986).

Lead shot is ingested by birds during feeding and while foraging for grit in feeding grounds where lead shot is present as a result of hunting or skeet shooting. In addition to the prevalence of lead shot, factors influencing the ingestion of shot include feeding habits, firmness of the substrate, depth of water, pellet size, and season (Sanderson and Bellrose, 1986). Availability of grit at the surface may affect the number of pellets ingested, i.e., lack of other grit types increases the likelihood that waterfowl will ingest lead pellets for use as grit (Sanderson and Bellrose, 1986).

Ingested shot may be retained in the gizzard for less than 24 hours to several weeks (Vyas et al., 2001; Hirai et al., 1991; Finley et al., 1976a). Sanderson and Bellrose (1986) indicate that a lead shot will disappear from the gizzard of a duck in about 20 days, either because it has been voided or because it has eroded to an undetectable particle, whereas other studies show that detectable lead shot may be retained for more than four weeks (Koranda et al., 1979; Finley et al., 1976a; Mautino and Bell, 1986).

Lead shot is mechanically ground down by the gizzard and dissolved by acid secreted by the proventriculus (stomach). The dissolved lead is absorbed into the bloodstream (Pain, 1996). Lead in the bloodstream may be deposited into soft tissues, primarily the liver and kidney, as well as into bone. Blood, liver, and kidney lead levels usually remain elevated for weeks to months after exposure (when exposure is not prolonged). Lead accumulates in bone throughout the lifetime, is relatively immobile, and therefore is not a good indicator of recent lead exposure (Pain, 1996).

Several studies have demonstrated the effects of lead on the activities of enzymes important in the synthesis of heme, particularly δ-aminolevulinic acid dehydratase (ALAD) (Rattner et al., 1989; Finley et al., 1976a; Finley et al., 1976b; Beyer et al., 1988; Mautino and Bell, 1986; Pain, 1996). Inhibition of ALAD activity occurs as soon as 24 hours after ingestion of one lead shot and is inversely correlated with lead concentration in the blood (Finley et al., 1976a). ALAD activity inhibition also is observed in the liver, but is first measurable in erythrocytes and persists for several weeks following exposure (Finley et al., 1976a). Finley et al. (1976a and 1976b) have shown that ALAD activity is inversely correlated ($P<0.01$) with the concentration of lead in the blood. It also has been shown that waterfowl and other birds are able to tolerate a reduction in erythrocyte ALAD activity without a corresponding reduction of hematocrit or hemoglobin concentration (Rattner et al., 1989; Mautino and Bell, 1986; Hirai et al., 1991). The inhibition of ALAD activity is not a permanent effect, and enzyme activity in the blood returns to normal within a few weeks postexposure (Mautino and Bell, 1986; Rattner, 1989; Finley, et al., 1976a). The lack of reduction of hematocrit or hemoglobin concentrations related to inhibition of ALAD activity indicates that ALAD activity is a useful indicator of recent exposure to lead, but is not a significant physiological effect in itself.

Although concentrations of lead in soft tissues and bone tend to increase with duration and level of lead exposure, most studies do not find a difference in lead levels in blood, liver, and kidney between male and female ducks administered similar doses. An exception to this occurs during breeding, when females may show significantly higher bone lead levels than males after exposure to lead shot. Finley et al. (1976b), in a study in which one No. 4 lead shot was administered to mallard males and laying mallard females, found that lead deposition in bone of mallard females was about 10 times higher than in males. They concluded that lead deposition into bone in females dosed with sublethal levels of lead may be greatly increased as a result of mobilization of calcium from the bone during eggshell formation. The highest lead residues were associated with skeletal regions containing high concentrations of medullary bone. In laying birds, medullary bone undergoes sequences of bone formation and destruction related to storage and liberation of calcium during shell formation. The study also found that eggshell lead concentrations from hens dosed with one No. 4 lead shot were approximately four times that from control hens. The biological significance of the lead levels found in eggs and the possible transfer of lead from the shell to the developing embryo were not determined in this study.

Factors Affecting Toxic Effects of Lead

In addition to species effects, several factors may affect lead toxicity including sex, age, size, dosing regime and most importantly diet (Pain, 1996). Studies indicate that lead deposition into blood and soft tissues does not differ significantly between the sexes (Finley et al., 1976a; Chasko et al., 1984; Longcore et al., 1974). However, studies have reported significantly higher levels of lead deposition into bone in laying females (Finley et al., 1976b). In laboratory studies, lead exposure affected younger mallards (less than 7 months of age) less than adults (Sanderson and Bellrose, 1986). The assumption is that a high proportion of the lead circulating in the bloodstream is deposited into the developing skeletons of the maturing mallards. As skeletal ossification progresses, the authors assumed less deposition of lead into bone as an explanation for the higher levels found in the blood after about 7 months of age. Sanderson and Bellrose (1986) also note that the larger the waterfowl, the less effect a given amount of lead has. This is shown by controlled experiments in which Canada geese showed the least effects of lead toxicosis, with increasing effects seen in mallards, pintails, and blue-winged teal (decreasing size). Only two studies were available that evaluated lead shot toxicity in a multiple dosing exposure scenario (Chasko et al. 1984; Rattner et al. 1989). However, it is not clear from these studies whether toxicity would increase in a repeated dosing scenario versus a single dosing scenario when the same dose (number of shot) is administered.

However, an important factor influencing the biological fate of lead is the quantity and quality of the diet (Longcore et al., 1974; Koranda et al., 1979; Sanderson and Bellrose, 1986; Pain, 1986; Sanderson, 2002). Two studies in particular (Koranda et al., 1979; Sanderson, 2002) investigated the effects of the quantity and quality of diet and conducted extensive analyses to determine the dietary factors that provided protection from lead toxicity. In both studies, mallards were dosed with up to five or six No. 4 lead shot pellets, divided into groups, and fed diets markedly different in protein and mineral content. Koranda et al. found that mallards fed a turkey-mash diet and administered 1, 3, or 6 pellets were protected against the toxic effects of lead and did not lose significant body weight. Mallards fed a henscratch diet and given the same amount of lead accumulated lead in the liver, kidney, and bone, lost significant amounts of weight, and died. Koranda et al. (1979) noted that the distribution of trace elements such as calcium and iron were altered in the organs of ducks fed henscratch. The major differences between the turkey-mash and henscratch diets were in protein, calcium, phosphorus, and total mineral content. The protein content was 27% for the turkey mash vs. 10% for the henscratch, calcium was 1.2% for the turkey mash vs. 0.025% for the henscratch, and phosphorus was 1.15% for the turkey mash vs. 0.36% for the henscratch. The turkey-mash diet resulted in at least a 10-fold reduction in tissue lead concentrations as compared to the henscratch diet. Results also indicate that mallards on the henscratch diet approached saturation in the tissue at one No. 4 shot, and were definitely at saturation at the three-shot dose. Koranda et al. (1979) suggests that the high calcium and protein diet both reduces absorption of lead from the GI tract and causes a lowering of the general body burden of lead in the animal.

Results presented in Sanderson (2002) also show the protective effects of a high protein and calcium diet (commercial duck food) compared with a diet of shelled corn. Mallards were dosed with five No. 4 lead shot pellets and fed corn, corn and soil, duck food, or duck food and soil. Dosed mallards fed corn survived an average of 7.3 days, and those on corn and soil survived an average of 17.0 days. All mallards fed duck food gained weight, and none died. The addition of 10 g of soil per day to the diet did not make a significant difference in the observed effects of lead on the mallards. Sanderson concluded that retention and excretion of lead differed between the corn and duck food diets, with the mallards on duck food able to excrete significantly higher amounts of the dissolved lead in their gizzards than those on corn. The difference was attributed to the higher absorption of dissolved lead by duck food than corn.

Data from the field also support the relationship between quality of diet and sensitivity to lead shot. Sanderson and Bellrose (1986) reviewed field data and attempted to rate the susceptibility of waterfowl species to lead toxicosis based on tendency to ingest shot, level of lead in wing bones (an indication of lifetime exposure and uptake), and food habits. They considered bone lead levels of greater than 20 ppm as dry weight to be elevated (Pain, 1996, determined background bone lead to be 10 to 20 ppm dry weight based on a literature review). They note that lead ingestion rates in bay diving ducks such as the canvasback, lesser scaup, redhead, and ring-necked duck are appreciably higher than in mallards and pintails. However, lesser scaups in this study had the lowest incidence (<1.0%) of wing bone lead concentration exceeding background among the species evaluated. The authors attribute this low accumulation of lead despite a relatively high shot ingestion rate to inhibition of lead absorption to the scaup's diet of molluscs, which are rich in protein and calcium.

In summary, although a number of factors affect the toxicity of lead shot to an individual, the overriding factor is diet. Thus, those studies that focus on toxicity of lead shot to birds that have a natural diet similar to the scaup and scoter (rich in protein and calcium) were considered most appropriate for the development of a lead shot NOAEL for diving ducks.

Development of Lead Shot NOAEL for Diving Ducks

A total of 26 papers were reviewed to assess toxicity of ingested lead shot to waterfowl. Of these, 14 described laboratory or controlled-dose studies, 10 reported data for waterfowl captured in the wild and assessed the presence of lead shot and associated symptoms or effects of toxicity, and two papers dealt with toxicity of lead shot to nonwaterfowl avian species. Mallards were the test species in most of the laboratory studies, but a few studies investigated the effects of lead shot ingestion on black ducks, and one study used ring-necked ducks. Experimental conditions such as season, diet, dosage, and pen conditions varied, as well as the age, sex, and species tested. Field studies varied in terms of geographic location, species collected and tested, and types of data gathered. Field studies did not provide appropriate data for determining a lead shot NOAEL, but field results did add to an understanding of the level and extent of exposure among species, and the factors affecting susceptibility of various species to lead poisoning. An understanding of field conditions and effects in turn allowed a better assessment of the applicability of laboratory results to lesser scaups and surf scoters wintering at Alameda Point.

Of the controlled, laboratory dose studies reviewed, those considered useful for determination of a lead shot NOAEL are described below. Papers that were not applicable included two studies of nonwaterfowl avian species (Hirai et al., 1991 and Vyas et al., 2001), studies that lacked a significant effect (Finley et al., 1976a; Finley and Dieter, 1978), and studies from which a NOAEL could not be determined in units of lead shot per bird (Irwin and Karstad, 1972; Finley et al., 1976b).

Several papers contained sufficient data to determine a NOAEL TRV for waterfowl exposed to lead shot by ingestion (Longcore et al., 1974; Finley et al., 1976b; Koranda et al., 1979; Chasko et al., 1984; Mautino and Bell, 1986; Rattner et al., 1989; and Sanderson, 2002). The remainder of this section summarizes these papers. These studies reported results for mallards, black ducks, and ring-necked ducks. A variety of effects were measured, the most indicative being change in body weight, organ tissue lead concentrations, and mortality. Most studies with only mortality data reported were not included, but one that is frequently cited (Longcore et al., 1974) is included for comparison.

Because none of the laboratory studies that contained sufficient data for determining a NOAEL used the shot pellet sizes found at the Skeet Range at Alameda Point (Nos. 7½, 8, and 9), the NOAELs determined from these studies must be converted to the appropriate shot size for Alameda Point. Shot pellet size decreases as the size number (e.g., No. 4, No. 6, No. 8, etc.) increases. Conversion of the No. 4 and No. 6 lead shot to No. 7½ to No. 9 shot pellet equivalents by surface area is shown in Table 4-3. The diameters of the various lead shot sizes are readily available and were converted to radii for use in the equation for the surface area of a sphere ($4\pi r^2$). The ratio of the larger shot size to the smaller shot size is the shot pellet equivalent. Surface area equivalents were used rather than weight equivalents because the rate of lead dissolution in the gizzard is strongly related to the severity of toxic effects, and surface area is the limiting factor in rate of dissolution of a pellet. Also, the use of surface area equivalents for conversion results in fewer No. 7½ to No. 9 shot pellets per No. 4 or No. 6 shot pellet than does the use of weight equivalents (conversion shown in Table 4-4), making this approach more conservative in terms of TRV development.

Table 4-5 shows the NOAEL as number of shot of the shot size used in each study and the equivalent number of Alameda Point shot, based on surface area (shown as the range of No. 7½ to No. 9 shot pellet equivalents). As shown in Table 4-5, three studies included in this discussion did not define a lead shot NOAEL. The study on ring-necked ducks (*Aythya collaris*) was included because it is the only study that used an *Aythya* species, which is the genus to which the lesser scaup belongs. Results showed 15% mortality in *Aythya collaris* dosed with one No. 4 lead shot (Mautino and Bell, 1986). All dosed birds were emaciated with decreased pectoral muscle

Table 4-3. Lead Shot Size Conversion by Surface Area

Lead Shot Size	Diameter[a] (mm)	Radius (mm)	Surface Area[b] (mm^2)	No. 4 Shot Equivalents[c]	No. 6 Shot Equivalents[c]
4	3.30	1.65	34.21		
6	2.79	1.395	24.45		
7.5	2.41	1.205	18.25	1.87	1.34
8	2.29	1.145	16.47	2.08	1.48
9	2.03	1.015	12.95	2.64	1.89

(a) From http://www.fiocchiusa.com/catalog/catalog.html#shot.
(b) Surface area = $4\pi r^2$.
(c) Equivalents calculated by taking the ratio of the No. 4 or No. 6 shot surface area to the surface area of the smaller shot size.

Table 4-4. Lead Shot Size Conversion by Weight

Lead Shot Size	Pellets/Oz.[a]	mg/Pellet[b]	No. 4 Shot Equivalents[c]	No. 6 Shot Equivalents[c]
4	136	208		
6	232	122		
7.5	345	82	2.54	1.49
8	409	69	3.01	1.76
9	585	48	4.30	2.52

(a) From http://www.fiocchiusa.com/catalog/catalog.html#shot
(b) 1 oz. = 28,350 mg; 28,350 mg/# pellets/oz. = mg/pellet
(c) Equivalents calculated by taking the ratio of the No. 4 or No. 6 shot mg/pellet to the mg/pellet for the smaller shot size.

and visible hepatic lesions. Blood lead levels peaked at 7 days, then recovered to predosing levels. The ducks used in the study were wild ducks acquired by trapping and then acclimated for 3 weeks prior to dosing. Studies comparing wild to domestic mallards or black ducks have found that wild ducks are more sensitive to lead poisoning, and attribute some of the difference to the stress experienced by wild ducks maintained in captivity (Rattner et al., 1989). In addition, the diet fed the ring-necked ducks in this study consisted of game bird mash and green forage. No data were provided regarding protein or calcium content of the diet, or the amount of food ingested per day, all of which are critical factors in protection from the toxic effects of lead. As noted previously, the diet of ring-necked ducks in the field does not provide protection from deposition of lead in wing bones (Sanderson and Bellrose, 1986), indicating that their natural diet is probably low in protein and calcium and not comparable to the scaup or scoter.

A study comparing wild black ducks and wild mallards captured and dosed with two or more No. 6 lead shot (Chasko et al., 1984) resulted in mortality of one black duck and weight loss of 20% in one mallard. The remaining five mallards dosed with two shot gained weight during the study and were not symptomatic. Two black ducks and two mallards died from each of the five shot doses. The "natural diet" fed in this study consisted of 3:1 millet:buckwheat *ad libitum*, with a supplement of duckweed and eelgrass three days a week, and a varied supplement of small fish and shellfish three days a week. This study showed higher mortality and weight loss rates compared to controls and data presented in the literature at that time, although a rigorous statistical analysis of the data was not presented. In addition, no ducks were dosed with only one lead shot, further complicating the identification of a NOAEL from data presented in this study.

The study by Longcore et al. (1974) is frequently cited in the literature. The main objective of this study was to compare the toxicity of bird shot made of various metals in a series of acute toxicity tests. Wild and pen-reared mallards and pen-reared black ducks were dosed with one No. 4 lead shot and fed whole-kernel yellow corn *ad libitum* throughout the study. Mortality of 19% resulted from this dosage, and the authors noted that survival was closely related to rapid shot voidance after dosing. Effects of various grit types also were measured, but a high dose (eight No. 6 shot) was administered for the grit test and mortality was the measured effect. The grit study results indicated that oyster shell grit reduced the severity of lead poisoning, but on such a poor diet and a high dose, 33% mortality still resulted. A whole corn diet without other supplementation is a lower quality diet than the natural diet of most waterfowl. As a result, this study is not appropriate for calculating a NOAEL for the purposes of this RI.

Table 4-5. Lead Shot Toxicity Data

Test Organism	Scientific Name	Measured Effect	Dose	Diet	NOAEL (Study)	NOAEL (Converted: No. 7½ - 9)	Reference
Mallard ducks	*Anas platyrhynchos*	Mortality, packed cell volume, organ weights, body weight	5 No. 4 lead shot	Duck food	5	9 - 13	Sanderson, 2002
Mallard ducks	*A. platyrhynchos*	Tissue lead, body weight, mortality	1, 3, 6 No. 4 lead shot	Turkey mash	6	11 - 16	Koranda et al., 1979
Black ducks Mallard ducks	*A. rubripes* *A. platyrhynchos*	Mortality, body weight	1 No. 4 lead shot (initial), added 2 or 4 more shot at 14 days	Pelleted feed	1	2 - 3	Rattner et al., 1989
Mallard ducks	*A. platyrhynchos*	Tissue lead	1 No. 4 lead shot	Half corn, half pellet mash	1	2 - 3	Finley et al., 1976b
Ring-necked duck	*Aythya collaris*	Body weight, mortality	1 No. 4 lead shot (334.8 mg/kg BW)	Natural diet	< 1	<2	Mautino and Bell, 1986
Black ducks Mallard ducks	*A. rubripes* *A. platyrhynchos*	Body weight, blood lead, mortality	2, 5 acute, 5 cumulative No. 6 lead shot	Natural diet	<2	<3 - 4	Chasko et al., 1984
Mallard ducks	*A. platyrhynchos*	Mortality	1 No. 4 lead shot	Corn	<1	<2	Longcore et al., 1974

In a study by Rattner et al. (1989), one No. 4 lead shot was administered to wild and pen-reared black ducks and wild and game farm mallards which were fed pelleted Beacon Duck Developer feed (which typically contains 13% protein and 0.8 to 1.0% calcium). They observed transient effects such as lethargy, droop of tail and wings, and green watery feces in a few birds from each group during the first week. Predosing weight was restored by day 14, and hematocrit was not affected by this exposure. An objective of the study was to compare the tolerance of black ducks and mallards, and, because the severe intoxication and mortality previously observed in black ducks by these authors did not occur with the initial dose, an additional two or four No. 4 shot were administered on day 15, bringing the total dose to three or five shot. Both doses resulted in weight loss for all four groups and in some mortality in all but the game farm mallards. A NOAEL calculated from this study would be one No. 4 shot, but data are not available to evaluate the toxicity of two No. 4 shot, which might also not elicit effects in these birds.

Finley et al. (1976c) showed that mallards administered one No. 4 lead shot and fed a "balanced diet" of half corn and half pellet mash did not accumulate high lead concentrations in the kidney or liver. This study also examined effects during laying and found that hens that laid the most eggs after dosage had the highest lead bone concentrations. Eggshell lead concentrations reflected dosage (half the birds were dosed with one No. 4 lead-iron shot, approximately 50:50 lead:iron) and blood lead concentrations. This and other studies show no decrease in eggs laid due to lead exposure. The effects of lead in eggshells on ducklings and embryo development were not investigated in this paper. No mortality occurred, and according to the authors, "all ducks were considered in excellent condition upon termination of the experiment." Doses higher than one No. 4 lead shot were not administered during the study, so it is not known if two No. 4 lead shot would elicit an effect.

Sanderson (2002) administered five No. 4 lead shot and fed four different diets to mallards. As discussed in Appendix D, ducks given duck food or duck food and soil did not show any effects of lead shot and gained weight, whereas ducks fed corn only or corn and soil lost significant body weight, and most died before the end of the 21-day study. Sanderson attributes the protective effects of the duck food diet to the larger cation exchange capacity (based on lead absorption profiles) of duck food than of corn. Duck food also has higher protein and calcium levels than corn, though the exact levels are not reported in the paper. Based on consumption of equal amounts of the two diets, the duck food could sorb approximately 228 mg more lead per day than corn could, allowing for greater excretion of lead, and reducing the toxic effects. Using the results for the mallards fed duck food, this study indicates a NOAEL of five No. 4 shot.

Koranda et al. (1979) made a thorough analysis of the differences in protein and mineral contents of two diets fed to mallards that had been administered one, three, or six No. 4 shot. Details of the dietary contents are presented in Appendix D. The study confirmed that the most important components in the diet are protein and calcium. No effects were seen in mallards administered lead shot and fed the high protein and high calcium turkey mash diet, whereas severe effects were seen in ducks on henscratch. The NOAEL for mallards fed a high protein and calcium diet in this study is six No. 4 shot.

In summary, of the 26 lead shot toxicity papers reviewed, only 7 contained adequate and relevant information to be included in the TRV development dataset (Table 4-5). Unfortunately, none of the available studies were completely applicable to the diving duck species and their diets, lead shot size, or dosing regime found at Skeet Range. Therefore, because the goal of the SLERA is to conduct a conservative screening analysis of potential effects in diving ducks exposed to lead shot, the minimum NOAEL identified in the literature (one No. 4 shot) is proposed as a conservative estimate of a toxicity reference value. Four studies identified a threshold of one No. 4 lead shot (Rattner et al., 1989; Finley et al., 1976b; Mautino and Bell, 1986; and Longcore et al., 1974). When converted to the shot sizes found at the Skeet Range at Alameda Point, this minimum NOAEL is approximately equivalent to two No. 7½ shot to three No. 9 shot. For conservatism, the minimum NOAEL was selected as the value that was converted to the largest of the shot sizes present at the Skeet Range (i.e., No. 7½ shot). Therefore, the NOAEL of two lead shot will be used for the SLERA. Because laboratory doses and anticipated exposure in the field consist of individual, primarily intact, lead shot pellets, the LOAEL is assumed to be the next incremental amount of lead that may potentially be consumed, two No. 4 lead shot (or approximately three No. 7½ shot).

4.1.2.2 Exposure Assessment

Based on studies conducted with captive mallards and field studies with canvasbacks and scaups, lead shot seems to be ingested as incidental uptake of grit rather than food (Trost, 1981; Moore et al., 1998). Diving ducks, like most bird species, ingest and store grit (small pieces of rock or shells) in their gizzards, the small muscular organ used to grind and crack hard food items in preparation for digestion. Different bird species require different sizes and shapes of grit to digest food (Hall and Fisher, 1985; Best and Gionfriddo, 1991; Gionfriddo and Best, 1996).

Binomial Probability Model

To assess the potential for exposure to lead shot, the probability that, while foraging for grit, a bird may ingest a lead shot within the grit size range needs to be estimated. Although other probability models are available, a site-specific probability model has been developed that focuses on diving ducks (e.g., scaups and scoters) foraging in subtidal sediments, because the subtidal habitat and receptors at the Alameda Point Skeet Range are significantly different from habitats and receptors examined in investigations of other skeet ranges. The probability model is developed from the binomial probability expansion formula that estimates the likelihood that a bird may ingest either grit or lead shot within the grit size range in a given number of attempts. The probability of an individual bird ingesting exactly *r* lead shot particles in *n* probes for grit is given by the binomial expression:

$$P(r) = \frac{n!}{r!(n-r)!} p^{r} (1-p)^{n-r} \tag{4-1}$$

where P(r) = probability of ingesting *r* lead shot particles in *n* probes for grit [P(r)];
r = no observed adverse effects level (NOAEL)-based number of lead shot pellets;
n = number of probes for grit a bird makes in a specified time period, and;
p = probability that an individual bird will encounter a lead shot pellet in a single probe.

The development of a NOAEL-based number of lead shot pellets *(r)*, was discussed at the end of Section 4.1.2.1. The number of probes for grit a bird makes in a specified time period (*n*) is based on literature-derived information, and is discussed further below. This value incorporates the amount of grit required by the bird, the amount of time per day the bird forages for grit at the Skeet Range as compared to other locations, and the amount of time grit is retained in the bird's system. The third variable in the model is the probability (*p*) that an individual bird will encounter a lead shot pellet within the appropriate size range in a single probe. This value is a function of the abundance of shot in sediment compared to the available grit-sized particles.

The output of the binomial probability model (shown in Equation 4-1) is an estimate of the probability that an individual bird will ingest the lead shot NOAEL (i.e., *r* number of lead shot) at the Alameda Point Skeet Range in a given number of probes (*n*), which is the number of probes made during the time it takes for the first lead shot ingested to be expelled from the bird's system or partition into bone, where it is stored. To estimate the probability that an individual will ingest **up to and including** *r* lead shot pellets in *n* probes for grit the following equation was used:

$$P(y \leq r) = P(0)+P(1)+P(2)+\ldots+P(r) \qquad (4\text{-}2)$$

To estimate the probability that an individual will ingest **greater than** *r* lead shot particles in n probes for grit, the following equation was used:

$$P(y>r) = 1 - [P(0)+P(1)+P(2)+\ldots+P(r)] \qquad (4\text{-}3)$$

To characterize risk at the local population level, the number of birds in the local population that may be adversely affected by lead shot ingestion was determined by comparing the probability [P(y>r)] that an individual will ingest greater than *r* lead shot pellets in *n* probes for grit, where r is equal to the NOAEL for lead shot, to the determined threshold for population risk (as discussed in Section 4.1.2.3). Cases in which the risk probability [P(y>r)] exceeds the population risk threshold indicate the potential for unacceptable risk.

The values used to estimate the parameters in the binomial probability model were derived from the literature. Site-specific, complete data sets for both the scoter and the scaup are unavailable for San Francisco Bay. Therefore, input parameters were developed based on a combination of information from both the scaup and scoter, and the estimates developed here are considered a representative and conservative estimate for both species. The input values for these parameters are discussed in further detail below.

Probability of Ingesting a Lead Shot Pellet in a Single Probe (p)

The probability (*p*) that an individual bird will encounter a lead shot pellet within the appropriate size range in a single probe is based upon the ratio of shot in sediment to the total number of grit-sized particles available. This parameter is defined as:

$$p = \left(\frac{A_{shot,\,2-4\,mm}}{A_{grit,\,2-4\,mm}} \times f_{2-4\,mm} \right) + \left(\frac{A_{shot,\,0.5-2\,mm}}{A_{grit,\,0.5-2\,mm}} \times f_{0.5-2\,mm} \right) \qquad (4\text{-}4)$$

where $A_{shot,\,2\text{-}4\,mm}$ = abundance of lead shot (Nos. 7½, 8, and 9 shot) per unit volume of sediment in the 2-4 mm particle size class;

$A_{grit,2\text{-}4\,mm}$ = total abundance of grit-sized particles per unit volume of sediment in the 2-4 mm particle size class;

$f_{2\text{-}4\,mm}$ = fraction of ingested grit in 2-4 mm particle size class.

$A_{shot,\,0.5\text{-}2\,mm}$ = abundance of lead shot (Nos. 7½, 8, and 9 shot) per unit volume of sediment in the 0.5-2 mm particle size class;

$A_{grit,0.5\text{-}2\,mm}$ = total abundance of grit-sized particles per unit volume of sediment in the 0.5-2 mm particle size class;

$f_{0.5\text{-}2\,mm}$ = fraction of ingested grit in 0.5-2 mm particle size class.

The value of *p* is a function of the abundance of shot in sediment and the fractional amount of ingested grit that is the same size as shot. The abundance of lead shot per unit volume of sediment ($A_{shot,i}$) and the total abundance of grit-sized particles per unit volume of sediment ($A_{grit,i}$) were determined from field data and were broken down into two particle sizes. Because the lead shot from the Skeet Range includes shot Nos. 7½, 8, and 9 (which are approximately 2.41, 2.29, and 2.03 mm in diameter), the fractional amount of ingested grit greater than about 2.0 mm in diameter is the primary size of interest. Therefore, the estimation of p is broken down into calculations for two size classes, greater than or equal to 2 mm in diameter and less than 2 mm in diameter. No specific studies were found that evaluated the grit-sized particle range desired by scaups; however, in a related species, *Aythya ferina*, 56.1% of the grit found in their gizzards was greater than 1 mm in diameter, and 17.8% was greater than 2.00 mm in diameter (Pain, 1990). For those grit in the larger size class (>2 mm), the mean grit size was 2.97 mm in diameter (Pain, 1990). Therefore, the fraction of ingested grit that is ≥2.0 mm in diameter was assumed to be 18% and measurements taken in the field for grit-sized particles between 2.0 and 4.0 mm ($f_{2\text{-}4\,mm}$) were used to approximate this particle size fraction. The fraction of ingested grit that is <2.0 mm in diameter was assumed to be 82%, and measurements taken in the field for grit-sized particles between 0.5 and 2.0 mm ($f_{0.5\text{-}2\,mm}$) were used to approximate this particle size fraction. Additionally, probabilities were calculated for each station for two depths, in the surface sediments from 0 to 5 cm and from 0 to 10 cm using the maximum lead shot to grit-sized particle ratio per depth per particle size.

Development of Parameter for Number of Probes for Grit (n)

The second input parameter required for the probability model is n, the number of probes for grit that a bird makes in a specified period of time. The parameter n is based on the amount of grit a bird needs, the amount of time each day the bird forages for grit at the Skeet Range as compared to other locations, and the amount of time that lead ingested as shot is retained in the blood and soft tissues of the bird that has ingested it. This parameter n, the number of probes for grit that a bird makes in a specified period of time, was mathematically derived as:

$$n = g \times SUF \times i \qquad (4\text{-}5)$$

where n = number of probes for grit that a bird makes in a specified period of time;
g = number of dives/day for grit;
SUF = site use factor;
I = blood lead retention time in days.

These parameters are discussed further below.

Number of Dives per Day for Grit (g)

Many studies have concluded that ducks are exposed to lead shot while ingesting grit (either intentionally or incidentally) rather than when foraging for food (Trost, 1981; Hall and Fisher, 1985; Pain, 1990; Moore et al., 1998; Mateo and Guitart, 2000). Therefore, the probability that a bird might ingest shot is based on the rate at which grit is ingested. The rate at which grit is ingested is dependent on the quantity and type of grit available in the habitat, the size of grit used by the bird, and diet (Norris et al., 1975; Trost, 1981; Skead and Mitchell, 1983; Gionfriddo and Best, 1995; Mateo and Guitart, 2000).

Grit ingestion studies have been conducted on upland birds such as ptarmigans and various passerines (Norris et al., 1975; Gionfriddo and Best, 1995) and dabbling ducks in the genus *Anas* (Trost, 1981; Skead and Mitchell, 1983; King and Bendell-Young, 2000). However, information on grit ingestion in diving ducks such as scoters or scaups was lacking in the published literature.

The only information specific to either species noted that scoter gizzards are only found containing large quantities of grit when the birds are not feeding on bivalves. When scoters are feeding on bivalves they use shell fragments as grit (Vermeer, 1981; Savard et al., 1998). It is assumed that this is also likely to be true for scaups. Thus, in San Francisco Bay where these species are feeding mainly on bivalves (Ohlendorf et al., 1986; Poulton et al., 2001), one would expect grit ingestion to be low as shell fragments would be used as grit. This is further supported by the observations made during the Skeet Range sampling that the majority of grit observed at the site was composed of shell hash.

No species-specific information on grit ingestion was found and there were no studies conducted on species with similar feeding behavior, so estimates of grit uptake for the scoter/scaup were made in the following way. First, the amount of time spent foraging per day was estimated. This proportion then was multiplied by the maximum number of dives that a duck could physically make in one day to determine the maximum number of foraging dives made per day. The proportion of grit to stomach contents was then multiplied by the number of foraging dives per day to estimate the number of foraging dives made per day to obtain grit. In keeping with the objectives of the SLERA, maximum estimates were used to ensure conservatism.

Foraging Time per Day. During feeding, birds dive and probe for food and grit in the sediments. Scaups in San Francisco Bay forage on average 24% of the time during a 24-hour day (Takekawa, 2002a). A study conducted by the United States Geological Survey (USGS) investigated the foraging behavior of scaups in the northern bay area (Poulton et al., 2002). This study provides estimates of the mean percentage of time that scaups engaged in feeding at five sites around San Pablo Bay. The study results show that at three of the sites considerable time is spent feeding, whereas at two of the sites limited time is spent feeding. Of the five mean percentages of time spent feeding, the highest was 42.2 % (Poulton, 2002). This value was selected for the SLERA as a conservative estimate of the amount of time scaups in San Francisco Bay spend feeding.

Potential Number of Dives per Day. Poulton et al. (2002) also provide dive duration data for the scaup in San Francisco Bay. The mean dive durations reported by Poulton et al. (2002) are 21.6 and 24.7 seconds. This is similar to the range of diving frequencies estimated for the scoter in its breeding habitat (Savard et al., 1998). Savard et al. (1998) reported dive durations of 11.4 to 32.9 seconds for adults, and approximately 8 dives every 5 minutes for ducklings. Assuming the ducks wait a few seconds between dives, birds can dive approximately twice per minute during a feeding bout. Therefore, the maximum number of dives that a scaup makes in a single day is 2,880 dives (2 dives/min × 60 min/hr × 24 hrs/d). Assuming 42.2 percent of the day is spent feeding, a duck is estimated to make approximately 1,215 dives per day (42.2% of 2,880 dives).

Proportion of Daily Dives for Grit. Birds do not ingest grit on every foraging dive, and in some cases ingest grit in areas separate from their feeding grounds (Thomas et al., 1977). No San Francisco Bay-specific information on grit ingestion was available for diving ducks. Therefore, once the number of foraging dives/day was estimated, the percentage of those foraging dives resulting in ingestion of grit was projected using the proportion of daily dives for grit. To provide an estimate of what proportion of dives/day result in grit ingestion, studies evaluating stomach/gizzard contents were reviewed. In a study of surf scoters in British Columbia, percentage wet weight of grit varied from 2% to 42%, and the mode of the means (6%) was equivalent to the mean of the single dataset collected over an entire year (Vermeer, 1981). In a study of a closely related species (the white-winged scoter *Melanitta fusca dixoni*), conducted in Humboldt Bay California, grit content in the gut was 1.3% to 12.2% of volume (Grosz and Yocom, 1972), a range which is similar, but lower, than the range reported by Vermeer (1981). The maximum percentage of grit in surf scoter stomach contents (42%) reported by Vermeer (1981) was selected as a conservative estimate of the proportion of grit in stomach contents and was used to represent the proportion of foraging dives used to acquire grit.

The grit ingestion rate was calculated by multiplying the foraging time per day (42.2%) by the maximum potential number of dives per day (2,880) by the proportion of daily dives for grit (42%). This resulted in a maximum number of daily dives for grit of 510 dives/day (42% of 1,215 dives). It is likely that the number of dives/day for grit at the Skeet Range is much less than this range. The values used to generate this estimate include upper bound estimates of foraging time and the proportion of grit ingested relative to stomach contents. The combination of upper-bound estimates results in a rare, worst-case scenario.

Moreover, during sampling at the Skeet Range, a very dense mat of *Ampelisca* (amphipod) tubes was observed on the surface of the sediment (see Figure 2-2). In fact, the *Ampelisca* mat was so dense, that it was difficult to physically separate the shot from the sediment below the mat. It is probable that diving ducks would have similar difficulties in breaking through these mats to get at the bivalves below and to consume the shot (Takekawa, 2002b).

Site Use Factor (SUF)

The Alameda Point Skeet Range is about 1,300 ft by 800 ft or 856,910 ft^2 or 0.08 km^2. To estimate how much time a scoter or scaup may forage at the Skeet Range versus other areas (e.g., SUF), studies evaluating the home range of scoters and scaups in San Francisco Bay were reviewed.

Scoter. No San Francisco Bay-specific home range studies have been conducted for the scoter (Takekawa, 2001). However, a two-year radiotelemetry study conducted in the Commencement Bay Area of Puget Sound found that wintering birds stayed within 9 to 11 km of their capture location. Most birds used between 2 to 7 locations (defined as 1 km in diameter areas) 76% to 87% of the time studied (Mahaffy et al., 1995). If one assumes that on average, three locations are visited the majority of the time by scoters (the mean number of locations visited during the first tracking season was 2.5 and for the second year, 3.9), the average diameter for a foraging area would be 3 km. This would result in a foraging area (assuming that it is round) of 7 km^2, assuming that the foraging area within this 7 km^2 area is similar to habitat near Alameda Point.

Scaup. The USGS studied greater and lesser scaup in San Francisco Bay during the winters of 1998-99 and 1999-2000 using radiotelemetry to determine their home ranges and foraging depth preferences (Wainwright-De La Cruz et al., 2001). Unpublished data from this study was used to estimate home range sizes in the Bay using the kernel method (Takekawa et al., 2001). Mean (SD) 95% kernel home range for greater scaup was 258.99 (182.58) km^2 and for lesser scaup was 168.59 (193.08) km^2. These values were estimated for both study seasons, both sexes and all ages combined.

To develop a conservative estimate for a SUF taking into account the birds' estimated home range during the time they are in San Francisco Bay, one divides the area of the Skeet Range by the area of the bird's home range. Using the calculated foraging area of the scoter (7 km^2), the SUF is about 1%. Using the more conservative of the greater and lesser scaup mean kernel home ranges (168.59 km^2) results in a SUF of about 0.0005. However, to address uncertainty associ-ated with the foraging range datasets and to meet the SLERA objectives, a conservative SUF of

100% was used. One hundred percent is the maximum value a SUF can take, as it assumes that all foraging occurs on the Skeet Range.

Blood Lead Retention Time (i)

Lead retention time in blood is the third parameter used to determine the number of probes in a given time period (n) for the binomial probability model. The number of probes (n) depends on the length of time that the first shot ingested could remain in the duck's system and exert toxic effects. To select a value for this parameter, the amount of time that lead spends in the gizzard, blood, and soft tissues was evaluated.

No studies have been conducted on shot or grit retention rates conducted on diving ducks such as scaups and scoters, so it is assumed that shot retention rates will be similar to those estimated for dabbling ducks such as mallards. Vyas et al. (2001), Hirai et al. (1991), and Finley et al. (1976a) determined that ingested shot may be retained in the gizzard from less than 24 hours to several weeks. Early work conducted by Bellrose (Bellrose, 1959, as cited in Sanderson and Bellrose, 1986) found that if a bird does not die as a result of lead poisoning, lead shot will disappear from the gizzard in about 20 days (either through erosion or by voiding).

Trost (1981) also developed gizzard retention rates for grit and steel shot in captive mallards. Trost found that steel shot was retained significantly longer in the gizzard than grit and noted that in another study steel shot also was found to be retained longer in the gizzard than lead shot (Sanderson and Irwin, 1976, as cited in Trost, 1981). To test whether lead shot is retained in the gizzard at a similar rate as grit, Trost compared his grit retention rate to the 20-day lead shot retention rate developed by Bellrose (Bellrose, 1959, as cited in Sanderson and Bellrose, 1986) and concluded that lead shot is retained similarly to grit. Using Trost's estimated grit retention rate of 0.54/48 hr interval, only 5% of grit/shot remains in the gizzard after 10 days.

Assuming that grit is retained at a similar rate to lead shot, other studies evaluating grit retention rates can be used to develop shot retention times. In a study of mallard ducklings, a grit retention rate of 0.02/hr was measured (King and Bendell-Young, 2000). This study found that ducklings replace 100% of their grit in about 100 hours or about 4 days. Similar results were found for passerine birds where grit retention times were on the order of 5 days with up to 40% of the grit retained for only a few hours (Gionfriddo and Best, 1995).

Mautino and Bell (1986) present data that indicate that concentrations of lead in the blood of ring-necked ducks dosed with one No. 4 shot (equivalent to 2-3 No. 7½, 8, or 9 shot) were highest one week after dosing, but then gradually returned to control levels in 4 weeks. The ducks experienced a mild, but significant, secondary increase in week 6, before blood lead levels returned to control levels again at 7 weeks.

Therefore, lead shot, once ingested, may be voided intact, remain in the gizzard for a period of time prior to excretion/voiding, or become eroded in the gizzard and mobilized into the bloodstream and soft tissues. Retention times in ducks for lead ingested as shot range from 0 to 49 days, depending on whether the shot is voided intact, partially eroded and excreted, or dissolved and absorbed. The maximum amount of time that lead ingested as shot is estimated to remain in the gizzard, blood, and soft tissues is 7 weeks (49 days), based on the data presented by Mautino and Bell (1986). This value was selected as a conservative estimate of lead retention time in the gizzard, blood, and soft tissues of diving ducks.

This value likely overestimates lead retention time in diving ducks, because study results demonstrated blood lead levels initially returned to control levels four weeks after shot ingestion (Mautino and Bell, 1986). Furthermore, shot reportedly can be voided intact at any time and may not be eroded to a great extent in the gizzard.

***Development of* n**

As discussed above, a maximum value was selected for each input parameter for Equation 4-5. This was done in recognition of the uncertainty associated with these inputs; thus, that uncertainty was bounded by selecting a conservative, upper-bound estimate for each parameter, the combination of which results in a rare, worst-case scenario, which has a negligible chance of actually occurring. A summary of these conservative parameter estimates can be found in Table 4-6.

Table 4-6. Proposed Toxicity and Exposure Parameters

Parameter	Proposed Value
NOAEL Lead Shot	2 shot (No. 7½ , 8 or 9 shot)
Parameter *n*, the number of probes for grit that a bird makes in a specified period of time at Alameda Skeet Range	
g = number of dives/day for grit	510
SUF	1
i = grit/shot retention time (days)	49

Risk Probabilities

As discussed in Section 4.1.1.4, the measurement endpoints used in this assessment to evaluate risk to wildlife are based on probabilities of ingesting a toxic level of lead shot in a given number of probes (n) for grit. The result of the probability model, the risk probability [P(y>r)], equals the probability of ingesting greater than r lead shot particles in n probes for grit. In other words, the result is the probability of exceeding the NOAEL in n attempts.

Probabilities were calculated on a station-by-station basis using these conservative estimates for model input parameters (see Table 4-6). For the SLERA, the maximum values for number of dives/day for grit (g), SUF, and grit/shot retention time in days (i) were used.

Probabilities were calculated for each station for two depths, in the surface sediments from 0 to 5 cm and from 0 to 10 cm using the maximum lead shot to grit-sized particle ratio per depth per particle size. The results of these calculations are presented in Tables 4-7 and 4-8.

At a majority of sampling stations, the probability that an individual bird will encounter a lead shot pellet in a single probe is driven by analytical results in the 2-4 mm sieve size. At only one station (SK-3) is the probability that an individual bird will encounter a lead shot particle in a single probe driven by the smaller, 0.5-2 mm sieve size. This is consistent with the observation that the majority of the shot collected was still whole and had not been eroded into smaller pieces.

Table 4-7. Risk Probabilities for Lead Shot from 0-5 cm Depth at Each Station

Station	Depth (cm)	Probabilities per Sieve Size		Probability	Max Parameters	
		0.5-2 mm P	2-4 mm P	Combined P	P (y<=2)	P (y>2)
SK-1	0-5	0.000	0.000	0.000	1.000	0.000
SK-2	0-5	0.000	0.000	0.000	1.000	0.000
SK-3	0-5	0.205	NS	0.205	0.000	**1.000**
SK-4	0-5	0.000	0.000	0.000	1.000	0.000
SK-5	0-5	0.000	0.030	0.030	0.000	**1.000**
SK-6	0-5	0.000	0.000	0.000	1.000	0.000
SK-7	0-5	0.001	0.031	0.032	0.000	**1.000**
SK-8	0-5	0.001	0.000	0.001	0.000	**1.000**
SK-9	0-5	0.000	0.034	0.034	0.000	**1.000**
SK-10	0-5	0.006	0.041	0.046	0.000	**1.000**
SK-11	0-5	0.000	0.000	0.000	1.000	0.000
SK-12	0-5	0.000	0.076	0.076	0.000	**1.000**
SK-13	0-5	0.000	0.003	0.003	0.000	**1.000**
SK-14	0-5	0.000	0.165	0.165	0.000	**1.000**
SK-15	0-5	0.043	0.154	0.197	0.000	**1.000**
SK-16	0-5	0.000	0.000	0.000	1.000	0.000
SK-17	0-5	0.001	0.000	0.001	0.000	**1.000**
SK-18	0-5	0.000	NS	0.000	1.000	0.000
SK-19	0-5	0.047	0.172	0.219	0.000	**1.000**
SK-20	0-5	0.000	0.060	0.060	0.000	**1.000**
SK-21	0-5	0.000	NS	0.000	1.000	0.000
SK-22	0-5	0.000	0.000	0.000	1.000	0.000
SK-23	0-5	0.000	0.120	0.120	0.000	**1.000**
SK-24	0-5	0.000	NS	0.000	1.000	0.000
SK-25	0-5	0.000	0.000	0.000	1.000	0.000
SK-26	0-5	0.000	0.005	0.005	0.000	**1.000**
SK-27	0-5	0.000	0.000	0.000	1.000	0.000
SK-28	0-5	0.000	0.000	0.000	1.000	0.000
SK-29	0-5	0.000	0.064	0.064	0.000	**1.000**
SK-30	0-5	0.000	0.000	0.000	1.000	0.000
SK-31	0-5	0.000	0.006	0.006	0.000	**1.000**
SK-32	0-5	0.000	0.000	0.000	1.000	0.000
SK-33	0-5	0.000	0.083	0.083	0.000	**1.000**
SK-34	0-5	0.000	0.097	0.097	0.000	**1.000**
SK-35	0-5	0.000	0.000	0.000	1.000	0.000
SK-36	0-5	0.001	0.047	0.049	0.000	**1.000**
SK-37	0-5	0.000	0.000	0.000	1.000	0.000
SK-38	0-5	0.000	0.047	0.047	0.000	**1.000**
SK-39	0-5	0.000	0.180	0.180	0.000	**1.000**
SK-40	0-5	0.000	0.082	0.082	0.000	**1.000**
SK-41	0-5	0.009	0.049	0.057	0.000	**1.000**
SK-42	0-5	0.000	0.058	0.058	0.000	**1.000**
SK-43	0-5	0.000	0.000	0.000	1.000	0.000
SK-44	0-5	0.010	0.074	0.084	0.000	**1.000**
SK-45	0-5	0.000	0.004	0.004	0.000	**1.000**

Table 4-7. Risk Probabilities for Lead Shot from 0-5 cm Depth at Each Station (Continued)

Station	Depth (cm)	Probabilities per Sieve Size 0.5-2 mm P	2-4 mm P	Probability Combined P	Max Parameters P (y<=2)	P (y>2)
SK-46	0-5	0.006	0.039	0.046	0.000	**1.000**
SK-47	0-5	0.000	0.000	0.000	1.000	0.000
SK-48	0-5	0.000	0.000	0.000	1.000	0.000
SK-49	0-5	0.011	0.044	0.055	0.000	**1.000**
SK-50	0-5	0.000	0.000	0.000	1.000	0.000
SK-51	0-5	0.006	0.092	0.097	0.000	**1.000**
SK-52	0-5	0.000	0.000	0.000	1.000	0.000
SK-53	0-5	0.004	0.007	0.010	0.000	**1.000**
SK-54	0-5	0.020	0.165	0.186	0.000	**1.000**
SK-55	0-5	0.000	0.000	0.000	1.000	0.000
SK-56	0-5	0.004	0.180	0.184	0.000	**1.000**
SK-57	0-5	0.003	0.012	0.015	0.000	**1.000**
SK-58	0-5	0.000	0.000	0.000	1.000	0.000
SK-59	0-5	0.000	0.000	0.000	1.000	0.000
SK-60	0-5	0.013	0.026	0.039	0.000	**1.000**
SK-61	0-5	0.000	0.000	0.000	1.000	0.000
SK-62	0-5	0.000	0.000	0.000	1.000	0.000
SK-63	0-5	0.000	0.082	0.082	0.000	**1.000**
SK-64	0-5	0.000	0.000	0.000	1.000	0.000
SK-65	0-5	0.000	0.000	0.000	1.000	0.000
SK-66	0-5	0.000	0.000	0.000	1.000	0.000
SK-67	0-5	0.000	0.000	0.000	1.000	0.000

Table 4-8. Risk Probabilities for Lead Shot from 0-10 cm Depth at Each Station

Station	Depth (cm)*	Probabilities per Sieve Size 0.5-2 mm P	2-4 mm P	Probability Combined P	Max Parameters P (y<=2)	P (y>2)
SK-1	0-10	0.000	0.000	0.000	1.000	0.000
SK-2	0-10	0.000	0.000	0.000	1.000	0.000
SK-3	0-10	0.205	0.024	0.229	0.000	**1.000**
SK-4	0-10	0.000	0.000	0.000	1.000	0.000
SK-5	0-10	0.000	0.030	0.030	0.000	**1.000**
SK-6	0-10	0.000	0.000	0.000	1.000	0.000
SK-7	0-10	0.002	0.087	0.089	0.000	**1.000**
SK-8	0-10	0.001	0.026	0.027	0.000	**1.000**
SK-9	0-10	0.000	0.045	0.045	0.000	**1.000**
SK-10	0-10	0.006	0.068	0.073	0.000	**1.000**
SK-11	0-10	0.000	0.000	0.000	1.000	0.000
SK-12	0-10	0.000	0.076	0.076	0.000	**1.000**
SK-13	0-10	0.000	0.017	0.017	0.000	**1.000**
SK-14	0-10	0.000	0.165	0.165	0.000	**1.000**
SK-15	0-10	0.043	0.154	0.197	0.000	**1.000**
SK-16	0-10	0.001	0.000	0.001	0.000	**1.000**
SK-17	0-10	0.004	0.049	0.053	0.000	**1.000**
SK-18	0-10	0.000	NS	0.000	1.000	0.000

Table 4-8. Risk Probabilities for Lead Shot from 0-10 cm Depth at Each Station (Continued)

Station	Depth (cm)*	Probabilities per Sieve Size 0.5-2 mm P	2-4 mm P	Probability Combined P	Max Parameters P (y<=2)	P (y>2)
SK-19	0-10	0.047	0.172	0.219	0.000	**1.000**
SK-20	0-10	0.000	0.090	0.090	0.000	**1.000**
SK-21	0-10	0.000	0.020	0.020	0.000	**1.000**
SK-22	0-10	0.000	0.000	0.000	1.000	0.000
SK-23	0-10	0.014	0.173	0.187	0.000	**1.000**
SK-24	0-10	0.000	0.000	0.000	1.000	0.000
SK-25	0-10	0.000	0.000	0.000	1.000	0.000
SK-26	0-10	0.000	0.005	0.005	0.000	**1.000**
SK-27	0-10	0.000	0.000	0.000	1.000	0.000
SK-28	0-10	0.000	0.000	0.000	1.000	0.000
SK-29	0-10	0.000	0.064	0.064	0.000	**1.000**
SK-30	0-10	0.000	0.000	0.000	1.000	0.000
SK-31	0-10	0.000	0.006	0.006	0.000	**1.000**
SK-32	0-10	0.000	0.000	0.000	1.000	0.000
SK-33	0-10	0.000	0.083	0.083	0.000	**1.000**
SK-34	0-10	0.000	0.097	0.097	0.000	**1.000**
SK-35	0-10	0.000	0.000	0.000	1.000	0.000
SK-36	0-10	0.001	0.047	0.049	0.000	**1.000**
SK-37	0-10	0.000	0.000	0.000	1.000	0.000
SK-38	0-10	0.000	0.047	0.047	0.000	**1.000**
SK-39	0-10	0.000	0.180	0.180	0.000	**1.000**
SK-40	0-10	0.000	0.082	0.082	0.000	**1.000**
SK-41	0-10	0.009	0.049	0.057	0.000	**1.000**
SK-42	0-10	0.000	0.058	0.058	0.000	**1.000**
SK-43	0-10	0.000	0.000	0.000	1.000	0.000
SK-44	0-10	0.010	0.074	0.084	0.000	**1.000**
SK-45	0-10	0.000	0.004	0.004	0.000	**1.000**
SK-46	0-10	0.006	0.039	0.046	0.000	**1.000**
SK-47	0-10	0.000	0.000	0.000	1.000	0.000
SK-48	0-10	0.000	0.000	0.000	1.000	0.000
SK-49	0-10	0.011	0.044	0.055	0.000	**1.000**
SK-50	0-10	0.000	0.000	0.000	1.000	0.000
SK-51	0-10	0.006	0.092	0.097	0.000	**1.000**
SK-52	0-10	0.000	0.000	0.000	1.000	0.000
SK-53	0-10	0.004	0.007	0.010	0.000	**1.000**
SK-54	0-10	0.020	0.165	0.186	0.000	**1.000**
SK-55	0-10	0.000	0.000	0.000	1.000	0.000
SK-56	0-10	0.004	0.180	0.184	0.000	**1.000**
SK-57	0-10	0.003	0.012	0.015	0.000	**1.000**
SK-58	0-10	0.000	0.000	0.000	1.000	0.000
SK-59	0-10	0.000	0.000	0.000	1.000	0.000
SK-60	0-10	0.013	0.026	0.039	0.000	**1.000**
SK-61	0-10	0.000	0.000	0.000	1.000	0.000
SK-62	0-10	0.000	0.000	0.000	1.000	0.000
SK-63	0-10	0.000	0.082	0.082	0.000	**1.000**
SK-64	0-10	0.000	0.000	0.000	1.000	0.000
SK-65	0-10	0.000	0.000	0.000	1.000	0.000
SK-66	0-10	0.000	0.000	0.000	1.000	0.000
SK-67	0-10	0.000	0.000	0.000	1.000	0.000

4.1.2.3 Risk Characterization

To evaluate the effect on these birds of ingesting lead shot, an acceptable risk level for the San Francisco Bay diving duck population was defined. The value of 1×10^{-3} (e.g., one in a thousand) was suggested by the United States Fish and Wildlife Service (Haas, 2002) as a reasonable level of health-protectiveness. Population level risk was evaluated by comparing the probability of individual diving ducks ingesting greater than the no effect level of lead shot to the 1×10^{-3} population risk threshold. Where probabilities of exceeding the NOAEL were greater than the population risk threshold of 1×10^{-3} (one in one thousand), the potential for unacceptable population level risk was indicated.

Risk probabilities calculated for each station are shown in Table 4-7 and 4-8. Because of the extremely conservative nature of the assumptions in the SLERA, risk probabilities equaled one at all stations for which lead shot was found. For stations where no lead shot was found in the sieve sizes (0.5-2 mm, 2-4 mm) and depths (0-5 cm, 0-10 cm) evaluated, the probability (p) of a diving duck ingesting lead shot in an individual dive for grit equaled zero, and risk probabilities were therefore equal to zero. A review of the 0 to 5 cm depth results indicates that less than half the stations (31 out of 67) had risk probabilities of zero. The remaining stations had a probability of 1.0. A review of the 0 to 10 cm depth results indicates that 29 stations out of 67 showed acceptable risk (risk probabilities equaled zero); the risk probabilities for the remaining stations equaled 1.0.

The results of the screening level binomial probability modeling indicate that lead shot measured at the Skeet Range may pose a potential risk to benthic-feeding birds that use the site under conditions resulting in maximum exposure. For example, maximum and upper bound estimates of each exposure parameter were combined in this SLERA to provide an upper-bound estimate of the potential for risk at the site. The maximum SUF value (1.0) in particular is a conservative, upper bound estimate of the true use of the entire site by diving ducks. These conservative exposure parameter estimates were combined using a binomial probability model to produce a worst-case estimate of risk that has a negligible chance of occurring. To determine the probability of these worst-case exposures occurring and to evaluate long-term, average estimates of potential risk, these conservative exposure parameters must be refined. Refining these conservative estimates of site-wide exposure will be a key means of reducing uncertainty in the BERA.

4.1.3 Summary

Although the Skeet Range is in an area of sediment accumulation, lead shot was found in the surface sediment, and where risk was identified, it was driven by the particles greater than 2 mm in size. PAHs were found across the site at concentrations that were elevated above sediment benchmark levels.

The results of the SLERA indicate that using conservative assumptions and maximum exposure parameters results in risk probabilities for lead shot ingestion that exceed population level thresholds at approximately half the sampling stations at the site. Because of the conservatism inherent in the SLERA, a finding of risk does not mean that risk is present, just that additional evaluation is necessary; therefore, refined estimates of site-wide exposure are needed to better characterize potential risks to diving ducks at the site. These refined estimates will be generated in the BERA.

The potential for unacceptable risk from exposure to PAHs from clay targets to birds is unknown due to the lack of toxicity and effects data for avian species preventing a quantitative evaluation of risk to benthic-feeding birds from PAH exposure. This will be discussed in more detail in the Uncertainty Evaluation (Section 6.0).

4.2 Baseline ERA

In the SLERA, lead shot and PAHs were identified as contaminants that may be of potential concern to ecological receptors. Therefore, a baseline ecological risk assessment (BERA) was conducted. Because of the very conservative assumptions used in the SLERA, a more in-depth evaluation of risk was required in the BERA to determine whether the COPECs retained for further evaluation pose an unacceptable risk. The purpose of the BERA is to re-evaluate the COPECs carried forward from the SLERA for further evaluation, and to eliminate those COPECs that were retained due to use of very conservative exposure scenarios. Using reasonable yet protective assumptions, the goal of the BERA is to use these new estimates to refine the list of COPECs by focusing on only those constituents that pose unacceptable risk.

The complete exposure pathways (Figure 4-2) and COPEC list (Table 4-2) identified in the SLERA are evaluated in more detail in the BERA. The BERA includes a Tier 2 COPEC screen for PAHs and an exposure assessment that incorporates site-wide exposure into a final risk characterization.

4.2.1 Problem Formulation

The first step of the BERA was to refine the preliminary problem formulation and CSM developed in Section 4.1.1. The CSM (Figure 4-2) was re-evaluated in light of the outcome of the SLERA and was found to require no additional revisions. The AEs and MEs selected in the SLERA also were found to be applicable and relevant to the BERA.

The next step was to conduct the Tier 2 COPEC screen and to statistically compare PAH concentrations at the Skeet Range to ambient levels in San Francisco Bay. Distribution shift tests were conducted according to Navy guidance in order to statistically compare site data to the distribution of ambient concentrations. Four distribution shift tests were used—the t-test, Gehan test, quantile test, and slippage test. Each distribution shift test yielded a test statistic and an associated significance level (also known as a p-value). The significance level is the probability that the test statistic would be as large or larger than the one produced if the two data sets were from the same distribution (i.e., were both from the ambient distribution). A small significance level (i.e., $p<0.05$) indicates that it is not likely that two given data sets come from the same distribution (i.e., the constituent "fails" the test). COPECs that fail one or more tests were retained for evaluation in the BERA. Constituents that pass all tests are assumed to be present at the site in concentrations within the range of ambient concentrations. The tests are not conclusive for cases where either the site data or ambient data have a detection rate of less than 50%.

In these tests, surface sediment chemistry results for the Skeet Range were compared to data from San Francisco Bay ambient locations to determine if site-specific chemical concentrations were higher than ambient levels in San Francisco Bay. The data used to represent ambient conditions in San Francisco Bay were collected as part of the Bay Protection and Toxic Hotspot Cleanup Program (BPTCP) and the SFEI's Regional Monitoring Program (RMP). All available sediment chemistry results from 1993 through 1997 from stations classified as ambient (RWQCB, 1998) were used. For chemicals that were not analyzed by the RMP or BPTCP, results were used from sediment samples collected at ten San Francisco Bay reference stations for the Navy's 1998 Alameda Point ERA (TtEMI, 1998) and the Navy's *Hunters Point Shipyard Validation Study (VS) Work Plan* (Battelle et al., 2001c).

The distribution shift test results for PAHs are listed in Table 4-9. The tests were performed by comparing the November 2001 field results to the combined ambient levels. The PAH totals (sums of analytes within a suite) are based on sums that use half the detection limits for nondetects. Each PAH constituent failed one or more of the distribution shift tests and, consequently, was carried forward through the BERA for risk characterization. Distributions of site data and San Francisco Bay ambient data for all of the detected chemicals are summarized in boxplots presented in Appendix A.

Table 4-9. Distribution Shift Test Results for Organic Constituents in Surface Sediment Samples

PAHs	Ambient Data Set	No. of Ambient Samples	Test Results
2-Methylnaphthalene	RMP, BPTCP	185	F
Acenaphthene	RMP, BPTCP	185	F
Acenaphthylene	RMP, BPTCP	185	F
Anthracene	RMP, BPTCP	199	F
Fluorene	RMP, BPTCP	185	F
Naphthalene	RMP, BPTCP	160	F
Phenanthrene	RMP, BPTCP	192	F
Benzo(a)anthracene	RMP, BPTCP	199	F
Benzo(a)pyrene	RMP, BPTCP	199	F
Benzo(b)fluoranthene	RMP, BPTCP	199	F
Benzo(g,h,i)perylene	RMP, BPTCP	199	F
Benzo(k)fluoranthene	RMP, BPTCP	199	F
Chrysene	RMP, BPTCP	199	F
Dibenzo(a,h)anthracene	RMP, BPTCP	199	F
Fluoranthene	RMP, BPTCP	197	F
Indeno(1,2,3-cd)pyrene	RMP, BPTCP	199	F
Pyrene	RMP, BPTCP	197	F
Sums of Analytes[(a)]			
Total HPAHs (10)	RMP, BPTCP	197	F
Total HPAHs (6)	RMP, BPTCP	197	F
Total LPAHs	RMP, BPTCP	178	F

(a) Sum of analytes within the suite with nondetects included as 0.
F = fail. One or more statistical tests indicate a shifted site distribution.
P = pass. No statistically significant results for any of the distribution shift tests.
BPTCP = Bay Protection and Toxic Cleanup Program.
RMP = (San Francisco Estuary Institute) Regional Monitoring Program.

A number of PAHs are slightly elevated above ambient at a few stations (see boxplots in Appendix A and Section 3.1.1), but clay targets are unlikely to be the source of these PAHs. As determined in the PAH fingerprinting analysis, it was found that the PAHs in sediment were chemically distinct from the chemical composition found in clay targets and it was concluded that the clay target were not the source of PAHs in sediment.

4.2.2 Effects and Exposure Assessment

To address the (1) uncertainty associated with the exposure and effects parameters used to estimate risk in the SLERA, and (2) the conservatism in the SLERA that resulted in a worst-case estimate of risk that has a negligible chance of occurring, a refinement to these parameters was conducted in the BERA. To aid in this refinement, a Monte Carlo analysis was conducted to evaluate the effects of uncertainty in input variable values for the binomial probability risk model and the sensitivity of the predictive capability of the model to the input variables. In Monte Carlo analyses, a large number of scenarios can be evaluated based upon a range of continuous input values for each model parameter. Input values are randomly drawn from each input variable's distribution to generate a value for the model output variable. This process is then repeated multiple times to derive a distribution of values for the output variable.

4.2.2.1 Effects Assessment

There are no Navy/BTAG TRVs for PAHs, and thus potential toxicity due to exposure to PAHs will be discussed in the Uncertainty Evaluation (Section 6.0).

Available data on effects of lead shot in avian resources was discussed in detail in the SLERA (Section 4.1.2.1). For screening purposes, the NOAEL for lead shot derived for use in the SLERA was the minimum NOAEL identified in the literature (one No. 4 shot converted to two No. 7½ shot). However, this value may be an overly conservative estimate of the toxicity threshold for diving ducks in San Francisco Bay. As discussed in Section 4.1.2.1, diet appears to be the single most determining factor in the toxicity of lead shot to waterfowl. The studies from which the SLERA NOAEL were derived (Rattner et al., 1989; Finley et al., 1976b; Mautino and Bell, 1986; and Longcore et al., 1974) were conducted on waterfowl fed diets that may not be representative of the diets consumed by diving ducks in San Francisco Bay. Therefore, as part of the BERA, a distribution of NOAELs was developed that includes NOAELs from studies with diets that are more representative of the diets consumed by diving ducks in San Francisco Bay as presented in Table 4-5. This included studies by Sanderson (2002) and Koranda et al. (1979) that found NOAEL values at higher shot doses (5 and 6 No. 4 shot, respectively) when high quality diets where fed the birds. Because scaups and scoters feeding at Alameda Point are consuming primarily bivalves (grit found during sampling consisted mainly of shell hash confirming the quantity of bivalves available at the site as prey), a NOAEL based on such a diet is appropriate.

The NOAELs identified in these studies were converted to the range of shot sizes found at the Skeet Range at Alameda Point and these values were used to derive the NOAEL distribution for the Monte Carlo analysis. For conservatism, the distribution was generated from the values that were converted to the largest of the shot sizes present at the Skeet Range (i.e., No. 7½ shot).

Because a limited number of studies were available for deriving a NOAEL distribution, the NOAEL was represented in the BERA using a triangular distribution. The minimum value selected for the NOAEL distribution was the screening level value of two No. 7½ shot. The maximum number of shot identified as a NOAEL in a key study was six No. 4 lead shot (Koranda et al., 1979). When converted to No. 7½ shot, the maximum value is 11 lead shot. Because there were several key studies that, when converted to the shot size present at the Skeet Range at Alameda Point, resulted in a NOAEL of three No. 7½ shot, the most likely value for this distribution was assigned a value of three (Figure 4-3).

None of the identified studies provided a comprehensive dataset for evaluating dose-response relationships in diving ducks. Thus, the distribution used to evaluate effects in diving ducks in San Francisco Bay primarily evaluates the uncertainty in measurement and natural variability in the lead shot NOAEL.

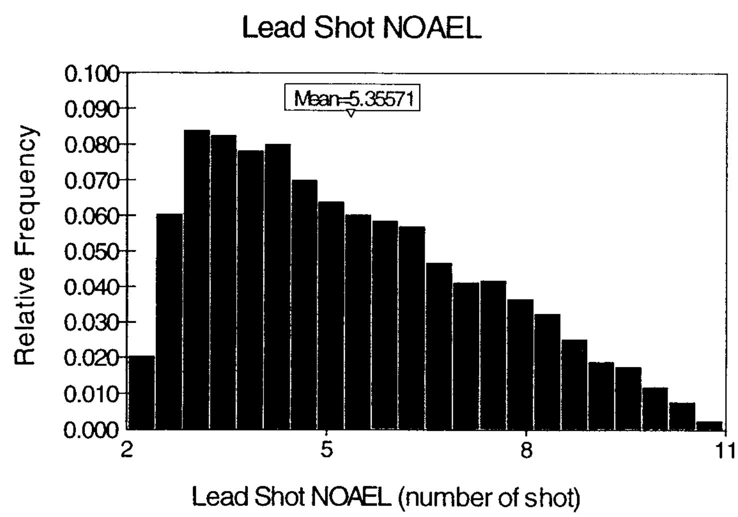


Figure 4-3. Distribution of Lead Shot NOAELs Used in Monte Carlo Analysis

4.2.2.2 Exposure Assessment

Because sufficient toxicity data are not available to quantitatively evaluate risks to diving ducks from PAHs, diving duck exposures to PAHs were not quantitatively assessed in the BERA. The toxicity, exposure and potential for risk to diving ducks from PAHs are discussed in the Uncertainty Analysis (Section 6.0).

Exposure to lead shot by diving ducks was quantitatively evaluated using the binomial probability model developed in the SLERA. In the SLERA, each exposure parameter used in the binomial probability model was defined using an individual conservative point estimate. As part of the BERA, exposure parameter estimates used in the binomial probability model were refined through the development of a statistical distribution for each parameter. The distribution for each exposure parameter represents the uncertainty and/or variability associated with that parameter. The distributions used to refine exposure parameters used in the binomial probability model are presented in Table 4-10 and include the following parameters:

- (*p*): the probability of ingesting a lead shot pellet in a single probe;
- (*g*): the number of dives/day, which is derived by:
  - potential dives/day,
  - foraging time, and
  - proportion of daily dives for grit.
- SUF, which is derived by:
  - site area, and
  - foraging area.
- (*i*) blood lead retention time.

The refinement of these parameters are discussed in the following sections.

Probability of Ingesting Lead Shot in a Single Probe (p)

In the SLERA, the probability of an individual bird ingesting a dose of lead shot that exceeds the NOAEL was calculated for each sampling station, using the maximum reported concentration at each station. Realistically, the maximum concentration is only representative of a discrete location on the site with a majority of the other locations containing much lower concentrations. Moreover, calculation of station- by-station probabilities conservatively assumes that the receptors of concern would be foraging 100% of the time from the same station when visiting the Skeet Range. Scaups and scoters in fact feed over large areas (see Section 4.1.1.1 for a more detailed discussion). As a result, it is more realistic to expect that a receptor will forage over the entire site, rather than spending all of its on-site foraging time at one sampling station. Therefore, to refine the exposure estimate for the Skeet Range, a site-wide estimate of the probability of an individual bird encountering lead shot was generated to account for spatial variation of lead shot found throughout the site using a 95 percent upper confidence limit on the mean (95UCL) of sample location probabilities derived using non-parametric bootstrap methods. By definition, there is a 95 percent probability that the true mean probability (*p*) is equal to or less than the 95UCL probability (p-95UCL).

Table 4-10. MCA Model Input Parameters

Binomial Model Variables		MCA Input Distribution	Distribution	Parameter Values	Reference
n = Number of Trials (Number of probes made in a specified time period) n = g x SUF x i	g = number of dives per day for grit	Foraging Time per Day (proportion)	Triangular	minimum: 0.078, most likely: 0.243, maximum: 0.353	Poulton et al., 2002
		Potential Dives per Day (number of dives/day)	Point Estimate	24 hours x 60 minutes x 2 times a minute	Poulton et al., 2002
		Proportion Daily Dives for grit (proportion)	Triangular	minimum: 0.02, most likely: 0.06, maximum: 0.42	Vermeer, 1981
	i	Blood lead retention time (days)	Triangular	minimum: 20, most likely: 28, maximum: 49	Trost, 1981; Bellrose, 1959; King and Bendell-Young, 2000, Mautino and Bell, 1984
	SUF	Foraging Range (km^2)	Normal	mean: 168.59, st. dev: 193.08; truncated below 0	Takekawa et al., 2001

The algorithms for calculating the p-95UCL are based upon the statistical distribution of the data. The distribution of values of *p* for the individual sampling stations was tested to determine the distribution of the data. The untransformed, arcsine transformed, and log transformed data points were significantly different from a normal distribution ($p<0.05$). The bootstrap resampling method is a non-parametric statistical method. Non-parametric methods require no assumptions about the shape of the data distribution, and therefore, these methods are preferred in cases where the distribution cannot be determined (U.S. EPA, 2002). The bootstrap resampling method involves repeated samples drawn with replacement from the given data set. The process is repeated a large number of times (in this case 5,000 times), and each time an estimate of the desired unknown parameter (e.g., the mean) is computed. The 95UCL is derived from these resampling events (U.S. EPA, 2002). As a result of the normality testing, the bootstrap resampling method was selected to calculate a 95UCL of $p=0.058$ using data collected from the top 10 cm of sediment and $p=0.053$ from the top 5 cm of sediment.

Number of Dives per Day for Grit (g)

The variable *g* in the probability model, number of dives per day for grit, was calculated by multiplying the potential dives per day by the foraging time and the proportion of daily dives for grit. As shown in Table 4-10, the exposure estimate for *g* was refined by developing a statistical distribution to represent two of these three underlying variables.

Foraging Time per Day (proportion)

In the SLERA, foraging time per day was estimated based upon the maximum mean percentage of time that scaups spent feeding at one of five study sites in northern San Francisco Bay (Poulton et al., 2002).

To refine this exposure parameter for the BERA, additional data from this study were used to develop a distribution of foraging time. In their study, Poulton et al. (2002) report mean feeding times for all five study sites, and conclude that at three of the sites considerable time is spent feeding, whereas at two of the sites limited time is spent feeding. These five study site means were used to develop a triangular distribution for this exposure parameter. The maximum value (35.3%) was estimated as the mean of the three most-used feeding areas. The most likely value (24.3%) was estimated as the mean of all five study sites. The minimum value (7.8%) was estimated as the mean of the two areas where minimal feeding took place.

It is important to note that the data presented by Poulton et al. (2002) is summarized as mean feeding time per study site, and the triangular distribution used in the BERA is derived from a range of means. Although this distribution is not derived from the full range of data, the goals of the Monte Carlo analysis presented in this BERA is to generate a refined estimate of risk based on reasonable estimates of long-term exposure. Mean feeding times present an estimate of long-term, average behavior, and therefore, are considered suitable for development of a distribution for this exposure parameter.

The amount of time that ducks spend feeding in a particular location can vary depending on food availability, water depth, and duck preferences. The data presented in Poulton et al. (2002) demonstrate the range of time spent foraging at different sub-sites in the Bay area. Therefore, the triangular distribution for foraging time per day is designed to evaluate the variability in time spent feeding by diving ducks, given site-specific characteristics and duck preferences (Figure 4-4).

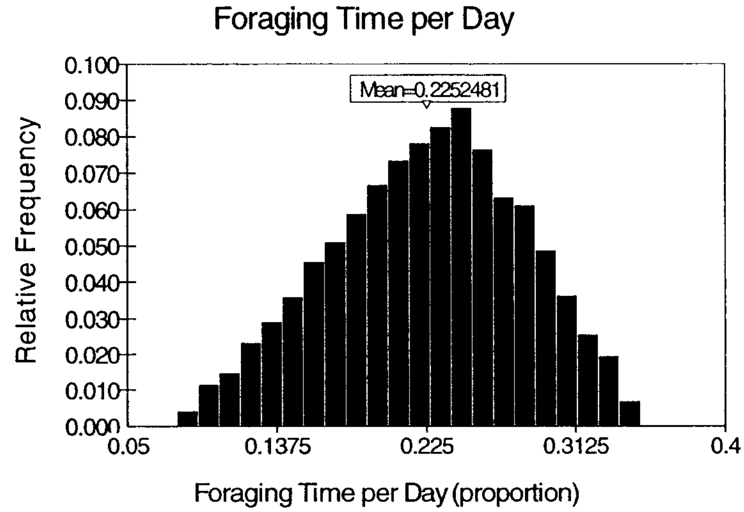


Figure 4-4. Foraging Time Distribution Used in Monte Carlo Analysis

Potential Dives per Day (number of dives/day)

In the SLERA, a point estimate of 2,880 was used to represent the maximum potential dives made by a diving duck in a given day. This value was estimated based on a review of Poulton et al. (2002), which provides dive duration data for scaup in San Francisco Bay. The mean dive durations are 21.6 and 24.7 seconds. Assuming the ducks wait a few seconds before diving again, the estimate of 2 dives per minute used in the preliminary uncertainty analysis was determined to be most appropriate. This model variable was assigned a point estimate of 2,880 potential dives per day (2 dives/min x 60 min/hr x 24 hrs/d). This value also was used to estimate the maximum potential dives per day in the BERA.

Proportion of Daily Dives Used to Collect Grit (proportion)

In the SLERA, the estimate of the proportion of daily dives used to collect grit was the maximum percentage of grit in surf scoter stomach contents reported by Vermeer (1981). As this value represents the highest reported percentage, it is expected to overestimate exposure and risk.

As part of the BERA, the distribution for the proportion of daily dives used to collect grit was determined from the entire set of data summarized by Vermeer (1981). Vermeer (1981) presents the mean percentage grit in stomach contents from surf scoters in British Columbia at eight sites during the spring, summer, and fall over a two year period. Because the distribution is derived from multiple subsets, representing a range of study periods and methods, a comprehensive distribution analysis was not possible. Therefore, a triangular distribution was selected for this parameter.

The parameters for the triangular distribution were selected by taking the minimum, maximum, and observation-weighted mean of the site mean grit percentages presented by Vermeer (1981). The mode of the means (6%) was equivalent to the mean of the one dataset collected over an entire year. This value was selected as the most likely value for the triangular distribution, as it best represents long-term expected value for the proportion of daily dives used by surf scoters to collect grit. This distribution therefore represents the variability in this parameter due to seasonality, as well as other factors that contribute to the amount of grit ingested by diving ducks (Figure 4-5).

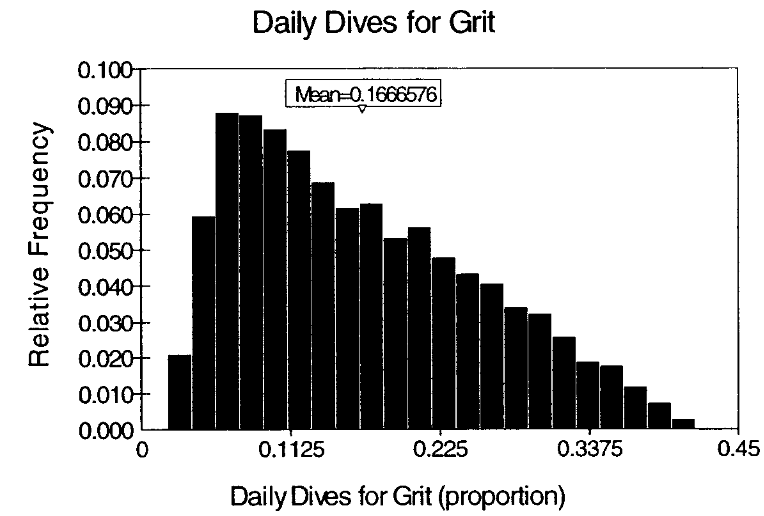


Figure 4-5. Daily Dives for Grit Distribution Used in Monte Carlo Analysis

Site Use Factor

The SLERA evaluated potential risks to diving ducks using a SUF of 1. This SUF assumes that diving ducks use the Skeet Range exclusively to forage for food and grit. Although limited data are available in the literature regarding foraging ranges for these species, this assumption is likely conservative, given the estimates of home ranges for scaups and scoters identified in the literature.

The SUF was refined as part of the BERA. The SUF is calculated by dividing the site area by the foraging range. Therefore, a distribution was developed for the SUF by identifying a distribution for receptor foraging range and dividing this value into the site area. Because the site area is a fixed value, a distribution was only developed for the foraging range.

Site Area (km^2)

The site area is approximately 0.08 km^2. This value was represented in the model using this point estimate.

Foraging Range (km^2)

As discussed in Section 4.1.2.2, limited data are available regarding scoter home or foraging ranges, and no site-specific or regional data are available regarding scoter feeding behavior or ranges. However, for the greater and lesser scaup, recent data collected by the USGS in northern San Francisco Bay are available (Takekawa et al., 2001). Because site-specific data were available for scaups and because differences in feeding behavior suggest that scaups are more likely to come into contact with lead shot in sediment (see Section 4.1.1.4), the USGS data were selected as the most appropriate dataset for defining the distribution for foraging range for diving ducks.

For several years, the USGS has been using radiotelemetry to study the home ranges and foraging depth preferences of greater and lesser scaup in San Francisco Bay (Wainwright-De La Cruz et al., 2001). Takekawa et al. (2001) has calculated home ranges from these data collected on radiotagged scaup during the winters of 1998-99 and 1999-2000. Home ranges were calculated using the kernel method (Wainwright-De La Cruz, 2003). Mean (SD) 95% kernel home range for greater scaup was 258.99 (182.58) km^2 and for lesser scaup was 168.59 (193.08) km^2, values for both study years, both sexes, and all ages combined. This method calculates an animal's "utilization distribution," by mapping and calculating the area in which the animal has a high probability of occurring (95% confidence), based upon high densities of observed activity in those areas (Worton, 1987 and 1989). The kernel method highlights areas of concentrated activity and provides a more refined estimate of home range use than simple polygon methods which define home range by estimating the smallest area that contains all location points and can include internal space that is not used by the animal (Worton, 1987). Figure 4-6 demonstrates the difference in these methods using a generic example and graphically illustrates how the kernel method provides a more conservative estimate of home range use.

Because the kernel method assumes a bivariate normal distribution, this distribution was assigned a normal distribution in the Monte Carlo analysis. Because smaller home ranges provide more conservative (i.e., larger) SUFs, the lesser scaup mean and standard deviation were used to develop the distribution. To avoid non-negative inputs, this distribution was truncated at a value of zero (Figure 4-7). As a result, the distribution is slightly skewed toward lower foraging range values, and higher, more conservative SUFs.

It is recognized that at lower SUFs birds are foraging more in other areas of San Francisco Bay than at Alameda Point. This provides opportunities for birds to be exposed to lead shot at other areas within their foraging range. To evaluate the possibility that lead shot exposure could occur off site, other subtidal skeet ranges within the foraging range of the scaup in San Francisco Bay were identified. Besides the skeet range at Clipper Cove off of Treasure Island, no other subtidal skeet ranges were identified within San Francisco Bay. Because lead shot at Clipper Cove is buried under clean sediment, shot are unavailable to foraging ducks and exposure is expected to be *de minimus*. Thus, the assumption that exposure to lead shot for diving ducks is limited to the Alameda Point skeet range is reasonable.

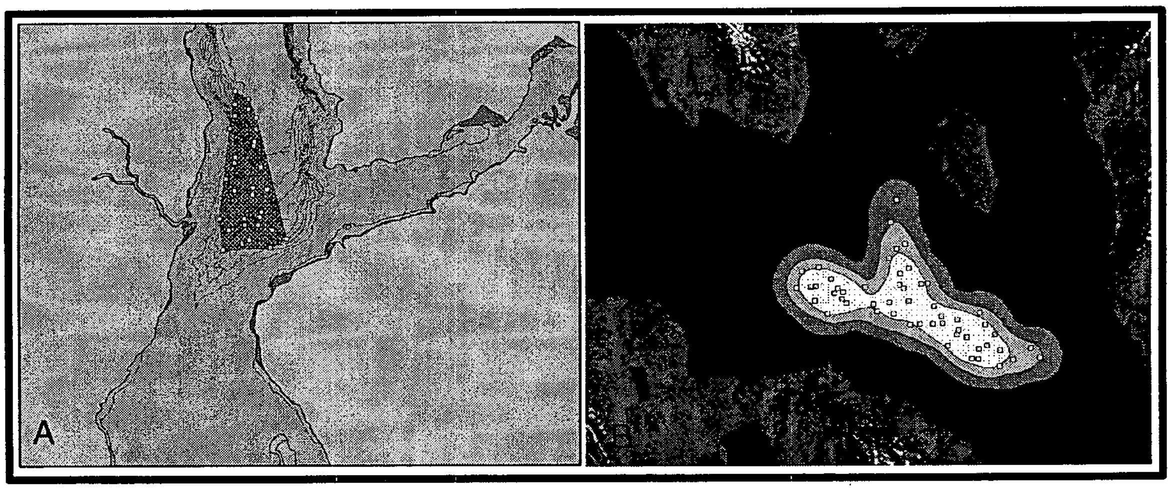


Figure 4-6. Generic Example of Home Range Estimates Developed Using the (A) Minimum Convex Polygon Method and (B) the Kernel Home Range Method

(graphics from P.N. Hooge and B. Eichenlaub, 2000. Animal movement extension to Arcview ver. 2.0. Alaska Science Center – Biological Science Office, U.S. Geological Survey, Anchorage, AK, USA. http://www.absc.usgs.gov/glba/gistools/animmov.ppt)

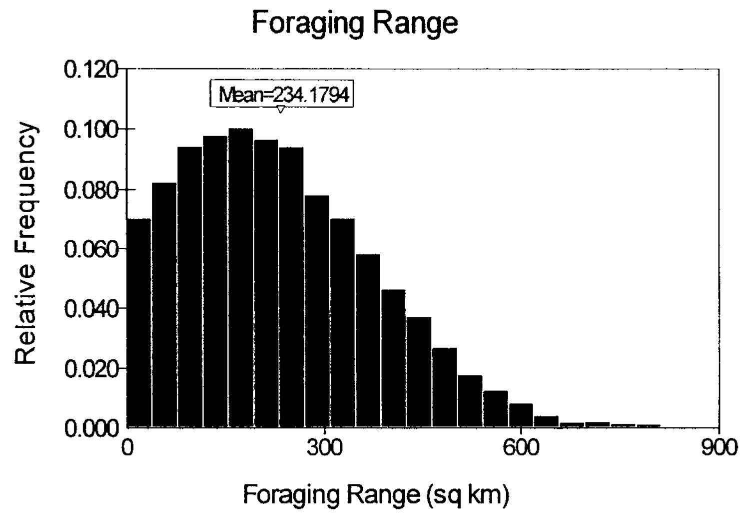


Figure 4-7. Foraging Range Distribution Used in Monte Carlo Analysis

4.2.2.3 Blood Lead Retention Time

In the SLERA, blood lead retention time was estimated as the number of weeks (in days) that it took for blood lead levels to return to control lead levels in a study conducted by Mautino and Bell (1986). Based on this study, seven weeks (49 days) was used as a conservative estimate of blood lead retention time for screening purposes.

In the BERA, the conservative estimate of this parameter was refined by deriving a statistical distribution from data on blood lead retention time and grit retention time in the gizzard as presented in Section 4.1.2.2.

Because lead shot may be eroded and dissolved in the gizzard and absorbed into the bloodstream (Sanderson and Bellrose, 1986; Pain, 1996), the distribution for lead retention time in ducks is primarily derived from the blood lead retention data presented by Mautino and Bell (1986). In this study, concentrations of lead in the blood of ring-necked ducks dosed with one No. 4 shot (equivalent to 2 to 3 No. 7½, 8, or 9 shot) were highest one week after dosing, but then gradually returned to control levels in 4 weeks. The ducks experienced a mild, but significant secondary increase in week 6, before blood lead levels returned to control levels again at 7 weeks. Therefore the maximum value for the parameter distribution was identified as 49 days, and the most likely value was identified as 28 days. Because grit and shot may be voided intact, the true distribution of lead retention time should reflect a minimum value of zero. However, for conservatism, the maximum grit retention time in the gizzard, 20 days (Bellrose, 1959 as cited in Sanderson and Bellrose, 1986; Trost, 1981), was used as an estimate of the minimum parameter for this input distribution.

A comprehensive analysis of the distribution of lead retention times in diving ducks was not possible because data are limited regarding grit and lead shot retention times in the gizzard, blood, and soft tissues, and retention depends on many factors specific to individual bird behavior. Therefore, a triangular distribution was used to describe the variability and uncertainty associated with this exposure parameter (Figure 4-8). Because shot can be theoretically voided intact at any time, including almost immediately following ingestion, the distribution developed here is likely to be a conservative estimator of blood lead retention time and evaluates both uncertainty in measurement and the natural variability in lead retention times in ducks.

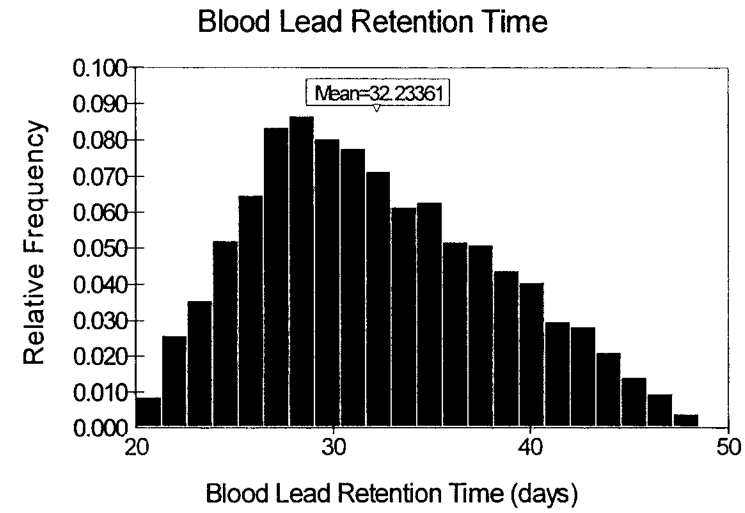


Figure 4-8. Blood Lead Retention Time Distribution Used in the Monte Carlo Assessment

4.2.2.4 Integration of Exposure Parameter Distributions into Binomial Probability Model

The distributions selected for each exposure parameter were combined in the binomial probability model using a Monte Carlo analysis to evaluate uncertainty and variability in inputs and to estimate a distribution of risk probabilities. All input variables were assumed to be independent (i.e., correlation was not specified for the variables in the model). The binomial probability model contains variables which may be correlated, and assumption of independence of variables may affect the resulting output distribution by selecting input values for these variables which are not likely to co-occur in nature. However, there was insufficient data in the literature to determine whether these variables are correlated and if so, to what extent. Although data are unavailable regarding the potential correlation of these variables, each variable's expected value is a long-term average that incorporates temporal fluctuations, and independence was assumed for these variables. The results of the Monte Carlo analysis are discussed in Section 4.2.3.2.

4.2.3 Risk Characterization

Potential risks to diving ducks from exposure to PAHs and lead shot from the former Skeet Range at Alameda Point were evaluated separately. Because avian toxicity data for PAHs are unavailable, potential risks to ducks from PAH exposure is evaluated qualitatively. Potential risks to diving ducks from exposure to lead shot were evaluated quantitatively, using probabilistic methods to evaluate uncertainty in exposure parameter and risk estimates.

4.2.3.1 Characterization of Risk from PAHs

As discussed in the SLERA, the potential for unacceptable risk from exposure to PAHs from clay skeet targets to birds is unknown due to the lack of toxicity and effects data for avian species preventing a quantitative evaluation of risk to benthic-feeding birds from PAH exposure. This will be discussed in more detail in the Uncertainty Evaluation (Section 6.0). However, it is expected that the availability of site-related PAHs from clay skeet targets will be limited by the ubiquitous mat of *Ampelisca* tubes and the recalcitrance of the clay matrix. Additionally, only a few stations have PAH concentrations that exceed ambient concentrations, further supporting a qualitative conclusion that PAHs are unlikely to be significantly contributing to risk at the Skeet Range.

4.2.3.2 *Characterization of Risk from Lead Shot*

The distribution developed as part of the effects assessment was combined with the distributions developed in the exposure assessment in the binomial probability model using Monte Carlo analysis to characterize risk and evaluate the effects of uncertainty and variability in exposure parameter estimates. The simulation used Monte Carlo sampling and the seed for random number generation was picked randomly by the software program. The simulation consisted of 10,000 iterations, to ensure convergence and to achieve sufficient model stability. The Monte Carlo analysis was conducted using @Risk, Version 4.5, Professional Edition (Palisade Corporation, 2001).

The output of the binomial probability model is the risk probability, defined as the probability of a diving duck ingesting greater than the NOAEL number of shot in a specified time period (i.e., the blood lead retention time). Therefore, the output distribution for the Monte Carlo analysis conducted on the model is a distribution of risk probabilities. Each simulation included 10,000 iterations. The result of each simulation (i.e., p-95UCL) is therefore a range of 10,000 calculated individual risk probabilities for each data set (i.e., 0-10 cm depth and 0-5 cm depth).

Monte Carlo analysis simulations were conducted using the 95UCL (p-95UCL) on the mean of the values of p at all sampling stations to represent the input parameter p in the model. The 95UCL was calculated for two sets of data, using data from the top 10 cm of sediment and using data from the top 5 cm of sediment.

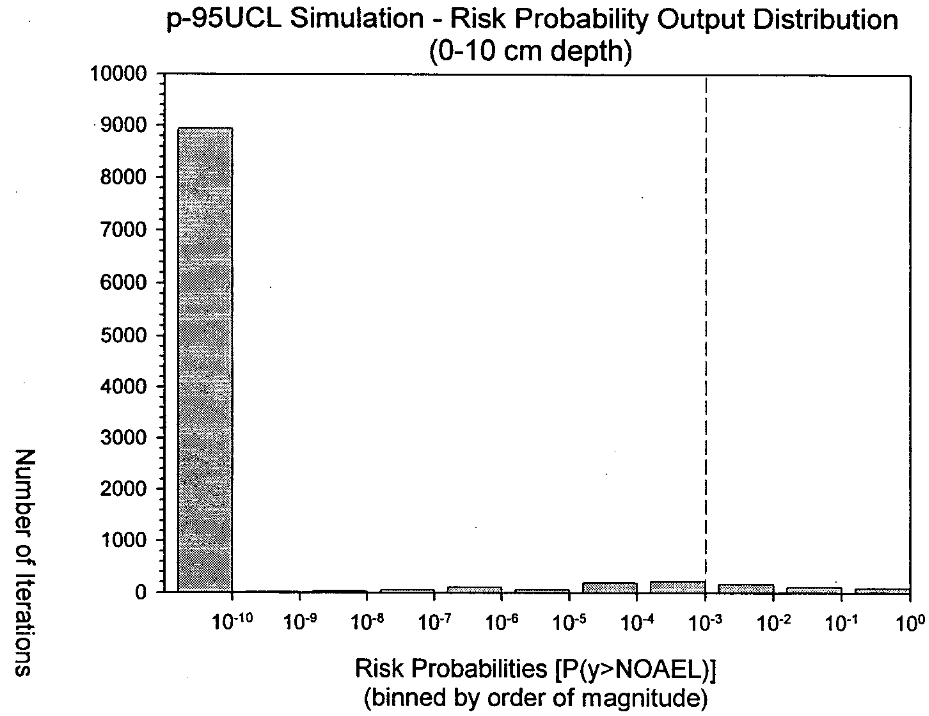
Simulation Results

The model proved to be highly stable, due to the large number of iterations. The distributions of risk probabilities produced by the model had considerable variability, ranging several orders of magnitude, and were strongly skewed toward low probabilities. Histograms summarizing the output distributions are shown in Figure 4-9. These results are discussed in further detail below. Because the results of the simulations were very similar, the results of the more conservative simulation (i.e., p-95UCL for the depth range of 0-10 cm) will be described in text as an example.

Model Stability

The U.S. EPA (2001) defines the numerical stability of a probabilistic model as "the observed numerical changes in parameters of the output distribution (e.g., median, 95th percentile) from a Monte Carlo simulation as the number of iterations increases." As the number of iterations is increased, the stability of the output distributions increases, and the values of distribution parameters change less with additional iterations.

The software used to conduct this analysis (Palisade, 2002) provides convergence monitoring via three primary statistics: the average percent change in distribution percentiles divisible by 5 (e.g., 0%, 5%, 10%, 15%., up to and including 100%), the percent change in the mean, and the percent change in the standard deviation. @RISK calculates these statistics for each output at selected intervals throughout the simulation. These statistics then were compared with the same statistics calculated at the prior interval during the simulation. The amount of change in statistics due to the additional iterations is then calculated. As more iterations are run, the amount of change in the statistics becomes less until they "converge" or change less than a threshold percent set by the user. Although it is crucial to run a sufficient number of iterations to ensure that output distributions and distribution statistics are reliable, there is a point at which the time spent for additional iterations is essentially wasted because the statistics generated are not changing significantly (Palisade, 2002).



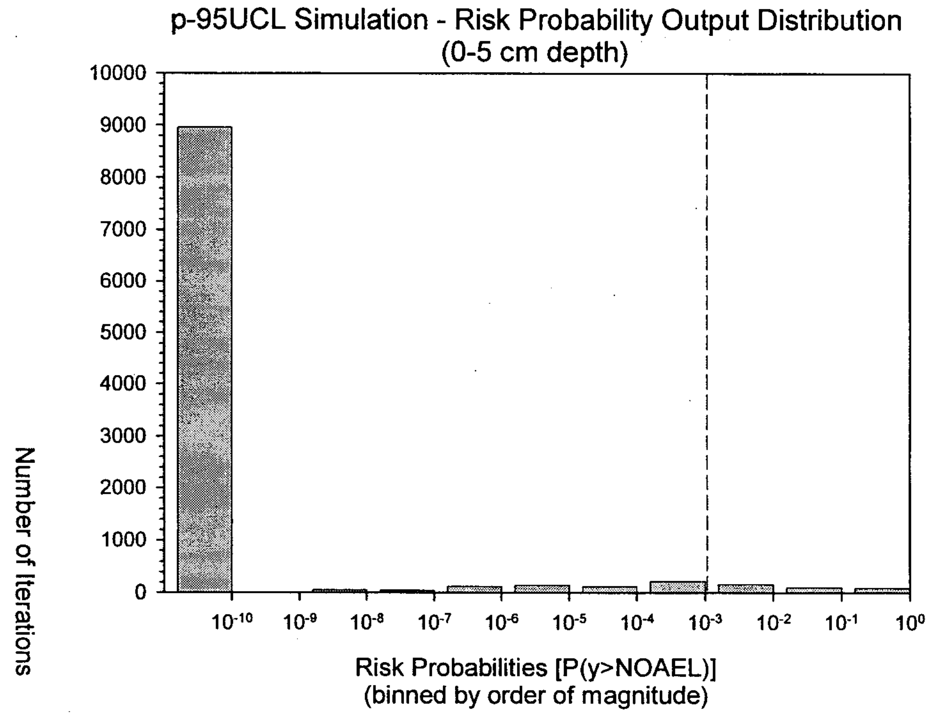


Figure 4-9. Output Distribution of Monte Carlo Analysis

The system was set to monitor these distribution parameter statistics every 100 iterations, and the threshold for convergence was set at 1%. U.S. EPA (2001) suggests that less than 1% change in upper bound percentiles (i.e., 95th percentile for risk estimates) is a sufficient measure of stability, because values in the tails of the distribution typically are less stable than the estimates of central tendency.

The final set of statistics (i.e., between the 9,900th and 10,000th iteration) are shown in Table 4-11. As demonstrated by the statistics, the model proved to be stable, with less than 1% change in parameter values by the end of the simulation. This stability is likely due to the large number of iterations used in the analysis. Additional iterations beyond 10,000 are not considered necessary for confidence in the output distribution statistics for this Monte Carlo analysis.

Table 4-11. Convergence Statistics

Output Distribution	Iterations	% Change In Percentiles	% Change In Mean	% Change In Std Dev
P(y>NOAEL), p-95UCL, 0-10 cm depth	10,000	0%	-0.92%	-0.497%
P(y>NOAEL), p-95UCL, 0-5 cm depth	10,000	0.00%	-0.94%	-0.498%

Output Distributions

The range of individual risk probabilities [i.e., the probability of an individual bird consuming > NOAEL shot, or P(y>r)] predicted by the model in both sets of simulations was zero (0 percent chance of ingesting > NOAEL lead shot) to 1.0 (100 percent chance of ingesting >NOAEL lead shot). However, the distributions of individual risk probabilities were heavily skewed towards zero. For example, approximately 89 percent of the iterations in the p-95UCL simulation that used data collected from 0-10 cm in depth resulted in a risk probability of zero. Output distributions for each simulation are presented in Figure 4-9.

As shown in Figure 4-9, the majority of each distribution consists of risk probabilities less than the population level benchmark probability (1×10^{-3}). For example, the benchmark probability (1×10^{-3}) for the p-95UCL simulation using data collected from 0-10 cm in depth equaled approximately the 96th percentile of the output distribution. Therefore, in approximately 96 percent of the iterations in the p-95UCL analysis, the risk probability did not exceed the population level benchmark probability (1×10^{-3}). In other words, approximately 96 percent of the time, less than 1 in 1,000 birds foraging at the site would potentially be at risk.

The upper tail of the risk probability distribution for the p-95UCL simulation evaluating the upper 10 cm of sediment can be characterized as follows: An additional 1.65 percent of the iterations resulted in a risk probability of between 1×10^{-3} and 1×10^{-2}; 1.08 percent of the iterations resulted in a risk probability between 1×10^{-2} and 1×10^{-1}. Less than one percent (0.94%) of the iterations resulted in a risk probability greater than 0.1. Ten iterations in 10,000 (0.1 percent probability of occurrence) resulted in 100 percent probability that waterfowl would ingest greater than the lead shot NOAEL. Based on these negligible probabilities, adverse population effects are expected to be extremely rare.

Although a small percent of the iterations (i.e., approximately four percent for the p-95UCL simulation for sediment 0-10 cm in depth) result in risk probabilities that suggest a potential for adverse effects in individuals, these extreme values must be considered in the context of model assumptions. Given the conservatism incorporated into the model (i.e., use of blood retention time to estimate *n*, range of NOAELs based on conversion of key study data to largest shot size found on site), the model is anticipated to provide a range of potential risks to waterfowl that represents reasonable, if not upper-bound estimates of risk. Overall, potential effects on the local waterfowl population as a result of incidental ingestion of lead shot are likely to be negligible.

Sensitivity Analysis

A sensitivity analysis also was conducted as part of each Monte Carlo analysis simulation to determine the influence of each input variable on the output probability distribution. Variables that influence the model results strongly (i.e., minor changes in input values result in large fluctuations in model output values) are described as "sensitive" variables. Sensitivity in variables was evaluated by examining the correlation between the magnitude of input values (i.e., exposure parameters) and the corresponding output values (i.e., the risk probabilities).

Correlation coefficients range from 0 to 1 or −1. The higher the correlation coefficient, the more sensitive the model's output is to changes in the parameter's input values. The sign of the coefficient (+ or −) indicates the direction of the effect in the modeled output (i.e., if the sign is negative, as the input variable increases, the model output decreases).

The sensitivity analysis confirmed that the most sensitive variable in the model for each simulation was foraging range. Figure 4-10 presents the correlation coefficients for exposure parameters for which distributions were developed. The length and direction of the bar in each tornado chart demonstrates the sensitivity of the model output to each parameter. For example, foraging range had a moderately high correlation coefficient of -0.487 for the p-95UCL simulation evaluating the top 10 cm of sediment. This correlation coefficient indicates that as foraging range increases, individual bird risk probabilities decrease. The proportion daily dives for grit, the NOAEL, foraging time per day, and blood lead retention time were the next most influential variables, in order of decreasing model sensitivity.

4.2.4 BERA Summary

In the BERA, conservative exposure and toxicity assumptions equating to worst-case exposure scenarios were refined to better describe the exposure scenario at the Skeet Range. Monte Carlo analysis methods were used to evaluate the remaining uncertainty and natural variability in model exposure parameters and characterize the potential for risk to diving ducks at Alameda Point. Based on this refined, yet still conservative assessment, there is very limited potential for unacceptable risk from exposure to lead shot posed to the avian community that may use the site (see Figure 4-9). The results of the Monte Carlo analysis showed that, approximately 96 percent of the time, less than 1 in 1,000 birds foraging at the site would potentially be at risk.

Although exposure to PAHs were not quantitatively evaluated, any potential risks should not be significantly different from prevailing conditions throughout much of San Francisco Bay, given that a majority of the stations had PAH concentrations within ambient concentrations. Additionally, it is unlikely that clay targets are the source of the PAHs measured in the sediment at the site.

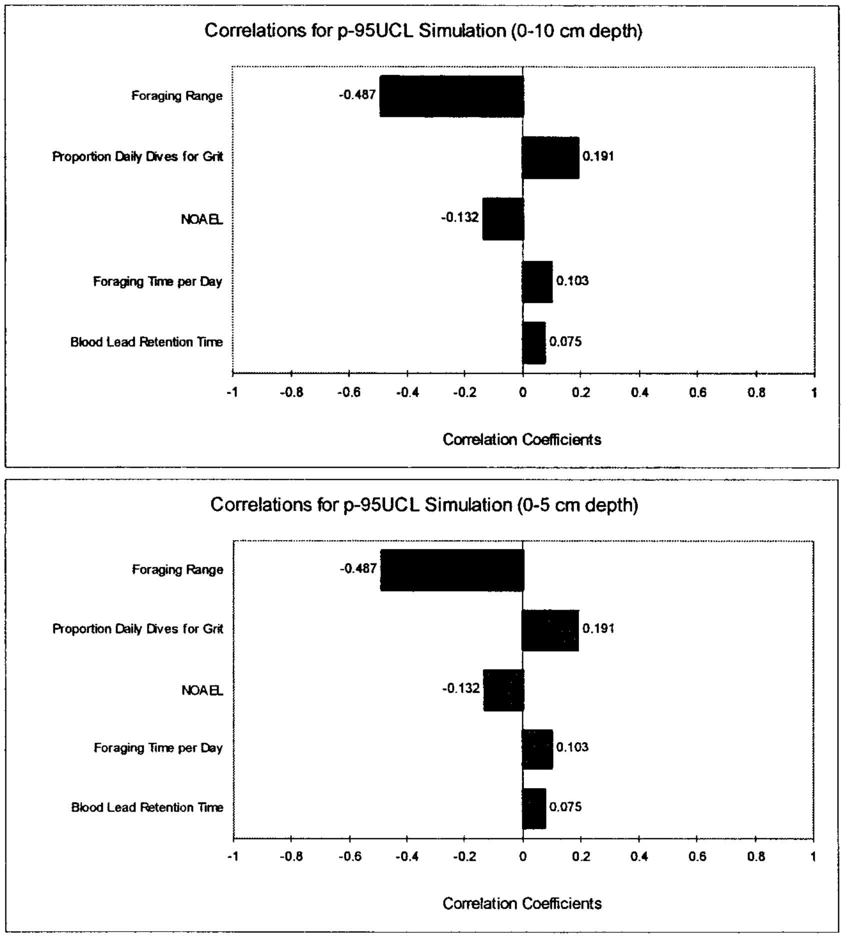


Figure 4-10. Sensitivity Analysis Results

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5.0 HUMAN HEALTH CONCEPTUAL SITE MODEL

This section evaluates the potential exposures of lead shot and PAHs to human receptors by presenting a CSM that defines the conditions of exposure and likely scenarios associated with the Skeet Range. This model represents the sources of contaminants, the means by which they are released and transported within and among media, and the exposure pathways and routes by which they may come into contact with human receptors.

5.1 Sources

As stated in Section 2.0, the only contaminants of concern are PAHs and lead shot measured in sediment that are related to historical activities associated with the Skeet Range. It is evident that the presence of lead shot is associated with the shooting activities involved at the range; however, there appears to be more uncertainty related to the source of PAHs. Although it was originally hypothesized that the source of the PAHs was from leaching of organic binder used in manufacture of clay target fragments, it was found through PAH fingerprinting analysis (Section 3.2) that the majority of the PAHs and TPHs measured in the clay target are chemically different from those found in sediment. In fact, PAH and TPH signatures of the clay targets were not detected in the sediment samples in which they were first encountered, which is further evidence that the organic binder was not a source of the hydrocarbons in sediment. To further investigate the source of PAHs at the Skeet Range, an ancillary analysis was performed following PAH fingerprinting techniques and is presented in Section 7.1. For the remainder of this analysis, the media of contamination is sediment containing PAHs and lead shot.

5.2 Potential Migration Pathways

Lead is introduced into the sediment at the Skeet Range as lead shot with the vast majority remaining in the shot form. However, there is a potential for the shot to become weathered and released into the sediment as lead oxides, sulfides, and lead ions absorbed onto sediment particles. Dissolved lead in the water column or in sediment porewater also can result from dissolution of shot. Generally, in most surface water, the concentration of dissolved lead is minimal, because lead forms compounds with anions with low water solubilities that precipitate out of the water column (ATSDR, 1993). To evaluate if other forms of lead are present at the Skeet Range, the 1996 investigation (TtEMI, 2000) determined the concentration of sorbed lead in sediment and lead dissolved in sediment porewater. As noted in Section 1.1.3.1, it was found that the nonparticulate lead concentrations observed in core sample are consistent with ambient conditions, and that dissolution of lead shot was not considered a significant pathway influencing the biological availability of lead (TtEMI, 2000). The dissolved lead concentrations in sediment porewater were compared to the most conservative AWQC (i.e., for marine life) and were found to be sufficiently below AWQC that the dissolved lead was unlikely to cause adverse effects. Consequently, the only form of lead evaluated in this assessment is lead shot.

Once lead shot is discharged from a firearm, it follows an arc until it impacts either a clay target or deposits into the waters of the Skeet Range. Once in sediment, the lead shot may be reworked due to currents or wave action or buried through accretion. Based on the sediment dynamics study discussed in Section 3.3, the estimated net sediment accumulation rate is between 0.65 and 1.0 cm/yr. However, if the deposition environment was relatively quiescent and undisturbed, then lead shot would not be found in the upper 5-8 cm of sediment 10 years after the shooting range ceased operation. Lead shot concentrations were greatest between 4-20 cm below the surface with majority of the lead shot found in clayey silt (>80% fines) within the fall zone, which suggests that little postdepositional transport has taken place. The horizontal and vertical distribution of shot supports the hypothesis that lead shot has not been transported significant distances and that gradual burial is occurring through sediment resuspension.

To further investigate whether lead shot has migrated beyond the footprint of the Skeet Range, the 2001 investigation (Battelle et al., 2001a) collected cores from Stations SK-66, SK-2, and SK-67 located along the perimeter of the range. No lead shot was found at Stations SK-2 and SK-66, whereas only three lead pellets were sieved at the 15-20 cm depth from Station SK-67. It appears that minimal transport has occurred after the lead shots were deposited into the sediment as suggested by the sediment dynamics study.

It was originally suspected that the source of PAHs was the dissolution of the binding agent used in the manufacture of clay targets. Although no relationship was found between the hydrocarbons present in sediment and clay targets, the potential migration pathways of hydrocarbons in sediment were evaluated. In aquatic environments, PAHs are generally sorbed to suspended sediment or organic matter. When various mixtures of PAHs are present (such as low and high molecular weight PAHs), the fate of these compounds in solution, bound to suspended particulates, and in sediment will vary by phases, but frequently approximately 30 to 35% of the compound will occur in dissolved form (Eisler, 1987). In the absence of penetrating radiation and oxygen, PAHs degrade slowly in aquatic sediment and may persist for long periods of time in anoxic sediment (Eisler, 1987). To determine the nature of PAHs at the Skeet Range, the 1996 investigation (TtEMI, 2000) assessed the concentration of PAHs in sediment and sediment porewater. As discussed in Section 1.1.3.1, no dissolved PAH was detected above analytical detection limits in porewater. The detection limits for these analyses were set equivalent to the acute and chronic national AWQC for protection of marine life and higher trophic level organisms that rely on marine life for food. It was concluded that PAHs are not dissolving at levels that could cause adverse ecological effects and that majority of the PAHs are sorbed to sediment particles.

The findings of the sediment dynamics study indicate that it is unlikely that the PAH-impacted sediments are migrating a significant distance, and that sediment resuspension is gradually burying the surface sediments to limit bioavailability. PAHs were detected at reference stations along the perimeter of the range (Battelle et al., 2001a), which suggests that a PAH source exists that are not associated with the historical site operations. In addition, numerous natural sources of PAHs in the environment may have resulted in the levels being observed at these reference stations (see Section 7.1).

5.3 Potential Receptor Populations

In accordance with U.S. EPA (1989) guidance, both present and reasonably likely future land-use scenarios are considered in order to identify potential receptors and exposure pathways. Potential current and future human receptor populations include:

- On-site Navy worker (current);
- Off-site recreational user (future); and
- Off-site outdoor maintenance worker (future).

Access to the site from onshore is currently restricted along IR Site 1. The entire perimeter of the property is fenced and only visitors accompanied by authorized Navy personnel have access to the site beyond the checkpoint. All of the historical structures related to the shooting ranges have been removed from the property. The sandy beach located on the western boundary of IR Site 1 facing the Skeet Range contains riprap and remnants of former concrete ramp. Access to the site by vessel is limited as there is no usable boat ramp or mooring available.

Future development of the onshore area consists of open space and recreational areas including golf course, baseball diamonds, and soccer fields (ARRA, 1996). Future recreational users of the proposed developed space as well as outdoor maintenance workers maintaining the recreational areas may be present once the ARRA plans are implemented. Risks to future sportsmen through exposure of lead shot via ingestion of waterfowl were not evaluated in this assessment since risks associated with this exposure pathway are not attributable to historical operations at the Skeet Range.

5.4 Potential Exposure Pathways

An exposure pathway defines a probable path by which a receptor may come in contact with contaminated sediment. In order for an exposure pathway to be complete, the following four elements must be present:

- A source and mechanism of chemical release;
- A retention or transport medium;
- A point of receptor contact with the medium; and
- A route of exposure (i.e., dermal contact or ingestion) at the contact point.

If any of these components is missing, then the pathway is incomplete and does not contribute to receptor exposure. The Skeet Range fall zone where majority of the lead shot and PAHs have been detected is located in the sediment between the 4 to 20 cm deep. The adjacent onshore area consists of fill material deposited on coastal mudflats, marshlands and sloughs in the 1930s and 1940s. The majority of the fill material was sediment dredged from San Francisco Bay. The onshore area has relatively flat topography and most of the shoreline is lined with riprap, which contains remnants of concrete ramp. No significant streams, rivers or other surface water bodies discharge into the bay in the vicinity of Skeet Range except for Oakland Inner Harbor directly north of Alameda Point.

The potential exposures associated with historical activities at the Skeet Range are primarily limited to lead shot and PAHs in offshore sediments, located within the fall zone. Due to the offshore location of lead shot and clay targets, direct human exposures are very limited because access to the site is restricted. No unauthorized use of the site for recreational purposes is currently allowed and, consequently, exposures through direct contact (via ingestion, dermal contact, and inhalation) are incomplete. Potential indirect exposures (e.g., fishing, clamming) were similarly incomplete given that these recreational activities are currently not allowed on the property. However, indirect exposures were considered as part of the Western Bayside evaluation (Battelle, 2000a) and based on the results of the risk assessment, it was concluded that Western Bayside was unlikely to pose an increased risks to humans and the environment relative to the rest of San Francisco Bay.

In the future use scenario when the site is developed into an open space and/or recreational park, the riprap along the shoreline will deter access to the beach areas of the Skeet Range. Consequently, direct exposures continue to be incomplete. Indirect exposures via fishing may occur on the property; however, risk associated with ingestion of local catch is a bay-wide issue that has resulted in health advisories on all major waterways in the bay area. Due to the migration of majority of sports fish species found in the bay, it is difficult to quantify the risks attributed to the site versus baywide conditions. Fortunately, no evidence supporting biomagnification of PAHs in aquatic food webs was found by Suedel et al. (1994) and significant bioaccumulation of PAHs by vertebrate species has not been reported in the literature (Hartung, 1995).

In addition, a preliminary screening evaluation (Battelle, 2000a) was conducted on data collected from the Western Bayside which included a full suite of analytes taken along the shoreline of the Skeet Range. Potential human health exposures to sediment-associated contaminants at Western Bayside were assumed to occur through direct contact (e.g., wading or walking along the beach) as well as the consumption of shellfish collected from the site. Four chemicals (i.e., arsenic, benzo(a)pyrene, benzo(g,h,i)perylene, and phenanthrene) were identified as chemicals of concern in intertidal surface sediment, but in the subsequent refined screening, were found to be present at levels that were generally within the range observed in samples from ambient locations in San Francisco Bay.

Given that no current complete exposure pathways exist, and that future development of the Skeet Range will limit access to the shoreline and that the chemical concentrations were consistent with ambient stations, there is minimum potential risk associated with exposure to sediment by recreational users at the Skeet Range. Therefore, further evaluation of potential human health risks associated with the Skeet Range is not warranted.

6.0 UNCERTAINTY ANALYSIS

This section discusses the uncertainty associated with the data and methods used in the RI for the Skeet Range. Uncertainty can be introduced through the use of assumptions in the absence of scientific data or through interpretation of the data itself. This uncertainty analysis will focus on uncertainty associated with analytical chemistry data, lead shot and grit count, and the ecological and human health assessments used to support the RI.

6.1 Uncertainty Associated with Field Data

Sources of uncertainty associated with sediment chemistry, lead shot and grit count, and clay target fragments compositing are presented below, along with the potential influence of these uncertainties on the RI.

6.1.1 Sediment Chemistry

In general, the sediment chemistry data generated for the Skeet Range RI were of high quality, with good sensitivity, and good spatial coverage. The data were reviewed by an independent data validator to reduce the uncertainty associated with the analyses. A few potential uncertainties exist, but overall, the data are adequate to support the RI.

Blank contamination was noted for 2-methylnaphthalene, naphthalene, and phenanthrene at stations SK-6, SK-7, SK-8, SK-9, SK-18, SK-21, SK-22, SK-24, SK-66, and SK-67. A majority of the data was requalified after the independent validation as either nondetect or a positive detection if the laboratory result sufficiently exceeded the maximum amount detected in the blank. Samples collected at Station SK-1 had elevated PAHs (i.e., benzo(a)anthrancene, benzo(a)pyrene, and pyrene) at depths of 70-75 cm and 95-100 cm. The sample was diluted in order to quantify the PAH results at these depths which were one to two orders of magnitude higher than concentrations found at the surface. It is suspected that this station may have been impacted from historical releases from industrial sources in the Oakland Inner Harbor.

6.1.2 Lead Shot and Grit Count

The lead and grit counts were conducted following the protocol described in Section 2.4. In general, the lead and grit counts associated with the core samples were of high quality with minimal error. The cores were of limited volume and consequently, were easily sieved and counted in the laboratory. The grab samples were more difficult to process, as the volume was ten times greater than the volume collected from the cores. Although several different techniques were applied to degrade the *Ampelisca* tubes from the samples, there is a possibility that some of the grit contained in the *Ampelisca* matrix were removed during the decanting process. Because of this, it is likely that the grit measurements may be lower than the number of grit actually contained in the sample.

For grab samples containing more than 200 pieces of grit, the sample was subdivided into equal portions, each containing approximately 100 pieces of grit. It was assumed that each subdivision would contain equal amounts of grit by weight. This method has the potential of overestimating and/or underestimating the actual number of grit contained in each sample. This uncertainty did not occur with the lead shot counts because all lead shot pellets were counted by hand regardless of the quantity.

6.1.3 Clay Fragments Compositing

A total of six composites were made with the inventory of clay target fragments recovered from the Skeet Range. At the time the pieces were composited, a visual inspection of the pieces was performed in an attempt to group pieces found in similar locations and make. As shown in Figure 3-7, several pieces from different locations were grouped inadvertently due to the similar make. In particular, pieces from the surface at southern Station SK-61 were composited with pieces collected from the middle of the range (i.e., SK-31 and SK-18) as well as northern sampling station such as SK-6. In addition, clay targets manufactured using both petroleum-derived and coal tar pitch residue were used at the Skeet Range. In a majority of the cases, similar manufactured target pieces were combined to reduce this uncertainty. As seen in the PAH fingerprinting analysis (Section 3.2), a clear fingerprint of both petroleum and coal-derived targets were found that were matched to the composited fragments to ensure that the compositing was conducted to minimize mixtures of the two residues.

6.2 Uncertainty Associated with Ecological Risk Assessment

The uncertainty inherent in an ERA is an important factor that must be considered in risk-based decision-making. Although it is standard practice to make conservative assumptions in risk assessment where site-specific data is lacking to minimize the potential for underestimating risk, these assumptions are the source of significant uncertainty that must be identified and incorporated into the report conclusions. Several major sources of uncertainty have been identified that affect the interpretation of the risk assessment for the Site. Sources of uncertainty are associated with each step of the risk assessment process are discussed in the following subsections.

6.2.1 Screening Level Ecological Risk Assessment

The SLERA primarily addressed uncertainty by incorporating conservatism into the assessment to over-estimate potential risks. This conservatism was incorporated into the COPEC screening process, the toxicity assessment, and the use of the binomial probability model.

6.2.1.1 COPEC Screening Process

The major source of uncertainty associated with the COPEC screening process is:

- Benchmark selection: In the Tier 1 COPEC screen, ER-L benchmark values were compared to site sediment concentrations. ER-Ls are derived from a compilation of datasets characterized as toxic by the original investigators, and represent the low end of a range of levels at which effects were observed in the compiled studies and values at which toxicity may begin to be observed in sensitive species (Long and Morgan, 1991; Long et al., 1995). However, many of the data used in the development of ER-Ls come from field samples from sites classified as toxic and containing multiple potential toxicants, although these consensus-based values are identified as chemical-specific. As a result, ER-Ls likely overestimate rather than underestimate potential effect levels for many constituents, making the use of ER-Ls for screening purposes very conservative. Although uncertainty is associated with the use of these screening values to eliminate COPECs that likely do not pose unacceptable risk at the site, the screening process likely overestimates rather than underestimates potential for risk.

6.2.1.2 Toxicity Assessment

Selection and development of a no-effect level for use as a benchmark for receptors of concern involves a number of uncertainties, including interspecies extrapolation, appropriate NOAEL selection, exposure duration, and dose conversion. The major sources of uncertainty associated with the toxicity assessment are:

- Lead shot test species: The NOAELs used in this assessment to evaluate risk to receptors of concern are based on the no observed effect levels in test species in laboratory studies. Because no studies were identified that evaluated effects of No. 7½ , 8, or 9 lead shot in the receptors of concern (i.e., greater scaups or surf scoters), a NOAEL was derived from studies that used surrogate species, including mallards, black ducks, and ring-necked ducks. Therefore, the NOAEL represents only an estimate of real effects, and use of a surrogate species for NOAEL development could potentially overestimate or underestimate risk. Each wildlife species has unique characteristics that may make them more or less susceptible to constituent exposure. However, because the mallard is a closely related species to the scaup and the surf scoter and is a member of the benthic feeding guild, the use of a surrogate species in this risk assessment is expected to add minimal uncertainty to the effects assessment.

- Lead shot NOAEL selection: Seven studies were identified (Sanderson, 2002; Koranda et al., 1979; Rattner et al., 1989; Finley et al., 1976b; Mautino and Bell, 1986; Chasko et al., 1984; Longcore et al., 1974) that demonstrated effects of lead toxicity in mallards, black ducks, and ring-necked ducks and from which a NOAEL could be derived. The NOAELs derived from these studies ranged from one to six No. 4 shot, and one study resulted in a NOAEL of two No. 6 shot. The lowest of these NOAELs (one No. 4 shot) was selected for use as the lead shot NOAEL in the SLERA to incorporate conservatism into the risk assessment. Because the lowest value was selected without consideration of important factors that may mitigate toxicity such as diet, use of the lowest NOAEL likely contributes to an overestimation of risk.

- Exposure duration: Diving ducks foraging at the Skeet Range may be exposed to lead shot repeatedly over a number of days. Few toxicity studies were available that addressed the potential for increased toxicity with repeated dosing. Thus it is uncertain whether NOAELs developed on a single dosing regime underestimate potential toxicity to diving ducks.

- Lead shot NOAEL conversion: Uncertainty can be associated with the use of a NOAEL that is derived from a lead shot pellet size (No. 4) other than the pellet sizes found at the Skeet Range (Nos. 7½, 8, and 9). The uncertainty associated with evaluating effects of smaller shot sizes using a larger shot size was limited by converting the NOAEL developed from one No. 4 shot to No. 7½, 8, and 9 lead shot equivalents using a ratio of larger to smaller sphere surface areas ($4\pi r^2$) for the shot sizes. The No. 7½ equivalent (approximately 2 shot) was selected for use as the NOAEL, because it was the most conservative of the three converted values resulting from the larger surface area. As the lead shot used at the Skeet Range also consisted of smaller shot sizes (Nos. 8 and 9), the use of the largest shot size to estimate effects likely contributes to an overestimation of risk.

- Lack of PAH TRV: Navy/BTAG TRVs for PAHs do not exist and sufficient toxicity and effects data for avian species are not available to develop PAH TRVs. Due to metabolic processes, PAHs are generally not considered to have high bioaccumulative potential, but they can be toxic. The toxicity of PAHs tends to increase with increasing molecular weight, especially increasing alkyl substitution. For example, HPAHs are known to be carcinogenic, mutagenic, and teratogenic to a wide variety of organisms, including birds. Uptake and depuration may be critical in determining the long-term biological fate and effects of the chemicals. Although the potential for adverse effects may exist due to exposure to PAHs measured in sediments at the Skeet Range, the probability of such impacts is considered low based on measured concentrations. The majority of the PAHs measured at different stations were within ambient concentrations for San Francisco Bay. Based on the supporting data, ambient concentrations of PAHs in San Francisco Bay are insignificantly impacting bird populations in the bay.

6.2.1.3 Exposure Assessment

The major sources of uncertainty associated with the use of the probability model in the SLERA are:

- Binomial probability model: Risk was estimated at the site using a binomial probability model, with input parameters consisting of field measurements and exposure parameters from the literature. Uncertainty is inherent in using modeled values for exposure and risk, but the associated uncertainty can be minimized by the selection of appropriate input parameters. The use of literature values as opposed to site-specific data introduces uncertainty into the exposure and risk estimates, as these values may not accurately represent site-specific parameters.

- Exposure parameters, including number of probes for grit (*n*), SUF, and fraction of ingested grit in each size class: The input parameter (*n*) is made up of three separate parameters (number of dives per day, SUF, and lead retention time), which were taken from the literature. Because limited data were provided in the literature, the true distribution of values for these three parameters is unknown. To address this uncertainty, a range of estimates was identified for each parameter, and the most conservative value for each parameter was used in the model. The maximum number of dives per day for grit, the maximum SUF, and maximum lead retention time were used to develop *n*.

  The SUF, a component of the calculation for number of probes for grit (*n*), is in fact the most sensitive input parameter to the model. As the value increases, the model is more likely to produce a probability [P(y>r)] of exceeding the population risk threshold. The most time that an individual bird can spend at the site is 100 percent of the time. Therefore, the use of a SUF of 1 (100%) is a conservative estimate of site use. As a result, the maximum SUF likely contributes to an overestimate of exposure and risk.

  The fraction of ingested grit in each size class (*f*) was derived from the literature. Pain (1990) determined the fraction of ingested grit that is greater than or equal to 2.0 mm in diameter (0.18), and the value for the fraction less than 2.0 mm in diameter was derived from this value (0.82) value in an evaluation of *Aythya ferina*. Although *A. ferina* is a closely related species to the scaup and the surf scoter, *A. ferina* may ingest different grit size fractions than the receptors of concern, which could contribute to an overestimation or underestimation of risk. However, the use of a surrogate species for this input parameter is expected to add minimal uncertainty.

  The probability that an individual bird will encounter a lead shot particle within the appropriate size range in a single probe (*p*) was estimated using the abundance of shot in sediment per size fraction (*f*) at each sampling station. Calculation of a risk probability for each sampling station based on a single station *p* assumes that an individual bird will forage exclusively at that particular sampling location. Given the data available in the literature regarding home and foraging ranges, which range from 7 km^2 to more than 200 km^2, the assumption that an individual bird will forage exclusively at a single sampling station overestimates exposure.

6.2.2 Baseline Ecological Risk Assessment

In the BERA, uncertainty was reduced by conducting a probabilistic ecological risk assessment. Conservative model input values used in the SLERA were replaced with statistical or assumed distributions, and the binomial probability model and the resulting output were evaluated using Monte Carlo analysis methods. The uncertainties in the toxicity assessment, exposure assessment, and risk characterization were refined and evaluated as discussed below.

6.2.2.1 Toxicity Assessment

- Lead shot NOAEL selection: Two of the key studies identified in the SLERA (Sanderson, 2002; Koranda et al., 1979) demonstrated effects of diet on lead toxicity in mallards and from which a NOAEL could be derived. These studies are likely the most appropriate studies for developing a lead shot NOAEL, and were used to estimate the maximum NOAEL value in the NOAEL distribution used in the Monte Carlo analysis of the binomial probability model. Koranda et al. (1979) produced a NOAEL of six No. 4 lead shot, but no LOAEL was determined in this study (Koranda et al., 1979). Sanderson (2002) produced a NOAEL of five No. 4 lead shot, and a LOAEL value could not be determined from this study, as well. Because these NOAELs are unbounded (i.e., these results are not associated with an effects level), using either of these values is a conservative approach because it is unknown at what level adverse effects will be seen.. In this case, the higher number from the two studies (six No. 4 shot, or 11 No. 7½ shot) was selected for use as the maximum NOAEL (Koranda et al., 1979). Because the diet in the Koranda et al. (1979) and Sanderson (2002) studies consisted of similar protein and calcium levels as the expected diet of scaups and scoters feeding in the winter at Alameda Point, the uncertainty associated with use of these studies to bound the distribution of NOAELs is considered to be low.

6.2.2.2 Exposure Assessment

- Exposure parameters, including number of probes for grit (n), SUF, and fraction of ingested grit in each size class: The conservative values used in the SLERA were refined in the BERA, by developing distributions of each parameter that represent the uncertainty or variability in that parameter. Because limited data were provided in the literature, the true distributions of values for these input parameters are unknown. However, the uncertainty associated with the bounds of these distributions, the minimum and maximum values, is considered low.

  The input parameter (n) is made up of three separate parameters (number of dives per day, SUF, and blood lead retention time), which were taken from the literature. Minimum, most likely, and maximum values were extracted from the literature for the foraging time per day, proportion of daily dives used to collect grit, and blood lead retention time. Because the binomial probability model requires an input for the value of n that is equal to or greater than the value of r (the NOAEL), the value of r was used for estimates of n that were calculated to be less than the value of r. As a result, scenarios that result in low values of calculated n which are less than r actually overestimate risk because the value used for n (the value of r) is higher than the calculated n value.

  Foraging range, a component of the calculation for SUF and consequently for number of probes for grit (n), is in fact the most sensitive input parameter to the model, as demonstrated in the BERA sensitivity analysis. As the size of the foraging range decreases, the model is more likely to produce a probability [P(y>r)] that exceeds the population risk threshold (1×10^{-3}). The distribution for foraging range in the BERA is based upon site-specific (bay area) and receptor-specific (lesser scaup) data. Although these data were collected in San Pablo Bay and it is unknown whether environmental conditions there are exactly comparable to Central Bay conditions, the level of uncertainty with this distribution is considered low.

In addition, there are limited data in the literature regarding lead toxicokinetics in waterfowl. The literature suggests that some amount of lead ingested as lead shot may be dissolved, absorbed into the bloodstream, and circulated to tissues. A limited number of studies related blood lead levels to ingested lead shot, and only one study evaluated the retention time for lead in the blood and tissues of waterfowl. The SLERA assumed an exposure timeframe (i.e., *n*, the number of trials, estimated as the retention time of lead in the body) equal to the maximum reported amount of time lead shot spent in the bloodstream. In the BERA this value was refined, by using the maximum amount of time lead shot may spend in the gizzard (20 days) as the minimum amount of time that lead may spend in an individual bird's system. Because lead shot may be voided intact as quickly as it is ingested, this range of values) from 20 to 49 days) likely contributes to an overestimate of risk.

- Calculation of the 95UCL probability (p): To address some of the uncertainty associated with using the mean or the spatially weighted average probability (p), the p-95UCL also was calculated, and separate analyses were conducted on this p estimate. The 95UCL is used in risk assessments conducted at Superfund and hazardous waste sites as a conservative, upper-bound estimate of the concentration likely to be contacted over time (U.S. EPA, 1989 and 1992). By definition, there is a 95 percent chance that the true mean, or average, probability of an individual bird encountering a lead shot pellet in Skeet Range sediments, is less than or equal to the 95UCL. Therefore, there is a low amount of uncertainty associated with this point estimate used in the Monte Carlo analysis. Because this is an upper-bound estimate of p, this value contributes to an overestimation of risk.

6.2.2.3 Risk Characterization

An uncertainty analysis was conducted as part of the BERA using Monte Carlo assessment methods. The Monte Carlo analysis was designed to characterize and evaluate the effects of uncertainty and variability in model input parameters on the interpretation and characterization of risks to diving ducks from lead shot at the Skeet Range at Alameda Point.

- Limited data were available in the literature for describing several input parameter distributions. Where the shape of the input parameter distribution could not be determined conclusively, triangular distributions were used, in accordance with U.S. EPA (2002) guidance. Therefore, uncertainty and variability in input parameter values was reduced, but not eliminated. To address the remaining uncertainty for these variables, conservative estimates were used for minimum and maximum values used to estimate triangular distributions, and for conservatism, most likely values were skewed toward the low end of the distributions. By incorporating conservatism into the selection of distributions for input parameters, risk is likely overestimated in the BERA.

- Although local data and distribution shape information were not available for the majority of variables, the results of the sensitivity analysis show that the most influential variable in the model is foraging range, the best characterized value. The distribution for this parameter is based upon site-specific and species-specific data, and therefore, uncertainty is limited for this key model variable.

- In the SLERA, the NOAEL was conservatively estimated by using the minimum NOAEL identified in the literature. In the BERA, the range of NOAEL values for the largest size shot present at the Skeet Range (2 to 11 shot) was used for the NOAEL variable, and the most likely value was set at the low end of the range (3 shot). Therefore, although uncertainty associated with using the minimum reported NOAEL was reduced, it was not eliminated. However, the range of values still represents considerable conservatism in the model. The range of NOAELs represents primarily unbounded no effect levels. Moreover, these values were based upon a larger shot size than present at the Skeet Range, which was converted to the largest size present at Alameda Point (No. 7½). Therefore, although the uncertainty and variability in the NOAEL was reduced by incorporation of a range of values into the quantitative risk assessment, the assessment of toxicity still contains a substantial measure of conservatism.

In this analysis, uncertainty in model variables primarily contributes to an overestimation of risk. The least uncertainty is associated with the most sensitive model variable; the distribution for this variable was estimated using site-specific and receptor-specific data. Therefore, the results of the BERA demonstrate that, by refining inputs to the binomial probability model, uncertainty and variability in exposure can be reduced while generating reasonably conservative estimates of exposure and risk; thus, due to the use of refined, yet conservative, estimates of exposure and toxicity, there is low potential for risk to waterfowl from lead shot at the Skeet Range.

6.3 Uncertainty Related to the Human Health CSM

The sources of uncertainty associated with the human health CSM and the potential biases in the findings are presented in this section. Qualitative discussion of the sources, potential migration pathways, potential receptors, and exposure pathways are based on the current understanding of the proposed future land use, accessibility of the site, and possible exposure scenarios. All of the findings are related to the assumptions put forth in the CSM and consequently, the uncertainties associated with each of these assumptions are discussed below.

- The source of the lead shot is very well characterized and is known to be associated with the historical operation of the site. However, the PAH concentrations were found to unrelated to the clay target fragments. A second, ancillary analysis was performed as presented in Section 7.1, which further investigates the sources of PAHs at the Skeet Range. The findings from this study indicate that the PAH levels are consistent with ambient levels and likely the result from a mixture of environmental factors including historical fires and releases from the historical former manufacturing gas plant. No additional source or release of PAHs is currently known to be occurring at Alameda Point that may potentially impact the Skeet Range. The evaluation of PAHs in the CSM is conservative.

- Based on the 2001 field investigations, it appears that lead shot has not migrated beyond the footprint of the original high impact fallout zone. Although lead shot was found in approximately 50% of the surface samples collected from the site, higher lead shot densities were found in the subsurface as compared to the surface in the core samples. It is difficult to draw a conclusion without additional cores from the high density area, but from the data provided, it appears that gradual sedimentation has buried a majority of the lead shot with occasional resuspension. Some uncertainty exists regarding the findings from the sediment dynamics study, which are further discussed in Appendix C.

- The CSM was developed based on assumed current and future land use of the Skeet Range. Current restrictions to the site are in place for the safety of the general public; however, this does not deter potential trespassers from visiting the site. Generally, this is unlikely given that the area is barren with little vegetation and no shelter available. This CSM also does not address potential exposure pathways and receptors beyond the proposed open space usage of the site.

7.0 SUMMARY AND CONCLUSIONS

This section summarizes the major findings of the Skeet Range RI and provides conclusions regarding potential remedial actions at the Skeet Range.

7.1 Summary

The Skeet Range RI presents the current understanding of the sources of contamination, the nature and extent of sediment contamination based on recent field investigation, and the methods and results of the ecological risk assessment and human health conceptual site model. All of these elements were combined to determine whether the site poses a potential health threat to human health and the environment, requiring evaluation in a FS of remedial alternatives. The Skeet Range was historically developed offshore as two active shooting ranges (northern and southern) for approximately 30 to 40 years until its closure in 1993. A majority of the lead shot located in the Skeet Range sediment occurs at approximately 5 to 10 ft below mean low water. Petroleum pitch binding agents were used in the manufacture of clay targets and are the suspected source of PAHs found in sediment. Based on the historical practices that occurred at the Skeet Range, lead shot and PAHs appear to be the primary contaminants attributable to historical Skeet Range activities.

Data collected from the recent 2001 field investigation were used in the ecological risk assessment and human health CSM to determine potential adverse health effects associated with exposure to lead shot and PAHs found in sediment. The findings from the assessments were used to determine whether any area at the Skeet Range poses an unacceptable risk that warrants evaluation of remedial alternatives. The following sections present a summary of the findings presented in the RI.

7.1.1 Source of Contaminants

One of the objectives of the 2001 investigation was to collect appropriate data to determine if the PAHs measured in sediment are associated with clay targets and determine the accretion rate to evaluate if lead shot is available for uptake by diving birds. The results of both studies are detailed in Appendices B and D of this report.

7.1.1.1 PAH Fingerprinting

Twenty-five (25) cores were collected at the Skeet Range and analyzed for TPH-DRO and for 43 alkylated and nonalkylated PAHs for the forensic investigation. In addition to the cores, clay target fragments were hand-collected to establish the PAH signature unique to targets. The chemical analysis of the target fragments identified both a unique coal pitch tar derivative and petroleum-derived residues used in the manufacture of clay targets. The chemical compositions of sediment and fragment samples were evaluated using PCA. The primary objective of the PCAs conducted for this study was to aid in the classification of PAH in sediment and clay target fragments according to their chemical similarities or differences, without any preclassification as to their nature/source(s).

The PCAs revealed that nearly all of the sediment samples were chemically distinct from the chemical composition of clay target fragments. The total extractable hydrocarbon and PAH fingerprints of the clay target fragments were not detected in the sediment samples from which they were most closely associated. This result suggests that the abrasions or leaching of any organic binder from clay fragments was not the source of hydrocarbons, including PAHs, in the sediments. A second, ancillary analysis was conducted following the PAH fingerprinting techniques to determine the source of PAHs. Measurements of parent and alkylated PAHs were gathered from two studies of San Francisco Bay sediments for comparison purposes with the Skeet Range. Study 1 identified and monitored six background locations for one to three sampling events between 1998 and 2000 (Battelle, 2002b). Study 2 traced the hydrocarbon signature of a former manufactured gas plant (FMGP) from the landside source into the distant sediment (Battelle, 2000b). The samples from Study 2 are included, because the close proximity of IR Site 25 and its potential influence on the local sediments around Alameda Point. Average concentrations were calculated for each background sampling location (Study 1) or similar sample group (Study 2) in order to simplify the graphical comparison of background and Skeet Range samples. The use of average concentrations was validated by repeating the analyses demonstrated in the PAH fingerprinting study (Section 3.2) on individual sample measurements and deriving identical conclusions.

The average concentration was calculated for the background samples collected in Study 2. These included:

Background Location	Single Sample Collected by Year
Island #1	1999, 2000
Marconi Cove	1999
North Site	1999, 2000
Paradise Cove	1998, 1999, 2000
South Site	1999, 2000
Tubbs Island	1999, 2000

Likewise, the grouping of similar samples from Study 2 was based on detailed chemical signatures generated from high-resolution hydrocarbon fingerprints, parent and alkylated PAH concentrations, and triterpane biomarker patterns. For the purposes of this report, these groupings were assigned as follows:

Group	Samples
IR Site 25 Tar	122-S25-135, 122-S25-136
IR Site 25 Sediments + Tar	122-S25-123, 122-S25-124, 122-S25-130, 122-S25-131, 122-S25-113, and 122-S25-118
IR Site 25 Sediments + Trace Tar	122-S25-114, 122-S25-119

The PAH composition indicates three primary source signatures among these collective background samples (Figure 7-1). First, background PAH levels in San Francisco Bay are relatively consistent over a broad geographical area as represented by the average North Site sample (Figure 7-1A). This pyrogenic pattern is dominated by fluoranthene/pyrenes flanked by approximately equal amounts of phenanthrenes/ anthracenes and benz(a)anthracenes/chrysenes. The ratio of benzo(b)fluoranthene to benzo(k)fluoranthene ranged from approximately 3.4 to 4.2 for all of the Study 1 background samples. Second, the Marconi Cove sediment differed from all background samples with its petrogenic 2- and 3-ring PAHs (Figure 7-1B). This signature suggests the overprinting of background sediments with a petroleum material, such as crude oil or middle distillate. Third, trace level tar sourced to a FMGP near the Skeet Range resembled the general background signature in North Site with a slight enrichment of 4- to 6-ring PAHs (Figure 7-1C). In this sample, the parent PAHs are more abundant than the alkylated homologues relative to the North Site sample, and the ratio of benzo(b)fluoranthene to benzo(k)fluoranthene ranged from 0.8 to 1.1 with increasing distance from the FMGP site. The increasing ratio was attributed to mixing with sediments like North Site described above (approximate ratio of benzo(b)fluoranthene to benzo(k)fluoranthene = 3.5).

The PCA loading factors described in Section 3.2 were used to compare the Skeet Range samples to the background samples described in Studies 1 and 2. In addition to the background samples, PAH ratios generated from a newly purchased clay pigeon (Winchester clay target) also were included in the PCA.

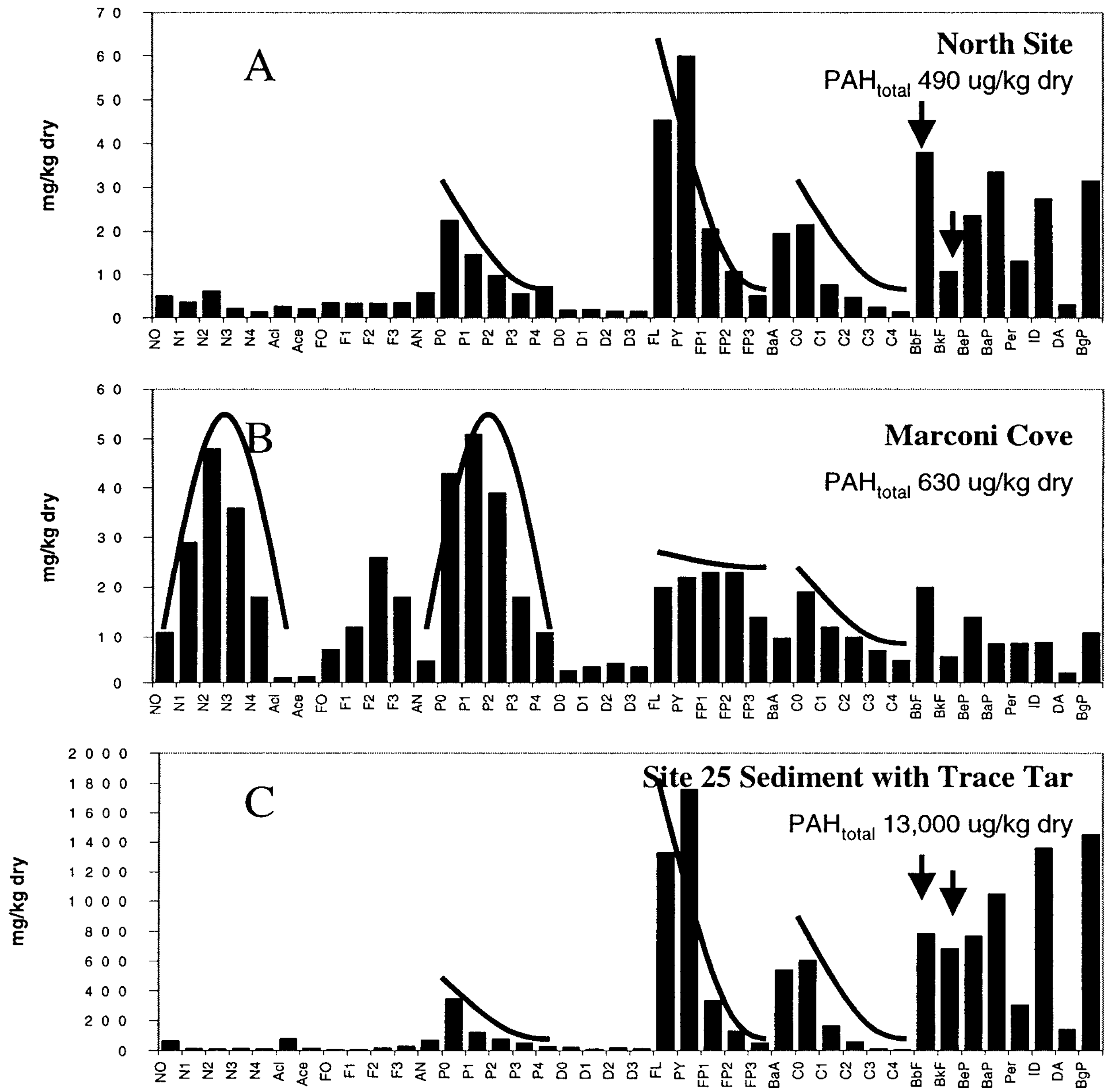

Figure 7-1. PAH Histograms of Selected Samples from Background PAH Studies in the San Francisco Bay Area. Average concentrations are reported for sample locations that were monitored for multiple years. (A) Most of the background samples resemble the North Site. (B) The Marconi Cove sediment exhibits a mixture of petrogenic 2- and 3-ring PAH and pyrogenic 4- to 6-ring PAH characteristic of local petroleum releases imprinted on background sediments like North Site. (C) Proximate sediments from Site 25 more closely resemble samples collected near the Skeet Range.

In general, this PCA describes many compositional features of the San Francisco Bay sediments. First, the Study 1 background samples cluster, indicating a similar composition (Figure 7-1) with one exception. The Marconi Cove sample contains a 2- to 3-ring petrogenic signature not present in the other background samples as discussed previously; hence, its far distance from the other background samples. The Winchester clay target sample is located near a pigeon fragment (F-SK30-0 [i.e., AAE-596-B/C]) with a similar (not identical) residual petroleum binder. The IR Site 25 samples approach the Skeet

Range cluster with descending concentration and increasing distance from the FMGP site. Simultaneously, the total PAH concentration trend among the Skeet Range sediments increases and intersects the sediments with trace FMGP tar. It is significant that the surficial Skeet Range sediment samples do not trend towards any of the clay pigeon fragments. It would be expected that sediments containing higher concentrations of total PAHs correspond to areas containing fragment samples if the local source of PAHs were fragmented or abraded clay pigeons.

In summary, the PCA results indicate that the Skeet Range sediments are likely a mixture of San Francisco Bay background sediment and trace level FMGP tar. The signature of the pyrogenic skeet fragments is similar, but chemically distinct from the ambient sediments from which they were recovered. As previously noted, composite samples, like Z037 and Z038, appear to be mixtures of skeet fragments with a petroleum binder and asphaltic particles. Finally, samples from the deepest depths of the SK-1 core (70-100 cm) exhibit a weathered lower temperature pyrogenic signature, possibly generated by historical fire.

7.1.1.2 Sediment Dynamics

Three sediment cores were collected and analyzed for radioisotopes Pb-210 and Cs-137 to estimate sediment accumulation rates. The use of radioisotope profiling is further described in Appendix C. The objective of the study was to determine the amount of Pb-210 formed by the radioactive decay of its gaseous parent, Rn-222. Using a half-life of Pb-210 of 22.3 years, the accretion rate can be estimated by determining decrease of Pb-210 activity with depth until it reaches supported Pb-210 level. However, mixing or disturbance of the sediment column by organisms and other processes will disrupt the smooth profile and reduce the accuracy of the estimated dates and sediment accumulation rates.

None of the cores were ideal for application of the Pb-210 dating method because the profiles were disrupted to various degrees. Based on the data for Core SK-1, an estimated average sediment accumulation rate of 0.9 cm/yr was calculated. The Cs-137 profiles in Cores SK-1 and SK-3 indicated an average sediment accumulation rate between 0.65 and 1.0 cm/yr based on the depth of the first appearance of Cs-137. The presence of Cs-137 to a depth of >1 m in Core SK-2 implies a sediment accumulation rate of >2 cm/yr; however, this could not be verified with Pb-210 due to the increased activity of Pb-210 with depth in Core SK-2.

The major source of sediment to the area is most likely suspended sediment that is deposited when tidal velocities decrease. Some of this suspended material may originate from dredging operations at the Port of Oakland and Alameda. As previously noted, no significant surface water bodies enter San Francisco Bay in the vicinity of the Skeet Range, and little material is likely to erode from the low-lying, armored shoreline.

Information on site characteristics and estimated sediment accumulation rates were used to qualitatively evaluate the potential for erosion and exposure of lead shot at the Skeet Range. The Skeet Range operated for 30 to 40 years, and the estimated net sediment accumulation rate is estimated to be between 0.65 and 1.0 cm/yr. The horizontal and vertical distribution of shot supports the hypothesis that lead shot has not been transported significant distances and that gradual burial is occurring. However, the shallow depth and exposed location of the fall zone and less than ideal radioisotope profiles indicate that episodic sediment resuspension and disturbance occur in the Skeet Range offshore area.

7.1.2 Ecological Risk Assessment

To evaluate potential risks to ecological receptors, a tiered process was used that encompasses the eight steps consistent with the U.S. EPA and Navy guidelines. In the first tier, a SLERA was conducted which included a development of the CSM, identification of COPECs, and screening-level dose assessment using conservative assumptions. If the risk probabilities exceeded the acceptable threshold, then the exposure assumptions were refined further in the BERA. Risks then were characterized for each receptor of concern.

7.1.2.1 SLERA

A SLERA initially was conducted to develop a preliminary CSM, identify COPECs, and determine dose estimates using conservative assumptions. Based on the historical use of the area for Skeet Range shooting, lead shot and PAHs from clay targets were identified as preliminary COPECs. The primary release mechanism and exposure route is through direct exposure to lead shot and PAHs. Benthic-feeding avian species, specifically diving ducks, possess the greatest potential for significant exposure to Skeet Range COPECs through incidental ingestion of sediment-borne lead shot or PAH-containing clay target fragments. Using the avian species as the AE would provide sufficient health-protection to lesser-exposed guilds.

The selected AE and their associated MEs are as follows:

AE-1: Protection of the benthic-feeding avian community at the former Skeet Range

ME-1: Estimated probabilities of a benthic-feeding bird foraging at the site ingesting a sufficient dose of lead shot to exceed levels in the literature that produce toxic effects.

ME-2: Comparison of risk probabilities of benthic feeding birds to a risk-based population threshold indicating effects observed at a population level.

ME-3: Evaluation of the likelihood of exposure by benthic-feeding birds to PAHs at levels that elicit toxic effects.

Benthic-feeding birds (e.g., scaups and scoters) were identified as the receptors of concern at the Skeet Range because their life histories suggest that, during foraging, these receptors may ingest lead shot within the grit size range either inadvertently or intentionally selected for use as grit. In order to evaluate potential effects associated with exposure to lead shot, TRVs were developed based on literature review of research conducted on the toxicity of lead shot ingested by water-fowl. Section 4.1.2.1 presents a summary of the lead shot toxicity studies that were reviewed. Although a wide range of NOAELs were identified based on these toxicity studies, due to the conservative nature of the SLERA, a NOAEL of five No. 4 shot was developed. The lead shot pellets used in the Skeet Range were in the No. 7½ to 9 class range. Based on the size and relative surface area of shot in this range versus that reported in the literature, an approximate equivalent NOAEL for the SLERA was developed, which conservatively converts to approximately 2 lead pellets in the No. 7½, 8, and 9 class ranges. No TRVs were developed for PAHs due to lack of toxicity and effects data for avian species.

To assess the potential for exposure to lead shot, the probability that a bird may ingest a lead shot within the grit size range while foraging for grit was estimated. Based on studies conducted with captive mallard, canvas backs, and scaups, it was found that these birds ingest lead shot as grit for grinding food in their gizzard. A site-specific probability model was developed to estimate the likelihood that a bird may ingest either grit or lead shot within the grit size range at every attempt. The model accounts for the amount of grit required by the bird, the amount of time per day the bird forages for grit at the Skeet Range as compared to other locations (e.g., SUF), and the amount of time grit is retained in the gizzard. A detailed discussion of the model is presented in Section 4.1.2.2.

Using the field-collected data to estimate the abundance of lead shot by area and ranges of values for SUF, amount of grit ingested, grit/shot retention time, the model was run to estimate the probability that an individual bird will ingest the NOAEL daily dose of lead shot at the Alameda Point Skeet Range. Conservative inputs were chosen for all exposure parameters including the assumption that diving ducks spend 100% of their time at each station (SUF=1). Using conservative assumptions and maximum exposure parameters, SLERA results indicate that risk probabilities for ingestion of lead shot exceed population level thresholds at approximately half the sampling stations at the site. Because of the conservatism inherent in the SLERA, a finding of risk does not mean that risk is present, just that additional evaluation is necessary; therefore, refined estimates of site-wide exposure are needed to better characterize potential risks to diving ducks at the site. Further refinement of the model and the conservative input parameters were considered in the BERA.

7.1.2.2 BERA

The goal of the BERA was to use protective assumptions to refine the list of COPECS by focusing on only those constituents that pose an unacceptable risk. These refinements include statistical comparison of constituent concentrations to background levels. Because lead shot is not naturally occurring, lead shot was retained as a COPEC. Distribution shift tests were conducted to statistically compare site data to distribution of ambient concentrations in San Francisco Bay. The distribution shift test results indicated that all analytes failed at least one distribution test and, therefore, were carried forward in the BERA for risk characterization (Table 4-9).

To address the (1) uncertainty associated with the exposure and effects parameters used to estimate risk in the SLERA, and (2) the conservatism in the SLERA that resulted in a worst-case estimate of risk that has a negligible chance of occurring, a refinement to these parameters was conducted in the BERA. To aid in this refinement, a Monte Carlo analysis was conducted to evaluate the effects of uncertainty in input variable values for the binomial probability risk model and the sensitivity of the predictive capability of the model to the input variables. For the analysis, a larger number of scenarios can be evaluated based upon a range of continuous input values for each model parameter. Input values are randomly drawn from each input variable's distribution to generate a value for the model output variable. This process is then repeated multiple times to derive a distribution of values for the output variable.

Distributions were developed for the NOAEL and the input parameters to the binomial probability model. A site-wide estimate of the probability of an individual bird encountering lead shot also was generated to account for spatial variation of lead shot found throughout the site using a 95 percent upper confidence limit (95UCL) on the mean of sample location probabilities.

Monte Carlo analysis methods were used to evaluate the remaining uncertainty and natural variability in model exposure parameters and characterize the potential for risk to diving ducks at Alameda Point. Based on this refined, yet still conservative assessment, there is very limited potential for unacceptable risk from exposure to lead shot posed to the avian community that may use the site. The results of the analysis showed that, approximately 96 percent of the time, less than 1 in 1,000 birds foraging at the site would potentially be at risk. Exposure of diving ducks to lead shot may even be more limited given the thick mats of *Ampelisca* tubes found on the surface of all the samples collected from the Skeet Range.

Although exposure to PAHs were not quantitatively evaluated, any potential risks associated with exposure to these compounds should not be significantly different from prevailing conditions throughout much of San Francisco Bay, given that a majority of the stations had PAH concentrations within ambient concentrations. Additionally, it is unlikely that clay targets are the source of the PAHs measured in the sediment at the site.

7.1.3 Human Health CSM

The human health CSM identifies the conditions of exposure and likely scenarios in which human receptors may come in contact with impacted sediment at the Skeet Range. The potential exposures associated with historical activities at the Skeet Range are primarily limited to lead shot and PAHs in offshore sediment located within the fall zone. Due to the offshore location of lead shot and clay targets, direct human exposures currently are limited because access to the site is restricted. Consequently, exposures through direct contact are incomplete. Potential indirect exposures through recreational use (e.g., fishing, clamming, etc.) are similarly incomplete, because these activities currently are not allowed on the onshore parcel.

Under a future land use scenario, when the site is developed into an open space and/or recreational park, the riprap along the shoreline will deter access to the beach areas and minimize potential direct exposures to recreational users. Previous screening analysis performed on data collected from Western Bayside indicates that chemical concentrations are consistent with ambient stations. Indirect exposures via fishing may occur on the property; however, there is no evidence that PAHs biomagnify in aquatic food webs or bioaccumulate in vertebrate species. It also is unlikely that any fish species will ingest lead shot from the surface of the sediment because the thick mat of *Ampelisca* tubes reduces bioavailability of these contaminants through the food chain. Therefore, risks from exposures to PAHs and lead shot are considered *de minimis*.

7.2 Conclusions

The primary objective of the RI was to identify the area of the sediment that pose an unacceptable risk and require evaluation in the FS. Conclusions of the RI are as follows:

- PAH concentrations in sediment are chemically distinct from PAHs found in clay targets. This result indicates that abrasions or leaching of any organic binder from clay targets was not the source of hydrocarbons in sediment, including PAHs.
- An ancillary PAH study shows that majority of the PAHs found in sediment have a consistent signature to background levels and trace levels from historical FMGP activities.
- The estimated net sediment accumulation rate is estimated to be between 0.65 and 1.0 cm/yr. The horizontal and vertical distribution of shot supports the hypothesis that lead shot has not been transported significant distances and that gradual burial is occurring.
- The presence of *Ampelisca* tubes at the Skeet Range is an indication of the low impact that lead shot and PAHs have on the environment.
- The ecological risk assessment identified diving ducks (e.g., scaups and scoters) as the receptors having the highest potential exposure to lead shot at the Skeet Range.
- The results of the Monte Carlo analysis showed that, approximately 96 percent of the time, less than 1 in 1,000 birds foraging at the site would potentially be at risk.
- The presence of dense mats of *Ampelisca* tubes on the surface of the sediment may limit the availability of lead shot to diving birds.
- No complete direct route of exposure was determined through the human health CSM based on the current and proposed future land use. Indirect exposures through fishing or clamming

may be complete once the area is developed; however, no evidence has been found which suggests that PAHs biomagnify and bioaccumulate in the environment.

Based on all these considerations, *de minimis* risks are associated with exposure to this site based on the ecological and human health assessments. Because the PAH levels are indicative of background levels and majority of the lead shot is being gradually buried and at times are under a thick mat of *Ampelisca* tubes, exposures to sediment do not pose a health threat to current or future human receptors and the environment. Consequently, a no further action determination is recommended for this site.

8.0 REFERENCES

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ALAMEDA POINT
SSIC NO. 5090.3

APPENDIX A – FIELD DATA

FINAL REMEDIAL INVESTIGATION REPORT
SKEET RANGE

DATED 01 JULY 2004

N00236.001903
ALAMEDA POINT
SSIC NO. 5090.3

APPENDIX A – FIELD DATA IS CONTAINED IN ELECTRONIC FORMAT

TO VIEW THE DATA, CONTACT:

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APPENDIX B – DRAFT PAH FINGERPRINTING REPORT

FINAL REMEDIAL INVESTIGATION REPORT SKEET RANGE

DATED 01 JULY 2004

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APPENDIX B – DRAFT PAH FINGERPRINTING REPORT IS CONTAINED IN ELECTRONIC FORMAT

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APPENDIX C – SKEET RANGE SEDIMENT DYNAMICS EVALUATION

FINAL REMEDIAL INVESTIGATION REPORT SKEET RANGE

DATED 01 JULY 2004

APPENDIX C – SKEET RANGE SEDIMENT DYNAMICS EVALUATION IS CONTAINED IN ELECTRONIC FORMAT

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APPENDIX D – PROBABILITY MODEL ISSUE PAPER

FINAL REMEDIAL INVESTIGATION REPORT SKEET RANGE

DATED 01 JULY 2004

APPENDIX D – PROBABILITY MODEL ISSUE PAPER IS CONTAINED IN ELECTRONIC FORMAT

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APPENDIX E – ECOLOGICAL RISK ASSESSMENT SUPPORTING DOCUMENTATION

FINAL REMEDIAL INVESTIGATION REPORT SKEET RANGE

DATED 01 JULY 2004

APPENDIX E – ECOLOGICAL RISK ASSESSMENT SUPPORTING DOCUMENTATION IS CONTAINED IN ELECTRONIC FORMAT

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APPENDIX F – AGENCY COMMENTS AND RESPONSES TO AGENCY COMMENTS

FINAL REMEDIAL INVESTIGATION REPORT SKEET RANGE

DATED 01 JULY 2004

APPENDIX F – AGENCY COMMENTS AND RESPONSES TO AGENCY COMMENTS IS CONTAINED IN ELECTRONIC FORMAT

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