U.S. Fish & Wildlife Service

Ecological Risk Assessment for the Prime Hook National Wildlife Refuge Lead Shot Site Milton, Delaware

CBFO-C03-04

August 2004

Contaminated area before (background) and after restoration (below)

TABLE OF CONTENTS

Ecological Risk Assessment for the Prime Hook Lead Pellet Site

Prime Hook National Wildlife Refuge Milton, DE

Publication No. CBFO-CO3-04

Prepared by

Christopher P. Guy
Mark Huston
Sherry Krest
Dan Murphy

U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
177 Admiral Cochrane Drive
Annapolis, MD 21401

August 2004

ACKNOWLEDGMENTS

We appreciate the assistance and input of Susan Lingenfelser (USFWS) and Dick Peddicord (Dick Peddicord & Company) in the design of this risk assessment. Thanks to the staff and volunteers of the Prime Hook National Wildlife Refuge and the staff of the USFWS, Chesapeake Bay Field Office who withstood many hot, buggy days in the field collecting the data necessary for this study. Thanks to Harding ESE for their extensive sampling and analysis, and to the USFWS Patuxent Analytical Control Facility (PACF) for their responsiveness to our last minute requests. Thanks to Beth McGee and Fred Pinkney for reviewing drafts of this report. Thanks to Patty McCawley for help in the preparation of this report. This project was funded by the USFWS, Division of Environmental Quality (DEQ) and the USFWS, Division of Refuges and Wildlife as a Refuge Cleanup project (Regional Project ID #5C25).

C:\cguy\Prime Hook\ERA\Prime Hook Final Report.wpd

EXECUTIVE SUMMARY

This site involved approximately 27 acres or 10.93 hectares of the Prime Hook National Wildlife Refuge (NWR) in Milton, Delaware, located adjacent to the Broadkiln Sportsman's Club. The Club operated a range with five trap houses for approximately 40 years. The objective of this project was to evaluate the ecological effects of lead shot and the associated lead contaminated soil and sediment at the NWR.

Lead had been identified as a contaminant at the site, based on the historical use of the trap range. Although arsenic, antimony, and copper are impurities in lead shot, concentrations of these metals were generally low in soil and were always co-located with lead. In addition, clay pigeons have been shown to contain high levels of polycyclic aromatic hydrocarbons (PAHs). Although normally associated with trap range contamination, PAHs were not included as a site contaminant because there is no evidence that clay pigeons reached refuge property. Therefore, arsenic, antimony, copper, and PAHs were excluded from this evaluation and lead was selected as the contaminant of concern.

The ecological risk assessment was designed to evaluate the potential threats to ecological receptors from direct exposure to lead contaminated soil and sediment as well as from ingestion of lead shot. Toxicity tests, food chain accumulation models, and lead shot ingestion probability models were used to evaluate the risk to receptors that use this area.

The results of the samples collected from the trap range indicate that the site had been heavily contaminated with lead and lead shot. Lead was detected in surface samples up to 100,000 mg/kg and shot density was recorded up to 68,564 shot/ft^2. In toxicity tests, earthworms had reduced survival and rye grass had reduced growth when exposed to lead contaminated soils. The hazard quotients calculated with food chain accumulation models for insectivorous birds and mammals exceeded 1 (using a maximum soil concentration compared to a lowest observable adverse effect level). The results of the probability models indicated that waterfowl and terrestrial birds were at risk due to the ingestion of lead shot.

Based on the results of the studies, preliminary remediation goals (PRGs) were developed for the cleanup of lead contaminated soil, sediment, and lead shot. Because this site may be dry for long periods of time, the PRGs were developed to be protective of all species, without designating separate soil or sediment cleanup values. A comparison of the LOAELs calculated for the toxicity tests and the food chain accumulation models indicated that 421 mg/kg lead was the lowest LOAEL. A comparison of the NOAELs calculated for the toxicity tests and food chain models indicated that 310 mg/kg was the highest NOAEL that was still less than the lowest LOAEL. Therefore, the targeted PRG for soil and sediment should be within the range of these values (310 - 421 mg/kg lead) to be protective of the endpoints evaluated in this risk assessment. A risk management decision to use 421 mg/kg lead was made as the PRG for this site. This decision was made by following the example of the EPA Superfund program that often uses the lowest site specific LOAEL value developed in the risk assessment to develop a PRG. By accepting an ingestion probability of 0.10, a PRG for lead shot was established at between 7 and 9 lead shot/ft^2 for the protection of waterfowl and upland birds.

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

AUF	area use factor
AWQC	Ambient Water Quality Criteria
BAF	bioaccumulation factor
BSAF	biota-soil/sediment accumulation factor
BW	body weight
CCC	criterion continuous concentration
CMC	criterion maximum concentration
cm	centimeters
COPC	contaminants of potential concern
ft^2	square foot
g	grams
ha	hectare
HQ	hazard quotient
kg	kilograms
LD_{50}	lethal dose that kills 50 percent of test animals
LOAEL	lowest observable adverse effect level
μg/L	micrograms per liter
mg	milligrams
mL	milliliter
mm	millimeter
NOAEL	no observable adverse effect level
NWR	National Wildlife Refuge
PAHs	polycyclic aromatic hydrocarbons
ppb	parts per billion
ppm	parts per million
ppt	parts per thousand
PRG	Preliminary Remediation Goal
RI	Remedial Investigation
TRV	Toxicity Reference Value

1.0 INTRODUCTION

The objective of this project was to evaluate the ecological effects of lead shot and the associated lead contaminated soil and sediment at the Prime Hook National Wildlife Refuge (NWR), Milton, DE. Toxicity tests, food chain accumulation models, and lead shot ingestion probability models were used to evaluate the risk to receptors that use this area. Based on the results of the studies, Preliminary Remediation Goals (PRGs) were developed for the cleanup of lead shot and lead contaminated soil and sediment.

1.1 Site History

The site consists of approximately 27 acres (10.93 hectares) of the NWR in located adjacent to the Broadkiln Sportsman's Club (Figure 1). The club was in operation for approximately 40 years and operated five trap ranges. The trap houses are between 100 and 130 yards away from the NWR property line. When in operation, shot was deposited on the refuge, and the clay pigeons fell on club property and not on refuge property.

1.2 Ecological Setting

The ecological setting of the site includes approximately 4 acres (1.62 hectares) of mature upland forest dominated by white oak (*Quercus alba*). Other overstory species include loblolly pine (*Pinus taeda*) and black oak (*Quercus velutina*). Understory species include American holly (*Ilex opaca*), mountain laurel (*Kalmia latifolia*), and greenbrier (*Smilax* sp.). Approximately 3 acres (1.21 hectares) of the site include early successional forest dominated by red maple *(Acer rubrum)* and sweetgum *(Liquidambar styraciflua)*. The successional forest is dominated by well drained, poorly buffered Coastal Plain sandy soils that typically provide habitat for many different species of terrestrial wildlife. This early successional community gives way to approximately 20 acres (8.09 hectares) of poorly drained, mature forested wetlands dominated by an understory of greenbrier, a midstory of American holly and sweet pepper bush (*Cletbra alnifolia*), and a canopy of red maple and sweet bay magnolia (*Magnolia virginiana)*. The wetlands are bisected by a braided stream that discharges into Prime Hook Creek.

During wet years, a majority of the wetland soils are generally saturated with overlying water from a few centimeters to a third of a meter or more in depth. The braided stream and adjacent wetlands have highly organic sediments containing an unconsolidated organic layer up to approximately 2 feet thick with a sandy mineral layer underneath. This rich medium supports a wide variety of benthic invertebrates, which in turn support a wide variety of wildlife. Fish sampling using minnow traps identified Eastern Mudminnows (*Umbra pygmaea*) in the braided stream. No other fish species have been observed in the stream. Mudminnows typically inhabit such marginal habitats that are too shallow for most other fish species.

This wetland and braided stream are part of the flood plain drainage to Prime Hook Creek. Prime Hook Creek is a non-tidal coastal river (approximately 60 meters wide) that drains into the Delaware Bay. However, during storm events, the tide may back up, changing the creek to a temporary tidal system and providing some low saline environments (less than five parts per thousand). Prime Hook Creek is host to several species of fish including largemouth bass (*Micropterus salmoides)*, carp (*Cyprinus carpio*), sunfish (*Lepomis sp*), catfish (*Ictalurus sp.*), and pickrel (*Esox sp.*) and a large number of waterfowl and wading birds.

A complete list of species that have been confirmed on the NWR was compiled by the staff and volunteers from the NWR (Appendix A). The federally endangered Delmarva fox squirrel (*Sciurus niger*) is known to inhabit the refuge and has been seen in close proximity to this site. In addition, the threatened bald eagle (*Haliaeetus leucocephalus*) is a frequent visitor to the refuge. These are the only federally-listed species known or suspected around the site.

2.0 TECHNICAL APPROACH

2.1 Identification of Contaminants of Potential Concern (COPCs)

Lead had been identified as a contaminant at the site based on the historical use of the trap range. Although arsenic, antimony, and copper are impurities in lead shot, concentrations of these metals were generally low in soil and were always co-located with lead (Harding/ESE 2001). There was a significant correlation between lead and arsenic ($p<0.05$) and lead and antimony ($p<0.05$) based on number of soil samples. There was no correlation between lead and copper, and the concentration of copper was usually a magnitude of order below that of lead. Clay pigeons have been shown to contain high levels of polynuclear aromatic hydrocarbons (PAHs). Although normally associated with trap range contamination, PAHs were not included as a site contaminant because there is no evidence that clay pigeons reached refuge property (i.e., no clay fragments were observed in shot zone, while large numbers of clay fragments were observed on club property). Therefore, arsenic, antimony, copper, and PAHs were excluded from this evaluation and lead was selected as the contaminant of concern.

2.2 Exposure Characterization

The objective of the exposure characterization was to determine the media and the pathways through which assessment endpoints may be affected by site contaminants. Potential exposure pathways are dependent on the extent and magnitude of contamination, the site habitat, the receptor species present at the site, and the environmental fate and transport of the COPCs.

On-site receptors are potentially exposed to contaminants in soil and sediment through direct contact, intentional ingestion (e.g., consumption of grit-sized particles), and incidental ingestion (e.g., sediment particles adhered to or entrained in food items). Transfer of the contaminants to receptors could also occur through processes of bioaccumulation and bioconcentration, whereby upper trophic level receptors are exposed to site contaminants through the ingestion of contaminated prey items.

2.3 Problem Formulation

This ecological risk assessment was designed to evaluate the potential threats to ecological receptors from the direct exposure to lead contaminated soil and sediment as well as from the direct ingestion of lead shot. The problem formulation process for this risk assessment includes the identification of the COPC, the identification of the exposure pathways for the COPC, a determination of the assessment endpoints for the site, the formulation of testable hypotheses, the development of a conceptual model, the determination of the measurement endpoints for the site, and an analysis of the uncertainties that may be associated with the risk assessment. The problem formulation presented below was developed according to the Ecological Risk Assessment Guidance for Superfund (U.S. EPA 1997).

2.4 Assessment Endpoints

Assessment endpoints are explicit expressions of the actual environmental values (e.g., ecological resources) that are to be protected. Valuable ecological resources include those without which ecosystem function would be significantly impaired or those providing critical resources (e.g., habitat). Appropriate selection and definition of assessment endpoints are critical to the utility of a risk assessment as they focus risk assessment design and analysis. It is not practical or possible to directly evaluate potential risks to all of the individual components of the ecosystem at the site; thus, assessment endpoints are used to focus the risk assessment on particular components of the ecosystem that could be adversely affected by the contaminants released from the site. In general, the assessment endpoints selected for the site are aimed at the viability of terrestrial and aquatic populations and organism survivability.

A review of the habitat of the NWR and its associated wetlands provided information for the selection of assessment endpoints. A variety of invertebrates, vertebrates, and plants inhabit the area. In addition, many birds and mammals inhabiting this and adjacent areas could prey on the flora and fauna in the study area. Therefore, the assessment endpoints focused on these biological groups.

Reptiles and amphibians were considered as assessment endpoints for this risk assessment. However, due to the lack of toxicological information in the literature, finding suitable measurement endpoints was problematic. It was assumed in this risk assessment that the protection of the other trophic guilds will allow us to be protective of these assessment endpoints. In addition, piscivorous birds and mammals were also considered assessment endpoints for this risk assessment. Although mudminnows were collected from this area, they tend to burrow during the day and are not likely to be available as a food source to piscivorous birds and mammals. Furthermore, because better foraging areas are likely to be in Prime Hook Creek and ponds, it is expected that these areas are preferred by piscivorous birds and mammals. In addition, the results of the bird survey conducted by the staff of the NWR indicated the absence of piscivorous birds in this area. Therefore, we propose that there is not a complete exposure pathway to piscivorous birds or piscivorous mammals in the area impacted by lead and lead shot.

Seven assessment endpoints were developed to evaluate the potential risk of contaminants in the NWR. By evaluating and protecting these assessment endpoints, the ecosystem as a whole should also be protected.

2.5 Selection of Measurement Endpoints

Measurement endpoints are ecological characteristics that are related to the valued characteristics selected as assessment endpoints. Measurement endpoints should be linked to assessment endpoints by the mechanism of toxicity and the route of exposure. Measurement endpoints are used to derive a quantitative estimate of potential effects, and to form a basis for extrapolation to the assessment endpoints.

Measurement endpoints were selected on the basis of potential presence of receptors at the site, and the potential for exposure to contaminants of concern. The availability of the appropriate toxicity information on which risk calculations could be based was also an important consideration. Endpoints selected were determined to be representative of exposure pathways and assessment endpoints identified for the site.

Lower trophic levels were evaluated by site specific toxicity tests. For example, although the assessment of wetland community structure and function cannot be directly evaluated, the potential impacts to benthic invertebrate populations may be assessed via toxicity tests with a surrogate benthic species.

Food chain accumulation models and comparison to literature-based toxicity data were used to evaluate risk to avian and mammalian species that utilize the site as a feeding area. Appropriate forage species were identified as receptors. Dietary exposure of receptors to contaminants was quantified and compared to existing toxicity data for these, or other closely related species.

Receptor species were selected from several trophic levels when appropriate. Organisms that are likely to be exposed to contaminants because of specific behaviors, patterns of habitat use, or feeding habits were selected for evaluation in this risk assessment. The availability of appropriate toxicity information on which risk calculations could be based was also an important consideration.

2.6 Conceptual Model

The conceptual model is based on contaminant and habitat characteristics and was used to identify critical exposure pathways to the selected assessment endpoints. At the site, contaminants in the soil, water, and sediment may come in contact with the aquatic, benthic, and terrestrial receptors inhabiting the wetland, stream, and adjacent upland areas of the site. Benthic invertebrates in the wetland may be exposed to site contaminants through direct contact with and/or ingestion of the sediment and water. Mammals and birds may be exposed to site contaminants via ingestion of contaminated food and incidental ingestion of sediment; additionally for birds, the ingestion of lead shot. Although the surface water samples contained lead at concentrations that exceeded water quality criteria, the exposure to lead in the water was not considered in the conceptual models because the magnitude of the contamination in the soil and sediment far exceeded the contamination in the water samples.

Based on this conceptual model, available information, the following receptors were evaluated in this risk assessment:

I. Plants
   Direct contact with soils

II. Aquatic Invertebrates
   Direct contact with sediment
   Ingestion of sediment

III. Soil Invertebrates
   Direct contact with soil
   Ingestion of soil

IV. Insectivorous Birds
   Ingestion of soil
   Ingestion of invertebrates

V. Insectivorous Mammals
   Ingestion of soil
   Ingestion of invertebrates

VI. Omnivorous Waterfowl
   Direct ingestion of lead shot

VII. Upland Birds
   Direct ingestion of lead shot

2.7 Assessment Endpoint No. 1 - Protection of the terrestrial plant communities' structure and function

The terrestrial rooted vascular plant community provides many functions within the ecosystem. Included within these functions are: erosion prevention (both water and wind caused erosion); promotion of rain water percolation; restriction of sheet flow leading to reduced flooding potential; reduction of surface wind velocity; provision of nesting and cover habitat for wildlife; primary production via photosynthesis; and a source of organic matter input (energy) to streams and soil systems. Because the terrestrial plant community is critical to the overall function of the terrestrial ecosystem, a viable terrestrial plant community was selected as an assessment endpoint for this risk assessment.

Direct contact with contaminated soil is the primary route of exposure for terrestrial plant communities. A soil toxicity test was selected as the measurement endpoint for this assessment endpoint. The rye grass (Lolium perenne) was exposed for 28 days to soil samples collected along a gradient of lead contamination, following the method described in EPA (1989) and ASTM (1998b). Both No Observed Adverse Effects Level (NOAEL) and Lowest Observed Adverse Effects Level (LOAEL) concentrations were developed from this test.

The testable hypothesis for this endpoint was that lead contaminated soil had no effect on growth or survival of a representative plant.

2.8 Assessment Endpoint No. 2 - Protection of aquatic invertebrate community structure and function

Invertebrate communities constitute the base of the food chain in aquatic systems. Impacts to invertebrate communities would have significant direct and indirect effects (e.g., loss or reduction of forage or transfer of bioaccumulative compounds) on higher trophic organisms (e.g., fish, birds, and herpetifauna). Invertebrates process organic material in the stream and are thus important in nutrient and energy transfer and stream ecosystem functions.

Direct contact with, and ingestion of, contaminated sediments are the primary routes of exposure for aquatic invertebrate communities. An amphipod toxicity test was selected as the measurement endpoint for this assessment endpoint. The amphipod (*Hyalella azteca*) was exposed for 10 days to sediment samples collected along a gradient of lead using the methods described in EPA 2000. A NOAEL and LOAEL were developed from this test.

The hypothesis for this endpoint was that exposure to lead contaminated sediment had no effect on the growth or survival of a representative benthic invertebrate.

2.9 Assessment Endpoint No. 3 - Protection of terrestrial invertebrate community structure and function

Terrestrial invertebrate communities constitute the base of the food chain in terrestrial systems. Impacts to invertebrate communities would have significant direct and indirect effects (e.g., loss or reduction of forage or transfer of bioaccumulative compounds) on higher trophic organisms (e.g., birds and mammals). Terrestrial invertebrates process organic material in the soil and are therefore important in nutrient and energy transfer.

Direct contact with, and ingestion of, contaminated soil are the primary routes of exposure for terrestrial invertebrate communities. An earthworm toxicity test was selected as the measurement endpoint for this assessment endpoint. The earthworm (Eisenia foetida) was exposed for 28 days to soil samples collected along a gradient of lead using the methods described in ASTM (1998a). A NOAEL and LOAEL were developed from this test. In addition, the worms were analyzed for lead at the completion of the test and bioaccumulation factors were calculated.

The hypothesis for this assessment endpoint was that exposure to lead contaminated soil had no effect on the growth or survival of a representative soil invertebrate.

2.10 Assessment Endpoint No. 4 - Protection of insectivorous birds

Insectivorous birds are important in regulating of potentially harmful aquatic insects, such as mosquitoes. Impacts to insectivorous birds would allow species of potentially harmful aquatic insects to obtain higher population levels than would typically occur in a system that was not impacted. Insectivores are important in nutrient processing and energy transfer between the aquatic and terrestrial environment.

The ingestion of contaminated food and the incidental ingestion of soil are the primary routes of exposure for insectivorous birds. A food chain accumulation model using the American robin (*Turdus migratorius*) was selected as the measurement endpoint for this assessment endpoint. Risk was evaluated by comparing the dose calculated from the food chain models to literature values to determine the potential risk to the survival and reproduction of insectivorous birds.

The hypothesis for this assessment endpoint was that exposure to lead contaminated soil had no effect on the growth or survival of representative insectivorous birds.

2.11 Assessment Endpoint No. 5 - Protection of insectivorous mammals

Insectivorous mammals are important in the population regulation of insects. Impacts to insectivorous mammals would allow species of potentially harmful insects to obtain higher population levels than would typically occur in a system that was not impacted. Insectivores are important in nutrient processing and energy transfer in the terrestrial environment, and play an important role in the terrestrial food chain.

The ingestion of contaminated food and the incidental ingestion of soil are the primary routes of exposure for insectivorous mammals. A food chain accumulation model using the short-tailed shrew (Blarina brevicauda) was selected as the measurement endpoint for this assessment endpoint. Risk was evaluated by comparing the dose calculated from the food chain models to literature values to determine the potential risk to the survival and reproduction of insectivorous mammals.

The hypothesis for this assessment endpoint was that exposure to lead contaminated soil had no effect on growth or survival of representative insectivorous mammals.

2.12 Assessment Endpoint No. 6 - Protection of omnivorous waterfowl

Omnivorous birds rely on both animal tissue and plant matter for forage. The foraging behavior of omnivorous birds may represent a pathway by which nutrients and energy are transferred from lower to higher links in the food chain. Omnivores may also transfer energy from the detrital food chain to the grazing food chain where they consume detritivores (e.g., amphipods). In addition, the feeding mechanism used by omnivorous waterfowl make them susceptible to the ingestion of lead shot pellets.

Some birds are resident year-round and some are migratory. The variable mobility of potential avian receptors, relatively large home range, variable diet, and often seasonal residency suggest that the potential for exposure and the identification of specific exposure routes and concentrations are associated with some uncertainty.

The ingestion of lead shot pellets is the primary route of exposure for omnivorous waterfowl. An ingestion-based probability model (Peddicord and LaKind 2000) using the mallard (Anas platyrynchos) was selected as the measurement endpoint for this assessment endpoint. Risk was evaluated by calculating the probability that a mallard duck will ingest lead shot at this site.

The hypothesis for this assessment endpoint was that there is little probability that lead pellets would be taken into the crop of representative omnivorous waterfowl.

2.13 Assessment Endpoint No. 7 - Protection of omnivorous upland birds

Omnivorous birds were selected for evaluation because of their diverse methods of foraging (i.e., grazing for seeds). Of the bird species utilizing the system, omnivorous birds have been reported to have the greatest soil/sediment ingestion rates. Soil/sediment ingestion typically accounts for a vast majority of the contaminant uptake in food chain accumulation models. Omnivorous birds also help to regulate the growth of vegetation and terrestrial invertebrates. Omnivorous birds are an important pathway for nutrient and energy cycling in the ecosystem.

The ingestion of lead shot pellets is the primary route of exposure for upland birds. An ingestion-based probability model (Peddicord and LaKind 2000) using the mourning dove (*Zenaida macroura carolinensis*) was selected as the measurement endpoint for this assessment endpoint. Risk was evaluated by calculating the probability that a mourning dove will ingest lead shot at this site.

The hypothesis for this assessment endpoint was that there is little probability that lead pellets would be taken into the crop of representative omnivorous upland birds.

3.0 METHODS

A Global Positioning System (GPS) survey of the site was used to map the sampling locations. Parallel sampling transects were established perpendicular to the alignment of the shooting ranges. Each transect was located approximately 50 yards from the adjacent transect and extended from the trap houses to a maximum distance of approximately 300 yards down range. Sampling locations were established only on NWR property every 50 yards along a given transect. A total of 68 sampling locations were established by equally distributing transects across the entire trap range.

3.1 Soil/Sediment Sampling

Surface and subsurface soil and sediment samples were collected to determine the lead concentrations in the soil and sediment at the site. Surface samples were collected from 68 locations on-site (35 surface soil and 33 surface sediment). In addition, subsurface samples were collected from 12 locations (six upland locations and six wetland locations). Samples from subsurface were collected from depths of 6 inches, 1 foot, and 2 feet below ground surface. The details of the soil sampling methods are described in Harding/ESE (2001).

3.2 Shot Determination

Surface and subsurface samples were collected to evaluate the number of lead pellets per square foot as well as to characterize the depth to which lead pellets were present. A total of 75 surface soil samples (68 on-site locations and 7 reference locations) were collected for pellet counts. In summary, a soil sample was collected from a 12 inch by 12 inch grid to a depth of 1 inch. Lead pellet counts were done by weight and conversion means. A correlation between shot and weight is described in Harding/ESE (2001). Any sample containing less than

15 g of shot (approximately 150 pellets) was counted manually. The weight and conversion method was used and consisted of weighing and counting the number of pellets in a volume of soil. Based on the number of pellets, 12 locations were further selected (6 from the upland area and 6 from the wetland area) for pellet counts from 6 inches and 1 foot below the ground surface. A detailed description of the method is provided in Harding/ESE (2001).

3.3 Toxicity Tests

The results of the toxicity test using amphipods, rye grass, and earthworms were used to estimate the effects of lead contamination. The selection of these endpoints was based on a review of the life history of the organism (Appendix B). Toxicity tests were used to evaluate the risk to the following endpoints: protection of aquatic invertebrate communities; protection of terrestrial plant communities; and the protection of terrestrial invertebrate communities. NOAEL and LOAEL values for lead were identified by comparing the measured levels of each contaminant in each sample to the toxicity of that sample. The NOAEL is described as the highest dose or concentration of lead in soil or sediment that is not statistically different from reference concentration or dose. The LOAEL is described as the lowest dose or concentration of lead in soil or sediment in which a statistically different (from reference concentration or dose) adverse effect is observed. The resulting NOAELs and LOAELs provide a range below which the concentration of lead is expected to be protective of the benthic invertebrate communities.

3.3.1 Earthworm Toxicity Testing

Six soil samples were collected for earthworm toxicity testing. These samples represented a range of lead concentrations. The measured lead concentrations for these six samples were 35, 80, 310, 620, 2,500 and 4,200 mg/kg total lead. The earthworms were exposed to site soils for a total of 28 days. Survival was also recorded at 14 days. Following a 28-day exposure, the surviving worms were composited from each replicate and frozen. This provided for a total of five tissue samples and the tissue was analyzed for several metals. Methods followed those described in ASTM (1998a). Details of the earthworm toxicity test can be found in Harding/ESE (2001).

3.3.2 Plant Toxicity Testing

Seven soil samples were collected for rye grass toxicity testing. These samples provided a range of lead concentrations. The measured lead concentrations for these seven samples were 15, 162, 350, 505, 759, 1,030, and 1,779 mg/kg total lead. The rye grass seeds were exposed to site soils for 28 days to determine germination and growth (measured as height and biomass). Following the 28-day exposure, the percent germination, percent survival, mean height, mean above ground dry weight, and mean below ground dry weight were measured. Methods followed those described in ASTM (1998b) and EPA (1989). Details of the plant toxicity test are provided in EnviroSystems, Inc. (2001).

3.3.3 Amphipod Toxicity Testing

Six sediment samples were collected for amphipod toxicity testing. These samples provided a range of lead concentrations. The measured lead concentrations for these six samples were 17.5, 101, 165, 216, 837, and 3,375 mg/kg total lead. The amphipods were exposed to site sediment for 10 days to determine survival and growth (measured as weight). Following the 10-day exposure, the percent survival and mean growth were measured. Method followed those described in EPA (2000). Details of the amphipod toxicity test are described in University of Maryland (2001).

3.4 Food Chain Accumulation Models

To determine the risk associated with the exposure of higher trophic level receptors to site-related contaminants, ingestion-based exposure models were used. Life history information was obtained for each receptor (Appendix B). The hazard quotient (HQ) for higher trophic level species was calculated using food chain models with site specific risk assumptions. A variety of soil, sediment, or biota concentrations were used together with literature-based NOAELs and LOAELs (Appendix C). A literature search was conducted to determine levels of exposure to contaminants at which no adverse effects would be expected. If a NOAEL was not available for lead or receptor species, then a converted LOAEL or lethal dose that kills 50 percent of the test animals (LD_{50}) was used. A factor of 10 was used to convert an LD_{50} to a LOAEL, and to convert a LOAEL to a NOAEL. All NOAELs and LOAELs were based on the most sensitive endpoint of survival, growth, or reproduction.

Exposure to upper level trophic receptors is expressed in food web models using the formula:

$$D_t = \frac{I_p + I_i}{BW} * A$$

Where:
D_t = dose (mg/kg/day)
I_p = (food ingestion rate) * (prey concentration (mg/kg/day))
Prey concentration is calculated by taking the total lead concentration in soil and multiplying it by the BSAF found

in the earthworm study.
I_i = (incidental ingestion of soil) * (bioavailable fraction of total lead (mg/kg/day))
BW = body weight (kg)
A = Area Use

3.4.1 Insectivorous Bird

The American robin was selected as the representative of the insectivorous bird. Life history parameters were selected that provide a reasonable exposure to lead contaminated food items and soil. The specific parameters for use in the food chain models (e.g., food and soil ingestion rates) are listed in Appendix B. A site specific area use factor (AUF) was developed based on the bird survey conducted by refuge personnel. For this species, an AUF of 0.22 was recorded, which is based on the highest percent of use at the three locations surveyed for this project. For the exposure scenario, a variety of soil lead concentrations were used in the models. The dose calculated from these exposure scenarios was compared to both NOAEL and LOAEL toxicity reference values (TRVs). In addition, the food chain accumulation models were used in order to calculate a concentration of lead in soil that would result in an HQ of 1. This allowed for the development of a preliminary remediation goal (PRG) based on the exposure of insectivorous birds to contaminated soil.

3.4.2 Insectivorous Mammal

The short-tailed shrew was selected as a representative insectivorous mammal. Life history parameters were selected which provide a reasonable exposure to lead contaminated food items and soil. The specific parameters for use in the food chain models (e.g., food and soil ingestion rates) are listed in Appendix B. For this species, an AUF of 1 was selected because of the very small home range in comparison to the size of the site. For the exposure scenario, a variety of soil lead concentrations were used in the models. The dose calculated from these exposure scenarios was compared to both NOAEL and LOAEL TRVs. In addition, the food chain accumulation models were used in order to calculate a concentration of lead in soil that would result in a HQ of 1. This allowed for the development of a preliminary remediation goal based on the exposure of insectivorous mammals to contaminated soil.

3.5 Probability Models

Lead shot exposure to mallard and mourning dove was calculated by using the model developed by Peddicord and LaKind (2000) for evaluating the probability that a bird will ingest lead shot in its lifetime. The model is as follows:

$$P = S * P_s + (1 - S)P_o$$
$$N = Y(D_e/D_p)$$
$$P_t = 1 - (1 - P)^N$$

Where

P = Probability that a single selected particle will be a lead shot.

P_s = Fraction of grit sized particle on-site that is lead shot (Harding ESE 2001).

P_o = Fraction of grit sized particles off site that is lead shot (we assumed 100% of lead shot was coming from this site. Therefore, P_o is assumed to be 0 for this model).

S = Fraction of foraging time (area use factor) on site (Appendix B).

P_t = Probability that a bird will ingest at least one lead shot in a lifetime.

N = Number of particles selected and retained in the gizzard in a lifetime.

Y = Number of years a bird lives. These numbers were derived from the literature. We assumed 1.47 years for the mallard (Chasko et al. 1984) and 1.5 years for the dove (McConnell 1967).

D_e = Number of days per year that a bird forages in the area. We assumed that the season was from March 15 to November 15, or 245 days, for both species.

D_p = Retention time for a shot in gizzard (days). Literature-based values were chosen for D_p. We assumed a retention time of 21 days for the mallard (Chasko et al, 1984) and 6 days for the dove (McConnell 1967).

The percentage of grit sized particles that were pellets was calculated by the following formula:

$$P_s = \frac{P_p}{P_g + P_p}$$

Where:

P_s = percentage of grit-sized pellets that were pellets.

P_p = the percentage of the soil that was comprised of pellets.

P_g = the percentage of soil that was grit. (P_g) was defined as the fraction (by weight) of particles (excluding lead shot), that passed through a standard No. 4 sieve, but were retained on a No. 40 sieve. These values are presented in Harding/ESE (2001).

The next step was to determine P_p.

During the 2001 field sampling event, the total weight of the soil collected from the 12" x 12" x 1" (236 cm^3) grid was not calculated. This weight is necessary to calculate P_p. Since we did not have this data we estimated the total weight of soil by collecting a similar soil type and weighing it. This sample was collected using the same grid (12" x 12" x 1" or 236 cm^3) as used during the 2001 field event. This volume of soil weighed 2,200 g. We assumed, for this risk assessment, that the soil weight remained constant. The total weight of the soil sample, including pellets, was calculated by adding the total weight of the soil and the total weight of the pellets, measured as g/cm^3. The percentage of soil that was comprised of pellets (P_p) was determined by dividing the total weight of the pellets by the total weight of the soil. Finally, to calculate P_s, P_p was divided by P_g plus P_p.

We used regression analysis to confirm the relationship between the total number of lead pellets in a sample and the percentage of grit-sized particles that were pellets (P_s). The analysis was performed using the software program, Sigma Stat®. It should be noted that because the wetlands on the site may be dry during some period of the year, all samples in which pellets were counted were used in this analysis (n=24), whether designated as soil or sediment. Results indicated a significant relationship between total number of lead pellets and P_s ($p < 0.05$, $R^2 = 0.69$). From this analysis, we developed the following regression equation:

$$Ps = -0.0659 + [0.0885x \text{ Log10(Pellet Count)}]$$

By inserting the regression equation into the model, it was possible to back-calculate the number of pellets that resulted in different probabilities of birds ingesting a lead shot. Preliminary remediation goals for lead pellets were estimated by setting the probability of a bird ingesting a lead shot at 0.10 or 10 percent. For the purposes of this risk assessment, it was assumed that the ingestion of one pellet would cause an adverse impact to both waterfowl and terrestrial birds.

With the exception of the AUF, appropriate life history inputs (e.g., life span, foraging days, and shot retention time) were determined from the literature. A site specific AUF was developed for the dove. Based on the bird survey conducted by refuge personnel, it was determined that the dove has an AUF of 0.11 (Appendix A). This is the highest percentage use at the three locations surveyed during the bird count.

No ducks were counted during the bird survey. This may have been due to low water conditions at the time of the survey, because nest boxes were covered to specifically discourage use, or that the thick vegetation present at the time of the survey prevented the use of the site by ducks. However, because ducks, such as mallard, use this site for nesting, it is anticipated that they would also feed heavily in this area. Therefore, an AUF of 1 was selected for the mallard. These life history parameters were inserted in the Peddicord and LaKind (2000) model listed above and the probability of a bird ingesting a pellet was calculated.

4.0 RESULTS

Thirty-five surface soil samples, 33 surface sediment, six subsurface soil, and six subsurface sediment were collected by Harding /ESE (2001) from the site and analyzed for total lead. With the exception of the grain size analysis, all analytical results for soil/sediment were reported as milligrams of lead per kilogram of soil (mg/kg). Results of the grain size analysis were reported as percent composition. The analytical results generated from the analysis of sediment and soil are reported by the laboratories on a dry weight basis.

4.1 Results of Soil Analysis

The concentration of lead in soil samples that did not contain lead shot ranged from 5 to 350 mg/kg (mean of 46 mg/kg, Table 1), and the concentration of lead in samples that did contain lead shot ranged from 18 to 21,000 (mean of 5,169 mg/kg). The concentration of lead in soil samples decreased with depth. Soil samples collected at 6 inches below ground surface had a mean lead concentration of 328 mg/kg, samples collected from 12 inches below ground surface had a mean lead concentration of 40 mg/kg, and samples collected from 24 inches below ground surface had a mean lead concentration of 14 mg/kg (Table 2).

4.2 Sediment Results

The concentration of lead in sediment samples that did not contain lead shot ranged from 22 to 3,600 mg/kg (mean of 358 mg/kg,,Table 3) and the concentration of lead in samples that did contain lead shot ranged from 110 to 100,000 (mean of 15,906 mg/kg). The concentration of lead in sediment samples decreased with depth (Table 4). Sediment samples collected at 12 inches below ground surface had a mean lead concentration of 1,297 mg/kg and samples collected from 24 inches below ground surface had a mean lead concentration of 26 mg/kg.

4.3 Results of Shot Determination

During this survey, lead shot in soil ranged from 0 pellets /ft^2 to 68,564 pellets /ft^2 (Table 1). Only one of the soil samples collected from a depth of 6 inches below ground surface contained pellets (34 pellets in sample150D-0) and no pellets were found in the samples collected from 12 or 24 inches below ground surface (Table 2).

In sediment, lead shot ranged from 0 pellets /ft^2 to 29,541 pellets /ft^2 (Table 3). No pellets were found in the sediment samples collected from 12 or 24 inches below ground surface (Table 4).

4.4 Results of Earthworm Toxicity Tests

The toxicity of six soil samples was determined using an earthworm test (Harding /ESE 2001). Survival was measured at both 14 and 28 days (Table 5). The earthworm toxicity tests were started on August 18, 2000, and terminated on August 29, 2000, due to excessive mortality believed to be a result from high water content. The tests were restarted on August 31, 2000. Because the test was stopped and restarted, the holding times suggested by the ASTM method for completing the tests were exceeded. However, because the soil samples were maintained in the refrigerator, the exceedance of the holding time was not believed to have a significant impact on the results. In the second trial, the test met all performance measures, with the control having greater than 80 percent survival (required by the (EPA 1989) and (ASTM 1998b) methods). Survival of the controls was 94 percent for the artificial soil control and 98 percent for the compost control at 28 days.

At 14 days, there was a statistically significant reduction in survival, using analysis of variance (ANOVA), in samples containing greater than 620 mg/kg lead when compared to the reference and control samples ($P<0.05$). At 28 days, survival in the control samples was significantly different from the survival in samples containing lead at 35, 80,620, 2,500, and 4,200 mg/kg lead (Table 5). The percent survival (84%) and mean growth (0.189 g/worm) in a sample containing 310 mg/kg lead was not significantly different than the survival (96%) or growth (0.23 g/worm) in the control samples. Therefore, a concentration of 310 mg/kg lead in soil was selected as the NOAEL. The LOAEL for this test was determined to be 620 mg/kg lead. There is some uncertainty associated with this test as there was a significant decrease in survival at 80 mg/kg lead when compared to control after 28 days. However, the low survival at 28 days was attributed to low organic content and not believed to be attributed to lead.

4.5 Results of Plant Germination Test

Seven soil samples were analyzed using a rye grass germination test (ESI 2001). Survival, germination, height, above ground weight, and below ground weight were measured at 28 days (Table 6).

The soil samples were received at the lab on July 17, 2001 and the test was initiated on August 3, 2001 and terminated on August 31, 2001. There was no deviation in the test protocol with the exception of a slight drop in the temperature during 6 days of the test. On those days, the temperature fell to 21°C, which is below the minimum of test requirement of 22°C. Germination and survival in the controls was 95 percent, well above the 80 percent requirement in the EPA (1989) method.

The mean height in samples PHDRY 9 and PHDRY 10 was significantly less than the control samples. The soil samples contained lead at concentrations of 1,779 and 1,030 mg/kg, respectively. In addition, the mean above ground dry weight in samples PHDRY 8 and PHDRY 9 was significantly different than the controls. These samples contained lead at concentrations of 350 and 1,779 mg/kg, respectively. However, there was no dose-response relationship for this endpoint because above ground dry weight for the sample that contained 759 mg/kg lead was not significantly different than the control.

Therefore, a concentration of 759 mg/kg lead was selected as a NOAEL. This was the highest lead concentration in which there was no significant differences in germination, survival, or growth. The LOAEL for this test was determined to be 1,030 mg/kg lead.

4.6 Results of the Amphipod Toxicity Test

Six sediment samples were analyzed using the amphipod (*Hyallela azteca*) test (University of Maryland 2001) and measured for survival and growth after 10 days of exposure (Table 7).

The soil samples were received at the lab on July 12, 200. The tests were initiated on July 17, 2001, and completed on July 27, 2001. There were no deviations from the standard protocols for this test. Survival of the control amphipods was 82.5 percent, which is above the 80 percent survival criteria established by EPA (2000). None of the sediment samples caused a significant reduction in amphipod survival. In addition, growth was not impacted by any of the sediment samples. The growth of the amphipods in 5 of the 6 samples was greater than the control samples. This may be due to the large amount of organic matter in the samples. The large amount of organic matter may have reduced the bioavailability of the lead and possibly provided a food source. Based on the results of this test, a NOAEL was determined to be 3,375 mg/kg lead. A LOAEL could not be determined based on the results of these tests.

4.7 Food Chain Accumulation Models

4.7.1 Insectivorous Birds

Using average ingestion rate, body weight, and an area use factor of 0.22 (Appendix B), a dose was calculated to the American robin (Table 8).

Based on a NOAEL TRV, concentrations of lead exceeding 150 mg/kg resulted in HQs greater than 1. However, when compared to a LOAEL, concentrations of lead exceeding 1,320 mg/kg result in HQs greater than 1.

4.7.2 Insectivorous Mammals

Using average ingestion rate, body weight, and an area use factor of 1.0, a dose was calculated to the short-tailed shrew (Table 9). Based on a NOAEL TRV, concentrations of lead exceeding 42 mg/kg result in HQs greater than 1. When compared to a LOAEL, concentrations of lead exceeding 421 mg/kg result in HQs greater than 1.

4.8 Probability Models

4.8.1 Omnivorous Waterfowl

Probability models using site specific data were used to determine if mallards are at risk from ingesting shot at this site (Table 10). The results of the models indicate that a mallard has a 10 percent probability of ingesting a shot at levels of approximately 7 shot/ft^2.

4.8.2 Omnivorous Upland Birds

Probability models using site specific data were used to determine if mourning doves are at risk from ingesting shot at this site (Table 11). The results of the models indicate that a dove has a 10 percent probability of ingesting a shot at levels of approximately 9 shot/ft^2.

5.0 RISK CHARACTERIZATION

5.1 Assumptions

The following conservative assumptions were made to conduct the risk characterization:

- For direct toxicity, total lead (leachable and non leachable fraction)was used as the dose (the benchmarks are expressed in total lead).

- Mean body weight and mean ingestion rates were used when possible to estimate dose in food chain models.

- A biota to soil/sediment accumulation factor (BAF) of 0.39 was assumed for soil to terrestrial invertebrates. A BAF of 0.39 was chosen because it was the only BAF calculated using a population of earthworms that had greater than 80 percent survival.

- Contaminants in food items were assumed to be 100 percent bioavailable, and were not metabolized and/or excreted during the life of the receptor.

- Simplified diets were used for American robin and short-tailed shrew.

- A literature search was conducted to determine the chronic toxicity of lead in the food chain model. In addition, acute toxicity values for lead were also obtained from the literature if chronic values were not available. If no toxicity values could be located for the receptor species, values reported for a closely related species were used. Studies were critically reviewed to determine whether the study design and the methods used were appropriate. If values for chronic toxicity were not available, LD_{50} (median lethal dose) values were used. For the purposes of this risk assessment, a factor of 100 was used to convert the reported LD_{50} to a NOAEL. A factor of 10 was used to convert a reported LOAEL to a NOAEL. If several toxicity values were reported for a receptor species, the most conservative value was used. For the chronic toxicity endpoints, values obtained from long-term feeding studies were used in preference to those obtained from single dose oral studies. No other safety factors were incorporated into this risk assessment.

- In some cases, sediment, soil, and/or food ingestion rates were based on information for a similar species or calculated from an allometric equation. It was assumed that these estimated ingestion rates were representative of the true ingestion rates for the receptor species in question.

- For both the mallard and the mourning dove, it was assumed that the ingestion of one shot would be sufficient to cause a response.

- Because the initial weight of the soil sample was not recorded, it was assumed that the weight of a soil sample collected from a 12" x 12' x 1" plot would be 2.2 kg without shot. Therefore, the percent grit that is pellet is also based on weight.

- In some cases, toxicity values in the literature were reported as ppm contaminant in the diet. These were converted to daily intake (in milligrams per kilogram body weight per day; [mg/kg BW/day]) by using the following formula:

  Daily Intake (mg/kg/day) = Contaminant Dose (mg/kg diet) x Ingestion Rate (kg/day) x 1/BW (kg)

This conversion allowed dietary toxicity levels cited to be converted to a daily dose based on body weight.

5.2 Risk Characterization Methodology

A risk characterization was conducted by determining the NOAEL and LOAEL using site specific toxicity tests. For food chain models, an HQ was calculated by using a variety of exposure concentrations and comparing them to a TRV. For pellet ingestion, a probability model was used to determine risk. For this ecological risk assessment, we concluded that risk is unlikely if the HQ calculated from the assumptions presented and the NOAEL is equal to or less than one. If the HQ is equal to or exceeds one (using the assumptions presented and the LOAEL), we concluded that there are sufficient concentrations of lead present to pose risk. Concentrations of lead that fall between the NOAEL and the LOAEL have the potential to cause ecological risk.

5.3 Risk Characterization Results

5.3.1 Assessment Endpoint 1: Protection of plant community structure and function.

Direct contact with contaminated soil and sediment is the primary route of exposure for plants. Risk was evaluated by calculating the NOAEL and LOAEL based on the site specific toxicity test. The NOAEL and LOAEL were based on a response of reduced growth as measured by a reduction in mean plant height. The results of this determination indicate that levels below 759 mg/kg lead (NOAEL) are unlikely to cause adverse effects in plants. Concentrations of lead in soil above 1,030 mg/kg (LOAEL) are sufficient to pose a risk to plants.

5.3.2 Assessment endpoint 2: Protection of aquatic invertebrate community structure and function.

Direct contact with and ingestion of contaminated sediment and surface water are the primary routes of exposure for benthic macroinvertebrates. Risk was evaluated by calculating a NOAEL and a LOAEL from site specific toxicity tests using the amphipod (*Hyalella azteca*). The results of these determinations indicate that lead concentrations in sediment below 3,375 mg/kg (NOAEL) are unlikely to pose a risk to benthic macroinvertebrates. Because this was the largest concentration of lead in the sediment toxicity test, the concentration sufficient to pose a risk to benthic macroinvertebrates remains unknown.

5.3.3 Assessment endpoint 3: Protection of terrestrial invertebrate community structure and function.

Direct contact and ingestion of contaminated soil are the primary routes of exposure for terrestrial invertebrates. Risk was evaluated by calculating a NOAEL and a LOAEL from a site specific toxicity test using the earthworm. The results of these determinations indicate that concentrations of lead in soils below 310 mg/kg (NOAEL) are unlikely to pose a risk to terrestrial invertebrates. This endpoint is based on both survival and growth. However, lead concentrations in soils above 620 mg/kg (LOAEL) are sufficient to pose a risk to terrestrial invertebrates. It should be noted that this LOAEL is based on a lethal response by the worms (significantly reduced survival when compared to the control animals).

5.3.4 Assessment endpoint 4: Protection of insectivorous birds from direct toxicity or adverse effects on growth, survival and/or reproductive success from the ingestion of lead in soil or biota.

The ingestion of contaminated prey and the incidental ingestion of soil are the primary routes of exposure for insectivorous birds. A food chain accumulation model using the American robin was used to determine a NOAEL and a LOAEL. The results of the HQ calculation in the food chain models indicated that a concentration of lead in the soil below 130 mg/kg are unlikely to pose a risk to insectivorous birds. However, lead concentrations above 1,320 mg/kg are sufficient to pose a risk to insectivorous birds.

5.3.5 Assessment endpoint V: Protection of insectivorous mammals from adverse effects on growth, survival and/or reproductive success from ingestion of lead in soil or biota.

The ingestion of contaminated prey and the incidental ingestion of soil are the primary routes of exposure for insectivorous mammals. A food chain accumulation model using the short-tailed shrew was used to determine a NOAEL and a LOAEL. The results of the HQ calculation in the food chain models indicated that a concentration of lead in the soil below 42 mg/kg are unlikely to pose a risk to insectivorous mammals. However, lead concentrations above 421 mg/kg are sufficient to pose a risk to insectivorous mammals.

5.3.6 Assessment endpoint IV: Protection of waterfowl from direct toxicity or adverse effects on growth, survival and/or reproductive success from the direct ingestion of lead shot.

The mallard (*Anas platyrynchos*) was selected as a receptor for the lead shot ingestion pathway in wetland habitats. Risk was evaluated by determining the probability that a mallard will ingest a pellet from this site in its life time. The results indicate that levels of lead shot in the sediments greater than 7 pellets/ft^2 are sufficient to pose a risk to growth, survival, and/or reproductive success of waterfowl. This number is based on accepting a probability of 10 percent.

5.3.7 Assessment endpoint V: Protection of upland birds from adverse effects on growth, survival and/or reproductive success from ingestion of lead shot.

The mourning dove (*Zenaida macroura carolinensis*) was selected to represent an upland bird that may directly ingest lead shot. Risk was evaluated by determining the probability that a mourning dove will ingest a pellet from this site in its lifetime. The results indicate that levels of lead shot in the soils greater than 9 pellet/ft^2 are sufficient to pose a risk to growth, survival and/or reproductive success of upland bird species. This number is based on accepting a probability of 10 percent.

5.4 Sources of Uncertainty

There are factors inherent in the risk assessment process which contribute to uncertainty and must be considered when interpreting results. Major sources of uncertainty include natural variability, error, and insufficient knowledge.

Natural variability is an inherent characteristic of ecological receptors, their stressors, and their combined behavior in the environment. Biotic and abiotic parameters in these systems may vary to such a degree that the exposure to ecological receptors in two identical conceptual models may differ temporally and spatially. Factors that contribute to temporal and spatial variability may be differences in an individual organism's behavior (within the same species), changes in the weather or ambient temperature, unanticipated interference from other stressors, differences between microenvironments, stochasticity, and numerous other factors. Thus, the conservative nature of this risk assessment assumes that the highly variable environmental conditions and the behavior of organisms and their stressors are interacting in such a manner that allows the contaminants to move freely through the identified exposure pathways, and to produce the same effects identified in the exposure profile.

Uncertainty associated with natural variability also arises from the use of literature toxicity values in which a study has examined a single species/single contaminant system under highly controlled conditions. If conducted in a laboratory, these studies do not take into account the effects of the environmental factors and other stressors that are present in natural systems. These factors may have synergistic, antagonistic, or neutral effects upon the receptor-contaminant interaction. Point estimates of exposure such as NOAELs, LOAELs, LD_{50}s, and mathematical means which are presented in the literature also have an inherent variability that is by default incorporated into the risk assessment.

In addition, uncertainty associated with natural variability is introduced from the use of literature values for sediment, water and food ingestion rates, dietary compositions, and body weights. These values reported in the literature are from studies that may have been conducted at a certain time of year or in a certain location that does not necessarily give an accurate representation of the life histories of the species assessed at the site under consideration in the risk assessment.

Error may be introduced into the risk assessment through the use of invalid assumptions in the conceptual model. Conservative assumptions were made in light of the uncertainty associated with the risk assessment process (i.e., natural variability). Conservative assumptions were used to minimize the possibility of concluding that risk is not present when a threat actually does exist (i.e., the elimination of false negatives). For example, NOAELs used to calculate HQs were the lowest values found in the literature, regardless of toxic mechanism. While there is uncertainty associated with each conservative assumption used, this consistent selection process assures that the uncertainty associated with this type of error will err on the side of a protective outcome.

Literature values for the toxicity of lead were not available for all receptor species. An attempt was made to identify studies using closely related species to make risk estimates for the selected receptors. Species respond differently to exposure to toxicants; responses to lead by the indicator species may be different from species for which the toxicity data are reported.

A literature search was conducted to identify appropriate NOAELs and LOAELs for this risk assessment. The values used to calculate HQs were the lowest values found in the literature. In many of the studies reviewed, adverse effects were observed at the lowest exposure concentration. This made it impossible to identify appropriate NOAELs for some receptors. In these cases, a factor of 10 was used to convert the LOAEL to a NOAEL, which added uncertainty to the NOAEL-based calculations.

Doses in toxicological studies can be reported in units of mg contaminant/kg diet, or in units of mg contaminant/kg body weight/day. All doses reported as mg/kg in diet were converted to units of mg/kg BW/day. If body weights were reported for the test animals in a given study, these values were used for making this conversion. Otherwise, the body weight and ingestion rate for the species reported in other literature sources were used.

Another source of uncertainty arises from the use of toxicity values reported in the literature which are derived from single-species, single-contaminant laboratory studies. Prediction of ecosystem effects from laboratory studies is difficult. Laboratory studies cannot take into account the effects of environmental factors which may add to the effects of contaminant stress. NOAELs were generally selected from studies using single contaminant exposure scenarios.

There is very little information available in the literature regarding the rates of incidental soil/sediment ingestion for wildlife species. In this risk assessment, most of these values were based on estimates reported for species similar to the indicator species.

Exposure concentrations were calculated (daily intake as described previously) for each target receptor species based on levels of contaminants detected in site media, daily food ingestion rates, incidental soil/sediment ingestion rates, and body weight reported in the literature.

This risk assessment did not examine the contribution of dermal absorption, transfer across epithelial membranes, or inhalation exposure as part of the exposure pathway. In contrast to the use of conservative assumptions, the error introduced into this risk assessment by the omission of these routes of exposure may err on the side of a less protective outcome. The relative contribution of this error to alter the outcome of the risk assessment is unknown at this time.

Life history information and literature values for the toxicity of the contaminants of concern are not always available for all of the receptor species. By using closely related species, it is possible to make risk estimates. In reality, however, the information may vary substantially among species, thereby introducing another source of uncertainty.

The fact that we did not weigh the soil in the initial sampling event required that we estimate the soil weight and percent of soil that is grit for probability models. This uncertainty is minimized by the fact that soil weight was estimated using site soils and by using conservative assumptions in the probability models.

The fact that there was a significant decrease in survival at 80 mg/kg lead when compared to control after 28 days in the earthworm toxicity tests raises some uncertainty surrounding the growth and reproductive endpoints of this test. It also raises some uncertainty with the bioaccumlation of lead in the earthworm tissue.

The low survival at 28 days was attributed to low organic carbon and not attributed to lead. However, this artificial stressor in the test design may have affected the earthworm's responses causing a greater adverse response than may actually be occurring on site.

Using a 10 percent probability that birds will ingest lead pellets may over or underestimate the risk of birds ingesting lead pellets. However, given that this value is based on the probability of 1 bird ingesting lead in its life time it is unlikely that this uncertainty would lead to population effects.

6.0 CONCLUSIONS

The results of the samples collected from the skeet and trap range indicate that the site has been heavily contaminated with lead and lead shot. Results of the ecological risk assessment indicate that there is a risk to every receptor group modeled except for aquatic invertebrates. Because this site may be dry for long periods of time, the Preliminary Remediation Goals (PRGs) were developed to be protective of all species, without designating separate soils and sediment cleanup values.

The lowest LOAEL of 421 mg/kg, based on a comparison of the toxicity tests and the food chain accumulation models indicate that this is an acceptable upper bound PRG for this site (Table 12). The highest NOAEL above the lowest LOAEL was found in the earthworm toxicity test at 310 mg/kg lead. Therefore, this value is an acceptable lower bound PRG for this site.

In addition to the impacts of lead in soil and sediment, probability models were run to determine the risk to aquatic and avian receptors from the ingestion of lead shot. Accepting an ingestion probability of 0.10, the range of PRGs for lead shot was established at between 7 and 9 pellets/ft^2 for the protection of both terrestrial birds and waterfowl (Table 13).

7.0 REFERENCES

American Society for Testing and Materials (ASTM). 1998a Standard guide for conducting laboratory soil toxicity or bioaccumulation tests with the lumbricid earthworm *Eisenia fetida* E1876-97. Annual book of ASTM Standards. Volume 11.05, ASTM West Conshohoken, PA.

American Society for Testing and Materials (ASTM). 1998b Standard guide for conducting early seedling growth tests E-1598-94. Annual Book of ASTM standards. Volume 11.05, ASTM West Conshohoken, PA.

Chasko, G.G., T.R. Hoehn., and P. Howell-Heller, 1984. Toxicity of lead shot to wild black ducks and mallards fed natural foods. *Bulletin of Environmental Contamination and Toxicology* 32:417-428.

EnviroSystems, Inc. 2001. Evaluation of Toxicity of Soil Samples to the Rye Grass, Lolium perenne. Prime Hook NWR., Reference Number USFWS9711-01-08.

Harding Engineering and Environmental Services (Harding ESE). 2001. Preliminary Assessment - Site Investigation Shotgun Range. Prime Hook National Wildlife Refuge. Milton, DE. Task Order 00-Y025.

McConnell, C.A. 1967. Experimental lead poisoning of bobwhite quail and mourning doves. *Proc. Ann. Conf. Southeast Assoc.* Game Fish Comm. 21:208-219.

Murphy, Daniel R., 1999 Prime Hook National Wildlife Refuge lead shot survey, Publication No. CBFO-C99-02, U.S. Fish and Wildlife Service, Annapolis, MD.

Peddicord, R.K. and J.S. LaKind. 2000. Ecological and Human Health Risks at an Outdoor Firing Range. *Environmental Toxicology and Chemistry* 19(10)2602-2613.

Soeder, D.J. and C.V. Miller, 2003. "Ground -water Contamination From Lead Shot at Prime Hook National Wildlife Refuge, Sussex County, Delaware" USGS Water-Resources Investigations Report)2-4282.

U.S. Environmental Protection Agency (EPA). 1989. Protocol for short term toxicity screening of hazardous waste sites. EPA Washington, DC.

U.S. Environmental Protection Agency (EPA). 1997. Ecological Risk Assessment Guidance for Superfund: Process for designing and conducting Ecological Risk Assessments, Interim Final, US EPA, Edison, NJ.

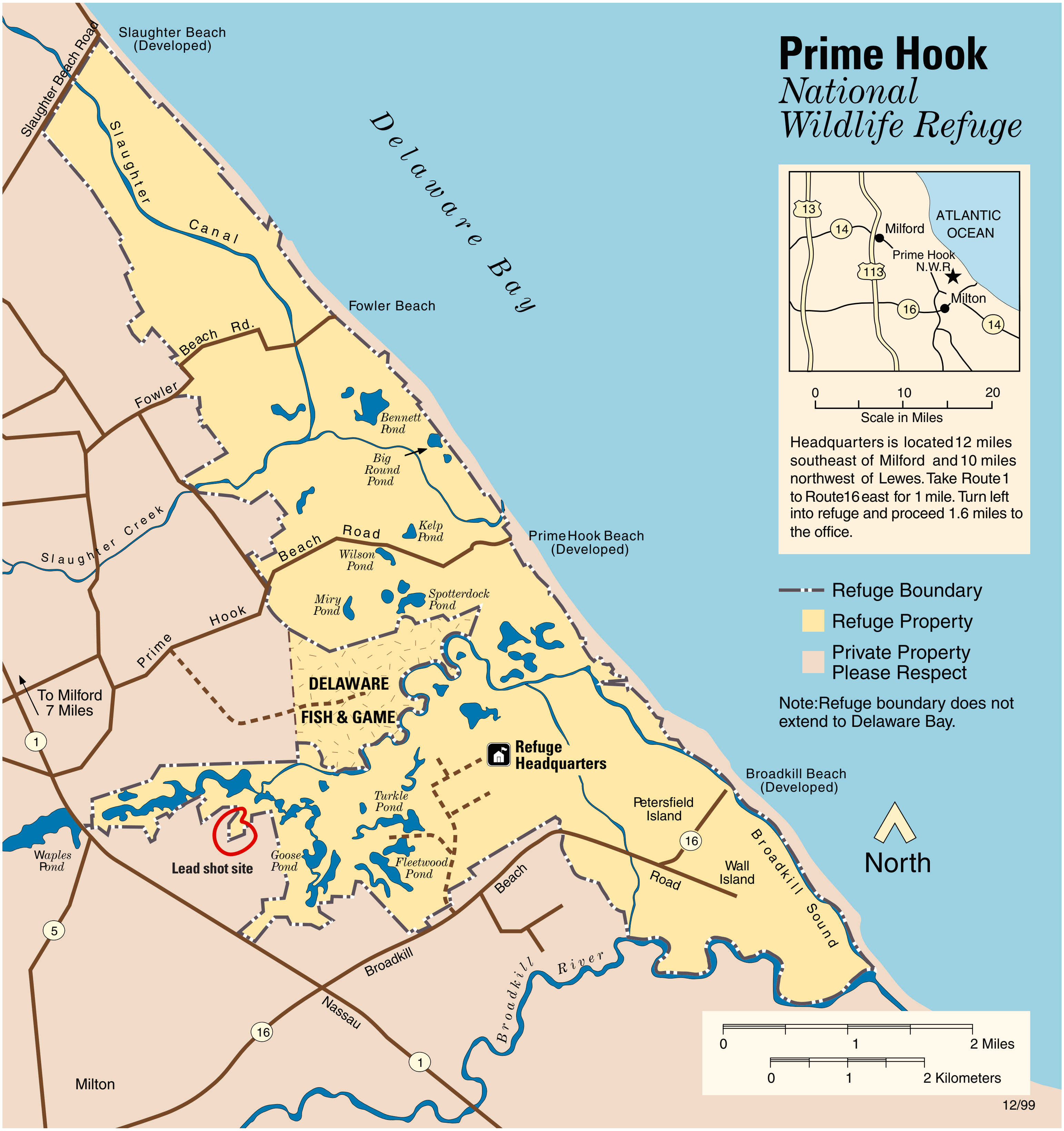
U.S. Environmental Protection Agency (EPA). 1999. National recommended water quality criteria - correction. U.S. EPA, Office of Water, Washington, DC. EPA 822-Z-99-001.

U.S. Environmental Protection Agency (EPA). 2000. Methods for measuring the toxicity and bioaccumulation of sediment associated contaminants with freshwater invertebrates. Second ed.
EPA /600/R-99/064. U.S. Environmental Protection Agency, Deluth, MN. 192 pp.

U.S. Fish and Wildlife Service (FWS). 2001. Results of water sampling analysis. ECDMS Analytical Report 7/9/01.

University of Maryland. 2001. Toxicity of Sediment Samples from Prime Hook Wildlife Refuge, Delaware using the freshwater amphipod, *Hyalella azteca* 10-d whole sediment survival and growth test. Wye Research and Education Center, Queenstown, MD.

Figure 1.
Map of Prime Hook National Wildlife Refuge
showing the location of the lead shot site.


Prime Hook
National Wildlife Refuge
ATLANTIC OCEAN
Milford
Prime Hook N.W.R.
Milton
13
14
113
16
14
0
10
20
Scale in Miles
Headquarters is located 12 miles southeast of Milford and 10 miles northwest of Lewes. Take Route 1 to Route 16 east for 1 mile. Turn left into refuge and proceed 1.6 miles to the office.
Refuge Boundary
Refuge Property
Private Property Please Respect
Note: Refuge boundary does not extend to Delaware Bay.
Delaware Bay
Slaughter Beach (Developed)
Slaughter Beach Road
Slaughter Canal
Fowler Beach
Beach Rd.
Fowler
Bennett Pond
Big Round Pond
Slaughter Creek
Beach Road
Kelp Pond
Wilson Pond
Prime Hook Beach (Developed)
Miry Pond
Spotterdock Pond
Prime Hook
To Milford 7 Miles
DELAWARE FISH & GAME
Refuge Headquarters
Broadkill Beach (Developed)
Turkle Pond
Petersfield Island
Waples Pond
Lead shot site
Goose Pond
Fleetwood Pond
Beach
Road
Wall Island
Broadkill Sound
North
Broadkill
Broadkill River
Nassau
Milton
1
5
16
16
1
0
1
2 Miles
0
1
2 Kilometers
12/99

Tables

Table 1. Results of lead and lead shot in surface soil samples

Location	Depth	Total Lead Pellets	Total Steel Pellets	Total Shot Pellets	Total Lead (mg/kg)
0D - 100L	0 - 1 "	0	0	0	83
0D - 150L	0 - 1 "	0	0	0	13
0D - 200L	0 - 1 "	0	0	0	63
50D - 100L	0 - 1 "	58	0	58	160
50D - 150L	0 - 1 "	0	0	0	62
50D - 200L	0 - 1 "	0	0	0	14
50D - 200L (D)	0 - 1 "	0	0	0	n/a
50D - 250L	0 - 1 "	0	0	0	26
100D - 250R	0 - 1 "	0	0	0	11
100D - 200R	0 - 1 "	0	0	0	18
100D - 150R	0 - 1 "	1	0	1	18
100D - 100R	0 - 1 "	68	0	68	5100
100D - 100R (D)	0 - 1 "	n/a	n/a	n/a	4300
100D - 50R	0 - 1 "	2751	2	2753	4700
100D - 50R (D)	0 - 1 "	n/a	n/a	n/a	7000
100D - 100L	0 - 1 "	1	0	1	22
100D - 150L	0 - 1 "	0	0	0	16
100D - 200L	0 - 1 "	0	0	0	14
100D - 250L	0 - 1 "	0	0	0	12
100D - 300L	0 - 1 "	0	0	0	n/a
150D - 300R	0 - 1 "	0	0	0	n/a
150D - 100R	0 - 1 "	1252	0	1252	21000
150D - 50R	0 - 1 "	8647	4	8651	3100
150D - 0	0 - 1 "	68564	0	68564	5100
150D - 0 (D)	0 - 1 "	n/a	n/a	n/a	5000
150D - 50L	0 - 1 "	3590	0	3590	22000
150D - 125L	0 - 1 "	5	0	5	7300
150D - 150L	0 - 1 "	0	0	0	47
150D - 250L	0 - 1 "	0	0	0	34
150D - 300L	0 - 1 "	0	0	0	n/a
200D - 250R	0 - 1 "	0	0	0	9
250D - 150R	0 - 1 "	0	0	0	81
250D - 100R	0 - 1 "	0	0	0	59
300D - 100L	0 - 1 "	0	0	0	5

(D) indicates a duplicate analysis

Table 2. Results of lead and lead shot in subsurface soil samples

Location	Total Lead Pellets*	Total Lead (mg/kg)
100D - 100R	0	120
100D - 100R	0	7
100D - 100R	0	29
100D - 50R	0	210
100D - 50R	0	5
100D - 50R	0	2
150D - 150R	0	5
150D - 150R	0	2
150D - 150R	0	2
50D - 100L	0	27
50D - 100L	0	5
50D - 100L	0	27
150D - 100R	0	510
150D - 100R	0	28
150D - 100R	0	8
150D - 50R	0	270
150D - 50R	0	10
150D - 50R	0	4
150D - 50L	0	180
150D - 50L	0	180
150D - 50L	0	4
150D - 0	34	1300
150D - 0	0	81
150D - 0	0	33

* no steel pellets found at depth

Table 3. Results of lead contaminated sediment and shot in surface samples

Location	Depth	Total Lead Pellets*	Total Lead (mg/kg)
0D - 250L	0 - 1"	0	53
100D - 300R	0 - 1"	0	n/a
150D - 250R	0 - 1"	0	26
150D - 200R	0 - 1"	1	110
150D - 150R	0 - 1"	4	47
150D - 100L	0 - 1"	258	n/a
150D - 200L	0 - 1"	0	350
175D - 0	0 - 1"	29541	2900
175D - 50L	0 - 1"	682	100000
200D - 200R	0 - 1"	0	40
200D - 150R	0 - 1"	0	81
200D - 125R	0 - 1"	0	280
200D - 100R	0 - 1"	9	4700
200D - 50R	0 - 1"	19	2600
200D - 50R	0 - 1"	23	n/a
200D - 0	0 - 1"	77	29000
200D - 0	0 - 1"	n/a	130
200D - 50L	0 - 1"	0	3600
200D - 50L	0 - 1"	1	1800
200D - 100L	0 - 1"	8	2000
200D - 150L	0 - 1"	0	250
200D - 200L	0 - 1"	0	260
200D - 200L DUP	0 - 1"	Not Reqd	280
200D - 200L	0 - 1"	0	n/a
200D - 250L	0 - 1"	0	710
200D - 250L DUP	0 - 1"	Not Reqd	150
200D - 250L	0 - 1"	0	n/a
200D - 250L	0 - 1"	24	n/a
225D - 0	0 - 1"	0	140
250D - 200R	0 - 1"	0	n/a
250D - 50R	0 - 1"	0	22
250D - 0	0 - 1"	0	58
250D - 50L	0 - 1"	0	37
250D - 100L	0 - 1"	0	190
250D - 150L	0 - 1"	0	170
250D - 200L	0 - 1"	0	170
300D - 100R	0 - 1"	0	n/a
300D - 50R	0 - 1"	0	n/a
300D - 0	0 - 1"	0	n/a
300D - 50L	0 - 1"	0	n/a

* no steel pellets found in surface samples

Table 4. Results of lead contaminated sediment and shot in subsurface samples

Sample Station	Depth	Total Lead Pellets*	Total Lead (mg/kg)
200D - 50R	12"	0	990
200D - 50R	12"	0	1,000
200D - 50R	24"	0	56
175D - 0	12"	0	360
175D - 0	12"	0	20
175D - 0	24"	0	12
200D - 0	12"	0	5,400
200D - 0	12"	0	9
200D - 0	24"	0	10

* no steel pellets found in subsurface samples

Table 5. Summary of *Eisenia foetida* toxicity and bioaccumulation test.

	Soil Lead Conc. (mg/kg)	14-Day Survival (%)	28-Day Survival (%)	Mean Weight at 28-days (g/worm)	Earthworm Tissue Concentration				Lead BAF
					Antimony (mg/kg)	Arsenic (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	
Artificial Soil Control	NA	97	94	0.201	-	-	-	-	-
Compost Control	NA	98	98	0.263	-	-	-	-	-
250D 150R (Ref.)	35	90	42 a	0.155a	<1.0	2.3	2.7	300	8.57
50D 100L	80	81	46 a	0.127 b	<1.0	3.2	3.1	330	4.13
100D 50R	310	96	84	0.189	<1.0	1.1	2.1	120	0.39*
150D 100L	620	38	14 b	0.109 b	<1.0	2.2	2.5	270	0.44
150D 50L (0.5)	2,500	13	1b,c	0.082	-	-	-	-	-
150D 50L (1.0)	4,200	23	0 b,c	n/a	<17	<17	<17	1,700	0.44

a - Statistically different (lower) than the control samples ($P<0.05$)
b - Statistically different (lower) than the reference based on a single pair-wise comparison ($P<0.05$)
c - Statistically different (lower) than the reference based on a multiple comparison ($P<0.05$)
BAF -Biota-soil accumulation factor
* 0.39 used as BAF for model calculations
NA = not analyzed in this study. Expected to be low.

Table 6. Results of the 28-day toxicity test using rye grass, *Lolium perenne*

Location	Lead Soil Lead (mg/kg)	Mean Germination (%)	Mean Survival (%)	Mean Height (mm)	Mean AGDW (mg/plant)	Mean BGDW (mg/plant)
lab control	NA	95	95	213.8	7.8515	2.1165
PHDRY02 (REF)	15	75	93	182.0	5.8740	2.5792
PHDRY03	162	85	100	193.8	6.5088	1.5030
PHDRY08	350	90	100	171.8	4.4658*	6.4598
PHDRY06	505	100	95	169.8	6.1130	1.7478
PHDRY05	759	100	95	166.8	5.3945	2.8275
PHDRY10	1030	100	96	146.3*	4.8392	4.0088
PHDRY09	1779	100	100	129.8*	3.4498*	10.8785

*statisticaly different from reference ($P<0.05$)
AGDW - Above ground dry weight
BGDW - Below ground dry weight
NA = not analyzed for this study but expected to be low

Table 7. Results of the 10-day toxicity test using the freshwater amphipod, *Hyalella azteca*

Location	Sediment Lead (mg/kg)	Mean Survival (%)	Mean Weight (mg)
Lab Control	105	82.5	0.082
PHSBHA01 (ref)	17.5	90.0	0.073
PHSBHA02	837	88.8	0.098
PHSBHA03	3375	87.5	0.098
PHSBHA04	216	85.0	0.104
PHSBHA07	165	78.8	0.114
PHSBHA09	101	86.3	0.104

Table 8. NOAEL Hazard Quotient calculations for the American Robin

Lead Conc. in Soil* (mg/kg)	Soil Ingestion Rate (kg/day)	Lead Bioaccumulation Factor (BAF)	Lead Concentration in Worms[a] (mg/kg)	Food Ingestion Rate[b] (kg/day)	Area Use Factor[c]	Body Weight[d] (kg)	Dose (mg/kg BW/day)	TRV (NOAEL) (mg/kg BW/day)	HQ
30	0.0009	0.39	12	0.0087	0.22	0.083	0.3	1.5	0.2
100	0.0009	0.39	39	0.0087	0.22	0.083	1.0	1.5	0.7
150	0.0009	0.39	59	0.0087	0.22	0.083	1.5	1.5	1.0
200	0.0009	0.39	78	0.0087	0.22	0.083	2.0	1.5	1.3
250	0.0009	0.39	98	0.0087	0.22	0.083	2.5	1.5	1.6
400	0.0009	0.39	156	0.0087	0.22	0.083	4.0	1.5	2.6
500	0.0009	0.39	195	0.0087	0.22	0.083	4.9	1.5	3.3
750	0.0009	0.39	293	0.0087	0.22	0.083	7.4	1.5	4.9
1000	0.0009	0.39	390	0.0087	0.22	0.083	9.9	1.5	6.6

Notes:

For complete receptor life history and exposure profile see Appendix B.

* Concentrations represent a Site gradient and are not actual site sample lead concentrations

(a) the lead concentration in worms = the concentration of lead detected in the soil times the BAF (0.39) was not actual measured concetrations in earthworm.

(b) FIR = Food Ingestion Rate, an average adult robin can consume up to 8.7 grams of food per day (Levey and Karasov 1989).

(c)AUF = Area Use Factor. An AUF of 0.22 was used in these calculations see Appendix A

(d) A mean body weight (83 g) (U.S. EPA 1993) is used in the dose calculation.

Dose = [(Conc. in soil)(SIR)+(Conc. in Worms)(FIR)/Body Weight] x (AUF).

BW = Body Weight.

TRV = Toxicity Reference Value (Edens et al. 1976, see appendix C)

HQ = Hazard Quotient (Dose/TRV).

BAF =Bioaccumulation factor from earthworm toxicity test.

Table 9. LOAEL Hazard Quotient Calculations for the American Robin

Lead Conc. in Soil (mg/kg)	Soil Ingestion Rate (kg/day)	Lead Bioaccumulation Factor	Lead Concentration in Worms[a] (mg/kg)	Food Ingestion Rate[b] (kg/day)	Area Use Factor[c]	Body Weight[d] (kg)	Dose (mg/kg BW/day)	TRV (LOAEL) (mg/kg BW/day)	HQ
50	0.0009	0.39	20	0.0087	0.2	0.083	0.5	15.0	0.0
100	0.0009	0.39	39	0.0087	0.2	0.083	1.0	15.0	0.1
150	0.0009	0.39	59	0.0087	0.2	0.083	1.5	15.0	0.1
200	0.0009	0.39	78	0.0087	0.2	0.083	2.0	15.0	0.1
250	0.0009	0.39	98	0.0087	0.2	0.083	2.5	15.0	0.2
400	0.0009	0.39	156	0.0087	0.2	0.083	4.0	15.0	0.3
500	0.0009	0.39	195	0.0087	0.2	0.083	4.9	15.0	0.3
750	0.0009	0.39	293	0.0087	0.2	0.083	7.4	15.0	0.5
1500	0.0009	0.39	585	0.0087	0.2	0.083	14.8	15.0	1.0

Notes:
For complete receptor life history and exposure profile see Appendix B.
* Concentrations represent a Site gradient and are not actual site sample lead concentrations
(a) the lead concentration in worms = the concentration of lead detected in the soil times the BAF (0.39) was not actual measured concetrations in earthworm.
(b) FIR = Food Ingestion Rate, an average adult robin can consume up to 8.7 grams of food per day (Levey and Karasov 1989).
(c)AUF = Area Use Factor. An AUF of 0.22 was used in these calculations see Appendix A
(d) A mean body weight (83 g) (U.S. EPA 1993) is used in the dose calculation.
Dose = [(Conc. in soil)(SIR)+(Conc. in Worms)(FIR)/Body Weight] x (AUF).
BW = Body Weight.
TRV = Toxicity Reference Value (Edens et al. 1976, see appendix C)
HQ = Hazard Quotient (Dose/TRV).
BAF =Bioaccumulation factor from earthworm toxicity test.

Table 10. NOAEL Hazard Quotient Calculations for the Short-Tailed Shrew

Location	Lead Conc. in Soil (mg/kg)	Soil Ingestion Rate (kg/day)	Lead Bioaccumulation Factor	Lead Concentration in Worms (mg/kg)	Food Ingetion Rate (kg/day)	Area Use Factor	Body Weight (kg)	Dose (mg/kg BW/day)	TRV (NOAEL) (mg/kg BW/day)	HQ
	40	0.00074	0.39	16	0.00795	1.0	0.021	7.3	7.7	1.0
	100	0.00074	0.39	39	0.00795	1.0	0.021	18.3	7.7	2.4
	150	0.00074	0.39	59	0.00795	1.0	0.021	27.4	7	3.9
	200	0.00074	0.39	78	0.00795	1.0	0.021	36.6	0.77	47.5
	250	0.00074	0.39	98	0.00795	1.0	0.021	45.7	0.77	59.4
	400	0.00074	0.39	156	0.00795	1.0	0.021	73.2	0.77	95.0
	500	0.00074	0.39	195	0.00795	1.0	0.021	91.4	0.77	118.8
	750	0.00074	0.39	293	0.00795	1.0	0.021	137.2	0.77	178.1
	1000	0.00074	0.39	390	0.00795	1.0	0.021	182.9	0.77	237.5

Notes:
For complete receptor life history and exposure profile see Appendix B.
(a) The lead concentration in worms = The concentration detected in soil times the BAF calculated in the 28 day earthworm toxicity test.
(b) FIR = Food Ingestion Rate (U.S. EPA 1993).
(c) AUF = Area Use Factor. A conservative AUF of 1 was used in these calculations.
(d) Adult short-tailed shrews weigh from 12 to 30 grams (Jones and Birney 1988; Merritt 1987).
Dose = [(Concentration in worms)(FIR)/Body Weight] x (AUF).
TRV = Toxicity Reference Value
BW = Body Weight.
HQ = Hazard Quotient (Dose/TRV).

Table 11. loaeLHazard Quotient Calculations for the Short-Tailed Shrew

Lead Conc. in Soil* (mg/kg)	Soil Ingestion Rate (kg/day)	Lead Bioaccumulation Factor	Estimated Lead Concentration in Worms (mg/kg)	Food Ingestion Rate (kg/day)	Area Use Factor	Body Weight (kg)	Dose (mg/kg BW/day)	TRV (LOAEL) (mg/kg BW/day)	HQ
50	0.00074	0.39	20	0.00795	1.0	0.021	9.1	77	0.1
100	0.00074	0.39	39	0.00795	1.0	0.021	18.3	77	0.2
150	0.00074	0.39	59	0.00795	1.0	0.021	27.4	77	0.4
200	0.00074	0.39	78	0.00795	1.0	0.021	36.6	77	0.5
250	0.00074	0.39	98	0.00795	1.0	0.021	45.7	77	0.6
400	0.00074	0.39	156	0.00795	1.0	0.021	73.2	77	1.0
500	0.00074	0.39	195	0.00795	1.0	0.021	91.4	77	1.2
750	0.00074	0.39	293	0.00795	1.0	0.021	137.2	77	1.8
1000	0.00074	0.39	390	0.00795	1.0	0.021	182.9	77	2.4

Notes:

For complete receptor life history and exposure profile see Appendix B.

(a) The lead concentration in worms = The concentration detected in soil times the BAF calculated in the 28 day earthworm toxicity test.

(b) FIR = Food Ingestion Rate (U.S. EPA 1993).

(c) AUF = Area Use Factor. A conservative AUF of 1 was used in these calculations.

(d) Adult short-tailed shrews weigh from 12 to 30 grams (Jones and Birney 1988; Merritt 1987).

Dose = [(Concentration in worms)(FIR)/Body Weight] x (AUF).

TRV = Toxicity Reference Value

BW = Body Weight.

HQ = Hazard Quotient (Dose/TRV).

Table 12. Probability of a Mallard Ingesting Shot

Receptor	Number of Pellets	Number of Pellets (log)	Percent Grit that is Pellet (Ps)	Area Use Factor (AUF) (S)	Percent Grit*AUF (P)	Lifespan (Y)	Foraging days per Year (De)	Shot Retention (Dp)	Number of Particles Selected (N)	Probability
Mallard	6	0.778	0.003	1	0.003	1.47	245	21	17.15	0.05
	7	**0.813**	**0.006**	**1**	**0.006**	**1.47**	**245**	**21**	**17.15**	**0.10**
	8	0.903	0.014	1	0.014	1.47	245	21	17.15	0.22
	10	1.000	0.023	1	0.023	1.47	245	21	17.15	0.32
	11	1.041	0.026	1	0.026	1.47	245	21	17.15	0.37
	100	2.000	0.111	1	0.111	1.47	245	21	17.15	0.87
	1500	3.176	0.215	1	0.215	1.47	245	21	17.15	0.98
	50000	4.699	0.350	1	0.350	1.47	245	21	17.15	1.00
	65000	4.813	0.360	1	0.360	1.47	245	21	17.15	1.00

Table 13. Probability of a Dove Ingesting Shot

Receptor	Number of Pellets	Number of Pellets (log)	Percent Grit that is Pellet (Ps)	Area Use Factor (AUF) (S)	Percent Grit*AUF (P)	Lifespan (Y)	Foraging days per Year (De)	Shot Retention (Dp)	Number of Particles Selected (N)	Probability
Dove	6	0.778	0.003	0.11	0.000	1.5	245	6	61.25	0.02
	7	0.813	0.006	0.11	0.001	1.5	245	6	61.25	0.04
	8	0.903	0.014	0.11	0.002	1.5	245	6	61.25	0.09
	9	**0.929**	**0.016**	**0.11**	**0.002**	**1.5**	**245**	**6**	**61.25**	**0.10**
	11	1.041	0.026	0.11	0.003	1.5	245	6	61.25	0.16
	100	2.000	0.111	0.11	0.012	1.5	245	6	61.25	0.53
	1500	3.176	0.215	0.11	0.024	1.5	245	6	61.25	0.77
	50000	4.699	0.350	0.11	0.038	1.5	245	6	61.25	0.91
	65000	4.813	0.360	0.11	0.040	1.47	245	6	60.025	0.91

Table 14. Preliminary Remediation Goal (PRG) Based on Soil Lead Concentration

Assessment Endpoint	Measurement Endpoint	NOAEL (mg/kg)	LOAEL (mg/kg)
Terrestrial plants	Rye grass	759	1030
Terrestrial invertebrates	Earthworm	310	620
Avian insectivore	American Robin	30	1500
Terrestrial insectivore	Short-tailed Shrew	40	**421**

Remedial Goal Option - The lowest LOAEL of the data set

Table 15. Preliminary Remediation Goal (PRG) Based on Lead Shot Ingestion

		No. of Shot/Ft^2
Terrestrial omnivore	Mourning dove	9
Aquatic omnivore	Mallard duck	7

Remedial Goal Option - 10 percent probability that any in

Appendix A
Bird Monitoring Results, USFWS 2001

Prime Hook NWR Pb-Shot Site Bird Monitoring Results - 2001

Bimonthly point count surveys were performed from May to September at three stations (A, B, & C) located within a 12-acre area containing 1 lead shot pellet per square foot or greater. This area is characterized as a forested wetland. Point A is in upland forest, point B at upland/water interface and point C is located in a wetland forest. Data from 9 conducted surveys recorded 34 bird species using the area, and 85 % of the birds using the lead shot area were passerines (See attached Survey Species List). Listed birds were identified as (S) = Summer Resident (on refuge from April to October) or (R) = 12-month-long resident on refuge. Approximately 74% of all bird species recorded were identified by sound, which implies mostly adult males were recorded. Only 2 independent recordings of juvenile birds were noted in field survey sheets, both on 06/12/01. {Site A - 2 prothonotary warblers (PROW) and on Site C - 2 gray catbirds (GRCA)}.

The main focus of this monitoring was avian species, however any reptile, amphibian, or mammal sightings were also noted. White-tailed deer were the only non-avian species observed using the lead shot study site. Results were used to calculate area use factors as part of an ecological risk assessment (ERA) for the site.

Species List and Bird Numbers Per Survey Date Per Site Summary

---

05/07/01	**Site A**
OVEN	1
GCFL	1
WOTH	1
REVI	1
COYE	1
CARW	1
RBWO	1
WITU	1
COGR	1
HAWO	1
Total = 10 species	10 Birds

05/07/01	**Site B**
NOCA	2
WOTH	1
OVEN	1
COYE	1
PROW	1
REVI	1
RBWO	1
Total = 7 species	8 Birds

05/07/01	**Site C**
WITU	1
GCFL	1
AMCR	1
OVEN	1
CAGO	1
CARW	1
GTBH	1

BWWA	1
EATO	1
Totals = 9 Species	9 Birds

05/24/01	**Site A**
WITU	1
REVI	2
WOTH	1
GRCA	1
BRTH	1
OVEN	2
GCFL	1
PROW	2
ETTI	1
AMRO	1
CARW	1
DOWO	1
EATO	1
NOCA	1
SCTA	1
AMCR	2
BLJA	1
RBWO	1
Totals = 18 species	23 Birds

05/24/01	**Site B**
GCFL	1
AMRO	1
WOTH	2
PROW	3
OVEN	1
REVI	1
EATO	1
CARW	1
NOCA	1
AMCR	1
Totals = 10 species	15 Birds

05/24/01	**Site C**
CARW	1
WOTH	2
REVI	1
BRTH	1
ACFL	1
Totals 5 species	6 Birds

06/12/01	**Site A**
AMCR	3
WOTH	2
GCFL	1
BRTH	1
REVI	1

OVEN	1
ETTI	2
YBCH	1
BGGN	1
CARW	2
PROW	4
EAWP	1
FISP	1
EATO	1
Totals 14 species	23 Birds

06/12/01	**Site B**
OVEN	1
WOTH	1
REVI	1
RBWO	1
GCFL	1
NOFL	1
SCTA	1
BRTH	1
ETTI	1
PROW	1
WITU	1
Totals = 11 Species	11 Birds

06/12/01	**Site C**
BRTH	1
WOTH	1
AMRO	1
GCFL	1
WITU	1
YBCH	1
REVI	1
GRCA	2
CARW	1
Totals = 9 Species	10 Birds

06/26/01	**Site A**
REVI	2
AMCR	1
RWBL	1
SCTA	1
WOTH	1
CARW	1
ETTI	1
EAWP	1
NOCA	1
Totals = 9 species	10 Birds

06/26/01	**Site B**
OVEN	1
GCFL	1
PROW	1

NOCA	1
CARW	1
WOTH	1
REVI	1
Totals = 7 species	7 Birds

06/26/01	**Site C**
OVEN	1
REVI	1
NOCA	1
CARW	1
WOTH	1
WEVI	1
Totals = 6 species	6 Birds

07/16/01	**Site A**
SCTA	1
REVI	2
NOCA	1
EAWP	1
ETTI	1
CARW	1
BLJA	1
WOTH	1
Totals = 8 species	9 birds

07/16/01	**Site B**
WOTH	1
REVI	1
COYE	1
NOFL	1
RWBL	1
WEVI	1
EATO	1
CARW	1
DOWO	1
Totals = 9 species	9 birds

07/16/01	**Site C**
WEVI	1
YBCU	1
COYE	1
AMGO	1
MODO	1
AMCR	1
Totals = 6 species	6 birds

08/01/01	**Site A**
RBWO	1
CARW	3
NOFL	1
AMCR	1
YBCU	1

BLJA	1
REVI	1
ETTI	2
Totals = 8 species	11 birds

08/01/01	**Site B**
BLJA	1
AMGO	1
DOWO	1
Totals = 3 species	3 birds

08/01/01	**Site C**
AMCR	1
NOCA	1
CARW	3
YBCU	1
RBWO	1
AMGO	1
GRCA	1
WOTH	1
Totals = 8 species	10 birds

08/21/01	**Site A**
CARW	2
BLJA	2
REVI	1
EAWP	1
GCFL	1
Totals = 5 species	7 birds

08/21/01

	Site B
CAWR	2
AMCR	2
REVI	1
EATO	1
RBWO	1
AMRO	1
GRCA	1
Totals = 7 spcies	9 birds

08/21/01	**Site C**
AMCR	1
WEVI	1
RTHU	1
AMGO	1
EABL	1
Totals = 5 species	5 birds

09/10/01	**Site A**
EAWP	1
RBWO	1
COGR	1
BLJA	1

CAWR	1
Totals = 5 species	5 birds

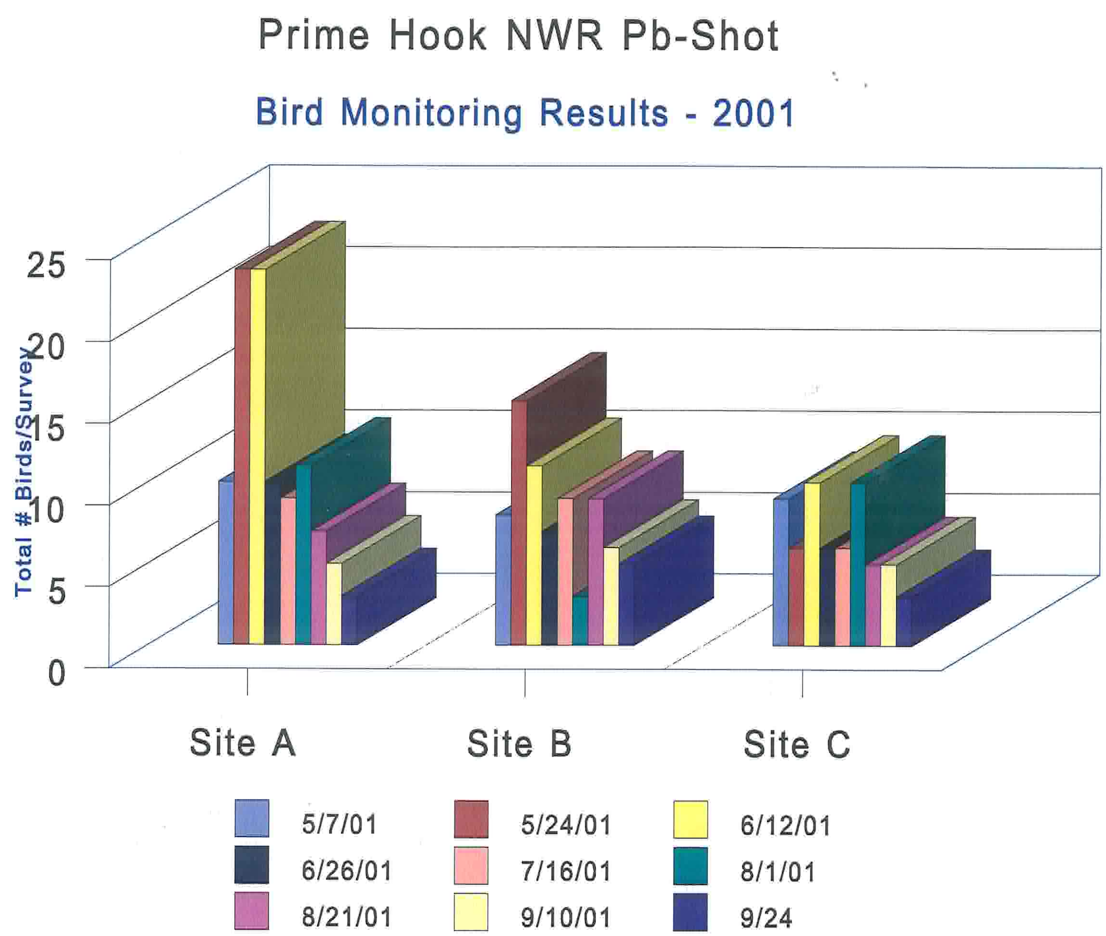
09/10/01	**Site B**
RBWO	1
EATO	1
MODO	1
GRCA	1
CAWR	1
ETTI	1
Totals = 6 species	6 birds

09/10/01	**Site C**
RBWO	1
AMCR	1
WEVI	1
ETTI	1
CARW	1
Totals = 5 species	5 birds

09/24/01	**Site A**
BLJA	1
CAWR	1
EASO	1
Totals = 3 species	3 birds

09/24/01	**Site B**
NOFL	1
CARW	1
COGR	1
DOWO	1
GRCA	1
Totals = 5 species	5 birds

09/24/01	**Site C**
NOFL	1
CARW	1
COGR	1
Totals = 3 species	3 birds


Prime Hook NWR Pb-Shot
Bird Monitoring Results - 2001
Total # Birds/Survey
25
20
15
10
5
0
Site A
Site B
Site C
5/7/01
5/24/01
6/12/01
6/26/01
7/16/01
8/1/01
8/21/01
9/10/01
9/24

PRIME HOOK NWR LEAD SHOT SITE BIRD MONITORING RESULTS - 2001

Species List For Survey Data For All Three Sites (A, B, & C)

CODE	Common Name	Scientific Name	Summer (S) or Year Round Resident (R)
1) WITU	Wild Turkey	*Meleagris gallopavo*	R
2) REVI	Red-eyed Vireo	*Vireo olivaceus*	S
3) WOTH	Wood-thrush	*Hylocichla mustelina*	S
4) GRCA	Gray Catbird	*Dumetella carolinensis*	S
5) BRTH	Brown-thrasher	*Toxostoma rufum*	S
6) OVEN	Ovenbird	*Seiurus aurocapillus*	S
7) GCFL	Great-crested Flycatcher	*Myiarchus crinitus*	S
8) PROW	Prothonary Warbler	*Protnotaria citrea*	S
9) ETTI	Eastern Tufted Titmouse	*Baeolophus bicolor*	R
10 AMRO	American Robin	*Turdus migratorius*	R
11 CARW	Carolina Wren	*Thryothorus ludovicianus*	R
12 DOWO	Downy Woodpecker	*Picoides pubescens*	R
13 EATO	Eastern Towhee	*Pipilo erythrophthalmus*	S
14 NOCA	Northern Cardinal	*Cardinalis cardlnalis*	R
15 SCTA	Scarlet Tanager	*Piranga olivacea*	S
16 AMCR	American Crow	*Corvus brachyrhynchos*	R
17 BLJA	Blue Jay	*Cyanocitta cristata*	R
18 RBWO	Red-bellied woodpecker	*Melanerpes carolinus*	R
19 ACFL	Acadian Flycatcher	*Empidonax virescens*	S
20 HAWO	Hairy Woodpecker	*Picoides villosus*	R
21 BWWA	Blue-winged warbler	*Vermivora pinus*	S
22 YBCH	Yellow-breasted Chat	*Icteria virens*	S
23 BGGN	Blue-gray Gnatcatcher	*Polioptila caerulea*	S
24 EAWP	Eastern Wood-Pewee	*Contopus virens*	S
25 FISP	Field Sparrow	*Spizella pusilla*	R
26 NOFL	Northern Flicker	*Colaptes auratus*	R
27 WEVI	White-eyed Vireo	*Vireo griseus*	S
28 COYE	Common Yellowthroat	*Geothlypis trichas*	S
29 YBCU	Yellow-bellied Cuckoo	*Coccyzus americanus*	S
30 AMGO	American Goldfinch	*Carduelis tristis*	R
31 RTHU	Ruby-throated Hummingbird	*Archilochus colubris*	R
32 EABL	Eastern Bluebird	*Guiraca caerulea*	R
33 EASO	Eastern Screech Owl	*Otus asio*	R
34 MODO	Mourning Dove	*Zenaida macroura*	R

SITE SPECIFIC AREA USE FACTORS (%) BY AVIAN SPECIES - LEAD SHOT MONITORING RESULTS 2001 AT PRIME HOOK NWR			
SPECIES	SITE A	SITE B	SITE C
WITU	33	0	33
REVI	78	67	44
WOTH	56	44	44
GRCA	11	33	33
BRTH	22	0	22
OVEN	33	44	22
GCFL	44	33	22
PROW	22	44	0
ETTI	56	22	11
AMRO	11	22	11
CARW	100	67	67
DOWO	22	33	0
EATO	22	44	11
NOCA	33	33	22
SCTA	33	11	0
AMCR	44	22	56
BLJA	56	11	11
RBWO	56	44	44
ACFL	0	0	11
HAWO	11	0	0
BWWA	0	0	11
YBCH	0	0	11
BGGN	11	0	0

SITE SPECIFIC AREA USE FACTORS (%) BY AVIAN SPECIES - LEAD SHOT MONITORING RESULTS 2001 AT PRIME HOOK NWR			
EAWP	56	0	0
FISP	11	0	0
NOFL	11	22	22
WEVI	0	11	11
COYE	11	22	11
YBCU	11	0	0
AMGO	0	11	11
RTHU	0	0	11
EABL	0	0	11
EASO	11	0	0
MODO	0	11	11

Appendix B
Life History/Exposure Profile

Below is a review of the general life history for each of the selected receptor species to evaluate as measurement endpoints. This information indicates that the selected species may use or inhabit the site areas, supporting their use as valid measurement endpoints.

Aquatic Invertebrates

Justification

Benthic macroinvertebrates are good indicator organisms and have been used to determine stream health. Examples of macroinvertebrates include: stonefly nymphs, mayfly nymphs, caddisfly larvae, dragonfly nymphs, and midge larvae. Also included are mollusks, crustaceans and worms. The amphipod *(Hyalella azteca)* was selected as a representative of benthic invertebrates because 1) individuals are in direct contact with sediment for a significant portion of their life cycle, 2) they are widely distributed in aquatic systems, and 3) they are an important link in the aquatic food chain. This species is also likely to occur in the surface sediment at the site.

Life History *(Hyalella azteca)*

The amphipod, *Hyalella azteca*, is commonly found in freshwater lakes, streams, ponds, and rivers throughout North and South America. In preferred habitats, they are known to reach densities in excess of 10,000 per square meter. They may also be found in sloughs, marshes, and ditches, but generally in lower numbers (U.S. EPA 1994).

Hyalella azteca are epibenthic detritivores that feed on coarse particulate organic material. They typically burrow into surface sediment, and avoid bright light. Because of their feeding and behavioral characteristics, they are ideal test organisms for toxicological evaluation of freshwater sediments. Avoidance of light by movement into the sediment keeps these organisms almost constantly in contact with sediment contaminants (U.S. EPA 1994).

Reproduction in this crustacean is sexual. Males are larger than females and have larger front gnathopods that are presumably used for holding the female during amplexus and copulation. During amplexus, the male and female feed together for a period of up to one week. The pair separates temporarily while the female goes through a molting period. Immediately after the molt, the two rejoin and copulation begins. During copulation, the male releases sperm near the female's marsupium. The female sweeps the sperm into her marsupium, and simultaneously releases eggs from her oviducts into the marsupium where fertilization takes place. The average brood size for female *Hyalella azteca* is 18 eggs per brood, but this number varies with environmental conditions and physiological stress (U.S. EPA 1994).

Developing embryos and hatched young are kept inside the female's marsupium until she undergoes a second molt. At that time, juvenile *Hyalella azteca* are released into the surrounding environment. Under favorable conditions, each female produces approximately one brood during every 10-day time period (U.S. EPA 1994).

Hyalella have a minimum of nine instars, with five to eight pre-reproductive stages. The first five stages are juvenile stages; instars six and seven form the adolescent stages; and stages eight and higher are considered adult (fully reproductive) stages (U.S. EPA 1994).

Exposure Profile for *Hyalella* azteca

Since direct contact with and ingestion of contaminated sediment are the primary routes of exposure for *Hyalella azteca*.

Terrestrial Invertebrates

Justification

Earthworms (*Eisenia foetida*) are in direct contact with soil, and may comprise as much as three fourths of the soil animal biomass in many terrestrial ecosystems (Cocking et al.1994). They benefit the soil structure by increasing aggregate formation, aerating, and increasing moisture-holding capacity. Earthworms are an important food source for many terrestrial mammals and birds.

Life History

The oligochaetes include earthworms and a group of related, mostly freshwater, species of annelids, and over 3,000 species are known (Hickman and Roberts 1994). Earthworms are segmented, and segments each contain elements of such body systems as circulatory, nervous, and excretory tracts (Brusca and Brusca 1990). Segmentation increases the efficiency of body movement by allowing the effect of muscle contraction to be extremely localized, and it enables the development of greater complexity in general body organization (Brusca and Brusca 1990).

Besides being segmented, the body wall of earthworms is characterized by circular and longitudinal muscle fibers surrounded by a moist, acellular cuticle that is secreted by an epidermal epithelium. Earthworms are schizocoelous, with a large and well-developed true coelom that is lined with mesoderm. The coelom is partially subdivided by septa. Hydrostatic pressure is maintained across segments and helps maintain body rigidity, allowing muscle contractions to bend the body without collapsing it (Brusca and Brusca 1990).

The internal organs of earthworms are well developed. They include a closed, segmentally-arranged circulatory system. The digestive system is a complete tube with mouth and anus. Gases are exchanged through the skin, or sometimes through specialized gills or modified parapodia. Each segment typically contains a pair of nephridia. The nervous system includes a pair of cephalic ganglia attached to double nerve cords that run the length of the animal along the ventral body wall, with ganglia and branches in each segment. Earthworms have some combination of tactile organs, chemoreceptors, balance receptors, and photoreceptors; and some species have fairly well developed eyes, including lenses (Brusca and Brusca 1990). Oligochaetes possess permanent sex organs. Most are hermaphroditic, and development is direct, resulting in young that resemble tiny adults (Hickman and Roberts 1994).

Ecologically, earthworms range from passive filter feeders to voracious and active predators, and feed primarily on detritus and algae. Earthworms cycle large quantities of soil through their guts, a process that speeds the turnover of nutrients in soil and increases productivity.

Earthworms pass a mixture of both organic and inorganic materials through their guts when feeding (Cocking et al. 1994). Earthworms are sometimes classified into two groups depending on depth of activity. The first group, the deep-working group, move through the full depth of available surface and subsurface soil; whereas the second group, the shallow-working group, confine their activities to the upper 15 centimeters (Cocking et al. 1994). Larger earthworms, that feed on organic matter by drawing leaves and other materials into their mouth, ingest larger quantities of soil, compared to smaller worms that consume fragmented litter (Cocking et al. 1994).

Exposure Profile

Earthworms cycle large quantities of soil through their guts, as they feed. Since direct contact with and ingestion of contaminated soil are the primary routes of exposure for *Eisenia foetida*.

Waterfowl exposed directly to lead shot

Justification

The forested wetlands and Prime Hook Creek support large numbers of waterfowl either seasonally or year-round. Exposure to lead shot creates a potential for direct toxicity to these waterfowl. The mallard *(Anas platyrynchos)* was selected as a receptor for the lead shot ingestion pathway because it is a common waterfowl species that uses grit.

Life History

The mallard is the most abundant and widely distributed wild duck in the Northern hemisphere (Bellrose 1976). It is a medium to large sized dabbling duck that is most recognizable by the male's green head and white collar around the neck. The female has an overall brown color, and both sexes have orange feet with a purple-blue speculum outlined in white on both sides.

Mallards are very common throughout North America. As migratory waterfowl, they winter south of Canada, throughout the United States south to Central America. Mallards arrive on nesting grounds in northern parts of the United States and in Canada between March and April. Mallards are also common throughout much of Europe, Asia and Africa.

Once mallards arrive in their nesting territory in the spring, the females build down-lined nests, usually on the ground, using dead grass and reeds. The location is selected at the edge of a lake, pond or marsh. The female lines the nest with her down in preparation for laying her eggs. Although mallards are seasonally monogamous, the male leaves the female after the first week of incubation. The female incubates the 5 to 14 eggs by herself, until they hatch some time between March and July, about 26 to 30 days later. The downy young leave the nest soon after hatching and may fly 49 to 60 days later.

Mallards feed by dabbling and filtering through sediments, by tipping their bodies into water, bill first with tail in the air, to forage for food. Mallards are highly adaptable feeders, and consume numerous and diverse native plant species. Their diet is 90 percent vegetarian, consisting mainly of seeds of grasses, sedges, pondweeds and other aquatic vegetation. In spring, however, females shift from a herbivorous diet to one of invertebrates to obtain protein for molting and egg production (U.S. EPA 1993). In the Chesapeake Bay region, on freshwater marshes, mallards predominately feed on seeds of smartweeds, soft-stem and three-square bulrushes, and bur reeds; whereas, on brackish marshes, mallards feed on seeds of widgeon grass, pondweeds, smartweeds, and the leaves and stems of submerged aquatic plants (Bellrose, 1976).

Exposure Profile

The male is approximately 0.680 to 1.72 kilograms (kg), average 1.25 kg, and the female is slightly smaller at about 0.544 to 1.72 kg, average 1.11 kg (Bellrose, 1976). Mallards are generally 20 to 28 inches long with a wingspan from 30 to 40 inches (Bellrose, 1976). The home range of mallards differ greatly in size, depending on habitat (e.g., the type and distribution of water) and population density. Home ranges vary from 173 to 1,532 acres (U.S. EPA 1993).

No ducks were counted during the bird survey conducted by refuge personnel (Appendix A). This may have been due to low water conditions at the time of the survey, because nest boxes were covered to specifically discourage use, or that the thick vegetation present at the time of the survey prevented the use of the site by ducks. However, because ducks, such as mallard, use this site for nesting, it is anticipated that they would also feed heavily in this area. Therefore, an AUF of 1 was selected for the mallard.

For this assessment, the fraction of grit particles that is lead shot was determined by site specific data from Harding ESE (2001). In addition, the number of days per year that a bird forages was assumed to be 245 (based on the assumption that a mallard has migrated from November 15 to March 15). The retention time for shot in the gizzard is 21 days (Chasko 1984) and the average life span for a mallard is 1.47 years (Palmer, 1976).

Terrestrial bird exposed directly to lead shot

Justification

Large numbers of upland birds use areas within the former skeet and trap range either seasonally or year-round to hunt for food. Exposure to lead shot creates a potential for direct toxicity to these birds. The mourning dove (*Zenaida macroura carolinensis*) was selected as a receptor for the lead shot ingestion pathway, because it is a common bird species that uses grit. Also, several publications have documented the potential for toxicity to this species following ingestion of lead shot (Lewis and Legler 1968; Kendall et al. 1996; Buerger et al. 1986; McConnell 1967; Marn et al. 1988).

Life History

Mourning doves are one of the most abundant game birds in North America. These birds are medium sized, brownish, with a rounded or pointed white-tipped tail. The males are larger (130.4 g) than the females (124.7 g), and are typically brighter colored (Basket et al. 1993).

Mourning doves are very common throughout North America. This species breeds throughout south Canada, and all of the continental United States into Baja California and Mexico south to Puebla. As migratory birds, they winter throughout most of their breeding range, except central Canada and north-central United States south to Central America (Mirarchi and Baskett 1994).

Doves mate for life, with a breeding season ranging from April to August. Doves typically nest in trees along the edges of fields, pastures, or clearings. Flimsy nests, in trees and shrubs, are made using grass and twigs. The clutch size ranges from one to four, with a mean of two eggs, and egg color is pure white. Incubation is performed by both sexes, male by day, female by night, and generally lasts between 13 and 14 days (Ehrlich et al.1988). The pair may raise 2-5 broods/season, with fledging occurring within 12 to 14 days.

Mourning doves are predominately seed eaters, and consume a wide variety of seeds, including buckwheat, millet, corn, wheat, rye, and peanuts, (Ehrlich et al. 1988). Favorite non-agricultural seeds include a variety of grasses, supurges, goosefoots and saltbushes, ragweed, pokeweed, and poppies. Grit is an essential component of diet, but function appears mechanical rather than nutritive (Mirarchi and Baskett 1994). Doves prefer seeds that lie on the ground, and pick up grit to help grind the seeds. It has been estimated that 20 percent of each day is spent feeding, including searching procuring and handling food and grit, drinking, and pecking at bark (Mirarchi and Baskett 1994).

Exposure Profile

Mourning doves average 22.5 to 34 cm, and have an average wingspread of 43 to 48 cm (Mirarchi and Baskett 1994). Daily home ranges vary from 50 to 1,200 hectare (ha), with an average of 218 ha (Mirarchi and Baskett 1994).

An area use factor of 0.11 was selected for this species based on the bird survey conducted by refuge personnel (Appendix A). This survey indicated that out of three areas surveyed, mourning doves had AUFs of 11% at 2 of the sites (Sites B and C), and were not recorded using the third site (Site A). Therefore, the highest area use factor of 0.11 was selected for this risk assessment.

For this assessment, the fraction of grit particles that is lead shot was determined by site specific data from Harding ESE (2001). In addition, the number of days per year that a bird forages was assumed to be 245 (based on the assumption that a dove has migrated from November 15 to March 15). The retention time for shot in the gizzard is 6 days (McConnell 1967) and the average life span for a mourning dove is 1.5 years (Mirarchi and Baskett 1994).

Avian Insectivore

Justification

The American robin (*Turdus migratorius*) was selected as an appropriate omnivorous bird species to evaluate effects of accumulation of lead within the food web. The diet of the American robin consists of seasonally variable proportions of invertebrates (earthworms, snails, beetles, caterpillars, spiders, etc.) and fruit (dogwood, cherry, sumac, hackberries, raspberries, etc.) (U.S. EPA 1993, Ehrlich et al. 1988). They are common in the area and are likely summer residents at the site.

Life History

The American robin is one of the best known birds in North America, and can be found from Alaska to Mexico during some part of the year. American robins are about 10 inches in length with a brick to orange-red breast, white eye-rings, black head and gray back. The male robin's breast is more brightly colored than the females. Young are born without feathers, but are soon covered with a gray down. As they grow their first set of feathers, both sexes have black spots on their breasts and the coloring of females. In late summer or early fall, young molt and more closely resemble adults, but with duller colors. After molting after their first mating, the birds have adult colored feathers.

In the spring, robins usually migrate back to the same area, and continue this year after year. The females are the primary nest builders. The nest is composed of dry leaves, grass, and moss, which are connected internally with a thick layer of mud and roots, lined with pieces of straw and fine grass, and occasionally a few feathers. The female robin lays 3 to 4 eggs, usually light blue, that are incubated for about 12 days before hatching. Once the fledglings leave the nest, the male continues to feed and train the young birds, while the female begins another clutch. When food is abundant, a third clutch in the same year may occur.

Exposure Profile

Adult American robins reportedly weigh between 63.5 and 103 g (U.S. EPA 1993). Territory sizes vary from 0.3 to 1 acre, with foraging home ranges reported up to 2 acres (U.S. EPA 1993). The mean body weight (83.3 g) and an area use factor of 0.22 were used for this risk assessment (Appendix A NWR Prime Hook 2001).

The mean food ingestion rates of 1.52 g/g BW/day and water ingestion rate of 0.14 g/g BW/day (mean) are reported (U.S. EPA 1993). Using the mean body weight of 83.3 g BW, and the mean food and water ingestion rates of 1.52 and 0.14 g/g BW/day, respectively, an American robin can be expected to consume 126.6 g/day of food and 11.7 g/day of water.

The diet of the American robin consists of seasonally variable proportions of invertebrates (earthworms, snails, beetles, caterpillars, spiders, etc.) and fruit (dogwood, cherry, sumac, hackberries, raspberries, etc.) (U.S. EPA 1993, Ehrlich et al. 1988). During spring, summer, and fall (when the robins will likely be found on site) the dietary composition is reported to change from 93 percent invertebrates to 7 percent fruit in the spring (nesting season) to 92 percent fruit and 8 percent invertebrates in fall (migratory season). The summer dietary proportion is reported as 68 percent fruit and 32 percent invertebrates (U.S. EPA 1993). For the purposes of this assessment 100 percent of the diet was assumed to be earthworm. Minimum , mean and maximum earthworm concentrations from the earthworm toxicity study (dry weight) were used in this model.

An incidental soil ingestion rate for the American robin could not be found in the literature. However, a rate of 7.5 g/day for the American woodcock was substituted (Beyer et al. 1994). Although, the prey species of the two species is similar, this was a conservative estimate for the robin. The woodcock is reported to primarily feed by probing its beak into the ground, while the robin primarily feeds by gleaning the surface of the ground (Ehrlich et al. 1988). The robin's technique may lead to a lower soil ingestion rate.

Terrestrial insectivore

Justification

The short-tailed shrew (*Blarina brevtcauda*)was selected as representative of insectivorous mammals, because of its dietary composition, relative abundant distribution in both moist and dry habitats, and likelihood of occurrence at the site. Although their diets may consist of plants and insects, they tend to favor soil invertebrates when they are in abundance. Hence, by assuming that their dietary composition comprises solely invertebrates in this risk assessment, this species may represent an insectivorous mammal.

Life History

The short-tailed shrew is an extremely active, large, and heavy-bodied shrew common within its range (Jones and Birney 1988). It occupies a variety of moist and dry habitats such as marshes, bogs, moist forest floors with ample decaying matter, brushland, fencerows, weedfields, and pastures (Barbour and Davis 1974; Jones and Birney 1988). Short-tailed shrews are active both day and night throughout the year, although most of this activity is subterranean (Merritt 1987). During harsh winters, this species may undergo a period of torpor (Hoffmeister 1989).

The home range of this species varies with their dramatic population cycles. In peak years, animal density may be greater than 25 individuals per acre (Schwartz and Schwartz 1981). In other years, this species may have an animal density of one individual per acre (Merritt 1987).

Although short-tailed shrews strongly prefer animal matter, they are opportunistic omnivores and voraciously consume whatever food items are in ample supply (Barbour and Davis 1974). These food items include earthworms, slugs, snails, insects, arthropods, fungi, vegetable matter, seeds, snakes, salamanders, small mammals, and young birds (Barbour and Davis 1974; Jones and Birney 1988; Schwartz and Schwartz 1981). Prey items that are not consumed immediately are stored in a cache (Merritt 1987). Plant matter is generally consumed to a greater extent in winter (Schwartz and Schwartz 1981). In some regions, plant matter may constitute up to 20 percent of the shrew's diet (Barbour and Davis 1974). Submaxillary glands produce a venom that quickly immobilizes their prey (Merritt 1987).

Using echolocation and scent-marking, short-tailed shrews rely heavily on their hearing and sense of smell to locate food and to move about (Hoffmeister 1989). An elaborate system of runways and tunnels are constructed, usually just a few inches below the ground surface (Schwartz and Schwartz 1981). Two types of nests are built by this species, a breeding nest and a resting nest. Both nests are built underground beneath a log, rock, or other cover, and have multiple entrances. The breeding nest is typically larger than the resting nest (Merritt 1987).

Breeding appears to commence in early spring and extends into the fall, although in some regions, breeding may subside in early and midsummer, but peak again in early fall (Hoffmeister 1989; Jones and Birney 1988). Gestation periods are approximately 21 to 22 days with litter sizes of approximately 4 to 10 young (Jones and Birney 1988; Schwartz and Schwartz 1981). The young are fully mature from one to three months of age (Barbour and Davis 1974; Schwartz and Schwartz 1981). Both sexes may breed their first spring (Schwartz and Schwartz 1981).

Natural predators of the short-tailed shrew include fish, snakes, owls, hawks, shrikes, opossums, raccoons, foxes, weasels, bobcats, skunks, and feral cats, although most of these predators do not consume the shrew (or at least all of the shrew), because of their distasteful musk glands (Barbour and Davis 1974; Jones and Birney 1988; Merritt 1987; Schwartz and Schwartz 1981). The life expectancy of a short-tailed shrew in the wild is approximately one year (Schwartz and Schwartz 1981).

Exposure Profile

Adult short-tailed shrews weigh from 12 to 30 g (Jones and Birney 1988; Merritt 1987) with a mean body weight of 21 g. An area use factor of one was selected for this risk assessment due to the very small home range of the shrew.

The short-tailed shrew is primarily carnivorous. Its diet includes invertebrates (insects, earthworms, snails, and spiders), but it also feeds on vertebrates, such as voles, amphibians, and birds (Merritt 1987, U.S. EPA 1993). Plant roots, nuts, fruits, and fungi are also part of the shrew's diet (Merritt 1987). Food ingestion rates ranging from 0.49 to 0.62 g/g of BW per day (g/g BW/day) have been reported (U.S. EPA 1993). An average food ingestion rate of 7.95 g/day has also been reported (U.S. EPA 1993). The average food ingestion rate of 7.95 g/day was used for the purposes of this risk assessment.

A water ingestion rate of 0.223 g/g BW/day has been reported (U.S. EPA 1993). To express this value in units of g/day, the water ingestion rate was multiplied by the lowest reported body weight of 12 g to yield a water ingestion rate of 2.7 g/day (2.7 milliliters per day [ml/day]).

A soil ingestion rate for the short-tailed shrew was not available from the literature, therefore, the soil ingestion rate of the opossum was used. The opossum's diet is similar to that of the short-tailed shrew, since they are both opportunistic omnivores with a strong preference for animal matter (Schwartz and Schwartz 1981). A soil ingestion rate of 9.4 percent of the diet was reported for the opossum (Beyer et al. 1994). This value was multiplied by the highest food ingestion rate of the short-tailed shrew (7.95 g/day) to yield a soil ingestion rate of 0.74 g/day. For the food chain model in this risk assessment, it was assumed that 100 percent of the diet of the short-tailed shrew was comprised of invertebrates.

REFERENCES

Barbour, R.W. and W. H. Davis. 1974. *Mammals of Kentucky.* Lexington, KY: University of Kentucky Press, 322 pp.

Baskett, T.S., M. W. Sayre, R.E. Tomlinson, and R.E. Mirarchi (eds.) 1993. *Ecology and Management of the Mourning Dove.* Stackpole Books, Harrisburg, PA.

Bellrose, F.C. 1976. *Ducks, Geese, and Swans of North America.* Harrisburg, PA: Stackpole Books Publishers, 540 pp.

Beyer, W. N., E. E. Connor, and S. Gerould. 1994. Estimates of soil ingestion by wildlife. *Journal of Wildife. Management* 58(2):375-382.

Brusca, R. C. and G. J. Brusca.1990. *Invertebrates.* Sunderland, MA: Sinauer Associates.

Buerger, T. T., R.E. Mirarchi, and M.E. Lisano. 1986. Effects of lead shot ingestion oncaptive mourning dove survivability and reproduction. *J. Wildl. Manage.* 50(1):1-8.

Chasko, G.G., Hoehn T. R., and Howell-Heller, P. 1984. "Toxicity of Lead Shotto Wild Black Ducks and Mallards Fed Natural Foods". Bulletin of Environmental Contamination and Toxicology, 32:417-428.

Cocking, D., M.L. King, L. Ritchie, and R. Hayes. 1994. Earthworm bioaccumulation of mercury from contaminated flood plain soils. In *Mercury Pollution Integration and Synthesis.* C.J. Watras and J. W. Huckabee (eds.), Boca Raton, FL: Lewis Publishers, 381-395.

Ehrlich, P.R., D.S. Dobkin, and D. Wheye. 1988. *The Birders Handbook: a Field Guide to the Natural History of North American Birds.* New York: Simon and Schuster Inc., 785 pp.

Hickman, C.P. and L. S. Roberts. 1994. *Animal Diversity.* W. C. Brown, Dubuque, IA.

Hoffmeister, D.F. 1989. *Mammals of Illinois.* Urbana, IL: University of Illinois Press. 348 pp.

Jones, Jr., J. K .J. and E.C. Birney. 1988. *Handbook of Mammals of the North Central States.*Minneapolis, MN: University of Minnesota Press, 346 pp.

Kendall, R. J., T. E. Lacher, Jr., C. Bunck, B. Daniel, C. Driver, C.E. Grue, F. Leighton, W. Stansley, P.G. Watanabe, and M. Whitworth. 1996. An ecological risk assessment of lead shot exposure in non-waterfowl avian species: upland game birds and raptors. *Environmental Toxicology and Chem*estry 15(1)4-20.

Lewis, J. C. and E. Legler, Jr. 1968. Lead shot ingestion by mourning doves and incidence in soil. *Journal of Wildlife Management* 32(3):476-482.

Marn, C.M., R.E. Mirarchi, and M.E. Lisano. 1988. Effects of diet and cold exposure on captive female mourning doves dosed with lead shot. *Archive Environmental Contaminant Toxicology*. 17:589-594.

McConnell, C.A. 1967. Experimental lead poisoning of bobwhite quail and mourning doves. Proc. Ann. Conf. Southeast Assoc. Game Fish Comm. 21:208-219.

Merritt, J. F. 1987. *Guide to the Mammals of Pennsylvania*. Pittsburgh, PA: University of Pittsburgh Press. 408 pp.

Mirarchi, R.E. and T.S. Baskett. 1994. Mourning Dove. In *The Birds of North America*, A.F. Poole, P. Stettenheim, F.B. Gill (eds.) The American Ornithologists' Union and the Academy of Natural Sciences of Philadelphia. Washington, D.C. and Philadelphia, PA., No. 117.

Palmer, RS. 1976. Handbook of North American Birds, Volume 2. New Haven and London, Yale University Press, p. 304.

Schwartz, C. W. and E. R. Schwartz. 1981. *The Wild Mammals of Missouri, Revised Edition*. Columbia, MO: University of Missouri Press and Missouri Dept. Conserv. 356 pp.

U.S. EPA. 1993. *Wildlife Exposure Factors Handbook, Volume I of II*. United States Environmental Protection Agency, Office of Research and Development, Washington, D.C. EPA/600/R-93/187a.

U.S. EPA. 1994. *Methods for Measuring the Toxicity and Bioaccumulation of Sediment associated Contaminants with Freshwater Invertebrates*. United States Environmental Protection Agency, Office of Research and Development, Washington, D.C. EPA/600/R-94/024.

Appendix C
Toxicity Profiles

Lead Shot

Birds ingest lead shot while foraging in the wetland substrate and on adjacent soils in search of food and grit. Grit refers to the small stones or other hard material retained in the muscular stomach of some birds that is used to help grind up food items. The size of the lead shot used for trap and skeet is the preferred size of grit and plant seeds for ducks and geese. Transfer of lead shot through the food chain may also occur in animals that prey on birds that have ingested lead shot. For example, a mallard may ingest two pellets of #4 lead shot in its gizzard, and as the bird becomes weak and disoriented from lead poisoning, it becomes an easy food source for all predators, including raptors. Once the bird is eaten by a hawk, owl, or eagle, the lead enters the raptor's body and may cause its death. Bald eagles (*Haliaeetus leucocephalus*) appear especially susceptible, since they utilize dead or crippled waterfowl extensively, and appear to be poor at regurgitating the shot once they ingest it. Heavy predation at wetlands helps prevent the accumulation of dead animals that might cause a noticeable die-off.

The toxicity of ingested lead shot is dependent on many factors, such as temperature, diet, age, sex, and species. The toxic action of lead is that it blocks the sulfur-hydrogen linkages in enzymes, resulting in a reduction of oxygen consumption by all tissues, a reduction in glycolysis, and an almost complete cessation of hydrogen transfer reactions in nerve tissues. It also interferes with the production of hemoglobin, resulting in severe anemia (Pain 1996), and may impair reproduction and immune system functions. Clinical signs of lead poisoning often include muscular weakness. A progressive illness results in a few weeks and may terminate in death with the ingestion of only a single lead shot (Buerger et al. 1986).

Waterfowl are believed to be at the greatest risk from deposited lead shot because of their food habits, grit use, and attraction to wetlands. The waterfowl-lead shot exposure pathway may be incomplete in deep water and dense emergent vegetation. The mourning dove may be at the greatest risk from lead shot contamination in uplands, due to their food habits and grit use. The shot remains available on the ground or in the sediment until it is turned under or settles deep enough to no longer pose a threat. This can be a period of extended time, since studies have shown no significant difference in the settling rates between large (#2) and small (#6) shot. One study in Utah showed that 75% of the #4 shot deposited were still in the top inch of the marsh sediment after 1 year (Low and Studinski 1967).

Lead (Pb)

Birds

The gastric motility of adult male and female red-tailed hawks (*Buteo jamaicensis*) fed 0.82 and 1.64 mg/kg BW/day (mg/kgBW/day concentration reported by authors) for 3 weeks was evaluated through the use of surgically implanted transducers. Neither concentration had any effect on gastric contractions or egestion of undigested material pellets (Lawler et al. 1991).

Adult male and female red-tailed hawks were administered lead acetate by gavage at a concentration of 0.82 mg Pb/kg BW/day for 3 weeks (Redig et al. 1991). Compared to control birds, there was an 83 percent decrease in delta-aminolevulinic acid dehydratase activity and a 74 percent increase in the levels of free porphyrins circulating in the blood of experimental birds. Immune function (as measured by antibody titers to foreign red blood cells or mitogenic stimulation of T-lymphocytes) was not significantly affected at this exposure level.

Beyer et al. (1988) fed red-winged blackbirds (*Agelaius phoeniceus*), brown-headed cowbirds (*Molothrus ater*), common grackles (*Quiscalus quiscula*), northern bobwhites (*Colinus virginianus*) and eastern screech owls (*Otus asio*) diets containing lead acetate. The dietary concentration was increased by 60 percent weekly until half of the birds in each treatment group died. Because the exposure concentrations changed throughout the experiment, this study was not used to derive TRVs for this risk assessment.

One-day old American kestrel (*Falco sparverius*) chicks were dosed orally with metallic lead at concentrations of 0, 25, 125 or 625 mg/kgBW/day for 10 days (Hoffman et al. 1985a and 1985b). Forty percent of the birds in the highest dose group died after 6 days of exposure. Growth rates of birds which received lead at concentrations of 125 or 625 mg/kgBW/day were significantly lower than the growth rates of control birds.

The effect of lead on survival of American kestrels was evaluated by feeding the birds either a control diet, or a diet containing mallard ducks (*Anas platyrhynchos*) which had died of lead poisoning (mean lead concentration was 29.3 mg/kg) for 60 days (Stendell 1980). No kestrels died or exhibited visible signs of lead poisoning during the 60-day exposure period. An ingestion rate of 0.0307 kg/day (Barrett and Mackey 1975) and a body weight of 0.111 kg (Dunning 1993) were used to convert the exposure concentration to units of mg/kgBW/day. A NOAEL of 8.1 mg/kgBW/day was calculated based on the results of this experiment.

Ringed turtle doves (*Streptopelia capicola*) received 0 or 100 µg/ml lead in their drinking water from two weeks prior to breeding throughout a breeding cycle (Kendall and Scanlon 1981). Exposure to lead did not increase the time required to produce eggs, and no adverse effects on egg production or fertility were observed. Bone lead concentrations in adult birds and bone and liver lead concentrations in juveniles were higher than in control birds or progeny of control birds. A water ingestion rate of 0.017 L/day (calculated using an allometric equation from Calder and Braun 1983) and a body weight of 0.16 kg (Schwarzbach et al. 1991) were used to convert the exposure concentration to units of mg/kgBW/day. A NOAEL of 0.01 mg/kgBW/day was calculated based on the results of this experiment.

Bobwhite quail were fed diets supplemented with lead (as lead acetate) at concentrations of 0, 500, 1000, 1500, 2000 and 3000 mg/kg for 6 weeks (Damron and Wilson 1975). Weight gain and food consumption were significantly decreased in birds receiving the two highest exposure concentrations. Mortality of birds receiving 3000 mg/kg lead was 46.7 percent, much greater than any other exposure group; however it was not statistically significant due to large variability among replicate pens. In another experiment, male bobwhite were fed diets containing 0, 500, 1000 or 1500 mg/kg lead (as lead acetate) for 8 weeks. Mortality, food consumption, sperm concentration and sperm viability were measured; no effects were observed at any exposure concentration. A food ingestion rate of 0.0143 kg/day and adult body weight of 0.169 kg were used to convert the exposure concentrations to units of mg/kgBW/day; 2000 mg/kg was selected as the NOAEL level. A NOAEL of 127 (exposure concentration of 1500 mg/kg, endpoint measured sperm concentration and viability) and an estimated LOAEL of 1270 mg/kgBW/day were calculated based on the results of this experiment.

Day-old Canada geese (*Branta canadensis*) were fed diets supplemented with lead-contaminated sediment at lead concentrations of 1.9 (control diet), 414, 828 and 1656 µg/g lead for 6 weeks (Hoffman et al. 2000). Mortality was observed only in the highest exposure group (22 percent), but it was not significantly different from the control group. Hematocrit, hemoglobin, and ALAD activity were significant lower and protoporphyrin levels were higher in the two highest exposure groups. Renal tubular degeneration was observed in one gosling from the 1656 µg/g group, but histopathologic lesions most commonly associated with lead poisoning in waterfowl were not observed in other geese. Growth was decreased in goslings from the highest exposure group. Because none of the effects measured in this experiment are considered ecologically relevant, results of this experiment were not used to derive TRVs for exposure of birds to lead.

Day-old mallard ducklings were fed diets supplemented with lead-contaminated sediment at lead concentrations of 1.9 (control diet), 414 and 828 µg/g lead for 6 weeks (Hoffman et al. 2000b). A clean sediment-supplemented control (24 percent sediment) and a positive control diet containing lead acetate at a concentration equivalent to the 828 µg/g lead-contaminated sediment diet were included in the experimental design. Mortality was observed only in the lead acetate group (7 percent), but was not significantly different from the control group. Hematocrit and hemoglobin were significantly lower in ducklings which received lead acetate. Blood ALAD activity levels were significantly lower and protoporphyrin levels were higher in both groups which received lead-contaminated sediment and the ducklings which received lead acetate. Acid-fast renal tubular inclusion bodies and nephrosis are abnormalities associated with lead poisoning; inclusion bodies were observed in 50 percent and tubular nephrosis was observed in 75 percent of ducklings fed lead acetate. Renal inclusion bodies were observed in 2 of 9 ducklings from the 414 µg/g group, and in 4 of 9 ducklings from the 828 µg/g group. Growth was affected only in ducklings fed lead acetate. Because none of the effects measured in this experiment are considered ecologically relevant, results of this experiment were not used to derive TRVs for exposure of birds to lead.

Heinz et al (1999) studied the bioavailability and toxicity of lead-contaminated sediment to adult mallards. In the first experiment, ducks were fed a pelleted commercial duck diet containing 0, 3, 6, 12 or 24 percent lead-contaminated sediment (103, 207, 414 and 828 µg/g lead, respectively) for 5 weeks. Ducks fed the 24 percent lead-contaminated sediment exhibited atrophy of the breast muscles, green staining of the feathers around the vent, viscous bile, green staining of the gizzard lining, and renal tubular intranuclear inclusion bodies; 1 of 10 birds died. In the second experiment, the dietary concentration of the lead-contaminated sediment was increased to 48 percent, but only about 20 percent was actually ingested due to food washing by the birds. Duration of this experiment was also 5 weeks. Protophyrin levels were elevated, and all of the lead-exposed birds had renal tubular intranuclear inclusion bodies. A third experiment was conducted to determine if the effects of lead were greater when birds were fed a nutritionally deficient diet. Ducks were fed a control diet, a commercial duck mash with 24 percent lead-contaminated sediment, of a ground corn diet with 24 percent lead-contaminated sediment for 15 weeks. Food washing was again observed; actual ingestion rates were 17 and 14 percent for the lead-contaminated duck mash and ground corn diets, respectively. Mortality occurred in 4 of 5 birds fed the lead-contaminated ground corn diet. At necropsy, all birds fed the lead-contaminated ground corn diet were emaciated, had renal tubular intranuclear inclusion bodies, and blackish-green bile. Based on the clinical signs of lead poisoning observed in the first experiment, an exposure concentration of 828 μg/g lead was selected as the LOAEL from this experiment. An ingestion rate of 0.139 kg/day and body weight of 1.25 kg (Piccirillo and Quesenberry 1980) were used to convert the exposure concentrations to units of mg/kgBW/day. A LOAEL of 92 mg/kgBW/day and a NOAEL of 46 mg/kgBW/day were calculated based on the results of this experiment.

Day-old Japanese quail (*Coturnix coturnix*) were fed diets containing lead (as lead acetate) at concentrations of 0, 1, 10, 100, 500 or 1000 mg/kg for 5 weeks (Morgan et al. 1975). Body weight, packed cell volume, and hemoglobin were significantly reduced in birds that received 1000 mg/kg lead. At five weeks of age, testes size was also significantly reduced in the highest exposure group. Mean body weights of the 500 and 1000 mg/kg exposure groups at three weeks were 65 and 55 g. Ingestion rates were calculated as a percent of the adult ingestion rate of 18 g/day (body weight of 0.12 kg; <www.feathersite.com/Poultry/Stuff/FeatherFancier/FeathFancQuail.html>), resulting in ingestion rates of 9.8 and 8.3 g/day, respectively. A LOAEL of 151 mg/kgBW/day and a NOAEL of 75.4 mg/kgBW/day were calculated based on the results of this experiment.

Nine raptors (5 red-tailed hawks, 3 rough-legged hawks (*Buteo lagopus*) and 1 golden eagle(*Aquila chrysaetos*)) were administered 3 mg/kgBW lead daily in the form of a lead acetate trihydrate solution by mouth for 30 weeks. Control birds (6 red-tailed hawks, 1 Swainsons hawk (*Buteo swainsoni*)) were dosed with a sodium acetate solution by mouth. Clinical signs of lead toxicosis (anorexia, green bile-stained feces and anemia) were observed in 8 of the 9 experimental birds. Three birds died 3 to 4 weeks following the onset of clinical symptoms. This study was not used to derive the TRVs for this risk assessment because dosing was via solution rather than dietary, and because different species were included within the experimental group.

Edens et al. (1976) exposed Japanese quail to four dietary concentrations of lead acetate (1,10, 100 and 1000 mg/kg) for a period of 12 weeks. Percent hatch of setable eggs was significantly decreased in hens exposed to 100 mg/kg lead. Dietary lead at a concentration of 1000 mg/kg almost completely suppressed egg production. The results from this experiment will be used to develop the NOAEL and LOAEL values because of the ecological significance of the endpoints and the method and duration of exposure. An ingestion rate of 18 g/day and adult body weight of 0.12 kg (<www.feathersite.com/Poultry/Stuff/FeatherFancier/FeathFancQuail.html>) were used to convert the exposure concentration to units of mg/kgBW/day. A LOAEL of 15 mg/kg

BW/day (100 mg/kg) and a NOAEL of 1.5 mg/kg BW/day will be used to evaluate the risk posed by Pb to avian receptors.

Barrett, G.W. and C.V. Mackey. 1975. Prey selection and caloric ingestion rate of captive American kestrels. Wilson Bull. 87(4):514-519.

Beyer, W.N., J.W. Spann, L. Sileo and J. C. Franson. 1988. Lead poisoning in six captive avian species. Arch. Environ. Contam. Toxicol. 17:121-130.

Calder, W.A. and E.J. Braun. 1983. Scaling of osmotic regulation in mammals and birds. Am. J. Physiol. 244:R601-R606.

Damron, B.L. and H.R Wilson. 1975. Lead toxicity of Bobwhite quail. Bull. Environ. Contam. Toxicol. 14(4):489-496.

Dunning, J.B. Jr. 1993. CRC Handbook of Avian Body Masses. CRC Press, Boca Raton, FL.

Edens, F.W., E. Benton, S.J. Bursian, and G.W. Morgan. 1976. "Effect of Dietary Lead on Reproductive Performance in Japanese Quail, *Caturnix columnix japonica.*" *Toxicol. App. Pharmarcol*, 38:307-314.

Heinz, G.H., D.J. Hoffman, L. Sileo, D.J. Audet and L.J. LeCaptain. 1999. Toxicity of lead-contaminated sediment to mallards. Arch. Environ. Contam. Toxicol. 36:323-333.

Hoffman, D.J., J.C. Franson, O.H. Pattee, C.M. Bunck and A. Anderson. 1985a. Survival, growth and accumulation of ingested lead in nestling American kestrels (*Falco sparverius*). Arch. Environ. Contam. Toxicol. 14:89-94.

Hoffman, D.J., J.C. Franson, O.H. Pattee, C.M. Bunck and H.C. Murray. 1985b. Biochemical and hematological effects of lead ingestion in nestling American kestrels (*Falco sparverius*). Comp. Biochem. Physiol. 80C(2):431-439.

Hoffman, D.J., G.H. Heinz, L. Sileo, D.J. Audet, J.K. Campbell, L.J. LeCaptain and H.H. Obrecht. 2000a. Developmental toxicity of lead-contaminated sediment in Canada geese (*Branta canadensis*). J. Toxicol. Environ. Health. 59:235-252.

Hoffman, D.J., G.H. Heinz, L. Sileo, D.J. Audet, J.K. Campbell, and L.J. LeCaptain. 2000b. Developmental toxicity of lead-contaminated sediment to mallard ducklings. Arch. Environ. Contam. Toxicol. 39:221-232.

Kendall, R.J. and P.F. Scanlon. 1981. Effects of chronic lead ingestion on reproductive characteristics of ringed turtle doves Streptopelia risoria and on tissue lead concentrations of adults and their progeny. Environ. Pollut. (Series A). 26:203-213.

Lawler, E.M., G.E. Duke, and P.T. Redig. 1991. "Effect of Sublethal Lead Exposure on Gastric Motility of Red-Tailed Hawks." *Arch. Environ. Contam. Toxicol.*, 21:78-83.

Morgan, G.W., F.W. Edens, P. Thaxton and C.R. Parkhurst. 1975. Toxicity of dietary lead in Japanese quail. Poult. Sci. 54:1636-1642.

Redig, P.T., E.M. Lawler, S. Schwartz, J.L. Dunnette, B. Stephenson, and G.E. Duke. 1991. "Effects of Chronic Exposure to Sublethal Concentrations of Lead Acetate on Heme Synthesis and Immune Function in Red-Tailed Hawks." *Arch. Environ. Contam. Toxicol.*, 21:72-77.

Reiser, M.H. and S.A. Temple. 1980. Effects of chronic lead ingestion on birds of prey. Pages 21-25 *in: Recent Advances in the Study of Raptor Diseases. Proceedings of the International Symposium on Diseases of Birds of Prey.* Cooper, J.E. and A.G. Green (eds.). July 1980, London.

Schwarzbach, S.E., D.M. Fry, B.E. Rosson and D.M. Bird. 1991. Metabolism and storage of p,p-dicofol in American kestrels (*Falco sparverius*) with comparisons to ring neck doves (Streptopelia risoria). Arch. Environ. Contam. Toxicol. 20:206-210.

Stendell, R.C. 1980. Dietary exposure of kestrels to lead. J. Wildl. Manage. 44(2):527-530.

Lead (Pb)

Mammals

Mason and MacDonald (1986) evaluated the effect of Pb and Cd on otter (*Lutra lutra*). Daily Pb intake was estimated on the basis of measured fecal Pb levels, the known ingestion rate for otter, and gastrointestinal Pb absorption rates for mammals. Estimated Pb intake correlated well with levels measured in major fish prey species. No apparent impact on population levels was found when Pb intake was less than 0.15 mg/kg BW/day whereas otter populations were reduced in sites where the estimated Pb intake exceeded 2 mg/kg BW/day.

Adult pregnant mice (C57Bl strain) were fed a diet containing Pb concentrations of 0, 0.125, 0.25, 0.5, and 1 percent for 48 hours following observation of the presence of a vaginal plug (Jacquet et al. 1976). Dietary Pb concentrations of 0.125 percent, 0.25 percent, and 0.5 percent resulted in an increase in the number of embryos in the 4-cell stage versus the 8-cell stage. At a dietary exposure level of 1 percent, an increase in the number of undivided embryos was observed. In normal mouse embryo development, after 48 hours the embryo is in the 8-cell stage and is placed near the end of the oviduct ready to be discharged to the uterus. Effects of delayed cleavage on embryo loss prior to implantation is not known. An ingestion rate of 0.0058 kg/day and adult body weight of 0.033 kg (U.S. EPA 1988) were used to convert the exposure concentration to units of mg/kgBW/day. A LOAEL of 220 mg/kg BW/day, and an estimated NOAEL of 80 mg/kg BW/day were calculated based on the results of this experiment.

Pregnant female mice were given lead acetate in their drinking water at concentrations of 0, 500, 750 and 1000 mg/L starting on gestation day 12 and continuing to 4 weeks postpartum (Waalkes et al. 1995). Offspring were weaned and received lead in their drinking water after weaning for 112 weeks. Renal lesions (atypical tubular hyperplasia or tumors) occurred rarely in control male mice (4 percent) and increased in dose related fashion for lead exposed male offspring: 500 ppm, 16 percent; 750 ppm, 24 percent; and 1000 ppm, 48 percent. The number of lesions in the 1000 mg/L group was significantly higher than for the control group. Lead-treated females also developed renal lesions, but at much lower rates. An ingestion rate of 0.0058 kg/day and adult body weight of 0.033 kg (U.S. EPA 1988) were used to convert the exposure concentration to units of mg/kgBW/day. A LOAEL of 176 mg/kg BW/day, and a NOAEL of 132 mg/kg BW/day were calculated based on results of this study.

Azar et al. (1973) administered Pb to rats at six dietary levels (1, 10, 50, 100, 1000 and 2000) for three generations and measured changes in reproduction and growth. No effects on number of pregnancies, number of pups born alive, fertility index, viability index or lactation index were observed at any exposure levels. An exposure concentration of 1000 mg/kg resulted in reduced offspring weight and kidney damage in the young. An ingestion rate of 0.027 kg/day and adult body weight of 0.35 kg (U.S. EPA 1988) were used to convert the exposure concentration to units of mg/kgBW/day. A LOAEL of 77 mg/kg BW/day, and a NOAEL of 7.7 mg/kg BW/day will be used to evaluate the risk posed by Pb to mammalian receptors

Azar, A., H.J. Trochimowicz, and M.E. Maxwell. 1973. Review of Lead Studies in Animals Carried Out at Haskell Laboratory: Two-Year Feeding Study and Response to Hemorrhage Study. In: Environmental Health Aspects of Lead: International Symposium (eds.). D. Barth et al. Commission of European Communities. p. 199-210.

Jacquet, P., A. Leonard and G. B. Gerber. 1976. "Action of Lead on Early Divisions of the Mouse Embryo." *Toxicology,* 6:129-132.

Mason, C.F. and S.M. MacDonald. 1986. "Levels of Cadmium, Mercury and Lead in Otter and Mink Feces from the United Kingdom." *Sci. Total Environ.,* 53:139-146.

U.S. EPA. 1988. Recommendations for and documentation of biological values for use in risk assessment. EPA/600/6-87/008.

Waalkes, M.P., B.A. Diwan, J.M. Ward, D.E. Devor and R.A Goyer. 1995. Renal tubular tumors and atypical hyperplasias in B6C3F1 mice exposed to lead acetate during gestation and lactation occur with minimal chronic nephropathy. Cancer Research. 55:5256-5271.