Final
Baseline Ecological Risk Assessment
Study Design for
Iron Mountain Road Ranges

Fort McClellan
Calhoun County, Alabama

Prepared For:

U.S. Army Corps of Engineers
Mobile District
109 St. Joseph Street
Mobile, Alabama 36602

Prepared By:

IT Corporation
312 Directors Drive
Knoxville, Tennessee 37923

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List of Acronyms

ATSDR	Agency for Toxic Substances and Disease Registry
AUF	area use factor
BCF	bioconcentration factor
BERA	Baseline Ecological Risk Assessment
bgs	below ground surface
BGR	Bains Gap Road
BTV	background threshold value
COPEC	constituents of potential ecological concern
CSM	conceptual site model
DQO	data quality objective
ESV	ecological screening values
EE/CA	engineering evaluation and cost analysis
EPA	U.S. Environmental Protection Agency
FTMC	Fort McClellan
HQ_{screen}	screening-level hazard quotient
IMR	Iron Mountain Road
IT	IT Corporation
L/kg/day	liters per kilogram per day
LOAEL	lowest observed adverse effect level
MDCC	maximum detected constituent concentration
mg/kg	milligrams per kilogram
mg/kg/day	milligrams per kilogram per day
mg/L	milligrams per liter
NOAEL	no observed adverse effect level
PAH	polycyclic aromatic hydrocarbon
ppm	parts per million
SLERA	screening-level ecological risk assessment
SVOC	semivolatile organic compound
USFWS	U.S. Fish and Wildlife Service
VOC	volatile organic compound

1.0 Introduction

This baseline ecological risk assessment (BERA) study design report describes the biological sampling that will be conducted at the small arms ranges at Iron Mountain Road (IMR) at Fort McClellan (FTMC), Calhoun County, Alabama, and the various analyses that will be completed to answer the risk questions raised in the BERA problem formulation report (IT Corporation [IT], 2002a). This BERA study design report is based on the results and conclusions presented in the *Screening Level Ecological Risk Assessment for the Iron Mountain Road Ranges* (SLERA) (IT, 2002b) and the BERA *Problem Formulation for Small Arms Ranges at Iron Mountain Road* (IT, 2002a). The data utilized in these reports were originally presented in the *Engineering Evaluation and Cost Analysis for the Small Arms Ranges at Iron Mountain Road* (EE/CA) (IT, 2001). As the result of comments received from the U.S. Environmental Protection Agency (EPA), supplemental data were collected from the IMR ranges and presented in the BERA problem formulation report (IT, 2002a). The procedures and methods discussed in this study design report conform to guidelines in the EPA's *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (EPA, 1997) and *Guidelines for Ecological Risk Assessment* (EPA, 1998). This study design represents Step 4 of the EPA's eight-step ecological risk assessment process (EPA, 1997).

2.0 Ecological Setting

The terrestrial habitat at the IMR ranges fall into two general categories: "cleared" areas and forested areas. It is important to note that the richness of the ecosystem in open or cleared areas is significantly less than in the relatively unaltered forested areas. It is also important to note that the areal extent of contamination is centered within the cleared range areas where small arms firing took place. The cleared areas are those areas that were formerly maintained as lawns or mowed fields. Since maintenance activities have ceased in these areas, pioneer species are now colonizing these ranges. Typically, the species most likely to colonize these areas are the "weed" species that tend to be vigorous pioneer plants that grow and spread rapidly. The first of the pioneer species to invade these abandoned areas are the grasses and herbaceous species. These formerly maintained grassy areas are classified as being in an early old field successional state. Over time, the grass and herbaceous species will be followed by shrubs and small trees. The early old field successional areas at the IMR ranges are dominated by various grasses and herbs, including dock *(Rumex spp.)*, clover *(Trifolium spp.)*, vetch *(Astragalus spp.)*, milkweed *(Ascelepias spp.)*, bed straw *(Galium spp.)*, ox-eye daisy *(Chrysanthemum leucanthemum)*, and Johnson grass *(Sorghum halepense)*. Other old field herbaceous species occurring at the IMR ranges are black raspberry *(Rubus occidentalis)*, poison ivy *(Toxicodendron radicans)*, smooth sumac (*Rhus glabra)*, green briar (*Smilax rotundiflora)*, Japanese honeysuckle *(Lonicera japonica)*, fox grape *(Vitus labrusca)*, and multifloral rose *(Rosa multiflora)*.

The forested areas outside of the cleared areas are best characterized as mixed deciduous/coniferous forest. With the exception of the forest stand around the Skeet Range, these rich and relatively unaltered forested regions represent the large safety fans across the Main Post. The cover species typically found in the forested areas surrounding the IMR ranges include scrub pine *(Pinus virginiana)*, loblolly pine *(Pinus taeda)*, white oak *(Quercus alba)*, post oak *(Quercus stellata)*, chestnut oak *(Quercus prinus)*, southern red oak *(Quercus falcata)*, wild black cherry *(Prunus serotina)*, hackberry *(Celtis occidentalis)*, black walnut *(Juglans nigra)*, and flowering dogwood *(Cornus florida)*. These mixed deciduous/coniferous forests exhibit sparse, shade-tolerant undergrowth species such as Virginia creeper *(Parthenocissus quinquefolia)*, Christmas fern *(Polystrichum acrotichoides)*, and poison ivy *(Toxicodendron radicans)*. Descriptions of the habitat at each of the small arms ranges at IMR are presented in the following sections.

2.1 Skeet Range Habitat

The Skeet Range consists of two main habitat types. The cleared area encompasses approximately two acres at and adjacent to the firing lines. The habitat in this area is dominated by grasses and early old field successional species. In the past, this area was maintained lawn with concrete walkways throughout. Since maintenance activities have ceased, the grasses have grown uncontrolled and early successional species have intruded. Various grasses and herbaceous species dominate this habitat type. Scrub pine (*Pinus virginiana*) saplings have also begun to encroach on this cleared area. The forested areas surrounding the cleared area at the Skeet Range can be characterized as mixed deciduous/coniferous forest. Scrub pine and southern red oak dominate this habitat. There are minimal understory or herbaceous layers in this forest type, as fallen leaves and pine needles form a thick mat that precludes the germination of smaller plants. White-tailed deer, wild turkey, gray squirrel, and various songbirds were observed on site. Details regarding site history, physical characteristics, and other background information are presented in the EE/CA for the IMR ranges (IT, 2001).

Remount Creek, which runs along the western boundary of the Skeet Range, and its tributaries, which generally run east-to-west across the Skeet Range, exhibit mostly gravel and cobble substrate with very little organic matter. Remount Creek is narrow and shallow (less than 5 feet across and less than 6 inches deep) when there is water present. This ephemeral creek and its tributaries are dry during significant portions of the year, and the presence or absence of water is highly dependent upon the volume of precipitation. During dry periods, the creek may be entirely dry for significant portions of the year (6 to 8 months). The ephemeral nature of Remount Creek and its tributaries in this area limits their ability to support many aquatic organisms (e.g., large fish) and other organisms that rely on aquatic species for food (e.g., piscivores). Remount Creek and its tributaries may support semi-aquatic species (e.g., amphibians) and provide a breeding ground for some small fish species during the periods when water is present.

Site walks conducted on May 10, 2002, revealed potential impacts to the habitat of Remount Creek and the surrounding creek corridor from activities associated with construction of the "Eastern Bypass." Moreover, it is possible that the bypass construction will require significant alterations to Remount Creek in the vicinity of the IMR ranges.

Remount Creek in the vicinity of the Skeet Range has historically been identified as a moderate to low quality foraging area for the federally listed endangered gray bat (*Myotis grisescens*) (Garland, 1996). This section of Remount Creek has been identified as a gray bat foraging area because it allegedly provides habitat for aquatic insects, which are fed upon by the gray bat. However, Remount Creek is dry during significant portions of the year, which precludes the presence of aquatic insects during those dry periods. Additionally, construction of the Eastern Bypass directly adjacent to the Remount Creek corridor has eliminated a significant portion of the tree and shrub canopy that formerly covered Remount Creek. Because the gray bat requires continuous cover while traveling to and from its foraging habitats and while foraging, the elimination of significant portions of the forest in this area would negatively affect its foraging habits. Based on the ephemeral nature of Remount Creek in this area and the elimination of significant portions of the forest canopy, the creek may no longer provide adequate foraging habitat for the gray bat.

2.2 Range 19 Habitat

The total site, including the extensive forested range fan, encompasses 1,529 acres. The main study area is limited to approximately 5 to 7 acres. Details regarding site history, physical characteristics, and other background information are presented in the EE/CA for the IMR ranges (IT, 2001). The study area of Range 19 consists almost entirely of maintained lawn, mowed fields, unvegetated soil, and roadways. Since maintenance activities have ceased, the grasses have grown uncontrolled and early successional species have intruded. Various grasses and herbaceous species dominate this habitat type. Scrub pine saplings (*Pinus virginiana*) have also begun to encroach into these previously maintained areas. The embankment on the eastern side of the site is almost completely void of vegetation, due to the fact that soil was historically scraped and graded along this embankment for maintenance purposes when the ranges were active. The area surrounding the cleared areas of Range 19 can be characterized as mixed deciduous/coniferous forest. Scrub pine and southern red oak dominate this habitat. There are minimal understory or herbaceous layers in this forest type, as fallen leaves and pine needles form a thick mat that precludes the germination of smaller plants. White-tailed deer, wild turkey, gray squirrel, and various songbirds were observed on site.

Remount Creek is dry for significant periods of time over most of the distance that it passes along the western boundary of Range 19 (approximately 1,000 feet). The presence of small pools of water (one to two feet in length) in this portion of Remount Creek may be due to groundwater discharge. The creek is narrow and shallow (less than 3 feet across and less than 6 inches deep) when water is present and has a variable substrate of mud and leaf litter interspersed with areas of sand and gravel. Again, the presence of water in Remount Creek adjacent to Range 19 is highly dependent upon significant precipitation.

The portion of Remount Creek adjacent to Range 19 has historically been classified as low quality foraging habitat for the federally listed endangered gray bat (*Myotis grisescens*) (Garland, 1996). This classification has not taken into account the impacts on Remount Creek habitat resulting from construction of the Eastern Bypass.

2.3 Range 13 Habitat

The total area of Range 13, including the range safety fan, encompasses 549 acres. The main study area is limited to approximately 5 acres, which are described herein as the cleared areas. The cleared area of Range 13 is dominated by grasses and early successional species. In the past, this area consisted of maintained lawn, mowed field, unvegetated soil, and roadways. Since maintenance activities have ceased, the grasses have grown uncontrolled and early successional species have intruded. Various grasses and herbaceous species dominate this habitat type. Scrub pine saplings (*Pinus virginiana*) have also begun to encroach into these previously maintained areas. The forested areas surrounding the cleared area at Range 13 can be characterized as mixed deciduous/coniferous forest. Scrub pine and southern red oak dominate this habitat. There are minimal understory or herbaceous layers in this forest type, as fallen leaves and pine needles form a thick mat that precludes the germination of smaller plants. White-tailed deer, wild turkey, gray squirrel, and various songbirds were observed on site. Details regarding site history, physical characteristics, and other background information are presented in the EE/CA for the IMR ranges (IT, 2001).

Remount Creek, along the 800 foot length that runs adjacent to the western boundary of Range 13, exhibits sections of very slow moving water (zero to 6 inches deep) and areas which are completely dry. Similar to Range 19, the presence of small, intermittent areas of water (less than one foot to several feet in length) may be due to groundwater discharge. The creek is narrow (less than 3 feet across) and shallow (less than 6 inches deep), when water is present, and has a variable substrate of mud and leaf litter interspersed with areas of sand and gravel. Again, the presence of water in Remount Creek adjacent to Range 13 is highly dependent upon significant precipitation.

The portion of Remount Creek adjacent to Range 13, has historically been classified as low quality foraging habitat for the Federally endangered gray bat (*Myotis grisescens*) (Garland, 1996). This classification has not taken into account the impacts on Remount Creek habitat resulting from construction of the Eastern Bypass.

2.4 Range 12 Habitat

The total area of Range 12, including the range safety fan, encompasses 311 acres. The main study area is limited to approximately 5 acres, which are described herein as the cleared areas. The cleared area of Range 12 is dominated by grasses and early successional species. In the past, this area consisted of maintained lawn, mowed field, and roadways. Since maintenance activities have ceased, the grasses have grown uncontrolled and early successional species have intruded. Various grasses and herbaceous species dominate this habitat type. Scrub pine saplings (*Pinus virginiana*) have also begun to encroach into these previously maintained areas. The forested areas surrounding the cleared area at Range 12 can be characterized as mixed deciduous/ coniferous forest. Scrub pine and southern red oak dominate this habitat. There are minimal understory or herbaceous layers in this forest type, as fallen leaves and pine needles form a thick mat that precludes the germination of smaller plants. White-tailed deer, wild turkey, gray squirrel, and various songbirds were observed on site. Details regarding site history, physical characteristics, and other background information are presented in EE/CA for the IMR ranges (IT, 2001).

Along the 400-foot length of Remount Creek that runs adjacent to the western boundary of Range 12, the creek exhibits sections of very slow-moving water (zero to 6 inches deep) and areas which are completely dry. Similar to Range 19, the presence of small, intermittent areas of water (less than one foot to several feet in length) may be due to groundwater discharge. The creek is narrow and shallow (less than 3 feet across and less than 6 inches deep) when water is present and has a variable substrate of mud and leaf litter interspersed with areas of sand and gravel. Again, the presence of water in Remount Creek adjacent to Range 12 is highly dependent upon significant precipitation.

The portion of Remount Creek adjacent to Range 12 has historically been classified as low quality foraging habitat for the federally listed endangered gray bat (*Myotis grisescens*) (Garland, 1996). This classification has not taken into account the impacts on Remount Creek habitat resulting from construction of the Eastern Bypass.

2.5 Remount Creek Habitat

In the vicinity of the IMR ranges, Remount Creek is a small, ephemeral stream that flows (when water is present) from south to north. The physical characteristics of Remount Creek and the surrounding land use vary along its length, from its headwaters at Yahou Lake to its confluence with Cane Creek near the west-northwest boundary of the Main Post. The headwaters of Remount Creek are formed by the discharge from Yahou Lake and its tributaries, approximately 0.75 mile south of Range 12. Remount Creek runs in a northerly direction along the topographic low formed by gently sloping hills to the east and west of the creek. Most of the length of Remount Creek between Yahou Lake and the IMR ranges runs through the Eastern Bypass corridor. Virtually all of the trees in the bypass corridor have been clear-cut and all of the vegetation removed. The entire area has been covered with mulch that was created by "chipping" the vegetation that was cut down. The land surrounding Remount Creek adjacent to Ranges 12 and 13 is characteristic of the clear-cut areas associated with the Eastern Bypass corridor. It is likely that portions of the creek adjacent to the IMR ranges will be significantly altered (e.g., rerouted, culverted) as a result of construction of the Eastern Bypass.

Immediately north of the Skeet Range, Remount Creek flows through a culvert under the old parade grounds/athletic fields and then through the grounds of the Cane Creek Golf Course until its confluence with Cane Creek in the west-northwestern corner of the Main Post.

The ecological value of Remount Creek is greatest as it flows through the Cane Creek Golf Course and intersects Cane Creek. It is in this stretch (downstream of the IMR ranges) that the creek will support foraging of insectivorous mammals and a functional aquatic ecosystem. Remount Creek and its tributaries in the vicinity of the IMR ranges may support semi-aquatic species (e.g., amphibians) and provide a breeding ground for some small fish species during the periods when water is present.

3.0 Conceptual Site Model

The ecological conceptual site model (CSM) traces the movement of constituents of potential ecological concern (COPEC) from sources through the different environmental compartments within the local ecosystems to the various receptors. The exposure scenarios include the sources, environmental transport, partitioning of the contaminants amongst various environmental media, potential chemical/biological transformation processes, and identification of potential routes of exposure for the ecological receptors. The information necessary to construct a CSM includes the following:

- COPECs
- Potential target media
- Media parameters and characteristics
- Potential receptors in each medium
- Potential exposure routes
- Migration and transport potential of COPECs
- Potential secondary, tertiary, and quaternary COPEC sources.

3.1 Constituents of Potential Ecological Concern

The SLERA for the IMR ranges initially identified a number of COPECs in soil for each of the ranges, as well as for the surface water and sediment of Remount Creek and its tributaries. COPECs were initially identified by calculating screening-level hazard quotients (HQ_{screen}), which were developed via a three-step process as follows:

- Comparison of maximum detected constituent concentrations (MDCC) to ecological screening values (ESV)

- Identification of essential macronutrients

- Comparison to naturally occurring background concentrations.

Constituents detected in environmental media at the IMR ranges were evaluated against the ESVs by calculating an HQ_{screen} for each constituent in each environmental medium. An HQ_{screen} was calculated by dividing the MDCC in each environmental medium by its corresponding ESV as follows:

$$HQ_{screen} = \frac{MDCC}{ESV}$$

where:

HQ_{screen}	=	screening-level hazard quotient
MDCC	=	maximum detected constituent concentration
ESV	=	ecological screening value.

A calculated HQ_{screen} value of one or less indicated that the MDCC was equal to or less than the chemical's conservative ESV, and was interpreted in the SLERA as a constituent that does not pose a potential for adverse ecological risk. Conversely, an HQ_{screen} value greater than one indicated that the MDCC was greater than the ESV and that the chemical might pose adverse ecological hazards to one or more receptors.

A constituent was initially identified as a COPEC in the SLERA if all of the following conditions were met:

- The MDCC exceeded the ESV
- The MDCC was 10 times the background threshold value (BTV) if the constituent is a macronutrient
- The MDCC exceeded the BTV for inorganics.

If a constituent in a given environmental medium did not meet all of these conditions, then it was not considered a COPEC at the IMR ranges and was not considered for further assessment. Identification of a constituent as a COPEC in the SLERA simply indicated that further assessment of that particular constituent in a given environmental medium was deemed appropriate and did not imply that that particular constituent posed a definite risk to ecological receptors.

In the BERA problem formulation, additional lines of evidence were used to refine the list of COPECs that would be assessed in the BERA. These additional lines of evidence included frequency of detection, magnitude of the calculated HQ, association with known U.S. Army activities at the ranges and bioaccumulation and toxicity potential. The COPECs identified for surface soil, surface water, sediment, and groundwater at the IMR ranges are presented in Table 3-1.

3.1.1 COPECs in Surface Soil

Antimony, copper, lead, and zinc were frequently detected in surface soil at all of the IMR ranges at concentrations that exceeded their respective ESVs. The highest concentrations of

Table 3-1

Summary of COPECs at Iron Mountain Road Ranges
Fort McClellan, Calhoun County, Alabama

COPECs	Skeet Range Surface Soil	Range 12 Surface Soil	Range 13 Surface Soil	Range 19 Surface Soil	Remount Cr. & Tributaries Surface Water	Remount Cr. & Tributaries Sediment
antimony	*X*	*X*	*X*	*X*		
arsenic		*O*	*O*	*O*		*X*
barium						*X*
beryllium	*O*					*O*
cobalt	*O*					
copper	*X*	*X*	*X*	*X*		*X*
iron						*O*
lead	*X*	*X*	*X*	*X*	*X*	*X*
manganese	*O*					*X*
nickel						*O*
silver				*O*		
thallium						*X*
vanadium						*O*
zinc	*X*	*X*	*X*	*X*		
benzo(a)pyrene	*O*					
fluoranthene	*O*					
phenanthrene	*O*					
pyrene	*O*					
4,4'-DDT		*O*				

O - HQ_{screen} > 1.0, however additional lines of evidence indicate that this constituent is not a COPEC.

X - Constituent identified as a COPEC.

these four constituents were found in locations that are associated with small arms use (i.e., soil berms that are the impact areas). Thus, it was concluded that these constituents are site related and could be considered COPECs in surface soil at all of the IMR ranges. The surface soil sample locations at the IMR ranges and the COPEC concentrations at each of the sampling locations are presented in Figures 2-1 through 2-4 in the BERA problem formulation report (IT, 2002a).

3.1.2 COPECs in Surface Water

Lead was the only COPEC detected in surface water from Remount Creek and its tributaries in the vicinity of the IMR ranges. Four surface water samples from the Skeet Range exhibited lead concentrations that were greater than the ESV. Surface water samples from the other IMR ranges did not exhibit elevated concentrations of any constituent. Since lead was identified as a COPEC in surface soil and is associated with small arms training activities, it has been identified as a COPEC in surface water at the IMR ranges, although the extent of lead contamination in surface water appears to be limited to the Skeet Range. The surface water sample locations and COPEC concentrations are presented in Figure 2-5 in the BERA problem formulation report (IT, 2002a).

3.1.3 COPECs in Sediment

Arsenic, barium, copper, lead, manganese, and thallium were identified as COPECs in sediment from Remount Creek and its tributaries in the vicinity of the IMR ranges. These COPCs were detected at elevated concentrations only in samples from the ditches and tributaries at the Skeet Range. The sediment sample locations and COPEC concentrations are presented in Figure 2-5 in the BERA problem formulation report (IT, 2002a).

3.1.4 COPECs in Groundwater

Surface water ESVs were used to assess groundwater at the IMR ranges in order to determine the potential for impacts to aquatic organisms from groundwater if groundwater intrusion to Remount Creek and its tributaries does occur.

During the course of field investigations at the IMR ranges, surface water was not consistently observed flowing through the stream channel adjacent to the study area. During the majority of field observations, the stream channel was largely dry, with some small pools of surface water (estimated 2 to 4 feet in diameter) observed in depressions in the stream channel.

During soil boring and well installation activities, groundwater was encountered at depths ranging from 15 to 88 feet below ground surface (bgs). It appears that there are two groundwater-bearing zones present at the IMR ranges, one within the residuum and the other within the bedrock. Groundwater in residuum was encountered at depths ranging from 15 to 45 feet bgs. Groundwater in bedrock was encountered at 73 and 88 feet bgs. Comparing the static water levels measured at the site on January 8, 2002 (Table 3-2), to the depths at which groundwater was encountered during drilling, it appears that groundwater in the residuum is under confined or semiconfined conditions. Based on a comparison of the approximate elevations at which groundwater was encountered during drilling to the elevation of the Remount Creek streambed, it appears that groundwater in the residuum at the IMR ranges does not contribute substantially to surface water flow within Remount Creek. Furthermore, comparing the static water levels from both January 2002 and November 2001 on either side of the creek to the location and elevation of Remount Creek, it appears that the potentiometric surface is below the base of the creek bed. This suggests that Remount Creek is not being fed by the residuum groundwater under base flow conditions. However, it does not rule out the possibility that during periods of heavy rainfall, residuum may become saturated locally and temporarily discharge to the surface water in Remount Creek.

As discussed in the BERA problem formulation report for the IMR ranges (IT, 2002a), none of the constituents detected in groundwater at an elevated concentration relative to its surface water ESV was detected in surface water at an elevated concentration. In fact, the only constituent detected in surface water at elevated concentrations (lead) was not found in groundwater at elevated concentrations. Ecological receptors have the potential to be exposed to groundwater only through surface water exposure pathways. Although there may be groundwater/surface water interchange during periods of high precipitation, there does not appear to be a significant exchange of contaminants between the two media.

Based on the extremely low concentrations of the constituents detected in groundwater, the infrequency of detection, and the fact that none of the groundwater constituents was detected at elevated concentrations in surface water at the IMR ranges, it was concluded that there are no COPECs in groundwater at the IMR ranges.

3.1.5 Summary of COPECs

The COPECs that were initially identified in the SLERA, refined in the problem formulation report, and form the basis for this BERA study design for the IMR ranges are the following:

- ***Surface Soil*:** antimony, copper, lead, and zinc
- ***Surface Water*:** lead
- ***Sediment*:** arsenic, barium, copper, lead, manganese, and thallium.

Table 3-2

Groundwater Elevations and Screening Intervals
Ranges at Iron Mountain Road, Parcels 69Q, 70Q, 71Q and 75Q
Fort McClellan, Calhoun County, Alabama

Well Location	Date	Depth to Water (ft BTOC)	Top of Casing Elevation (ft amsl)	Ground Elevation (ft amsl)	Groundwater Elevation (ft amsl)	Screen Interval (ft bgs)	Screen Interval (ft amsl)
HR-69Q-MW01	8-Jan-02	20.28	799.58	797.73	779.30	27 - 47	770.73 - 750.73
HR-69Q-MW02	8-Jan-02	20.5	799.58	797.73	779.08	92 - 102	705.73 - 695.73
HR-70Q-MW01	8-Jan-02	27	899.89	897.9	872.89	9.6 - 29.6	888.3 - 868.3
HR-70Q-MW02	8-Jan-02	77.29	899.9	897.88	822.61	66 - 76	831.88 - 821.88
HR-71Q-MW01	8-Jan-02	15.43	877.31	875.25	861.88	21 - 36	854.25 - 839.25
HR-75Q-MW01	8-Jan-02	21.31	844.33	842.56	823.02	21 - 36	821.56 - 806.56
HR-75Q-MW03	8-Jan-02	85.72	839.62	837.67	753.90	63 - 83	774.67 - 754.67
HR-75Q-MW04	8-Jan-02	9.71	847.93	846.19	838.22	23 - 38	823.19 - 808.19

Elevations referenced to the North American Vertical Datum of 1988 (NAVD88).

bgs - below ground surface
BTOC - Below top of casing
ft - Feet
amsl - Above mean sea level

3.2 COPEC Fate and Transport

The environmental fate and transport of the COPECs in the various media at the IMR ranges will govern the potential for exposures to wildlife. In general, COPECs in environmental media may be available for direct exposure (e.g., plants exposed to surface soil) and they may also have the potential to migrate to other environmental media or areas of the site. The mechanisms by which COPECs can be transported and the chemical properties that determine their transport are discussed in the following sections.

3.2.1 Fate and Transport in Soil

Contaminants in surface soil at the IMR ranges have the potential to be transported from their source area to other areas within the respective ranges and to off-site locations by a number of mechanisms, including volatilization, dust entrainment, surface runoff, and infiltration to subsurface soil/groundwater.

Several volatile organic compounds (VOC) were identified in the upper soil horizons at the IMR ranges. These volatile constituents have a high potential to volatilize to the atmosphere and be transported from their source area via air movement. The concentrations of VOCs detected in surface soil at the IMR ranges are low; therefore, this transport mechanism is expected to be insignificant with respect to other transport mechanisms active at this site. Most of the metals and semivolatile organic compounds (SVOC) in the surface soil at the IMR ranges are not expected to volatilize to any great extent, with the exception of mercury, which would be expected to volatilize relatively rapidly. Most of the metals and SVOCs in the surface soil at the IMR ranges are generally closely associated with particulate matter and would be transported from their source areas by fugitive dust generation and entrainment by the wind. Subsequent dispersion by atmospheric mixing could transport particulate-associated contaminants to other parts of the IMR ranges and to off-site locations. The generation of fugitive dust and subsequent transport by the wind is potentially a significant transport mechanism at the IMR ranges, based on the presence of nonvegetated areas and areas of sparse vegetation in certain areas of these ranges (e.g., impact areas and soil berms).

The transport of surface soil-associated contaminants by surface runoff is another potentially significant transport mechanism. Surface soil contaminants may be solubilized by rainwater and subsequently transported to drainage ditches, low-lying areas, and Remount Creek via surface runoff. The solubility of inorganics in rainwater is largely dependent upon the pH of the rainwater. Because the rainwater in this region is most likely slightly acidic, the inorganic constituents in surface soil are likely to solubilize to some degree in the rainwater and be subject to transport via runoff. Most of the SVOCs are strongly associated with soil particles and would not solubilize to a large extent. Contaminants that may be more strongly bound to particulate matter in surface soil (e.g., SVOCs and some of the inorganics) may be entrained in surface water runoff and transported to drainage ditches, low-lying areas, and Remount Creek via surface runoff. Many of the metals and semivolatiles are strongly sorbed to soil particles and could be transported from their source areas via this mechanism.

Contaminants in surface soil may be transported vertically to subsurface soils and groundwater via solubilization in rainwater and infiltration. Subsequent groundwater transport to surface water in Remount Creek could result in exposure of aquatic receptors to soil contaminants. Migration in this manner is dependent upon contaminant solubility and frequency of rainfall. Although the soil types in the vicinity of the IMR ranges (sand, stone, and gravel) are expected to promote relatively rapid infiltration of rainwater, the less soluble constituents (e.g., SVOCs) found at the IMR ranges are not likely to migrate to any great extent vertically, due to their relatively low solubilities. Inorganics in soil at the IMR ranges may migrate vertically due to the acidic nature of the rainwater in this area and the increased solubility of metals that acid rainwater produces. However, surface water and groundwater monitoring data indicate that this transport mechanism is insignificant at the IMR ranges, as only lead was detected in surface water at elevated concentrations and lead was not detected in any groundwater samples at elevated concentrations. Furthermore, other constituents detected in groundwater were not detected in surface water at the IMR ranges.

The transfer of contaminants in surface soil to terrestrial plants through root uptake and transfer to terrestrial animals through ingestion and other pathways are potentially significant transfer mechanisms. Many metals are readily absorbed from soil by plants, but they are not biomagnified to a great extent through the food web. There are several exceptions to this, namely, arsenic and nickel, which may bioconcentrate and/or biomagnify (Agency for Toxic Substances and Disease Registry [ATSDR], 1989 and 1995). Many of the SVOCs have the potential to bioaccumulate in lower trophic level organisms (e.g., terrestrial invertebrates), but most higher trophic level animals have the ability to metabolize these compounds rapidly, precluding the potential for bioconcentration (Eisler, 1987).

VOCs in the surface soil at the IMR ranges are expected to volatilize and/or photolyze rapidly (half-lives of 3 hours to 5 days) when exposed to sunlight (Burrows et al., 1989). The other surface soil contaminants (metals and semivolatiles) are expected to remain in the soil relatively unchanged by physical and/or chemical processes for much longer periods of time.

3.2.2 *Fate and Transport in Surface Water*

In general, contaminants present in the surface water associated with the IMR ranges (Remount Creek and tributaries) are the result of erosion and runoff from the ranges. Contaminants in surface water at the IMR ranges may be transported from their sources to other areas at the ranges or to off-site locations by the following mechanisms: 1) volatilization, 2) transfer to groundwater, 3) transfer to sediment, and 4) flow downstream. VOCs in surface water would be expected to rapidly volatilize from the water-air interface and be dispersed in the atmosphere. Therefore, transport of VOCs in surface water is not expected to occur for any significant distance.

Water in Remount Creek originates mainly from discharge from Yahou Lake and overland flow from the surrounding watershed. There also may be sporadic and localized contributions to creek flow from groundwater where the potentiometric surface exceeds the creek bed surface. The flow contribution to Remount Creek from groundwater varies according to the amount of precipitation, with an increase in groundwater contribution when precipitation raises the potentiometric surface.

Thus constituents in groundwater could migrate to surface water in Remount Creek and its tributaries after significant precipitation occurs. This transport mechanism appears to be relatively insignificant, based on the fact that only lead has been detected in surface water at concentrations that are elevated with respect to its ESV. Other constituents detected in groundwater have not been detected in surface water at elevated concentrations. Additionally, elevated lead concentrations in surface water are restricted to Remount Creek and small tributaries at the Skeet Range. Contaminant transfer to sediments represents another significant transfer mechanism, especially where contaminants are in the form of suspended solids or are hydrophobic substances (e.g., polynuclear aromatic hydrocarbons [PAH]) that can become adsorbed to organic matter in the sediments. The metals detected in surface water have the potential to associate with suspended particulate matter.

Contaminants in surface water can be transported to other ranges along Iron Mountain Road or off site via Remount Creek. Transfer of contaminants in surface water to aquatic organisms is also a potentially significant transfer pathway. Some of the inorganic constituents detected in surface water may bioaccumulate in lower trophic level organisms. Most of the inorganics detected in surface water are not highly bioconcentratable; therefore, transfer through the food web is expected to be minimal for these compounds.

3.2.3 Fate and Transport in Sediment

Contaminant transfer between sediment and surface water potentially represents a significant transfer mechanism, especially when contaminants are in the form of suspended solids. Sediment/surface water transfer is reversible; sediments often act as temporary repositories for contaminants and gradually release contaminants to surface waters. This is especially true in surface water systems that are acidic, as is the case with Remount Creek in the vicinity of the IMR ranges. Sorbed or settled contaminants can be transported with the sediment to downstream locations. Much of the substrate of Remount Creek and its tributaries in the vicinity of the IMR ranges is best characterized as gravel or cobbles. Very few areas of high organic content sediment or muck are present. The very low organic content of gravel and cobble create a substrate with very low binding capacity; therefore, constituents released to Remount Creek and its tributaries via surface runoff or other transport mechanisms would most likely remain suspended in the surface water and be transported downstream and would not be sequestered in the stream substrate directly adjacent to the IMR ranges.

Directly downstream of the Skeet Range, Remount Creek passes the former location of Motor Pool 3100, flows through a concrete culvert beneath the former parade grounds, and then flows through the Cane Creek Golf Course before its confluence with Cane Creek. The portion of Remount Creek directly downstream of the Skeet Range exhibits small reaches with characteristics of both high-energy (scouring) and low-energy (depositional) environments. Short reaches of Remount Creek directly downstream of the Skeet Range in the vicinity of Motor Pool 3100 exhibit a low gradient and a narrow and shallow channel, which are characteristic of a low-energy stream environment. If sediment-associated contamination was being transported by Remount Creek downstream of the IMR ranges, it could be expected to be deposited in these low-energy sections of Remount Creek in the vicinity of the former Motor Pool 3100. There are also sections of Remount Creek in the vicinity of Motor Pool 3100 that exhibit characteristics of a high-energy environment. These creek reaches exhibit deep erosional channels and cobble and boulder substrate. Deposition of sediment-associated COPECs is not expected in these high-energy portions of Remount Creek.

Although transfer of sediment-associated contaminants to bottom-dwelling biota also represents a potentially significant transfer mechanism, it is not expected to be a major mechanism at the IMR ranges. Lower trophic level organisms may accumulate metals and PAHs; however, higher trophic level organisms have the ability to metabolize PAHs and therefore reduce their accumulative properties. Most of the inorganics detected in sediment are not bioaccumulative. Mercury and copper may bioaccumulate to some extent due to exposures to sediment.

3.2.4 Constituent-Specific Fate and Transport Properties

The following subsections describe the fate and transport properties of each of the COPECs identified at the IMR ranges.

3.2.4.1 Antimony

Antimony binds to soil, particularly to particles containing iron, manganese, or aluminum. It is also oxidized by bacteria in the soil. In water, antimony is oxidized when exposed to atmospheric oxygen. Antimony is not significantly metabolized and is excreted in the urine and feces. It does not biomagnify in terrestrial food chains but can bioconcentrate in aquatic organisms. Antimony may be taken up by plants, the rate of which is dependent upon the solubility of the antimony in the soil. It should also be noted that antimony is associated with ammunition, being present in lead alloys in bullets and in materials used as primers. Antimony can be present in both the 3+ and 5+ valence states, depending on pH, oxidation-reduction potential, and several other chemical properties of the environmental medium in which it is found. Antimony can methylate via chemical and/or biological reactions into an organic form under reducing conditions such as those commonly found in highly organic fine sediments.

3.2.4.2 Arsenic

Most arsenic in the environment exists in soil or rock. Because many arsenic compounds tend to adsorb to soils or sediments, leaching usually results in transportation over only short distances in soil (Moore, et al., 1988).

Transport and partitioning of arsenic in water depends upon the chemical form (oxidation state and counter ion) of the arsenic and on interactions with other materials present. Soluble forms move with the water, and may be carried long distances by rivers and streams (Callahan, et al., 1979). However, arsenic may be adsorbed from water onto sediment or soil, especially clays, iron oxides, aluminum hydroxides, manganese compounds, and organic material (Callahan, et al., 1979). Sediment-bound arsenic may be released back into the water by chemical or biological interconversions of arsenic species.

Bioconcentration of arsenic occurs in aquatic organisms, primarily in algae and lower invertebrates. Bioconcentration factors measured in freshwater invertebrates and fish for several arsenic compounds ranged from 0 to 17 (EPA, 1980). Biomagnification in aquatic food chains does not appear to be significant (Callahan, et al., 1979). Terrestrial plants may accumulate arsenic by root uptake from the soil or by absorption of airborne arsenic deposited on the leaves (EPA, 1982).

Arsenic in water can undergo a complex series of transformations, including oxidation-reduction reactions, ligand exchange, and biotransformation (Callahan, et al., 1979). The factors most strongly influencing the fate processes in water include the oxidation-reduction potential, pH, metal sulfide and sulfide ion concentrations, iron concentrations, temperature, salinity, and distribution and composition of the biota (Callahan, et al., 1979). The predominant form of arsenic in surface water is usually arsenate (EPA, 1982), but aquatic microorganisms may reduce the arsenate to arsenite and a variety of methylated arsenicals (Benson, 1989). Arsenate also predominates in groundwater, but arsenite may be an important component, depending upon the characteristics of the water and surrounding geology (Robertson, 1989).

Transformations of arsenic in soil are similar to those occurring in aquatic systems, with As (+5) predominating in aerobic soils, As (+3) in slightly reduced soils (e.g., temporarily flooded), and arsine methylated arsenic, and elemental arsenic in very reduced conditions (e.g., swamps and bogs). Organoarsenical pesticides (e.g., MMA, DMA) applied to soil are metabolized by soil bacteria to alkylarsines, arsenate, and MMA (Hood, 1985). The half-life of DMA in soil is about 20 days (Hood, 1985).

3.2.4.3 Barium

In aquatic media, barium is likely to precipitate out of solution as an insoluble salt (i.e., as $BaSO_4$ or $BaCO_3$). Waterborne barium may also adsorb to suspended particulate matter (Bodek, et al., 1988). Sedimentation of suspended solids removes a large portion of the barium content from surface waters (Benes, et al., 1983). Barium in sediments is found largely in the form of barium sulfate (barite). The uptake of barium by fish is also an important removal mechanism (Schroeder, 1970).

Barium is not very mobile in most soil systems. The rate of transportation of barium in soil is dependent on the characteristics of the soil material. Soil properties that influence the transportation of barium to groundwater are cation exchange capacity and calcium carbonate content. In soil with a high cation exchange capacity (e.g., fine textured mineral soils or soils with high organic matter content), barium mobility will be limited by adsorption (Kabata-Pendias and Pendias, 1992). High $CaCO_3$ content limits mobility by precipitation of the element as $BaCO_3$ (Lagas, et al., 1984). Barium will also precipitate as barium sulfate in the presence of sulfate ions (Lagas, et al., 1984). Humic and fulvic acids have not been found to increase the mobility of barium (EPA, 1984).

Under natural conditions barium will form compounds in the +2 oxidation state. Barium does not hydrolyze appreciably except in highly alkaline environments (i.e., at pH levels greater than or equal to 10) (Bodek, et al., 1988). Appreciable levels of barium sulfate occur because natural water often contains high sulfate concentrations. Since the solubility of barium sulfate is low, only trace amounts of barium dissolve in surface water (Bodek, et al., 1988). Barium forms salts of low solubility with arsenate, chromate, fluoride, oxalate, and phosphate ions (Bodek, et al., 1988). The chloride, hydroxide, and nitrate of barium are water soluble and are frequently detected in aqueous environments (Rai, et al., 1984).

Barium reacts with metal oxides and hydroxides in soil and is subsequently adsorbed onto soil particulates (Rai, et al., 1984). Adsorption onto metal oxides in soils and sediments probably acts as a control over the concentration of barium in natural waters (Bodek, et al., 1988). Barium is also adsorbed onto soil through electrostatic interactions. The cation exchange capacity of the sorbent largely controls the retention of barium in soils. Barium is strongly adsorbed by clay minerals (Kabata-Pendias and Pendias, 1992).

Barium can also form salts with acetate, nitrate, chloride, and hydroxide ions in soil. The mobility of barium in soils increases upon formation of these water soluble salts (Bodek, et al., 1988). In general, the solubility of barium compounds increases with decreasing pH.

3.2.4.4 Copper

Copper's movement in soil is determined by a host of physical and chemical interactions with the soil components. In general, copper will adsorb to organic matter, carbonate minerals, clay minerals, or hydrous iron and manganese oxides. Sandy soils with low pHs have the greatest potential for leaching. When the amount of organic matter is low, the mineral content or iron, manganese, and aluminum oxides become important in determining the adsorption of copper. Copper binds to soil much more strongly than other divalent cations, and the distribution of copper in the soil solution is less affected by pH than other metals (ATSDR, 1990).
Copper binds primarily to organic matter in sediment, unless the sediment is organically poor. It also binds to iron oxides.

The bioconcentration factor (BCF) of copper in fish obtained in field studies ranges from 10 to 100, indicating a low potential for bioconcentration. The BCF is higher in mollusks, where it may reach 30,000. This may be due to the fact that many mollusks are filter feeders, and copper concentrations are higher in particulates than in water. There is abundant evidence, however, that there is no biomagnification of copper in the food chain. No evidence of bioaccumulation in herbivorous, omnivorous, and carnivorous mammals was obtained during a study of 10 mammal species in Donana National Park in Spain. A study of metals in cottontail rabbits showed that, while the concentration of copper in surface soil was 130 percent higher than in control areas, the concentration of copper in foliar samples was insignificant. No significant increase in copper was observed in rabbit muscle, femur, kidney, or liver, indicating that copper was not bioaccumulating in the food chain. Even at the lowest levels of the food chain, there is little evidence of copper bioaccumulation. In a study of earthworms *(Eisenia fetida)* and soil from 20 different sites, copper concentrations in earthworms poorly correlated with copper in soil (ATSDR, 1990).

At the pH values and carbonate concentrations characteristic of natural waters, most dissolved copper exists as carbonate complexes rather than as free (hydrated) cupric ions. The concentration of dissolved copper depends on factors such as pH, oxidation-reduction potential, and the presence of competing cations (e.g., Ca^{2+}, Fe^{2+}, Mg^{2+}), anions of insoluble cupric salts (e.g., OH^-, S^{2-}, PO_4^{3-}), and organic and inorganic complexing agents. Allard (1995) reported that copper can exist in the form of freely dissolved divalent copper cation at a pH of less than 6. Complexation of copper with humic acids can increase the mobility of copper in groundwater and/or surface water but will also reduce the bioavailability to biota. The most significant precipitate formed in natural waters is malachite [$Cu_2(OH)_2CO_3$]. The combined processes of complexation, adsorption, and precipitation control the level of free copper. The chemical conditions in most natural waters are such that, even at relatively large copper concentrations, these processes will reduce the free copper concentration to extremely low values (ATSDR, 1990).

Between pH 5 and 6, adsorption is the principal process for removing copper from water; above pH 6, precipitation becomes more dominant. Copper binding in soil is correlated with pH, cation exchange capacity, organic content of the soil, and presence of iron oxides. Copper may also be incorporated into mineral lattices, where it is unlikely to have ecological significance. In soils with high organic carbon content, copper will be tightly bound to organic matter (ATSDR, 1990).

3.2.4.5 Lead

The chemistry of lead in aqueous solution is highly complex because this element can be found in a multiplicity of forms. The form of lead at any given site is very important, since its bioavailability and uptake dynamics are generally dictated by its form. For example, lead fumes, as from a smelter or gasses generated from the discharge of artillery or bullets, are more bioavailable than mining wastes or intact pieces of lead fragments. The difference is therefore not only the size of the particles, but the chemical form of the lead. It should also be noted that lead in soil can slowly undergo speciation to more insoluble sulfate, sulfide, oxide, and phosphate salts (National Library of Medicine, 1996). Lead has a tendency to form compounds of low solubility with the major anions of natural water. In the natural environment, the divalent form is the stable ionic species of lead. Hydroxide, carbonate, sulfide, and sulfate may act as solubility controls in precipitating lead from water. The amount of lead that remains in solution depends upon the pH of the water and the dissolved salt content. Lead is more soluble in softer water and in low pH-water (ATSDR, 1988). Complexation of lead with humic acids can increase the mobility of lead in groundwater and/or surface water but will also reduce the bioavailability to biota.

A significant fraction of lead carried by surface water is expected to be in an undissolved form, which can consist of colloidal particles or lead compounds incorporated in other components of surface particulate matter from runoff. Lead may occur as sorbed ions or surface coatings on sediment mineral particles, or it may be carried as a part of suspended living or nonliving organic matter in water. The ratio of lead in suspended solids to lead in dissolved form ranges from 4:1 to 27:1 (ATSDR, 1988).

Most lead in soil is retained there and very little is transported into surface water or groundwater (ATSDR, 1988). Low alkalinity and low pH conditions in soils can enhance the potential for bioconcentration of lead in mammals, birds, mosses, lichens, lower trophic level animals, and plants (Jenkins, 1981).

Most lead does not appear to bioaccumulate significantly in most fish. However, bioaccumulation of tetraethyl lead can occur in aquatic organisms (ATSDR, 1988). Plants commonly take up lead from soil and, therefore, may return it upon decomposition. Because the bioavailability of lead is dependent upon site-specific conditions, the accuracy of the ecological assessment of lead depends heavily on site-specific tests of bioavailability and subsequent toxicity and accumulation.

3.2.4.6 Manganese

The transport and partitioning of manganese in water is controlled by the solubility of the specific chemical form present, which in turn is determined by Eh, pH, and the characteristics of the available anions. The metal may exist in water in any of four oxidation states (2+, 3+, 4+, or 7+). Divalent manganese (Mn+2) predominates in most waters (pH 4 – 7), but may become oxidized at pH greater than 8 or 9 (EPA, 1984). The principal anion associated with Mn (+2) in water is usually carbonate (CO_3^{-2}), and the concentration of manganese is limited by the relatively low solubility of Mn CO_2 (Schaaming, et al., 1988). In relatively oxidized water, the solubility of Mn (+2) may be controlled by manganese oxide equlibria, with manganese being converted to the (+3) or (+4) valence states. In extremely reduced water, the fate of manganese tends to be controlled by formation of the poorly soluble sulfide (EPA, 1984).

Manganese is often transported in rivers and streams as suspended sediments. Manganese in water may be significantly bioconcentrated at lower trophic levels. In general, the data indicate that lower trophic level organisms such as algae have larger BCFs than higher trophic level organisms. Thus, biomagnification of manganese in the food chain does not appear to be significant (EPA, 1984).

The tendency of soluble manganese compounds to adsorb to soils and sediments depends mainly on the cation exchange capacity and the organic composition of the soil (Curtin, et al., 1980). At low concentrations, manganese may be "fixed" by clays, and will not be released into solution readily. At higher concentrations, manganese may be desorbed by ion exchange mechanisms with other ions in solution (Rai, et al., 1986).

Manganese in water may undergo oxidation at high pH or Eh, and is also subject to microbial activity. Likewise, the oxidation state of manganese in soils and sediments may be altered by microbial activity.

3.2.4.7 Thallium

Thallium exists in water primarily as a monovalent ion (thallium^{+}); thallium may be trivalent (Tl^{3+}) in very oxidizing water (Callahan, et al., 1979). Thallium may precipitate from water as solid mineral phases. However, thallium chloride, sulfate, carbonate, bromide, and hydroxide are very soluble in water. In extremely reducing water, thallium may precipitate as a sulfide (Tl_2S), and in oxidizing water, Tl^{3+} may be removed from solution by the formation of $Tl(OH)_3$ (Lee, 1971).

Thallium may be bioconcentrated by organisms from water. The experimentally-derived BCF value for thallium in bluegill sunfish was reported to be 34 (Barrows, et al., 1978). Thallium is absorbed by plants from soil and thereby enters the terrestrial food chain. Thallium can be absorbed by roots of higher plants from the rhizosphere (Cataldo and Wildung, 1983). There is no evidence to suggest that thallium is biotransformed in the environment.

3.2.4.8 Zinc

Zinc occurs in the environment mainly in the +2 oxidation state. Sorption is the dominant reaction, resulting in the enrichment of zinc in suspended and bed sediments. Zinc in aerobic waters is partitioned into sediment through sorption onto hydrous iron and manganese oxides, clay minerals, and organic material. The efficiency of these materials in removing zinc from solution varies according to their concentrations, pH, oxidation-reduction potential, nature and concentration of complexing ligands, cation exchange capacity, and the concentration of zinc (ATSDR, 1994). Similar to copper, zinc is complexed at high pHs and can exist as freely dissolved divalent cations at lower pHs, thus enhancing its bioavailability.

Zinc is an essential nutrient that is present in all organisms. Although biota appear to be a minor reservoir of zinc relative to soils and sediments, microbial decomposition of biota in water can produce ligands, such as humic acids, that can affect the mobility of zinc in the aquatic environment through zinc precipitation and adsorption (ATSDR, 1994). Zinc can accumulate in freshwater animals at 51 to 130 times the concentration present in water. In general, zinc does not biomagnify through food chains. Furthermore, although zinc bioaccumulates to some degree in aquatic systems, biota appear to represent a relatively minor sink compared to sediments. Steady-state zinc BCFs for 12 aquatic species range from 4 to 24,000, with most being less than 100. With respect to bioconcentration from soil by terrestrial plants, invertebrates, and mammals, BCFs of 0.4, 8, and 0.6, have been reported, respectively. In general, plants do not concentrate zinc above levels present in the soil (ATSDR, 1994).

3.3 Potential Receptors and Exposure Pathways

For exposures to occur, a complete exposure pathway must exist between the contaminant and the receptor. A complete exposure pathway requires the following four components:

- A source mechanism for contaminant release
- A transport mechanism
- A point of environmental contact
- A route of uptake at the exposure point (EPA, 1989).

If any of these four components are absent, then a pathway is generally considered incomplete. The following sections describe the CSM for the IMR ranges and the exposure pathways that are potentially complete for the feeding guilds expected to occur at the IMR ranges.

Ecological receptors may be exposed to the COPECs in soils via direct and/or secondary exposure pathways. Direct exposure pathways include soil ingestion, dermal absorption, and inhalation of COPECs adsorbed to fugitive dust. Significant exposure via dermal contact is limited to organic constituents that are lipophilic and can penetrate epidermal barriers. Mammals are less susceptible to exposure via dermal contact with soils because their fur prevents skin from coming into direct contact with soil. Because the COPECs identified at the IMR ranges are all inorganic compounds, dermal absorption is expected to be minimal. Although inhalation of

COPECs via fugitive dust is a potential exposure pathway, it is expected to be insignificant compared to the ingestion pathway. Soil ingestion may occur while grooming, preening, burrowing, or consuming plants, insects, or invertebrates resident in soil.

Ecological receptors may be exposed to the sole COPEC in surface water (lead) via direct contact or through consumption of water. As was the case with soils, dermal absorption of COPECs from surface water is expected to be minimal due to the low dermal permeability of lead (the only COPEC identified in surface water).

Because the constituents detected in sediment are inorganic compounds that are not prone to volatilization, volatilization from sediments is not considered an important fate mechanism. Additionally, the moist nature of the sediments precludes the generation of fugitive dust. Therefore, inhalation of constituents originating from the sediment is not a significant exposure pathway. Exposure via dermal contact may occur, especially for benthic organisms and wading birds or other animals that may use Remount Creek as a feeding area. However, dermal absorption of the COPECs in sediment is expected to be minimal due to the low dermal permeabilities of the COPECs found in sediment. Some aquatic organisms consume sediment and ingest organic material from the sediment. Inadvertent ingestion of sediments may also occur as the result of feeding on benthic organisms and plants.

While constituents in soils may leach into groundwater, environmental receptors generally will not come into direct contact with constituents in groundwater, since there is no direct exposure route. The only potential exposure pathways for ecological receptors to groundwater would be via surface water exposure routes. As described previously, groundwater discharge to surface water at the IMR ranges may be a viable transport mechanism for dissolved constituents; however, exposure to these constituents by ecological receptors is only possible via surface water exposure routes. Potential exposure to groundwater-related constituents is expected to be insignificant, based on the fact that lead was the only constituent detected at elevated concentrations in surface water at the IMR ranges, and lead was not detected in any groundwater samples at elevated concentrations. Furthermore, other constituents detected in groundwater samples at elevated concentrations were not detected in surface water at the IMR ranges. Therefore, although there may be groundwater/surface water interchange, there does not appear to be a significant exchange of contaminants between the two media. These data suggest that ecological exposure to constituents in groundwater through surface water exposure pathways is insignificant.

Secondary exposure pathways involve constituents that are transferred through different trophic levels of the food chain and may be bioaccumulated. This may include constituents bioaccumulated from soil into plant tissues or into terrestrial species that ingest soils. These plants or animals may, in turn, be consumed by animals at higher trophic levels. Water-borne and sediment-borne COPECs may bioaccumulate into aquatic organisms, aquatic plants, or animals which frequent surface waters and then be passed through the food chain to impact organisms at higher trophic levels.

Potential ecological receptors at the IMR ranges fall into two general categories: terrestrial and aquatic. Within these two general categories there are several major feeding guilds that could be expected to occur at the IMR ranges: herbivores, insectivores, omnivores, carnivores, and, to a lesser extent, piscivores. All of these feeding guilds are expected to be directly exposed to various combinations of surface soil at the IMR ranges and surface water and sediment in Remount Creek and its tributaries near the IMR ranges via various activities (e.g., feeding, drinking, grooming, bathing). These feeding guilds may also be exposed to site-related chemicals via food web transfers.

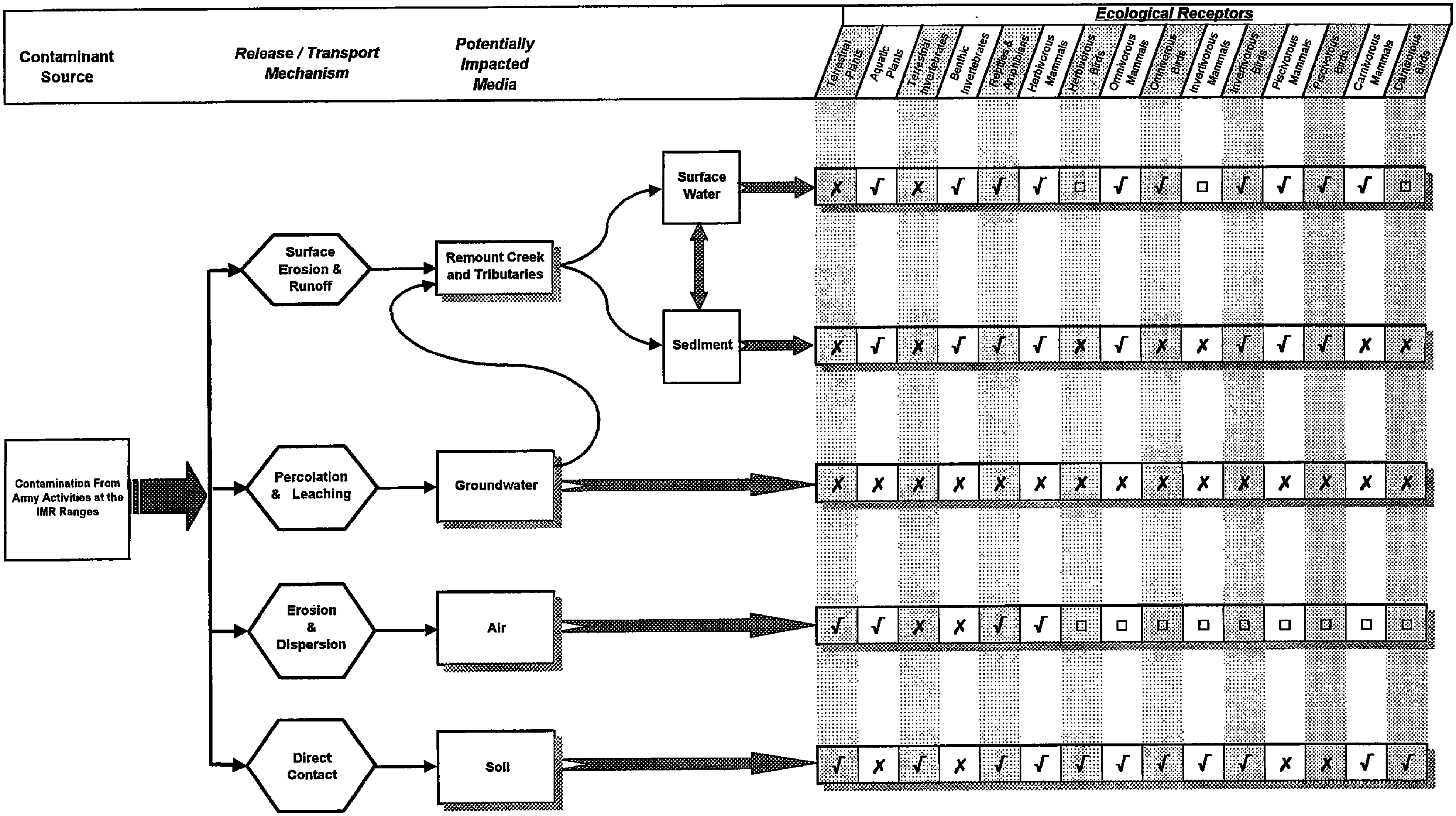
As discussed above, ingestion of COPECs in soil, surface water, and sediment is the exposure pathway for ecological receptors at the IMR ranges. Dermal absorption and inhalation exposures are expected to be insignificant. Food web transfers of COPECs are also possible exposure pathways for ecological receptors at the IMR ranges, although none of the COPECs at the IMR ranges has high bioconcentration or biomagnification potential.

The potentially complete exposure pathways are depicted in the CSM presented in Figure 3-1 and are described in the following sections for the various feeding guilds.

3.3.1 Herbivorous Feeding Guild

The major route of exposure for herbivores is through ingestion of plants that may have accumulated contaminants from the soil, surface water, or sediment. The vegetation at the formerly maintained areas of the IMR ranges is mainly grasses and sedges, which are remnants of the maintained grass that was present when the IMR ranges were operational. Since terrestrial herbivores by definition are grazers and browsers, they could be exposed to chemicals that have accumulated in the vegetative tissues of plants at the site. Terrestrial herbivores may also be exposed to site-related chemicals in soil through incidental ingestion of soil while grazing or grooming or during other activities.

Figure 3-1
Conceptual Site Model
For Iron Mountain Road Ranges
Fort McClellan, Calhoun County, Alabama



Media	Terrestrial Plants	Aquatic Plants	Terrestrial Invertebrates	Benthic Invertebrates	Reptiles & Amphibians	Herbivorous Mammals	Herbivorous Birds	Omnivorous Mammals	Omnivorous Birds	Invertivorous Mammals	Invertivorous Birds	Piscivorous Mammals	Piscivorous Birds	Carnivorous Mammals	Carnivorous Birds
Surface Water	✗	√	✗	√	√	√	□	√	√	□	√	√	√	√	□
Sediment	✗	√	✗	√	√	√	✗	√	✗	✗	√	√	√	✗	✗
Groundwater	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
Air	√	√	✗	✗	√	√	□	□	□	□	□	□	□	□	□
Soil	√	✗	√	✗	√	√	√	√	√	√	√	✗	✗	√	√

Key To Potential Exposure Routes

√ - Potentially complete exposure pathway
✗ - Incomplete exposure pathway
□ - Potentially complete exposure pathway but insignificant

Typical herbivorous species that could be expected to occur at the IMR ranges and are commonly used as sentinel species in ecological risk assessment include eastern cottontail (*Sylvilagus floridanus*), eastern gray squirrel (*Sciurus carolinensis*), pine vole (*Pitymys pinetorum*), whitetail deer (*Odocoileus virginianus*), and wild turkey (*Meleagris gallopavo*).

Aquatic herbivores, such as muskrat (*Ondatra zibethicus*) and mallard (*Anas platyrhynchos*), could be exposed to site-related constituents in surface water and/or sediment in Remount Creek and its tributaries. However, aquatic herbivores are not expected to routinely occur at Remount Creek in the vicinity of the IMR ranges, due to the ephemeral nature of the creek in this area.

3.3.2 Invertivorous Feeding Guild

Invertivores specialize in eating insects and other invertebrates. As such, they may be exposed to site-related chemicals that have accumulated in insects and other invertebrates. Invertivores may also be exposed to site-related chemicals in soil through incidental ingestion of soil while probing for insects or grooming or during other activities. Ingestion of soil while feeding is potentially a major exposure pathway for terrestrial invertivores, since much of their food (e.g., earthworms *[Eisenia fetida]* and other invertebrates) lives on or below the soil surface.

Typical terrestrial invertivorous species that could be expected to occur at the IMR ranges and are commonly used as sentinel species in ecological risk assessment include American woodcock (*Philohela minor*), carolina wren (*Thryothorus ludovicianus*), shorttail shrew (*Blarina brevicauda or Blarina carolinensis*), and eastern mole (*Scalopus aquaticus*). Aquatic invertivores (those species that live in water) could include the wood duck (*Aix sponsa*) and blacknose dace (*Rhinichthys atratulus*). However, aquatic invertivores are not expected to routinely occur at Remount Creek in the vicinity of the IMR ranges due to the ephemeral nature of the creek in this area.

Invertivores that feed on emergent aquatic insects, however, do have the potential to feed in the vicinity of the IMR ranges during periods of the year when water is present in the ephemeral ditches and tributaries that occur in the vicinity of these ranges. These riparian invertivores could be exposed to site-related chemicals in sediment through the ingestion of emergent aquatic insects that live in the sediment of Remount Creek and its tributaries. Aquatic insects could accumulate site-related chemicals from the sediment and could potentially be ingested by invertivores that feed in the vicinity of the IMR ranges. Typical riparian invertivores that feed on emergent aquatic insects include the little brown bat (*Myotis lucifugus*) and the marsh wren (*Cistothorus palustris*).

3.3.3 Omnivorous Feeding Guild

Omnivores consume both plant and animal material in their diet, depending upon availability. Therefore, they could be exposed to chemicals that have accumulated in the vegetative tissues of plants at the site and also to chemicals that may have accumulated in smaller animal tissues that the omnivores prey upon. They may also be exposed to surface water through ingestion of water in Remount Creek near the IMR ranges. Omnivores may also be exposed to site-related chemicals in soil through incidental ingestion of soil while feeding or grooming or during other activities.

Typical omnivorous species that are expected to occur at the IMR ranges and are commonly used as sentinel species in ecological risk assessment include red fox (*Vulpes vulpes*), white-footed mouse (*Peromyscus leucopus*), and American robin (*Turdus migratorius*).

Aquatic omnivores, such as raccoon (*Procyon lotor*) and creek chub (*Semotilus atromaculatus*), could be exposed to COPECs in surface water and sediment in Remount Creek and its tributaries in the vicinity of the IMR ranges. However, aquatic omnivores are not expected to routinely occur at Remount Creek in the vicinity of the IMR ranges due to the ephemeral nature of the creek in this area.

3.3.4 Carnivorous Feeding Guild

Carnivores are meat-eating animals and are, therefore, exposed to site-related chemicals through consumption of prey animals that may have accumulated contaminants in their tissues. Carnivores are quite often top predators in a local food web and are often subject to exposure to contaminants that have biomagnified through the food web. Food web exposures for carnivores are based on the consumption of prey animals that have accumulated COPECs from various means. Smaller herbivores, omnivores, invertivores, and other carnivores may consume soil, surface water, sediment, plant, and animal material as food and accumulate COPECs in their tissues. Subsequent ingestion of these prey animals by carnivorous animals would expose them to COPECs. Carnivores may also be exposed to site-related chemicals in soil through incidental ingestion of soil while feeding or grooming or during other activities. Most inorganic compounds are not accumulated in animal tissues to any great extent (Shugart, 1991; U.S. Army Environmental Hygiene Agency, 1994), and the COPECs at the IMR ranges do not significantly bioconcentrate or biomagnify in higher trophic levels organisms. Therefore, food web exposures to these chemicals are expected to be minimal.

Typical carnivorous species that are expected to occur at the IMR ranges and are commonly used as sentinel species in ecological risk assessment include red-tailed hawk (*Buteo jamaicensis*), black vulture (*Coragyps atratus*), and bobcat (*Lynx rufus*). Exposures of carnivores to COPECs are expected to be minimal due to the fact that the inorganic COPECs at the IMR ranges do not accumulate or magnify significantly in the prey items of carnivores.

Because Remount Creek and its tributaries in the vicinity of the IMR ranges are narrow and shallow, they do not have the capability to support large aquatic carnivores. Carnivorous fish such as largemouth bass (*Micropterus salmoides*) and spotted gar (*Lepisosteus oculatus*) do not occur in Remount Creek in the vicinity of the IMR ranges due to the habitat restrictions. Additionally, carnivorous mammals such as the mink (*Mustela vison*) would not be expected to occur in the vicinity of the IMR ranges for the same reason, lack of suitable prey habitat.

3.3.5 Piscivorous Feeding Guild

Piscivores are specialists that feed mostly on fish. Therefore, they may be exposed to site-related chemicals that have accumulated in small fish that may inhabit small pools within Remount Creek in the vicinity of the IMR ranges. They may also be exposed to surface water and sediment in the creek system through ingestion of drinking water and during feeding. Although these creeks are dry during certain periods of the year, they do hold flowing and/or standing water during portions of the year and could be utilized for drinking purposes. Although piscivorous species could be expected to visit the areas around the creek system in the vicinity of the IMR ranges during periods of the year when the creeks hold water, they would not be expected to live near the IMR ranges due to the ephemeral nature of the creek.

Food web exposures for piscivores are based on the consumption of fish that have accumulated COPECs from surface water and sediment. Forage fish may consume surface water, sediment, benthic invertebrates, aquatic plants, and planktonic material as food and accumulate COPECs in their tissues. Subsequent ingestion of these forage fish by piscivorous animals would expose them to COPECs. However, the inorganic COPECs at the IMR ranges are not accumulated in fish tissues to any great extent. Therefore, food web exposures to these chemicals are expected to be minimal.

Typical piscivorous species that could occur near the IMR ranges during the sporadic periods when water is present in the creek and are commonly used as sentinel species in ecological risk assessment include great blue heron (*Ardea herodias*) and belted kingfisher (*Ceryle alcyon*). Larger piscivorous fish species (e.g., small mouth bass, spotted gar) and piscivorous mammals (e.g., mink) do not occur in the creek system at the IMR ranges due to the ephemeral nature of Remount Creek in this area and its inability to support larger fish and other aquatic species.

3.3.6 Threatened and Endangered Species

Four species listed as threatened or endangered by the U.S Fish and Wildlife Service (USFWS) have been recorded at FTMC. These threatened and endangered species are as follows:

- Gray bat (*Myotis grisescens*)
- Blue shiner (*Cyprinella caerules*)
- Mohr's Barbara buttons (*Marshallia mohrii*)
- Tennessee yellow-eyed grass (*Xyris tennesseensis*).

The only federally listed species that has the potential to occur in the vicinity of the IMR ranges is the gray bat (Garland, 1996). The other federally listed species occur at Pelham Range or Choccolocco Creek.

The gray bat is almost entirely restricted to cave habitats and, with rare exceptions, roosts in caves year-round. Approximately 95 percent of the entire known population of gray bats hibernates in only nine caves each winter, with more than half in a single cave. Gray bat summer foraging habitat is found primarily over open water of rivers and reservoirs. They apparently do not forage over sections of rivers or reservoirs that have lost their normal woody vegetation along the banks (USFWS, 1982). Gray bats usually follow wooded corridors from their summer caves to the open water areas used as foraging sites. Forested areas surrounding and between caves, as well as over feeding habitats, are clearly advantageous to gray bat survival, as the cover provides increased protection from predators such as screech owls. In addition, surveys have demonstrated that reservoirs and rivers that have been cleared of their adjacent forest canopy are avoided as foraging areas by gray bats (USFWS, 1982).

The gray bat is entirely insectivorous, and surveys have shown that gray bats feed almost exclusively on mayflies at certain times of the year (Mount, 1986). Therefore, gray bats could be exposed to site-related constituents that have accumulated in aquatic insects from Remount Creek. Because gray bats are flying mammals and the IMR ranges do not provide roosting habitat, no other exposure pathways are complete for the gray bat.

Most foraging occurs within 5 meters of the water's surface, usually near a shoreline or stream bank. Mist net surveys were conducted on and adjacent to FTMC in 1995. Gray bats were captured along both Choccolocco Creek (east of FTMC Main Post) and Cane Creek on Pelham Range (west of FTMC Main Post) during these mist net surveys (Garland, 1996). These preliminary data suggest that these major stream corridors at FTMC may provide at least a minimum foraging habitat for gray bats. However, gray bat surveys have not been conducted on Remount Creek in the vicinity of the IMR ranges.

3.4 Assessment and Measurement Endpoints

Assessment and measurement endpoints are the basis of the study design phase of the BERA and define the ecological values that require protection and the methodologies by which those ecological values are measured, respectively. The following sections describe the assessment endpoints that have been identified for the IMR ranges, the risk hypotheses, and the corresponding measurement endpoints.

3.4.1 Selection of Assessment Endpoints

An assessment endpoint is "an explicit expression of the environmental value that is to be protected" (EPA, 1992). Assessment endpoints focus the risk assessment on particular valuable components of the ecosystem(s) that could be adversely affected by contaminants at the site. Individual assessment endpoints usually encompass a group of species or populations with some common characteristic, such as a specific exposure route or contaminant sensitivity.

Assessment endpoints for the IMR ranges were selected based on the ecosystems, communities, and species present at the IMR ranges. Selection of the assessment endpoints was dependent upon the following factors:

- The COPECs, their characteristics, and their concentrations at the IMR ranges
- The mechanisms of toxicity of the COPECs to different groups of organisms
- Ecologically relevant receptors that are potentially sensitive or highly exposed to the COPECs
- The presence of complete exposure pathways contributing to potential risk.

Following a site walk of the IMR ranges on May 10, 2002, by EPA, USFWS, FTMC and IT personnel, it was agreed that the terrestrial habitat types and receptor assemblages at the four IMR ranges were similar in structure and function and that they should be considered as a single ecological unit to the extent practicable. As such, assessment endpoints were selected to be inclusive of the systems and receptors at greatest risk across the four ranges. The habitat and receptor assemblages of Remount Creek and its tributaries at the IMR ranges were also determined to be similar in structure and function; therefore, the creek system was also addressed as a single ecological unit.

Based on the fact that the COPECs at the IMR ranges do not bioconcentrate or biomagnify appreciably through the food chain and do not accumulate appreciably in plant tissues (Kabata-

Pendias and Pendias, 1992), the ecological receptors with the potential for the greatest exposure to COPECs at the IMR ranges were determined to be invertivorous and omnivorous small mammals and birds. Herbivores were considered to have a lower exposure potential to COPECs because the COPECs do not accumulate appreciably in plant tissues, the herbivores' main food source. Carnivores were determined to have lower exposure potential to COPECs because the COPECs do not biomagnify in the food chain and would not be expected to occur at elevated concentrations in prey animal tissues. Additionally, carnivores in general have larger home ranges that would tend to minimize their exposures to COPECs at the IMR ranges. Likewise, piscivores were determined to have lower exposure potential to COPECs because the COPECs do not bioconcentrate or biomagnify in fish tissue to any appreciable extent and fish are not readily found in Remount Creek at the IMR ranges. Therefore, the assessment endpoints for the IMR ranges focus on the protection of the terrestrial omnivorous and invertivorous feeding guilds and the riparian invertivores mammals and birds potentially present at the IMR ranges.

3.4.1.1 Terrestrial Assessment Endpoints

Given the overall goal of protecting the integrity and quality of the terrestrial old field ecosystem at the IMR ranges, the terrestrial assessment endpoints focus on critical community niches within the old field system. As discussed above, the ecological receptors with the potential for the greatest exposure to COPECs at the IMR ranges were determined to be invertivorous and omnivorous small mammals and birds. Additionally, the terrestrial invertebrate community has the potential for significant exposure to COPECs. These ecological communities formed the basis for the assessment endpoints described herein.

The terrestrial invertebrate community forms a critical link in many terrestrial food webs and constitutes a food source for many omnivorous and invertivorous birds and mammals. Terrestrial invertebrates also perform an important function in the degradation of organic matter in soil through their bioturbative activities. Terrestrial invertebrates may also accumulate COPECs in their tissues and act as a conduit for the transfer of COPECs to higher trophic level organisms in the food chain. For these reasons, the terrestrial invertebrate community was identified as an important ecological resource at the IMR ranges. The assessment endpoint that has been identified with respect to the terrestrial invertebrate community is the following:

- Maintenance of a healthy terrestrial invertebrate community at the IMR ranges.

Invertivorous mammals and birds were identified as having significant potential for exposure to COPECs at the IMR ranges, mainly through ingestion of terrestrial invertebrates that may have accumulated COPECs in their tissues. In addition to the fact that this feeding guild has the potential to be maximally exposed to COPECs due to their feeding habits, these species also form an important food group for higher trophic level organisms. Carnivorous mammals and/or birds may prey on small invertivorous mammals and birds and thus become exposed to COPECs through ingestion of COPECs that have become incorporated into the prey species' tissues. For these reasons, invertivorous mammals and birds were identified as being an important ecological resource at the IMR ranges. The assessment endpoint that has been identified with respect to the invertivorous mammal and bird feeding guild is the following:

- Maintenance of healthy populations and communities of terrestrial invertivorous small mammals and birds at the IMR ranges.

Omnivorous mammals and birds were identified as having significant potential for exposure to COPECs at the IMR ranges, mainly because a portion of their diet includes terrestrial invertebrates that may have accumulated COPECs in their tissues. In addition to the fact that this feeding guild has the potential to be maximally exposed to COPECs due to their feeding habits, these species also form an important food group for higher trophic level organisms. Carnivorous mammals and/or birds may prey on small omnivorous mammals and birds and thus become exposed to COPECs through ingestion of COPECs that have become incorporated into the prey species' tissues. For these reasons, omnivorous mammals and birds were identified as being an important ecological resource at the IMR ranges. The assessment endpoint that has been identified with respect to the omnivorous mammal and bird feeding guilds is the following:

- Maintenance of healthy populations and communities of terrestrial omnivorous small mammals and birds at the IMR ranges.

The assessment endpoints that have been identified for the IMR ranges are summarized in Table 3-3.

Because these terrestrial assessment endpoints are highly dependent upon the bioavailability of the COPECs in soil, a study was conducted of the binding capacity of the soils found at the IMR ranges and the Bains Gap Road (BGR) ranges. It was assumed that soils with similar physical and chemical binding capacities would exhibit similar bioavailabilities for a given COPEC, regardless of where the soil and COPEC were located (i.e., regardless of what range the soil or COPEC were found on). IT collected a total of eight surface soil samples from the IMR ranges (Parcels 69Q, 70Q, 71Q, and 75Q) and the BGR ranges (Parcels 77Q, 78Q, 80Q, and 85Q). The surface soil samples were collected from five soil mapping units (U.S. Department of Agriculture, 1961): Anniston and Allen gravelly loams, Anniston ad Allen stony loams, Stony

Table 3-3

Assessment Endpoints, Risk Hypotheses, and Measurement Endpoints for the IMR Ranges Fort McClellan, Calhoun County, Alabama

(Page 1 of 2)

Assessment Endpoint	Risk Hypothesis	Measurement Endpoint
Terrestrial Ecosystems :		
I. Maintenance of a healthy invertebrate community.	I. Survival of terrestrial invertebrates exposed to surface soil collected from IMR ranges is statistically significantly different from that of invertebrates exposed to reference soil from non-impacted areas.	IA. Statistical comparison of earthworm survival rates between earthworms exposed to soils from the IMR ranges to earthworms exposed to reference site soils.
		IB. Statistical comparison of COPEC concentrations in tissues of earthworms exposed to soils from the IMR ranges to COPEC concentrations in earthworms exposed to reference site soils.
II. Maintenance of healthy local populations and communities of terrestrial invertivorous small mammals and birds.	II. Calculated hazard quotients using measured body burdens of COPECs in earthworms, site-specific diet composition, and area use factors indicate statistically significant potential for risk to either terrestrial invertivorous small mammals or birds.	II. Calculation of hazard quotients for terrestrial invertivorous small mammal (shorttail shrew) and invertivorous bird (American woodcock) using measured earthworm tissue concentrations of COPECs.
III. Maintenance of healthy local populations and communities of terrestrial omnivorous small mammals and birds.	III. Calculated hazard quotients using measured body burdens of COPECs in earthworms, site-specific diet composition, and area use factors indicate statistically significant potential for risk to terrestrial omnivorous small mammals or birds.	III. Calculation of hazard quotients for terrestrial omnivorous small mammal (white-footed mouse) and omnivorous bird (American robin) using measured earthworm tissue concentrations of COPECs and modeled vegetation concentrations of COPECs.

Table 3-3

Assessment Endpoints, Risk Hypotheses, and Measurement Endpoints for the IMR Ranges Fort McClellan, Calhoun County, Alabama

Assessment Endpoint	Risk Hypothesis	Measurement Endpoint
Riparian Ecosystems :		
I. Maintenance of a healthy aquatic benthic invertebrate community.	I. Survival of aquatic benthic invertebrates exposed to sediment collected from Cane Creek is statistically significantly different from that of benthic invertebrates exposed to sediment from non-impacted reference stream.	I. Statistical comparison of survival and growth of *Chironomus sp.* exposed to sediment from Cane Creek to survival and growth of *Chironomus sp.* exposed sediment from reference stream.
II. Maintenance of healthy local populations and communities of riparian invertivorous small mammals and birds.	II. Calculated hazard quotients using modeled COPEC concentrations in emergent aquatic insects, site-specific diet composition, and area use factors indicate statistically significant potential for risk to either riparian invertivorous small mammals or birds.	II. Calculation of hazard quotients for riparian invertivorous small mammal (little brown bat) and invertivorous bird (marsh wren) using modeled tissue concentrations of COPECs in emergent aquatic insects.

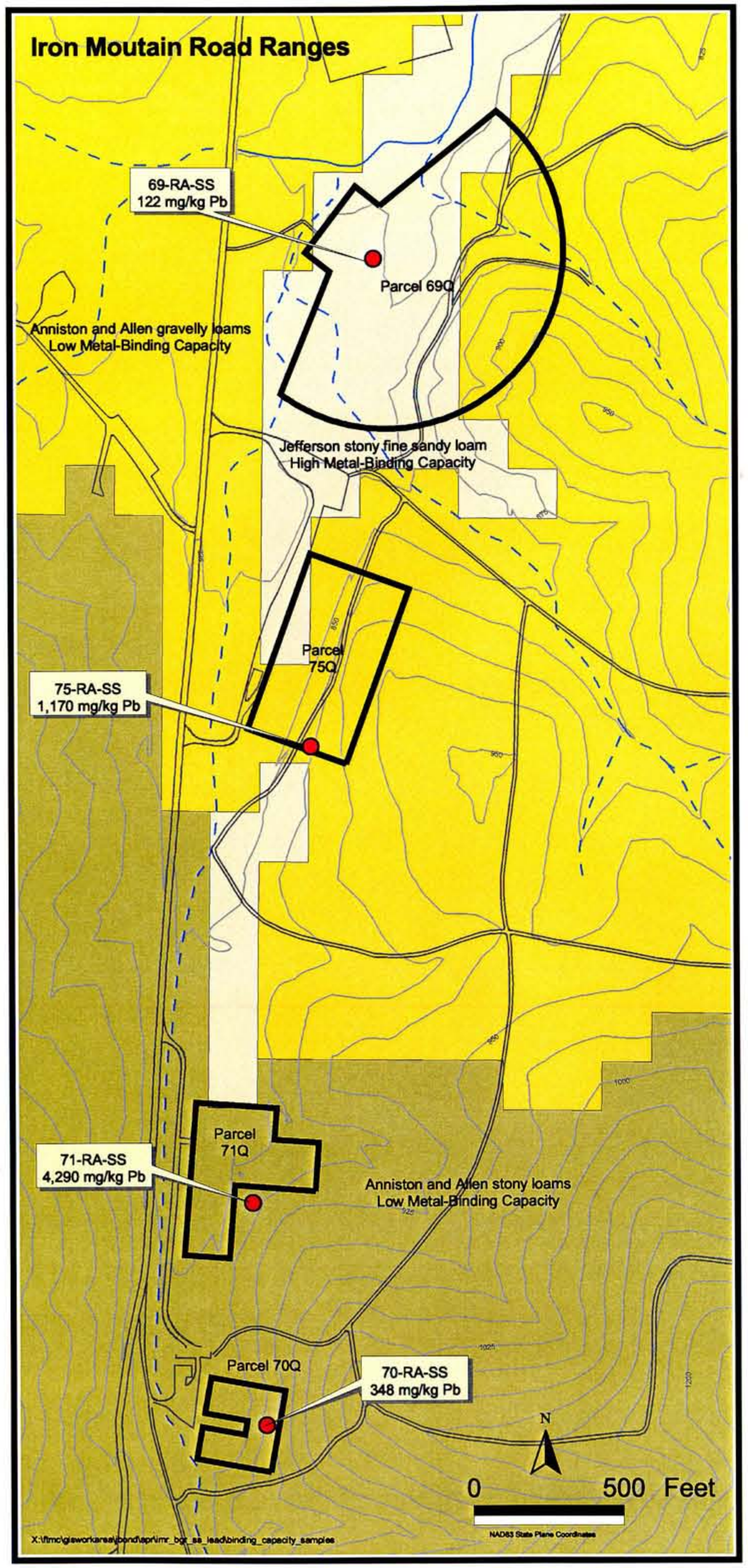
Rough Land Sandstone; Jefferson stony fine sandy loam, and Jefferson gravelly fine sandy loam. Figure 3-2 shows the location of the surface soil samples and the soil mapping units.

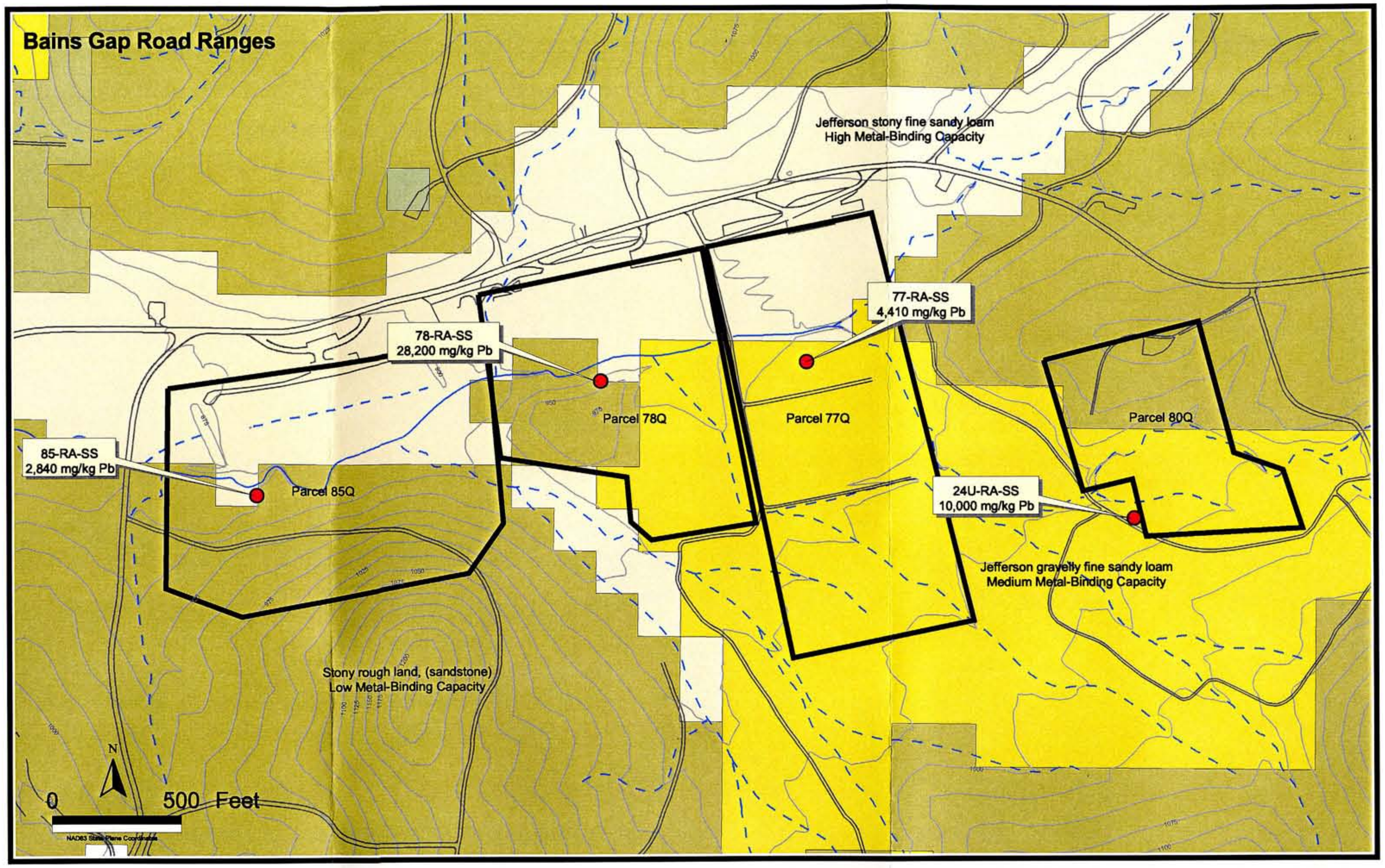
The surface soil samples were laboratory analyzed for the following physical and chemical characteristics:

- Texture
- pH
- Phosphate
- Total organic carbon
- Total carbonate
- Cation exchange capacity
- Iron oxyhydroxide content
- Total metals concentrations (aluminum, barium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, nickel, potassium, silicon, sodium, and titanium).

These physical and chemical analyses were conducted on "whole" surface soil samples. Sieving was not conducted prior to analysis. Table 3-4 presents the results of the analyses conducted on the eight surface soils from the IMR and BGR ranges. To determine the relative metal-binding capacity of the soils present at the sample locations, the analytical results for pH, cation exchange capacity, total organic carbon, texture (used in conjunction with the physical description recorded by the sampler at the time of sample collection), and total lead concentrations were used. Lead was used in this analysis because it is a significant COPEC at all of these ranges and has been used to identify areas of contamination at all of these ranges.

Based on the analysis of the results, the relative metal-binding capacities of the soils present at the sample locations were divided into three categories: low, medium, and high. The low, medium, and high metal-binding capacities were then assigned to the soil mapping units present at the ranges. The table below lists the relative metal-binding capacity assigned to each soil mapping unit.





Legend

- Study Area
- Roads
- Streams (dashed where intermittent)
- Topographic Contours (25-foot interval)
- Location of sample collected for soil binding capacity determination

Soil Mapping Units

- Anniston and Allen gravelly loams
- Anniston and Allen stony loams
- Jefferson gravelly fine sandy loam
- Jefferson stony fine sandy loam
- Stony rough land, (sandstone)
- mine or quarry (D)

Figure 3-2

Surface Soil Sample Locations and Lead Results Used to Determine Soil Metal-Binding Capacity

Iron Mountain Road and Bains Gap Road Ranges, Fort McClellan, Alabama

U.S. Army Corps of Engineers Mobile District

IT CORPORATION

Contract No. DACA21-96-D-0018

Table 3-4

Physical/Chemical Properties of Soil Related to Binding Capacity
Fort McClellan, Calhoun County, Alabama

Chemical Properties

Parameter	Sample Number							
	69Q	70Q	71Q	75Q	77Q	78Q	80Q	85Q
	SSFSL	AASL	AASL	AAGL	JGFSL	SRLS	JGFSL	JSFSL
pH (s.u.)	6.3	4.7	4.1	4.1	5.1	5.9	5.7	5.3
Phosphate (mg/kg)	76	48	52	33	110	1000	180	38
Total Organic Carbon (mg/kg)	22000	22000	58000	15000	19000	52000	20000	18000
Total Carbonate (mg/kg)	53000	40000	82000	62000	16000	68000	47000	57000
Cation Exchange Capacity (meq Na/100 g)	26	20.5	42.7	25.8	13.8	27.7	26.6	27.7
Iron Oxyhydroxide Content (mg/kg)	1600	1300	1110	1310	893	751	579	1480
Total Aluminum (mg/kg)	5590	6490	4770	4300	3890	1820	2030	3880
Total Barium (mg/kg)	78.1	33.5	85.2	48.3	81.6	181	122	214
Total Cadmium (mg/kg)	<0.684	<0.676	1.48	1.23	2.42	2.52	2.66	1.42
Total Calcium (mg/kg)	1330	153	1010	616	562	3170	9000	1930
Total Chromium (mg/kg)	11.2	6.84	7.30	6.32	6.42	2.8	7.17	5.07
Total Copper (mg/kg)	12.6	64.5	454	234	657	3780	927	94.8
Total Iron (mg/kg)	12900	5100	5200	5260	9780	3000	8720	5900
Total lead (mg/kg)	122	348	4290	1170	4410	28200	10000	2480
Total Magnesium (mg/kg)	290	195	232	165	337	273	479	317
Total Manganese (mg/kg)	452	97.2	303	50.9	637	1290	397	817
Total Nickel (mg/kg)	8.37	1.66	1.76	<1.44	3.51	1.90	4.60	2.01
Total Potassium (mg/kg)	262	89.6	151	127	463	182	241	451
Total Silicon (mg/kg)	125.3	59.26	140.9	133.9	126.1	45.06	8.015	116.5
Total Sodium (mg/kg)	8.55	6.86	8.41	5.18	7.34	6.93	7.08	6.39
Total Titanium (mg/kg)	10.66	12.76	18.48	12.68	6.637	7.942	5.321	3.67

Soil Mapping Units:
- AAGL - Anniston and Allen gravelly loams
- AASL - Anniston and Allen stony loams
- SRLS - Stony rough land, sandstone
- JGFSL - Jefferson gravelly fine sandy loam
- JSFSL - Jefferson stoney fine sandy loam

Table 3-4

Physical/Chemical Properties of Soil Related to Binding Capacity
Fort McClellan, Calhoun County, Alabama

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Physical Properties

Tyler Sieve	Diameter (mm)	Sample Number/Percent Finer							
		69Q	70Q	71Q	75Q	77Q	78Q	80Q	85Q
3"	75.0	100	100	100	100	100	100	100	100
1.5"	37.5	100	100	100	100	100	100	100	100
0.75"	19.0	100.0	93.2	100.0	96.2	100	97.3	93.6	96.5
0.375"	9.50	91.2	80.7	81.9	88.8	81.0	74.9	78.1	81.7
#4	4.75	88.6	68.5	60.9	79.6	72.1	48.8	62.3	73.7
#10	2.00	86.0	61.8	55.5	75.1	65.1	33.3	51.9	70.8
#20	0.850	83.2	59.2	52.8	71.9	59.9	25.5	45.7	67.1
#40	0.425	74.1	56.4	46.6	63.8	49.3	17.4	37.3	58.6
#60	0.250	64.2	53.3	39.7	54.4	40.2	12.5	29.7	48.5
#100	0.149	54.2	42.4	31.5	42.7	31.4	9.4	22.9	37.7
#140	0.106	46.4	31.2	25.0	34.1	25.4	8.0	19.4	30.9
#200	0.075	40.1	26.1	20.2	28.0	19.5	7.0	16.6	25.1
--	0.0478	37.6	25.0	--	26.6	17.9	--	--	--
--	0.0340	33.6	22.3	16.2	24.6	13.6	5.8	15.2	18.5
--	0.0226	29.7	19.1	13.7	22.6	11.9	4.8	12.1	16.6
--	0.0131	22.7	14.9	11.2	18.0	7.1	4.2	11.1	12.8
--	0.00931	18.0	12.8	9.1	13.3	6.5	3.9	8.6	8.9
--	0.00665	14.1	9.6	7.1	10.7	4.9	3.0	8.1	7.0
--	0.00473	11.0	6.4	5.6	9.3	3.8	2.1	6.6	5.1
--	0.00329	9.4	5.3	5.1	7.3	2.7	1.8	5.6	4.5
--	0.00138	5.5	3.7	3.0	5.3	2.2	1.8	4.0	3.2
% Gravel		11.4	32.5	39.1	10.4	27.9	51.2	37.7	26.3
% Sand		48.5	41.4	40.7	51.5	52.6	41.8	45.7	48.6
% Silt/Clay		40.1	26.1	20.2	28.0	19.5	7.0	16.6	25.1
USCS Code		SC	SM	SM	SM	SM	GP-GM	SM	SM

s.u. - Standard unit.

mg/kg - Milligrams per kilogram.

mm - Millimeter.

USCS - Universal Soil Classification System.

Metal-Binding Capacity	Soil Mapping Unit
Low	Stony Rough Land Sandstone
	Anniston and Allen stony loams
	Anniston and Allen gravelly loams
Medium	Jefferson gravelly fine sandy loam
High	Jefferson stony fine sandy loam

These three "soil types," based on metal-binding capacity, are used in the study design to identify sample locations and COPEC concentration gradients. Based on the data collected as part of the BERA, the soil classifications may be refined to reflect the inherent variability expected in the sample analysis.

3.4.1.2 Aquatic Assessment

While not truly an assessment endpoint, it was determined by EPA, USFWS, FTMC, and IT personnel during the site reconnaissance conducted May 10, 2002, that protection of the aquatic community downstream of the IMR ranges was an important goal of the risk assessment and risk management at the IMR ranges. Remount Creek downstream of the IMR ranges is perennial in nature and supports a relatively diverse and robust aquatic community. Although the aquatic ecosystem at the IMR ranges is ephemeral in nature, has been impacted by construction of the Eastern Bypass, and will continue to be impacted by the bypass and associated activities, it serves as the headwaters of Remount Creek. The aquatic communities downstream of the IMR ranges in the vicinity of the Cane Creek Golf Course have been shown to support the federally listed gray bat (*Myotis grisescens*) (3D/International, Inc., 1998). Therefore, Remount Creek downstream of the IMR ranges was identified as a significant ecological resource that requires protection.

In order to protect the downstream reaches of Remount Creek from contaminant migration and to determine whether COPECs from the IMR ranges were migrating downstream, an analysis was conducted of on-site surface water and sediment data compared to off-site data. This analysis consisted of comparing surface water and sediment concentrations of the COPECs in on-site samples to concentrations of COPECs in off-site surface water and sediment samples. The hypothesis was that, if downstream concentrations of COPECs were determined to be significantly less than on-site concentrations, then it could be assumed that site-related COPECs were not adversely impacting the downstream reaches of Remount Creek.

The analysis consisted of identifying the maximum COPEC concentrations in surface water and sediment from within the IMR range study area. The closest downstream surface water and sediment data were from sample location FTA-147-SW/SD02, which is located on Remount Creek, approximately 75 meters downstream of the Skeet Range study area; data from this location were collected as part of the site investigation for Motor Pool 3100. Additional downstream surface water and sediment data collected in the vicinity of the 11th Chemical Motor Pool were also included in this assessment, as they were the next-closest surface water and sediment data available. Three surface water and sediment samples were collected from Remount Creek adjacent to the 11th Chemical Motor Pool as part of the investigation for that parcel. These sample locations are approximately 1,500 feet downstream of the Skeet Range and are presented in Figure 2-6 in the BERA problem formulation report (IT, 2002a). Because Remount Creek downstream of the IMR ranges includes areas of scouring and areas of deposition, all of the downstream sediment samples were collected from depositional zones due to the fact that these were the only areas with sediment present. Thus, the downstream sediment samples represent the maximum potential COPEC concentrations downstream of the IMR ranges.

The results of the comparison of on-site data to downstream data are presented in Table 3-5. As presented in this table, the downstream concentrations of lead in surface water are less than the on-site lead concentration and also less than the BTV. In fact, lead was not detected in any of the surface water samples in the vicinity of the 11th Chemical Motor Pool. Downstream sediment concentrations of copper are generally (3 out of 4 samples) less than the on-site concentrations of copper and are also generally less than the ESV and BTV for copper. A single sediment sample located adjacent to the 11th Chemical Motor Pool exhibited a concentration of copper that was equal to the ESV and slightly greater than the BTV. Lead concentrations in downstream sediment samples were significantly less than on-site lead concentrations and were also less than the BTV for lead. Downstream concentrations of arsenic, barium, manganese, and thallium in sediment were all less than on-site concentrations.

These results indicate that COPECs in surface water and sediment are not migrating downstream from the IMR ranges to any significant extent. In fact, the concentrations of COPECs in surface water and sediment directly downstream of the IMR ranges are generally less than the BTVs established for FTMC.

The ephemeral tributaries and drainage ditches located in the eastern portion of the Skeet Range have the potential to support semi-aquatic species (e.g., amphibians) and some small fish species that migrate upstream during periods of significant rainfall. Aquatic insects could also be present in these tributaries and drainage ditches during periods of high precipitation. Because of

TABLE 3-5

COMPARISON OF ON-SITE SURFACE WATER AND SEDIMENT COPEC CONCENTRATIONS TO DOWNSTREAM CONCENTRATIONS
Fort McClellan, Calhoun County, Alabama

Environmental Media		COPEC	Maximum IMR Range Conc.[1]	Downstream Concentrations[2] FTA-147-SW/SD02	FTA-29-SW/SD01	FTA-29-SW/SD02	FTA-29-SW/SD03	Ecological Screening Value [3]	Background Threshold Value [4]	Upper Background Range [5]
Surface Water:	(ug/L)	Lead	87.1	1.8	ND (< 3.0)	ND (< 3.0)	ND (< 3.0)	1.32	8.67	47
Sediment:	(mg/kg)	Arsenic	38	3.2	8.6	4.4	6.8	7.24	11.3	20
		Barium	478	49	256	80.6	ND (<25.4)	NA	98.9	272
		Copper	153	7.6	18.7	9.1	9.5	18.7	17.1	59
		Lead	2,420	35.4	34.1	34.9	18.5	30.2	37.8	110
		Manganese	2,830	293	2,330	468	247	NA	712	2,050
		Thallium	2.7	ND (<1.5)	ND (<1.2)	ND (<1.2)	ND (<1.3)	NA	0.13	0.22

[1] Maximum detected COPEC concentration from surface water and sediment samples collected at the IMR ranges.
[2] Sample FTA-147-SW/SD02 collected at a location along Remount Creek approximately 75 meters downstream of the IMR ranges adjacent to Motor Pool 3100. Samples FTA-29-SW/SD01 through SW/SD03 collected further downstream (approximately 1,500 ft. downstream of the Skeet Range) on Remount Creek in the vicinity of the 11th Chemical Motor Pool.
[3] Ecological screening values are presented in "Human Health and Ecological Screening Values and PAH Background Summary Report" (IT Corp., 2000).
[4] Background Threshold Value is 2-times the arithmetic mean background concentration as reported in *Final Background Metals Survey Report, Ft. McClellan, Alabama* (SAIC, 1998).
[5] Upper range of detected concentrations from background samples as reported in *Final Background Metals Survey Report, Ft. McClellan, Alabama* (SAIC, 1998).

the presence of these aquatic species during limited periods of the year, an assessment endpoint was identified for these species.

The benthic invertebrate community forms a critical link in many aquatic food webs and constitutes a food source for many riparian invertivorous birds and mammals. Aquatic benthic invertebrates also perform an important function in the degradation of organic material in sediment. Aquatic benthic invertebrates may also accumulate COPECs in their tissues and act as a conduit for the transfer of COPECs to higher trophic level organisms in the food chain. For these reasons, the aquatic benthic invertebrate community was identified as an important ecological resource at the IMR ranges. The assessment endpoint that has been identified with respect to the aquatic benthic invertebrate community is the following:

- Maintenance of healthy aquatic benthic invertebrate populations and communities in Remount Creek and its tributaries at the IMR ranges.

Riparian insectivorous mammals and birds were identified as having the potential for exposure to COPECs in sediment at the IMR ranges, mainly through ingestion of emergent aquatic insects that may have accumulated COPECs from the sediment in their tissues. In order to differentiate the invertivores that feed mainly on terrestrial invertebrates from those that feed mainly on aquatic invertebrates, this latter group is termed "riparian invertivores" for this assessment. In addition to the fact that this feeding guild has the potential to be maximally exposed to COPECs in sediment due to their feeding habits, these species also form an important food group for higher trophic level organisms (i.e., raptors). Raptors may prey on flying insectivorous mammals (e.g., bats) and insectivorous birds (e.g., swallows, wrens) and thus potentially become exposed to COPECs through ingestion of COPECs that have become incorporated into the prey species' tissues. For these reasons, riparian invertivorous mammals and birds were identified as being an important ecological resource at the IMR ranges. The assessment endpoint that has been identified with respect to the riparian invertivorous mammal and bird feeding guild is the following:

- Maintenance of healthy populations and communities of riparian invertivorous small mammals and birds at the IMR ranges.

The assessment endpoints that have been identified for the IMR ranges are summarized in Table 3-3.

3.4.2 Risk Hypotheses

The risk hypotheses for a BERA are questions about the relationships among the assessment endpoints and the predicted responses at a given site. The risk hypotheses are based on the assessment endpoints and provide a basis for developing the study design. The most basic question applicable to most sites is whether site-related contaminants are causing or have the potential to cause adverse effects on the assessment endpoints. Using this basic premise, risk hypotheses were developed for the assessment endpoints identified in the previous section.

The risk hypothesis identified as appropriate to address the assessment endpoint of "maintenance of a healthy invertebrate community" was determined to be the following:

- Survival of terrestrial invertebrates exposed to surface soil collected from the IMR ranges is significantly different from that of invertebrates exposed to reference soil from nonimpacted areas.

This risk hypothesis will identify differences in invertebrate survivability when exposed to on-site soils and off-site reference soils in laboratory toxicity tests.

The risk hypothesis identified as appropriate to address the assessment endpoint of "maintenance of healthy local populations and communities of terrestrial invertivorous small mammals and birds" was determined to be the following:

- Calculated hazard quotients using measured body burdens of COPECs in earthworms, site-specific diet composition, and area use factors indicate statistically significant risk potential to terrestrial invertivorous small mammals or birds.

This risk hypothesis will determine whether calculated daily doses of COPECs exceed feeding guild-specific toxicity reference values.

The risk hypothesis identified as appropriate to address the assessment endpoint of "maintenance of healthy local populations and communities of terrestrial omnivorous small mammals and birds" was determined to be the following:

- Calculated hazard quotients using measured body burdens of COPECs in earthworms, site-specific diet composition, and area use factors indicate statistically significant risk potential to terrestrial omnivorous small mammals or birds.

This risk hypothesis will determine whether calculated daily doses of COPECs exceed feeding guild-specific toxicity reference values.

Table 3-3 presents the risk hypothesis for each of the terrestrial assessment endpoints. It is important to note that the hypothesis is expressed as a positive response in order to minimize the likelihood of a Type II statistical error (i.e., a false negative decision) at a standard confidence level of $p = 0.05$.

Daily doses of COPECs for terrestrial invertivorous and omnivorous small mammals and birds will be calculated using standard exposure algorithms. These algorithms will incorporate species-specific natural history parameters (e.g., feeding rates, water ingestion rates, dietary composition) and will also utilize site-specific area use factors (AUF). Additionally, measured COPEC concentrations in earthworms will be used as input to the exposure algorithm as the concentration in the invertebrate portion of the food of the terrestrial invertivorous and omnivorous small mammals and birds. Literature-derived bioaccumulation factors will be used to estimate COPEC concentrations in the terrestrial vegetation portions of the receptor species' diets. If the food web models indicate that the vegetative portion of the receptors' diets represent a significant contribution of the total COPEC dose, then site-specific vegetation concentrations of COPECs derived from on-site sampling will be proposed.

In order to calculate COPEC exposures, indicator species that represent the feeding guilds of interest must be identified. For this risk assessment, the small terrestrial invertivorous mammal will be represented by the shorttail shrew (*Blarina brevicauda*), and the terrestrial invertivorous bird will be represented by the American woodcock (*Philohela minor*). The small terrestrial omnivorous mammal will be represented by the white-footed mouse (*Peromyscus leucopus*), and the omnivorous bird will be represented by the American robin (*Turdus migratorius*). Natural history parameters for these indicator species (Table 3-6) will be used in combination with site-specific exposure parameters to estimate exposures to terrestrial invertivorous and omnivorous small mammals and birds at the IMR ranges.

The algorithm that will be used to estimate exposures to COPECs by terrestrial invertivorous and omnivorous small mammals and birds is the following:

$$TDD_{wildlife} = \left[\left(IR_{food} \times f_{worm} \times C_{worm}\right) + \left(IR_{food} \times f_{veg} \times C_{veg}\right) + \left(IR_{water} \times C_{water}\right) + \left(IR_{food} \times f_{soil} \times \left\{1 - M_{diet}\right\} \times C_{soil}\right)\right] \times AUF$$

TABLE 3-6

TERRESTRIAL FOODWEB MODEL INPUT PARAMETERS

Iron Mountain Road Ranges
Fort McClellan, Calhoun County, Alabama

Common Name	Scientific Name	Feeding Guild	Foraging Area (acres)	Area Use Factor (unitless)	Body Weight (kg)	Water Ingestion Rate (L/kg/day)	Food Ingestion Rate (kg/kg/day) (wet weight)	Soil Ingestion Rate[f] (kg/kg/day) (dry weight)	Dietary Fraction (unitless)	Dietary Component
White-Footed Mouse	*Peromyscus leucopus*	Omnivorous Mammal	1.0 (b)	1.0	0.0225 (b)	0.2180 (a)	0.2588 (a)	0.0012 (c)	0.254 0.746	Terrestrial Invertebrates Terrestrial Vegetation (seeds & young grass / fruit)
American Robin	*Turdus migratorius*	Omnivorous Bird	0.61 (a)	1.0	0.081 (a)	0.140 (a)	1.181 (a)	0.0246 (d)	0.375 0.625	Terrestrial Invertebrates Terrestrial Vegetation (fruit)
Short-Tailed Shrew	*Blarina brevicauda*	Invertivorous Mammal	0.964 (a)	1.0	0.0168 (a)	0.223 (a)	0.547 (a)	0.00845 (e)	0.887 0.113	Terrestrial Invertebrates Terrestrial Vegetation (roots / young grass)
American Woodcock	*Scolopax minor*	Invertivorous Bird	74.7 (a)	0.24	0.1700 (a)	0.10 (a)	0.754 (a)	0.0158 (a)	0.95 0.05	Terrestrial Invertebrates Terrestrial Vegetation (seeds)

Notes:

All of the values presented in this table represent arithmetic mean values if more than one value was presented in the referenced source.

a USEPA, 1993. *Wildlife Exposure Factors Handbook*. EPA/600/R-93/187a

b Burt, W.H. and R.P. Grossenheider. *Mammals, Peterson Field Guide*.

c Talmage and Walton, 1993. *Food Chain Transfer and Potential Renal Toxicity of Mercury to Small Mammals at a Contaminated Terrestrial Field Site*. Ecotoxicology 2: 243-256.

d Assumed value based on soil ingestion values for other birds presented in USEPA (1993).

e Sample, B.E., M.S. Alpin, R.A. Efroymson, G.W. Suter, and C.J.E. Welsh, 1997. Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants.

f Soil ingestion rates (dry weight) were calculated using the following relationship $IR_{soil} = IR_{food} \times Diet_{soil} \times (1 - Diet_{moist})$

where:
IR_{soil} = ingestion rate of soil (kg/kg/day, dry weight);
IR_{food} = food ingestion rate (kg/kg/day, wet weight);
$Diet_{soil}$ = percentage of diet that is soil (percent); and
$Diet_{moist}$ = weighted average moisture content of diet (percent).

where:

$TDD_{wildlife}$	=	total daily dose of COPEC received by omnivorous or invertivorous mammals and birds through ingestion (milligrams per kilogram [mg/kg] per day [mg/kg/day])
IR_{food}	=	ingestion rate of food by receptor species (kg/kg/day)
f_{worm}	=	fraction of daily diet consisting of invertebrates (percent)
C_{worm}	=	concentration of COPEC in invertebrate tissue (mg/kg)
f_{veg}	=	fraction of daily diet consisting of vegetation (percent)
C_{veg}	=	concentration of COPEC in terrestrial vegetation (mg/kg)
IR_{water}	=	ingestion rate of water by invertivorous or omnivorous mammals and birds (liters per kilogram per day [L/kg/day])
f_{water}	=	fraction of drinking water from the IMR ranges (percent)
C_{water}	=	concentration of COPEC in drinking water (milligrams per liter [mg/L])
f_{soil}	=	fraction of daily diet comprised of soil (percent)
M_{diet}	=	weighted average moisture content of diet (percent)
C_{soil}	=	concentration of COPEC in soil (mg/kg)
AUF	=	area use factor (percent).

Because portions of the receptor species' diets consist of vegetative material, COPEC concentrations in plant matter will need to be estimated in order to calculate a total COPEC dose. The COPEC concentrations in plant matter will be estimated using the empirically derived plant BCFs reported in Baes et al., (1984) and recommended by EPA (1999). These plant BCFs will be applied to the soil concentrations of COPECs to estimate concentrations of COPECs in vegetative food material in the following manner:

$$C_{veg} = C_{soil} \times BCF_{veg} \times (1 - M_{veg})$$

where:

C_{veg}	=	COPEC concentration in terrestrial vegetation (mg/kg, wet weight)
C_{soil}	=	COPEC concentration in soil (mg/kg, dry weight)
BCF_{veg}	=	soil-to-plant bioconcentration factor (unitless)
M_{veg}	=	average moisture of vegetative material in diet (percent).

The soil ingestion rate for the receptor species is most often represented as a percentage of a receptor species' diet. In order to account for the methodology used in the estimation of soil ingestion rates, the moisture content of the receptor species' diets must be accounted for. The relationship used to estimate the soil ingestion rates for the invertivorous and omnivorous small mammals and birds that have been identified as receptors in this ecological risk assessment is as follows:

$$IR_{soil} = IR_{food} \times Diet_{soil} \times (1 - M_{diet})$$

where:

IR_{soil}	=	ingestion rate of soil (kg/kg/day, dry weight)
IR_{food}	=	ingestion rate of food (kg/kg/day, wet weight)
$Diet_{soil}$	=	portion of diet that is soil (percent)
M_{diet}	=	weighted-average moisture content of receptor species' diet (percent).

The moisture content of the invertebrate and vegetative material in the receptor species' diets was referenced from the EPA's *Wildlife Exposure Factors Handbook* (EPA, 1993), as follows:

- Earthworms - 84 percent
- Fruit - 77 percent
- Roots/young grass - 82 percent
- Seeds - 9.3 percent
- Fruit/young grass - 78 percent.

The weighted-average moisture content of the diets of the receptor species of interest has been estimated as follows:

		Percent Moisture	Weighted-Average Moisture Content
White-footed mouse:			
invertebrates	=	84 percent	53.9 percent
vegetation	=	43.6 percent	
American robin:			
invertebrates	=	84 percent	79.6 percent
vegetation	=	77 percent	
Shorttail shrew:			
invertebrates	=	84 percent	83.8 percent
vegetation	=	82 percent	
American woodcock:			
invertebrates	=	84 percent	80.3 percent
vegetation	=	9.3 percent	

It was assumed that, if a receptor species' diet contained multiple vegetative components, then the percentage of each vegetative component would be equal. For instance, the vegetative component of the shorttail shrew's diet was assumed to consist of 50 percent roots and 50 percent young grass.

Dietary composition for the indicator species will be simplified for modeling purposes but will incorporate the major food types for the different feeding guilds. It will be assumed that food intake for invertivores consists almost entirely of terrestrial invertebrates (i.e., earthworms). It will also be assumed that omnivores consume both plant and animal material, a portion of which will consist of terrestrial invertebrates.

The AUFs for each of the indicator species will take into account the home range and habitat requirements for each species and the size of the contaminated areas and viable habitat at the IMR ranges.

The use of measured COPEC concentrations in earthworms from a broad range of soil concentrations will allow the calculation of daily doses at a number of different COPEC concentrations. Different COPEC concentrations in the various exposure media will provide valuable information necessary to estimate media concentrations that are protective of the ecological communities at the IMR ranges.

It will be necessary to assess these terrestrial risk hypotheses for each of the soil types that were determined based on the metal-binding capacity of the soils at the IMR and BGR ranges. Therefore, the earthworm toxicity/bioaccumulation tests and the food web models will be assessed for three binding capacity-related soils ("high," "medium," and "low") at the IMR ranges.

The risk hypothesis that was identified as being appropriate to address the assessment endpoint of "maintenance of healthy aquatic benthic invertebrate populations and communities in Remount Creek and it tributaries" was the following:

- Survival and growth of aquatic benthic invertebrates exposed to sediment collected from Cane Creek and its tributaries is statistically significantly different from that of aquatic benthic invertebrates exposed to sediment from a non-impacted reference stream.

This risk hypothesis will identify differences in aquatic benthic invertebrate survivability and growth when exposed to on-site sediments from Cane Creek and off-site reference sediments in laboratory toxicity tests.

The risk hypothesis that was identified as being appropriate to address the assessment endpoint of "maintenance of healthy local populations and communities of riparian invertivorous mammals and birds" was determined to be the following:

- Calculated hazard quotients using modeled COPEC concentrations in aquatic insects, site-specific diet composition, and area use factors indicate statistically significant risk potential to riparian invertivorous mammals or birds.

This risk hypothesis will determine whether calculated daily doses of COPECs exceed feeding guild-specific toxicity reference values and will determine if COPECs in sediment have the potential to be transferred through the riparian food chain via emergent aquatic insects.

Table 3-3 presents risk hypotheses for each of the assessment endpoints. It is important to note that the hypotheses are expressed as a positive response in order to minimize the likelihood of Type II statistical errors (i.e., a false negative decision) at a standard confidence level of $p = 0.05$.

Daily doses of COPECs for riparian invertivorous mammals and birds will be calculated using standard exposure algorithms. These algorithms will incorporate species-specific natural history parameters (i.e., feeding rates, water ingestion rates, dietary composition, etc.) and will also utilize site-specific area use factors (AUF). Laboratory-derived bioaccumulation factors will be used to estimate COPEC concentrations in the aquatic insect portions of the receptor species' diets.

In order to calculate COPEC exposures, indicator species that represent the feeding guilds of interest must be identified. For this risk assessment, the riparian invertivorous mammal will be represented by the little brown bat (*Myotis lucifugus*) and the riparian invertivorous bird will be represented by the marsh wren (*Cistothorus palustris*). Natural history parameters for these indicator species (Table 3-7) will be used in combination with site-specific exposure parameters to estimate exposures to riparian invertivorous mammals and birds at the IMR ranges.

The algorithm that will be used to estimate exposures to COPECs by riparian invertivorous mammals and birds is the following:

$$TDD_{wildlife} = \left[\left(IR_{food} \times f_{insect} \times \left\langle C_{sed} \times BCF_{insect} \times \{1 - M_{insect}\}\right\rangle\right) + \left(IR_{water} \times C_{water}\right)\right] \times AUF$$

TABLE 3-7

RIPARIAN FOODWEB MODEL INPUT PARAMETERS

Iron Mountain Road Ranges

Fort McClellan, Calhoun County, Alabama

Common Name	Scientific Name	Feeding Guild	Foraging Area (acres)		Area Use Factor (unitless)	Body Weight (kg)		Water Ingestion Rate (L/kg/day)		Food Ingestion Rate (kg/kg/day) (wet weight)		Soil Ingestion Rate [e] (kg/kg/day) (dry weight)	Dietary Fraction (unitless)	Dietary Component
Little Brown Bat	*Myotis lucifugus*	Invertivorous Mammal	12 Km	(c)	0.1	0.008	(b)	0.1680	(e)	0.5300	(d)	NA	1.0	Aquatic Emergent Invertebrates
Marsh Wren	*Cistothorus palustris*	Invertivorous Bird	0.13	(a)	1.0	0.0106	(a)	0.270	(a)	0.870	(a)	NA	1.0	Aquatic Emergent Invertebrates

Notes:

All of the values presented in this table represent arithmetic mean values if more than one value was presented in the referenced source.

a USEPA, 1993. *Wildlife Exposure Factors Handbook*. EPA/600/R-93/187a

b Burt, W.H. and R.P. Grossenheider. *Mammals, Peterson Field Guide*.

c LaVal, et al., 1977. Foraging Behavior and Nocturnal Activity Patterns of Missouri Bats, with Emphasis on the Endangered Species *Myotis grisescens* and *Myotis sodalis*.

d Anthony and Kunz, 1977. Feeding Strategies of the Little Brown bat, *Myotis lucifugus*, in Southern New Hampshire.

e Sample, et al., 1997. Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants.

where:

$TDD_{wildlife}$	=	total daily dose of COPEC received by riparian invertivorous mammals or birds through ingestion (mg/kg/day)
IR_{food}	=	ingestion rate of food by receptor species (kg/kg/day)
f_{insect}	=	fraction of daily diet comprised of emergent aquatic insects (percent)
C_{sed}	=	concentration of COPEC in sediment (mg/kg)
IR_{water}	=	ingestion rate of water by invertivorous mammals or birds (L/kg/day)
f_{water}	=	fraction of drinking water from the IMR ranges (percent)
C_{water}	=	concentration of COPEC in drinking water (mg/L)
M_{insect}	=	average moisture content of benthic invertebrates (percent)
AUF	=	area use factor (fraction of site used by receptor species (percent).

The receptor species' diets consist entirely of emergent benthic invertebrates; therefore, COPEC concentrations in benthic invertebrate tissues will need to be estimated in order to calculate a total COPEC dose. The COPEC concentrations in benthic invertebrate tissue will be estimated using laboratory-derived sediment-to-invertebrate BCF values as described in Appendix B of the *Baseline Ecological Risk Assessment Problem Formulation and Study Design for the Bains Gap Road Ranges* (IT, 2002). The total daily doses of COPECs received by the riparian invertivorous mammals and birds will not include the ingestion of soil or sediment as the receptors' diets are assumed to consist solely of emergent aquatic insects and the potential for exposure to site-related soil or sediment is minimal for these receptors.

The AUFs for each of the indicator species will take into account the home range and habitat requirements for each species and the size of the contaminated areas and viable habitat at the IMR ranges.

The calculation of COPEC concentrations in benthic invertebrates from a broad range of sediment concentrations will allow for the calculation of daily doses at a number of different COPEC concentrations. Different COPEC concentrations in the sediment will provide valuable information necessary to estimate media concentrations that are protective of the riparian ecological communities at the IMR ranges.

3.4.3 Selection of Measurement Endpoints

A measurement endpoint is "a measurable ecological characteristic that is related to the valued characteristic chosen as the assessment endpoint" and is a measure of biological effects (e.g., mortality, reproduction, growth) (EPA, 1992). Measurement endpoints are frequently numerical expressions of observations (e.g., toxicity test results, community diversity measures) that can be compared statistically to a control or reference site to detect adverse responses to site contaminants.

The measurement endpoint that has been identified to address the assessment endpoint of "maintenance of a healthy terrestrial invertebrate community" is the following:

- Statistical comparison of survival rates of earthworms exposed to soils exhibiting a gradient of COPEC concentrations from the IMR ranges to earthworms exposed to soils from a nonimpacted reference location.

Additionally, in order to estimate the bioavailability of the COPECs in soil at the IMR ranges and to provide data for the other assessment endpoints, a second measurement endpoint has been established to address the assessment endpoint of "maintenance of a healthy terrestrial invertebrate community." This measurement endpoint is the following:

- Statistical comparison of COPEC concentrations in tissues of earthworms exposed to soils from the IMR ranges to COPEC concentrations in tissues of earthworms exposed to soils from a nonimpacted reference location.

The measurement endpoint that has been identified to address the assessment endpoint of "maintenance of a healthy local population of small terrestrial invertivorous mammals and birds" is the following:

- Calculation of hazard quotients for invertivorous mammal (shorttail shrew) and invertivorous bird (American woodcock) using measured earthworm tissue concentrations of COPECs.

The measurement endpoint that has been identified to address the assessment endpoint of "maintenance of a healthy local population of small terrestrial omnivorous mammals and birds" is the following:

- Calculation of hazard quotients for omnivorous mammal (white-footed mouse) and omnivorous bird (American robin) using measured earthworm tissue concentrations of COPECs and modeled vegetation concentrations of COPECs.

These measurement endpoints will provide the necessary data to answer the risk hypotheses for the terrestrial ecosystems at the IMR ranges presented in Section 3.4.2. The measurement endpoint that has been identified to address the assessment endpoint of "maintenance of healthy aquatic benthic invertebrate populations and communities in Remount Creek and its tributaries" is the following:

- Comparison of survival and growth of the benthic amphipod *Chironomus riparius* exposed to sediment from Cane Creek at the BGR ranges to survival and growth of *Chironomus riparius* exposed to sediment from a reference stream.

The measurement endpoint that has been identified to address the assessment endpoint of "maintenance of healthy populations and communities of riparian invertivorous small mammals and birds at the IMR ranges" is the following:

- Calculation of hazard quotients for riparian invertivorous mammal (little brown bat) and riparian invertivorous bird (marsh wren) using modeled tissue concentrations of COPECs in emergent benthic invertebrates.

These measurement endpoints will provide the necessary data to answer the risk hypotheses for the riparian ecosystems at the IMR ranges presented in previous sections of this report.

An important factor in assessing these measurement endpoints is an understanding of the degree of impairment to a biological attribute that is understood to be biologically or ecologically significant. Statistically significant differences in population survivability, growth, reproduction, or hazard quotient values that cannot be related to biological or ecological significance should not be interpreted as indicating a population or community is at risk or that a remedy is necessary. Therefore, ecological and biological significance will be considered within the context of these measurement endpoints.

Table 3-3 presents the measurement endpoints corresponding to each assessment endpoint and risk hypothesis. The methodologies used to collect the necessary data and answer the risk hypotheses are presented in the following chapters.

4.0 Data Quality Objectives

Data quality objectives (DQO) are "qualitative and quantitative statements that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions" (EPA, 2000). The DQO process enables investigators to define performance criteria and limit the likelihood of committing Type I or Type II decision errors. EPA's DQO process is a seven-step process for the development of acceptance criteria. The initial five steps of the process focus on identifying qualitative criteria, while the sixth and seventh steps define quantitative criteria and a data collection design, respectively. The seven steps are addressed below in Sections 4.1 through 4.7.

4.1 Problem Statement

The SLERA conducted at the IMR ranges (IT, 2002b) identified four inorganic compounds (antimony, copper, lead, and zinc) in surface soil that have the potential to adversely effect ecological receptors at the IMR ranges. Although lead was detected in surface water and sediment in Remount Creek at the IMR ranges, it was determined that these constituents are not migrating downstream and do not pose a significant risk to downstream ecological resources. However, arsenic, barium, copper, lead, manganese, and thallium were identified as COPECs in sediment due to the fact that they exceed BTVs and may accumulate in lower trophic level organisms.

The IMR range problem formulation (IT, 2002a) and CSM suggest that exposure pathways to terrestrial and riparian receptors for the inorganic constituents identified as COPECs do exist and, therefore, require further study. The problem formulation (IT, 2002a) further identified the need for additional information to address questions related to constituent bioavailability, bioaccmulation potential, and site-specific toxicity.

Based on the findings of the SLERA and Problem Formulation, the objectives of the BERA for the IMR ranges include the following:

- Collect site-specific data to address bioavailability and bioaccumulation potentials in lower trophic level organisms that form the basis of the terrestrial and riparian food webs at the IMR ranges
- Collect site-specific data to address the existence and level of site-specific toxicity to terrestrial receptors resulting from exposure to the four soil COPECs

- Determine the level or concentrations of the COPECs within the surface soils and sediments of the IMR ranges which pose an unacceptable risk to terrestrial and riparian receptors

- Provide data of sufficient quality to develop a technically defensible characterization of risk at the IMR ranges for use by risk managers in their acceptance or rejection of present and future ecological risks posed by surface soil and sediment COPECs and, if necessary, develop ecologically based cleanup criteria.

4.2 Decision Identification

The following decisions require site-specific data in order to address the issues identified in the problem statement presented in the previous section.

- Determine if antimony, copper, lead, or zinc in surface soil at the IMR ranges is available for bio-uptake (i.e., bioavailable)

- Determine what levels of COPECs in soil promote acute or chronic toxicity to terrestrial invertebrates (earthworms)

- Determine if the soil COPECs bioaccumulate in the tissues of terrestrial invertebrates (e.g., earthworms) and, if so, to what extent

- Determine whether the tissue burdens of COPECs in terrestrial invertebrates have the potential to pose adverse effects to higher trophic level organisms that consume terrestrial invertebrates as a food source

- Develop constituent-specific cleanup goals for soil if the BERA concludes that there is the potential for unacceptable ecological risk.

- Determine what levels of COPECs in sediment promote acute or chronic toxicity to aquatic benthic invertebrates (e.g., chironomids);

- Determine if the COPECs bioaccumulate in the tissues of emergent aquatic invertebrates (e.g., chironomids) and, if so, to what extent;

- Determine whether the modeled tissue burdens of COPECs in emergent aquatic invertebrates have the potential to pose adverse effects to small riparian mammals or birds that consume emergent aquatic invertebrates as a food source; and

- Develop constituent-specific clean-up goals for sediment if the BERA concludes that there is the potential for unacceptable ecological risk

4.3 Decision Inputs

This step identifies the information required to support the decisions identified above. The following information will be required:

- Surface soil concentrations of the four COPECs (parts per million [ppm]) in the three binding capacity categories of soil (low, medium, and high)
- Earthworm mortality based on earthworm LC_{50} data (lethal concentration killing 50 percent of the test population) (ppm) for each of the three binding capacity categories of soil (low, medium, and high)
- Biouptake and accumulation potential based on the ratio of soil COPEC concentrations to earthworm tissue concentrations in each of the three binding capacity categories of soil (low, medium, and high)
- Projected dose estimates of the four soil COPECs in the invertivorous shorttail shrew and American woodcock, and the omnivorous American robin and white-footed mouse (mg COPEC per unit of body mass per day)
- Estimated levels of concern to the invertivorous shorttail shrew and American woodcock and the omnivorous American robin and white-footed mouse based on modeled hazard quotient (HQ) values (estimated total daily dose/literature-based effect value).
- Sediment concentrations of arsenic, barium, lead, copper, manganese, and thallium;
- Benthic invertebrate mortality based on Chironomid LC_{50} data (lethal concentration killing 50 percent of the test population) for sediment from Cane Creek;
- Bio-uptake and accumulation potential based on the ratio of sediment COPEC concentrations in Cane Creek to *Chironomus sp.* tissue concentrations;
- Projected dose estimates of the sediment COPECs in the riparian invertivorous little brown bat and marsh wren (mg COPEC per unit of body mass per day);
- Estimated levels of concern to the riparian invertivorous little brown bat and marsh wren based on modeled hazard quotient (HQ) values (estimated total daily dose/literature-based effect value).

These data will be used to help determine whether COPECs in surface soil or sediment at the IMR ranges present significant risk or will in the future present significant risk to ecological receptors at the IMR ranges. If ecological risks are predicted using the information presented above, then this information will also be used to determine the concentrations of COPECs in surface soil or sediment that are protective of the terrestrial and riparian receptors at the IMR ranges.

4.4 Study Boundaries

Study boundaries define the spatial scale of the assessment at the IMR ranges. In order to conduct a useful BERA, it is imperative to define the geographic and temporal boundaries of the potential risk and to identify the target populations of interest. The IMR ranges consist of four small arms firing ranges (the Skeet Range and Ranges 12, 13, and 19). The IMR SLERA and problem formulation identified the old field terrestrial ecosystem at the IMR ranges as the habitat at greatest potential risk given its quality, level of contamination, and receptors likely to be exposed to the COPECs. The ephemeral streams and tributaries in the vicinity of the Skeet Range were also identified as potential habitats for semiaquatic species and some drought-tolerant fish species. These habitats were also identified as posing potential ecological risk. The IMR BERA will, therefore, focus on the old field terrestrial ecosystem and riparian ecosystem associated with these ranges. The surface soils at these ranges have been classified with regard to their metal-binding capacity as high, medium, or low binding capacity soils. Because the binding capacity of a soil has the potential to significantly affect the COPECs' bioavailability and subsequent toxicity, each of these soil types will be assessed individually in the BERA.

Additionally, based on the historical nature of the contamination at the IMR ranges and the physical/chemical properties of the COPECs themselves, the concentrations of the COPECs are not likely to change over time due to natural processes. Therefore, temporal variability of COPEC concentrations is not considered an important variable for these static upland and riparian habitats.

The target populations for the BERA are the resident terrestrial invertebrate communities and the wildlife feeding guilds that may be present within the bounds of the IMR ranges. Additionally, the riparian wildlife feeding guilds that utilize the aquatic emergent invertebrates as a food source are also target populations for the BERA. Given the COPECs' relatively low propensity for biomagnification up food chains, the target populations of greatest concern are terrestrial invertebrates, such as the earthworm, terrestrial invertivorous and omnivorous small mammals and birds, and riparian invertivorous small mammals and birds.

In regard to target populations, it is important to reiterate that the terrestrial organisms selected for testing or modeling are representative of the old field terrestrial community, and the aquatic and riparian species are representative of the riparian community, and are therefore "sentinel species" for this BERA effort.

4.5 Decision Rule

The objective in developing specific decision rules is to construct theoretical "if...then..." statements relative to the ecological habitats, populations and COPECs. These statements can then be used by risk managers in deciding whether to accept or reject the characterized risk and, if necessary, in generating ecological based cleanup goals. The decision rules proposed for the IMR ranges BERA include the following:

- If COPECs in soils from the IMR ranges cause acute earthworm toxicity that is statistically greater than earthworm toxicity in soils from a reference site, then there is the potential for unacceptable risks to terrestrial invertebrate receptors at the IMR ranges.
- If earthworms exposed to soils from the IMR ranges demonstrate statistically higher tissue concentrations of COPECs than earthworms exposed to reference soils, then there is the potential for significant COPEC accumulation in terrestrial invertebrate tissues.
- If calculated doses of COPECs for invertivorous mammals or birds are greater than literature-derived toxicity reference values, then there is the potential for risk to invertivorous mammals or birds at the IMR ranges.
- If calculated doses of COPECs for omnivorous mammals or birds are greater than literature-derived toxicity reference values, then there is the potential for risk to omnivorous mammals or birds at the IMR ranges.
- If COPECs in sediment from Cane Creek cause acute chironomid toxicity, that is statistically greater than chironomid toxicity in sediment from a reference stream, then there is the potential for unacceptable risks to benthic invertebrates at the IMR ranges.
- If calculated doses of COPECs for riparian insectivorous mammals or birds are greater than literature-derived toxicity reference values, then there is the potential for risk to riparian insectivorous mammals or birds at the IMR ranges.
- If, based on the collective evaluation of the lines of evidence, COPECs are determined to pose unacceptable risks to terrestrial or riparian receptors at the IMR ranges, then remedial goals will be developed using the data collected during the BERA.

It is important to consider the role of background concentrations of COPECs when developing specific decision rules. It is possible that naturally-occurring concentrations of certain inorganic constituents in environmental media could result in a determination of unacceptable risk.

Therefore, background will be considered within the context of each of the aforementioned decision rules.

4.6 Tolerable Limits on Decision Errors

Chemical and biological data collected as part of the BERA process will be collected in a manner such that they are representative of the abiotic media and biotic communities at the IMR ranges. Since the collected data are only small subpopulations of the entire IMR ranges, they can only be used to predict responses that may actually occur at the IMR ranges under natural conditions. As such, these data must be interpreted with a level of confidence or probability, that will be less than 100 percent error free. The objective in establishing tolerable probability limits is to generate the proper quantity and quality of data to meet the targeted limit. The decision data employed in the BERA will be of sufficient quantity and quality as to result in a decision confidence level of 95 percent. The tolerable limit will be made on statistical probabilities of less than 95 percent.

4.7 Design Optimization

The objective in design optimization is to develop a "resource-effective" sampling and analysis plan for generating data. The sampling and analysis plans presented in Appendix A for surface soil and in Appendix B of the Baseline Ecological Risk Assessment Problem Formulation and Study Design for the Bains Gap Road Ranges (IT, 2002d) for sediment have been optimized to ensure that the tolerable limits on decision errors will be met.