6.0 Complete Exposure Pathways

For exposures to occur, complete exposure pathways 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 site conceptual model for the IMR ranges and the exposure pathways that are potentially complete for the feeding guilds expected to occur at the IMR ranges.

6.1 Site Conceptual Model

The ecological site conceptual model (SCM) traces the COPECs' movement 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 SCM include 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.

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 ingesting 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, etc.). 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 have high bioconcentration or biomagnification potential.

Potentially complete exposure pathways are depicted in the SCM as presented in Figure 6-1 and are described in the following sections for the various feeding guilds.

6.2 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, grooming, or other activities.

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 zibethica*) and mallard (*Anas platyrhynchos*) could be exposed to site-related constituents in surface water and/or sediment in Remount Creek and its tributaries.

6.3 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, grooming, or other activities. Ingestion of soil while feeding is potentially a major exposure pathway for invertivores since much of their food (i.e., earthworms and other invertebrates) lives on or below the soil surface.

Typical 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*), and eastern mole (*Scalopus aquaticus*). Aquatic invertivores could include the wood duck (*Aix sponsa*) and blacknose dace (*Rhinichthys atratulus*).

6.4 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 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, grooming, or 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 fulva*), 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.

6.5 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, grooming, or other activities. Most inorganic compounds are not accumulated in animal tissues to any great extent (Shugart, et al., 1991 and U.S. Army Environmental Hygiene Agency [USAEHA], 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*).

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.

6.6 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 and are commonly used as sentinel species in ecological risk assessment include great blue heron (*Ardea herodias*) and belted kingfisher (*Megaceryle alcyon*). Larger piscivorous fish species (e.g., small mouth bass, spotted gar, etc.) 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.

6.7 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, roots in caves year-round. Approximately 95 percent of the entire known population 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.

7.0 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 BERA 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.

The potential for toxic effects to individual receptors can have consequences at the population, community, and ecosystem level. Population level effects may determine the nature of changes in community structure and function, such as reduction in species diversity, simplification of food webs, and shifts in competitive advantages among species sharing a limited resource. Ecosystem function may also be affected by contaminants, which can cause changes in productivity or disruption of key processes.

Population level assessment endpoints are generally recognized in ecological risk assessments because of their role in maintaining biological diversity, ecological integrity, and productivity in ecosystems.

Following a site walk of the IMR ranges on May 10, 2002 by EPA, USFWS, FTMC and IT personnel, it was agreed that the 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 which 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 insectivorous mammals and birds potentially present at the IMR ranges.

7.1 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 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 guild is the following:

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

The assessment endpoints that have been identified for the IMR ranges are summarized in Table 7-1.

7.2 Aquatic Assessment

While not truly an assessment endpoint, it was determined by EPA, USFWS, FTMC, and IT personnel during the site reconnaissance conducted My 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

Table 7-1

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

Assessment Endpoint	Risk Hypothesis
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.
II. Maintenance of healthy local populations and communities of 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 invertivorous small mammals or birds.
III. Maintenance of healthy local populations and communities of 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 omnivorous small mammals or birds.
Aquatic Ecosystems :	
I. Maintenance of healthy local populations and communities of aquatic invertivorous small mammals and birds.	I. Calculated hazard quotients using modeled tissue concentrations of COPECs in emergent aquatic insects, site-specific diet composition, and area use factors indicate statistically significant potential for risk to either aquatic invertivorous small mammals or birds.

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*) (3DI, 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 surface water and sediment sampling location at the farthest downstream extent of the IMR ranges and comparing the data to the closest off-site surface water and sediment data. The on-site surface water and sediment data were from the sample location SAR-RC-SW/SD13, which is located on Remount Creek within the study area of the Skeet Range. 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. 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 7-2. As presented in this table, the downstream concentrations of lead in surface water are less than the

TABLE 7 - 2
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).

on-site lead concentration and also less than the background threshold value. 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.

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

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 "aquatic 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 become exposed to COPECs through ingestion of COPECs that have become incorporated into the prey species' tissues. For these reasons, aquatic 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 aquatic invertivorous mammal and bird feeding guild is the following:

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

The assessment endpoints that have been identified for the IMR ranges are summarized in Table 7-1.

7.3 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 in subsequent risk assessment steps. 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 that was identified as being 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 non-impacted 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 that was identified as being appropriate to address the assessment endpoint of "maintenance of healthy local populations and communities of 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 invertivorous small mammals or birds.

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

Additionally, measured COPEC concentrations in earthworms will be used as input to the exposure algorithm as the concentration in the food of the terrestrial invertivorous small mammals and birds.

In order to calculate COPEC exposures, indicator species that represent the feeding guilds of interest must be identified. For this risk assessment, the terrestrial small 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*). Natural history parameters for these indicator species will be used in combination with site-specific exposure parameters to estimate exposures to terrestrial invertivorous small mammals and birds at the IMR ranges, respectively.

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

$$TDD_{invert} = \left[\left(IR_{food} \times f_{worm} \times C_{worm}\right) + \left(IR_{water} \times f_{water} \times C_{water}\right) + \left(IR_{food} \times f_{soil} \times C_{soil}\right)\right] \times AUF$$

where:

TDD_{invert}	=	total daily dose of COPEC received by terrestrial invertivorous mammals or birds through ingestion (mg/kg/day);
IR_{food}	=	ingestion rate of food by invertivorous species (mg/kg/day);
f_{worm}	=	fraction of daily diet comprised of invertebrates (percent);
C_{worm}	=	concentration of COPEC in invertebrate tissue (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);
f_{soil}	=	fraction of daily diet comprised of soil (percent);
C_{soil}	=	concentration of COPEC in soil (mg/kg); and
AUF	=	area use factor (fraction of site used by receptor species (percent).

The risk hypothesis that was identified as being appropriate to address the assessment endpoint of "maintenance of healthy local populations and communities of 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 omnivorous small mammals or birds.

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 AUFs. 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 omnivorous small mammals and birds. Literature-derived bioaccumulation factors will be used to estimate COPEC concentrations in the terrestrial vegetation portions of the omnivorous small mammals' and birds' 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 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 will be used in combination with site-specific exposure parameters to estimate exposures to omnivorous small mammals and omnivorous birds at the IMR ranges, respectively.

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

$$TDD_{omni} = \left[\left(IR_{food} \times f_{worm} \times C_{worm}\right) + \left(IR_{food} \times f_{veg} \times C_{veg}\right) + \left(IR_{water} \times C_{water}\right) + \left(IR_{food} \times f_{soil} \times C_{soil}\right)\right] \times AUF$$

where:

TDD_{omni}	=	total daily dose of COPEC received by omnivorous mammals or birds through ingestion (mg/kg/day);
IR_{food}	=	ingestion rate of food by omnivorous species (mg/kg/day);
f_{worm}	=	fraction of daily diet comprised of invertebrates (percent);
C_{worm}	=	concentration of COPEC in invertebrate tissue (mg/kg);
f_{veg}	=	fraction of daily diet comprised of vegetation (percent);
C_{veg}	=	concentration of COPEC in terrestrial vegetation (mg/kg);
IR_{water}	=	ingestion rate of water by omnivorous 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);
f_{soil}	=	fraction of daily diet comprised of soil (percent);
C_{soil}	=	concentration of COPEC in soil (mg/kg); and
AUF	=	area use factor (fraction of site used by receptor species (percent).

The risk hypothesis that was identified as being appropriate to address the assessment endpoint of "maintenance of healthy local populations and communities of aquatic 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 aquatic 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 aquatic food chain via emergent aquatic insects.

Daily doses of COPECs for aquatic 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). Site-specific bioaccumulation factors (BAFs) derived from laboratory testing using sediment from Cane Creek and *Chironomus sp.* will be used to estimate COPEC concentrations in the emergent 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 aquatic invertivorous mammal will be represented by the little brown bat (*Myotis lucifugus*) and the aquatic invertivorous bird will be represented by the marsh wren (*Cistothorus palustris*). Natural history parameters for these indicator species will be used in combination with site-specific exposure parameters to estimate exposures to aquatic invertivorous mammals and birds at the IMR ranges.

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

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

where:

$TDD_{wildlife}$	=	total daily dose of COPEC received by aquatic 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 benthic invertebrates (percent);

C_{sed}	=	concentration of COPEC in sediment (mg/kg);
BAF_{insect}	=	sediment-to-insect bioaccumulation factor (unitless);
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).

Table 7-1 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 $p = 0.05$.

Based upon the binding capacities of the soils at the different IMR ranges, it may be necessary to define more than one soil type. An analysis will be conducted of the binding capacities of the soils at each of the IMR ranges. If the binding capacities of the soils at the different ranges are determined to be similar, then they will be considered a single soil type and a range of COPEC soil concentrations will be collected from the IMR ranges, irrespective of location. If the binding capacities of the soils at the different ranges are determined to be significantly different, then the soils will be grouped according to similar binding capacities and a range of COPEC concentrations will be sampled from each binding capacity-defined soil type.

The use of measured COPEC concentrations in earthworms from a broad range of soil concentrations will allow for 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.

Because a portion of the omnivores' diet consists 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 BCF 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.

Dietary composition of 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 is comprised 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.

It is important to note that there are several limitations related to the calculation of hazard quotients in ecological risk assessment. Hazard quotients are not population- or community-based measures; rather, they are measures of sensitive individuals. As such, hazard quotients are protective of individuals within specific feeding guilds and are more conservative than population- or community-based endpoints. Hazard quotients are not linearly scaled. A hazard quotient of five does not necessarily imply a significantly greater potential risk than a hazard quotient of two. Because the feeding guild-specific exposure algorithms are conservative in nature, very low contaminant concentrations tend to result in hazard quotients that are in exceedence of acceptable thresholds. The methodology for calculating hazard quotients does not take into account many chemical and physiological interactions for the sake of simplicity and standardization. Therefore, the potential exists that the calculated hazard quotients may be physiologically or toxicologically impossible. Also, hazard quotients are not true measures of risk; rather, they are measures of levels of concern. These limitations and uncertainties related to the calculation of hazard quotients generally result in over-estimations of risk for the sake of conservatism. A significant level of conservatism is acceptable at the SLERA stage of an assessment because it is important not to under-estimate risks and eliminate constituents from further assessment, when in fact they may contribute to a site's over-all risks. However, in the BERA, these uncertainties will be reduced by using as many site-specific parameters and toxicity values as possible, and utilizing more realistic exposure parameters in the exposure algorithms.

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