5.0 CONTAMINANT FATE AND TRANSPORT

The mobility and persistence of a contaminant in the environment are significant in determining the environmental fate and transport of that contaminant. Contaminant fate and transport are also dependent on the chemical and physical characteristics of the site and environmental medium in which the contaminant resides. Examples of chemical characteristics of the site/medium include pH of the soil and water, organic content of soil, oxidation-reduction potential (ORP), and the presence of inorganics (e.g., carbonates, sulfates, iron). Examples of physical characteristics include geological and hydrological parameters (e.g. hydraulic conductivity, porosity, and hydraulic gradients), temperature, the presence of surface water bodies, buildings, ground cover, etc. Additionally, the presence or absence of oxygen and microbial organisms in the environmental medium could determine the persistence of certain contaminants, particularly organic contaminants. Although the degree of impact is uncertain, because of the capacity of some contaminants to move from one medium to another or to become degraded by one or more biotic and/or abiotic processes, the analysis of contaminant fate and transport can be used to assess the potential rate of migration and fate of contaminants.

Analysis of contaminant fate and transport provides information that can be used to support development of the CSM. The CSM uses available information on the nature and extent of contamination from the RI to identify the potentially complete human or environmental exposure pathways that form the basis of evaluations for the BRA. The CSM for the ISOU is presented schematically in Figure 6-3, as well as in Figure K-3 of Appendix K (BRA). The CSM assumes that current and future land use for the SLDS is industrial/commercial in an urban setting. Under current land use, exposure pathways are evaluated assuming current physical configurations of contaminants existing in inaccessible soil areas (e.g., beneath or adjacent to buildings and structures), sewers and soil adjacent to sewers, and soil on building and structural surfaces. Under future land use, exposure pathways are evaluated assuming scenarios in which the inaccessible soil areas become accessible due to removal or gross degradation of ground cover (i.e., in the forms of buildings/structures, roadways, RRs, asphalt/concrete pavement, etc.). The ISOU CSM identifies the following types of potential exposure pathways assumed for both the current and reasonably anticipated future land use scenarios: (1) complete and potentially significant, (2) potentially complete but insignificant, and (3) incomplete. Complete and potentially significant exposure pathways are retained for further quantitative evaluations in the BRA. A complete exposure pathway is comprised of each of the following elements:

- a contaminant source,
- a release/transport mechanism,
- an exposure medium (or point) where humans could contact the contaminated medium, and
- an exposure route (i.e., ingestion, dermal contact, inhalation, or external radiation).

Sources are discussed in Section 5.1. The extent to which either MED/AEC sources or non-MED/AEC sources contributed to the each of the COPCs is not known. However, the identification, characterization, and evaluation of other non-MED/AEC sources are outside of the scope of this RI. The remaining three elements are discussed in Section 5.2, with a focus on contaminant release and transport mechanisms. Appendix K, Section K.2.3, provides greater detail in the description of exposure media, human and ecological receptors, and exposure routes. Section 5.3 discusses the chemical and physical characteristics of contaminants and the environmental media that govern environmental fate and transport. Section 5.4 discusses the chemical and physical characteristics of COPCs and provides a means to assess which fate and transport processes are likely to be dominant under ISOU-specific conditions.

The CSM developed for this RI presents sources, release mechanisms, transport pathways, and exposure pathways for ISOU media. It does not present this information for soil that is in currently accessible areas that have been or are being remediated under the 1998 ROD.

5.1 INACCESSIBLE SOIL OPERABLE UNIT SOURCES OF CONTAMINATION

Historical MED/AEC contaminant sources at the SLDS include uranium ores and radioactive residues and wastes resulting from processing and waste handling, storage, and hauling activities. Previous remedial actions at the SLDS have removed all of the historical MED/AEC-processing buildings, except for Plant 1 Building 25, and have remediated much of the radiologically contaminated accessible soil to levels that are protective of human health and the environment in accordance with the 1998 ROD.

Although the MED/AEC-processing and waste-handling activities that created the contaminant sources at the SLDS ceased in the 1950s, constituents present in the source areas may have migrated to other media still present at the site. These remaining media are identified as current contaminant and exposure sources in the ISOU CSM. A source material is defined by USEPA (1991c) as “material that includes or contains hazardous substances, pollutants or contaminants that act as a reservoir for migration of contamination to ground water, to surface water, to air, or acts as a source for direct exposure.” For the purposes of the CSM, a source is an environmental medium that has been directly impacted by former MED/AEC operations. The CSM (Figure 6-3) identifies three main categories of potential sources of contamination and exposure within the ISOU: (1) contaminated inaccessible soil, (2) radiologically contaminated particles (e.g., soil) on structural surfaces, and (3) contaminated sewers. These potential source media are further discussed in Sections 5.1.1 through 5.1.3.

5.1.1 Inaccessible Soil Sources

Inaccessible soil is further characterized in the CSM as soil beneath ground cover and inaccessible soil with no ground cover. These sources are inclusive of inaccessible soil beneath or adjacent to buildings, the soil beneath or adjacent to the levee, soil beneath or adjacent to the RRs, and soil beneath or adjacent to roadways. Some soil areas adjacent to buildings, RRs, roadways, and the levee are beneath ground cover (e.g., pavement). Soil areas without ground cover were considered to be inaccessible due to concerns of compromising the integrity of the adjacent building, RR, roadway, or levee during remediation and therefore, could not be remediated in accordance with the 1998 ROD.

Based on exceedances of radiological and arsenic PRGs, the inaccessible soil areas within all properties investigated during the RI are considered to be potential sources of contamination to other media and for receptor exposures. The properties, along with the COPCs identified in inaccessible soil that are to be evaluated in the BRA are listed below. Radiological COPCs include Ac-227, Pa-231, Ra-226, Ra-228, Th-230, Th-232, U-235, and U-238. Arsenic is the only metal COPC retained for properties and segments of RRs and roadways within the former uranium-ore processing boundary.

- Plant 1: Radiological COPCs
- Plant 2: Radiological COPCs and Arsenic
- Plant 6: Radiological COPCs and Arsenic
- Mallinckrodt Security Gate 49: Radiological COPCs
- DT-2: Radiological COPCs
- DT-4 North: Radiological COPCs

- DT-6: Radiological COPCs
- DT-8: Radiological COPCs
- DT-10: Radiological COPCs and Arsenic
- DT-15: Radiological COPCs
- DT-29: Radiological COPCs
- DT-34: Radiological COPCs
- West of Broadway Property Group (Plants 3, 8, 9, and 11, and DT-20, DT-23, DT-27, DT-35, and DT-36): Radiological COPCs
- South of Angelrodt Property Group (DT-13, DT-14, DT-16, and DT-17): Radiological COPCs
- DT-3: Radiological COPCs
- DT-9 Main Tracks: Radiological COPCs and Arsenic
- DT-9 Rail Yard: Radiological COPCs
- DT-9 Levee: Radiological COPCs
- Terminal RR Soil Spoils Area: Radiological COPCs
- DT-12: Radiological COPCs and Arsenic
- Hall Street: Radiological COPCs and Arsenic
- North Second Street: Radiological COPCs
- Bremen Avenue: Radiological COPCs
- Salisbury Street: Radiological COPCs
- Mallinckrodt Street: Radiological COPCs and Arsenic
- Destrehan Street: Radiological COPCs and Arsenic
- Angelrodt Street: Radiological COPCs
- Buchanan Street: Radiological COPCs

5.1.2 Soil on Buildings and Structures

Interior and exterior surfaces of buildings and permanent structures (identified in Table 4-6) were radiologically surveyed during the RI. The results of the surveys were compared to a structural surface PRG derived for protection of the most limiting receptor, the industrial site worker. Because of the PRG exceedances, which were not related to NORM, the buildings/structures listed below are identified as potential radiological sources for human exposures. These sources are represented in the source column of Figure 6-3 as “Structural Surfaces.” Radiological COPCs identified for these surfaces are those associated with accessible soil (i.e., COCs identified in the 1998 ROD) because soil contamination of these surfaces was likely to originate from accessible soil areas, rather than inaccessible soil areas. Environmental release and transport mechanisms associated with these areas are discussed in Section 5.2.2. The isolated exceedances of the PRGs were observed on interior surface areas inside of seven buildings and exterior surface and/or roof areas on four buildings, as summarized in the following list:

<u>*Interior Surface Exceedances:*</u>

- Plant 1
  - Building 7
  - Building 26
- Plant 2
  - Building 41
  - Building 508
- DT-6
  - Storage Building

- DT-10
    - Wood Storage Building
    - Metal Storage Building

Exterior Surface Exceedances:

- Plant 1
    - Building 25
    - Building X
- DT-10
    - Wood Storage Building
- DT-14
    - One area on a horizontal beam going from the L-shaped building to the brick warehouse

5.1.3 Sewers

The two primary media of concern for sewers, sewer sediment, and soil adjacent to sewer lines, are discussed as being potential source media in Sections 5.1.3.1 and 5.1.3.2, respectively. This source is presented in Figure 6-3 as "Sewers (Sediment)," because the sediment inside of the sewer lines is the first of the two sewer media to have been contaminated by former MED/AEC operations. After contamination of the sewer sediment, it is assumed that leaks of contaminated water and sediment from the sewer lines flowed into the adjacent soil outside of sewer lines, thereby resulting in potential contamination of the soil.

5.1.3.1 Sewer Sediment

During the RI, sediment samples were collected from inside of sewer lines at Plants 1, 2, 6, and 7 and from DT-11. Subsequent sewer sediment data comparisons with radiological PRGs resulted in the identification of the following radiological and metal COPCs: Ra-226, Ra-228, U-238, and arsenic. The sewer sediment locations identified as potential sources of these COPCs are presented in Table 5-1. These sources are represented in the source column of Figure 6-3 as "Sewers (Sediment)."

Table 5-1. Summary of Sewer Sediment Locations Exceeding Radiological and Metals PRGs

Property	Sewer Sediment Location	COPCs
Plant 1	SLD123489	Radiological and Arsenic
	SLD123490	Radiological and Arsenic
	SLD123491	Radiological and Arsenic
	SLD123492	Radiological and Arsenic
	SLD123493	Radiological and Arsenic
	SLD123494	Radiological and Arsenic
	SLD123495	Radiological and Arsenic
	SLD123496	Radiological and Arsenic
	SLD123497	Radiological and Arsenic
	SLD123498	Radiological and Arsenic

Table 5-1. Summary of Sewer Sediment Locations Exceeding Radiological and Metals PRGs (Continued)

Property	Sewer Sediment Location	COPCs
Plant 2	SLD123503	Radiological and Arsenic
	SLD123504	Radiological and Arsenic
	SLD123505	Radiological and Arsenic
	SLD123740	Radiological and Arsenic
	SLD123741	Radiological [a]
	SLD123742	Radiological and Arsenic
	SLD123743	Radiological and Arsenic
	SLD123744	Radiological and Arsenic
	SLD123749	Radiological and Arsenic
	SLD123750	Radiological and Arsenic
	SLD123751	Radiological [a]
Plant 6	SLD123746	Radiological and Arsenic
	SLD123747	Radiological and Arsenic
	SLD123748	Radiological and Arsenic
Plant 7	SLD123745	Radiological and Arsenic
DT-8	SLD123488	Radiological and Arsenic

[a] No metals data were collected from location.

5.1.3.2 Soil Adjacent to Sewer Lines

Historically, breaks and leaks in sewer lines may have resulted in releases of MED/AEC-related contamination to the inaccessible soils adjacent to the sewer lines. Therefore, during the RI, soil samples were collected adjacent to sewer lines, the data for which were subsequently compared to radiological and metals soil PRGs. Soil samples adjacent to the sewer lines were collected from Plants 1, 2, 6, 6E, and 7N and DT-12, DT-2, DT-8, and DT-11. Some of the samples were collected from excavations during sewer line removals (i.e., at Plant 6, Plant 7N/DT-12, and DT-2). Soil sampling locations adjacent to sewer lines exceeding the PRGs are summarized in Table 5-2. Because of the PRG exceedances, the soil locations presented in Table 5-2 are identified as potential sources of the following radiological and metal COPCs: Ac-227, Pa-231, Ra-226, Ra-228, Th-230, U-238, arsenic, cadmium, and lead. These sources are represented in the source column of Figure 6-3 as “Inaccessible Soil Adjacent to Sewer Lines.” The potential environmental release and transport mechanisms associated with these sources are discussed in Section 5.2.

Table 5-2. Summary of Soil Locations Adjacent to Sewer Lines Exceeding Radiological and Metals PRGs

Property	Soil Location	COPCs
Plant 1	SLD124538	Radiological, Arsenic, Cadmium, and Lead
	SLD124540	Radiological, Arsenic, Cadmium, and Lead
	SLD124542	Radiological, Arsenic, Cadmium, and Lead
	SLD124544	Radiological, Arsenic, Cadmium, and Lead
	SLD124546	Radiological, Arsenic, Cadmium, and Lead
	SLD124548	Radiological, Arsenic, Cadmium, and Lead
	SLD124550	Radiological, Arsenic, Cadmium, and Lead

Table 5-2. Summary of Soil Locations Adjacent to Sewer Lines Exceeding Radiological and Metals PRGs (Continued)

Property	Soil Location	COPCs
Plant 1 (Continued)	SLD124552	Radiological, Arsenic, Cadmium, and Lead
	SLD124554	Radiological, Arsenic, Cadmium, and Lead
	SLD124556	Radiological, Arsenic, Cadmium, and Lead
	SLD124558	Radiological, Arsenic, Cadmium, and Lead
	SLD124560	Radiological, Arsenic, Cadmium, and Lead
	SLD124564	Radiological, Arsenic, Cadmium, and Lead
	SLD124566	Radiological, Arsenic, Cadmium, and Lead
	SLD124568	Radiological, Arsenic, Cadmium, and Lead
	SLD124570	Radiological, Arsenic, Cadmium, and Lead
	SLD125283	Radiological, Arsenic, Cadmium, and Lead
	SLD125521	Radiological, Arsenic, Cadmium, and Lead
Plant 2	SLD124574	Radiological, Arsenic, Cadmium, and Lead
	SLD124576	Radiological, Arsenic, Cadmium, and Lead
	SLD124578	Radiological, Arsenic, Cadmium, and Lead
	SLD125385	Radiological, Arsenic, Cadmium, and Lead
Plant 6	HTZ88929	Radiological [a]
	HTZ88930	Radiological [a]
	SLD127572	Radiological, Arsenic, Cadmium, and Lead
Plant 7 and DT-12	SLD124586	Radiological, Arsenic, Cadmium, and Lead
	SLD131146	Radiological [a]
	SLD131156	Radiological [a]
	SLD131166	Radiological [a]
	SLD131176	Radiological [a]
	SLD93275	Radiological [a]
	SLD93276	Radiological [a]
	SLD93277	Radiological [a]
DT-2 Levee	SLD120945	Radiological [a]
	SLD120946	Radiological [a]
	SLD120947	Radiological [a]
	SLD120948	Radiological [a]
DT-8 and DT-11	SLD124590	Radiological, Arsenic, Cadmium, and Lead
	SLD124592	Radiological, Arsenic, Cadmium, and Lead
	SLD124594	Radiological, Arsenic, Cadmium, and Lead

[a] No metals data were collected from location.

5.2 INACCESSIBLE SOIL OPERABLE UNIT CONTAMINANT RELEASE AND TRANSPORT MECHANISMS

Under the current conditions of the ISOU, release of COPCs from inaccessible soil and sewer sources of contamination, followed by subsequent transport in the environment, can potentially occur where ground cover (i.e., in the form of buildings, RRs, roadways, pavement, and gravel) does not exist. Also, radiological COPCs from radiologically contaminated soil on building/structural surfaces can also be released and be transported in the environment. Environmental mechanisms facilitating release and transport of COPCs from inaccessible soil and soil adjacent to sewer lines in areas beneath ground cover are limited, because the existing ground covers act as physical barriers to these mechanisms. However ground cover may become removed or deteriorated in the future, thereby increasing the likelihood of the occurrence of release and transport of inaccessible soil COPCs and soil COPCs adjacent to sewer lines. However, releases of contaminants in sediment from inside of sewers to the adjacent soil can occur regardless of the presence of ground cover, as these releases are governed by water flow within the sewer and breaks in the sewer line. The CSM considers release/transport mechanisms associated with ISOU source media and areas, under both current and assumed future land use scenarios, which assume conditions inclusive and exclusive of ground cover, respectively.

Release and transport of COPCs can result in direct and indirect contact exposures. Direct contact exposures occur at the source, whereas indirect contact exposures occur away from the source Indirect contact exposures to COPCs identified in all ISOU source media require contaminant release from those media and the availability of transport mechanisms, thereby making it possible for migration of the COPCs from the source to some downgradient/downwind receptor location or medium, where exposures can occur. Release mechanisms (e.g., leaching, particulate dust emissions, leakage from sewer lines, etc.) are those environmental processes that cause some or all of the contaminant concentrations to become unbound or mobilized from a source. Once released from a source, transport mechanisms provide a pathway (e.g., air transport, vertical infiltration/percolation, horizontal ground-water transport, etc.) by which contaminants can migrate in or through an environmental medium (i.e., “transport medium”). Generally, the transport pathways expected to be significant in the migration of contaminants within or away from ISOU sources include air transport, subsurface water transport (i.e., via infiltration/percolation, sewer line leaks, and ground-water flow), and surface-water runoff. These pathways and associated release mechanisms are summarized in the following list and depicted in each row of Figure 6-3:

- Air Transport Pathways
  - particulate emissions from inaccessible soil areas with little or no vegetative cover or ground cover (i.e., release by wind erosion or agitation of soil) followed by wind dispersion and air transport;
  - Radon (Rn)-222 emissions from inaccessible soil areas to indoor air;
  - particulate emissions from structural surfaces in the forms of dust potentially generated by construction/renovation activities followed by wind dispersion and air transport; and
  - particulate emissions from structural surfaces due to oxidation of metal surfaces followed by wind dispersion and air transport.
- Subsurface Water Transport Pathways
  - vertical infiltration/percolation of soil contaminants to deeper soil and ground water, predominantly in areas with no consolidated ground cover;
  - water/sediment leakage from inside of sewer lines to the adjacent soil; and
  - horizontal ground-water migration to downgradient locations/media (Mississippi River surface water and sediment).
- Surface Runoff Transport Pathways
  - surface runoff to downgradient locations/media (Mississippi River surface water and sediment); and
  - water runoff of soil and oxidized particles from building/structural surfaces.

In the CSM, those pathways that are identified as being potentially complete and “significant” are those that are comprised of all four of the pathway elements, plus the following:

- MED/AEC-contaminant concentrations at the source that exceed PRGs,

- contaminant-specific chemical/physical characteristics that strongly facilitate release and transport, and
- medium-specific chemical/physical characteristics that strongly facilitate release and transport.

ISOU pathways determined to be complete and can be characterized as “insignificant” by any of the following:

- low MED/AEC-contaminant concentrations (i.e., below PRGs) at the source,
- contaminant-specific chemical/physical characteristics that weakly facilitate release and transport, and/or
- medium-specific chemical/physical characteristics that weakly facilitate release and transport.

An environmental migration pathway from a source is “incomplete” if it lacks any of the four necessary pathway elements.

The three transport pathways (air transport, subsurface water transport, and surface-water runoff) and associated release mechanisms, along with the manner in which they support contaminant migration away from the ISOU sources are discussed in detail in the following sections.

5.2.1 Air Transport Pathways

5.2.1.1 Particulate Air Emissions and Transport from Inaccessible Soil Areas Beneath Unconsolidated Cover or No Cover

Under current conditions, the particulate emission of contaminants from inaccessible soil to the air is not a significant pathway due to the mitigating presence of ground cover (e.g., buildings, walkways, roads) over most of the ISOU. However, contaminants adsorbed to inaccessible soil in areas not under ground cover (e.g., some soil areas within 5 ft of buildings/structures and soil areas within 10 ft of RRs) may be released to the air as a result of wind agitation, and then be transported by the wind as fugitive airborne dust. Soil erosion by wind is more likely to occur in areas without a consolidated ground cover, with sparse vegetation. Because the sum of all inaccessible soil areas without consolidated ground cover is small relative to the total combined area of the SLDS and VPs, wind erosion of contaminated dusts from the uncovered areas of inaccessible soil are likely to be insignificant. Under current conditions, this pathway is rendered even more insignificant by the presence of tall buildings in close proximity to each other in the SLDS plant properties and VPs that can interfere with the air transport of wind-blown dusts. Although considered to be insignificant, this transport pathway could result in contaminant exposures via the inhalation of fugitive dusts at downwind locations. In the future, it is assumed that the removal of the structural barriers acting as ground cover could occur, thereby rendering the potential for particulate emissions and subsequent inhalation exposures as being much more significant.

5.2.1.2 Radon-222 Emissions from Inaccessible Soil Areas

Rn-222 is a naturally occurring radioactive gas that results from radioactive decay of Ra-226 as part of the U-238 decay chain. A fraction of the Rn-222 is produced from the radioactive decay of naturally occurring uranium in soil and rock, which accounts for natural background air concentrations. In addition to this natural source, Rn-222 is produced from the above background concentrations of radioactive materials present at the SLDS. When Rn-222 decay occurs in air, the decay products can cling to aerosols and dust, which makes them available for inhalation into the lungs.

Gaseous emissions of Rn-222 could occur from all inaccessible soil areas under both current and future land use scenarios. Site-related Rn-222 is only considered significant as a potential exposure pathway when average Ra-226 concentration levels exceed background levels beneath occupied or habitable buildings by greater than 5 pCi/g in surface soil and/or 15 pCi/g in subsurface soil, per 40 *CFR* 192.12(a). Additionally, Th-230 (which decays to Ra-226) is not considered significant unless average Th-230 concentrations above background exceed 14 pCi/g in surface soil and/or 43 pCi/g in subsurface soil, which would result in a buildup of Ra-226 to levels exceeding 40 *CFR* 192.12(a) levels (i.e., 5 pCi/g in surface soil and/or 15 pCi/g in subsurface soil) over a 1,000-year period. Also, Th-230, the parent of Ra-226, has a half-life of approximately 80,000 years and is at concentrations such that the buildup of Ra-226, during the next 1,000 years, would be less than 14 pCi/g.

Outdoor air concentrations of Rn-222 are typically low, but because Rn-222 can seep into buildings through foundation cracks or openings, it tends to build up to much higher concentrations indoors, if the sources are large enough. Therefore, only the indoor air of occupied or habitable buildings potentially warrant consideration of Rn-222 intrusion from the subsurface. The following sections discuss the potential significance of Rn-222 concentrations in indoor and outdoor air at ISOU.

5.2.1.2.1 Indoor Air

Although individual elevated measurement areas will be addressed in the FS, several ISOU areas have average Ra-226 and/or Th-230 concentration levels exceeding the values listed above. However, the Rn-222 pathway is currently considered potentially significant only for Plant 1 Building 26 and the DT-4 North-South Storage Building. The other areas are either not beneath occupied or habitable buildings, or it will take more than 1,000 years for the Ra-226 to build up from the decay of Th-230 to achieve significant levels.

The substantial variations in correlations between Ra-226 in soil and Rn-222 preclude accurate modeling of indoor radon in industrial structures especially if such structures do not have basements. Actual indoor air concentration of radon anticipated in structures is currently indeterminate. The need to measure radon concentrations in any occupied structure where there is the potential for Rn-222 in indoor air must be evaluated and the associated risk assessed individually based on such measurements.

Rn-222 monitoring is currently being conducted in Plant 1 Building 26 and the DT-4 North-South Storage Building; however, monitoring results are not yet available to determine associated risk. Risk and dose due to Rn-222 exposure will be determined and presented in the FS.

5.2.1.2.2 Outdoor Air

Surface soil is the largest source of outdoor Rn-222 air concentrations. Outdoor air concentrations are governed by the emission rate of Rn-222 from a source and atmospheric dilution factors, both of which are strongly affected by local meteorological conditions. Rn-222 levels in the atmosphere have been observed to vary as a function of the following factors: height above the ground, season, time of day, and location. The chief meteorological parameter governing airborne Rn-222 concentrations is atmospheric stability; however, the largest variations in atmospheric Rn-222 concentrations occur spatially (USEPA 1987).

At SLDS, inaccessible soil areas in outdoor areas are not considered to be significant for potential exposures to Rn-222 because of (1) the presence of ground cover in most areas reducing or minimizing the rate of Rn-222 emissions into the air and (2) infinite atmospheric dispersion and dilution of emissions that would occur in the outdoor environment. This is supported by the results of Rn-222 monitoring that has been conducted in accessible soil areas, during 14 years of active remediation under the 1998 ROD, in and around Plants 1, 2, 6, and 7 where no ground cover exists. Rn-222 alpha track detectors (ATDs) were used at the SLDS to measure alpha particles emitted from Rn-222 and its associated decay products as part of routine environmental monitoring (USACE 2011). ATDs were co-located with environmental thermoluminescent dosimeters three feet above the ground surface in housing shelters at locations representative of areas accessible to the public. Outdoor ATDs were collected approximately every six months and sent to an off-site laboratory for analysis. Recorded Rn-222 concentrations are listed in picocurie per liter (pCi/L), and are compared to the value of 0.5 pCi/L average annual concentration above background as listed in 40 *CFR* 192.02(b). The SLDS was found to be in compliance with the 0.5 pCi/L ARAR in 40 *CFR* 192.02(b). The last several years of environmental monitoring results acquired during remediation actions at the SLDS have not indicated that the outdoor air concentrations of Rn-222 warrant concern. The results from calendar year 2010 demonstrating compliance are discussed in Section 2.2.3 of the *St. Louis Downtown Site Annual Environmental Monitoring Data and Analysis Report for Calendar Year 2010* (USACE 2011).

5.2.1.3 Atmospheric Transport of Dust Emissions from Building and Structural Surfaces

The RI characterization shows that interior and exterior building contamination at the SLDS is primarily fixed with minimal amounts of removable contamination. However, future building renovations may release breathable particulate emissions into the air which could result in inhalation and ingestion exposures to renovation workers. Under this scenario, emissions of contaminated particulates into the air could become a significant pathway via the inhalation route.

5.2.1.4 Air Transport of Oxidized Particles from Building and Structural Surfaces

Elevated radioactivity measured primarily on exterior building/structure surfaces (i.e., as opposed to interior surfaces) could gradually become removable over time. Prolonged oxidation of the metallic surfaces may result in loose contaminated particulates that could become removable by high wind agitation and precipitation. This would result in the atmospheric transport to other on-site or off-site areas and subsequent deposition of the contaminated oxidized material in those areas. However, because the areas of elevated activity are relatively small and the potential for releases is minimal, this pathway is considered to be potentially complete but insignificant.

5.2.2 Subsurface Water Transport Pathways

5.2.2.1 Subsurface Water Transport Pathways for Contaminants in Inaccessible Soil Beneath Unconsolidated Cover or No Cover

Under current and future conditions, contaminants in inaccessible soil areas that are exposed to the environment can potentially migrate vertically through the subsurface soil to underlying deep soil and ground water. At the SLDS plant properties and VPs, the primary mechanisms for release of contaminants into subsurface environment ground water are the: (1) leaching of contaminants from soil via infiltration and percolation of rain water, (2) leaching of contaminants from contaminated soil due to fluctuations in the water table, and (3) the leaking of sediments from sewer lines into the adjacent soil. Once released, contaminants will migrate vertically until reaching ground water. Once in the ground water, horizontal migration to downgradient locations and media can occur. The following sections focus on transport of contaminants from the sewers and migration of contaminants in the ground water beneath SLDS.

5.2.2.2 Subsurface Water Transport Pathways for Contaminants in Sewer Sediment and Soil Adjacent to Sewers

Contaminants present in water and sediment contained within sewers could leak to underlying and/or adjacent inaccessible soil via structural defects such as cracks and breaks. Once sewer sediment contamination has reached adjacent soil, the more likely environmental fate would involve downward migration to ground water, followed by possible transport to the nearest downgradient surface water body, the Mississippi River. The primary mechanisms of release of contaminants from source sewer soils into ground water would be: (1) the leaching of contaminants via infiltration of rain water or sewer line water through contaminated subsurface soil and (2) leaching of contaminants from contaminated soil adjacent to sewer lines due to fluctuations in the water table. Water from precipitation events can infiltrate to the subsurface environment in areas where there is no impermeable ground cover (pavement, buildings, etc.). Of all the areas of contaminant sources identified at the ISOU, rain water infiltration would likely only occur at DT-2 due to the presence of mostly unconsolidated cover comprising the levee. Water reaching the subsurface contaminant sources could cause the contaminants to leach from the soils to which they are bound and to migrate deeper into the subsurface environment.

Similar to rain water, water from adjacent sewer lines could infiltrate into the previously described subsurface soil contaminant sources and trigger releases to the deeper subsurface environment. Water from sewer lines can originate from inside or outside of the lines. Active sewer lines are likely to have periods of significant interior water flow during which water can leak through cracks or breaches into the adjacent soils. Inactive sewers may also leak water during periods of interior flow, which are likely to be less significant than active sewer line flows. Both active and inactive lines can also serve as water conduits, or preferred water migration pathways, whereby subsurface water would flow along the exteriors of the lines, while allowing for some vertical migration to the deeper subsurface environment.

The soil to ground-water transport pathway is considered potentially complete but insignificant for soil adjacent to sewer lines. The sewer lines are situated within the fine-grained deposits of HU-A. As noted in Section 5.2.2.3, migration of metals and radionuclides via ground water to the underlying Mississippi Aquifer (HU-B) at the SLDS is limited due to the low permeability and high adsorption properties of the clay layers within the overlying HU-A. Once in ground water, no human exposures are expected, because ground water is not currently being used as a potable source, nor is it expected to be used as a potable source of water in the future. Likewise, the subsequent release of contaminants from ground water to the Mississippi River is even less significant because of the infinite dilution expected from the large volumetric water flow. Ingestion and dermal exposures to contaminants by aquatic life, though insignificant, could occur in the surface water and sediments.

5.2.2.3 Horizontal Ground-Water Migration of Contaminants to Downgradient Locations and Media

The inaccessible soil areas at the SLDS are situated within the upper hydrostratigraphic unit, HU-A. Evaluation of soil boring logs and geotechnical data indicates this unit consists primarily of fill overlying fine-grained deposits (silty clay, clay, silt, and sandy silt). The thickness of this unit typically ranges from 10 to 30 ft. An estimated hydraulic conductivity of 9.9E-06 cm per second (10 ft per year) was determined, based on one variable-head permeability test within HU-A (BNI 1990a). The effective CEC for the HU-A was determined to be 200 meq/100 g of soil (BNI 1994). This high CEC value indicates HU-A has a high capacity to hold cations and, therefore, will retard the migration of metals. The relatively small sources of contamination in inaccessible soil, the presence of clay-rich deposits, the high CEC value, and the low hydraulic conductivity value for HU-A support the conclusion that migration of metals and radionuclides via ground water to the underlying Mississippi Aquifer (HU-B) at the SLDS is limited. During ground-water transport in HU-B, additional advection, sorption, and dispersion processes would further reduce concentrations prior to reaching the Mississippi River.

Once in the ground water, contaminants may migrate horizontally to the Mississippi River. However, the cumulative impact of inaccessible soil contamination to ground water is reduced by the presence of overlying structural barriers that mitigate or minimize infiltration/percolation to ground water. As described in Section 3.3, the ground water at the SLDS is not being used as a drinking water source. Therefore, no human exposures to ground water are expected.

In summary, under current conditions in which most of the inaccessible soil areas are under consolidated ground cover, the soil to ground-water transport pathway is considered potentially complete but insignificant for areas where inaccessible soil is exposed to the environment. This is because the minimal concentrations reaching into ground water are expected to undergo immediate mixing in the aquifer, followed by dilution and attenuation during transport. In the future, it is assumed that ground cover is either removed or allowed to deteriorate, thereby increasing the significance of this pathway. However, once in ground water, under both current and future conditions, no human exposures are expected, because ground water is not currently being used as a potable source, nor is it expected to be used as a potable source in the future. Likewise, the subsequent release of contaminants from ground water to surface water is even less significant because of the infinite dilution expected from the large volumetric water flow of the Mississippi River. Ingestion and dermal exposures to contaminants by aquatic life, though insignificant, could occur in the surface water and sediments. Although the contribution of ground-water contamination from inaccessible soil is expected to be insignificant, all SLDS ground-water contamination associated with past MED/AEC activities is being addressed under the 1998 ROD.

5.2.3 Surface-Water Runoff Transport Pathways

5.2.3.1 Surface-Water Runoff Transport Pathways for Inaccessible Soil Beneath Unconsolidated Cover or No Cover

Surface-water runoff from inaccessible soil areas under unconsolidated cover could occur following a rain event, flood, or snowmelt. This action may erode soil bearing contaminants and carry those contaminants to downgradient locations or media via overland runoff water. However, the presence of the unconsolidated cover would reduce erosion of the underlying soil. Additionally, an extensive storm-water sewer drainage system is present at the SLDS where the ground surface is primarily covered by concrete, asphalt, or a roof. In these areas, surface water is quickly captured by the drainage system and collected and treated by the MSD. During periods of heavy rain, the storm sewers can become overloaded, resulting in some storm water not being treated. However, the vast majority of surface-water runoff resulting from storm events is captured by the storm-water sewer drainage system.

There are no surface ditches or streams leaving the SLDS plant properties or VPs, except for a surface ditch in the far northern portion (DT-9) of the ISOU study area, which channels water flows to the north, as well as topographically low areas of DT-12. Rainfall that does not result in runoff initially percolates through the upper few feet of fill material. The water accumulates at the upper surface of the natural soil, which is relatively impermeable due to its high clay content. The only property with conditions that vary from the industrial nature of the remaining properties is the eastern portion of the SLDS, which lies along the Mississippi River levee, is covered primarily by grass, and has a less extensive storm-water sewer drainage system. Surface water in this area would run directly into the Mississippi River.

Any contaminant runoff that may occur from environmentally exposed inaccessible soil is expected to be minimal, and could be transported to the nearest downgradient surface-water body, the Mississippi River. However, due to the large volumetric water flow of the river, it is expected that the minimal contaminant concentrations in the runoff entering the river would immediately undergo infinite dilution to undetectable concentrations at the surface-water interface, thus resulting in surface-water concentrations that would be insignificant relative to exposures that could impact human health.

For these reasons, the soil to surface-water transport pathway is considered to be potentially complete but insignificant for areas of inaccessible soil exposed to the environment. Likewise, potential exposures of humans and/or aquatic life to surface water and sediment, via the ingestion and dermal routes, are also insignificant.

5.2.3.2 Surface-Water Runoff Transport of Soil and Oxidized Particles from Buildings and Structural Surfaces

Prolonged oxidation of the metallic surfaces identified in Section 5.1.2 may result in loose contaminated particulates that could be washed away, along with soil particulates also adhered to a building/structure during a rain event. The release of contaminated soil and oxidized particles in this manner could occur as a result of the physical flushing action of the rain water, in conjunction with the slightly acidic pH that is characteristic of rain water. These release mechanisms would result in radiological contaminants in runoff from the building to the ground surface, and then to the combined sewer system, which flows to waste-water treatment facilities. During periods of heavy rain, the storm sewers can become overloaded resulting in some storm water not being treated. However, contaminant concentrations in the runoff are expected to be minimal due to the minimal releases expected from the small, localized building source areas, in conjunction with the large subsequent dilution that would occur over the course of transport to the storm sewers, then to the waste-water treatment facility. However, some residual levels of contamination may remain on the ground and not flow to the storm sewers during light or short rain events. Similarly, these residual levels of activity left on the ground surface would not be significant, because only minimal releases would be expected from the small building source areas, and because most of the existing contamination on the buildings is not easily removed by water action alone. Exposures to residual contamination on the ground would be insignificant. Therefore, this pathway is considered to be potentially complete but insignificant.

5.3 CONTAMINANT PERSISTENCE AND MOBILITY

Persistence and mobility are two key terms used to describe the movement and partitioning of chemicals in environmental media (i.e., air, surface water, ground water, soil, and sediment) and their likelihood of reaching an exposure point. Persistence is a measure of how long a compound will exist in air, water, or soil before it degrades or transforms, either chemically or biologically, into some other chemical. Mobility is defined as the potential for a chemical to migrate through a medium.

5.3.1 Chemical and Physical Properties

Chemical and physical properties that affect the fate and transport of metal and radiological COPCs include water solubility, speciation, partitioning and sorption, and degradation (or decay) rate. These properties are generally interrelated and are a function of a number of other variables, including ORP, pH, temperature, and the type and concentration of other chemicals capable of bonding with metal ions (e.g., sulfate, iron oxides, and natural organic matter).

5.3.2 Water Solubility

The water solubility of a chemical is one of the primary properties affecting the environmental transport of a chemical. Water solubility is the maximum concentration of a chemical that can dissolve in pure water at a given temperature and pH. Highly soluble chemicals (i.e., chemicals with solubility greater than 1,000 milligrams per liter [mg/L]) can be rapidly leached from contaminated soil and have a tendency to remain dissolved in water. They are less likely to partition to soil/sediment particles or volatilize. They are likely to be mobile and, therefore, are less likely to persist in the environment. Chemicals with lower water solubility (i.e., less than 1,000 mg/L) have a tendency to adsorb to soil and are generally less mobile. The solubility of chemicals that are not readily soluble in water can be enhanced in the presence of organic solvents or under acidic conditions.

5.3.3 Speciation

The fate and transport of metals is primarily driven by chemical speciation. Speciation can be described in terms of the chemical form (i.e., the oxidation state, charge, proportion, and nature of the complexed forms) and sometimes the physical form (distribution among soluble, colloidal, or particulate forms, and solid phases) in which it occurs (Moulin et al. 2005).

A variety of factors influence metal speciation, including pH, ORP, ionic strength, and the types and concentrations of ligands and complexing agents. In the pH range of natural water (between 5 and 9.5) and under aerobic conditions, free metal ions occur mainly at the low end of the pH range. With increasing pH, the carbonate and then oxide, hydroxide, or silicate solids precipitate (Connell and Miller 1984). In general, reduction of pH leads to increased desorption and remobilization of metal cations.

In the soil environment, metals can exist as cations (having a positive charge), anions (having a negative charge), or neutral species (having a zero charge). Their ionic form significantly affects their sorption, solubility, and mobility. For example, most soil particles are negatively charged; as a consequence, metal cations have a greater tendency to be sorbed by soil particles than do metal anions and, therefore, would have lower mobility (USEPA 2007).

Speciation is affected in two ways by oxidation-reduction (redox) conditions: (1) a direct change in the oxidation state of the metal ions and (2) redox changes in available and competing ligands or chelates. Redox is typically expressed in terms of ORP, where a positive value typically indicates oxidizing conditions and a negative value indicates reducing conditions. Reduced iron and manganese species are soluble and tend to be more mobile; whereas, oxidized forms of these metals (hydrous iron and manganese oxides) are in the particulate form and tend to cause other metals to sorb to their surfaces and tend to be less mobile.

5.3.4 Partitioning and Sorption

Partitioning and sorption are important mechanisms that affect the fate and transport of contaminants. The distribution of chemicals between a solid (soil or sediment), liquid, and gas is described as partitioning. The term sorption refers to removal of a solute from solution to a solid phase. The related term, adsorption, refers to two-dimensional accumulation of a solute on a solid surface (Smith 1999). Adsorption is generally pH-dependant, and pH changes exert strong controls on partitioning of contaminants between the aqueous and solid forms.

Four types of partitioning coefficients are important in predicting the behavior and mobility of chemicals within the environment: the K_d, the organic carbon partitioning coefficient (K_{oc}), the octanol-water partitioning coefficient (K_{ow}), and an air-water partitioning coefficient based on the Henry's Law constant (K). The K_{oc}, $K_{ow,}$ and K values are primarily used when evaluating organic chemicals. They generally are not important factors for evaluating the fate and transport of the metals and radionuclide COPCs for the ISOU and, therefore, are not discussed further.

Sorption and partitioning of inorganics can be expressed in terms of a K_d, also known as a distribution coefficient. The K_d value is simply the ratio of the concentration of a chemical in a solid phase to the corresponding aqueous-phase concentration. The K_d measures the relative mobility of a chemical in the environment and is typically expressed in units of Liters per kilogram (L/kg). In general, a high K_d value implies that the contaminant is tightly bound to the soil and will migrate slowly, while a small value implies the opposite. Values for K_d have been compiled for many of the common contaminants under a variety of hydrogeologic settings. The literature K_d values have wide ranges due to the large number of variables that can affect the measurements. The most important variables include pH and salinity of the water, grain size and mineralogy of the soil, concentrations of competing ions present, and the organic carbon content of the soil. Important adsorbent materials include iron oxides and hydroxides, manganese oxide, clay minerals, and particulate organic matter. Organic matter may form chelates or ligands with some metals, resulting in greater partitioning to soil with high organic content. The organic material in the soil also may sorb certain metals by other solutes through cation exchange.

5.3.5 Radioactive Decay Rate

The decay rate of a radionuclide is expressed in terms of a radionuclide-specific half-life and can be on the order of days, weeks, or years. The half-life of a radioactive substance is the time in which half of the atoms are transformed to another substance or daughter product.

Non-radioactive metals generally exhibit no potential to decay or degrade in environmental media. However, they may undergo chemical species transformations that affect their mobility in the environment. Radionuclides are subject to radioactive decay, which affects their environmental persistence. In general, decay of radionuclides occurs by the emission of alpha particles (a combination of two protons and two neutrons) and beta particles (negatively charged high-speed electrons). Decay of many radionuclides is accompanied by emission of gamma rays. The first radionuclide on the decay chain is called the parent compound, and specific products result from the decay of each parent. The parent radionuclides of importance at the SLDS are U-235, U-238, and Th-232. These parent radionuclides each yield radioactive decay products.

The U-238 decay series includes a number of decay products that would rapidly diminish in the environment because of their short half-lives if their long-lived parent isotopes were not present. However, continued presence of the long-lived isotopes U-234, U-238, Ra-226, and Pb-210 at relatively constant activity concentrations will cause their short-lived decay products to persist in solid media. For instance, Pb-210, which was not identified as a PCOC, has the shortest half-life of any of these COPCs (21 years). The half-life of Ra-226 is approximately 1,600 years, and the uranium isotopes have half-lives ranging from approximately 250,000 years to 4.5 billion years. Thus, radioactive decay is not of practical significance as a mechanism for reducing the COPC concentrations, particularly in sediment and surface materials.

5.4 CHARACTERISTICS OF INACCESSIBLE SOIL OPERABLE UNIT CONTAMINANTS OF POTENTIAL CONCERN

Radioactive isotopes of uranium, thorium, and radium, as well as the elemental forms of metals (i.e., arsenic, cadmium, and lead) were retained as COPCs based on the RI evaluation presented in Section 4.0. Table 4-14 shows that COPCs were identified in inaccessible soil, in sewer sediment, in soil adjacent to sewer lines, and on structural surfaces. This section describes the significant characteristics of each of the COPCs as they pertain to fate and transport.

5.4.1 Radionuclides

Residuals from the processing of uranium ore (i.e., radium, thorium, uranium, and their decay products) were inadvertently released into the environment. Radionuclides may exist either in solution or associated with solid particulates. In water, the partitioning of an element between dissolved and adsorbed forms is influenced greatly by the geochemical characteristics of the site. It is necessary, therefore, to rely on estimates of the K_d. A detailed review of K_d values reported in the literature is presented in the USEPA's three-volume guidance document *Understanding Variation in Partition Coefficient, K_d, Values* (USEPA 1999a, 1999b, 2004a). Based on the results of this review, USEPA developed formulas and lookup tables that can be used to estimate an appropriate range of K_d values for a contaminant at a particular site based on various site-specific parameters. Table 5-3 presents predicted K_d values for the ISOU radiological COPCs (radium, thorium, and uranium) based on measured values for site-specific parameters, including pH, soil type, and the dissolved concentration of the COPC in site ground water. The higher the K_d, the more adsorbed the radionuclide will be on the solid particulates and the less adsorbed the radionuclide will be in solution (USEPA 1993).

Table 5-3. Estimated Partitioning Coefficient (K_d) Values for the ISOU Contaminants of Potential Concern

Contaminant of Potential Concern	Estimated Range of Partitioning Coefficient (K_d) Values from the Literature (mL/g)	Predicted Site-Specific K_d Values (mL/g)	Basis for Predicted Site-Specific K_d Values	References
Arsenic	Arsenite (As^{3+}): 1.0 – 8.3 Arsenate (As^{5+}): 1.9 – 18	Predicted Values: As^{3+}: 3.3 As^{5+}: 6.7	Average soil pH at the SLDS is 7.9, based on recent soil pH tests conducted on SLDS soils. Predicted values are the geometric means of the literature K_d values for soil pH between 4.5 and 9.	Predicted values: *Soil Screening Guidance: Technical Background Document* (USEPA 1996c).

Table 5-3. Estimated Partitioning Coefficient (K_d) Values for the ISOU Contaminants of Potential Concern (Continued)

Contaminant of Potential Concern	Estimated Range of Partitioning Coefficient (K_d) Values from the Literature (mL/g)	Predicted Site-Specific K_d Values (mL/g)	Basis for Predicted Site-Specific K_d Values	References
Cadmium	1 – 12,600	Predicted Range (all soil types): 8 – 4,000 Predicted Range (clay-rich soil): 112 – 2,450 Predicted Value: 560	Predicted range (all soil types) corresponds to K_d values in the USEPA's lookup table for soil pH between 5 and 8. Average soil pH at the SLDS is 7.9, based on recent soil pH tests conducted on SLDS soils. Predicted value is based on geometric mean of literature K_d values for clay-rich soil.	Predicted range (all soil types): *Understanding Variation in Partition Coefficient, Kd, Values, Volume II* (USEPA 1999b). Predicted range (clay-rich soil) and predicted value: *Default Soil Solid/Liquid Partition Coefficients, K_ds, For Four Major Soil Types: A Compendium* (Sheppard and Thibault 1990)
Lead	150 – 44,580	Predicted Range (all soil types): 900 – 4,970 Predicted Value: 2,700	Predicted range corresponds to K_d values in the USEPA's lookup table for a soil pH between 6.4 and 8.7 and a range of equilibrium dissolved lead concentrations between 10 and 99.9 micrograms per Liter (µg/L). Average soil pH at the SLDS is 7.9 based on recent soil pH tests conducted on SLDS soils. Historical ground-water results indicate maximum lead concentration detected in site ground water was 17.8 µg/L. Predicted value is based on geometric mean of literature K_d values for clay-rich soil.	Predicted range: *Understanding Variation in Partition Coefficient, Kd, Values, Volume II* (USEPA 1999b). Predicted value: *Default Soil Solid/Liquid Partition Coefficients, K_ds, For Four Major Soil Types: A Compendium* (Sheppard and Thibault 1990)
Radium	57 – 530,000	Predicted Range (clay-rich soil): 696 – 56,000 Predicted Value: 9,100	Predicted range corresponds to K_d values for clay-rich soil. Predicted value is based on geometric mean of literature K_d values for clay-rich soil.	Predicted range and predicted value: *Default Soil Solid/Liquid Partition Coefficients, K_ds, For Four Major Soil Types: A Compendium* (Sheppard and Thibault 1990)
Thorium	20 – 300,000	Predicted Range (all soil types): 1,700 – 300,000 Predicted Range (clay-rich soil): 244 – 160,000 Predicted Value: 5,800	Predicted range (all soil types) corresponds to K_d values in the USEPA's lookup table for soil pH between 5 and 8. Average soil pH at the SLDS is 7.9 based on recent soil pH tests conducted on SLDS soils. Predicted value is based on geometric mean of literature K_d values for clay-rich soil.	Predicted range (all soil types): *Understanding Variation in Partition Coefficient, Kd, Values, Volume II* (USEPA 1999b). Predicted range (clay-rich soil) and predicted value: *Default Soil Solid/Liquid Partition Coefficients, K_ds, For Four Major Soil Types: A Compendium* (Sheppard and Thibault 1990)
Uranium	<1 – 1,000,000	Predicted Range (clay-rich soil): 46 – 395,100 Predicted Value: 146	Predicted range corresponds to K_d values for clay rich soil. Predicted value is based on measured K_d value (ASTM D4319) for samples collected in HU-A (clayey silt/silty clay) at the SLDS.	Predicted range (clay-rich soil): *Default Soil Solid/Liquid Partition Coefficients, K_ds, For Four Major Soil Types: A Compendium* (Sheppard and Thibault 1990). Predicted value: *Radiological, Chemical, and Hydrogeological Characterization Report for the SLDS* (BNI 1990a).

Chemical factors that influence the mobility of radionuclides in water include valence state, solubility, and redox conditions. Low-pH waters tend to carry more dissolved heavy radionuclides than high-pH waters. Thorium in the +4 valence state (Th[IV]) is highly immobile in all aqueous environments; whereas, radium in the +2 valence state (Ra[II]) is often mobile.

5.4.1.1 Uranium

Uranium is a common, naturally occurring, radioactive substance. Uranium is an actinide element and has the highest atomic mass of any naturally occurring element. In its refined state, it is a heavy, silvery-white metal that is malleable, ductile, slightly paramagnetic, and very dense, second only to tungsten. In nature, it is found in rocks and ores throughout the earth, with the greatest concentrations in the United States in the western states of Arizona, Colorado, New Mexico, Texas, Utah, and Wyoming (USEPA 1991b; Lide 1994). In its natural state, uranium occurs as a component of several minerals, such as carnotite and uraninite (including the variety commonly known as pitchblende), but is not found in the metallic state.

Uranium also may be introduced into the environment primarily by release as a result of mining and milling activities, by uranium processing facilities, or by burning coal.

Natural uranium is a mixture of the three isotopes U-234, U-235, and U-238. All three are the same chemical, but they have different radioactive properties. The only mechanism for decreasing the radioactivity of uranium is radioactive decay. Because all three of the naturally occurring uranium isotopes have very long half-lives (U-234 = 2.5×10^5 years; U-235 = 7.0×10^8 years; and U-238 = 4.5×10^9 years), the rate at which the radioactivity diminishes is very slow (NCRP 1984). Therefore, the activity of uranium remains essentially unchanged over periods of thousands of years.

By weight, natural uranium is approximately 0.01 percent U-234, 0.72 percent U-235, and 99.27 percent U-238. Approximately 48.9 percent of the radioactivity is associated with U-234; 2.2 percent is associated with U-235; and 48.9 percent is associated with U-238. The shorter half-life makes U-234 the most radioactive, while the longer half-life makes U-238 the least radioactive. Essentially, U-234 will be approximately 20,000 times more radioactive and U-235 will be 6 times more radioactive than U-238 (ATSDR 1999).

When U-238 gives off its radiation, it decays through a series of different radioactive materials, including U-234. This series, or decay chain, ends when it reaches the stable, non-radioactive element lead.

The mobility of uranium in soil and its vertical transport (leaching) to ground water depend on properties of the soil (such as pH, ORP, concentration of complexing anions, porosity of the soil, soil particle size, and sorption properties), as well as on the amount of water available (Allard et al. 1982; Bibler and Marson 1992). The sorption of uranium in most soil is such that it may not leach readily from surface soil to ground water, particularly in soil containing clay and iron oxide (Sheppard et al. 1987); although, other geological materials such as silica, shale, and granite have poor sorption characteristics (Bibler and Marson 1992; Erdal et al. 1979; Silva et al. 1979; Ticknor 1994). Redox conditions are important in the geologic transport and deposition of uranium. Oxidized forms of uranium (uranium in the +6 valence state [U(VI)]) are relatively soluble and can be leached from the rocks and migrate in the environment. When strong reducing conditions are encountered (e.g., presence of carbonaceous materials or hydrogen sulfide), precipitation of the soluble uranium will occur (ATSDR 1999).

As with soil, factors that control the mobility of uranium in water include ORP, pH, and sorbing characteristics of sediment and the suspended solids in the water (Brunskill and Wilkinson 1987;

Swanson 1985). The chemical form of uranium determines its solubility. Uranium behaves differently in oxidizing and reducing waters because of its two valence states (uranium in the +4 valence state [U(IV)] and [U(VI)]). In the reduced state, uranium is relatively immobile. In the oxidized state, uranium readily forms highly soluble complexes such as $UO_2\ (CO_3)_2^{2-}$ (McKelvey et al. 1955), which is very mobile in most natural surface-water and shallow ground-water environments (URS 2005).

Particle-size analysis and measurement of the CEC and the uranium K_d were performed as part of the RI conducted between 1989 and 1993 at the SLDS. These parameters give an indication of the capacity of the soil to retard uranium migration. Based on the soil properties (high content of fine-grained particles) and the uranium K_d value (146 mL/g), the uranium migration rate was estimated to be 300 to 400 times slower than the ground-water velocity (BNI 1994).

5.4.1.2 Thorium

Thorium is a naturally occurring radioactive substance. In the environment, thorium exists in combination with other minerals, such as silica. Small amounts of thorium are present in all rocks, soil, water, plants, and animals. Soil contains an average of approximately 6 parts of thorium per million parts of soil (6 parts per million). Some rocks in underground mines contain thorium in a more concentrated form. After these rocks are mined, thorium is usually concentrated and changed into thorium dioxide or other chemical forms.

Thorium is a metallic element of the actinide series. Thorium occurs in nature in four isotopic forms: Th-228, Th-230, Th-232, and Th-234. Thorium, like all radioactive materials, is not stable and breaks down through a decay chain/series of decay products until a stable product is formed. During these decay processes, radioactive substances are produced. These include radium and radon. These substances give off radiation, including alpha and beta particles and gamma radiation. Th-228 is the decay product of naturally occurring Th-232, and both Th-234 and Th-230 are decay products of natural U-238. Of these naturally produced isotopes of thorium, only Th-228, Th-230, and Th-232 have long enough half-lives to be environmentally significant. More than 99.99 percent of natural thorium is Th-232; the rest is Th-228 and Th-230.

The mobility of thorium in water is low because its solubility is low; therefore, thorium will most likely be present in suspended matter and sediment (Platford and Joshi 1986). Sediment resuspension and mixing also may control the transport of particle-sorbed thorium in water. The concentration of dissolved thorium in water may increase due to the formation of soluble complexes with carbonate, humic materials, or other ligands in the water (LaFlamme and Murray 1987).

The fate and mobility of thorium in soil are governed by the same principles that apply to water. In most cases, thorium will remain strongly sorbed to soil, and its mobility will be very slow (Torstenfelt 1986). The thorium content of soil normally increases with an increase in the clay content of soil (Harmsen and De Haan 1980). Normally, thorium compounds will not migrate long distances in soil. They will persist in sediment and soil (ATSDR 1990a). The contamination of ground water through the transport of thorium from soil to ground water will not occur in most soil, except soil that has low sorption characteristics and has the capability to form soluble complexes. The presence of ions or ligands (CO_3^{2-}, humic matter) in soil that can form soluble complexes with thorium should increase its mobility in soil. Chelating agents produced by certain microorganisms (e.g., *Pseudomonas aeruginosa*) present in soil may enhance the dissolution of thorium in soil (Premuzic et al. 1985). The plant-soil transfer ratio for thorium is less than 0.01 (Garten 1978), thus indicating that it will not bioconcentrate in plants from soil.

Table 5-3 provides a range of predicted site-specific K_d values for thorium based on two important parameters affecting thorium adsorption: soil pH and dissolved thorium concentrations (USEPA 1999b). The range of K_d values listed for the pH range of 5 to 8 on USEPA's lookup table (1,700 – 300,000 mL/g) is appropriate for the SLDS because this is the pH range within which most of the SLDS soil and ground-water pH measurements fall. The predicted K_d value for thorium at the SLDS, 5,800 mL/g, is based on the high content of fine-grained particles in SLDS soil (HU-A). This K_d value corresponds to the default value for clay soil (i.e., soil with > 35 percent clay-sized particles) (Sheppard and Thibault 1990). The high K_d value indicates that thorium is highly adsorbed to the soil at the SLDS.

5.4.1.3 Radium

Radium is a naturally occurring, silvery-white, radioactive metal that can exist as several isotopes. Usually, natural concentrations are very low. However, weathering and other geologic processes can form concentrated deposits of naturally radioactive elements, especially uranium and radium. Radium in soil and sediment does not biodegrade nor participate in any chemical reactions that alter it into other forms (ATSDR 1990b). The only degradation mechanism in air, water, and soil is radioactive decay.

Radium forms when isotopes of uranium or thorium decay in the environment. As a decay product of uranium and thorium, radium is common in virtually all rock, soil, and water. Radium's most common isotopes are Ra-224, Ra-226, and Ra-228. Ra-226 is found in the U-238 decay series, and Ra-228 and Ra-224 are found in the Th-232 decay series. Ra-226, the most common isotope, is an alpha emitter, with accompanying gamma radiation, and has a half-life of approximately 1,600 years. Ra-228 is principally a beta emitter and has a half-life of 5.76 years. Ra-224, an alpha emitter, has a half-life of 3.66 days (USEPA 2009a). Radium decays to form isotopes of the radioactive gas radon, which is not chemically reactive. Ra-226 decays by alpha particle radiation to an inert gas, Rn-222, which also decays by alpha particle radiation and has a short half-life of 3.8 days. Stable lead is the final product of this lengthy radioactive decay series.

Radium is known to be "readily adsorbed to clays and mineral oxides present in soil, especially near neutral and alkaline pH conditions" (Smith and Amonette 2006). Consequently, it is usually not a mobile constituent in the environment. Radium K_d values for clay minerals and other common rock-forming minerals have ranged from 2,937 to 90,378 mL/g in alkaline solutions (Benes et al. 1985; Benes et al. 1986). The magnitude of these adsorption constants indicates that partitioning to solid surfaces is a major removal mechanism of radium from water. The tendency for radium to coprecipitate with barite, and sparingly with soluble barium sulfate, is well known. Therefore, it is likely that radium in water does not migrate significantly from the area where it is released or generated (USEPA 1985). Radium may be transported in the environment in association with particulate matter. Its concentration is usually controlled by adsorption-desorption mechanisms at solid-liquid interfaces and by the solubility of radium-containing minerals.

Some radium salts are soluble in water. Radium in water exists primarily as a divalent radium ion (Ra^{2+}) and has chemical properties that are similar to barium, calcium, and strontium. The solubility of radium salts in water generally increases with increased pH levels. The removal of Ra^{2+} by adsorption has been attributed to ion exchange reactions, electrostatic interactions with potential determining ions at mineral surfaces, and surface-precipitation with $BaSO_4$. The adsorptive behavior of Ra^{2+} is similar to that of other divalent cationic metals in that it decreases with an increase in pH and is subject to competitive interactions with other ions in solution for adsorption sites. In the latter case, Ra^{2+} is more mobile in ground water that has a high total dissolved solids content. Limited field data also support the generalization that radium is not very mobile in ground water. It also appears that the adsorption of Ra^{2+} by soil and rocks may not be a completely reversible reaction (Benes et al. 1984; Benes et al. 1985; Landa and Reid 1982). Hence, once adsorbed, radium may be partially resistant to removal, which would further reduce the potential for environmental release and human exposure.

As shown on Table 5-3, there is a wide range of predicted K_d values for radium (696 – 56,000 mL/g). This range corresponds to the literature values for clay soil (i.e., soil with > 35 percent clay-sized particles) (Sheppard and Thibault 1990). The predicted K_d value for radium at the SLDS, 9,100 mL/g, corresponds to the geometric mean of the literature K_d values for clay soil (Sheppard and Thibault 1990).

5.4.2 Metals

All soil naturally contains a variety of metals. The presence of metals in soil is, therefore, not indicative of contamination. The background concentration of metals in uncontaminated soil is primarily related to the geology of the parent material from which the soil was formed. Depending on the local use of an area and the local geology, the concentration of metals in soil may exceed average concentrations for the United States.

The anthropogenic sources of metal to soil include diverse manufacturing, mining, combustion, and pesticide activities and deposition from atmospheric sources resulting from oil and coal combustion, mining and smelting, steel and iron manufacturing, waste incineration, phosphate fertilizers, cement production, and wood combustion (USEPA 1992a). Uranium-bearing ores that were processed by MED/AEC may have contained elevated levels of some metals (e.g., arsenic, cadmium, and lead) and may have also contained cadmium, a constituent of pyrite, which was a mineral constituent of the uranium ore. Although uranium (elemental) concentrations do not exceed the PRG, arsenic, cadmium, and lead concentrations do exceed the respective PRGs.

Although each metal has unique characteristics, as a group, metals are persistent in the environment and do not biodegrade but may alter in form. The primary factor influencing the mobility and persistence of metals is their speciation, which is affected by the geochemistry of the environment. Speciation refers to the occurrence of a metal in a variety of chemical forms. These forms may include free metal ions, metal complexes dissolved in solution and sorbed on solid surfaces, and metal species that have been coprecipitated in major metal solids or that occur in their own solids (USEPA 2007). Some metals can be transformed to other oxidation states in soil, making them less soluble and, thereby, reducing their mobility and toxicity (USEPA 1992a).

Metals are typically attenuated by clay soil, such as that found in the subsurface environment at the SLDS, primarily by precipitation and by exchange and adsorption processes, and not likely to leach significantly under natural conditions (i.e., undisturbed conditions and relatively neutral soil pH). Table 5-3 presents predicted K_d values for the metal COPCs (arsenic, cadmium, and lead) based on results of soil and ground-water sampling at the SLDS. These K_d values were estimated using site-specific values of soil pH and the equilibrium concentration of the COPC in SLDS ground water.

Three metal PCOCs have been retained as COPCs based on the RI evaluation presented in Section 4.0: arsenic, cadmium, and lead. Concentrations of all three metals have been detected above PRGs. Therefore, the physical/chemical characteristics of arsenic, cadmium, and lead are discussed in Sections 5.4.2.1 through 5.4.2.3.

5.4.2.1 Arsenic

Arsenic is a natural element found in the atmosphere, soil, rocks, natural waters, and organisms. There are numerous anthropogenic sources of arsenic. It is a byproduct of metal smelting and the burning of fossil fuels and also has been used as a component of pesticides, wood preservatives, glass, and pharmaceuticals. The largest natural source is volcanic activity (WHO 2001). Arsenic is mobilized in the environment through a combination of natural processes, such as wind or water erosion of small particles, leaching from soil or rock, volcanic activity, and biological activity, as well as through a range of anthropogenic activities.

Transport of arsenic in water depends upon its chemical species, oxidation state, and on interactions with other materials present. In an oxidized environment, arsenic is generally present as arsenate (As^{5+}), an immobilized form that tends to be ionically bound to soil. However, As^{5+} adsorption by soil is significantly reduced in environments where phosphate concentrations are high (WHO 2001). Sorption of As^{5+} is greatest at low pH but also depends on the availability of sorbing minerals. Under reduced conditions, As^{5+} is transformed to arsenite (As^{3+}), which is water soluble and, therefore, more mobile than As^{5+}. In a reducing environment and in the presence of sulfur, the relatively insoluble sulfides (As_2S_3 and arsenic sulfide [AsS]) form.

Arsenic minerals and compounds are readily soluble but migration is generally limited due to strong adsorption by clays, organic matter, iron oxides, magnesium oxides, and aluminum hydroxides. Arsenic adsorption does not appear to be significantly related to soil organic carbon or cation exchange capacity (Hayakawa and Watanabe 1982).

Arsenic is not subject to degradation. However, geochemical conditions created by microbial activity may create conditions that mobilize arsenic. Arsenic in water and soil may be reduced by fungi, yeasts, algae, and bacteria. Varying ORP conditions also may affect the speciation (valence state) of arsenic, which may affect both the toxicity and mobility.

Predicted site-specific K_d values for As^{5+}, and the more mobile form, As^{3+} are provided in Table 5-3. Limited availability of K_d values for arsenic on soil precluded the USEPA's calculation of K_d lookup tables for arsenic as a function of important parameters such as the iron oxide and clay content. The values presented in Table 5-3 are conservative and correspond to the geometric means of the literature values for soil pH ranging from 4.5 to 9 (USEPA 1996c). These relatively low K_d values indicate that arsenic can be expected to be more mobile in ground water than the other COPCs at the SLDS. The As^{5+} form is likely the predominant arsenic species under the oxidizing conditions found in the shallow soil at the SLDS. The As^{5+} form is expected to have limited mobility at the SLDS, because it is generally sorbed by iron oxides, manganese oxides, aluminum hydroxides, and clay minerals under near-neutral pH conditions.

5.4.2.2 Cadmium

Cadmium occurs naturally in the environment in deposits of zinc, lead, and copper-bearing ores; black shales; coal; and other fossil fuels. It is also released during volcanic eruptions. Typical concentrations in uncontaminated soil are less than 1 mg/kg (USEPA 1999a). Anthropogenic sources of cadmium include electroplating, paint pigments, plastic stabilizers, nickel-cadmium batteries, alloys, iron and steel production, mining of non-ferrous metals (e.g., lead and zinc), tire wear, coal combustion, oil burning, and limited use in some fertilizers (Korte 1999).

Cadmium is relatively mobile in soil and water systems. As with other cationic metals, cadmium sorption to mineral surfaces (especially oxide minerals) exhibits pH dependency, increasing as conditions become more alkaline (pH >6). Under acidic conditions (pH <6), cadmium is desorbed from soil (USEPA 1995a). In ground water with low to near-neutral pH, essentially all of the dissolved cadmium is expected to exist as the uncomplexed cadmium ion (Cd^{2+}). Under these conditions, cadmium also may form complexes with chloride and sulfate. Sorption also is influenced by the CEC of clays, carbonate minerals, and organic matter present in soil. Under reducing conditions, cadmium is expected to form insoluble cadmium sulfide (CdS) precipitates or coprecipitates with iron sulfide (FeS).

The most common cadmium species is likely Cd^{2+} under the oxidizing conditions typical of the shallow soil at the SLDS. The solubility and mobility of cadmium are greatly influenced by pH. Under the near-neutral pH conditions observed in shallow ground water at the SLDS, cadmium is expected to be adsorbed by the soil solid phase or to be precipitated, and mobility is expected to be reduced. Table 5-3 provides a range of predicted site-specific K_d values for cadmium based on soil pH and soil type (USEPA 1999b, Sheppard and Thibault 1990).

5.4.2.3 Lead

Lead is a heavy metal that occurs naturally in the earth's crust. It is rarely found naturally as a metal and, instead, is usually found combined with other elements to form lead compounds. It occurs as the mineral galena and also occurs in silicate minerals, such as feldspars, micas, amphiboles, and pyroxenes. It is usually found in ores with zinc, silver, and copper. Because it strongly sorbs onto clay minerals, it is also naturally found in some shales and clays. Lead is widespread in the environment as a result of human activities, primarily due to lead battery manufacturing, coal and oil burning, ammunition manufacture, metal smelting and processing, and former use in paints and gasoline (ATSDR 2007).

Lead is not very mobile in soil and, as a result, is typically present only in very low concentrations (on the order of 10^{-2} to 10^{-3} mg/L) in most river water and ground water (Hitchon et al. 2002). Under most conditions, the lead ion (Pb^{2+}) and lead-hydroxy complexes are the most stable forms of lead (Smith et al. 1995). The primary processes influencing the fate of lead in soil include adsorption, ion exchange, precipitation, and complexation with sorbed organic matter. The amount of lead that leaches to ground water is dependent on pH; lead sorbs extensively at much lower pH values than cadmium.

Based on lead's chemical characteristics, the most common lead species in the shallow soil and ground water at the SLDS are likely Pb^{2+} and lead-hydroxy complexes. Most lead would be retained in the soil due to adsorption, ion exchange, precipitation, and complexation with sorbed organic matter. This greatly limits the mobility of lead at the SLDS.

Table 5-3 provides a predicted range of site-specific K_d values for lead based on two important parameters affecting lead adsorption: pH and the equilibrium dissolved lead concentration. This range of K_d values was obtained from the USEPA's lookup table of lead K_d values (USEPA 1999b). One of the three pH categories in the lookup table is a range of 6.4 to 8.7, within which most of the SLDS soil and ground-water pH measurements fall. The lookup table range of 10 to 100 micrograms per Liter (µg/L) for the equilibrium lead concentration was selected for the SLDS, based on the maximum lead concentration in ground-water samples collected from SLDS monitoring wells (17.8 µg/L). The range of lead K_d values appropriate under these conditions is 900 to 4,970 mL/g. The estimate of the K_d value for lead at the SLDS is the median of this range, which is 2,935 mL/g. This high K_d value indicates that lead would be strongly adsorbed to the soil, resulting in limited transport at the SLDS.

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6.0 BASELINE RISK ASSESSMENT

The ISOU BRA was conducted to determine baseline dose and risks to the most likely human receptors identified at the SLDS properties based on assumed potential current and future exposures to radiological and metal COPCs identified in ISOU media (Section 4.0). Analytical data acquired primarily during the RI, as well as appropriate data from other USACE investigations at the SLDS, were used in the preparation of this BRA. The BRA consists of two components: the HHRA (Section 6.1) and the SLERA (Section 6.2).

6.1 HUMAN HEALTH RISK ASSESSMENT

The scope of the HHRA is the dose and risk evaluations of radiological and metal COPCs identified in all media not addressed under the 1998 ROD (USACE 1998a), as previously described in detail in Section 1.1.2, that exceed the risk-based PRGs presented in Section 4.0. Generally, these media include inaccessible soil, soil on interior and exterior building/structural surfaces, sewer sediment, and soil adjacent to sewer lines. Additionally, doses and risks were also characterized for radiological and metal COPCs in SLDS background soil and background sewer sediment, in an effort to assess background contributions to ISOU dose and risk. No background data are available for structural surfaces. In order to evaluate ISOU media, this HHRA was prepared using analytical data acquired primarily during the ISOU RI, as well as appropriate data from other USACE investigations at the SLDS. Potential risks and doses to individuals from assumed exposures to radiological and metal COPCs are assessed under sitewide, property-specific, building-specific, and sampling location-specific scenarios, depending on the ISOU medium. All HHRA evaluations are consistent with the current and expected future land use of the SLDS as a heavily industrial area in an urban setting. Evaluated receptor scenarios include the following:

- current industrial worker exposures to inaccessible soil and combined inaccessible/ accessible soil;
- future industrial worker exposures to inaccessible soil and combined inaccessible/ accessible soil;
- current/future recreational user exposures to inaccessible soil and combined inaccessible/ accessible soil in the levee areas associated with the St. Louis Riverfront Trail;
- current/future construction worker exposures to inaccessible soil;
- current/future utility worker exposures to inaccessible soil;
- current/future industrial worker exposures to interior building surfaces;
- current/future maintenance worker exposures to exterior building surfaces;
- current/future sewer maintenance worker exposures to sewer sediment; and
- current/future sewer utility worker exposures to soil adjacent to sewer lines.

Figures 6-1 and 6-2 present overviews of the ISOU HHRA process for sitewide and property/ location-specific evaluations, respectively, of soil. These figures primarily depict the processes for evaluating inaccessible soil and combined inaccessible/accessible soil exposures for the most limiting receptor under the industrial land use scenario (industrial worker), as well as for recreational users of the St. Louis Riverfront Trail. The above scenarios assume (1) current land use configurations in which ground cover is present over most inaccessible soil areas, but is absent from accessible soil areas, and (2) future land use configurations in which ground cover is absent from both inaccessible and accessible soil areas. In other words, for future exposure scenarios, the HHRA assumes that inaccessible soil has become accessible due to degradation or complete loss of ground cover. The assumed presence or absence of ground cover under current and future scenarios, respectively, affects the industrial exposure scenarios, but not the other receptor scenarios (as discussed in greater detail in Appendix K, Section K2.3). Therefore, current and future industrial workers are always presented as separate receptor scenarios, as they are presented in the above list of receptors, and the remaining receptors are presented as "current/future" scenarios.

The purpose of the HHRA is to provide risk and dose estimates and HI values for ISOU media and properties. All dose, CR, and HI estimates are compared to the target dose of 25 mrem/yr, the USEPA's target CR range of 1.0E-06 to 1.0E-04, and the target HI of 1.0. However, these comparisons do not constitute judgments being made with respect to the need for action. Application of these target criteria is a health-conservative approach, because the current and expected future land use of the SLDS is that of a heavily industrial area in an urban setting.

For the sitewide evaluations in the HHRA, receptor exposures to radiological and/or metal COPCs in the following media result in CRs above background that are within or exceed the USEPA's target CR range: inaccessible soil, combined inaccessible/accessible soil, and soil adjacent to sewer lines. Additionally, the HHRA results indicate that Plant 1 and DT-4 North exhibit radiological doses above background that exceed the target value of 25 mrem/yr. Of the 28 individual properties evaluated for radiological and metal exposures to inaccessible soil and/or combined inaccessible and accessible soil, 23 properties exhibit CRs above background that are within or exceed the USEPA's target CR range. The HHRA also shows that five buildings present at three properties (Plant 1, Plant 2, and DT-10) exhibit CRs for interior surfaces that are within the USEPA's target CR range. Only one building at DT-10 exhibits a CR for exterior surfaces within the USEPA's target CR range. None of the building surfaces exceed the target dose value. The sitewide evaluation of soil adjacent to sewers and the evaluations of eight individual soil locations adjacent to sewers resulted in exceedances of the target dose and/or resulted in the CRs being within or in exceedance of the target CR range for radiological exposures. All of the metal evaluations of soil adjacent to sewers resulted in all CRs and HIs being less than the target CR range and 1.0, respectively. All of the Adult Lead Model (ALM) evaluations of soil adjacent to sewers resulted in health risk due to lead being less than the USEPA's benchmark criterion. Of the metal COPCs evaluated in inaccessible soil (arsenic) and soil adjacent to sewers (arsenic, cadmium, and lead), ingestion of arsenic was the predominant contributor to risk. None of the sewer sediment locations exceed target dose or risk criteria.

For all media, the HHRA itself is generally comprised of several significant steps: identification of COPCs, exposure assessment, toxicity assessment, and dose and risk characterization. The methods and results of these HHRA components are summarized in Sections 6.1.1 and 6.1.2. The comprehensive HHRA is presented in Appendix K, with all supporting data, information, and calculations being provided in Appendices L through S.

6.1.1 Identification of Contaminants of Potential Concern

Sitewide COPCs being retained for radiological and/or metals dose/risk evaluations of all ISOU media were identified in Section 4.0 through comparisons with the risk-based PRGs that are presented in Table 4-1. The following items summarize the COPCs identified in each of the ISOU media that are quantitatively evaluated for dose and risk in the HHRA:

- Inaccessible Soil COPCs – Ac-227, Pa-231, Ra-226, Ra-228, Th-230, Th-232, U-235, U-238, and arsenic;
- Interior and Exterior Building/Structural Surface COPCs – Ac-227, Pa-231, Ra-226, Ra-228, Th-228, Th-230, Th-232, U-235, and U-238;

- Sewer Sediment COPCs – Ra-226, Ra-228, U-238, and arsenic; and
- COPCs for Soil Adjacent to Sewer Lines – Ac-227, Pa-231, Ra-226, Ra-228, Th-230, U-238, arsenic, cadmium, and lead.

Because each of the previous lists of COPCs is sitewide, they are applied uniformly across all properties and locations for each of the ISOU media.

Radionuclide-specific COPCs for interior and exterior building/structural surfaces were determined from comparisons of gross alpha survey measurements with the gross alpha PRGs derived in Appendix S. Where exceedances were observed, the accessible soil list of radionuclide COCs from the 1998 ROD were applied as the COPCs list. This is because it is assumed that the soil on surfaces originated predominantly from accessible soil areas.

Arsenic is identified as a COPC in inaccessible soil for each property located within the former uranium-ore processing boundary area presented on Figure 1-2, based on exceedances of the risk-based PRG, and because it is a metal associated with the pitchblende and domestic ores that were used in the former uranium processing operations. Arsenic, cadmium, and/or lead in sewer line sediments and in soil adjacent to sewer lines that served plants and buildings within the uranium-ore processing area were evaluated as COPCs, even if the sampling locations were outside of the uranium ore-processing area. Cadmium and lead were also associated with the pitchblende and domestic ores that were used in the former uranium processing operations.

Table 6-1 presents the COPCs being evaluated for each of the ISOU media, for each receptor scenario.

6.1.2 Exposure Assessment and Results of the Dose and Risk Characterization

A human health CSM for the ISOU is presented on Figure 6-3 and is discussed in Sections 5.0 and K2.3. The CSM presents complete and incomplete exposure pathways identified for ISOU media and receptors under current land use and physical configurations at the SLDS, as well as under foreseeable, future land use patterns. This includes contaminant sources, release/transport mechanisms, exposure media, and exposure routes that comprise the exposure pathways. Section 5.0 discusses contaminant sources and release/transport mechanisms. Section K2.3 discusses exposure media, potential receptors, and routes of exposure. Under current configurations (i.e., per Figure 6-3), the only potential exposure route for inaccessible soil contaminants beneath ground cover (e.g., buildings and pavement) is external radiation. For inaccessible soil with no cover (under current and future land use assumptions), ingestion, dermal contact, and external radiation could occur. Exposures to contaminated soil on building surfaces could occur via ingestion, inhalation, and external radiation. Exposures to sediment inside of manholes and sewer lines could occur via ingestion and dermal contact. Finally, exposures to inaccessible soil adjacent to sewer lines can occur via ingestion, dermal contact, inhalation of dusts, and external radiation.

The focus of this RI/BRA report is the assessment of the previously-described ISOU media. However, as discussed later in Section 6.2.2.1, this HHRA evaluates property-wide dose and risk for inaccessible soil, and combined inaccessible and accessible soil for some sitewide and property-specific scenarios. The results of COPC identifications and the exposure assessment are combined with radiological and chemical toxicity criteria to calculate: (1) dose and CRs for receptor exposures to radiological COPCs, and (2) CRs and non-carcinogenic HIs for exposures to metal COPCs. As stated previously, the resulting doses, CRs, and HIs were compared to the target criteria of 25 mrem/yr, the USEPA's target CR range of 1.0E-6 to 1.0E-4, and the USEPA's target HI of 1.0, respectively. Exceedances of dose/risk criteria indicate the need for further evaluations.

Lead was identified as a COPC in soil locations adjacent to sewer lines within Plants 1, 2, and 6, as well as at Plant7N/DT-12, DT-8, and DT-11, based on exceedances of the industrial PRG, which corresponds to the USEPA's industrial soil RSL (USEPA 2011a). Lead is classified as a B2 carcinogen and has known non-carcinogenic effects; however, no toxicity values have been established for lead. The USEPA regulates lead exposure using a biomarker (blood lead concentration [PbB]), which can be estimated using USEPA's ALM.

The ALM is a biokinetic model that predicts the relative increase in PbB that might result from an environmental exposure. The ALM can be used to predict the risk of elevated PbBs in a non-residential setting as a result of adult exposures to soil, with the ultimate receptor being the fetus. Biokinetic models work best when there is a known effect that is associated with a specific tissue concentration in humans. For lead, that effect is impaired nerve conduction velocity in children at 10 micrograms lead per deciliter blood (μg Pb/dL blood). The Centers for Disease Control and Prevention (CDC) established 10 μg Pb/dL blood as the federal level of concern in 1991. The USEPA's OSWER risk reduction policy calls for no child to have greater than a five percent probability of having a PbB >10 μg/dL. This benchmark is used as the benchmark for evaluating risk from lead exposures.

The following subsections (Sections 6.1.2.1 through 6.1.2.5) summarize the manner in which exposure point concentrations (EPCs) were derived and receptor scenarios were evaluated for inaccessible soil, soil on building/structural surfaces, sewer sediment, and soil adjacent to sewers. Generally, the EPC is determined as the lesser of the 95 percent UCL or the maximum detected concentration. Additionally, Sections 6.1.2.1 through 6.1.2.5 summarize the findings of the dose and risk characterizations performed for each of the associated scenarios. Table 6-1 summarizes the property-specific receptor scenarios evaluated in the HHRA. Doses and risks for the radiological COPCs in soil and sediment were determined using the RESRAD computer code. Doses and risks for the radiological COPCs in soil on building/structural surfaces were determined using the RESRAD-BUILD computer code.

During characterization discussions, comparisons are made versus the target dose of 25 mrem/yr, USEPA's target CR range, and the target HI of 1.0; however, the characterization is only a presentation of dose and risk results, and aforementioned comparisons do not constitute judgments being made with respect to the need for action. Only those dose and CR values that exceed the target dose and the USEPA's target CR range are presented in text in the characterization discussions (no exceedances of the target HI occur for any of the evaluated scenarios).

The maximum total radiological doses and risks for all sitewide and property-/location-specific receptor scenarios, including the corresponding maximum total background dose and risk, that occur over the 1,000-year evaluation period, are presented in Tables 6-2, 6-3A, 6-4, 6-5A, 6-6A, 6-7, 6-8, 6-9A, and 6-10A. These tables show dose above background (i.e., background dose is subtracted from the site dose), as well as CRs both with and without background risk. Doses and CRs are presented above background for consistency with the work being conducted under the 1998 ROD at the same properties being evaluated for ISOU-related doses and CRs. In Sections 6.1.2.1 through 6.1.2.5, all discussions of dose and CR pertain to dose and CR above background. Sections K2.5.4.1 through K2.5.4.9 in Appendix K also discuss CRs that are inclusive of background. As stated previously, the background doses and CRs for soil and sediment are estimated using the BVs as EPCs. Because the BVs are 95 percent UCLs derived from ranges of measured background concentrations, there are many instances of site doses and CRs estimated as being within or less than the corresponding background doses and CRs, which are indicated in the tables by "<BKGD." RESRAD and RESRAD-BUILD model outputs for all scenarios are presented in Appendices O and P, respectively.

Table 6-1. Property and Medium-Specific Receptor Scenarios for Evaluation in the Human Health Risk Assessment

Property	Inaccessible Soil [a] (Ground Cover Present)		Inaccessible Soil [a] (Ground Cover Absent)			Combined Inaccessible and Accessible Soil [a] (Ground Cover Absent in Accessible Areas)			Building/Structural Surfaces [b, c]		Sewers [d]	
	Current Industrial Worker [e]	Current/Future Recreational User [f]	Future Industrial Worker	Current/Future Construction Worker	Current/Future Utility Worker	Current Industrial Worker (Ground Cover Present in Inaccessible Areas) [e]	Future Industrial Worker (Ground Cover Absent from Inaccessible Areas)	Current/Future Recreational User (Levee Present as Ground Cover)	Current/Future Industrial Worker (Interior Surfaces)	Current/Future Maintenance Worker (Exterior Surfaces)	Current/Future Utility Worker (Soil Adjacent to Sewers)	Current/Future Sewer Maintenance Worker (Sediment)
Sitewide Scenarios												
Background [f]	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	Radiological	Radiological
SLDS (Sitewide) [g]	Radiological	---	Radiological + As	Radiological + As	Radiological + As	Radiological	Radiological + As	---	---	---	Radiological + As, Cd, Pb	Radiological + As
Combined Properties with St. Louis Riverfront Trail [h]	---	Radiological	---	---	---	---	---	Radiological	---	---	---	---
Property-Specific Scenarios												
Plant 1	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	Radiological	Radiological	Radiological + As, Cd, Pb	Radiological + As
Plant 2	Radiological	---	Radiological + As	Radiological + As	Radiological + As	Radiological	Radiological + As	---	Radiological	---	Radiological + As, Cd, Pb	Radiological + As
Plant 3	---	---	---	---	---	---	---	---	---	---	---	---
Plant 6	Radiological	---	Radiological + As	Radiological + As	Radiological + As	Radiological	Radiological + As	---	---	---	Radiological + As, Cd, Pb	Radiological + As
Plant 7N/DT-12	---	---	---	---	---			---	---	---	Radiological + As, Cd, Pb	Radiological + As
Mallinckrodt Security Gate 49	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
DT-2	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	Radiological	---
DT-4 North [i]	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
DT-6 [i]	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	Radiological	---	---	---
DT-8	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
DT-10	Radiological	---	Radiological + As	Radiological + As	Radiological + As	Radiological	Radiological + As	---	Radiological	Radiological	---	---
DT-11 and DT-8	---	---	---	---	---	---	---	---	---	---	Radiological + As, Cd, Pb	Radiological + As
DT-14	---	---	---	---	---	---	---	---	---	Radiological	---	---
DT-15	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---
DT-29	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
DT-34	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
West of Broadway Property Group [j]	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
South of Angelrodt Property Group [k]	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
DT-3	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
DT-9 Rail Yard	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
DT-9 Main Tracks	Radiological	---	Radiological + As	Radiological + As	Radiological + As	Radiological	Radiological + As	---	---	---	---	---
DT-9 Levee	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---
Terminal RR Association Soil Spoils Area	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
DT-12	Radiological	---	Radiological + As	Radiological + As	Radiological + As	Radiological	Radiological	---	---	---	---	---
Hall Street	Radiological	---	Radiological + As	Radiological + As	Radiological + As	---	---	---	---	---	---	---
North Second Street	Radiological	---	Radiological	Radiological	Radiological	---	---	---	---	---	---	---
Bremen Avenue	Radiological	---	Radiological	Radiological	Radiological	---	---	---	---	---	---	---
Salisbury Street	Radiological	---	Radiological	Radiological	Radiological	---	---	---	---	---	---	---
Mallinckrodt Street	Radiological	---	Radiological + As	Radiological + As	Radiological + As	---	---	---	---	---	---	---
Destrehan Street	Radiological	---	Radiological + As	Radiological + As	Radiological + As	---	---	---	---	---	---	---

Table 6-1. Property and Medium-Specific Receptor Scenarios for Evaluation in the Human Health Risk Assessment (Continued)

Property	Inaccessible Soil [a] (Ground Cover Present)		Inaccessible Soil [a] (Ground Cover Absent)			Combined Inaccessible and Accessible Soil [a] (Ground Cover Absent in Accessible Areas)			Building/Structural Surfaces [b, c]		Sewers [d]	
	Current Industrial Worker [e]	Current/Future Recreational User [f]	Future Industrial Worker	Current/Future Construction Worker	Current/Future Utility Worker	Current Industrial Worker (Ground Cover Present in Inaccessible Areas) [e]	Future Industrial Worker (Ground Cover Absent from Inaccessible Areas)	Current/Future Recreational User (Levee Present as Ground Cover)	Current/Future Industrial Worker (Interior Surfaces)	Current/Future Maintenance Worker (Exterior Surfaces)	Current/Future Utility Worker (Soil Adjacent to Sewers)	Current/Future Sewer Maintenance Worker (Sediment)
Angelrodt Street	Radiological	---	Radiological	Radiological	Radiological	---	---	---	---	---	---	---
Buchanan Street	Radiological	---	Radiological	Radiological	Radiological	---	---	---	---	---	---	---

[a] Radiological COPCs for inaccessible soil were identified by exceedances of corresponding PRGs by at least one sample result throughout the SLDS. Radiological COPCs always include the following: Ac-227, Pa-231, Ra-226, Ra-228, Th-230, Th-232, U-235, and U-238. Th-228 is not a COPC due to no exceedances of the PRG. Metals were only identified as COPCs if they exceed the PRG within the uranium ore processing area (see Figure 1-2) by at least one sample result. For the combined inaccessible and accesssible soil evaluations, the COPCs are the COCs identified in the 1998 ROD.

[b] Radiological COCs that were identified in the 1998 ROD are retained as the COPCs for soil on structural surfaces, because it is assumed that the soil on structural surfaces originated from accessible areas. These include the following: Ac-227, Pa-231, Ra-226, Ra-228, Th-228, Th-230, Th-232, U-235, and U-238. There are no metal COPCs for structural surfaces.

[c] The following identifies buildings at each property for which structural surfaces are being evaluated:

Plant 1 - Buildings 7, 25, 26, and X

Plant 2 - Buildings 41 and 508

DT-6 - Storage Building

DT-10 - Metal and Wood Storage Buildings

DT-14 - Horizontal Beam between L-Shaped Building and Brick Warehouse

[d] Radiological COPCs in sewer sediment include the following: Ra-226, Ra-228, and U-238. Radiological COPCs in soil adjacent to sewers include the following: Ac-227, Pa-231, Ra-226, Ra-228, Th-230, and U-238.

[e] Although arsenic is identified as an inaccessible soil COPC at the SLDS, Plant 2, Plant 6, and some properties, it is not being evaluated for the current industrial worker, because all exposure pathways are incomplete due to the presence of ground cover that acts as a physical barrier to exposures.

[f] The background values presented in Table 4-1 are used as the EPCs for determination of the soil and sewer sediment dose and risk. Calculations of background dose and risk incorporate the same assumptions about ground cover as those applied to the corresponding receptor scenario.

[g] The scenarios identified for the SLDS are for the Sitewide evaluations, and include all ISOU sampling locations and properties.

[h] Recreational users are evaluated for exposures to inaccessible soils in DT-2, DT-9 Levee, and DT-15, through which the St. Louis Riverfront Trail passes. The St. Louis Riverfront Trail evaluation includes all three of these VPs combined.

[i] The floors inside of the north salt dome at DT-4 and the storage building at DT-6 are currently earthen floors.

[j] West of Broadway Property Group consists of Plant 3, Plant 8, Plant 9, Plant 11, DT-20, DT-23, DT-27, DT-35, and DT-36.

[k] South of Angelrodt Property Group consists of DT-13, DT-14, DT-16, and DT-17.

"---" = No risk evaluation being performed for receptor at the identified property.

Table 6-2. Sitewide and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil and Accessible Soil: Current Industrial Worker

Property	Soil Operable Unit	Area (m^2)	Risk with Background	Dose & Risk Above Background [a]	
			Max. CR (unitless)	Dose (mrem/yr)	Max. CR (unitless)
Background [b]	Inaccessible [c]	10,000	NA	0.4	8.1E-06
	Accessible [d]	10,000	NA	10	1.8E-04
	Area-Wide [e]	20,000	NA	5.2	9.4E-05
SLDS (Sitewide)	Inaccessible [c]	381,357	1.1E-05	0.2	3.1E-06
	Accessible [d]	776,844	1.7E-04	<BKGD	<BKGD
	Sitewide [e]	1,158,201	1.1E-04	1.3	2.1E-05
Mallinckrodt Properties					
Plant 1	Inaccessible [c]	10,500	2.8E-05	1.0	2.0E-05
	Accessible [d]	11,700	1.9E-04	0.3	8.9E-06
	Property-Wide [e]	22,200	1.1E-04	1.1	1.9E-05
Plant 2	Inaccessible [c]	3,563	8.7E-06	0.03	5.6E-07
	Accessible [d]	16,531	1.7E-04	<BKGD	<BKGD
	Property-Wide [e]	20,094	1.4E-04	3.0	5.1E-05
Plant 6	Inaccessible [c]	2,370	1.5E-05	0.4	7.4E-06
	Accessible [d]	29,965	1.9E-04	0.5	7.7E-06
	Property-Wide [e]	32,335	1.8E-04	4.8	8.1E-05
Mallinckrodt Security Gate 49	Inaccessible [c]	5	6.4E-06	<BKGD	<BKGD
	Accessible [d]	435	1.5E-04	<BKGD	<BKGD
	Property-Wide [e]	440	1.5E-04	3.2	5.8E-05
Industrial/Commercial Vicinity Properties					
DT-2	Inaccessible [f]	12,665	6.1E-09	<BKGD	<BKGD
	Accessible [d]	77,475	1.7E-04	<BKGD	<BKGD
	Property-Wide [e]	90,140	1.5E-04	3.1	5.4E-05
DT-4 North	Inaccessible [c]	7,962	5.2E-05	2.3	4.4E-05
	Accessible [d]	6,178	1.8E-04	0.2	3.4E-06
	Property-Wide [e]	14,140	1.1E-04	0.9	1.5E-05
DT-6	Inaccessible [c]	3,582	2.3E-05	0.8	1.5E-05
	Accessible [d]	6,686	1.7E-04	<BKGD	<BKGD
	Property-Wide [e]	10,268	1.2E-04	1.6	2.5E-05

Table 6-2. Sitewide and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil and Accessible Soil: Current Industrial Worker (Continued)

Property	Soil Operable Unit	Area (m^2)	Risk with Background	Dose & Risk Above Background [a]	
			Max. CR (unitless)	Dose (mrem/yr)	Max. CR (unitless)
DT-8	Inaccessible [c]	20,471	6.7E-06	<BKGD	<BKGD
	Accessible [d]	85,560	1.8E-04	<BKGD	0.0E+00
	Property-Wide [e]	106,031	1.5E-04	3.0	5.3E-05
DT-10	Inaccessible [c]	726	9.7E-06	0.1	1.6E-06
	Accessible [d]	10,479	1.8E-04	3.3	<BKGD
	Property-Wide [e]	11,205	1.7E-04	7.6	7.5E-05
DT-15	Inaccessible [f]	5,505	5.4E-09	<BKGD	<BKGD
	Accessible [d]	3,754	1.1E-04	<BKGD	<BKGD
	Property-Wide [e]	9,259	4.4E-05	<BKGD	<BKGD
DT-29	Inaccessible [c]	533	5.7E-06	<BKGD	<BKGD
	Accessible [d]	1,345	1.8E-04	0.7	3.3E-06
	Property-Wide [e]	1,878	1.3E-04	2.8	3.9E-05
DT-34	Inaccessible [c]	4,780	9.0E-06	0.05	8.7E-07
	Accessible [d]	9,846	1.2E-04	<BKGD	<BKGD
	Property-Wide [e]	14,626	8.0E-05	<BKGD	<BKGD
South of Angelrodt Property Group	Inaccessible [c]	6,508	7.4E-06	<BKGD	<BKGD
	Accessible [d]	34,159	1.5E-04	<BKGD	<BKGD
	Combined Properties [e]	40,667	1.3E-04	1.9	3.3E-05
West of Broadway Property Group	Inaccessible [c]	33,043	6.4E-06	<BKGD	<BKGD
	Accessible [d]	50,847	1.5E-04	<BKGD	<BKGD
	Combined Properties [e]	83,890	9.3E-05	0.1	<BKGD
Railroad Vicinity Properties					
DT-3	Inaccessible [c]	6,363	9.5E-06	0.08	1.4E-06
	Accessible [d]	13,562	1.8E-04	0.01	<BKGD
	Property-Wide [e]	19,925	1.3E-04	2.0	3.1E-05
DT-9 Levee	Inaccessible [f]	84,920	4.7E-09	<BKGD	<BKGD
	Accessible [d]	188,158	1.7E-04	<BKGD	<BKGD
	Property-Wide [e]	273,078	1.1E-04	1.3	2.1E-05

Table 6-2. Sitewide and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil and Accessible Soil: Current Industrial Worker (Continued)

Property	Soil Operable Unit	Area (m^2)	Risk with Background	Dose & Risk Above Background [a]	
			Max. CR (unitless)	Dose (mrem/yr)	Max. CR (unitless)
DT-9 Main Tracks	Inaccessible [c]	36,630	9.8E-06	0.09	1.7E-06
	Accessible [d]	16,803	1.5E-04	<BKGD	<BKGD
	Property-Wide [e]	53,433	5.3E-05	<BKGD	<BKGD
DT-9 Rail Yard	Inaccessible [c]	24,384	2.0E-05	0.64	1.2E-05
	Accessible [d]	131,791	1.9E-04	0.2	6.4E-06
	Property-Wide [e]	156,175	1.6E-04	3.8	6.6E-05
Terminal RR Soil Spoils Area	Inaccessible [c]	10,636	2.5E-05	0.85	1.6E-05
	Accessible [d]	68,230	1.6E-04	<BKGD	<BKGD
	Property-Wide [e]	78,866	1.5E-04	2.9	5.1E-05
DT-12	Inaccessible [c]	23,009	7.3E-06	<BKGD	<BKGD
	Accessible [d]	13,730	1.6E-04	<BKGD	<BKGD
	Property-Wide [e]	36,739	6.6E-05	<BKGD	<BKGD
Roadways					
Angelrodt Street	Inaccessible [c]	NA	7.9E-06	<BKGD	<BKGD
Bremen Avenue	Inaccessible [c]	NA	1.1E-05	0.17	3.2E-06
Buchanan Street	Inaccessible [c]	NA	1.2E-05	0.19	3.6E-06
Destrehan Street	Inaccessible [c]	NA	1.3E-05	0.28	5.3E-06
Hall Street	Inaccessible [c]	NA	1.1E-05	0.14	2.7E-06
Mallinckrodt Street	Inaccessible [c]	NA	7.8E-06	<BKGD	<BKGD
North Second Street	Inaccessible [c]	NA	9.3E-06	0.07	1.2E-06
Salisbury Street	Inaccessible [c]	NA	5.4E-06	<BKGD	<BKGD

[a] For the site, dose and risk above background are calculated as the difference between dose and risk with background and background dose and risk. The values reported in the "Background" row, are the actual dose and risk estimated for background used in the calculations of dose and risk above background.

[b] The RESRAD default value of 10,000 m^2 was applied as the assumed area each for inaccessible soil and accessible soil areas for all receptor scenarios. Property-wide background dose and risk calculations for soil assume a total area of 20,000 m^2 for combined inaccessible and accessible soil areas for the industrial worker and recreational user scenarios, with 50 percent of the total background area assumed to be inaccessible soil and 50 percent of the total background area assumed to be accessible soil.

[c] Inaccessible soil dose and risk calculations for all properties under the current scenario, except for the levee properties (DT-2, DT-9 Levee, and DT15), assume a 1-foot thick soil cover is in place. Roadway areas are all considered to be inaccessible soil areas.

[d] Accessible soil dose and risk were calculated under the assumption of no ground cover.

[e] Property-wide dose and risk are calculated as weighted averages of inaccessible and accessible soil dose and risk.

[f] Inaccessible soil dose and risk for levee properties (DT-2, DT-9 Levee, and DT-15) were calculated by assuming a 1-meter thick soil cover is in place, and this assumption remains the same for both current and future scenarios, as the levee will remain in place.

m^2 - square meters; NA - Not applicable.

<BKGD - Indicates that dose or risk is within the range of background.

Table 6-3A. Sitewide and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil and Accessible Soil: Future Industrial Worker

Property	Soil Operable Unit	Area (m^2)	Risk with Background	Dose & Risk Above Background [a]	
			Max. CR (unitless)	Dose (mrem/yr)	Max. CR (unitless)
Background [b]	Inaccessible [c]	10,000	NA	10	1.8E-04
	Accessible [d]	10,000	NA	10	1.8E-04
	Area-Wide [e]	20,000	NA	10	1.8E-04
SLDS (Sitewide)	Inaccessible [c]	381,357	2.2E-04	2.5	4.3E-05
	Accessible [d]	776,844	1.7E-04	<BKGD	<BKGD
	Sitewide [e]	1,158,201	1.8E-04	0.2	4.4E-06
Mallinckrodt Properties					
Plant 1	Inaccessible [c]	10,500	7.0E-04	29	5.2E-04
	Accessible [d]	11,700	1.9E-04	0.3	8.9E-06
	Property-Wide [e]	22,200	4.3E-04	14	2.5E-04
Plant 2	Inaccessible [c]	3,563	1.7E-04	<BKGD	<BKGD
	Accessible [d]	16,531	1.7E-04	<BKGD	<BKGD
	Property-Wide [e]	20,094	1.7E-04	<BKGD	<BKGD
Plant 6	Inaccessible [c]	2,370	4.8E-04	18	3.0E-04
	Accessible [d]	29,965	1.9E-04	0.5	7.7E-06
	Property-Wide [e]	32,335	2.1E-04	1.7	2.9E-05
Mallinckrodt Security Gate 49	Inaccessible [c]	5	8.4E-05	<BKGD	<BKGD
	Accessible [d]	435	1.5E-04	<BKGD	<BKGD
	Property-Wide [e]	440	1.5E-04	<BKGD	<BKGD
Industrial/Commercial Vicinity Properties					
DT-2	Inaccessible [f]	12,665	6.1E-09	<BKGD	<BKGD
	Accessible [d]	77,475	1.7E-04	<BKGD	<BKGD
	Property-Wide [e]	90,140	1.5E-04	<BKGD	<BKGD
DT-4 North	Inaccessible [c]	7,962	9.7E-04	45	7.9E-04
	Accessible [d]	6,178	1.8E-04	0.2	3.4E-06
	Property-Wide [e]	14,140	6.2E-04	25	4.4E-04
DT-6	Inaccessible [c]	3,582	4.3E-04	15	2.5E-04
	Accessible [d]	6,686	1.7E-04	<BKGD	<BKGD
	Property-Wide [e]	10,268	2.6E-04	4.8	7.9E-05
DT-8	Inaccessible [c]	20,471	1.5E-04	<BKGD	<BKGD
	Accessible [d]	85,560	1.8E-04	<BKGD	0.0E+00
	Property-Wide [e]	106,031	1.7E-04	<BKGD	<BKGD
DT-10	Inaccessible [c]	20,471	2.1E-04	1.3	3.2E-05
	Accessible [d]	85,560	1.8E-04	3.3	<BKGD
	Property-Wide [e]	106,031	1.9E-04	2.9	6.2E-06
DT-15	Inaccessible [f]	5,505	5.4E-09	<BKGD	<BKGD
	Accessible [d]	3,754	1.1E-04	<BKGD	<BKGD
	Property-Wide [e]	9,259	4.4E-05	<BKGD	<BKGD

Table 6-3A. Sitewide and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil and Accessible Soil: Future Industrial Worker (Continued)

Property	**Soil Operable Unit**	**Area (m^2)**	**Risk with Background**	**Dose & Risk Above Background [a]**	
			Max. CR (unitless)	**Dose (mrem/yr)**	**Max. CR (unitless)**
***Industrial/Commercial Vicinity Properties* (Continued)**					
DT-29	Inaccessible [c]	36,630	9.4E-05	<BKGD	<BKGD
	Accessible [d]	16,803	1.8E-04	0.7	3.3E-06
	Property-Wide [e]	53,433	1.2E-04	<BKGD	<BKGD
DT-34	Inaccessible [c]	4,780	1.7E-04	<BKGD	<BKGD
	Accessible [d]	9,846	1.2E-04	<BKGD	<BKGD
	Property-Wide [e]	14,626	1.3E-04	<BKGD	<BKGD
South of Angelrodt Property Group	Inaccessible [c]	6,508	1.6E-04	<BKGD	<BKGD
	Accessible [d]	34,159	1.5E-04	<BKGD	<BKGD
	Combined Properties [e]	40,667	1.5E-04	<BKGD	<BKGD
West of Broadway Property Group	Inaccessible [c]	33,043	1.3E-04	<BKGD	<BKGD
	Accessible [d]	50,847	1.5E-04	<BKGD	<BKGD
	Combined Properties [e]	83,890	1.4E-04	<BKGD	<BKGD
Railroad Vicinity Properties					
DT-3	Inaccessible [c]	6,363	1.9E-04	0.1	9.0E-06
	Accessible [d]	13,562	1.8E-04	0.01	<BKGD
	Property-Wide [e]	19,925	1.8E-04	0.04	2.8E-06
DT-9 Levee	Inaccessible [f]	84,920	4.7E-09	<BKGD	<BKGD
	Accessible [d]	188,158	1.7E-04	<BKGD	<BKGD
	Property-Wide [e]	273,078	1.1E-04	<BKGD	<BKGD
DT-9 Main Tracks	Inaccessible [c]	36,630	1.9E-04	<BKGD	6.0E-06
	Accessible [d]	16,803	1.5E-04	<BKGD	<BKGD
	Property-Wide [e]	53,433	1.7E-04	<BKGD	<BKGD
DT-9 Rail Yard	Inaccessible [c]	24,384	4.9E-04	17	3.1E-04
	Accessible [d]	131,791	1.9E-04	0.2	6.4E-06
	Property-Wide [e]	156,175	2.3E-04	2.8	5.4E-05
Terminal RR Soil Spoils Area	Inaccessible [c]	10,636	4.4E-04	14	2.6E-04
	Accessible [d]	68,230	1.6E-04	<BKGD	<BKGD
	Property-Wide [e]	78,866	2.0E-04	0.9	2.2E-05
DT-12	Inaccessible [c]	23,009	1.3E-04	<BKGD	<BKGD
	Accessible [d]	13,730	1.6E-04	<BKGD	<BKGD
	Property-Wide [e]	36,739	1.4E-04	<BKGD	<BKGD
Roadways					
Angelrodt Street	Inaccessible [c]	NA	1.7E-04	<BKGD	<BKGD
Bremen Avenue	Inaccessible [c]	NA	2.2E-04	2.9	4.2E-05
Buchanan Street	Inaccessible [c]	NA	2.3E-04	3.3	4.8E-05
Destrehan Street	Inaccessible [c]	NA	2.3E-04	2.1	4.7E-05

Table 6-3A. Sitewide and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil and Accessible Soil: Future Industrial Worker (Continued)

Property	Soil Operable Unit	Area (m^2)	Risk with Background	Dose & Risk Above Background [a]	
			Max. CR (unitless)	Dose (mrem/yr)	Max. CR (unitless)
***Roadways* (Continued)**					
Hall Street	Inaccessible [c]	NA	2.3E-04	2.9	5.5E-05
Mallinckrodt Street	Inaccessible [c]	NA	1.3E-04	<BKGD	<BKGD
North Second Street	Inaccessible [c]	NA	1.8E-04	<BKGD	<BKGD
Salisbury Street	Inaccessible [c]	NA	1.0E-04	<BKGD	<BKGD

[a] For the site, dose and risk above background are calculated as the difference between dose and risk with background and background dose and risk. The values reported in the "Background" row, are the actual dose and risk estimated for background used in the calculations of dose and risk above background.

[b] The RESRAD default value of 10,000 m^2 was applied as the assumed area each for inaccessible soil and accessible soil areas for all receptor scenarios. Property-wide background dose and risk calculations for soil assume a total area of 20,000 m^2 for combined inaccessible and accessible soil areas for the industrial worker and recreational user scenarios, with 50 percent of the total background area assumed to be inaccessible soil and 50 percent of the total background area assumed to be accessible soil.

[c] Inaccessible soil dose and risk calculations for all properties under the future scenario, except for the levee properties (DT-2, DT-9 Levee, and DT-15), assume no ground cover. Roadway areas are all considered to be inaccessible soil areas.

[d] Accessible soil dose and risk were calculated under the assumption of no ground cover.

[e] Property-wide dose and risk are calculated as weighted averages of inaccessible and accessible soil dose and risk.

[f] Inaccessible soil dose and risk for levee properties (DT-2, DT-9 Levee, and DT-15) were calculated by assuming a 1-meter thick soil cover is in place, and this assumption remains the same for both current and future scenarios, as the levee will remain in place.

NA - Not applicable.

<BKGD - Indicates that dose or risk is within the range of background.

Table 6-3B. Sitewide and Property-Specific Metals Risk Characterization for Inaccessible Soil and Accessible Soil within the Former Uranium-Ore Processing Area: Future Industrial Worker

Property	Soil Operable Unit	Area (m^2)	Total Property CR [a]	Total Property HI [a]
Background	Inaccessible [b]	--	1.9E-06	0.012
	Accessible [b]	--	1.9E-06	0.012
	Area-Wide [c]	--	1.9E-06	0.012
SLDS (Sitewide)	Inaccessible [b]	381,357	1.7E-05	0.10
	Accessible [b]	776,844	2.6E-06	0.017
	Sitewide [c]	1,158,201	7.2E-06	0.045
Plant 2	Inaccessible [b]	3,563	1.5E-06	0.0094
	Accessible [b]	16,531	2.9E-06	0.020
	Property-Wide [c]	20,094	2.7E-06	0.018
Plant 6	Inaccessible [b]	2,370	1.7E-06	0.011
	Accessible [b]	29,965	2.7E-06	0.017
	Property-Wide [c]	32,335	2.6E-06	0.017

Table 6-3B. Sitewide and Property-Specific Metals Risk Characterization for Inaccessible Soil and Accessible Soil within the Former Uranium-Ore Processing Area: Future Industrial Worker (Continued)

Property	Soil Operable Unit	Area (m^2)	Total Property CR [a]	Total Property HI [a]
DT-10	Inaccessible [b]	20,471	2.9E-05	0.18
	Accessible [b]	85,560	8.3E-06	0.052
	Property-Wide [c]	106,031	1.2E-05	0.076
DT-9 Main Tracks	Inaccessible [b]	36,630	1.4E-06	0.0090
DT-12	Inaccessible [b]	23,009	2.9E-05	0.18
Hall Street	Inaccessible [b]	NA	1.7E-06	0.011
Mallinckrodt Street	Inaccessible [b]	NA	2.6E-06	0.016
Destrehan Street	Inaccessible [b]	NA	3.0E-06	0.019

[a] Incidental ingestion of arsenic was the predominant contributor to all total CRs and HIs.

[b] Inaccessible soil CR and HI calculations for all properties under the future scenario assume no ground cover. Roadway areas are all considered to be inaccessible soil areas.

[c] Property-wide CRs and HIs are calculated as weighted averages of inaccessible and accessible soil CRs and HIs.

Gray shading indicates that the CR or HI exceeds the corresponding background CR or HI. The non-shaded CRs and HIs are within the range of background.

Table 6-4. Combined and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil and Accessible Soil within Properties Encompassing the St. Louis Riverfront Trail: Current/Future Recreational User

Property	Soil Operable Unit	Area (m^2)	Risk with Background	Dose & Risk Above Background [a]	
			Max. CR (unitless)	Dose (mrem/yr)	Max. CR (unitless)
Background [b]	Inaccessible [c]	10,000	NA	0	8.1E-11
	Accessible [d]	10,000	NA	0.4	2.9E-06
	Area-Wide [e]	20,000	NA	0.2	1.5E-06
Industrial/Commercial Vicinity Properties					
Combined Properties with St. Louis Riverfront Trail (DT-2, DT-9 Levee, and DT-15)	Inaccessible [c]	103,089	7.3E-11	0.00001	< BKGD
	Accessible [d]	269,387	2.7E-06	0.02	< BKGD
	Combined Properties [e]	372,476	1.9E-06	0.10	4.3E-07
DT-2	Inaccessible [c]	12,665	7.7E-11	0.00001	< BKGD
	Accessible [d]	77,475	2.8E-06	0.04	< BKGD
	Property-Wide [e]	90,140	2.4E-06	0.2	9.0E-07
DT-9 Levee	Inaccessible [c]	84,920	6.9E-11	0.00001	< BKGD
	Accessible [d]	188,158	2.7E-06	0.02	< BKGD
	Property-Wide [e]	273,078	1.9E-06	0.09	3.9E-07

Table 6-4. Combined and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil and Accessible Soil within Properties Encompassing the St. Louis Riverfront Trail: Current/Future Recreational User (Continued)

Property	Soil Operable Unit	Area (m^2)	Risk with Background	Dose & Risk Above Background [a]	
			Max. CR (unitless)	Dose (mrem/yr)	Max. CR (unitless)
***Industrial/Commercial Vicinity Properties* (Continued)**					
DT-15	Inaccessible [c]	5,505	7.5E-11	0.00001	< BKGD
	Accessible [d]	3,754	1.8E-06	<BKGD	< BKGD
	Property-Wide [e]	9,259	7.2E-07	<BKGD	< BKGD

[a] For the site, dose and risk above background are calculated as the difference between dose and risk with background and background dose and risk. The values reported in the "Background" row, are the actual dose and risk estimated for background used in the calculations of dose and risk above background.

[b] The RESRAD default value of 10,000 m^2 was applied as the assumed area each for inaccessible soil and accessible soil areas for all receptor scenarios. Property-wide background dose and risk calculations for soil assume a total area of 20,000 m^2 for combined inaccessible and accessible soil areas for the industrial worker and recreational user scenarios, with 50 percent of the total background area assumed to be inaccessible soil and 50 percent of the total background area assumed to be accessible soil.

[c] Inaccessible soil dose and risk calculations for levee properties (DT-2, DT-9 Levee, and DT-15) under the combined current/future scenario conservatively assume a minimal soil cover thickness of 1 meter for the levee.

[d] Accessible soil dose and risk were calculated under the assumption of no ground cover.

[e] Property-wide dose and risk are calculated as weighted averages of inaccessible and accessible soil dose and risk.

NA - Not applicable.

<BKGD - Indicates that dose or risk is within the range of background.

Table 6-5A. Sitewide and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil: Current/Future Construction Worker

Property	Risk with Background [a,b]	Dose & Risk Above Background [a]	
	Max. CR (unitless)	Max. Dose (mrem/yr)	Max. CR (unitless)
Background	NA	5.1	3.4E-06
SLDS (Sitewide)	4.2E-06	0.9	8.0E-07
Mallinckrodt Properties			
Plant 1	1.3E-05	15	9.6E-06
Plant 2	3.2E-06	<BKGD	<BKGD
Plant 6	9.7E-06	9.9	6.3E-06
Mallinckrodt Security Gate 49	1.5E-06	<BKGD	<BKGD
Industrial/Commercial Vicinity Properties			
DT-2	4.2E-06	0.9	8.0E-07
DT-4 North	1.8E-05	23	1.5E-05
DT-6	8.0E-06	7.9	4.6E-06
DT-8	2.8E-06	<BKGD	<BKGD
DT-10	4.0E-06	0.9	6.0E-07
DT-15	2.7E-06	<BKGD	<BKGD
DT-29	1.7E-06	<BKGD	<BKGD
DT-34	3.1E-06	<BKGD	<BKGD
South of Angelrodt Property Group	3.0E-06	<BKGD	<BKGD
West of Broadway Property Group	2.5E-06	<BKGD	<BKGD

Table 6-5A. Sitewide and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil: Current/Future Construction Worker (Continued)

Property	Risk with Background [a,b]	Dose & Risk Above Background [a]	
	Max. CR (unitless)	Max. Dose (mrem/yr)	Max. CR (unitless)
Railroad Vicinity Properties			
DT-3	3.6E-06	<BKGD	2.0E-07
DT-9 Levee	2.1E-06	<BKGD	<BKGD
DT-9 Rail Yard	9.3E-06	7.9	5.9E-06
DT-9 Main Line	3.5E-06	<BKGD	1.0E-07
Terminal RR Soil Spoils Area	8.3E-06	6.9	4.9E-06
DT-12	2.5E-06	<BKGD	<BKGD
Roadways			
Angelrodt Street	3.2E-06	<BKGD	<BKGD
Bremen Avenue	4.3E-06	1.9	9.0E-07
Buchanan Street	4.4E-06	1.9	1.0E-06
Destrehan Street	4.2E-06	0.9	8.0E-07
Hall Street	4.4E-06	1.9	1.0E-06
Mallinckrodt Street	2.5E-06	<BKGD	<BKGD
North Second Street	3.3E-06	<BKGD	<BKGD
Salisbury Street	1.9E-06	<BKGD	<BKGD

[a] Dose and risk calculations for all properties assume no ground cover for the construction worker.

[b] For the site, dose and risk above background are calculated as the difference between dose and risk with background and background dose and risk. The values reported in the "Background" row, are the actual dose and risk estimated for background used in the calculations of dose and risk above background.

NA - Not applicable.

<BKGD - Indicates that dose or risk is within the range of background.

Table 6-5B. Sitewide and Property-Specific Metals Risk Characterization for Inaccessible Soil within the Former Uranium-Ore Processing Area: Current/Future Construction Worker

Property	Total Property CR [a]	Total Property HI [a]
Background	4.0E-07	0.063
SLDS (Sitewide)	3.6E-06	0.56
Plant 2	3.2E-07	0.050
Plant 6	3.6E-07	0.057
DT-10	6.2E-06	0.96
DT-9 Main Tracks	3.1E-07	0.048
DT-12	6.3E-06	0.99
Hall Street	3.7E-07	0.058
Mallinckrodt Street	5.6E-07	0.088
Destrehan Street	6.5E-07	0.10

[a] CR and HI calculations for all properties assume no ground cover. Incidental ingestion of arsenic was the predominant contributor to all total CRs and HIs.

Gray shading indicates that the CR or HI exceeds the corresponding background CR or HI. The non-shaded CRs and HIs are within the range of background.

Table 6-6A. Sitewide and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil: Current/Future Utility Worker

Property	Risk with Background [a,b]	Dose & Risk Above Background [a]	
	Max. CR (unitless)	Max. Dose (mrem/yr)	Max. CR (unitless)
Background	NA	0.6	3.7E-07
SLDS (Sitewide)	4.6E-07	0.4	9.0E-08
Mallinckrodt Properties			
Plant 1	1.5E-06	1.4	1.1E-06
Plant 2	3.5E-07	0.4	<BKGD
Plant 6	1.0E-06	1.4	6.3E-07
Mallinckrodt Security Gate 49	1.7E-07	<BKGD	<BKGD
Industrial/Commercial Vicinity Properties			
DT-2	4.7E-07	0.4	1.0E-07
DT-4 North	2.0E-06	2.4	1.6E-06
DT-6	8.9E-07	0.4	5.2E-07
DT-8	3.1E-07	<BKGD	<BKGD
DT-10	4.4E-07	0.4	7.0E-08
DT-15	3.0E-07	<BKGD	<BKGD
DT-29	1.9E-07	<BKGD	<BKGD
DT-34	3.4E-07	<BKGD	<BKGD
South of Angelrodt Property Group	3.3E-07	<BKGD	<BKGD
West of Broadway Property Group	2.8E-07	<BKGD	<BKGD
Railroad Vicinity Properties			
DT-3	4.0E-07	0.4	3.0E-08
DT-9 Levee	2.4E-07	<BKGD	<BKGD
DT-9 Rail Yard	1.0E-06	0.4	6.3E-07
DT-9 Main Line	3.8E-07	0.4	1.0E-08
Terminal RR Soil Spoils Area	9.3E-07	0.4	5.6E-07
DT-12	2.7E-07	<BKGD	<BKGD
Roadways			
Angelrodt Street	3.5E-07	0.4	<BKGD
Bremen Avenue	4.5E-07	0.4	8.0E-08
Buchanan Street	4.8E-07	0.4	1.1E-07
Destrehan Street	4.7E-07	0.4	1.0E-07
Hall Street	4.9E-07	0.4	1.2E-07
Mallinckrodt Street	2.8E-07	<BKGD	<BKGD
Salisbury	2.1E-07	<BKGD	<BKGD
North Second Street	3.7E-07	0.4	0.0E+00

[a] Dose and risk calculations for all properties assume no ground cover for the utility worker.

[b] For the site, dose and risk above background are calculated as the difference between dose and risk with background and background dose and risk. The values reported in the "Background" row, are the actual dose and risk estimated for background used in the calculations of dose and risk above background.

NA - Not applicable.

<BKGD - Indicates that dose or risk is within the range of background.

Table 6-6B. Sitewide and Property-Specific Metals Risk Characterization for Inaccessible Soil within the Former Uranium-Ore Processing Area: Current/Future Utility Worker

Property	Total Property CR [a]	Total Property HI [a]
Background	4.5E-08	0.0070
SLDS (Sitewide)	4.0E-07	0.062
Plant 2	3.6E-08	0.0056
Plant 6	4.0E-08	0.0063
DT-10	6.9E-07	0.11
DT-9 Main Tracks	3.5E-08	0.0054
DT-12	7.1E-07	0.11
Hall Street	4.1E-08	0.0064
Mallinckrodt Street	6.3E-08	0.010
Destrehan Street	7.2E-08	0.011

[a] CR and HI calculations for all properties assume no ground cover. Incidental ingestion of arsenic was the predominant contributor to all total CRs and HIs.

Gray shading indicates that the CR or HI exceeds the corresponding background CR or HI. The non-shaded CRs and HIs are within the range of background.

Table 6-7. Radiological Dose and Risk Characterization for Interior Building Surfaces: Industrial Worker

Property	Building	Dose (mrem/year)	CR
Plant 1	Building 7	0.4	1.2E-06
	Building 26	0.4	1.3E-06
Plant 2	Building 41	0.4	1.2E-06
	Building 508	0.3	1.1E-06
DT-6	Storage Building	0.2	6.2E-07
DT-10	Metal Storage Building	0.3	1.0E-06
	Wood Storage Building	0.2	5.0E-07

Table 6-8. Radiological Dose and Risk Characterization for Exterior Building Surfaces: Maintenance Worker

Property	Building	Dose (mrem/year)	CR
Plant 1	Building 25	0.1	3.2E-07
	Building X	<0.1	1.2E-07
DT-10	Wood Storage Building	0.3	1.2E-06
DT-14	Horizontal Beam between L-Shaped Building & Brick Warehouse	<0.1	1.6E-07

Table 6-9A. Sitewide and Location-Specific Radiological Dose and Risk Characterization for Sewer Sediment: Current/Future Sewer Maintenance Worker

Property	Sewer Sediment Location	Risk with Background	Dose & Risk Above Background [a]	
		Max. CR (unitless)	Max. Dose (mrem/yr)	Max. CR (unitless)
Background	All Background Locations	NA	0.01	9.2E-09
SLDS (Sitewide)	All SLDS Locations	9.1E-09	0	<BKGD
Plant 1	SLD123489	8.4E-09	0	<BKGD
	SLD123490	8.0E-09	0	<BKGD
	SLD123491	1.5E-08	0.01	5.8E-09
	SLD123492	9.1E-09	0	<BKGD
	SLD123493	6.4E-09	0	<BKGD
	SLD123494	1.5E-08	0.01	5.8E-09
	SLD123495	5.2E-09	0	<BKGD
	SLD123496	8.4E-09	0	<BKGD
	SLD123497	1.1E-08	0	1.8E-09
	SLD123498	6.3E-09	0	<BKGD
Plant 2	SLD123503	4.1E-09	0	<BKGD
	SLD123504	6.8E-09	0	<BKGD
	SLD123505	6.4E-09	0	<BKGD
	SLD123740	6.5E-09	0	<BKGD
	SLD123741	5.8E-09	0	<BKGD
	SLD123742	1.1E-09	0	<BKGD
	SLD123743	7.0E-09	0	<BKGD
	SLD123744	7.0E-09	0	<BKGD
	SLD123749	6.1E-09	0	<BKGD
	SLD123750	7.0E-09	0	<BKGD
	SLD123751	6.6E-09	0	<BKGD
Plant 6	SLD123746	1.1E-08	0	1.8E-09
	SLD123747	6.9E-09	0	<BKGD
	SLD123748	7.0E-09	0	<BKGD
Plant 7	SLD123745	8.5E-09	0	<BKGD
DT-11	SLD123488	5.5E-09	0	<BKGD

[a] For the site, dose and risk above background are calculated as the difference between dose and risk with background and background dose and risk. The values reported in the "Background" row, are the actual dose and risk estimated for background used in the calculations of dose and risk above background.

NA - Not applicable.

<BKGD - Indicates that dose or risk is within the range of background.

Table 6-9B. Sitewide and Location-Specific Metals Risk Characterization for Sewer Sediment: Current/Future Sewer Maintenance Worker

Property	Sewer Sediment Location	Total Property CR [a]	Total Property HI [a]
Background	All Background Locations	4.0E-07	0.0029
SLDS (Sitewide)	All SLDS Locations	1.9E-07	0.0012
Plant 1	SLD123489	2.3E-07	0.0014
	SLD123490	3.6E-07	0.0022
	SLD123492	2.0E-07	0.0012
	SLD123493	2.7E-07	0.0017
	SLD123494	1.7E-07	0.0010
	SLD123495	1.1E-07	0.00066
	SLD123496	6.7E-07	0.0042
	SLD123497	8.7E-08	0.00054
	SLD123498	1.1E-07	0.00069
	SLD123503	1.7E-07	0.0011
	SLD123504	1.5E-07	0.00093
	SLD123505	1.7E-07	0.0010
Plant 2	SLD123740	7.5E-08	0.00047
	SLD123742	1.5E-07	0.00096
	SLD123743	6.7E-08	0.00042
	SLD123744	8.3E-08	0.00051
	SLD123749	5.1E-08	0.00032
	SLD123750	1.1E-07	0.00069
Plant 6	SLD123746	7.1E-08	0.00044
	SLD123747	3.9E-08	0.00025
	SLD123748	1.0E-07	0.00064
Plant 7	SLD123745	1.8E-07	0.0011
DT-8	SLD123488	1.5E-07	0.00096

[a] Incidental ingestion of arsenic was the predominant contributor to all total CRs and HIs.

Gray shading indicates that the CR or HI exceeds the corresponding background CR or HI. The non-shaded CRs and HIs are within the range of background.

Table 6-10A. Sitewide and Location-Specific Radiological Dose and Risk Characterization for Soil Adjacent to Sewer Lines: Current/Future Sewer Utility Worker

Property	**Soil Locations Adjacent to Sewers**	**Risk with Background** [a,b]	**Dose & Risk Above Background** [a]	
		Max. CR (unitless)	**Max. Dose (mrem/yr)**	**Max. CR (unitless)**
Background	All Background Locations	NA	0.3	2.6E-07
SLDS (Sitewide)	All SLDS Locations	8.6E-06	11.7	8.3E-06
Plant 1	SLD124538	1.8E-07	<BKGD	<BKGD
	SLD124540	6.0E-07	0.7	3.4E-07
	SLD124542	1.6E-07	<BKGD	<BKGD
	SLD124544	2.6E-07	0.1	0.0E+00
	SLD124546	1.8E-07	<BKGD	<BKGD
	SLD124548	2.1E-07	0	<BKGD
	SLD124550	2.0E-07	0	<BKGD
	SLD124552	1.5E-07	<BKGD	<BKGD
	SLD124554	1.4E-07	<BKGD	<BKGD
	SLD124556	1.6E-07	<BKGD	<BKGD
	SLD124558	1.6E-07	<BKGD	<BKGD
	SLD124560	2.0E-07	0	<BKGD
	SLD124564	1.8E-07	<BKGD	<BKGD
	SLD124566	2.2E-07	0	<BKGD
	SLD124568	1.6E-07	<BKGD	<BKGD
	SLD124570	2.1E-07	0	<BKGD
	SLD125283	2.0E-07	0	<BKGD
	SLD125521	4.2E-07	0.7	1.6E-07
Plant 2	SLD124574	1.9E-07	0	<BKGD
	SLD124576	1.7E-07	<BKGD	<BKGD
	SLD124578	1.5E-07	<BKGD	<BKGD
	SLD124580	4.5E-07	0.7	1.9E-07
	SLD125385	2.5E-07	0	<BKGD
Plant 6	HTZ88929	1.1E-05	15	1.1E-05
	HTZ88930	1.4E-06	2.7	1.1E-06
	SLD127572	6.6E-07	0.7	4.0E-07
Plant 7/DT-12	SLD124586	2.2E-07	0	<BKGD
	SLD131146	7.5E-07	0.7	4.9E-07
	SLD131156	3.0E-07	0.1	4.0E-08
	SLD131166	1.9E-07	0	<BKGD
	SLD131176	3.7E-07	0.7	1.1E-07
	SLD93275	1.9E-04	259	1.9E-04
	SLD93276	5.5E-05	75	5.5E-05
	SLD93277	8.5E-05	115	8.5E-05
DT-2 Levee	SLD120945	2.1E-05	29	2.1E-05
	SLD120946	1.4E-05	20	1.4E-05
	SLD120947	2.2E-05	30	2.2E-05
	SLD120948	9.8E-07	0.7	7.2E-07

Table 6-10A. Sitewide and Location-Specific Radiological Dose and Risk Characterization for Soil Adjacent to Sewer Lines: Current/Future Sewer Utility Worker (Continued)

Property	Soil Locations Adjacent to Sewers	Risk with Background [a,b]	Dose & Risk Above Background [a]	
		Max. CR (unitless)	Max. Dose (mrem/yr)	Max. CR (unitless)
DT-8 and DT-11	SLD124590	2.0E-07	0	<BKGD
	SLD124592	1.1E-07	<BKGD	<BKGD
	SLD124594	1.7E-07	<BKGD	<BKGD

[a] Dose and risk calculations for all properties assume no ground cover for the utility worker.

[b] For the site, dose and risk above background are calculated as the difference between dose and risk with background and background dose and risk. The values reported in the "Background" row, are the actual dose and risk estimated for background used in the calculations of dose and risk above background.

NA - Not applicable.

<BKGD - Indicates that dose or risk is within the range of background.

The CRs and HIs estimated for metals for all sitewide and property-/location-specific receptor scenarios, including the corresponding background CRs and HIs, are presented in Tables 6-3B, 6-5B, 6-6B, 6-9B, 6-10B, and 6-10C. Unlike the radiological dose and risk characterization tables, only CRs and HIs inclusive of background are being presented for metals for consistency with CERCLA methodology, which are then qualitatively compared to background CRs and HIs estimated for the corresponding receptor scenarios. Similar to the radiological doses and CRs, there are numerous instances in which site CRs and HIs are within or less than the ranges of background. Site CRs and HIs for metals that exceed corresponding background are shaded in the tables. All risk calculation spreadsheets are presented in Attachment Q-1 of Appendix Q for metals and in Attachment Q-2 of Appendix Q for lead (i.e., ALM results). All SLDS doses and CRs below corresponding background doses and risks are also noted in the tables.

Table 6-10B. Sitewide and Location-Specific Metals Risk Characterization for Soil Adjacent to Sewer Lines: Current/Future Sewer Utility Worker

Property	Soil Locations Adjacent to Sewers	Total Property CR [a]	Total Property HI [a]
Background	All Background Locations	4.5E-08	0.0072
SLDS (Sitewide)	All SLDS Locations	8.2E-08	0.036
Plant 1	SLD124538	1.9E-08	0.0031
	SLD124540	4.0E-07	0.069
	SLD124542	2.1E-08	0.0033
	SLD124544	4.5E-08	0.0073
	SLD124546	2.6E-07	0.041
	SLD124548	8.9E-08	0.35
	SLD124550	5.6E-08	0.0089
	SLD124552	7.7E-08	0.012
	SLD124554	3.4E-08	0.011
	SLD124556	4.3E-08	0.0079
	SLD124558	6.4E-08	0.010
	SLD124560	9.3E-08	0.016
	SLD124564	2.7E-08	0.0047
	SLD124566	7.3E-08	0.012
	SLD124568	3.4E-08	0.0055
	SLD124570	1.8E-07	0.028
	SLD125283	1.8E-08	0.0029
	SLD125521	1.3E-07	0.027

Table 6-10B. Sitewide and Location-Specific Metals Risk Characterization for Soil Adjacent to Sewer Lines: Current/Future Sewer Utility Worker (Continued)

Property	Soil Locations Adjacent to Sewers	Total Property CR [a]	Total Property HI [a]
Plant 2	SLD124574	3.2E-08	0.0054
	SLD124576	1.1E-08	0.0019
	SLD124578	3.9E-08	0.0062
	SLD125385	7.3E-08	0.012
Plant 6	SLD127572	4.6E-08	0.0074
Plant 7N/DT-12	SLD124586	3.0E-08	0.0081
DT-8 and DT-11	SLD124590	1.7E-08	0.0028
	SLD124592	1.4E-08	0.0023
	SLD124594	3.9E-08	0.0062

[a] CR and HI calculations for all properties assume no ground cover. Incidental ingestion of arsenic was the predominant contributor to all total CRs and HIs.

Gray shading indicates that the CR or HI exceeds the corresponding background CR or HI. The non-shaded CRs and HIs are within the range of background.

Table 6-10C. Sitewide and Location-Specific Risk Characterization for Lead in Soil Adjacent to Sewer Lines: Current/Future Sewer Utility Worker

Property	Soil Locations Adjacent to Sewers	Predicted 95th Percentile PbB Concentration Among Fetuses of Adult Utility Workers (µg/dL) [a]	Probability That Fetal Blood Lead Levels Will Exceed 10 µg/dL [a]
Background	All Background Locations	2.7	0.0051%
SLDS (Sitewide)	All SLDS Locations	2.8	0.0065%
Plant 1	SLD124538	2.4	0.0023%
	SLD124540	3.4	0.027%
	SLD124542	2.4	0.0026%
	SLD124544	2.4	0.0026%
	SLD124546	2.4	0.0023%
	SLD124548	2.6	0.0045%
	SLD124550	2.5	0.0033%
	SLD124552	2.4	0.0023%
	SLD124554	2.4	0.0023%
	SLD124556	2.6	0.0036%
	SLD125283	2.4	0.0022%
	SLD124558	2.4	0.0025%
	SLD124560	2.9	0.009%
	SLD125521	2.9	0.008%
	SLD124564	2.4	0.0022%
	SLD124566	2.4	0.0025%
	SLD124568	2.4	0.0022%
	SLD124570	3.1	0.013%
Plant 2	SLD124574	2.4	0.0022%
	SLD124576	7	2%
	SLD124578	2.4	0.0022%
	SLD125385	2.5	0.0028%

Table 6-10C. Sitewide and Location-Specific Risk Characterization for Lead in Soil Adjacent to Sewer Lines: Current/Future Sewer Utility Worker (Continued)

Property	Soil Locations Adjacent to Sewers	Predicted 95th Percentile PbB Concentration Among Fetuses of Adult Utility Workers (µg/dL) [a]	Probability That Fetal Blood Lead Levels Will Exceed 10 µg/dL [a]
Plant 6	SLD127572	3.3	0.02%
Plant 7N/DT-12	SLD124586	2.6	0.0040%
DT-8 and DT-11	SLD124590	2.4	0.0022%
	SLD124592	2.4	0.0022%
	SLD124594	2.4	0.0022%

[a] ALM calculations assume no ground cover for the sewer utility worker.

Gray shaded values exceed corresponding background levels of 2.9 µg/dl for fetal PbB concentration and a 0.0096% probability of exceeding the fetal PbB target 10 µg/dl. The non-shaded values are within the range of background.

All radiological and metals doses and risks estimated for SLDS background soil and sewer sediment are presented for each receptor scenario in Tables 6-11A and K-11B, respectively, as well as in the aforementioned tables.

Table 6-11A. Receptor-Specific Radiological Dose and Risk Characterization for SLDS Background Soil, Sewer Line Sediment and Soil Adjacent to Sewer Lines

Receptor	ISOU Medium [a]	Total Dose/Risk Max. Dose (mrem/yr)	Total Dose/Risk Max. CR (unitless)
Current Industrial Worker	Inaccessible Soil (Ground Cover Present)	0.4	8.1E-06
	Accessible Soil (Ground Cover Absent)	10	1.8E-04
	Property-Wide [b]	5.2	9.4E-05
Future Industrial Worker	Inaccessible Soil (Ground Cover Absent)	10	1.8E-04
	Accessible Soil (Ground Cover Absent)	10	1.8E-04
	Property-Wide [b]	10.1	1.8E-04
Current/Future Recreational User	Inaccessible (Levee Present as Ground Cover)	0	8.1E-11
	Accessible Soil (Ground Cover Absent)	0.4	2.9E-06
	Property-Wide [b]	0.2	1.5E-06
Current/Future Construction Worker	Inaccessible Soil (Ground Cover Absent) [b]	5	3.4E-06
Current/Future Utility Worker	Inaccessible Soil (Ground Cover Absent) [b]	0.6	3.7E-07
Current/Future Sewer Maintenance Worker	Sediment Inside Sewer Lines [c]	0.01	9.2E-09
Current/Future Utility Worker	Soil Adjacent to Sewer Lines [c]	0.3	2.6E-07

[a] SLDS background soil risks were calculated using the soil BV as the EPC, which is presented in Table 4-1. The soil BV was calculated from SLDS background data presented by USACE (1999a). SLDS background soil risks are being compared to those estimated for inaccessible soil and soil adjacent to sewer line receptor scenarios. Background sewer sediment risks were calculated using the SLDS sediment BV as the EPC, which is presented in Table 4-1. The background sediment data collected during the ISOU RI were used to calculate the BV (see Appendix I). The SLDS background sediment risks are being compared to those estimated for sewer sediment receptor scenarios.

[b] The RESRAD default value of 10,000 m^2 was applied as the assumed area of contamination each for inaccessible soil and accessible soil areas for all receptor scenarios. Property-wide background dose and risk calculations for soil assume a total area of 20,000 m^2 for combined inaccessible and accessible soil areas for the industrial worker and recreational user scenarios, with 50 percent of the total background area assumed to be inaccessible soil and 50 percent of the total background area assumed to be accessible soil.

[c] The area of contamination assumed for background sewer sediment and background soil adjacent to sewers is 180 m^2.

Table 6-11B. Receptor-Specific Metals Risk Characterization for SLDS Background Soil, Sewer Line Sediment and Soil Adjacent to Sewer Lines

Receptor [a]	ISOU Medium [b]	Carcinogenic Risk		Non-Carcinogenic Risk	
		Total Background CR	Risk Driver COPC	Total Background HI	Risk Driver COPC
Future Industrial Worker	Inaccessible Soil (Ground Cover Absent)	1.9E-06	Arsenic	0.012	Arsenic
	Accessible Soil (Ground Cover Absent)	1.9E-06	Arsenic	0.012	Arsenic
	Property-Wide [c]	1.9E-06	Arsenic	0.012	Arsenic
Current/Future Construction Worker	Inaccessible Soil (Ground Cover Absent) [d]	4.0E-07	Arsenic	0.063	Arsenic
Current/Future Utility Worker	Inaccessible Soil (Ground Cover Absent) [d]	4.5E-08	Arsenic	0.0070	Arsenic
Current/Future Sewer Maintenance Worker	Sediment Inside Sewer Lines [d]	4.7E-07	Arsenic	0.0029	Arsenic
Current/Future Utility Worker	Soil Adjacent to Sewer Lines [d]	4.5E-08	Arsenic	0.0072	Arsenic

[a] Background risks are not presented for the current industrial worker and current/future recreational user scenarios because of the determinations of no complete exposure pathways and no metal COPCs, respectively.

[b] SLDS background soil risks were calculated using the soil BV as the EPC, which is presented in Table 4-1. The soil BV was calculated from SLDS background data presented by USACE (1999a). SLDS background soil risks are being compared to those estimated for inaccessible soil and soil adjacent to sewer line receptor scenarios. Background sewer sediment risks were calculated using the SLDS sediment BV as the EPC, which is presented in Table 4-1. The background sediment data collected during the ISOU RI were used to calculate the BV (see Appendix I). The SLDS background sediment risks are being compared to those estimated for sewer sediment receptor scenarios.

[c] For metals risk calculations, unlike radiological dose and risk calculations, assumptions regarding the area of contamination are not necessary, but can be used in the calculation of the property-wide, area-weighted average risk for exposures to combined inaccessible and accessible soils. Therefore, for consistency with the radiological dose and risk calculations, 10,000 m^2 was applied as the assumed area of contamination each for inaccessible soil and accessible soil areas for all receptor scenarios. Property-wide background risk calculations for soil assume a total area of 20,000 m^2 for combined inaccessible and accessible soil areas for the future industrial worker scenario, with 50 percent of the total background area assumed to be inaccessible soil and 50 percent of the total background area assumed to be accessible soil.

[d] Assumptions regarding the area of contamination for background inaccessible soil for current/future construction and utility workers, background sewer sediment for current/future maintenance workers, and background soil adjacent to sewers for current/future utility workers are not applicable to risk calculations for metals.

NA - Calculation of a total background CR or HI and determination of risk driver COPCs is not applicable for the scenario due to incomplete exposure pathways (current industrial worker) or no metals data were collected (current/future recreational user).

For the purpose of discussion, the two industrial/commercial VP groupings (South of Angelrodt and West of Broadway Property groups) are discussed in the following subsections as "properties," along with the individual properties, because the two VP groupings are assessed as single properties. Additionally, all eight roadways are considered to be comprised of only inaccessible soil areas, so combined inaccessible and accessible exposures for the industrial worker are not evaluated.

6.1.2.1 Inaccessible Soil and Combined Inaccessible and Accessible Soil

Property-wide evaluations of soil dose and risk are assessed in the HHRA that assume: (1) current land use configurations in which ground cover is present over most inaccessible soil areas, but is absent from accessible soil areas, and (2) future land use configurations in which ground cover is absent from both inaccessible and accessible soil areas, or has been allowed to degrade to conditions that no longer afford health protection from exposures to the underlying soil. The types of ground cover that exist at the SLDS under current configurations include, but may not be limited to, buildings/structures, RRs, roadways, and pavement.

The distinction between current and future scenarios applies mainly to the industrial worker. Under the current land use scenario, industrial worker evaluations of inaccessible soil assume the presence of existing physical configurations relative to the ground cover, which is present over most inaccessible soil areas (i.e., in the forms of buildings/structures, RRs, roadways, pavement, etc.). The current industrial worker scenario also assumes that ground cover is absent over all accessible soil areas, for consistency with past and ongoing evaluations being conducted to support remedial actions under the 1998 ROD. The future land use scenario assumes that ground cover is absent from both inaccessible and accessible soil areas. In other words, for future exposure scenarios, the HHRA assumes that inaccessible soil has become accessible for industrial worker exposures due to degradation or complete loss of ground cover. Although the presence of ground cover may not eliminate external gamma exposures to radiological COPCs in the underlying inaccessible soil, it likely prevents direct contact exposures to the underlying radiological and metal COPCs by the industrial worker that would otherwise occur via incidental ingestion, dermal contact, and inhalation of dusts. Therefore, the difference between the current and future exposure scenarios for the industrial worker is the level of health protectiveness or non-protectiveness afforded by the presence or absence of ground cover. However, for the current scenario, exposures to all radionuclides, via all pathways, are evaluated using the RESRAD model, even though ground cover is assumed to be present, because RESRAD incorporates a cover erosion rate. On the other hand, calculations of metals exposures do not incorporate cover erosion; therefore, all metals exposure pathways are treated as being incomplete under the current scenario. In the future scenario, in which no ground cover is assumed for inaccessible soil or accessible soil areas, all exposure pathways are assumed to be complete for both radiological and metal COPCs. Several different types of cover materials can exist across any given property (e.g., soil, concrete, and asphalt). For the purposes of conducting sitewide and property-wide evaluations of the current industrial worker in the HHRA, only one type of cover material, soil (1 ft thick), is applied in the RESRAD calculations for the current industrial worker. The assumption of a soil cover is a more health conservative assumption than assuming a more dense cover, such as asphalt and concrete, because it affords the least protection from external gamma exposures. In the FS, the actual existing cover present in each area will be evaluated for health protectiveness in order to support development and evaluations of remedial alternatives.

The recreational user scenario is used to evaluate potential inaccessible soil exposures to users of the St. Louis Riverfront Trail, which traverses the levee along the Mississippi River, through the following properties: DT-2, DT-9 Levee, and DT-15. The inaccessible soils in these areas are beneath the levee and are assumed to remain beneath the levee under current and future scenarios. The levee is assumed to be the only ground cover present at DT-2, DT-9 Levee, and DT-15. A cover depth of 1 m is conservatively assumed for the recreational user, which is less than the shallowest depth of a radiological PRG exceedance. Therefore, both current and future scenarios are the same for the recreational user relative to exposure assumptions. Although the inaccessible soil at the St. Louis Riverfront Trail is beneath the levee, it is conservatively assumed that the recreational users are exposed to radiological COPCs via ingestion, dust inhalation, and external radiation.

The industrial workers and the recreational users are evaluated for inaccessible soil exposures, and then are evaluated again for combined inaccessible/accessible soil exposures. The purpose of the latter evaluation is to assess doses and risks for all soils at the SLDS and for all soils within each of the individual properties. For the sitewide evaluation and for each property evaluation, separate EPCs are calculated for inaccessible and accessible soils. Inaccessible soil dose and risk are determined using the inaccessible soil EPC, and accessible soil dose and risk is determined using the accessible soil EPC. After summing dose and risk across all pathways, the combined inaccessible/accessible soil dose or risk is determined as an area-weighted average of the total inaccessible and total accessible soil doses or risks. Calculation of the combined inaccessible/accessible soil dose and risk as area-weighted averages allows for RESRAD model application of ground cover over inaccessible soil areas and of no ground cover over accessible soil areas when evaluating the current industrial worker and current/future recreational user scenarios. This evaluation would not be possible if area weighting was applied to EPCs rather than doses or risks. For evaluations of industrial worker exposures to metal COPCs in inaccessible soil, only the future scenario is evaluated, because the presence of ground cover in the current scenario results in incomplete exposure pathways.

Construction and utility worker exposures to inaccessible soil always assume the requirement of excavation in which the cover must be removed, thereby facilitating exposures to radiological and metal COPCs under current and future scenarios. Therefore, the exposure assumptions for these receptors are the same under current and future conditions.

The following items summarize the inaccessible soil and combined inaccessible/accessible soil exposure scenarios evaluated in the HHRA. Appendix K tables presenting the EPCs associated with each scenario are identified in parentheses in the following list.

Current Industrial Worker Exposures to Radiological COPCs: Sitewide and Property-Specific Evaluations across All Properties (EPC Table K-2A of Appendix K) include:

- incidental ingestion of inaccessible soil (ground cover present),
- incidental ingestion of accessible soil (ground cover absent),
- inhalation of particulate dust emissions from inaccessible soil (ground cover present),
- inhalation of particulate dust emissions from accessible soil (ground cover absent),
- external gamma exposures from inaccessible soil (ground cover present),
- external gamma exposures from accessible soil (ground cover absent), and
- all exposure routes – combined (area-weighted average) inaccessible soil (ground cover present) and accessible soil (ground cover absent).

Future Industrial Worker Exposures to Radiological and Metal COPCs: Sitewide and Property-Specific Evaluations across All Properties (EPC Tables K-2A and K-2B of Appendix K) include:

- incidental ingestion of inaccessible soil (ground cover absent),
- incidental ingestion of accessible soil (ground cover absent),
- dermal contact with inaccessible soil (ground cover absent) (only metals),
- dermal contact with accessible soil (ground cover absent) (only metals),
- inhalation of particulate dust emissions from inaccessible soil (ground cover absent),
- inhalation of particulate dust emissions from accessible soil (ground cover absent),
- external gamma exposures from inaccessible soil (ground cover absent),
- external gamma exposures from accessible soil (ground cover absent), and
- all exposure routes – combined (area-weighted average) inaccessible soil (ground cover absent) and accessible soil (ground cover absent).

Current/Future Recreational User Exposures to Radiological COPCs: Individual and Combined St. Louis Riverfront Trail Properties (DT-2, the DT-9 Levee, and DT-15) (EPC Table K-2A of Appendix K) include:

- incidental ingestion of inaccessible soil (ground cover [levee] present),
- incidental ingestion of accessible soil (ground cover absent),
- inhalation of particulate dust emissions from inaccessible soil (ground cover [levee] present),
- inhalation of particulate dust emissions from accessible soil (ground cover absent),
- external gamma exposures from inaccessible soil (ground cover [levee] present),
- external gamma exposures from accessible soil (ground cover absent), and
- all exposure routes – combined (area-weighted average) inaccessible soil (ground cover [levee] present) and accessible soil (ground cover absent).

Current/Future Construction Worker Exposures to Radiological and Metal COPCs: Sitewide and Property-Specific Evaluations across All Properties (EPC Tables K-2A and K-2B of Appendix K) include:

- incidental ingestion of inaccessible soil (ground cover absent),
- dermal contact with inaccessible soil (ground cover absent) (only metals),
- inhalation of particulate dust emissions from inaccessible soil (ground cover absent), and
- external gamma exposures from inaccessible soil (ground cover absent).

Current/Future Utility Worker Exposures to Radiological and Metal COPCs: Sitewide and Property-Specific Evaluations across All Properties (EPC Tables K-2A and K-2B of Appendix K) include:

- incidental ingestion of inaccessible soil (ground cover absent),
- dermal contact with inaccessible soil (ground cover absent) (only metals),
- inhalation of particulate dust emissions from inaccessible soil (ground cover absent), and
- external gamma exposures from inaccessible soil (ground cover absent).

Exposure assumptions for these receptors are presented for radiological and metals evaluations in Tables K-6 and K-8, respectively. For consistency with the 1998 ROD (USACE 1998a), the industrial worker is a SLDS plant/VP employee assumed to work indoors 1,600 hours per year (200 days per year) and also performs light excavation/construction work outdoors for an additional 400 hours per year (50 days per year). An additional 125 hours is assumed for the indoor time fraction to account for the possibilities of early arrivals to work, having lunch on-site, and late departures. The construction worker is assumed to be a contractor (i.e., not a SLDS plant/VP employee) who performs one-time, deep excavation and construction activities at the ISOU, at a frequency of 90 days per year over a one-year duration. The utility worker also performs one-time deep excavation and construction activities at the ISOU, but at a frequency of 10 days per year. The recreational user is assumed to use the St. Louis Riverfront Trail along the levee (at DT-2, DT-9 Levee, and DT-15) for walking, jogging, and biking. These exposure scenarios are consistent with the current and anticipated future land use patterns expected for the ISOU. Of the three receptor scenarios, the industrial worker is considered to be the limiting receptor that drives the dose and risk status of each property/area and the need for further evaluation in the CERCLA process.

Summary of Dose and Risk Characterization

Table 6-2 presents the maximum total radiological dose and CR results estimated for all current industrial worker exposures to inaccessible soil and combined inaccessible/accessible soil for the sitewide and 28 individual property-specific scenarios. Radiological dose estimates above background for inaccessible soil and property-wide soil (inaccessible and accessible soil combined) for all sitewide and property-specific scenarios evaluated are less than the target criterion of 25 mrem/yr. When considering inaccessible soil CRs above background, most CRs are within USEPA's target CR range, with those estimated for Plant 2 and DT-34 being less than the target range. Estimates of CRs above background for combined inaccessible and accessible soil are all CRs within USEPA's target range. The current industrial worker was not evaluated for health risks associated with inaccessible soil exposures to metals because of no complete direct contact pathways due to the presence of ground cover.

Tables 6-3A and 6-3B present the maximum total radiological dose and CR results, and the metals CRs and HIs, respectively, estimated for all future industrial worker exposures to inaccessible soil and combined inaccessible/accessible soil for the sitewide and 28 individual property-specific scenarios. The maximum radiological dose estimates above background for future industrial worker exposures to inaccessible soil at Plant 1 (29 mrem/yr) and DT-4 North (45 mrem/yr) exceed the target criterion of 25 mrem/yr. When considering radiological inaccessible soil CRs above background, only the CRs estimated for Plant 1 (5.2E-04), Plant 6 (3.0E-04), DT-4 North (7.9E-04), and DT-6 (2.5E-04) exceed the target CR range. All remaining inaccessible soil CRs above background are within the target CR range. Combined radiological inaccessible and accessible soil CRs above background for Plant 1 (2.5E-04), DT-4 North (4.4E-04), and DT-9 Rail Yard (3.1E-04) exceed the target CR range. The remainder of the combined inaccessible and accessible soil CRs above background are within the target CR range.

For metals, the total CRs for all inaccessible soil scenarios and all combined inaccessible/accessible soil scenarios are within USEPA's target CR range due to future industrial worker ingestion exposures to arsenic. All HI values estimated for all future industrial worker exposures to inaccessible soil, as well as to combined inaccessible and accessible soil, are less than the USEPA's target value of 1.0.

Table 6-4 presents the maximum total radiological dose and CR results, estimated to occur over the 1,000-year evaluation period, for inaccessible soil exposures, as well as for combined inaccessible and accessible soil exposures, to current/future recreational users in the 3 properties that encompass the St. Louis Riverfront Trail (DT-2, DT-9 Levee and DT-15). Maximum radiological dose estimates above background for recreational user exposures to inaccessible soil, as well as to combined inaccessible/accessible soil, do not exceed the target criteria of 25 mrem/yr at any of the 3 properties evaluated, both separately and combined, that contain the St. Louis Riverfront Trail. All maximum CRs above background estimated for inaccessible soil, as well as for the combined inaccessible/accessible soil, are less than the target CR range for all property scenarios. The current/future recreational user was not evaluated for potential health risks associated with metal COPCs, because no metal COPCs were identified in inaccessible or accessible soil at any of the 3 properties containing the St. Louis Riverfront Trail.

Tables 6-5A and 6-5B present the maximum total radiological dose and CR results, and the metals CRs and HIs, respectively, estimated for all current/future industrial worker exposures to inaccessible soil for the sitewide and 28 individual property-specific scenarios. Evaluation of maximum radiological dose above background results in all dose estimates for current/future construction worker exposures to inaccessible soil as being less than the target criterion of 25 mrem/yr for the sitewide scenario and all 28 property-specific scenarios. The maximum radiological CR above background estimated for construction worker exposures results in the following properties being within USEPA's target CR range: Plant 1, Plant 6, DT-4 North, DT-6, DT-9 Rail Yard, Terminal RR Soil Spoils Area, Buchanan Street, and Hall Street. All other CRs are less than the target CR range and/or background. The total CRs above background estimated for construction worker exposures to metals in inaccessible soil are within USEPA's target CR range for DT-10 and DT-12 within the former uranium-ore processing boundary. All other CRs are less than the target CR range and/or background. The predominant contributor to inaccessible soil risk for these properties is ingestion of arsenic. For the non-carcinogenic evaluations, the sitewide HI and all property-specific HIs are less than the target HI of 1.0.

Tables 6-6A and 6-6B present the maximum total radiological dose and CR results, and the metals CRs and HIs, respectively, estimated for all current/future industrial worker exposures to inaccessible soil for the sitewide and 28 individual property-specific scenarios. Maximum radiological dose estimates above background for current/future utility worker exposures to inaccessible soil are all less than the target criteria of 25 mrem/yr. The maximum radiological CRs above background estimated for utility worker exposures are within the USEPA's target range for Plant 1 and DT-4 North, with all remaining sitewide and property-specific scenarios being less than the target CR range and/or background. The total CRs and HIs estimated for all sitewide and property-specific utility worker scenarios within the former uranium-ore processing boundary are less than the USEPA's target CR range and 1.0, respectively, as well as background.

6.1.2.2 Soil on Surfaces of Buildings and Structures

Industrial workers who are working indoors can be exposed to radiological soil COPCs on interior surfaces of buildings/structures. These exposures are assumed to occur 8 hours per day, 250 days per year, for 25 years. During maintenance or renovation/demolition activities involving existing structures, industrial workers could directly contact and become exposed to radiologically contaminated soil on building or structural surfaces. Potential exposures to these surfaces are assumed to occur throughout the duration of a typical maintenance activity, which would likely be a once-in-a-lifetime event for an industrial worker (SLDS plant/VP employee), lasting for 10 days.

EPCs for building and structural surfaces are calculated as the lesser of the 95 percent UCL or maximum gross alpha measurement, and as discussed in Section K2.3.1.2 in Appendix K, converted to the unit of picocuries per square meter (pCi/m^2). Individual radionuclide-specific EPCs were calculated by multiplying the gross alpha value (lesser of the 95 percent UCL and maximum gross alpha) by radionuclide-specific activity fractions for SLDS soil (see Table K-3A of Appendix K), as obtained from the 1993 BRA (DOE 1993).

The HHRA scenarios for evaluating current/future industrial and maintenance worker exposures to radiological COPCs in soil on contaminated interior and exterior building surfaces are summarized below. Appendix K tables presenting the EPCs associated with each scenario are identified in parentheses in the following list.

Current/Future Industrial Worker Exposures to Radiological COPCs on Interior Building/Structural Surfaces (Table K-3B of Appendix K) include:

- incidental ingestion of soil on building/structural surfaces,

- inhalation of particulate dust emissions from building/structural surfaces, and
- external gamma exposures.

Current/Future Industrial (Maintenance) Worker Exposures to Radiological COPCs on Exterior Building/Structural Surfaces (Table K-3C of Appendix K) include:

- incidental ingestion of soil on building/structural surfaces,
- inhalation of particulate dust emissions from building/structural surfaces, and
- external gamma exposures.

Radiological dose and risk for buildings/structures were calculated by entering the surface EPC and the exposure assumptions into the RESRAD-BUILD model. All exposure assumptions used as model inputs are presented in Table K-7.

Summary of Dose and Risk Characterization

Tables 6-7 and 6-8 present the maximum total radiological dose and CR results, estimated to occur over the 1,000-year evaluation period, for industrial worker and maintenance worker exposures to radiological COPCs on interior and exterior surfaces of buildings, respectively. The maximum total doses determined for all interior building surfaces are less than the target value of 25 mrem/yr. The maximum total CRs estimated for interior building surfaces are within USEPA's target CR range at five of the buildings evaluated: Plant 1 Building 7, Plant 1 Building 26, Plant 2 Building 41, Plant 2 Building 508, and DT-10 Metal Storage Building. The maximum total doses determined for all exterior surfaces are less than the target value of 25 mrem/yr. The maximum total CRs estimated for all exterior building surfaces are less than USEPA's target CR range, except for the DT-10 Wood Storage Building, the CR of which is within the target CR range.

6.1.2.3 Sewer Sediment

During infrequent maintenance work on the interiors of manholes and sewer lines (assumed to be 1 day per year over 25 years), the potential exists for ingestion and dermal exposures to radiological and metal COPCs in sewer sediment. Sewer maintenance worker inhalation exposures to sediments are not likely to occur via the generation of particulate emissions during work activities due to the high moisture content that is characteristic of sediment. Exposure to infiltrating ground water could potentially occur but is unlikely and was not assessed during the HHRA. The HHRA scenario for evaluating sewer maintenance worker exposures to metal COPCs in sewer sediment is summarized in the following list.

Current/Future Sewer Maintenance Worker Exposures to Radiological and Metal COPCs in Sewer Sediments (Tables K-4A and K-4B of Appendix K) include:

- incidental ingestion of sewer sediment,
- dermal contact with sewer sediment, and
- external gamma exposures.

Because only one sample was collected from each location, with large distances between individual locations, EPCs are represented by the measured sample concentrations reported for each COPC at each location. Additionally, sitewide EPCs were calculated for each COPC to determine dose and risk estimates for all sampled sewer sediment locations.

All exposure assumptions for radiological and metals exposures for this receptor are presented in Tables K-6 and K-8, respectively.

Summary of Dose and Risk Characterization

Tables 6-9A and 6-9B present the maximum total radiological dose and CR results, and metals CRs and HIs, respectively, estimated to occur over the 1,000-year evaluation period, for current/future sewer maintenance worker exposures to sewer sediment. All maximum total radiological doses and CRs (inclusive of background and above background) estimated for this receptor are less than the target value of 25 mrem/year and USEPA's target CR range, respectively. Arsenic is the only metal COPC identified for sewer sediment. This receptor is evaluated for sitewide sewer sediment exposures to arsenic, as well as for sewer sediment exposures to arsenic at 23 individual manhole/surface drain locations within Plants 1, 2, and 6 and DT-8. All total property CRs and HIs estimated for sewer maintenance worker exposures to arsenic in sediment are below the USEPA's target CR range and 1.0, respectively.

6.1.2.4 Soil Adjacent to Sewer Lines

The exposure scenario used for evaluating soil adjacent to sewer lines assumes that direct contact with this medium can only occur to individuals when excavation is performed (i.e., during removal/replacement of sewer lines). During an excavation scenario, the sewer utility worker is assumed to be the most exposed individual to small localized areas of inaccessible soil. Therefore, the HHRA scenario for evaluating sewer utility worker exposures to radiological and metal COPCs in soil adjacent to sewer lines is summarized in the following list:

Current/Future Sewer Utility Worker Exposures to Radiological and Metal COPCs in Soil Adjacent to Sewer Lines (Tables K-5A and K-5B of Appendix K) include:

- incidental ingestion of soil adjacent to sewer lines,
- dermal contact with soil adjacent to sewer lines,
- inhalation of particulate dust emissions from excavated soil adjacent to sewer lines, and
- external gamma exposures from soil adjacent to sewer lines.

Sitewide EPCs were calculated for each COPC to determine dose and risk estimates for all soil locations sampled adjacent to sewer lines. Additionally, EPCs were determined for radiological COPCs, arsenic and cadmium at each borehole sampling location as the lesser of the 95 percent UCL or the maximum detection for each borehole. Because two or three depth intervals were sampled per soil location, and because 95 percent UCLs cannot be reliably determined for only two or three samples, the EPC for each soil location is represented by the maximum detected concentration at each location. Sitewide EPCs and location-specific EPCs for lead in soil adjacent to sewer lines were calculated as mean concentrations in accordance with USEPA (2003b) methodology for assessing risks to adult workers.

Assumptions and RESRAD model inputs used for evaluating sewer utility worker exposures to radiological and metal COPCs in inaccessible soil adjacent to sewer lines are presented in Tables K-6 and K-8, respectively, of Appendix K. Lead in inaccessible soil adjacent to sewer lines was assessed using the ALM.

Summary of Dose and Risk Characterization

Table 6-10A presents the maximum total radiological dose and CR results, estimated to occur over the 1,000-year evaluation period, for current/future utility worker exposures to radiological COPCs in soil adjacent to sewer lines at Plants 1, 2, and 6, Plant 7N/DT-12, DT-2, and DT-8 and DT-11. Of the sitewide and 40 individual locations evaluated, the maximum total radiological doses above background estimated for the following five locations exceeded the target value of 25 mrem/year:

- Location SLD93275 in Plant 7N/DT-12 (259 mrem/yr),
- Location SLD93276 in Plant 7N/DT-12 (75 mrem/yr),
- Location SLD93277 in Plant 7N/DT-12 (115 mrem/yr),
- Location SLD120945 in DT-2 (29 mrem/yr), and
- Location SLD120947 in DT-2 (30 mrem/yr).

When maximum total CRs above background are considered, the following location exceeds the USEPA's target CR range:

- Location SLD93275 in Plant 7N/DT-12 (1.9E-04).

The following locations are within the USEPA's target CR range when maximum total CRs above background are evaluated:

- sitewide evaluation,
- Location HTZ88929 in Plant 6,
- Location HTZ88930 in Plant 6,
- Location SLD93276 in Plant 7N/DT-12,
- Location SLD93277 in Plant 7N/DT-12,
- Location SLD120945 in DT-2,
- Location SLD120946 in DT-2, and
- Location SLD120947 in DT-2.

Table 6-10B presents the total CRs and HIs estimated for combined arsenic and cadmium exposures for the sitewide scenario, as well as for 27 location-specific scenarios. All total CRs and HIs are less than the USEPA's target CR range and 1.0, respectively.

Table 6-10C presents potential health risks for pregnant utility workers exposed to lead in soil adjacent to sewer lines. Probabilities of less than 5 percent that fetal PbBs will exceed the established target of 10 µg/dL blood are considered to be protective. None of the 27 soil locations adjacent to sewers had a predicted probability that fetal PbBs would exceed the established target of less than 5 percent.

6.2 SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT

A SLERA was conducted for the ISOU that followed the USEPA's approach for the first step of the SLERA process, Problem Formulation, which included:

- Environmental Setting and Contaminants at the Site,
- Contaminant Fate and Transport,
- Ecotoxicity and Potential Receptors, and
- Complete Exposure Pathways.

The findings of a September 10, 2010, site visit were used as the basis in completing the SLERA. These findings are documented in the USEPA's Ecological Checklist in Appendix R, which includes detailed information regarding the environmental setting, potential receptors, contaminant fate and transport, and exposure pathways per USEPA guidance (USEPA 1997b). Based on these findings, there are no complete or significant exposure pathways for ecological receptors at the ISOU. In addition, remedial actions conducted at the SLDS under the 1998 ROD have reduced the likelihood that ISOU media will be impacted by accessible soil contamination. As a result, no further action was recommended from an ecological perspective. The comprehensive version of the SLERA is presented in Section K3.0 of Appendix K.

6.3 SUMMARY

As described previously and detailed in Appendix K, a comprehensive HHRA was completed based on the identification of radiological and metal COPCs in Section 4.0. The purpose of the HHRA is to provide risk and dose estimates and HI values for ISOU media and properties. The following nine receptor scenarios and the associated data sets were evaluated:

- current industrial worker exposures to inaccessible soil and combined inaccessible/ accessible soil;
- future industrial worker exposures to inaccessible soil and combined inaccessible/ accessible soil;
- current/future recreational user exposures to inaccessible soil and combined inaccessible/accessible soil in the levee areas associated with the St. Louis Riverfront Trail;
- current/future construction worker exposures to inaccessible soil;
- current/future utility worker exposures to inaccessible soil;
- current/future industrial worker exposures to interior building surfaces;
- current/future maintenance worker exposures to exterior building surfaces;
- current/future sewer maintenance worker exposures to sewer sediments; and
- current/future sewer utility worker exposures to soil adjacent to sewer lines.

The above scenarios assume (1) current land use configurations in which ground cover is present over most inaccessible soil areas, but is absent from accessible soil areas, and (2) future land use configurations in which ground cover is absent from both inaccessible and accessible soil areas. In other words, for future exposure scenarios, the HHRA assumes that inaccessible soil has become accessible due to degradation or complete loss of ground cover. Each of the above scenarios, except for building/structural surfaces, were evaluated for sitewide dose and risk. Additionally, property-specific evaluations were conducted for inaccessible soil and combined inaccessible/accessible soil, building-specific evaluations were evaluated for soil on interior and exterior building/structural surfaces, and sampling location-specific dose and risk evaluations were conducted for sewer sediment and soil adjacent to sewer lines.

The maximum total radiological doses and risks for all sitewide and property-/location-specific receptor scenarios, including the corresponding maximum total background dose and risk, that occur over the 1,000-year evaluation period, are presented in Tables 6-2, 6-3A, 6-4, 6-5A, 6-6A, 6-7, 6-8, 6-9A, and 6-10A. These tables show dose above background (i.e., background dose is subtracted from the site dose), as well as CRs both with and without background. Radiological doses and CRs estimated for background are presented in Table 6-11A, as well as in the aforementioned dose and CR summary tables. Doses and CRs are presented above background for consistency with the work being conducted under the 1998 SLDS ROD at the same properties being evaluated for ISOU-related doses and CRs.

The CRs and HIs estimated for metals for all sitewide and property-/location-specific receptor scenarios, including the corresponding background CRs and HIs, are presented in Tables 6-3B, 6-5B, 6-6B, 6-9B, 6-10B, and 6-10C. Unlike the radiological dose and risk characterization tables, only CRs and HIs inclusive of background are being presented for metals for consistency with CERCLA methodology, which are then qualitatively compared to background CRs and HIs estimated for the corresponding receptor scenarios. Background CRs and HIs for metals are presented in Table 6-11B, as well as in the aforementioned site CR and HI summary tables.

For the sitewide evaluations in the HHRA, receptor exposures to radiological and/or metal COPCs in the following media result in CRs above background that are within or exceed the USEPA's target CR range: inaccessible soil, combined inaccessible/accessible soil, and soil adjacent to sewer lines. Additionally, the HHRA results indicate that Plant 1 and DT-4 North exhibit radiological doses above background that exceed the target value of 25 mrem/yr. Of the 28 individual properties evaluated for radiological and metal exposures to inaccessible soil and/or combined inaccessible and accessible soil, 23 properties exhibit CRs above background that are within or exceed the USEPA's target CR range. The HHRA also shows that five buildings present at 3 properties (Plant 1, Plant 2, and DT-10) exhibit CRs for interior surfaces that are within the USEPA's target CR range. Only 1 building at DT-10 exhibits a CR for exterior surfaces within the USEPA's target CR range. None of the building surfaces exceed the target dose value. The sitewide evaluation of soil adjacent to sewers and the evaluations of eight individual soil locations adjacent to sewers resulted in exceedances of the target dose and/or resulted in the CRs being within or in exceedance of the target CR range for radiological exposures. All of the metal evaluations of soil adjacent to sewers resulted in all CRs and HIs being less than the target CR range and 1.0, respectively. All of the ALM evaluations of soil adjacent to sewers resulted in health risk due to lead being less than the USEPA's benchmark criterion. Of the metal COPCs evaluated in inaccessible soil (arsenic) and soil adjacent to sewers (arsenic, cadmium, and lead), ingestion of arsenic was the predominant contributor to risk. None of the sewer sediment locations exceed target dose or risk criteria.

Based on the findings from site visit that occurred during the RI, as documented in Appendix R, along with the findings of the SLERA described in Section K3.0 in Appendix K potential impacts to ecological receptors from ISOU media at the SLDS are likely to be insignificant.

7.0 SUMMARY AND CONCLUSIONS

This section summarizes the results and conclusions of the RI. Section 7.1 presents a brief summary of the nature and extent of contamination for the inaccessible soil, buildings and structures, and sewers. Section 7.2 presents a summary of the fate and transport of the COPCs. Section 7.3 presents a summary of the BRA. Section 7.4 presents the conclusions, potential data limitations and recommendations, and RAOs.

7.1 NATURE AND EXTENT OF CONTAMINATION

Information obtained from the RI has been used to evaluate the nature and extent of contamination associated with inaccessible soil areas, buildings and structures, and sewers at the SLDS. The following RI field activities were conducted between May 2009 and August 2010 to evaluate the nature and extent of contamination:

- subsurface soil sampling of inaccessible soil beneath or immediately adjacent to buildings and other permanent structures (including the levee, RRs, and roadways),
- GWSs,
- building and structural radiological surveys,
- sewer sediment sampling of manholes and surface grates, and
- subsurface soil sampling adjacent to sewer lines.

It should be noted that SLDS BVs were not subtracted from the analytical results, but are included in the summary tables to provide a point of reference for data evaluation.

7.1.1 Inaccessible Soil Areas

Inaccessible soil exceeded PRGs throughout the SLDS. All of the radiological PCOCs exhibit at least one PRG exceedance throughout all of SLDS, except for Th-228; while only arsenic results exceed the metals PRGs. Ra-226, Ra-228, and arsenic exceed the PRGs in almost all cases, while U-238 exceeds the PRG in approximately half of the samples. Ra-226, Ra-288, and arsenic exceed the BV at frequencies of approximately 27, 22, and 42 percent, respectively. Table 7-1 presents the number of samples exceeding the BV and the PRG for each PCOC from inaccessible soil throughout the SLDS.

Table 7-1. Number of Inaccessible Soil Samples Exceeding Background and the Preliminary Remediation Goal

PCOC	Number of Samples Collected	Number of Samples Exceeding Background	Number of Samples Exceeding the PRG
Radiological			
Ac-227	4,536	917	40
Pa-231	4,537	244	232
Ra-226	4,541	1,233	4,541
Ra-228	4,541	1,012	4,531
Th-228	4,537	1,353	0
Th-230	4,541	2,070	105
Th-232	4,541	1,035	2
U-235	4,537	2,518	5
U-238	4,541	2,703	2,723

Table 7-1. Number of Inaccessible Soil Samples Exceeding Background and the Preliminary Remediation Goal (Continued)

PCOC	Number of Samples Collected	Number of Samples Exceeding Background	Number of Samples Exceeding the PRG
Metals			
Arsenic	92	39	90
Cadmium	92	49	0
Uranium metal	64	[a]	0

[a] Uranium metal has no BV.

7.1.2 Buildings and Structures

Interior and exterior surface activity measurements above the PRGs were detected at isolated areas on 10 of the 60 buildings and numerous structures surveyed. Table 7-2 presents the buildings and surfaces exceeding the PRGs.

Table 7-2. Structural Surfaces Exceeding the Preliminary Remediation Goals

Structure/Building	Portion of Structure Exceeding the PRG
Plant 1 Building 7	Interior
Plant 1 Building 25	Exterior
Plant 1 Building 26	Interior
Plant 1 Building X	Roof
Plant 2 Building 41	Interior
Plant 2 Building 508	Interior
DT-6 Storage Shed	Interior
DT-10 Metal Storage Shed	Interior
DT-10 Wood Storage Building	Interior, Exterior, and Roof
DT-14 Metal Beam between L-Shaped Building & Brick Warehouse	Exterior

7.1.3 Sewers

The RI sampling results indicate that three of the radiological PCOCs (Ra-226, Ra-228, and U-238) and one metal PCOC (arsenic) exceed their respective PRGs in sewer sediment. Ra-226, Ra-228, and arsenic exceeded the PRGs in almost all cases while only exceeding the BV at frequencies of only 23, 15, and 4 percent, respectively.

In soil samples collected adjacent to the sewers, six of the radiological PCOCs (Ac-227, Pa-231, Ra-226, Ra-228, Th-230, and U-238) and three of the metal PCOCs (arsenic, cadmium, and lead) exceed their respective PRGs. Ra-226, Ra-228, and arsenic exceed the PRGs in almost all samples while only exceeding the BV approximately 11, 26, and 25 percent of the time, respectively.

Table 7-3 presents the number of samples exceeding the BV and the PRG for each PCOC for sewers throughout the SLDS.

Table 7-3. Number of Samples Associated with Sewers Exceeding Background and the Preliminary Remediation Goals

PCOC	Number of Samples Collected	Number of Samples Exceeding Background	Number of Samples Exceeding the PRG
Sewer Sediment			
Radiological			
Ac-227	26	3	0
Pa-231	26	4	0
Ra-226	26	6	26
Ra-228	26	4	26
Th-228	26	9	0
Th-230	26	7	0
Th-232	26	4	0
U-235	26	10	0
U-238	26	9	5
Metals			
Arsenic	23	1	21
Cadmium	23	3	0
Cobalt	23	2	0
Copper	23	6	0
Lead	23	0	0
Manganese	23	1	0
Molybdenum	23	5	0
Nickel	23	21	0
Selenium	23	7	0
Uranium metal	23	12	0
Vanadium	23	1	0
Zinc	23	5	0
Soil Adjacent to Sewers			
Radiological			
Ac-227	160	34	5
Pa-231	160	10	10
Ra-226	160	17	158
Ra-228	160	41	160
Th-228	160	48	0
Th-230	160	29	11
Th-232	160	41	0
U-235	160	77	0
U-238	160	64	66
Metals			
Arsenic	81	20	77
Cadmium	81	30	1
Cobalt	81	40	0
Copper	81	6	0
Lead	81	7	5
Manganese	81	20	0
Molybdenum	81	16	0
Nickel	81	27	0
Selenium	81	67	0
Uranium metal	81	0 [a]	0
Vanadium	81	11	0
Zinc	81	19	0

[a] Uranium metal has no BV.

7.1.4 Identification of Contaminants of Potential Concern

COPCs were conservatively identified on a sitewide basis based on a single exceedance of their risk-based PRG. These COPCs are carried forward into the BRA. Because data comparisons with BVs were conducted only for the purpose of characterization, no COPCs were eliminated from evaluation in the BRA based on results being less than BVs.

The sitewide lists of COPCs for each ISOU medium that were evaluated in the BRA are presented in Table 7-4.

Table 7-4. Contaminants of Potential Concern

Media	Radiological	Metals
Inaccessible Soil	Ac-227, Pa-231, Ra-226, Ra-228, Th-230, Th-232, U-235, U-238	Arsenic
Sewer Sediment	Ra-226, Ra-228, U-238	Arsenic
Soil Adjacent to Sewers	Ac-227, Pa-231, Ra-226, Ra-228, Th-230, U-238	Arsenic, Cadmium, Lead
Structural Surfaces	Ac-227, Pa-231, Ra-226, Ra-228, Th-228, Th-230, Th-232, U-235, U-238	NA

NA = Not applicable.

7.2 SUMMARY OF FATE AND TRANSPORT

Analysis of contaminant fate and transport, along with information regarding the nature and extent of contamination and the physical features of the ISOU provides information that was used to support development of the CSM. The CSM identifies the potentially complete human or environmental exposure pathways that form the basis of the BRA. The CSM for the ISOU is presented schematically in Figures 6-3 and K-3.

The CSM assumes that current and reasonably anticipated future land use for the SLDS is industrial/commercial in an urban setting. Under current land use, exposure pathways are evaluated assuming the current physical configurations that exist relative to the ISOU media (i.e., ground cover in the forms of buildings, RR, roadways, and other permanent structures being present). Under future land use, exposure pathways are evaluated assuming scenarios in which the inaccessible soil areas become accessible due to removal or gross degradation of ground cover. The ISOU CSM identifies the following types of potential exposure pathways assumed for both the current and reasonably anticipated future land use scenarios: (1) complete and potentially significant, (2) potentially complete but insignificant, and (3) incomplete. Complete and potentially significant exposure pathways identified by the CSM are retained for further quantitative evaluations in the BRA. Generally, a complete exposure pathway is comprised of the following elements:

- a contaminant source,
- a release/transport mechanism,
- an exposure medium (or point) where humans could contact the contaminated medium, and
- an exposure route (i.e., ingestion, dermal contact, inhalation, or external radiation).

7.2.1 Potential Sources of Contamination

A source material is defined by the USEPA as “material that includes or contains hazardous substances, pollutants or contaminants that act as a reservoir for migration of contamination to ground water, to surface water, to air, or acts as a source for direct exposure” (USEPA 1991c). For the purposes of the CSM, a source is an environmental medium that has been directly impacted by former MED/AEC operations. The CSM identifies three main categories of potential sources of contamination and exposure within the ISOU: (1) contaminated inaccessible soil, (2) radiologically contaminated particles (i.e., soil) on structural surfaces, and (3) contaminated sewer media. Source media identified for the sewers include sewer sediment and soil adjacent to sewer lines.

The identification of specific properties, buildings/structural surfaces, sewer sediment locations, and soil locations adjacent to sewers associated with source media for evaluation in the BRA was determined by the presence of COPCs within each of the media. Radiological and metal COPCs were determined based on sitewide concentration exceedances of risk-based PRGs by at least one sample per medium. The results of the evaluation of nature and extent of contamination indicate that all inaccessible soil properties that were investigated are considered to be potential source areas of radiological COPCs. Potential sources of metal COPCs within the boundary of the former uranium-ore processing area include Plant 2, Plant 6, and DT-10, DT-9 and DT-12, Hall Street, Mallinckrodt Street, and Destrehan Street. All sewer sediment locations and soil locations adjacent to sewers that were investigated are potential sources of radiological and metal COPCs.

Interior and exterior surfaces of buildings and permanent structures were radiologically surveyed during the RI. Radiological COPCs identified for these surfaces are those associated with accessible soil (i.e., COCs identified in the 1998 ROD) because soil contamination of these surfaces was likely to have originated from accessible soil areas, rather than from inaccessible soil areas. The sources determined by isolated exceedances of the PRGs consist of interior surfaces inside of seven buildings and exterior surface and/or roof areas on four buildings. These sources are presented above in Table 7-2.

7.2.2 Contaminant of Potential Concern Release and Transport Mechanisms

The CSM considers release/transport mechanisms associated with ISOU source media and areas, under both current and assumed future land use scenarios, which assume conditions inclusive and exclusive of ground cover, respectively. Release and transport of COPCs can result in direct and indirect contact exposures. Direct contact exposures occur at the source, whereas indirect contact exposures occur away from the source. Indirect contact exposures to COPCs identified in all ISOU source media require COPC release from those media and the availability of transport mechanisms that make it possible for the migration of COPCs from the source to some downgradient/downwind receptor location or medium. Release mechanisms (e.g., leaching, particulate dust emissions, leakage from sewer lines) are those environmental processes that cause some or all of the COPC concentrations to become unbound or mobilized from a source. Once released from a source, transport mechanisms provide a pathway (e.g., air transport, vertical infiltration/percolation, horizontal ground-water transport, etc.) by which COPCs can migrate in or through an environmental medium (i.e., "transport medium"). The potentially significant transport pathways and associated release mechanisms are summarized below:

- Air Transport Pathways
    - particulate emissions from inaccessible soil areas with little or no vegetative cover or ground cover (i.e., release by wind erosion or agitation of soil) followed by wind dispersion and air transport;
    - Rn-222 emissions from inaccessible soil areas to indoor air;
    - particulate emissions from structural surfaces in the forms of dust potentially generated by construction/renovation activities followed by wind dispersion and air transport; and

  - particulate emissions from structural surfaces due to oxidation of metal surfaces followed by wind dispersion and air transport.

- Subsurface Water Transport Pathways
  - vertical infiltration/percolation of soil contaminants to deeper soil and ground water, predominantly in areas with no consolidated ground cover;
  - water/sediment leakage from inside of sewer lines to the adjacent soil; and
  - horizontal ground-water migration to downgradient locations/media (Mississippi River surface water and sediment).

- Surface Runoff Transport Pathways
  - surface runoff to downgradient locations/media (Mississippi River surface water and sediment); and
  - water runoff of soil and oxidized particles from building/structural surfaces.

7.2.3 Characteristics of Contaminants of Potential Concern

Persistence and mobility are two key terms used to describe the movement and partitioning of chemicals in environmental media (i.e., air, surface water, ground water, soil, and sediment) and their likelihood of reaching an exposure point. Persistence is a measure of how long a compound will exist in air, water, or soil before it degrades or transforms, either chemically or biologically, into some other chemical. Mobility is defined as the potential for a chemical to migrate through a medium.

Based on an evaluation of COPC-specific and site-specific characteristics, all radiological and metal COPCs are expected to persist in ISOU media. An examination of the ranges of K_d values estimated for the COPCs indicate that cadmium, lead, radium, thorium, and uranium are expected to be relatively immobile in ISOU media. On the other hand, the K_d values estimated for arsenic indicate a higher potential for mobility. However, the presence of consolidated ground cover over most of the inaccessible soil areas minimizes the potential for environmental release and transport of arsenic, as well as all COPCs identified in inaccessible soil and soil adjacent to sewers.

7.3 SUMMARY OF FINDINGS OF THE BASELINE RISK ASSESSMENT

As summarized in Section 6.0, a BRA was performed to estimate current and potential future dose and risks to human and ecological receptors that could result from exposures to radiological and metals COPCs in inaccessible soil and sewer sediment and that were not addressed in the 1998 ROD (USACE 1998a). The comprehensive BRA is presented in Appendix K. The BRA consists primarily of two components: a quantitative HHRA and a SLERA, the summaries and findings of which are discussed in Sections 7.3.1 and 7.3.2, respectively.

7.3.1 Human Health Risk Assessment

A HHRA was completed based on the identification of radiological and metal COPCs in Section 4.0. The purpose of the HHRA is to provide risk and dose estimates and HI values for ISOU media and properties. The following nine receptor scenarios and the associated data sets were evaluated:

- current industrial worker exposures to inaccessible soil and combined inaccessible/ accessible soil,

- future industrial worker exposures to inaccessible soil and combined inaccessible/ accessible soil,
- current/future recreational user exposures to inaccessible soil and combined inaccessible/ accessible soil in the levee areas associated with the St. Louis Riverfront Trail,
- current/future construction worker exposures to inaccessible soil,
- current/future utility worker exposures to inaccessible soil,
- current/future industrial worker exposures to interior building surfaces,
- current/future maintenance worker exposures to exterior building surfaces,
- current/future sewer maintenance worker exposures to sewer sediment, and
- current/future sewer utility worker exposures to soil adjacent to sewer lines.

The above scenarios assume (1) current land use configurations in which ground cover is present over most inaccessible soil areas, but is absent from accessible soil areas, and (2) future land use configurations in which ground cover is absent from both inaccessible and accessible soil areas. In other words, for future exposure scenarios, the HHRA assumes that inaccessible soil has become accessible due to degradation or complete loss of ground cover. Each of the previous scenarios, except for building/structural surfaces, were evaluated for sitewide dose and risk. Additionally, property-specific evaluations were conducted for inaccessible soil and combined inaccessible/accessible soil; building-specific evaluations were evaluated for soil on interior and exterior building/structural surfaces; and sampling location-specific dose and risk evaluations were conducted for sewer sediment and soil adjacent to sewer lines.

Dose and risk characterization summaries for inaccessible soil and combined inaccessible/ accessible soil exposures to radiological and metal COPCs are presented in Tables 7-5 and 7-6, respectively. Radiological dose and risk characterization summaries for soil on interior and exterior building/structural surfaces are presented in Table 7-7. The radiological dose and risk characterization summary for soil adjacent to sewers is presented in Table 7-8. The doses and CRs presented in the aforementioned tables are those doses greater than 25 mrem/yr and CRs above background that are within or exceed the USEPA's target CR range of 1.0E-6 to 1.0E-4. HIs estimated for metals are not summarized in the tables because all HIs were below the target value of 1.0 for all evaluated scenarios. Also, the summary tables do not include a radiological dose and CR summary for sewer sediment, nor do they include a metals CR and HI summary for sewer sediment because all doses, CRs and HIs are less than target criteria.

7.3.2 Screening Level Ecological Risk Assessment

Based on the findings from a site visit that occurred during the RI, as documented in the USEPA's Ecological Checklist presented in Appendix R, along with the findings of the SLERA described in Section K3.0 in Appendix K, potential impacts to ecological receptors from ISOU media at the SLDS are likely to be insignificant. Both the Ecological Checklist and the SLERA were conducted in accordance with USACE guidance (USACE 2010b) and USEPA guidance (USEPA 1997b).

Table 7-5. Radiological Doses and Risks Above Background for Inaccessible and Accessible Soil

Property	**Soil Operable Unit**	**Current Industrial Worker** [a]		**Future Industrial Worker** [b]		**Current/Future Recreational User** [c]		**Current/Future Construction Worker** [d]		**Current/Future Utility Worker** [d]	
		Dose (mrem/yr)	**CR (unitless)**	**Dose (mrem/yr)**	**CR (unitless)**	**Dose (mrem/yr)**	**CR (unitless)**	**Dose (mrem/yr)**	**CR (unitless)**	**Dose (mrem/yr)**	**CR (unitless)**
SLDS (Sitewide)	Inaccessible	---	3.1E-06	---	4.3E-05	NA	NA	---	---	---	---
	Accessible	---	---	---	---	NA	NA	NA	NA	NA	NA
	Sitewide	---	2.1E-05	---	4.4E-06	NA	NA	NA	NA	NA	NA
Mallinckrodt Properties											
Plant 1	Inaccessible	---	2.0E-05	29	5.2E-04	NA	NA	---	9.6E-06	---	1.1E-06
	Accessible	---	8.9E-06	---	8.9E-06	NA	NA	NA	NA	NA	NA
	Property-Wide	---	1.9E-05	---	2.5E-04	NA	NA	NA	NA	NA	NA
Plant 2	Inaccessible	---	---	---	---	NA	NA	---	---	---	---
	Accessible	---	---	---	---	NA	NA	NA	NA	NA	NA
	Property-Wide	---	5.1E-05	---	---	NA	NA	NA	NA	NA	NA
Plant 6	Inaccessible	---	7.4E-06	---	3.0E-04	NA	NA	---	6.3E-06	---	---
	Accessible	---	7.7E-06	---	7.7E-06	NA	NA	NA	NA	NA	NA
	Property-Wide	---	8.1E-05	---	2.9E-05	NA	NA	NA	NA	NA	NA
Mallinckrodt Security Gate 49	Inaccessible	---	---	---	---	NA	NA	---	---	---	---
	Accessible	---	---	---	---	NA	NA	NA	NA	NA	NA
	Property-Wide	---	5.8E-05	---	---	NA	NA	NA	NA	NA	NA
Industrial/Commercial Vicinity Properties											
DT-2	Inaccessible	---	---	---	---	---	---	---	---	---	---
	Accessible	---	---	---	---	---	---	NA	NA	NA	NA
	Property-Wide	---	5.4E-05	---	---	---	---	NA	NA	NA	NA
DT-4 North	Inaccessible	---	4.4E-05	45	7.9E-04	NA	NA	---	1.5E-05	---	1.6E-06
	Accessible	---	3.4E-06	---	3.4E-06	NA	NA	NA	NA	NA	NA
	Property-Wide	---	1.5E-05	25	4.4E-04	NA	NA	NA	NA	NA	NA
DT-6	Inaccessible	---	1.5E-05	---	2.5E-04	NA	NA	---	4.6E-06	---	---
	Accessible	---	---	---	---	NA	NA	NA	NA	NA	NA
	Property-Wide	---	2.5E-05	---	7.9E-05	NA	NA	NA	NA	NA	NA
DT-8	Inaccessible	---	---	---	---	NA	NA	---	---	---	---
	Accessible	---	---	---	---	NA	NA	NA	NA	NA	NA
	Property-Wide	---	5.3E-05	---	---	NA	NA	NA	NA	NA	NA
DT-10	Inaccessible	---	1.6E-06	---	3.2E-05	NA	NA	---	---	---	---
	Accessible	---	---	---	---	NA	NA	NA	NA	NA	NA
	Property-Wide	---	7.5E-05	---	2.0E-06	NA	NA	NA	NA	NA	NA

Table 7-5. Radiological Doses and Risks Above Background for Inaccessible and Accessible Soil (Continued)

Property	Soil Operable Unit	Current Industrial Worker [a]		Future Industrial Worker [b]		Current/Future Recreational User [c]		Current/Future Construction Worker [d]		Current/Future Utility Worker [d]	
		Dose (mrem/yr)	CR (unitless)	Dose (mrem/yr)	CR (unitless)	Dose (mrem/yr)	CR (unitless)	Dose (mrem/yr)	CR (unitless)	Dose (mrem/yr)	CR (unitless)
DT-29	Inaccessible	---	---	---	---	NA	NA	---	---	---	---
	Accessible	---	3.3E-06	---	3.3E-06	NA	NA	NA	NA	NA	NA
	Property-Wide	---	3.9E-05	---	---	NA	NA	NA	NA	NA	NA
South of Angelrodt Property Group	Inaccessible	---	---	---	---	NA	NA	---	---	---	---
	Accessible	---	---	---	---	NA	NA	NA	NA	---	NA
	Combined Properties	---	3.3E-05	---	---	NA	NA	NA	NA	NA	NA
Railroad Vicinity Properties											
DT-3	Inaccessible	---	1.4E-06	---	9.0E-06	NA	NA	---	---	---	---
	Accessible	---	---	---	---	NA	NA	NA	NA	NA	NA
	Property-Wide	---	3.1E-05	---	2.8E-06	NA	NA	NA	NA	NA	NA
DT-9 Levee	Inaccessible	---	---	---	---	---	---	---	---	---	---
	Accessible	---	---	---	---	---	---	NA	NA	NA	NA
	Property-Wide	---	2.1E-05	---	---	---	---	NA	NA	NA	NA
DT-9 Main Tracks	Inaccessible	---	1.7E-06	---	6.0E-06	NA	NA	---	---	---	---
	Accessible	---	---	---	---	NA	NA	NA	NA	NA	NA
	Property-Wide	---	---	---	---	NA	NA	NA	NA	NA	NA
DT-9 Rail Yard	Inaccessible	---	1.2E-05	---	3.1E-04	NA	NA	---	5.9E-06	---	---
	Accessible	---	6.4E-06	---	6.4E-06	NA	NA	NA	NA	NA	NA
	Property-Wide	---	6.6E-05	---	5.4E-05	NA	NA	NA	NA	NA	NA
Terminal RR Soil Spoils Area	Inaccessible	---	1.6E-05	---	2.6E-04	NA	NA	---	4.9E-06	---	---
	Accessible	---	---	---	---	NA	NA	NA	NA	NA	NA
	Property-Wide	---	5.1E-05	---	2.2E-05	NA	NA	NA	NA	NA	NA
***Roadways* [e]**											
Bremen Avenue	Inaccessible	---	3.2E-06	---	4.2E-05	NA	NA	---	---	---	---
Buchanan Street	Inaccessible	---	3.6E-06	---	4.8E-05	NA	NA	---	1.0E-06	---	---
Destrehan Street	Inaccessible	---	5.3E-06	---	4.7E-05	NA	NA	---	---	---	---
Hall Street	Inaccessible	---	2.7E-06	---	5.5E-05	NA	NA	---	1.0E-06	---	---
North Second Street	Inaccessible	---	1.2E-06	---	---	NA	NA	---	---	---	---

[a] Current industrial worker scenario assumes a soil cover in inaccessible soil areas that is 0.3048 meters thick and no ground cover in accessible soil areas.

[b] Future industrial worker scenario assumes no ground cover in inaccessible or accessible soil areas.

[c] Current/future recreational user scenario assumes the levee is present as ground cover in inaccessible soil areas at a minimum thickness of 1 m and that there is no ground cover in accessible soil areas.

[d] Current/future construction and utility worker scenarios assume no ground cover in inaccessible soil areas. Accessible soil areas are not evaluated for these receptor scenarios as they are evaluated under the more limiting industrial worker scenarios and the the recreational user scenarios.

[e] No accessible soil areas exist at roadways.

--- Indicates that dose or risk is within the range of background and/or less than the target dose of 25 mrem/yr and/or less than the CERCLA risk range.

NA - Calculation of dose or risk is not applicable.

Table 7-6. Cancer Risks for Metals Above Background for Inaccessible and Accessible Soil

Property	Soil Operable Unit	Future Industrial Worker [a]	Current/Future Construction Worker	Current/Future Utility Worker
		CR [a] (unitless)	CR [a] (unitless)	CR [a] (unitless)
SLDS (Sitewide)	Inaccessible	1.7E-05	3.6E-06	---
	Accessible	2.6E-06	NA	NA
	Sitewide	7.2E-06	NA	NA
Plant 2	Inaccessible	---	---	---
	Accessible	2.9E-06	NA	NA
	Property-Wide	2.7E-06	NA	NA
Plant 6	Inaccessible	---	---	---
	Accessible	2.7E-06	NA	NA
	Property-Wide	2.6E-06	NA	NA
DT-10	Inaccessible	2.9E-05	6.2E-06	---
	Accessible	8.3E-06	NA	NA
	Property-Wide	1.2E-05	NA	NA
DT-12 [b]	Inaccessible	2.9E-05	6.3E-06	---
Mallinckrodt Street [b]	Inaccessible	2.6E-06	---	---
Destrehan Street [b]	Inaccessible	3.0E-06	---	---

[a] Incidental ingestion of arsenic was the predominant contributor to all total CRs. All HIs for all receptor scenarios are less than 1.0.

[b] Accessible soil metals data are not available for calculating CRs for the property indicated.

--- Indicates that CR is within the range of background and/or less than the CERCLA target risk range.

NA - Calculation of dose or risk is not applicable.

Table 7-7. Radiological Dose and Risk Characterization for Building Surfaces

Property	Building	Interior Surfaces [a]		Exterior Surfaces [b]	
		Dose (mrem/yr)	CR (unitless)	Dose (mrem/yr)	CR (unitless)
Plant 1	Building 7	---	1.2E-06	NA	NA
	Building 26	---	1.3E-06	NA	NA
Plant 2	Building 41	---	1.2E-06	NA	NA
	Building 508	---	1.1E-06	NA	NA
DT-10	Metal Storage Building	---	1.0E-06	NA	NA
	Wood Storage Building	---	---	---	1.2E-06

[a] An industrial worker was evaluated for interior surface exposures.

[b] A maintenance worker was evaluated for exterior surface exposures.

--- Indicates that dose or risk is less than the target does of 25 mrem/yr or the CERCLA risk range.

NA - Calculation not applicable due to no PRG exceedances.

Table 7-8. Radiological Doses and Risks Above Background for Soil Adjacent to Sewer Lines

Property	Soil Locations Adjacent to Sewers	Current/Future Sewer Utility Worker	
		Dose (mrem/yr)	CR (unitless)
SLDS (Sitewide)	All SLDS Locations	---	8.3E-06
Plant 6	HTZ88929	---	1.1E-05
	HTZ88930	---	1.1E-06
Plant 7/DT-12	SLD93275	259	1.9E-04
	SLD93276	75	5.5E-05
	SLD93277	115	8.5E-05
DT-2 Levee	SLD120945	29	2.1E-05
	SLD120946	---	1.4E-05
	SLD120947	30	2.2E-05

--- Indicates that dose or risk is within the range of background and/or less than the target dose of 25 mrem/yr.

7.4 CONCLUSIONS

The BRA assessed the dose and risk status of each property, based on evaluations of combined accessible soil and ISOU data sets. The information provided in this RI/BRA forms the basis for identifying and evaluating potential remedial alternatives in the FS to address those areas having COPC concentrations exceeding the CERCLA risk range. Based on the results of the RI/BRA, radiological and metals COCs are retained for further evaluation in the FS. The COCs driving risk in inaccessible soil include: Ac-227, Pa-231, Ra-226, Ra-228, Th-230, Th-232, U-235, U-238, and arsenic. There are no COCs for soil on building/structural surfaces or for sewer sediment. The following radiological COCs were identified for soil adjacent to sewer lines at Plant7/DT-12 (per sewer excavation data at locations SLD93275 and SLD93277): Ac-227, Pa-231, Ra-226, Ra-228, Th-230, and U-238. There are no metal COCs identified for soil adjacent to sewer lines.

7.4.1 Data Limitations and Recommendations for Future Work

It is recommended that the ISOU proceed to the FS phase of the CERCLA process. During the RI, the extent and depth of contaminants were examined. However, some limited additional sampling of sewers, inaccessible soils, and buildings may be necessary to support development of alternatives and designs. Additional radiological surveys/sampling may be necessary to fulfill requirements for release like those found in the *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)* (DOD 2000) (hereafter referred to as MARSSIM). Radon monitoring at Plant 1 Building 26 and DT-4 North-South Storage Building is in progress, and results will be available prior to finalization of the FS. Risk and dose due to Rn-222 exposure will be determined and will also be presented in the FS. Some additional monitoring may be conducted and data may be reported as part of the ongoing environmental monitoring program for the SLDS until remedial actions are completed under the 1998 ROD.

7.4.2 Preliminary Remedial Action Objectives

Following completion of the RI/BRA, an FS will be conducted that will focus on those ISOU media and areas having COPC concentrations exceeding radiological-specific ARARs, the CERCLA risk range, or a HI of 1.0. Generally, as part of the RI/FS process, RAOs are developed to specify the requirements that remedial alternatives must fulfill to protect human health and the environment. Preliminary RAOs have been developed for the ISOU and are presented in the following list.

- Prevent exposure to inaccessible soil beneath buildings or other structures contaminated with radiological and chemical specific ARARs, or result in an excess lifetime CR greater than the acceptable risk range.
- Prevent exposure to inaccessible soil adjacent to sewer lines contaminated with MED/AEC-related COCs at concentrations that exceed radiological and chemical specific ARARs, or result in an excess lifetime CR greater than the acceptable risk range.
- Prevent exposures to COCs in ground water originating from inaccessible soil.
- Prevent exposures to radon emanating from inaccessible soils above ARARs and risk-based criteria.

These preliminary RAOs are subject to modifications and refinement as the ISOU progresses through the FS process. Preliminary RAOs are not presented for ISOU media not exceeding the target dose criterion, CERCLA risk range, or HI of 1.0 (i.e., building surfaces and sewer sediment). Additionally, no RAO is necessary for addressing lead in soil adjacent to sewers because ALM evaluations indicate no exceedance of USEPA's target risk criterion for lead.