FINAL

REMEDIAL INVESTIGATION AND BASELINE RISK ASSESSMENT REPORT FOR THE INACCESSIBLE SOIL OPERABLE UNIT AT THE ST. LOUIS DOWNTOWN SITE

ST. LOUIS, MISSOURI

SEPTEMBER 20, 2012

U.S. Army Corps of Engineers
St. Louis District Office
Formerly Utilized Sites Remedial Action Program

FINAL

REMEDIAL INVESTIGATION AND BASELINE RISK ASSESSMENT REPORT FOR THE INACCESSIBLE SOIL OPERABLE UNIT AT THE ST. LOUIS DOWNTOWN SITE

ST. LOUIS, MISSOURI

SEPTEMBER 20, 2012

prepared by:
U.S. Army Corps of Engineers, St. Louis District Office
Formerly Utilized Sites Remedial Action Program

with assistance from:
Science Applications International Corporation
under Contract No. W912P9-12-D-0506, Delivery Order 0001

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF APPENDICES

BACK COVER

LIST OF ACRONYMS AND ABBREVIATIONS

ε_i	instrument efficiency
ε_s	surface efficiency
µg	microgram(s)
µg Pb/dL	micrograms lead per deciliter
µg/dL	micrograms per deciliter
µg/kg-day	microgram(s) of chemical per kilogram body weight per day
µg/L	microgram(s) per Liter
$\mu g/m^3$	microgram(s) per cubic meter
95/95 UTL	95 percent UCL at 95 percent sample coverage
1993 BRA	*Baseline Risk Assessment for Exposure to Contaminants at the St. Louis Site*
1998 FS	*Feasibility Study for the St. Louis Downtown Site*
1998 ROD	*Record of Decision for the St. Louis Downtown Site*
Ac	actinium
AEC	Atomic Energy Commission
ALM	Adult Lead Model
amsl	above mean sea level
ANL	Argonne National Laboratory
ANSI	American National Standards Institute
ARAR	applicable or relevant and appropriate requirement
As^{+3}	arsenite
As^{+5}	arsenate
AsS	arsenic sulfide
ATD	alpha track detector
bgs	below ground surface
BNSF	Burlington-Northern Santa Fe
BRA	baseline risk assessment
BV	background value
C-T	Columbium-Tantalum
Cd^{2+}	cadmium ion
CdS	cadmium sulfide
CDC	Centers for Disease Control and Prevention
CDI	chronic daily intake
CEC	cation exchange capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
cm	centimeter
cm^2	square centimeter(s)
cm^2-event	square centimeter(s) per event
COC	contaminant of concern
COPC	contaminant of potential concern
cpm	counts per minute
cpm/dpm	counts per minute per disintegrations per minute
CR	cancer risk
CSF	cancer slope factor
CSM	conceptual site model
CSR	*Code of State Regulations*

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

DAD	dermally absorbed dose
DCGL	derived concentration guideline level
dL	deciliter
DOD	U.S. Department of Defense
DOD QSM	*Department of Defense Quality Systems Manual for Environmental Laboratories*
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
dpm	disintegrations per minute
dpm/100 cm^2	disintegrations per minute per 100 square centimeters
DQO	data quality objective
DSR	dose-to-source ratio
EC	exposure concentration
ERAGS	*Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments*
EPC	exposure point concentration
FeS	iron sulfide
FFA	Federal Facility Agreement
FGR	Federal Guidance Report
FOD	frequency of detection
FS	feasibility study
FSS	final status survey
FSSE	final status survey evaluation
FSSP	final status survey plan
FSSP for Structures	*Final Status Survey Plan for Structures and Other Consolidated Material Left in Place at the St. Louis Site*
ft	foot/feet
FUSRAP	Formerly Utilized Sites Remedial Action Program
g	gram(s)
GI	gastrointestinal
GIABS	gastrointestinal absorption fractions
GIS	geographic information system
GOF	goodness of fit
GPS	global positioning system
GSD_i	geometric standard deviation of blood level
GWS	gamma walkover survey
HHRA	human health risk assessment
HI	hazard index
HISS	Hazelwood Interim Storage Site
HQ	hazard quotient
hr	hour
HU	hydrostratigraphic unit
ICP	Inductively Coupled Plasma
IDOT	Illinois Department of Transportation
IDW	investigation-derived waste
IRIS	Integrated Risk Information System
ISOU	Inaccessible Soil Operable Unit

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

IUR	inhalation unit risk
K	Henry's Law constant
K_d	soil-water partitioning coefficient
K_{oc}	organic carbon partitioning coefficient
K_{ow}	octanol-water partitioning coefficient
keV	kiloelectron Volt(s)
kg	kilogram(s)
kg/m^3	kilogram(s) per cubic meter
kg/mg	kilogram(s) per milligram
L	Liter(s)
L/kg	Liter(s) per kilogram
LCS	laboratory control sample
LLC	Limited Liability Company
LOAEL	lowest observed adverse effects level
m	meter
m^2	square meter(s)
m^3	cubic meter(s)
MARSSIM	*Multi-Agency Radiation Survey and Site Investigation Manual*
MDA	minimum detectable activity
MDC	minimum detectable concentration
MDCR	minimum detectable count rate
MDL	method detection limit
MDNR	Missouri Department of Natural Resources
MED	Manhattan Engineer District
meq	milliequivalent(s)
mg	milligram(s)
mg/cm^2-event	milligram(s) per square centimeters per event
mg/kg	milligram(s) per kilogram
mg/kg-day	milligram(s) per kilogram body weight per day
mg/L	milligram(s) per liter
mg/m^3	milligram(s) per cubic meter
mL	milliliter(s)
mL/g	milliliter(s) per gram
MoDOT	Missouri Department of Transportation
MoECA	Missouri Environmental Covenants Act
MoRBCA	Missouri Risk Based Corrective Action
mrem/yr	millirem per year
MSD	Metropolitan St. Louis Sewer District
NAD	normalized absolute difference
NaI	sodium-iodide
NAPL	non-aqueous phase liquid
NC	North St. Louis County
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NHANES III	Third National Health and Nutrition Examination Survey
NOAEL	no observed adverse effects level
NORM	naturally occurring radioactive material
NRC	U.S. Nuclear Regulatory Commission

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

NRHP	National Register of Historic Places
NUREG	U.S. Nuclear Regulatory Commission Regulation
ORP	oxidation-reduction potential
ORNL	Oak Ridge National Laboratory
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
Pa	protactinium
PAH	polycyclic aromatic hydrocarbons
Pb	lead
Pb^{2+}	lead ion
PbB	blood lead concentration
pCi	picocurie(s)
pCi/g	picocuries per gram
pCi/L	picocuries per liter
pCi/m^2	picocuries per square meter
PCOC	potential contaminant of concern
PDI	pre-design investigation
PE	Performance Evaluation
PID	photoionization detector
PP	Proposed Plan
PRAR	post-remedial action report
PRG	preliminary remediation goal
QA	quality assurance
QAPP	*Quality Assurance Project Plan for the St. Louis Airport and Downtown Sites*
QC	quality control
QCSR	Quality Control Summary Report
Ra	radium
Ra(II)	radium in the +2 valence state
Ra^{2+}	radium ion
RAGS	*Risk Assessment Guidance for Superfund*
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RESRAD	Residual Radioactivity (model)
RfC	reference concentration
RfD	reference dose
RG	remediation goal
RI	remedial investigation
RI WP	*Remedial Investigation Work Plan for the Inaccessible Soil Operable Unit at the St. Louis Downtown Site*
Rn	radon
ROD	record of decision
ROW	right-of-way
RPD	relative percent difference
RR	railroad
RSR	risk-to-source ratio
RSL	regional screening level

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

SAG	*Sampling and Analysis Guide for the St. Louis Site*
SAIC	Science Applications International Corporation
SARA	Superfund Amendments and Reauthorization Act
SF	slope factor
SLAPS	St. Louis Airport Site
SLDS	St. Louis Downtown Site
SLERA	Screening Level Ecological Risk Assessment
SLS	St. Louis Sites
SQL	sample quantitation limit
SQL/2	one-half the reported sample quantitation limit
SVOC	semivolatile organic compound
T&E	threatened and endangered
TEDE	total effective dose equivalent
Th	thorium
Th(IV)	thorium in the +4 valence state
U	uranium
U(IV)	uranium in the +4 valence state
U(VI)	uranium in the +6 valence state
UCL	upper confidence limit
UF_4	uranium tetrafluoride (green salt)
UMTRCA	Uranium Mill Tailings Radiation Control Act
UNH	uranyl nitrate hexahydrate
UO_2	uranium oxide
UO_3	uranium trioxide
USACE	U.S. Army Corps of Engineers
USCS	Unified Soil Classification System
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UTL	upper tolerance limit
VCP	vitrified clay pipe
VOC	volatile organic compound
VP	vicinity property
VQ	validation qualifier
WP	work plan

EXECUTIVE SUMMARY

This Remedial Investigation (RI) and Baseline Risk Assessment (BRA) Report for the Inaccessible Soil Operable Unit (ISOU) at the St. Louis Downtown Site (SLDS) was developed in support of the Formerly Utilized Sites Remedial Action Program (FUSRAP). The SLDS is located in an industrial area in the eastern portion of the City of St. Louis, just west of the Mississippi River. The SLDS is comprised of approximately 210 acres of land, which includes the former Mallinckrodt property and 38 surrounding vicinity properties (VPs). The former Mallinckrodt property comprises approximately 44.5 acres of land, where uranium was processed for the nation's early atomic weapons development program conducted under the Manhattan Engineer District (MED) and the U.S. Atomic Energy Commission (AEC). The 38 surrounding VPs comprise more than 165 acres of land. The former Mallinckrodt property and the surrounding VPs have the potential for radiological and chemical contamination as a result of the historical MED/AEC operations and/or subsequent transportation, storage, or migration of MED/AEC-related residues. The RI areas for the ISOU include:

- Former Mallinckrodt Plants 1, 2, 3, 6, 7, 8, 9, and 11; and
- 38 VPs (i.e., DT-1 through DT-37 and the Terminal Railroad [RR] Soil Spoils Area).

The RI activities generated data, which when combined with applicable existing data, provided sufficient information to assess risks to various receptors within the ISOU. RI activities included a review of the available history and usage of the sites, determination of potential contaminants of concern (PCOCs), inaccessible soil sampling, gamma walkover surveys (GWSs), radiological surveys of structures, sewer investigations, determination of contaminants of potential concern (COPCs), contaminant dose and risk evaluation, and development of this RI/BRA report.

PURPOSE AND SCOPE

The purpose of this RI/BRA is to define the nature and extent of MED/AEC soil contamination present in the ISOU and assess the associated risk to human health and the environment under the current and reasonably anticipated future land use (industrial/commercial in an urban setting) for the SLDS. The results of this RI/BRA will be used to determine if MED/AEC-related contaminants are present at concentrations sufficiently low to be fully protective of human health and the environment.

The *Record of Decision for the St. Louis Downtown Site* (USACE 1998a) (hereafter referred to as the 1998 ROD) addressed accessible soil contamination and ground-water contamination. The scope of the ISOU includes all media not covered by the 1998 ROD that may have become contaminated as a result of the deposition or migration of MED/AEC-related contaminated media. Specifically, these media include the following:

- Soil that is inaccessible due to the presence of buildings and other permanent structures, including the supporting subsoil within the footprint of a structure of which remediation would reasonably be expected to affect the stability of the structure.
- Soil located under active RRs, including the supporting soil in the associated right-of-way (ROW).
- Soil located under roadways, including the supporting soil in the associated ROW. Roadways are defined as the public and private streets. Inaccessible soil does not include soil beneath driveways, parking lots, or other paved surfaces that were addressed as accessible soil areas.

- Soil on the exteriors and interiors of buildings and permanent structures (e.g., tanks, bridges, sheds, loading docks, utility poles, traffic signals, piping, rail tracks, and equipment boxes).
- Sewers (e.g., structures and interior sediment) not directly encountered within an excavation area during the remedial action conducted under the 1998 ROD.
- Soil adjacent to sewers located beneath buildings, permanent structures, RRs, and/or roads.

During preparation of the *Remedial Investigation Work Plan for the Inaccessible Soil Operable Unit at the St. Louis Downtown Site* (USACE 2009a) (hereafter referred to as the RI Work Plan [WP]), detailed reviews of historical usage of the SLDS areas within the scope of this RI were conducted to determine appropriate PCOCs. In addition, several characterization studies of various media (i.e., soil, sediment, ground water, sewers, and buildings) have been conducted at the SLDS since 1977. The characterization data that resulted from these studies and the results of the *Baseline Risk Assessment for Exposure to Contaminants at the St. Louis Site* (DOE 1993) were used during development of the RI WP to streamline the data needs for this RI.

Data collected from pre-design investigations (PDIs) and final status surveys (FSSs) conducted as part of the remediation activities for accessible soil was also useful in determining potentially contaminated inaccessible soil areas or structures. In addition, data resulting from ongoing investigations in support of the remediation of accessible soil have been used to supplement, modify, or amend RI sampling, as appropriate.

The PCOCs determined for the ISOU were identified based on the results of previous investigations. The radioactive contaminants in soil and sediment are: actinium (Ac)-227 and protactinium (Pa)-231, radium (Ra)-226, Ra-228, thorium (Th)-228, Th-230, Th-232, uranium (U)-235, and U-238 (USACE 1998a). Uranium-bearing ores that were processed for MED/AEC may have contained elevated levels of some metals. For the inaccessible soil within the uranium-ore processing area, the metal PCOCs are those that were identified as contaminants of concern (COCs) for accessible soil in the 1998 ROD (i.e., arsenic, cadmium, and uranium metal) (USACE 1998a). Because sediment present in the drains, manholes, and sewers used for MED/AEC operations had not been analyzed for metals during past investigations, metals associated with formerly used pitchblende and domestic ores (i.e., arsenic, cadmium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, vanadium, zinc, and uranium metal) were identified as PCOCs for sampling and analysis of sewer sediment and soil adjacent to sewers.

The scope of response actions authorized under FUSRAP at SLDS is limited to responding to contamination resulting from MED/AEC-related activities in support of the nations' early atomic energy program. Due to the history and diverse nature of industries located at and surrounding SLDS, there are many possible sources of chemical and radioactive contamination. The sources of metals contamination throughout SLDS, in particular, have not been established. For the purpose of providing a comprehensive assessment, the RI/BRA investigated and analyzed radiological and metal PCOCs regardless of source. The purpose of this risk analysis was only to establish site risk and should not be taken as an admission by USACE that such contamination is the result of MED/AEC-related activities. Additional information may be considered during the development of alternatives regarding site-specific sources of contamination. Response actions to address contamination not resulting from MED/AEC-related activities and not co-located with MED/AEC-related contamination are outside FUSRAP response authority.

FIELD ACTIVITIES AND FINDINGS OF THE REMEDIAL INVESTIGATION

As described in Section 2.0 of this report, a variety of field investigation methods were utilized to evaluate the presence of PCOCs for areas within the scope of this RI/BRA. Primary investigation methods consisted of:

Inaccessible Surface and Subsurface Soil Sampling: GWSs were conducted in indoor and outdoor areas that had the potential for MED/AEC-related radiological soil contamination. GWSs were conducted using a sodium-iodide (NaI) gamma scintillation detector coupled with a global positioning system (GPS) unit when possible in order to record both gamma radiation readings and geographic position data. At locations where GPS had limited effectiveness, GWSs were recorded manually. Surveys were focused on inaccessible soil areas beneath buildings, permanent structures, RRs, and roadways, and the results were used to identify biased soil sample locations.

Soil sampling was conducted in the inaccessible soil areas to determine the extent of radiological and metal PCOC contamination. Soil investigations were conducted at random, biased, and/or systematic soil sampling locations in inaccessible areas. Soil investigations consisted of surface (typically below ground cover) and subsurface soil sampling for radiological and metal PCOCs. All soil samples were analyzed for radionuclides, and only soil samples collected from some locations within the boundary of the former uranium-ore processing area were also analyzed for metals.

Radiological Structure Surveys: Structures with the potential for MED/AEC-related radiological soil contamination were surveyed. Radiological surveys included scanning for total alpha and beta surface activity and obtaining fixed-point measurements for total alpha and beta surface activity using portable radiological survey equipment. Building and structure surfaces that were surveyed included roofs, exposed exterior and interior surfaces, air vents, vertical and horizontal piping, and piping supports. The scoping surveys were biased, focusing on areas that are prone to accumulate contamination, such as horizontal surfaces, depressions, cracked surfaces, rusted or unpainted surfaces, intake and exhaust vents, etc.

Sewer Investigation: Soil and sediment samples associated with sewers were collected and analyzed to obtain sufficient and representative data to determine the extent of radiological and metals contamination associated with sewers. Specifically, two types of samples were collected:

- sediment samples from manholes and surface drains (grate inlets), and
- soil samples from areas adjacent to sewer lines.

The investigation included sewers that were used for MED/AEC operations, as well as sewers that could contain MED/AEC contamination due to receiving runoff from contaminated areas. Sediment sampling was conducted in manholes located upstream (west) of the Mallinckrodt facility to provide a background dataset for determining site-specific sewer sediment background values. Sediment and soil samples were analyzed for the metal and radionuclide PCOCs.

Section 4.0 of this report presents the findings of the RI field activities. Gross analytical results (i.e., results from which background concentrations have not been subtracted) generated for each PCOC in each media during the RI field activities were compared to appropriate USEPA risk-based preliminary remediation goals (PRGs). Concentrations below PRGs are unlikely to cause any health risks following exposure. PCOCs with concentrations exceeding their PRGs were subsequently defined as COPCs for quantitative evaluation in the BRA.

Table ES-1 summarizes the constituents that exhibited analytical results above the PRGs in each media. These COPCs were carried forward for quantitative evaluation in the BRA to determine human health carcinogenic and non-carcinogenic risks.

Table ES-1. 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.

FATE AND TRANSPORT

A conceptual site model (CSM) was developed based on analysis of contaminant fate and transport, along with information regarding the nature and extent of contamination and the physical features of the ISOU. The CSM identifies the potentially complete human or environmental exposure pathways that form the basis of evaluations for the BRA.

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).

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 CSM considers release/transport mechanisms associated with ISOU source media and areas, under both current and assumed future land use scenarios. 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 the COPCs from the source to some downgradient/downwind receptor location or medium. Once released from a source, transport mechanisms provide a pathway by which COPCs can migrate in or through an environmental medium (i.e., "transport medium"). The potentially significant transport pathways are Air Transport Pathways, Subsurface Water Transport Pathways, and Surface Runoff Transport Pathways.

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 soil-water partitioning coefficient (K_d) values estimated for arsenic indicate a higher potential for mobility. However, the presence of 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.

BASELINE RISK ASSESSMENT

A human health risk assessment (HHRA) was completed based on the identification of radiological and metal COPCs. The purpose of the HHRA is to provide risk and dose estimates and hazard index (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. Except for building/structural surfaces, each of the above scenarios, were evaluated for sitewide dose and risk and property-specific evaluations for inaccessible soil and combined inaccessible/accessible soil. Building-specific evaluations were conducted 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 sewers.

Dose and risk characterization summaries for inaccessible soil and combined inaccessible/ accessible soil exposures to radiological and metal COPCs are presented in Tables ES-2 and ES-3, respectively. Radiological dose and risk characterization summaries for soil on interior and exterior building/structural surfaces are presented in Table ES-4. The radiological dose and risk characterization summary for soil adjacent to sewers is presented in Table ES-5. The doses and

Table ES-2. 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 ES-2. 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 meter 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 ES-3. 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.

CRs – cancer risks; NA – Calculation of dose or risk is not applicable.

Table ES-4. 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.

mrem/yr – millirem per year; NA – Calculation not applicable due to no PRG exceedances.

Table ES-5. 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 and/or less than the CERCLA risk range.

cancer risks (CRs) presented in the aforementioned tables are those doses greater than 25 millirem per year (mrem/yr) and CRs above background that are within or exceed the USEPA's target CR range. 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.

Based on the findings from a site visit that occurred during the RI, as documented in the USEPA's Ecological Checklist, along with the findings of the Screening Level Ecological Risk Assessment (SLERA), potential impacts to ecological receptors from ISOU media at the SLDS are likely to be insignificant.

1.0 INTRODUCTION

This Remedial Investigation (RI) and Baseline Risk Assessment (BRA) Report for the Inaccessible Soil Operable Unit (ISOU) at the St. Louis Downtown Site (SLDS) was developed in support of the Formerly Utilized Sites Remedial Action Program (FUSRAP). In 1974, the U.S. Atomic Energy Commission (AEC) (later to become the U.S. Department of Energy [DOE] and the U.S. Nuclear Regulatory Commission [NRC]) established the FUSRAP to address sites, such as the SLDS, that were contaminated as a result of the nation's early atomic weapons development program.

The SLDS is one of two separate geographical areas collectively referred to as the St. Louis Sites (SLS). These two areas are comprised of multiple properties and are located in two distinct areas: downtown St. Louis City and North St. Louis County (NC) (Figure 1-1). These two areas are designated as the SLDS and the NC sites, respectively. The SLDS is divided into two operable units (OUs), one for accessible soil and ground water and another for inaccessible soil. This RI/BRA applies only to the SLDS ISOU.

The SLDS is located in an industrial area in the eastern portion of the City of St. Louis, just west of the Mississippi River. The SLDS consists of an active chemical processing facility and additional tracts of land called vicinity properties (VPs) (Figure 1-2). The chemical processing facility was formerly used to process uranium for the Manhattan Engineer District (MED) and the AEC and was previously owned and operated by Mallinckrodt Chemical Works, Inc., and Mallinckrodt, Inc., but is now owned and operated by Covidien. For the purpose of this RI/BRA report, the chemical plant property will be referred to by its historical designation as the "Mallinckrodt" plant area or property. The SLDS VPs consist of 37 numbered properties and one unnumbered property that surround the Mallinckrodt property and have potential radiological and metals contamination as a result of the historic MED/AEC operations and/or subsequent transportation, storage, or migration of MED/AEC-related residues.

1.1 PURPOSE

In 1980, Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (Public Law 96-510), also known as "Superfund," which was created to remedy threats to human health and the environment from releases of hazardous wastes from various industries. In 1986, CERCLA was reauthorized and amended by the Superfund Amendments and Reauthorization Act (SARA) requiring federal facilities to abide by the same CERCLA requirements. Response actions at FUSRAP sites are subject to the administrative, procedural, and regulatory provisions of CERCLA.

The CERCLA process includes the investigation, evaluation, and documentation of the contaminants present at a site or portions of a site (the RI); an assessment of the potential risks to human health and the environment posed by those contaminants (the BRA); and, if necessary, assessment screening and detailed evaluation of potential remedial alternatives for reducing unacceptable risk (a Feasibility Study [FS]). Based upon the results of the RI/BRA/FS process, a Proposed Plan (PP) is developed, and a remedial decision is documented in a Record of Decision (ROD).

In accordance with 40 *Code of Federal Regulations (CFR)* 300.430(a)(ii)(A), the CERCLA process may be completed in OUs when phased analysis and response is necessary or appropriate given the size or complexity of the site or to expedite site cleanup. The *Record of Decision for the St. Louis Downtown Site* (USACE 1998a) (hereafter referred to as the 1998 ROD), addressed accessible soil and ground-water contamination as one OU. The other OU (i.e., the ISOU), which this RI/BRA covers, includes soil and sediment at SLDS not addressed by the 1998 ROD that have the potential for MED/AEC contamination, as further described in Section 1.1.2.

The purpose of this RI/BRA is to define the nature and extent of MED/AEC soil contamination present in the ISOU and assess the associated risk to human health and the environment under the current and reasonably anticipated future land use (industrial/commercial in an urban setting) for the SLDS. The results of this RI/BRA will be used to determine if MED/AEC-related contaminants are present at concentrations sufficiently low to be fully protective of human health and the environment.

The scope of response actions authorized under FUSRAP at SLDS is limited to responding to contamination resulting from MED/AEC-related activities in support of the nations' early atomic energy program. Due to the history and diverse nature of industries located at and surrounding SLDS, there are many possible sources of chemical and radioactive contamination. The sources of metals contamination throughout SLDS, in particular, have not been established. For the purpose of providing a comprehensive assessment, the RI/BRA investigated and analyzed radiological and metal potential contaminants of concern (PCOCs) regardless of source. The purpose of this risk analysis was only to establish site risk and should not be taken as an admission by USACE that such contamination is the result of MED/AEC-related activities. Additional information may be considered during the development of alternatives regarding site-specific sources of contamination. Response actions to address contamination not resulting from MED/AEC-related activities and not co-located with MED/AEC-related contamination are outside FUSRAP response authority.

1.1.1 Regulatory Overview

In 1974, AEC established FUSRAP for the cleanup of sites contaminated from past activities involving radioactive materials. Because contamination related to MED/AEC activities was present at the SLDS at levels that required a response, the SLDS was designated for inclusion under the FUSRAP. At that time, one OU was established for the SLS.

In June 1990, a Federal Facility Agreement (FFA) for the SLS was established between the DOE and U.S. Environmental Protection Agency (USEPA) Region VII (DOE 1990). This agreement, pursuant to CERCLA Section 120, Federal Facilities, defined implementation and oversight roles for the respective agencies involved in the CERCLA process. The FFA stated that the DOE would conduct response actions at the SLS for the following materials:

- All wastes, including but not limited to radiologically contaminated wastes, resulting from or associated with MED/AEC uranium manufacturing or processing activities conducted at the SLDS; and
- Other chemical or non-radiological wastes that have been mixed or commingled with wastes resulting from or associated with MED/AEC uranium manufacturing or processing activities conducted at the SLDS (DOE 1990).

The DOE managed the FUSRAP until October 1997, when responsibility for the execution of the program was transferred to the U.S. Army Corps of Engineers (USACE) under the Fiscal Year 1998 Energy and Water Appropriations Act. Consistent with the transfer of authority, the USACE is the lead agency responsible for response actions at the SLDS. The DOE will assume a stewardship responsibility beginning two years after completion of the response actions at the SLDS.

Between 1989 and 1993, an RI/BRA for the SLS was conducted and included the sampling of accessible and inaccessible soil, buildings, sewers, surface water, sediment, and ground water at both the NC site and the SLDS. The *Baseline Risk Assessment for Exposure to Contaminants at the St. Louis Site* (DOE 1993) (hereafter referred to as the 1993 BRA) concluded that radiologically contaminated soil at the SLDS was the source of cancer risks (CRs) in excess of USEPA's CERCLA target CR range of 1 in 1,000,000 to 1 in 10,000 (i.e., 1.0E-06 to 1.0E-04) under current industrial and future land use scenarios. Based on these results, remedial action was judged to be warranted at the SLDS.

In 1991, the *Engineering Evaluation/Cost Analysis for Decontamination at the St. Louis Downtown Site* (DOE 1991) evaluated potential removal actions at the SLDS. In 1992, the *Action Memorandum for the Removal of Contaminated Materials at the St. Louis Downtown Site, St. Louis, Missouri* (DOE 1992) was issued to address four removal actions involving the demolition of several buildings at the Mallinckrodt Plant area remaining from MED/AEC operations. When the *Feasibility Study for the St. Louis Downtown Site* (USACE 1998b) (hereafter referred to as the 1998 FS) was published in 1998, it stated that the inaccessible soil beneath buildings and other permanent structures would be addressed as a subsequent CERCLA action, because the inaccessible soil did not present a significant threat in its current configuration and "remediation of these soils at this time would result in severe economic dislocations and community disruptions" (USACE 1998b).

The 1998 ROD was published by the USACE in consultation with the USEPA and with concurrence from the Missouri Department of Natural Resources (MDNR). It defined remedial actions for accessible soil at the Mallinckrodt property and VPs, plus ground water beneath the SLDS for MED/AEC-related hazardous substances. The selected remedy for accessible soil was Alternative 6, Selective Excavation and Disposal. Accessible soil is defined in the 1998 ROD as soil that is not beneath buildings or other permanent structures. Long-term monitoring was required for ground water beneath the site. The 1998 ROD also stated that contaminated sediment in sewers and drains considered accessible would also be remediated (USACE 1998a).

The principal risk identified in the 1998 ROD was exposure to radioactivity remaining from past MED/AEC operations. The radiological contaminants of concern (COCs) (i.e., one or more contaminants found on, in, or under a property at a concentration that exceeds the applicable site condition standards for the property) defined by the 1998 ROD were actinium (Ac)-227, protactinium (Pa)-231, radium (Ra)-226, Ra-228, thorium (Th)-228, Th-230, Th-232, uranium (U)-235, and U-238. The metal COCs applicable for soil inside the uranium-ore processing area of the SLDS were identified as arsenic, cadmium, and uranium metal. Soil remediation goals (RGs) for the radiological COCs identified in the 1998 ROD were consistent with applicable or relevant and appropriate requirements (ARARs) identified in accordance with CERCLA. RGs for metal COCs were developed based on site-specific risk-based values in accordance with CERCLA.

In March 2005, the *Memorandum for Record: Non-Significant Change to the Record of Decision for the St. Louis Downtown Site* was published, which provided specific clarifications regarding the delineation of the SLDS boundary (USACE 2005a). Additional VPs were determined to be impacted (i.e., potentially contaminated) by MED/AEC wastes from the SLDS. In addition, certain property boundaries and, in some cases, the associated property owners, differed from those originally identified in the 1998 ROD. The following specific revisions were stated in the Memorandum for Record:

- Designating VPs by assigning property-specific alphanumeric identification numbers to clearly identify each property and to minimize confusion resulting from changing property ownership (e.g., DT-2) (Table 1-1).
- Modifying some VP boundaries due to changes in property boundaries after issuance of the 1998 ROD.
- Clarifying that contaminated soil under active rail lines on the three "Railroad (RR) Properties" is inaccessible and will be addressed as part of the ISOU.
- Clarifying that the 1998 ROD "specifically includes the Remediated Levee Property east of the levee but excludes contamination present beneath the existing levee, which will be addressed as part of the future ISOU" (USACE 2005a).
- Amending the SLDS boundaries "to increase the geographical area/scope of the SLDS site to include additional areas to the north, south, and west of the site" (USACE 2005a).
- Adding the Terminal RR Soil Spoils Area, located south of the SLDS, to the amended geographical area of the SLDS.

Table 1-1. St. Louis Downtown Site Vicinity Properties

Current Property Name	VP Number
Kiesel (formerly Archer Daniels Midland and PVO Foods) [a]	DT-1
St. Louis City Property	DT-2
Norfolk Southern RR (formerly Norfolk and Western RR)	DT-3
Gunther Salt (North and South)	DT-4
AmerenUE	DT-5
Heintz Steel and Manufacturing	DT-6
Midwest Waste [a]	DT-7
PSC Metals, Inc. (formerly McKinley Iron Works)	DT-8
Terminal RR Association	DT-9
Thomas and Proetz Lumber Company	DT-10
Illinois Department of Transportation (IDOT) and the Missouri Department of Transportation (MoDOT) (also known as McKinley Bridge) (formerly the City of Venice, Illinois)	DT-11
Burlington-Northern Santa Fe (BNSF) RR (formerly Chicago, Burlington, and Quincy RR)	DT-12
Cash's Scrap Metal	DT-13
Cotto-Waxo Company	DT-14
Metropolitan St. Louis Sewer District (MSD) Lift Station	DT-15
Star Bedding Company	DT-16
Christiana Court, Limited Liability Company (LLC)	DT-17
Curley Collins Recycling (currently owned by the City of St. Louis)	DT-18
City of St. Louis Streets	DT-19
Richey	DT-20
Favre	DT-21
Tobin Electric	DT-22
InterChem	DT-23
Bremen Bank	DT-24
Eirten's Parlors	DT-25
United Auto Workers Local 1887	DT-26
Dillon	DT-27
Challenge Enterprise	DT-28
Midtown Garage (currently owned by Cash's Scrap Metal)	DT-29
ZamZow Manufacturing	DT-30
Porter Poultry	DT-31
Westerheide Tobacco [a, b]	DT-32

Table 1-1. St. Louis Downtown Site Vicinity Properties (Continued)

Current Property Name	VP Number
MoDOT Roads	DT-33
Hjersted	DT-34
Factory Tire Outlet	DT-35
OJM, Inc.	DT-36
Lange-Stegmann	DT-37
Terminal RR Soil Spoils Area	NA

[a] These VPs are not included in the scope of this OU because no inaccessible soil areas or buildings and structures remain at the property.

[b] Property was purchased by Mallinckrodt, building was demolished, and area is now a parking lot at Plant 8.

NA = Not applicable.

The *Remedial Investigation Work Plan for the Inaccessible Soil Operable Unit at the St. Louis Downtown Site* (USACE 2009a) (hereafter referred to as the RI Work Plan [WP]) was finalized in November 2009 after regulatory review by the USEPA and MDNR. The RI WP presented the sampling protocol for the ISOU based on an evaluation of data from characterization studies of various media (e.g., soil, sediment, sewers, and buildings) conducted at the SLDS since 1977. These studies provided a detailed understanding of the environmental setting and the nature of contamination at the SLDS. In addition, the data collected from 1977 to 1993 were used as part of the 1993 BRA to evaluate the human health and ecological risks associated with the impacted media at the SLDS, including both inaccessible and accessible soil. The existing characterization data and the results of the 1993 BRA were used to streamline the data needs for the ISOU RI.

Sampling for the ISOU RI began in June 2009 and ended in August 2010 with the majority of work being completed between October 2009 and May 2010. The results of the RI are detailed in this report.

1.1.2 Operable Unit Scope

The scope of the ISOU includes all media at the SLDS not covered by the 1998 ROD that may have become contaminated as a result of the deposition or migration of MED/AEC-related contaminated media. A conceptual view of the inaccessible areas is shown on Figure 1-2.

Media within the scope of the ISOU include:

- Soil that is inaccessible due to the presence of buildings and other permanent structures, including the subsoil within the footprint of a structure of which remediation would reasonably be expected to affect the stability of the structure.
- Soil located under active RRs, including the supporting soil in the associated right-of-way (ROW).
- Soil located under roadways, including the supporting soil in the associated ROW. Roadways are defined as the public and private streets. Inaccessible soil does not include soil beneath driveways, parking lots, or other paved surfaces located at plant or VP areas that were addressed as accessible soil areas.
- Soil on the exteriors and interiors of buildings and permanent structures (e.g., tanks, bridges, sheds, loading docks, utility poles, traffic signals, piping, rail tracks, and equipment boxes).
- Sewers (e.g., structures and interior sediment) not directly encountered within an excavation area during the remedial action conducted under the 1998 ROD.

- Soil adjacent to sewers located beneath buildings, permanent structures, RRs, and/or roads.

The following properties are excluded from the scope of the ISOU:

- Plant 7E and three VPs (DT-1, DT-7, and DT-32) are excluded because they do not contain inaccessible soil areas and there are no sewers, buildings, or structures impacted by MED/AEC operations present at these properties. Accessible soil contamination has been remediated at Plant 7E and DT-7 to standards specified in the 1998 ROD. DT-1 and DT-32 did not require remediation.
- The inaccessible soil and structures at Plant 10 have been excluded because Plant 10 was remediated by the DOE. The sewers used for MED/AEC operations at Plant 10 were included and evaluated in the RI WP and were determined to be non-impacted.
- Plant 5 is excluded because residual contamination is reasonably attributable to the Columbium-Tantalum (C-T) processing activities that were conducted at these areas by Mallinckrodt. C-T ores were processed by Mallinckrodt at Plant 5 under a separate NRC Source-Material License and, therefore, remediation of this radiologically contaminated soil is not within the scope of the FUSRAP. These ores contain natural uranium, thorium, and actinium decay series radionuclides.
- Plant 7W was previously used by MED/AEC for processing radioactive feed materials and by Mallinckrodt to store containerized tin slag feed material and the operation of the concrete-lined, waste-water neutralization ponds. Plant 7W is currently excluded from the ISOU, because historic sources of contamination have not been determined. If historic sources of contamination are determined to be from MED/AEC activities, inaccessible data will be added as an appendix to the current CERCLA document (i.e., RI or FS), and the results of the evaluation will be incorporated into that document (RI or FS). If the determination is made after the ROD is signed, a standalone document will be written to cover Plant 7W.

The status of the following properties has changed since the publication of the RI WP and, therefore, the inclusion of the specific property areas within the scope of the ISOU has also changed. These areas are now being addressed under the 1998 ROD.

- A sewer line at the northern edge of the 50-series excavation area in Plant 2 was characterized during the RI. Results of the soil sampling indicated subsurface soil adjacent to the sewer line was radiologically contaminated. In calendar year 2011, this area was made available for remediation by the owner and the sewer line and associated contaminated soil were removed. Therefore, the soil and sewer line at the northern edge of the 50-series excavation area are no longer included in the scope of the ISOU.
- Plant 6 Building 101 is planned for demolition by the USACE. Soil remaining within the footprint of Building 101 is considered accessible soil and is outside the scope of the ISOU.
- Soil at the northeastern corner of Plant 7N was defined in the RI WP as an "inaccessible area of detected contamination" and was proposed for sampling as part of the ISOU. The subsurface soil beneath this area was found to be radiologically contaminated. Because of the proposed remediation of Destrehan Street, this area at Plant 7N is proposed for accessible soil remediation under the 1998 ROD. Following the remediation, any inaccessible soil remaining will be evaluated as part of the ISOU. If any inaccessible soil remains, the inaccessible data will be added as an appendix to the current CERCLA

document (i.e., RI or FS), and the results of the evaluation will be incorporated into that document (RI or FS). If the determination is made after the ROD is signed, a standalone document will be written.

- The Hazardous Waste Storage Area at Plant 7N was razed in 2010, and the associated soil and sewer lines were remediated. Therefore, soil and sewer lines beneath this building are no longer defined as inaccessible and are outside the scope of the ISOU.
- ROW soil along the DT-12, was characterized during the RI, found to be radiologically contaminated, and then made available for remediation by the owner. Following the remediation, any inaccessible soil remaining will be evaluated as part of the ISOU.
- Soil beneath Destrehan Street, between Hall Street and DT-12, was characterized during the RI, found to be radiologically contaminated, and then made available for remediation by the owner. Following the remediation, any inaccessible soil remaining will be addressed as part of the ISOU.

1.2 SITE BACKGROUND

1.2.1 Location and General Site Description

The SLDS is located in an industrialized area on the eastern border of the City of St. Louis, just west of the Mississippi River (Figure 1-1). The SLDS consists of approximately 44.5 acres of the Mallinckrodt property, where MED/AEC activities were formerly conducted, and approximately 165 acres of surrounding VPs (Figure 1-2).

Mallinckrodt, Inc., became part of Covidien in 2007 and currently utilizes a number of plants (Plants 1 through 3 and 5 through 11) at the former Mallinckrodt facility. To maintain historic references, any actions taken prior to 2007 by the former Mallinckrodt, Inc., will be identified within this document as actions taken by Mallinckrodt. Similarly, any actions completed during and after 2007 will be identified as Covidien actions.

The Mallinckrodt property encompasses an area of approximately 12 city blocks roughly bounded by the McKinley Bridge on the north, Angelrodt Street on the south, North Broadway on the west, and DT-12 on the east (Figure 1-2).

Thirty-seven numbered VPs and one unnumbered VP surrounding the Mallinckrodt property, which are identified in Table 1-1 and shown on Figure 1-2, are part of the SLDS. The VPs are identified using the prefix of DT to represent the "downtown" site and are followed by a number for consistent identification regardless of changing property ownership. Most of the VPs are small parcels of land owned by individuals conducting industrial, commercial, manufacturing, or retail businesses, including a lumber distributor (DT-10), a steel manufacturing facility (DT-6), scrap metal recyclers (DT-8 and DT-13), a bedding manufacturer (DT-16), a salt packaging and storage facility (DT-4), a bank (DT-24), and a fertilizer company (DT-37). DT-37 has handled various materials, including potash, fertilizer, and bauxite, that are known to contain naturally occurring radioactive material (NORM) and exhibit radiation levels above background soil levels (NCRP 1995, USEPA 1999d).

Some VPs are roadways owned either by the City of St. Louis or Illinois Department of Transportation (IDOT) and Missouri Department of Transportation (MoDOT). The McKinley Bridge, which provides a vehicle transportation route over the Mississippi River between Illinois and Missouri, is owned by IDOT and MoDOT (State of Illinois 2002).

There are three RR main lines or lead tracks traversing the SLDS in a north-south direction, each having an associated network of spur tracks and sidings (Figure 1-2). These RR lines are defined as VPs and include the Norfolk Southern RR (DT-3), the Terminal RR Association (DT-9), and the BNSF RR (DT-12). The materials making up a section of railroad track consist of several components, including the rail and rail fasteners, the ties, and the rail bed materials (i.e., subgrade, sub-ballast, and ballast). The ballast consists of crushed stone, including materials such as granite that contain NORM. The constituents of this NORM are similar to the radiological PCOCs at the SLDS, so railroads can contain radioactive materials irrespective of historical MED/AEC activities (NCRP 1995). Portions of the RRs having RR ties constructed of lumber treated with arsenic could act as a potential source of arsenic contamination (MassDEP 2003).

Portions of the SLDS lie within the original floodplain of the Mississippi River. Such areas are now separated from the river by a levee and floodwall system identified as the St. Louis Flood Protection system. This system includes the Mississippi River levee, an earthen levee, and concrete floodwall that protect St. Louis from Mississippi River floodwaters. The levee is present on VPs DT-2, DT-9, and DT-15. The St. Louis Riverfront Trail, a recreational bike trail, runs parallel to the Mississippi River along the Mississippi levee area (Figure 1-2). This recreational bike trail was constructed in 1997.

The Terminal RR Soil Spoils Area is the one unnumbered VP and is located approximately 650 feet (ft) south of the contiguous portion of the SLDS (Figure 1-2). This 16.7-acre property is located south of Dock Street and is bounded by Branch Street on the north, North Market Street on the south, Produce Row and a RR line continuing to the north to Branch Street on the west, and Grossman Iron and Steel Company on the east.

Many of the buildings on the Mallinckrodt property were constructed in the early 1900s, prior to MED/AEC operations The buildings at the SLDS are constructed of a variety of materials, including wood, concrete, brick, granite, and other types of building stone. Portions of some of the buildings were constructed with materials such as granite, brick, ceramics, and some types of concrete, which exhibit naturally occurring elevated radioactivity (NCRP 1995).

An extensive network of utility services exists at the SLDS, including sewers, sprinklers, city water lines, natural gas lines, overhead electricity and telephone lines, and overhead plant process pipes. Some of the sewers and subsurface utilities (e.g., electricity) are owned by municipal or public utility companies. Runoff from the SLDS is directed to a sewer system that discharges to a publicly owned treatment facility, which then discharges to the Mississippi River.

1.2.2 Operating History

Chemical production operations at the Mallinckrodt property began in 1867 when the original chemical plant was constructed, continued during MED/AEC operations, and are ongoing by Covidien today. Historically, Mallinckrodt used, blended, and/or manufactured various chemicals at the site, including organic and inorganic compounds. Covidien currently manufactures pharmaceuticals, specialty chemicals, and other imaging products. Additionally, heavy industry and commercial processes have been performed throughout the SLDS and surrounding area for more than 100 years.

From 1942 to 1957, under contract to MED and AEC, Mallinckrodt processed uranium feed materials in support of the nation's early nuclear program. The contractual work from 1942 to 1947 was performed under MED. In 1947, the contract was transferred to the newly formed AEC and remained under AEC until operations ceased at the SLDS in 1957 (ORNL 1981).

The MED/AEC work conducted by Mallinckrodt included the development of uranium-processing techniques and the production of uranium metal. Processing of uranium ore was completed by digesting the ore in nitric acid to form uranyl nitrate, which was extracted with ether and water and denitrated by heating to produce uranium oxide (UO_2). Hydrofluoric acid was used to fluorinate the UO_2 to create uranium tetrafluoride (UF_4) (also referred to as "green salt"), which then was reduced with magnesium to produce uranium metal (DOE 1993). The main uranium ore processed for MED/AEC was African Congo pitchblende, though some domestic ores were also processed (DOE 1993). Early feed materials were relatively pure "black oxides," which had been extracted from uranium ores by other companies. Once stocks of "black oxides" were depleted, the plant began extracting uranium directly from uranium ores rather than merely purifying uranium from feed materials. In addition, some facilities were used for metallurgical processing of uranium and uranium recovery from metal slag (BNI 1990a). Process residuals, including radium, thorium, uranium, and their decay products, were inadvertently released into the environment. Uranium-bearing ores that were processed for MED/AEC may have contained elevated levels of some metals (e.g., arsenic, cadmium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, vanadium, or zinc) (USACE 1998a).

The MED/AEC work was conducted at Plants 1, 2, 6, 7, and 10 (formerly Plant 4) of the former Mallinckrodt Chemical Works. The historic layout of the MED/AEC and Mallinckrodt plant facility from 1958 is shown in Figure 1-3. Between 1942 and 1945, Plant 1 was used by MED/AEC for developmental work in refining triuranium octoxide feed and experimental processing of radium-containing pitchblende ores. The MED/AEC work at Plant 1 was performed in four pre-existing Mallinckrodt structures; Buildings 25, A, K, and X. Developmental work at the laboratory level to support Plant 2 and Plant 10 operations took place in the second floor laboratory of Building 25 and in the alley between Buildings 25 and K. Experimental processing of radium-containing pitchblende ores, which began in the 1944 to 1945 timeframe, was conducted in the second floor laboratory of Building 25. The pilot plant to test radium-extraction methods was located in Building K and in the alley between Buildings 25 and K. Building 25 also contained the project offices. Building A was used for general plant maintenance, Building X housed locker rooms, and Buildings P and Z contained the engineering and other offices. Plant 1 was not used after 1945 and the MED/AEC offices and laboratories moved to Plant 6.

Uranium refining operations began at Plant 2 in April 1942, producing approximately 4,400 tons of UO_2. Facilities for batch production were installed in Buildings 50, 51, 51A, 52, and 52A (the 50-series buildings) to produce uranium trioxide (UO_3) from ore concentrates. The concentrates were digested in nitric acid in Building 51 to produce uranyl nitrate, which was then transferred to Building 52 to be purified by ether extraction to uranyl nitrate hexahydrate (UNH). The UNH was converted in Building 51A first to UO_3 and then to UO_2. Building 50 was used as a warehouse to store incoming feed materials, outgoing product material, and tanks of process liquids. Building 55 contained the laboratory that tested samples. In the spring of 1945, Building 52A was added to serve as a pilot plant for a continuous ether extraction process to replace the existing batch process. Work at Plant 2 ended in 1946 when the plant was closed, and the work moved to the newly built Plant 6.

Late in 1942, Plant 10, a former sash and door works, was converted for uranium refining and dubbed "the metal plant." In 1943, production of green salts (UF_4) began at Plant 10. The metal production took place in Buildings 400 and 401B, and the UF_4 production took place in Building 400 (Figure 1-3). Production of uranium metal was moved from Plant 10 to Plant 6E (now known as Plant 6EH) in 1946, and the UO_2 to UF_4 process was moved to Plant 7 in the 1951 to 1952 timeframe. Plant 10 was refitted as an experimental development and metallurgical pilot plant processing uranium metal; consequently, Plant 10 was thereafter referred to as the "pilot plant." The ingot metal production process was developed and conducted at Plant 10 in the mid-1950s, along with sporadic ordinary metal derby production on a developmental basis. Plant 10 was used by AEC until 1956.

In 1944, the government decided to build a new refinery to extract uranium from pitchblende ore. The new facility, called the Destrehan Street Facility (Plants 6, 6E, and 7), began operations in 1946. Plant 6 was built in 1945 and 1946 on a site fronting Destrehan Street and was then referred to as "the refinery." Most of the administrative offices, laboratories, and support facilities for the uranium refining operations were located at Plant 6. The second new plant at the Destrehan Street site was Plant 7, the green salt plant. Construction included the 700-series buildings (703 to 708), which went into operation sometime during 1951 and 1952, when the UO_2 to UF_4 process was moved from Plant 10 to Plant 7.

The pitchblende ore-to-UO_2 part of the refining process was moved to Plant 6 in early 1946 from Plant 2, along with the laboratory work from Plant 1. At that time, UO_2 production in the 50-series buildings at Plant 2 ceased (NPS 1997). The UO_2-to-metal production remained at Plant 10. The incoming ore arrived by rail and was stored in Plant 6 Building 110 (Figure 1-3); however, in late 1950, an outdoor storage area was added for pitchblende ore. Building 104 processed mostly pitchblende ore and housed the continuous process equipment, which replaced the batch process equipment that had been used in Plant 2. In 1949, a second digest line was added in the building to process uranium ore concentrates. Most of the UO_2 produced at Plant 6 was trucked to Plant 10, with the rest going by rail to the Harshaw Chemical Company in Cleveland, Ohio, and the Linde Ceramics Plant in Tonawanda, New York. When equipment was added to Plant 7 to allow continuous UO_3 to UF_4 conversion, Plant 6 began to produce only UO_3. Milling of UO_3 and pre-digestion ore grinding, both conducted at Plant 6, were discontinued in 1950 and 1955, respectively. Pitchblende ore continued to be used as feed until early 1955.

Plant 6E (now known as Plant 6EH), located in the eastern portion of Plant 6 (Figure 1-3), was built as the new metal plant, which went into operation in late 1950. Metal production (UF_4-to-U-metal) operations at Plant 10 moved to Plant 6E, which was then referred to as "the metal plant." Metal production took place in Building 116. Building 116C was built in 1954 to recycle magnesium fluoride slag.

At Plant 7, a continuous process replaced the batch-type process used at Plant 10, and equipment was added later to allow for continuous production of UF_4 from UO_3 directly. Uranium metal recovery and some storage operations were moved to Plant 7 in 1952. Some reversion of UF_4 to UO_2 or UO_3 was done in 1954 and perhaps later. A new wet slag (interim residue) recovery operation was added in late 1955 in Building 701 as UF_4 was processed at Plant 7. Plant 7 Building 700 was built in 1955 as a warehouse, with a portion of Building 700 used for machining of reactor cores (Mason 1977). Plant 7E (Figure 1-3), regarded administratively as part of Plant 7, was used from 1955 to 1957 to process pitchblende raffinate (solids removed during the uranium refining by wet filtration). Pitchblende raffinate was used to produce a concentrated Th-230 solution by an acid digestion process similar to the uranium ore digestion. The concentrate was sent to the Mound Site in Ohio for further processing. Some Plant 7 operations continued up to 1957, when they were transferred to the Weldon Spring Chemical Plant, located in St. Charles County, Missouri.

When uranium processing operations began at the Mallinckrodt property, most of the streets and RRs now in existence at the SLDS had already been constructed. The raw material for the processing operations was transported to Mallinckrodt along the existing RRs. According to a

February 15, 1945, memorandum titled *Shipment Security Survey at Mallinckrodt Chemical Works,* the raw materials were sent to the plant in sealed, individual containers such as metal containers, wood barrels and boxes, or fiber drums via sealed RR cars (Mallinckrodt 1945).

During MED/AEC operations, most process, storm, and sanitary effluents for Mallinckrodt were collected in a combined sewer system. Effluent entered the combined system from the MED/AEC areas and passed through the system, ultimately discharging to the Mississippi River (prior to December 1970). Currently, sewer flow from the SLDS discharges to the Metropolitan St. Louis Sewer District (MSD) Bissell Point Treatment Plant. Sewers at the Mallinckrodt property were predominantly constructed from vitrified clay pipe (VCP) and vitrified brick sealed with bituminous tar or cementitious materials, but portions of the plumbing system (i.e., smaller diameter pipes within buildings that drain to the sewer) could have had lead as a component. Lead pipes and/or lead-based solder at piping connections are often found in older buildings (MDNR 2010). The bedding material commonly used during this era was granulated rock material, but some sewers may have been constructed without any bedding material (BNI 1990b).

From 1948 to 1950, decontamination activities were conducted at Plants 1 and 2. The decontamination efforts were conducted to meet criteria in effect at that time, and the plants were released in 1951 for use without radiological restrictions. Operations at Plant 10 were terminated during 1955 and 1956 (ORNL 1981). Operations in Plants 6 and 7 ceased in 1957. Shutdown of all remaining MED/AEC operations at Mallinckrodt began in 1958. During 1961 and 1962, AEC managed the decontamination efforts at Plants 6 and 10, removing radiologically contaminated buildings, equipment, and soil. AEC also returned Plants 6 and 10 to Mallinckrodt for use without radiological restrictions (ORNL 1981). Plant 7 was decontaminated to meet criteria and was released for use with no radiological restrictions in 1962 (DOE 1993). When MED/AEC operations at Mallinckrodt were completed in 1962, buildings owned by the government had either been demolished or transferred to Mallinckrodt. Since then, a number of buildings that existed in 1962 have been razed, and a number of new buildings have been constructed at Plants 6 and 10; some of these buildings are being used for the commercial production of chemicals by Covidien. Additionally, since 1962, much of the superstructure used for MED/AEC operations has been demolished, and some underground utilities have been abandoned in place.

Non-MED/AEC radiological work was also completed by Mallinckrodt. C-T ores were processed under a separate NRC Source-Material License. While a majority of the work was performed at Plant 5, C-T activities also took place at Plant 1, Plant 3, Plant 6, Plant 7, and Plant 8 areas. C-T activities began in 1961 and continued through 1985, and again briefly in 1987. Some C-T waste was buried at Plant 6 beneath Building 101 (Figure 1-3). In 1971, Mallinckrodt constructed wastewater neutralization ponds at the western edge of Plant 7 (Plant 7W) (Figure 1-2).

1.2.3 Previous Site Characterization Studies

Several characterization studies of various media (i.e., soil, sediment, ground water, sewers, and buildings) have been conducted at the SLDS since 1977. Table 1-2 provides an overview of some of the characterization studies that were conducted and the types of sampling activities that were completed. The RI WP provides a detailed discussion of the major characterization studies conducted at the SLDS and an overview of characterization studies on a property-by-property basis (USACE 2009a). The existing characterization data and the results of the 1993 BRA were used to predict the extent of contamination in the ISOU and to streamline the data needs for this RI. The 1998 ROD defined the nature of contamination at the SLDS based on the results of the previous RI and characterization studies at the SLDS.

Table 1-2. Historic Characterization Studies Supporting the Inaccessible Soil Operable Unit

Location	Characterization Study	Reference Document
Plants 1, 2, 6, 6E, 7, and 10	Oak Ridge National Laboratory (ORNL), July through September 1977 **Radiological survey and sampling at locations of MED/AEC processing activities** • Performed direct alpha and beta-gamma measurements and removable alpha and beta measurements on 21 buildings, including indoor walls, floors, ledges, drains, outdoor pads, loading docks, buildings, and roofs • Performed surface and subsurface soil sampling in areas of suspected contamination (e.g., below some buildings and parking lots and near RR spurs) • Collected ground-water samples from 31 auger holes • Collected sediment from indoor and outdoor building drains • Performed surface-water sampling along the Mississippi River at four locations where runoff from the site drains into the river	*Radiological Survey of Mallinckrodt Chemical Works* (ORNL 1981)
Plants 1, 2, 6, 7, and 10; DT-2; and Background Location	RI for the SLS: Site Characterization Phase 1 and Phase 2 • Performed walkover gamma scan of soil in specific areas with suspected contamination • Performed biased and systematic sampling of surface and subsurface soil for radiological and chemical analyses of metals, volatile organic compounds (VOCs), Resource Conservation and Recovery Act (RCRA) characteristics, and base/neutral and acid extractables • Installed nine ground-water monitoring wells and conducted ground-water sampling • Conducted a radiological survey and collected sediment samples from drains, manholes, sumps, and sewers • Performed direct alpha and beta-gamma measurements, and performed removable alpha and beta measurements on interior surfaces (e.g., floors, walls, ceilings, and roofs) of 20 buildings associated with processing operations • Collected biased soil samples of surfaces in building interiors for radiological analysis • Conducted additional surface and subsurface soil sampling for radiological and chemical analyses for metals and RCRA hazardous waste characteristics • Conducted soil testing (particle-size analysis, soil permeability, uranium partitioning coefficient) • Performed direct alpha and beta-gamma measurements and removable alpha and beta measurements on additional surfaces of former processing buildings	*Remedial Investigation Report for the St. Louis Site, St. Louis, Missouri* (BNI 1994) *Remedial Investigation Addendum Report for the St. Louis Site, St. Louis, Missouri,* (DOE 1995) *Radiological, Chemical, and Hydrogeological Characterization Report for the St. Louis Downtown Site* (BNI 1990a)

Table 1-2. Historic Characterization Studies Supporting the Inaccessible Soil Operable Unit (Continued)

Location	Characterization Study	Reference Document
Plant Areas, DT-1, DT-3, DT-8, DT-9, DT-10, and DT-12	RI Addendum: 1992 to 1993 • Performed supplemental soil sampling for radiological analysis to refine the boundaries of soil contamination at the plant areas as well as six VPs • Collected 10 background soil samples at Hyde Park to establish background for chemicals • Sampled sediment from manholes, sumps, and drain lines • Collected radon measurements in 19 buildings • Collected sediment samples from the Mississippi River • Installed an additional ground-water monitoring well • Performed beta-gamma survey on the interior of Building 101	*Remedial Investigation Report for the St. Louis Site, St. Louis, Missouri* (BNI 1994) *Remedial Investigation Addendum Report for the St. Louis Site, St. Louis, Missouri* (DOE 1995) *Preliminary Radiological Survey Report for the Chicago, Burlington, and Quincy Railroad Property in St. Louis, Missouri* (BNI 1989e) *Report on the Limited Radiological Survey of the PVO Foods, Inc. Property in St. Louis, Missouri* (BNI 1989f) *Preliminary Radiological Survey Report for the Norfolk and Western Railroad Property in St. Louis, Missouri* (BNI 1989d) *Preliminary Radiological Survey Report for the St. Louis Terminal Railroad Property in St. Louis, Missouri* (BNI 1989c) *Report on the Limited Radiological Survey of the Thomas and Proetz Lumber Company Property in St. Louis, Missouri* (BNI 1989b) *Report on the Limited Radiological Survey of the McKinley Iron Company Property in St. Louis, Missouri* (BNI 1989a)
City-owned Property Located North and South of the SLDS	Background Soil: 1998 • Sampled boreholes to provide background soil concentrations of chemicals and radionuclides	*Background Soils Characterization Report for the St. Louis Downtown Site* (USACE 1999a)
Plant Areas and VPs	PDI and FSSE: 1998 to 2010 • Characterized accessible soil • Characterized properties included in the boundary enlargement of the 2005 Memorandum for Record (USACE 2005a) • Conducted gamma walkover surveys (GWSs) to identify areas of elevated radiological contamination above background • Conducted systematic, random, and biased soil sampling • Conducted verification sampling at remediation areas • Identified inaccessible soil areas of detected contamination	Various titles including *Pre-Design Investigation Data Summary Report Gunther Salt North Vicinity Property (DT-4), FUSRAP St. Louis Downtown Site, St. Louis, Missouri* (IT 2001) *Post-Remedial Action Report for the Accessible Soils within the St. Louis Downtown Site Plant 2 Property* (USACE 2002a) *Post-Remedial Action Report for the Accessible Soils within the St. Louis Downtown Site, Heintz Steel and Manufacturing Vicinity Property (DT-6), and Midwest Waste Vicinity Property (DT-7), St. Louis, Missouri* (USACE 2005b) *Final Status Survey Evaluation for the Accessible Soils within the St. Louis Downtown Site Vicinity Properties West of Broadway, Mallinckrodt Plants 3, 8, 9, 11 and Parking Lots* (USACE 2006) *Pre-Design Investigation and Final Status Survey Evaluation for the Accessible Soils within the St. Louis Downtown Site Vicinity Properties DT-35 and DT-36* (USACE 2009b) *Post-Remedial Action Report and Final Status Survey Evaluation for the Accessible Soils within the St. Louis Downtown Site Vicinity Property Thomas and Proetz Lumber Company (DT-10)* (USACE 2010a)

Data collected from pre-design investigations (PDIs) and final status surveys (FSSs) conducted as part of the remediation activities for accessible soil also yielded characterization data useful in determining potentially contaminated inaccessible soil areas or structures. Ongoing work at the accessible portions of the SLDS under the authority of the 1998 ROD continues to yield new data that is relevant to the ISOU. Ongoing investigations have been used to supplement and/or modify RI sampling, as appropriate. This report captures the data collected up to June 15, 2011, and considers all areas in the typical inaccessible profile to be part of the ISOU unless specifically excluded or addressed under the 1998 ROD. Some completed PDI and final status survey evaluation (FSSE) reports are identified in Table 1-2.

1.3 REPORT ORGANIZATION

This RI was conducted in accordance with the USEPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA 1988a). Data collected as part of this RI are detailed in this report and provide a basis for defining the nature and extent of contamination. The RI data were used to perform a BRA to evaluate human health impacts from inaccessible soil, sewer sediment, soil adjacent to sewers, and buildings and other permanent structures in the ISOU. The report is organized as follows:

Section 1.0: Introduction describes the purpose of this report, as well the site background and previous characterization studies of the SLDS.

Section 2.0: Study Area Investigation includes a summary of the determination of the PCOCs originally identified in the RI WP, the completed sampling activities, descriptions of field methods used, and an evaluation of data usability.

Section 3.0: Physical Characteristics of Study Area describes the physical characteristics of the site, including geologic and hydrogeologic conditions, surface-water hydrology, ecological resources, demographics, and land use.

Section 4.0: Nature and Extent of Contamination describes the preliminary remediation goals (PRGs) used for comparisons with data; contaminant source areas; PCOCs; and the nature and extent of contamination in inaccessible soil areas, sewer sediment, soil adjacent to the sewers, and soil on buildings and other permanent structures.

Section 5.0: Contaminant Fate and Transport introduces the conceptual site model (CSM) as it pertains to source release mechanisms and environmental transport pathways under current ISOU conditions. This section also describes PCOC-specific contaminant mobility and persistence characteristics.

Section 6.0: Baseline Risk Assessment summarizes the human health risk assessment (HHRA) and Screening Level Ecological Risk Assessment (SLERA). The detailed BRA is presented in Appendix K.

Section 7.0: Summary and Conclusions includes a summary of site conditions for the ISOU, including identification of contaminants of potential concern (COPCs) (i.e., one or more contaminants found on, in or under a property that exceeds the initial site condition standards for the property) and the estimation of the nature and extent of the COPCs. This section also summarizes the HHRA and SLERA, describes data limitations, and defines potential remedial action objectives (RAOs) for the ISOU.

Section 8.0: References

2.0 STUDY AREA INVESTIGATION

This section summarizes the RI field investigation activities conducted to fill data needs identified in the RI WP. The RI methodology presented in the RI WP was developed using the USEPA's seven-step data quality objective (DQO) process as outlined in the *Guidance on Systematic Planning Using the Data Quality Objectives Process* (USEPA 2006) to ensure defensible data was obtained to evaluate the risk associated with the ISOU media.

2.1 POTENTIAL CONTAMINANTS OF CONCERN

The purpose of the RI is to define the nature and extent of MED/AEC soil contamination present in the ISOU media. Due to the history and diverse nature of the industries located at and surrounding the SLDS, many of the organic and non-radioactive inorganic chemicals detected during the previous characterization activities cannot be attributed to one source, industry, or event. A review of the past uranium processing activities at the SLDS indicated that chemical contamination consists primarily of elemental metals (USACE 1998b). The constituents that were evaluated in the 1993 BRA are those that the DOE is responsible for addressing during the remedial process. The 1993 BRA states: "*Such responsibilities are limited to all radioactive and nonradioactive contamination at the SLDS, [St. Louis Airport Site] SLAPS, and Latty Avenue Properties and their related vicinity properties that is associated with the original processes conducted at the SLDS under the MED/AEC programs. In addition, DOE is responsible for any other chemical (nonradioactive) contamination, not related to the process, that is commingled with identified radioactive wastes.*" The source of metals contamination has not been established and any analysis of the risk of those metals is only to establish site risk and should not be taken as an admission by the USACE that such metal contamination was caused by the DOE or the U.S. Government.

The 1993 BRA used the concentrations and distribution of potential radiological and chemical contaminants identified as being within the scope of MED/AEC to characterize the risks associated with the SLS, including the SLDS. The 1993 BRA concluded that the radionuclides of concern are those found in the U-238, Th-232, and U-235 decay series – primarily U-238, Ra-226, Th-230, lead (Pb)-210, Ac-227 and Pa-231. The 1993 BRA estimated that CRs to receptors from exposures to radioactive contaminants at the SLDS exceeded the USEPA's target CR range for most current industrial land use and all future land use scenarios evaluated (DOE 1993).

Chemical constituents in soil, sediment, and ground water evaluated for carcinogenic and non-carcinogenic risk in the 1993 BRA (DOE 1993) included volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), metals, and inorganic anions. Risk characterization tables in the 1993 BRA show that carcinogenic risks and/or non-carcinogenic hazard quotients (HQs) exceeded the USEPA's *de minimus* criteria of 1.0E-06 and 1.0, respectively, for each of the following contaminants: antimony, arsenic, beryllium, nickel, thallium, and polycyclic aromatic hydrocarbons (PAHs). During the 1998 FS, further evaluation of COCs for the SLDS was conducted. The 1998 FS evaluation concluded that, although thallium and PAHs were previously identified as PCOCs, these substances are not attributable to MED/AEC operations (USACE 1998b). The list of metals for soil was further refined to include only arsenic, cadmium, and uranium metal. Copper and nickel were eliminated during additional evaluations due to the low concentrations, distribution, and toxicity (USACE 1998a).

2.1.1 Inaccessible Soil Potential Contaminants of Concern

The inaccessible soil PCOCs selected as the starting point for the ISOU RI were those radionuclides and metals identified as COCs in the 1998 ROD (i.e., the primary radioactive contaminants in soil and sediment at the SLDS including Ac-227, Pa-231, Ra-226, Ra-228, Th-228, Th-230, Th-232, U-235, and U-238, and the metal contaminants including arsenic, cadmium, and uranium metal) (USACE 1998a).

The derivation of chemical contaminants potentially attributable to MED/AEC operations indicated that chemical contamination consists primarily of elemental metal compounds resulting from uranium-ore processing operations in specific areas of the SLDS (USACE 1998b). The plant properties within the boundary where the uranium-ore processing was conducted by MED/AEC are Plant 2, Plant 6, and Plants 7N and 7S (Figure 1-2). Some VPs that are adjacent to these plant areas were also included in the MED/AEC uranium-ore processing area due to potential migration of contaminants. These VPs include DT-10, portions of DT-9 between Plants 2 and 6, portions of DT-12 adjacent to Plants 6 and 7, portions of Destrehan Street adjacent to Plants 2 and 6 and Plants 7N and 7S, Hall Street between Plants 2 and 6, and portions of Mallinckrodt Street adjacent to Plant 2 (Figure 1-2). All other plant properties and VPs are outside of the uranium-ore processing area and, therefore, only have radiological PCOCs.

The same radiological PCOCs for soils are being evaluated for the building and structural surfaces. The 1993 BRA stated that chemical contaminants were not applicable to building surfaces; therefore, there are no metals PCOCs for building and structural surfaces (DOE 1993).

The list of PCOCs for the ISOU soil was defined as those radiological and chemical contaminants identified as being attributable to MED/AEC contamination, as shown in Table 2-1.

Table 2-1. Potential Contaminants of Concern for Soil in the Inaccessible Soil Operable Unit

Chemical Constituents [a]	Radiological Constituents
Arsenic	Ac-227
Cadmium	Pa-231
Uranium metal	Ra-226
	Ra-228
	Th-228
	Th-230
	Th-232
	U-235
	U-238

[a] Applicable to soil in the uranium-ore processing area: Plants 2, 6, and 7; DT-10; and portions of DT-9, DT-12, Hall Street, Mallinckrodt Street, and Destrehan Street (USACE 1998a).

2.1.2 Sewer Sediment and Soil Adjacent to Sewers Potential Contaminants of Concern

The same radiological PCOCs for soils are being evaluated for sediment in sewers used for MED/AEC operations, as well as the soil adjacent to those sewers. Additionally, sewer sediment and soil adjacent to sewers used for MED/AEC operations were not analyzed for metals during past investigations; therefore, all metals associated with formerly used pitchblende and domestic ores were identified as PCOCs for sampling and analysis of sediment and soil adjacent to sewers (See Table 2-2). These metals include arsenic, cadmium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, thorium-metal, uranium-metal, vanadium, and zinc. However, manganese, molybdenum, and vanadium do not meet the USEPA's National Oil and Hazardous

Substances Pollution Contingency Plan (NCP) (USEPA 1990) definition of a pollutant or contaminant.

The list of PCOCs for the ISOU sewer sediment and soil adjacent to sewers was defined as those radiological and chemical contaminants identified as being attributable to MED/AEC contamination, as shown in Table 2-2.

Table 2-2. Potential Contaminants of Concern for Sewer Sediment and Soil Adjacent to Sewers in the Inaccessible Soil Operable Unit

Chemical Constituents	Radiological Constituents
Arsenic	Ac-227
Cadmium	Pa-231
Cobalt	Ra-226
Copper	Ra-228
Lead	Th-228
Manganese	Th-230
Molybdenum	Th-232
Nickel	U-235
Selenium	U-238
Thorium metal	
Uranium metal	
Vanadium	
Zinc	

Note: Sewer sediment and soil adjacent to sewers had not been characterized for metals; therefore, all metals associated with pitchblende and domestic ores used in the former MED/AEC uranium-ore processing operations (DOE 1993) were identified as PCOCs in sewer sediment and soil adjacent to sewers.

2.2 SUMMARY OF REMEDIAL INVESTIGATION ACTIVITIES

RI sampling began in June 2009 and ended in August 2010 with the majority of work being completed between October 2009 and May 2010. The data collected, as well as data from previous characterizations and ongoing actions under the 1998 ROD, were used to evaluate the nature and extent of MED/AEC contamination in ISOU media of concern (Section 4.0), to identify contaminant ISOU-specific fate and transport mechanisms (Section 5.0), and to determine COPCs for the BRA (Section 6.0 and Appendix K).

The specific survey and sampling activities conducted and methods used during the RI are as listed below and discussed in this section:

- inaccessible soil investigations beneath buildings, structures, RRs, and roads (Section 2.2.1);
- building and structure radiological surveys (Section 2.2.2);
- sewer sediment and soil adjacent to sewers investigations (Section 2.2.3);
- quality assurance (QA)/quality control (QC) sampling and analysis (Section 2.2.4);
- equipment decontamination (Section 2.2.5);
- management of investigation-derived waste (IDW) (Section 2.2.6); and
- data validation and quality assessment (Section 2.2.7).

2.2.1 Inaccessible Soil Investigations

Soil sampling was conducted in the inaccessible soil areas to determine the extent of contamination of the PCOCs. Field soil sampling activities were conducted in accordance with the methods and procedures specified in the RI WP (USACE 2009a) and described below.

The horizontal boundaries for an inaccessible soil area associated with a structure are defined by the footprint of the structure. The footprint typically includes the area directly beneath the structure as well as an area surrounding the structure extending a minimum of 5 ft outward from the foundation (USACE 1999b) (Figure 2-1). Inaccessible areas associated with structures also include additional supporting soil extending outward beyond this 5-ft buffer zone at a slope that is determined based on soil properties and on site-specific engineering and safety concerns. The areas beyond the 5-ft buffer zone were investigated under the 1998 ROD. Therefore, for the purposes of this investigation, the initial boundaries for inaccessible soil areas associated with a structure were limited to the areas directly beneath the structure and the 5-ft buffer zone extending outward from the foundation.

The typical horizontal boundary for inaccessible soil beneath or adjacent to a roadway is defined as the roadway and its associated ROW extending 5 ft from the edge of the pavement (USACE 1999b) (Figure 2-2). Any additional inaccessible soil extending outward beyond the 5-ft buffer zone was not included in the investigation because it was characterized under the 1998 ROD. Therefore, for the purposes of this investigation, the initial boundaries for inaccessible soil areas associated with roadways were limited to the areas directly beneath the roadway and the 5-ft buffer zone.

The typical horizontal boundary for inaccessible soil beneath or adjacent to a RR track is defined as the area that includes the track and the associated RR ROW extending a distance of 10 ft from the outermost rail of the track (USACE 1999b) (Figure 2-3). Any additional inaccessible soil extending outward beyond the 10-ft buffer zone was not included in the investigation because it was characterized under the 1998 ROD. Therefore, for the purposes of this investigation, the initial boundaries for inaccessible soil areas associated with the RRs were limited to the areas directly beneath the RR tracks and the 10-ft buffer zone.

Gamma walkover surveys (GWSs) were conducted to identify elevated gamma radioactivity in soil beneath or associated with buildings, structures, roads, and RRs for potential biased soil sampling locations. GWSs were performed using a Ludlum Model 44-10 2 × 2 sodium-iodide (NaI) detector coupled with a global positioning system (GPS) when possible. GPS units have limited effectiveness inside or around structures due to satellite signal interference. In these situations, the GWS readings were recorded manually on paper survey forms.

GWS coverage was approximately 50 to 100 percent of the footprint of buildings or other permanent structures (e.g., roadway and RR). Typically, 100 percent coverage of the ground floor was attempted within buildings. However, coverage was sometimes affected by interferences (i.e., equipment, piping, materials, walls, etc.). Granite, brick, ceramics, and some concrete exhibit naturally occurring elevated radioactivity; therefore, the nature of the construction materials was considered when interpreting GWS results. The ambient background for each survey area was determined at the start of the survey, and locations exhibiting activity 1.5 times or higher above background were further investigated and, if appropriate, sampled.

GWSs have limitations due to gamma ray attenuation in areas covered by concrete floor slabs, roadway materials, and gravel. The effectiveness of the GWSs to detect gamma activity under consolidated material depends on the type of consolidated material, the thickness of the material, the radionuclides present, and radionuclide concentrations. Despite these limitations, GWSs are still useful in detecting elevated gamma activity underlying concrete, roadway materials, and gravel.

Soil investigations consisted of surface (typically within the first 0.5 ft below ground cover) and subsurface soil sampling for radiological and chemical PCOCs. All soil samples were analyzed for radionuclides (Ac-227, Pa-231, Ra-226, Ra-228, Th-228, Th-230, Th-232, U-235, and U-238), and soil samples from some locations inside the uranium-ore processing area were analyzed for metals (arsenic, cadmium, and uranium metal).

Soil investigations for radiological assessment were conducted at random, biased, and systematic soil sampling locations. Biased samples were collected at specific areas determined to have a greater likelihood of exceeding the PRG or at areas adjacent to remediated soil areas. Biased samples were also collected at locations where GWS measurements or scans were shown to be elevated above background. The soil sampling locations for metal PCOCs (arsenic, cadmium, and uranium metal) were selected from the biased radiological soil sampling locations.

Systematic samples for radiological PCOCs were collected at potentially contaminated inaccessible soil areas using uniform grid spacing. Random sampling for radiological PCOCs was conducted at inaccessible soil areas unlikely to be contaminated to provide reasonable assurance that an area has been sufficiently characterized. Systematic or random sampling for metal PCOCs was not completed, because it was expected that areas slated for biased sampling would best characterize any metal contaminants, because metals have predominantly been found commingled with higher concentrations of radiological PCOCs in the accessible portions of the SLDS.

Northing and easting coordinates for the sampling locations were determined using geographic information system (GIS) software and then located in the field using hand-held GPS units when possible. Sample locations inside structures were located by measuring from features (e.g., corners, doorways, etc.). Proposed sample locations were modified, if necessary, based on field conditions that would prevent effective sampling in the proposed locations (e.g., areas with access constraints).

Utility clearance was necessary prior to soil sampling. Prior to initiating soil sampling, available utility maps and historical data were reviewed to help identify utility lines. In the field, the proposed sampling locations were inspected for potential utility impacts. Determination of utility locations in public utility easements was performed through the Missouri "One-Call" system. The locations of overhead and underground utilities were identified, and the locations of the underground utilities were marked on the ground surface. If necessary, the proposed RI WP sample locations were moved a minimal distance to avoid utilities. Once the soil boring locations were determined to be clear of utilities, sampling activities began. In addition, modifications to the proposed sampling locations were necessary when auger refusal occurred prior to reaching the proposed sampling depth. Sampling locations where auger refusal occurred were relocated a minimal distance to ensure that relocation did not impact the intended sampling purpose.

Soil samples were primarily collected utilizing a drill rig with hollow stem augers and a split-spoon soil sampler. In areas that the drill rig could not access (e.g., inside buildings, areas with low overhead clearance), an electric coring machine was utilized to remove cover material (e.g., concrete, asphalt) and hand augers were used to collect soil samples. Surface soil sampling was initiated in the uppermost soil layer below any gravel material located beneath consolidated material (i.e., asphalt or concrete). Sampling began by removing a soil column of approximately 1.5 to 2.0 ft below original grade at the sampling location, with two samples collected from this initial soil column. The first sample (i.e., surface soil sample) was taken within the first 0.5 ft of the uppermost soil layer below any consolidated material and associated gravel. The second sample (i.e., subsurface soil sample) was collected from a 0.5-ft interval of the remaining column at the depth that exhibited the greatest radioactivity determined by using a NaI gamma radiation detector or instrument of equal or greater sensitivity. If the soil column exhibited a relatively uniform count rate, the subsurface sample was collected from the deepest 0.5-ft interval of the column. Subsurface sampling continued by removing subsequent soil columns of approximately 2 ft in length until a total minimum depth of 6 ft below original grade was obtained and radioactivity readings were at or near background. A subsurface soil sample was collected from the 0.5-ft interval that exhibited the greatest radioactivity within each 2-ft soil column as determined by using a NaI gamma radiation detector or instrument of equal or greater sensitivity. As noted above for the initial soil column, any subsequent subsurface sample was collected from the deepest 0.5-ft interval of a soil column if the soil column exhibited a relatively uniform gamma radiation count rate. Greater depths were sampled for specific VPs or plant areas as defined in the RI WP or if elevated readings were obtained at the deepest planned sampling depth. Samples for metals analysis were collected from the same 0.5-ft interval of soil from which a radiological sample was collected.

Samples were placed in a stainless steel bowl and were homogenized using a stainless steel spoon, spatula, or trowel prior to filling the sample container(s). Excess sample material was disposed of as IDW. Samples were logged and described in accordance with the Unified Soil Classification System (USCS) by a geologist, geotechnical engineer, or soil scientist. Sample containers were sealed and labeled and placed into coolers or other containers until delivered to the laboratory. Proper chain-of-custody documentation was kept with the samples. Copies of the soil boring logs for each sampling location are provided in Appendix A.

Industry-standard surveying equipment then was used to measure the as-built coordinates and the corresponding ground surface elevations for each sampling location.

The base reference for surveying coordinates for each sample location was a local, USACE-established, SLDS benchmark. The coordinate and elevation data for the SLDS benchmark and each sample location are referenced to the Missouri State Plane Coordinate System, the North American Datum of 1983, and the North American Vertical Datum of 1988.

Table 2-3 summarizes the number of locations and type of samples collected for evaluation of inaccessible soil by plant area or VP. Soil sampling results are discussed in Section 4.2.

2.2.2 Buildings and Structures Investigations

In accordance with the RI WP (USACE 2009a), building and structure surfaces (i.e., interior, exterior, and roof) were designated for a scoping survey based on a preliminary assessment that included evaluating previous data collected on the structure, the construction date, use of the structure, the proximity of the structure to MED/AEC processing operations, and the proximity to remediated accessible soil areas. Radiological surveys included scanning for total alpha and beta surface activity and fixed-point measurements for total alpha and beta surface activity using portable radiological survey equipment. Building surveys began in September 2009 and were completed in August 2010.

Table 2-3 summarizes the number of buildings and surfaces surveyed by plant area or VP. Results of the radiological investigation of buildings/structures are discussed in Section 4.3.

Building and structure surfaces that were surveyed included, but were not limited to, roofs, exposed exterior and interior surfaces, air vents, vertical and horizontal piping, and piping supports. The scoping surveys were biased, focusing on areas that are prone to accumulate contamination such as horizontal surfaces, depressions, cracked surfaces, rusted or unpainted surfaces, intake and exhaust vents, etc. While in the field, professional judgment also was used to select biased survey locations. The surfaces scanned were defined by the dimensions of each individual building or structure. Generally, 10 to 20 percent of each building or structure surface was scanned. The scoping surveys were conducted in accordance with the *Final Status Survey Plan for Structures and Other Consolidated Material Left in Place at the St. Louis Site* (USACE 2003) (hereafter referred to as the Final Status Survey Plan [FSSP] for Structures).

Table 2-3. Remedial Investigation Characterization Activities by Sample Media and Number of Sampling Locations

Property Area	Number of Inaccessible Soil Sampling Locations			Number of Building Surfaces Surveyed			Number of Sewer Sampling Locations	
	Systematic or Random Sampling	Biased Soil Sampling	GWS at Building, Roadway, or RR	Interior	Exterior	Rooftop	Sediment Sampling	Adjacent Soil Sampling
Plant 1	16	30	12	17	20	15	11	17
Plant 2	13	14	6	6	6	2	10	5
Plant 6	0	7	0	1	1	0	3	2[c]
Plant 7N and 7S	0	1	0	No buildings[a]			1	1[c]
Plant 10	Out of scope; previously remediated						Non-impacted[b]	
Mallinckrodt West Properties (Plants 3, 8, 9, and 11 and parking lots)	0	2	0	0	7	4	Non-impacted[b]	
Mallinckrodt Security Gate 49 Area	0	2	1	Non-impacted[b]			No sewers present	
DT-2	10	7	0	No buildings			0	0[c]
DT-4 North	15	23	4	3	5	3	No sewers present	
DT-4 South	Non-impacted[b]			Non-impacted[b]			Non-impacted[b]	
DT-6	14	10	2	2	2	1	No sewers present	
DT-8	41	8	9	5	6	1	0	3
DT-10	8	4	2	6	7	2	No sewers present	
DT-11	Included in roadways			No buildings; structures non-impacted[b]			1	0
DT-15	4	0	1	Non-impacted			Location identified with DT-8	
DT-29	Non-impacted[b]			Non-impacted[b]			Non-impacted[b]	
DT-34	Non-impacted[b]			Non-impacted[b]			Non-impacted[b]	
South of Angelrodt Property Group	Non-impacted[b]			0	1	1	Non-impacted[b]	
West of Broadway Property Group	Non-impacted[b]			0	5	5	Non-impacted[b]	
DT-3	70	10	1	No buildings; sewers addressed with property areas				
DT-9	127	17	3	No buildings; sewers addressed with property areas				
Terminal RR Soil Spoils Area	7	0	1	No buildings			Non-impacted[b]	
DT-12	165	7	1	No buildings; sewers addressed with property areas				
Roadways	83	45	8	No buildings; sewers addressed with property areas				
Background Locations (sewers)	NA			NA			11	0
Total Sample Locations	**573**	**187**	**51**	**40**	**60**	**34**	**37**	**28**

[a] The Hazardous Waste Storage Area at Plant 7N was dismantled in 2010.

[b] The specific media (inaccessible soil, sewers, or buildings) at the property were previously determined to be non-impacted as documented in the RI WP; therefore, no RI sampling was conducted.

[c] Excavation sidewall samples adjacent to sewers were collected for this area during remediation activities conducted under the 1998 ROD.

NA = Not applicable.

A Ludlum Model 2360 coupled with a Ludlum 43-89 (zinc sulfide plastic scintillator) or equivalent was used to perform the alpha and beta scans. Prior to performing field measurements, the detection sensitivity of the equipment was calculated to ensure that levels were below the RI WP screening level. Methods for evaluating this detection sensitivity are provided in the FSSP for Structures (USACE 2003). A minimum of 10 fixed data points were collected on structures identified as impacted by MED/AEC-related contaminants. The scan speed with these detectors was approximately 1 to 2 inches per second. Distance from the detector probe to the scanned surface was approximately 0.25 inches. Instrument response was monitored continuously during scanning through use of the audible instrument signal.

Scoping surveys were conducted from the ground level to the roof line to get representative data on exterior building surfaces. A manlift, capable of reaching 60 ft in height, was utilized for exterior building and roof surveys. Reasonable efforts were made to scan locations where safety considerations or other restrictions prevented access. These areas included those obstructed by overhead piping or utilities and those areas/surfaces (i.e., roofs) that would not safely support access. These areas were minimal and did not jeopardize the objective of the scoping survey.

Total alpha and beta surface activity (fixed-point) measurements were obtained from areas exhibiting elevated count rates. Fixed-point gross alpha and beta activity measurements were made with a 1-minute static count. The surface activity measurements for both alpha and beta were recorded in counts per minute (cpm), which, along with the appropriate instrument geometry, instrument background, instrument efficiency (ε_i), and surface efficiency (ε_s), was used to convert the data to disintegrations per minute per 100 square centimeters (dpm/100 cm^2), in accordance with the FSSP for Structures (USACE 2003), for comparison to the screening levels. The following equation was used to convert the data recorded in cpm to dpm/100 cm^2.

$$Result \left(\frac{dpm}{100\ cm^2} \right) = \frac{R_g - R_b}{(\varepsilon_i)(\varepsilon_s)(Probe\ Area/100\ )}$$

where:

R_g is the static data point gross count rate (cpm)
R_b is the field background count rate (cpm)
ε_i is the instrument efficiency (cpm/dpm)
ε_s is the surface efficiency
Probe Area is the open area of the detector face (square centimeters [cm^2])

Building materials, such as granite, brick, ceramics, and some concrete, exhibit alpha and beta activity above area background levels due to naturally occurring radioactivity. Portions of many of the buildings were constructed with materials that contain NORM. The construction material exhibiting the greatest alpha and beta activity from NORM was brown clay/ceramic brick-caps, due to the glaze used on such caps (NCRP 1995, NIST 2000). The average alpha activity detected on clay/ceramic brick-caps from three properties (DT-21, DT-22, and DT-25) west of North Broadway is approximately 1,900 dpm/100 cm^2. As a conservative assumption, 50 percent of this value (i.e., 950 dpm/100 cm^2) was attributed to naturally occurring radioactivity for the clay/ceramic brick-caps surveyed during the RI. Except for the clay/ceramic brick-caps measurements, the scoping survey results do not take into account the naturally occurring radioactivity of the various building materials.

2.2.3 Sewer Investigations

The objectives of sewer sampling were to obtain sufficient and representative data to determine the extent of MED/AEC contamination associated with sewers (i.e., interior sediment and surrounding soil) and to evaluate potential contaminant migration pathways associated with sewers.

During MED/AEC operations, most process, storm, and sanitary effluents for Mallinckrodt were collected in a combined sewer system. The sewer system consists of the following types of structures, listed in the direction of flow: (1) individual building drains (usually with diameters of 2 to 4 inches) that discharge into (2) building sewers (typically with diameters of 4 to 6 inches) that empty into (3) lateral sewers that feed into (4) mains, and then discharge to (5) trunk lines and interceptor sewers. Effluent entered the combined system from the MED/AEC areas and passed through the system, ultimately discharging to the Mississippi River (prior to December 1970). Currently, sewer flow from the SLDS discharges to the MSD Bissell Point Treatment Plant. Additional components of the sewer system include manholes, curb drains, surface drains, and sumps. Sewers at the Mallinckrodt property were predominantly constructed from VCP and vitrified brick sealed with bituminous tar or cementitious materials, but portions of the plumbing system (i.e., smaller diameter pipes within buildings that drain to the sewer) could have had lead as a component. Lead pipes and/or lead-based solder at piping connections are often found in older buildings (MDNR 2010). The bedding material commonly used during this era was granulated rock material, but some sewers may have been constructed without any bedding material (BNI 1990b).

Table 2-3 summarizes the number of samples of sewer sediment and of soil adjacent to sewers collected by plant area or VP. These areas include sewers that were used for MED/AEC operations or that were located downstream of areas where MED/AEC operations were conducted, based on available data concerning sewer flow directions. In addition to the sampling locations at the plant areas and VPs, sediment sampling was conducted in manholes located upstream (west) of the Mallinckrodt facility to provide background data for comparison. In general, the samples of sewer sediment and soil adjacent to sewers collected during the RI were analyzed for 9 radionuclide PCOCs and 12 metal PCOCs identified in Section 2.1. However, at those sampling locations where insufficient sediment was found to conduct both analyses, only the radionuclide analysis was conducted. RI field tasks for the sewers were initiated in December 2009 and completed in August 2010. The results of the sewer sampling are summarized in Section 4.4.

2.2.3.1 Manhole Sediment Sampling

Sediment sampling activities for the sewers began in December 2009, and were completed in January 2010. Sediment sampling was conducted in manholes and surface drains. All sewer field activities were completed from the ground surface (i.e., no sewers were entered due to confined space safety concerns). Before sampling activities began, manhole covers and grates were removed to inspect their integrity. Each manhole cover or surface drain grate was removed and photographs were then taken. Photographs were taken inside and outside the manhole to document the condition of the manhole and any visible portions of adjoining sewer lines. When visible, the depths to the flowlines of adjoining pipes were measured. If standing water was present, that depth to water in the sewer was also measured.

The thickness of sediment was measured to determine if sufficient volume was present for collection and analysis. If sufficient volume was not present, an attempt was made to collect samples from the nearest alternate location along the same sewer line. If the sample was within reach, a stainless steel scoop, spoon, or trowel was used to collect the sample. If the sample was not within reach, a sampling device (scoop or similar device) was mounted to an extendable handle to collect loose sediment, or a stainless steel hand auger with extensions was used to collect consolidated sediment. All samples were field-screened for organics using a photoionization detector (PID) or similar device and for external radiation using a NaI gamma radiation detector or instrument of equal or greater sensitivity.

Sediment samples were placed in a stainless steel bowl and free-standing water was drained. Each sample was homogenized by mixing it with a stainless steel spoon, spatula, or trowel prior to filling the sample container(s). Excess sample material was returned to the point of origin from which it was collected. Sediment samples were described in accordance with the USCS. Samples were labeled and kept chilled in coolers until delivered to the laboratory. Proper chain-of-custody documentation was kept with the samples.

Field activities were conducted in accordance with the methods and procedures specified in the RI WP (USACE 2009a) as described above. However, some field changes and/or additions to the proposed sampling locations originally identified in the RI WP were necessary based on information obtained during the field investigation. Some of the proposed manhole sampling locations were not sampled due to access problems (e.g., manhole cover or grate was covered or sealed closed), the lack of adequate volume of sediment required for analysis, or other site conditions (e.g., the presence of sanitary effluent). In these cases, the closest accessible manhole or surface drain was sampled to minimize any impact to the intended sampling purpose. The number of background sewer sediment sampling locations also was increased to provide a more statistically robust background dataset.

Other related field tasks, including surveying soil boring locations, decontaminating equipment, and managing IDW, were completed as discussed in Sections 2.2.1, 2.2.5, and 2.2.6, respectively. Sediment lithologic descriptions, field measurements, and other relevant information were recorded on sewer sediment manhole logs provided in Appendix A.

2.2.3.2 Soil Boring Sampling Adjacent to Sewers

The soil boring sampling approach for sewers was based on available information concerning the operational history of the sewers and the surrounding areas, available sewer maps, and historical analytical manhole sediment data for the SLDS. The borings were located adjacent to representative sections of sewer pipe, as well as adjacent to areas of the pipe where leakage was suspected based on historical maps. Consistent with the RI WP, the soil borings were drilled within a horizontal distance of approximately 2 ft of the sewer lines to get sufficiently close to sample the surrounding soil while also maintaining an adequate distance from the sewer lines to ensure the sewer line was not punctured.

Prior to soil sampling adjacent to the sewers, determination of utility locations was performed in the same manner as for soil borings. Drilling activities for the soil borings located adjacent to sewers began in February 2010 and were completed in July 2010.

Some modifications were made to the soil sampling approach outlined in the RI WP based on field conditions that would prevent effective sampling in the proposed locations (e.g., access constraints and the presence of utilities). The RI WP specified that a minimum of two soil samples would be collected from each boring at depth intervals of 0 to 2 ft and 2 to 4 ft beneath the base of the sewer line. Based on site conditions, three, rather than two, soil samples were collected from each boring to compensate for uncertainties concerning the depths of the sewer pipes. The additional soil sample was collected at an estimated depth interval from 2 ft above the base of the pipe to the base of the pipe. When the results of field screening indicated the presence of significant concentrations of radionuclides in the deepest sample, additional samples were collected from the underlying soil to bound the vertical extent of contamination.

Samples were placed in a stainless steel bowl and were homogenized by mixing with a stainless steel spoon, spatula, or trowel prior to filling the sample container(s). Excess sample material was disposed of as IDW. Samples were logged and described in accordance with the USCS by a geologist, geotechnical engineer, or soil scientist. Sample containers were sealed and labeled and placed in coolers or other containers until delivered to the laboratory. Proper chain-of-custody documentation was kept with the samples. Copies of the soil adjacent to sewers boring logs for each sampling location are provided in Appendix A.

2.2.4 Quality Assurance/Quality Control Sampling and Analysis

During RI characterization, QA/QC sampling and laboratory analysis activities were conducted in accordance with the performance criteria and QA objectives that were established in the RI WP (USACE 2009a), and that are presented in the bulleted items below. The QA/QC sample results are documented in the Quality Control Summary Report (QCSR) contained in Appendix B.

- Duplicate and split samples were each collected at a rate of approximately 5 percent for field and laboratory QC purposes.
- Precision is the degree to which the analytical result for a sample can be reproduced during separate measurements. Precision was determined by the collection of a parent sample along with a split sample and a duplicate sample. The acceptable relative percent difference (RPD) between a parent and duplicate samples or parent and split samples was 50 percent or less. The objective applied for the RPD when reported results are greater than five times their minimum detectable concentrations was 50 percent. If radiological sample results are less than five times their respective minimum detectable concentrations, then the normalized absolute difference (NAD) was used with the objective being an NAD less than 1.96.
- Accuracy provides a gauge or measure of the agreement between an observed result and the true value for an analysis. For this report, accuracy is measured through the use of the field split soil samples through a comparison of the prime laboratory results versus the results of an independent laboratory.
- Representativeness and comparability were used to ensure that the samples represent a characteristic of the location sampled and are assured through the selection and proper implementation of systematic sampling and measurement techniques, as well as compliance with analytical methods and sample hold times.
- Completeness refers to the portion of the data that meets acceptance criteria and is, therefore, usable for statistical testing and risk assessment. The objective applied for this RI was 90 percent.

The QA/QC samples included field duplicate samples and split samples collected and analyzed at a targeted frequency of 5 percent of the number of prime samples analyzed per environmental medium. Soil and sediment samples collected for radiological analyses were submitted to the USACE FUSRAP laboratory located in St. Louis, Missouri. Prime radiological samples analyzed by the USACE FUSRAP laboratory were split with TestAmerica in St. Louis, Missouri. Soil and sediment samples submitted for chemical analyses were sent to TestAmerica in St. Louis, Missouri. Prime chemical samples analyzed by TestAmerica were split with RTI Laboratories.

Laboratory analyses were conducted in accordance with the *Quality Assurance Project Plan for the St. Louis Airport and Downtown Sites* (USACE 1998c) (hereafter referred to as the QAPP).

2.2.5 Equipment Decontamination

Decontamination procedures were completed based on whether the type of sampling performed was for chemical or radiological laboratory analyses. For the purposes of this report, chemical sampling refers to the sampling of soil or sediment for chemical analysis (i.e., laboratory analysis for the metal PCOCs identified for inaccessible soil, soil adjacent to sewers, and sewer sediment). Radiological sampling refers to the sampling of soil or sediment for radiological analysis (i.e., laboratory analysis for the radiological PCOCs identified for inaccessible soil, soil adjacent to sewers, and sewer sediment). Small, reusable sampling equipment used for sampling media for chemical analysis was washed with phosphate-free detergent and tap water to remove visible contamination. The equipment was then rinsed with tap water, then alcohol, followed by a de-ionized water rinse. Equipment was air dried and wrapped in aluminum foil until additional sampling occurred.

Small, reusable equipment used for sampling media for radiological analysis was washed with phosphate-free detergent and water to remove visible soil from equipment. The equipment was then rinsed with tap water and allowed to air dry.

Following decontamination, all equipment was surveyed for radiological contaminants prior to release for unrestricted use. Equipment leaving the site for unrestricted use had alpha contamination levels at or below 100 dpm/100 cm^2 total average activity and 20 dpm/100 cm^2 removable activity.

Larger pieces of equipment, such as drill rigs, were decontaminated with pressurized hot water/steam as necessary. Steps were taken to assure that contamination did not spread to previously uncontaminated areas during the transport of sampling and other equipment. Any equipment deemed to be heavily contaminated was decontaminated in the immediate area of the sample collection or was wrapped in plastic prior to transit to a decontamination area.

2.2.6 Management of Investigation-Derived Waste

IDW included surplus soil from subsurface investigations, decontamination fluids, disposable sampling equipment, and personal protective equipment. During the RI sampling, efforts were made to minimize the volume of waste derived from sampling and decontamination procedures and to dispose of IDW in bulk, along with other wastes that may be generated during accessible soil remedial actions. Waste generated during field activities was drummed in 55-gallon containers at the site for disposal by the USACE. The drums of IDW were properly labeled with information including the waste generator, contact information, date of generation, contents, and potential health and safety hazards.

IDW generated during RI activities was taken to a USACE-approved location for staging and/or treatment prior to waste characterization and disposition. IDW was managed, stored, transported, and disposed in accordance with the *Sampling and Analysis Guide for the St. Louis Site, St. Louis, Missouri* (USACE 2000) (hereafter referred to as the Sampling and Analysis Guide [SAG]) and MDNR, USEPA, and U.S. Department of Transportation (DOT) regulations. In addition, the IDW disposal complied with the federal and/or state regulations applicable to the disposal facility.

2.2.7 Data Validation and Quality Assessment

Radiological data generated by the USACE FUSRAP laboratory and chemical data generated by TestAmerica in St. Louis, Missouri, were validated at a rate of 5 percent in accordance with the SAG and the RI WP. Data verification was performed on the remainder of all data from each laboratory that was not validated. Split sample data generated by the USACE's QA laboratory were verified before inclusion in the QCSR (Appendix B). Validations and verifications were performed electronically using the FUSRAP St. Louis Data and Environmental Information Management System, in which analytical qualifiers denoting data usability were applied based on comparisons to acceptance criteria established for checklist items presented in the QAPP. Reason codes also were generated with each analytical qualifier.

Data validation reports were written for the validated radiological data from the USACE FUSRAP laboratory, and data validation checklists were completed for the validated chemical data. Additionally, data validation checklists or verification summaries for each sample delivery group have been retained with the respective laboratory data. The validation/verification checklists, data qualifiers and reason codes, radiological data validation reports, and QCSR, all provide adequate documentation of the evaluations performed for determining quality and usability of the FUSRAP data for meeting project DQOs. Appendix B of this report presents the QCSR and radiological data validation reports.

As discussed in the Data Quality Assessment Summary of the QCSR, all validated/verified data were determined to be usable, with data qualifications and reason codes being applied due to minor issues. Minor data issues resulted in the qualification of some detect and non-detect results as being estimated with appropriate USEPA qualification flags.

3.0 PHYSICAL CHARACTERISTICS OF STUDY AREA

3.1 LAND USE AND DEMOGRAPHY

The SLDS is located in the City of St. Louis, Missouri, which is bordered by the Mississippi River on the east and by St. Louis County on the north, south, and west (Figure 1-1).

Land use within a 1-mile radius of the SLDS includes a mixture of commercial, industrial, and residential uses. The largest property found within the SLDS is the 45-acre former Mallinckrodt property that is currently owned by Covidien. The Mallinckrodt property currently includes a chemical manufacturing plant, support facilities, and administrative buildings that cover a large portion of the SLDS. The remainder of the complex is covered, mostly with asphalt or concrete pavement. The Mallinckrodt property is enclosed by a maintained and patrolled security fence. The closest resident is located on North Broadway approximately 200 ft southwest of the Mallinckrodt Plant 10 property (USACE 1998a).

The VPs encompass over 165 acres of land surrounding the Mallinckrodt property with similar topography, geology, hydrogeology, and surface-water features.

According to the City of St. Louis Zoning District Map, the SLDS properties are currently zoned as either “J Industrial District” or “K Unrestricted District” (City of St. Louis 2012a). Regardless of which of these two zoning classifications the SLDS properties fall under, it appears that based on the current configuration of SLDS properties buildings, no buildings may be erected or altered for residential dwelling purposes.

According to the City of St. Louis Strategic Land Use Map, which was adopted by the City of St. Louis’ Planning Commission on January 5, 2005, all SLDS properties are listed as “Business and Industrial Preservation and Development Area” or “Business and Industrial Development Area” (City of St. Louis 2012b). The long-term plans by the City of St. Louis for the SLDS area are to retain the industrial uses, encourage the wholesale produce district, and phase out the remaining, marginal residential uses.

3.2 TOPOGRAPHY, DRAINAGE, AND SURFACE WATER

St. Louis is located in an area of gently rolling uplands that feature low hills and broad, shallow valleys that gradually flatten out to the north and east in Illinois. The hilly terrain is cut by several broad river valleys (up to 10 miles wide) with steep bluffs. The Illinois and Mississippi Rivers converge northwest of St. Louis and are joined downstream by the Missouri River from the west. Both the Mississippi and the Missouri Rivers have cut large valleys with wide floodplains. St. Louis is built on bluffs that rise above the western banks of the Mississippi River, 13 miles downstream of the Missouri River – Mississippi River confluence.

At the SLDS, surface elevations range from approximately 430 ft above mean sea level (amsl) in the southwestern part of the site to 420 ft amsl near the Mississippi River. The SLDS ground surface slopes at an average of 0.4 percent eastward toward the Mississippi River. An extensive levee system parallel to the Mississippi River has been constructed near the riverbank to protect the city from flooding. The top of the Mississippi River levee is approximately 438 ft amsl and is designed to protect against a 500-year flood event. Surface drainage is directed through ditches and catchment basins into an extensive storm drainage system that discharges to a nearby MSD sewage treatment plant (i.e., the Bissell Plant). The surface water is treated at the plant prior to discharge to the Mississippi River. Much of the SLDS area is covered with concrete or asphalt, which interferes with natural surface-water runoff and ground-water recharge mechanisms (DOE 1993). No permanent surface-water bodies exist within the boundaries of the SLDS.

The Mississippi and Missouri Rivers are the major water supply sources for the St. Louis area. All of the St. Louis area municipal water intakes are located upstream of the SLDS except for the Illinois-American Water Plant, which supplies a small percentage of the water required by the City of East St. Louis, Illinois. The Illinois-American Water Plant intake is located approximately 8 miles downstream of the SLDS on the opposite (east) bank of the Mississippi River.

3.3 SITE GEOLOGY AND HYDROGEOLOGY

A generalized stratigraphic column for the SLDS is shown on Figure 3-1. Surficial fill is present over most of the property with an average thickness of 13 ft (BNI 1994). The fill consists of brick, concrete, organic material, and coal slag with minor sand, coal ash, coal cinders, and silt. Underlying the fill, there are two depositional units that are identified based on differences in their geologic properties: an upper unit, consisting of clay and silty clay with interbedded clay, silt, and sandy silt, ranging in thickness from 10 to 17 ft; and a lower unit comprised of sandy silt, silty sand, and gravelly sand deposits ranging in thickness from 0 to 60 ft.

The uppermost bedrock unit at the SLDS is the Mississippian-age Ste. Genevieve Formation, which consists of moderately fractured limestone with some dolomite. The erosional surface of the bedrock dips eastward from a depth of approximately 19 ft below ground surface (bgs) at the western edge of the SLDS to a depth of approximately 80 ft bgs near the Mississippi River.

Ground water at the SLDS is found within the following three hydrostratigraphic units (HUs), in order of increasing depth (Figure 3-1):

- HU-A, which consists of fill and underlying fine-grained deposits (primarily silty clay, clay, and silt);
- HU-B, also referred to as the Mississippi Alluvial Aquifer, which predominantly consists of somewhat coarser-grained deposits (sandy silt, silty sand, sand, and gravelly sand); and
- HU-C, the limestone bedrock.

HU-A overlies the Mississippi Alluvial Aquifer (HU-B) on the east side of the SLDS and overlies bedrock on the western side of the SLDS. HU-A is not an aquifer and is not considered a potential source of drinking water, because it has insufficient yield and poor natural water quality. Soil boring logs and results of particle-size analysis of soil samples from various borehole locations across the SLDS indicate that HU-A contains varying amounts of clay. Clays retard the movement of radionuclides and metals by a variety of processes, including adsorption, coprecipitation, and cation exchange. As part of the characterization activities conducted between 1989 and 1993 to support the RI/BRA for the SLS, the cation exchange capacity (CEC) was measured in the upper unit. The effective CEC for the HU-A was determined to be 200 milliequivalents per 100 grams (meq/100 g) of soil (BNI 1994). Results of one variable-head permeability test conducted within HU-A provided an estimated hydraulic conductivity value of 9.9E-6 cm per second (BNI 1990a). In addition, as part of the characterization activities conducted between 1989 and 1993 to support the RI/BRA for the SLS, one silty soil sample from HU-A was analyzed to determine the soil-water partitioning coefficient (K_d) for uranium, reported at 146 milliliters per gram (mL/g).

HU-B thins westward on the bedrock surface until it becomes absent beneath the SLDS, being truncated by the rising bedrock and the overlying HU-A. HU-B is one of the principal aquifers in the St. Louis area. It qualifies as a potential source of drinking water under the *Guidelines for Ground-Water Classification under the EPA Ground-Water Protection Strategy* (USEPA 1988b). However, expected future use of HU-B as a drinking water source at the SLDS is highly unlikely for several reasons: the industrial setting, the site's proximity to the Mississippi and Missouri Rivers (i.e., major water supply sources), and the poor natural water quality of HU-B. Because ground water in HU-B is hydraulically connected to the Mississippi River, ground-water flow direction and gradient are strongly influenced by river stage. The predominant ground-water flow direction is to the east, toward the Mississippi River.

Aquifers in this region also exist in the limestone bedrock (HU-C) underlying the alluvial deposits. HU-C would be an unlikely water supply source because it is deeper and less productive.

There are no known drinking water wells in the vicinity of the SLDS. The City of St. Louis has Ordinance 66777, which explicitly forbids the installation of wells into the subsurface for the purposes of using the ground water as a potable water supply (City of St. Louis 2005). The expected future use of SLDS ground water is not anticipated to change from its current use. USACE continues to evaluate ground-water impacts beneath the SLDS under the 1998 ROD.

3.4 ECOLOGICAL AND CULTURAL RESOURCES

The SLDS is located in the Oak-Hickory-Bluestem Parkland section of the Prairie Parkland Province. Pre-settlement vegetation is characterized by deciduous woodlands intermixed with open prairie. Today, the ecological resources at the SLDS are limited because of the site's location within an urban area of concentrated industrial and commercial developments (DOE 1993). Site vegetation consists of a mixture of prairie species, disturbance-related aggressive species, and species typical to old fields, including wild carrot, aster, clover, dandelion, milkweed, ragweed, and various grasses (DOE 1993).

Vertebrate fauna of the St. Louis area consist of species that have adapted to urban encroachment, including mammals (e.g., mice, opossum, eastern cottontail rabbit, gray squirrel, and eastern mole) (DOE 1993). Birds that inhabit the urban environment include the Canada goose, rock dove, mourning dove, American crow, American robin, and Northern cardinal (DOE 1993).

No wetlands occur within the SLDS boundaries, although according to the U.S. Fish and Wildlife Service's (USFWS) National Wetlands Inventory (USFWS 2008), a portion of the area directly north of the McKinley Bridge and east of the Mississippi River levee is classified as palustrine wetlands (i.e., non-tidal wetlands that are substantially covered with emergent vegetation), which are commonly found along the Mississippi River. Based on the "Environmental Assessment for Biota" presented in the 1993 BRA, and the conclusions of the SLERA conducted as part of this RI/BRA report (Sections 6.2 and Appendix K Section 3.0), no potentially sensitive habitats for biota occur either on site or adjacent to the SLDS (DOE 1993).

Available data indicate that no archaeological sites or historic buildings lie within the SLDS boundaries and no archeological survey has been conducted at the site. Due to the intensive industrial use of the site, it is unlikely that any significant archeological sites exist at the SLDS (USACE 1998b). Two sites listed in the March 1992 edition of the National Register of Historic Places (NRHP) for the state of Missouri exist within 1 mile of the SLDS. The first site is the Bissell Street Water Tower, located northwest of the SLDS, and the second is the Murphy-Blair Historic District, located 0.5 mile southwest from the SLDS. Additionally, an official historic district (Hyde Park) is located west and northwest of the SLDS.

4.0 NATURE AND EXTENT OF CONTAMINATION

This section presents the results of the RI sampling, additional characterization data from previous investigations and relevant data collected as part of ongoing activities for soil addressed by the 1998 ROD to define the nature and extent of contamination in ISOU media. A detailed overview of each plant or property, including a property description, history of MED/AEC use, summary of previous investigations, and a review of the previously existing characterization data, is provided in the RI WP (USACE 2009a). RI sampling was conducted between June 2009 and August 2010. The data collected as part of this RI were evaluated for the PCOCs as discussed in Section 4.2. The results of the RI for inaccessible soil are presented in Section 4.2; the results of building surveys are presented in Section 4.3; and the results of the sewer investigation are presented in Section 4.4. A summary of the nature and extent of contamination is provided in Section 4.5.

4.1 DATA EVALUATION PROCESS FOR THE POTENTIAL CONTAMINANTS OF CONCERN

Inaccessible soil evaluated for nature and extent of contamination in ISOU media included data collected from the RI sampling activities, inaccessible soil data collected from previous characterization activities, and relevant data collected as part of ongoing activities for soil addressed by the 1998 ROD at the SLDS. Previous characterization activities included soil sampling at locations within the typical inaccessible soil area boundary (e.g., the building foundation and extending out 5 ft). However, data collected during pre-1990 investigations (BNI 1989c; BNI 1989e; BNI 1990a) were not included for the ISOU RI evaluation. Although the RI WP used the pre-1990 data to identify potential areas for investigation, the sampling locations were not defined according to the Missouri State Plane Coordinate System, and sampling locations could not be replicated. Therefore, for this RI report, only samples collected at locations identified to the Missouri State Plane Coordinate System were used to define nature and extent. Additionally, although historic sewer sediment data were used to define some locations for sampling in the RI WP, the data were not included in the RI evaluation of nature and extent because of the changing conditions of the sewer system under continued operational use since the historical data were collected. Historical building radiological survey data were only available for Plant 1 Building 25 and some rooftops at Plants 1 and 2 and, likewise, these data were only used for planning potential sampling locations. Only building radiological survey data collected during the RI were used to define the nature and extent of contamination on buildings.

To evaluate the nature and extent of contamination at each plant area or VP, USEPA risk-based PRGs were adopted for each PCOC in inaccessible soil, sewer sediment, and soil adjacent to sewers, while site-specific, risk-based PRGs were derived for building and structure surfaces. Risk-based PRGs provide a tool to be used by risk assessors, remedial project managers, and others involved with risk assessment and decision making at CERCLA sites. The USEPA initially provided guidance on developing and using PRGs in the *Risk Assessment Guidance for Superfund* [RAGS]: *Volume I, Human Health Evaluation Manual: Part B, Development of Risk-based Preliminary Remediation Goals* (USEPA 1991a).

Soil PRGs were obtained for the ISOU from the most recent USEPA databases available and are more health conservative than the screening levels initially proposed in the RI WP. Soil PRGs were used for evaluating sewer sediment because no established, risk based PRGs are available for sediment. As discussed in Section 4.1.2, site-specific PRGs were derived and used for evaluating interior and exterior structural surfaces. All ISOU PRGs are presented in Table 4-1. All risk-based PRGs used for evaluations of the ISOU are concentration limits that were derived using carcinogenic and non-carcinogenic toxicity values, under assumed sets of exposure conditions deemed as being most applicable to the industrial land use, receptors, exposure pathways, and environmental conditions typically encountered at the SLDS. Concentrations below PRGs are not expected to cause any health risks following exposure, assuming exposures occur in a manner consistent with the exposure assumptions used to derive the PRGs. The PRGs for the RI/BRA were used in a conservative manner, because they were applied to individual sampling results and/or locations collected during the RI rather than to upper-bound average concentrations derived for an area per USEPA methodology (e.g., the 95 percent upper confidence limit [UCL] of the arithmetic mean concentration). PCOCs detected in an ISOU medium with at least one concentration exceeding the corresponding PRGs are being retained for further quantitative evaluations in the BRA as COPCs. One set of sitewide COPCs is being identified for each ISOU medium that will be applied to all sitewide and property-specific evaluations being conducted in the BRA except for metals COPCs in inaccessible soil. The metals COPCs in inaccessible soil will be applied to the uranium-ore processing area and the individual properties in the uranium-ore processing area.

In addition to risk-based PRGs, SLDS background values (BVs) were used in the characterization of inaccessible soil, sewer sediment, and soil adjacent to sewer lines to provide a reference point for evaluating if concentrations of PCOCs are a result of historical MED/AEC releases. The BVs are also presented in Table 4-1. Sections 4.1.1, 4.1.2, and 4.1.3 discuss the basis of the BVs, radiological PRGs, and metal PRGs.

Table 4-1. Preliminary Remediation Goals and Background Values for Potential Contaminants of Concern Identified for the Inaccessible Soil Operable Unit

Media [a]	PCOC	Soil Background Value [b]	Sewer Sediment Background Value [b]	Risk-Based PRG [c]
Inaccessible Soil	Ac-227 (picocuries per gram [pCi/g])	0.18	NA	11.4
	Pa-231 (pCi/g)	1.12	NA	1.25
	Ra-226 +D (pCi/g)	3.04	NA	0.0248
	Ra-228 +D (pCi/g)	1.00	NA	0.0538
	Th-228 (pCi/g)	1.26	NA	121
	Th-230 (pCi/g)	2.18	NA	20
	Th-232 (pCi/g)	1.18	NA	18.9
	U-235 +D (pCi/g)	0.1	NA	34.3
	U-238 +D (pCi/g)	1.67	NA	1.65
	Arsenic (milligrams per kilogram [mg/kg])	10.6	NA	1.6
	Cadmium (mg/kg)	1.03	NA	800
	Uranium metal (mg/kg)	NA	NA	3,100

Table 4-1. Preliminary Remediation Goals and Background Values for Potential Contaminants of Concern Identified for the Inaccessible Soil Operable Unit (Continued)

Media [a]	PCOC	Soil Background Value [b]	Sewer Sediment Background Value [b]	Risk-Based PRG [c]
Sewer Sediment and Soil Adjacent to Sewer Lines	Ac-227 (pCi/g)	0.18	0.0916	11.4
	Pa-231 (pCi/g)	1.12	0.265	1.25
	Ra-226 +D (pCi/g)	3.04	1.007	0.0248
	Ra-228 +D (pCi/g)	1.00	0.466	0.0538
	Th-228 (pCi/g)	1.26	0.527	121
	Th-230 (pCi/g)	2.18	1.127	20
	Th-232 (pCi/g)	1.18	0.51	18.9
	U-235 +D (pCi/g)	0.1	0.0848	34.3
	U-238 +D (pCi/g)	1.67	1.05	1.65
	Arsenic (mg/kg)	10.6	11.84	1.6
	Cadmium (mg/kg)	1.03	6.165	800
	Cobalt (mg/kg)	8.51	8.856	300
	Copper (mg/kg)	184	157.1	41,000
	Lead (mg/kg)	381	601.5	800
	Manganese (mg/kg)	576	626.2	23,000
	Molybdenum (mg/kg)	2.77	7.156	5,100
	Nickel (mg/kg)	24.7	34.01	20,000
	Selenium (mg/kg)	0.37	2.937	5,100
	Thorium Metal (mg/kg)	NA	NA	NA [d]
	Uranium Metal (mg/kg)	NA	17.86	3,100
	Vanadium (mg/kg)	39.1	19.36	5,200
	Zinc (mg/kg)	324	659.4	310,000
Interior Structural Surfaces [e,f]	Gross Alpha Activity (dpm/100 cm^2)	NA	NA	130
Exterior Structural Surfaces [e,f]	Gross Alpha Activity (dpm/100 cm^2)	NA	NA	3,200

[a] All depth intervals apply.

[b] All site-specific soil BVs presented for radionuclides and metals were obtained by USACE (1999a) and are not being used for data screening. Data comparisons to BVs are being done only for the purpose of characterization. Site-specific sewer sediment BVs for radionuclides and metals were estimated from data collected during the RI (see Tables I-3-1 and I-3-2 in Attachment I-3 of Appendix I for statistical summary). All soil and sediment BVs for radionuclides and metals were selected as the lower value of the 95 percent UCL and the maximum detected background concentration. All soil and sediment BVs equate to the 95 percent UCL.

[c] Radiological PRGs were obtained from USEPA's (August 2010) online Generic Preliminary Remediation Goals table for the outdoor worker (http://epa-prgs.oml.gov/radionuclides/download.html) (USEPA 2010c). USEPA PRGs for Ra-226, Ra-228, and U-238 incorporate the ingrowth of daughter products out to 100 years and are, therefore, designated as "+D." PRGs used for evaluating metal PCOCs are USEPA's (April 2012) industrial soil Regional Screening Levels (RSLs) (USEPA 2012a). All PRGs were established for soil and target a CR of 1.0E-06 or a non-carcinogenic hazard index of 1.0. No published sediment PRGs are available for human health.

[d] A PRG is not available for elemental thorium; however, it is the carcinogenic effects from radiological exposures to thorium isotopes that will drive risk evaluations of this PCOC.

[e] PRGs for interior and exterior structural surfaces were derived using the Residual Radioactivity (RESRAD)-BUILD computer model. No metal PRGs are needed for structural surfaces. No BV is available for structural surfaces.

[f] No structural surface PRGs were derived for gross beta activity because Ra-228 and Pb-210 were not determined to be significant dose contributors; therefore, all beta-emitting PCOCs are accounted for in the gross alpha PRG, as detailed in Appendix S.

NA = Not applicable.

The PRGs used in this RI/BRA report should not be confused with numerical RGs that will be determined later in the CERCLA process for the ISOU. Generally, the USEPA's recommended approach for developing RGs is to identify PRGs at scoping, modify them as needed at the end of the RI or during the FS based on site-specific information from the BRA, and ultimately select remediation levels in the ROD (USEPA 2010a). ARARs are also used to select the remediation levels in the ROD. The State of Missouri has provided an initial list of potential ARARs as follows:

- Uranium Mill Tailings Radiation Control Act (UMTRCA) (40 *CFR* 192.12(a), (b); 192.21; 192.22; 192.02(a); 192.40; 192.41);
- Office of Solid Waste and Emergency Response (OSWER) 9200.4-18;
- OSWER 9200.4-23;
- OSWER 9200.4-25;
- Missouri Clean Water Act;
- Missouri Water Well Driller's Law (RSMo 256.600 and 256.670) and Regulations (10 *Code of State Regulations* [*CSR*] 23);
- Missouri Risk Based Corrective Action (MoRBCA) guidance of long term stewardship; and
- Missouri Environmental Covenants Act (MoECA).

The inclusion of these potential ARARs does not constitute applicability or USACE acceptance. The potential ARARs will be evaluated during subsequent CERCLA documents in accordance with the time frames established in the NCP.

4.1.1 Background Values

SLDS soil and sediment BVs are being used to facilitate characterization efforts by providing a reference point for evaluating if concentrations at the SLDS are a result of historical MED/AEC releases or if they are due to releases from other anthropogenic activities not related to historical uranium-ore processing at the SLDS. The BVs are not being subtracted from site concentrations or added to PRGs in order to reflect concentrations above SLDS background. All soil and sediment BVs were selected as the lesser of the 95 percent UCL or the maximum detected concentrations calculated from SLDS background datasets. The soil background data were obtained from the *Background Soils Characterization Report for the St. Louis Downtown Site* (USACE 1999a).

No background data set was available for sewer sediment; therefore, background sediment samples were collected from manholes in areas upstream of the SLDS during the RI. A total of 11 background sediment samples were collected from manholes located in the industrial area located upstream (west) of the Mallinckrodt facility (Figure I-3-1). The RI WP identified 8 background sediment sample locations, but three manhole locations (SLD123754, SLD123755, and SLD123756) located further upstream of the plant were also sampled to provide a more statistically robust background dataset. Additional field changes to some of the proposed manhole sampling locations were made due to access restrictions and safety issues encountered in the field. The background sediment samples are generally described as consisting predominantly of fine to medium sand with varying amounts of silt and traces of fine gravel.

The data from the 11 upstream sewer sediment sampling locations provide an appropriate dataset for establishing background sediment concentrations for metals and radionuclides. Prior to determination of background values, statistical outlier evaluations were conducted. Results identified as outliers were removed from the background data set prior to calculations of summary statistics, goodness of fit (GOF), and BVs. Table I-4 of Appendix I summarizes the sewer sediment background statistics that were calculated for each PCOC, including the frequency of detection (FOD), mean, minimum, and maximum detected concentration; standard deviation; 95 percent UCL on the mean; and 95 percent upper tolerance limit (UTL) of the 95th percentile. Because all 95 percent UTL values are greater than the maximum detection, the sediment background value for each metal was set equal to the lower of the 95 percent UCL and the maximum detected background concentration. The use of the lower of the two concentrations is consistent with the method outlined in the *Guidance for Conducting Risk Assessments and Related Risk Activities for the DOE-ORO Environmental Management Program* (DOE 1999). A detailed description of the methodology used to develop the background statistics is presented in Appendix I. Results were used to develop a statistical background concentration for each of the PCOCs identified in Table 4-1.

Because representative building materials not impacted by site operations are unavailable for establishing site specific and medium-specific (e.g., metal, wood, and concrete) background levels, only instrument backgrounds were utilized.

The analytical results for the inaccessible soil samples, sewer sediment samples, and soil adjacent to sewers samples collected in MED/AEC areas were compared to the background values, as well as to the PRGs, to support evaluation of the nature and extent of the radionuclide and metal PCOCs in the ISOU.

Comparisons of site data versus BVs can result in some data being less than background. This is because the BV, as previously described, is an upper confidence limit calculated from a range of background concentrations following a particular distribution, which varies among COPCs. Therefore, it becomes possible for site data to be less than BVs, and also, for site doses and/or risk to be less than the corresponding background doses and/or risks.

4.1.2 Radiological Preliminary Remediation Goals

The USEPA's radiological risk-based PRGs for soil were obtained from the online generic PRGs table for the outdoor worker (USEPA 2010c). All radiological PRGs established for soil target a CR of 1.0E-06. Generally, the USEPA's outdoor worker is a long-term receptor exposed during the work day and is assumed to be a full-time employee, who works on site and spends most of the workday conducting maintenance activities outdoors. The activities for this receptor (e.g., moderate digging, landscaping) typically involve on-site exposures to surface soils, although the PRGs established by the USEPA for this receptor are applied to all inaccessible soils. The outdoor worker is expected to have an elevated soil ingestion rate (100 milligrams [mg] per day) and is assumed to be exposed to contaminants via the following pathways: incidental ingestion of soil, external radiation from contaminants in soil, and inhalation of fugitive dust. Relative to other worker receptors for which the USEPA has derived generic PRGs, the outdoor worker is expected to be the most highly exposed receptor in the outdoor environment under commercial/industrial conditions (USEPA 2010c). The USEPA's generic soil PRGs for the outdoor worker are purely risk-based and do not include background concentrations.

Each generic radiological PRG was derived by the USEPA to target a CR of 1.0E-06. Cancer slope factors used by the USEPA to derive generic soil PRGs for Ra-226, Ra-228, and U-238 incorporate the ingrowth of daughter products out to 100 years. PRGs in Table 4-1 that incorporate these slope factors with in-growth are designated as "+D."

The soil PRGs were used for evaluating sewer sediment because no established, risk based PRGs are available for sediment.

For soil on interior and exterior structural surfaces, industrial worker PRGs were determined by the USACE for gross alpha, as presented in Table 4-1. No structural surface PRGs were derived for gross beta activity, because Ra-228 and Pb-210 contributed less than 10 percent of the dose criteria and were considered to be insignificant dose contributors; therefore, all beta-emitting PCOCs are accounted for in the gross alpha PRG. The gross alpha PRG is based on radionuclide-specific derived concentration guideline levels (DCGLs) calculated using average soil concentrations from the 1993 BRA (DOE 1993) based on methods prescribed in *Derivation of Site-Specific DCGLs for North County Structures* (USACE 2004a). The building and structure radiological survey results are gross measurements that do not take into account the naturally occurring radioactivity of the various building materials. A detailed description of the calculation process for determining PRGs for structure surfaces, along with Residual Radioactivity (model) (RESRAD)-BUILD outputs, is presented in Appendix S.

4.1.3 Metal Preliminary Remediation Goals

PRGs used for evaluating metal PCOCs are the most current USEPA (April 2012) industrial soil Regional Screening Levels (RSLs) (USEPA 2012a). All metal PRGs established for soil target a CR of 1.0E-06 or a non-carcinogenic hazard index (HI) of 1.0. PRGs for characterizing metals contamination of inaccessible soil and soil adjacent to sewer lines are shown in Table 4-1. The metals PRGs are based on the current and expected future land use of the SLDS, which has been identified as heavily industrial within an urbanized setting (DOE 1993). Because published sediment PRGs are generally not available for human health protection from metals exposures, the soil PRGs for metals are also being used to evaluate metals concentrations in sewer sediment. Soil on structural surfaces was not investigated for metals contamination; therefore, no PRGs are presented. Similar to the USEPA's generic radiological PRGs, the metal PRGs represented by the USEPA's industrial soil RSLs are purely risk-based and do not include background.

4.2 NATURE AND EXTENT OF CONTAMINATION IN INACCESSIBLE SOIL

RI sampling activities for inaccessible soil were determined on a property-by-property basis using various information, including the MED/AEC historical activities conducted at the property, the results of previous sampling data, and the construction date of the structure (i.e., building, levee, RR, or roadway). Also evaluated were the locations where MED/AEC activities were conducted at the property, or the locations where accessible soil may have been excavated under the 1998 ROD, or structures that were constructed after MED/AEC operations were identified for inaccessible soil sampling. The evaluation of each property indicated that RI sampling was necessary at several Mallinckrodt plant areas, VPs, levee areas, RRs, and roadways.

Inaccessible soil was considered non-impacted in the RI WP and not subjected to additional sampling if previous data indicated contamination levels were below background or the 1998 ROD RGs and if the structure causing the soil to be inaccessible was constructed prior to MED/AEC processing operations. As such, no additional sampling for inaccessible soil was required at DT-4 South, DT-29, DT-24, the South of Angelrodt Property Group (DT-5, DT-13, DT-14, DT-16, and DT-18) or the West of Broadway Property Group (Plants 3, 8, 9, and 11 and DT-20, DT-23, DT-27, DT-35, and DT-36), and the Mallinckrodt Parking Lots (Figure 1-2) (USACE 2009a).

RI sampling was conducted in accordance with the RI WP (USACE 2009a) as described in section 2.1.1, with very few modifications to the sampling locations. The primary reason the locations were moved was the presence of utilities at the proposed location or auger refusal. The change in locations was typically minor (<10 ft).

The results of the RI sampling for inaccessible soil are discussed sitewide on a PCOC basis. The distribution of samples exceeding the PRG by PCOC is presented in Appendix C. The GWS data collected for each inaccessible soil area are presented in Appendix D. The analytical results for soil samples are presented in Appendix E, along with figures identifying sample locations on a property-by-property basis.

A summary of the radiological concentrations in inaccessible soil at the SLDS is shown in Table 4-2 on a property-by-property basis. A summary of the metals concentrations in inaccessible soil at the SLDS is shown in Table 4-3 on a property-by-property basis. The analytical results for each sample used in this RI are presented in Appendix E.

Table 4-2. Summary of Radiological Concentrations in Inaccessible Soil [a,b]

Location	Ac-227						Pa-231						Ra-226						Ra-228						Th-228					
	ISOU PRG = 11.4						ISOU PRG = 1.25						ISOU PRG = 0.0248						ISOU PRG = 0.0538						ISOU PRG = 121					
	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG
Plant 1	0.64	-0.47	**22.10**	275	46	4	0.57	-1.72	**27.70**	275	14	24	**6.58**	**0.39**	**623.00**	279	275	279	**0.82**	0.00	**2.15**	279	273	276	1.12	0.00	3.96	275	261	0
Plant 2	0.06	-0.30	1.55	166	1	0	0.07	-1.45	**1.30**	166	0	1	**1.72**	**0.28**	**12.20**	166	166	166	**0.78**	0.05	**13.10**	166	164	165	1 14	-0.01	16.30	166	160	0
Plant 6	0.32	-0.27	**13.50**	63	2	1	0.24	-1.13	**14.80**	63	2	2	**3.59**	**0.31**	**57.30**	63	63	63	**0.74**	**0.15**	**1.34**	63	61	63	0.99	0.15	1.74	63	59	0
Plant 7	0.05	-0.05	0.11	5	0	0	0.11	-0.31	0.26	5	0	0	**1.91**	**1.29**	**2.93**	5	5	5	**0.83**	**0.47**	**0.99**	5	5	5	1.26	0.70	1.73	5	5	0
Mallinckrodt Security Gate 49	0.12	-0.28	0.53	18	1	0	-0.15	-1.56	0.51	18	0	0	**4.13**	**1.30**	**10.30**	18	18	18	**0.83**	**0.28**	**1.35**	18	18	18	1.13	0.38	2.16	18	18	0
DT-4 North	4.68	-0.35	**186.00**	254	83	21	**4.77**	-1.79	**192.00**	254	41	57	**6.27**	**0.50**	**137.00**	254	254	254	**0.96**	0.05	**2.35**	254	250	253	1.33	0.11	3.06	254	250	0
DT-6	1.90	-1.62	**151.00**	135	21	5	**1.96**	-2.15	**160.00**	136	6	18	**3.90**	**0.60**	**31.50**	136	121	136	**0.84**	**0.17**	**2.32**	136	121	136	1.22	0.22	3.34	136	119	0
DT-8	0.08	-0.29	1.21	322	5	0	0.02	-1.84	**3.11**	322	1	7	**2.28**	**0.50**	**12.70**	322	322	322	**0.73**	-0.02	**2.44**	322	312	321	0.93	-0.02	3.22	322	310	0
DT-10	0.11	-0.27	1.15	47	6	0	0.03	-1.13	**1.30**	47	1	1	**3.91**	**0.96**	**9.70**	47	47	47	**0.77**	**0.12**	**1.36**	47	46	47	0.99	0.09	1.89	47	43	0
DT-29	-0.04	-0.09	0.01	2	0	0	0.17	0.09	0.25	2	0	0	**1.11**	**1.08**	**1.13**	2	2	2	**0.59**	**0.37**	**0.81**	2	2	2	1.09	0.49	1.68	2	2	0
DT-34	0.07	0.07	0.07	1	0	0	0.16	0.16	0.16	1	0	0	**2.37**	**2.37**	**2.37**	1	1	1	**0.93**	**0.93**	**0.93**	1	1	1	0.71	0.71	0.71	1	1	0
West of Broadway Property Group [c]	0.05	-0.18	0.36	40	0	0	0.12	-0.40	**1.45**	40	0	1	**1.92**	**0.91**	**4.70**	40	40	40	**0.73**	**0.31**	**1.25**	40	40	40	1.02	0.34	1.96	40	40	0
South of Angelrodt Property Group [d]	0.08	-0.17	0.57	14	0	0	0.13	-0.32	0.65	14	0	0	**2.06**	**0.67**	**5.84**	14	13	14	**0.70**	**0.13**	**1.35**	14	14	14	0.96	0.26	1.84	14	14	0
DT-2 Levee	0.03	-0.56	1.87	257	2	0	0.01	-1.78	**1.85**	257	0	3	**3.04**	**0.74**	**66.40**	257	257	257	**0.93**	**0.07**	**1.79**	257	251	257	1.19	0.18	2.64	257	254	0
DT-15 Levee	0.02	-0.25	0.41	44	0	0	0.07	-0.95	**2.50**	44	0	1	**1.90**	**1.02**	**7.21**	44	44	44	**0.88**	**0.33**	**1.96**	44	44	44	1.13	0.45	2.02	44	44	0
DT-3	0.06	-0.63	4.16	351	6	0	0.01	-1.97	**6.30**	351	0	10	**2.53**	**0.50**	**12.80**	351	351	351	**1.04**	**0.07**	**28.10**	351	346	351	1.25	0.12	27.70	351	345	0
DT-9 Rail Yard	0.18	-0.58	**13.80**	214	6	1	0.20	-2.43	**17.90**	214	3	16	**5.69**	**0.45**	**191.00**	214	214	214	**0.92**	0.04	**2.55**	214	211	213	1.13	0.05	2.84	214	206	0
DT-9 Levee	0.00	-0.37	0.41	131	1	0	0.02	-0.96	0.97	131	0	0	**1.40**	**0.65**	**3.48**	131	131	131	**0.88**	**0.06**	**1.58**	131	130	131	1.09	0.02	1.97	131	130	0
DT-9 Main Line	0.05	-0.37	1.10	454	6	0	0.05	-1.67	**4.23**	454	1	14	**2.37**	**0.61**	**28.20**	454	454	454	**0.85**	0.01	**64.80**	454	447	453	1.11	0.06	64.80	454	443	0
Terminal RR Spoils Area	0.26	-0.31	9.32	56	3	0	0.32	-0.77	**12.30**	56	1	3	**2.76**	**0.67**	**16.90**	56	56	56	**0.70**	**0.11**	**2.60**	56	54	56	0.93	0.04	2.60	56	51	0
DT-12	0.05	-0.65	1.42	483	16	0	0.01	-1.23	**2.42**	483	0	6	**2.02**	**0.32**	**8.95**	483	482	483	**0.65**	0.03	**1.80**	483	474	482	0.85	-0.02	2.86	483	456	0
North Second Street	0.17	-0.37	**12.70**	189	14	1	0.20	-1.30	**13.70**	189	5	9	**2.48**	**0.78**	**10.30**	189	189	189	**0.75**	0.03	**2.10**	189	187	188	1.01	-0.04	4.87	189	181	0
Hall Street	0.37	-0.40	**14.60**	264	34	1	0.37	-0.88	**15.00**	264	13	21	**2.93**	**0.47**	**85.20**	264	264	264	**0.79**	**0.13**	**2.09**	264	264	264	1.04	0.14	2.37	264	261	0
Bremen Avenue	0.59	-0.38	**14.60**	67	6	2	0.67	-0.83	**15.80**	67	3	3	**1.35**	**0.45**	**4.24**	67	67	67	**0.85**	**0.10**	**1.47**	67	66	67	1.09	0.10	1.95	67	64	0
Salisbury Street	0.06	-0.15	0.26	21	0	0	0.00	-0.56	0.40	21	0	0	**1.23**	**0.36**	**3.18**	21	21	21	**0.59**	**0.12**	**1.39**	21	20	21	0.87	0.18	1.98	21	19	0
Mallinckrodt Street	0.10	-0.44	2.29	81	4	0	0.19	-1.01	**3.71**	81	3	6	**1.46**	**0.50**	**3.93**	81	81	81	**0.71**	**0.12**	**1.70**	81	81	81	1.06	0.25	3.95	81	81	0
Destrehan Street	0.05	-0.82	2.26	288	8	0	0.02	-1.46	**4.23**	288	0	7	**2.48**	**0.60**	**25.10**	288	288	288	**0.80**	**0.07**	**7.35**	288	284	288	1.12	0.24	8.03	288	284	0
Angelrodt Street	0.07	-0.44	1.07	122	2	0	0.16	-1.16	**4.03**	122	0	5	**2.86**	**0.75**	**14.30**	122	122	122	**0.75**	**0.17**	**1.38**	122	121	122	1.01	0.16	2.32	122	120	0
Buchanan Street	0.89	-0.55	**37.40**	172	38	4	0.92	-2.38	**38.60**	172	14	17	**3.24**	**0.50**	**8.70**	172	172	172	**0.83**	**0.12**	**1.73**	172	169	172	1.14	0.11	3.28	172	166	0

Table 4-2. Summary of Radiological Concentrations in Inaccessible Soil [a,b] (Continued)

Location	Th-230						Th-232						U-235						U-238					
	ISOU PRG = 20						ISOU PRG = 18.9						ISOU PRG = 34.3						ISOU PRG = 1.65					
	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG
Plant 1	8.48	-95.80	**505.00**	279	273	16	0.95	0.00	3.38	279	261	0	0.72	-0.60	17.40	275	62	0	**13.05**	-31.20	**316.00**	279	200	189
Plant 2	1.64	-55.50	11.00	166	165	0	0.95	0.00	12.30	166	154	0	0.51	-0.15	19.80	166	27	0	**9.83**	-0.77	**394.00**	166	90	87
Plant 6	2.57	-11.30	**44.80**	63	62	1	0.88	0.07	1.80	63	61	0	1.85	-0.19	**95.40**	63	9	1	**36.80**	-1.19	**1949.00**	63	39	38
Plant 7	2.47	0.93	3.84	5	5	0	0.96	0.56	1.22	5	5	0	0.11	0.04	0.16	5	0	0	**3.34**	0.91	**6.26**	5	5	3
Mallinckrodt Security Gate 49	3.82	1.26	9.01	18	18	0	0.96	0.30	1.73	18	18	0	0.20	-0.05	0.68	18	2	0	**4.85**	-0.87	**10.90**	18	15	17
DT-4 North	**30.63**	-0.06	**1462.00**	254	249	35	1.10	0.04	2.50	254	249	0	2.63	-0.22	**81.30**	254	98	2	**46.67**	0.16	**1626.00**	254	237	232
DT-6	3.86	-221.38	**569.00**	136	121	4	0.98	0.25	2.78	136	120	0	0.80	-0.10	13.77	136	22	0	**13.75**	0.55	**244.74**	136	113	120
DT-8	1.57	-16.00	10.90	322	198	0	0.78	-0.02	2.44	322	311	0	0.14	-0.36	1.19	322	23	0	**2.58**	-0.82	**21.40**	322	242	163
DT-10	3.65	0.78	9.53	47	47	0	0.87	0.17	1.73	47	45	0	0.38	-0.09	1.98	47	9	0	**6.08**	0.83	**34.70**	47	46	38
DT-29	1.18	0.91	1.45	2	2	0	0.78	0.50	1.05	2	2	0	0.22	0.18	0.26	2	0	0	1.36	0.96	**1.76**	2	2	1
DT-34	2.86	2.86	2.86	1	1	0	1.46	1.46	1.46	1	1	0	0.06	0.06	0.06	1	0	0	**1.87**	**1.87**	**1.87**	1	1	1
West of Broadway Property Group [c]	2.09	0.97	7.13	40	40	0	0.82	0.37	1.43	40	40	0	0.09	-0.36	0.47	40	2	0	**2.09**	0.75	**8.24**	40	39	21
South of Angelrodt Property Group [d]	2.15	-0.06	4.99	14	13	0	0.75	0.18	1.39	14	13	0	0.14	-0.11	0.49	14	1	0	**2.50**	0.56	**7.03**	14	8	9
DT-2 Levee	2.38	-1.57	11.00	257	252	0	1.03	0.00	2.51	257	249	0	0.15	-0.49	1.56	257	6	0	**2.32**	-0.39	**12.50**	257	175	122
DT-15 Levee	1.97	0.95	7.80	44	44	0	0.99	0.24	2.32	44	44	0	0.09	-0.16	0.75	44	0	0	1.51	0.13	**4.99**	44	36	12
DT-3	2.70	0.36	**29.80**	351	351	1	1.07	0.03	**24.00**	351	340	1	0.20	-0.64	2.12	351	19	0	**3.29**	-2.71	**42.70**	351	258	205
DT-9 Rail Yard	5.83	0.62	**272.00**	214	214	6	0.98	-0.01	2.73	214	206	0	0.35	-0.38	12.30	214	15	0	**5.50**	0.37	**177.00**	214	192	170
DT-9 Levee	1.45	0.50	4.76	131	131	0	0.98	0.09	1.81	131	127	0	0.05	-0.34	0.46	131	0	0	1 28	-2 30	**3.88**	131	89	33
DT-9 Main Line	2.42	0.54	**71.50**	454	454	2	0.97	0.05	**64.80**	454	438	1	0.13	-0.49	1.41	454	10	0	**2.09**	-1.43	**14.30**	454	333	233
Terminal RR Spoils Area	9.26	0.58	**260.00**	56	56	4	0.76	0.05	2.60	56	52	0	0.33	-0.20	8 60	56	3	0	**6.45**	-0.85	**179.00**	56	39	26
DT-12	3.45	0.26	**53.90**	483	483	11	0.73	-0.03	1.74	483	439	0	0.16	-0.33	1.82	483	43	0	**2.82**	0.14	**33.50**	483	435	266
North Second Street	3.58	-0.58	**57.70**	189	186	2	0.90	-0.01	3.56	189	183	0	0.26	-0.19	1.99	189	38	0	**4.40**	-1.70	**32.10**	189	157	131
Hall Street	4.03	-6.24	**54.40**	264	258	9	0.91	0.00	1.90	264	259	0	0.28	-0.31	9.48	264	34	0	**4.65**	-0.66	**190.00**	264	206	143
Bremen Avenue	-1.67	-123.00	15.60	67	65	0	0.94	0.10	1.65	67	64	0	1.81	-0.40	**43.10**	67	19	2	**35.70**	-0.07	**856.00**	67	43	29
Salisbury Street	1.30	0.30	2.67	21	20	0	0.71	-0.02	1.84	21	19	0	0.05	-0.19	0.25	21	0	0	0.99	0.09	**3.37**	21	12	3
Mallinckrodt Street	2.23	-1.96	13.90	81	79	0	0.97	0.09	3.39	81	77	0	0.18	-0.27	2.38	81	9	0	**3.16**	-1.24	**50.30**	81	36	46
Destrehan Street	4.54	0.35	**411.00**	288	285	5	0.99	0.09	8.61	288	281	0	0.22	-0.53	4.48	288	39	0	**4.33**	-2.65	**75.90**	288	187	169
Angelrodt Street	3.14	0.34	**46.40**	122	115	1	0.87	0.14	1.74	122	120	0	0.15	-0.28	0.79	122	6	0	**2.57**	-0.43	**9.33**	122	99	81
Buchanan Street	5.16	0.64	**76.40**	172	171	8	0.93	0.03	1.92	172	166	0	1.10	-0.22	17.60	172	57	0	**19.59**	0.05	**326.00**	172	155	135

[a] This table does not include data for inaccessible soil adjacent to sewer lines.

[b] Appendix E provides the analytical results for each location at the property including summary statistics for each PCOC. Statistics include number of samples, minimum, maximum, average, median, and mode of the parameter concentration.

[c] 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.

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

Units are pCi/g.

Bold values and gray shading indicate samples collected at the property that exceeded the PRG.

Table 4-3. Summary of Metal Concentrations in Inaccessible Soil for Properties Within the Uranium-Ore Processing Area [a,b,c]

Location	Arsenic						Cadmium						Uranium					
	ISOU PRG = 1.6						ISOU PRG = 800						ISOU PRG = 3,100					
	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG
Plant 2	**6.19**	**2.7**	**10.5**	7	3	7	1.14	0.12	3.6	7	2	0	10.5	5.6	14.9	7	5	0
Plant 6	**7.19**	**3.5**	**15.1**	8	3	8	0.55	0.03	0.8	8	8	0	24	5.7	62.1	7	1	0
DT-10	**49.2**	0.74	**178**	8	5	7	1.88	0.76	3.3	8	2	0	53.6	12	104	8	8	0
DT-9	**6.87**	**2.8**	**14.6**	18	0	18	5.61	0.6	69.3	18	7	0	41.5	5.9	68.2	18	18	0
DT-12	**108**	1.5	**543**	34	15	33	2.35	0.48	6.7	34	17	0	12.9	12.1	13.5	12	3	0
Hall Street	**7.2**	**3.6**	**10**	6	5	6	1.86	0.83	2.4	6	1	0	42.33	7.5	84.9	6	1	0
Mallinckrodt Street	**12.35**	**9.9**	**14.8**	2	0	2	0.42	0.34	0.5	2	2	0	[c]	[c]	[c]	[c]	[c]	[c]
Destrehan Street	**13.47**	**6.1**	**25**	9	6	9	0.77	0.02	2.4	9	6	0	58.5	13.4	146	6	5	0

[a] Summary data do not include inaccessible soil associated with sewers (see Tables 4-12 and 4-13).

[b] Appendix E provides the analytical results for each location at the property including summary statistics for each PCOC. Statistics include number of samples, minimum, maximum, average, median, and mode of the parameter concentration.

[c] Uranium metal was not analyzed in samples collected at Mallinckrodt Street.

Units are mg/kg.

Samples were not collected at Plant 7N.

Bold values and gray shading indicate samples collected at the property that exceeded the PRG.

4.2.1 Comparison to Background

Inaccessible soil sample results were compared to BVs. As shown in Table 4-4, sample results exceeded the corresponding BV for each PCOC in the inaccessible soil.

Table 4-4. Number of Inaccessible Soil Samples Exceeding Background Values

PCOC	Number of Samples	Number of Samples Exceeding Background	Percentage of Samples Exceeding Background
Radiological			
Ac-227	4,536	917	20%
Pa-231	4,537	244	5%
Ra-226	4,541	1,233	27%
Ra-228	4,541	1,012	22%
Th-228	4,537	1,353	30%
Th-230	4,541	2,070	46%
Th-232	4,541	1,035	23%
U-235	4,537	2,518	55%
U-238	4,541	2,703	60%
Metals			
Arsenic	92	39	42%
Cadmium	92	49	53%
Uranium metal	64	[a]	[a]

[a] Uranium metal has no BV.

4.2.2 Comparison to Preliminary Remediation Goals

Inaccessible soil sample results were compared to the PRGs to determine which of the PCOCs would be carried forward for evaluation in the BRA and to identify those areas where concentrations of the PCOCs are high enough to warrant further evaluation. The data used for the RI showed that the PRGs are exceeded throughout the SLDS. A large percentage of the sample results exceeded the PRG for Ra-226, Ra-228, and arsenic as the PRG is less than background. A similar percentage of U-238 sample results exceeded the PRG as exceeded background as the values are almost equal (1.65 picocuries per gram [pCi/g] and 1.67 pCi/g, respectively). As shown in Table 4-5, at least one sample result exceeded the corresponding PRG for each of the radiological PCOCs except Th-228, and thus, all radiological PCOCs except Th-228 will be evaluated in the BRA. Only arsenic results exceeded the metals PRGs; therefore, arsenic is the only inaccessible soil metal that will be carried forward into BRA. The figures in Appendix C show the distribution of samples exceeding the PRG by PCOC.

Table 4-5. Number of Inaccessible Soil Samples Exceeding the Preliminary Remediation Goal

PCOC	PRG	Number of Samples	Number of Samples Exceeding the PRG	Percentage of Samples Exceeding the PRG
Radiological				
Ac-227	11.4 pCi/g	4,536	40	<1%
Pa-231	1.25 pCi/g	4,537	232	5%
Ra-226	0.0248 pCi/g	4,541	4,541	100%
Ra-228	0.0538 pCi/g	4,541	4,531	99%
Th-228	121 pCi/g	4,537	0	0%
Th-230	20 pCi/g	4,541	105	2%
Th-232	18.9 pCi/g	4,541	2	<1%
U-235	34.3 pCi/g	4,537	5	<1%
U-238	1.65 pCi/g	4,541	2,723	60%

Table 4-5. Number of Inaccessible Soil Samples Exceeding the Preliminary Remediation Goal (Continued)

PCOC	PRG	Number of Samples	Number of Samples Exceeding the PRG	Percentage of Samples Exceeding the PRG
Metals				
Arsenic	1.6 mg/kg	92	90	98%
Cadmium	800 mg/kg	92	0	0%
Uranium metal	3,100 mg/kg	64	0	0%

4.3 NATURE AND EXTENT OF CONTAMINATION ON BUILDINGS AND STRUCTURES

The RI survey activities for buildings were determined on a property-by-property basis using various information, including prior radiological survey data, construction date of the structure, use of the structure by MED/AEC, proximity to accessible soil remediation activities, and distance from MED/AEC operational areas (USACE 2009a). A building surface was considered impacted (i.e., building surface has the potential to be contaminated) in the RI WP and subjected to additional sampling if

- previous data indicate contamination levels are above background or the RI WP screening level criteria;
- the structure was used for MED/AEC processing activities;
- the structure was constructed prior to or during MED/AEC processing operations and is located on, or adjacent to, MED/AEC processing areas; or
- if accessible soil remediation occurred adjacent to, or within 6 meters (m) (20 ft) of, the structure.

Based on the evaluation conducted in the RI WP, the buildings at the following properties were determined to be non-impacted: Plant 7, Mallinckrodt Security Gate 49, DT-4 South, DT-11, DT-15, DT-29, and DT-34 (USACE 2009a). Buildings determined to be non-impacted were not surveyed in the RI. Additionally, no buildings are present at DT-2, the three RR properties (DT-3, DT-9, and DT-12), the Terminal RR Soil Spoils Area, or at any SLDS roadways.

The RI scoping surveys consisted of scanning for alpha and beta surface activity and fixed-point measurements for total alpha and beta activity in accordance with the RI WP as described in Section 2.2.2. There were more than 4,600 fixed-point measurements obtained during the RI.

The results of the building and structure surveys for the ISOU are discussed on a building-by-building basis. The buildings surveyed are shown on figures provided in Appendix E. The individual scoping survey results are presented in Appendix F. Pictures of the exterior of the structures exceeding the PRG and drawings of the interiors exceeding the PRG are presented in Appendix G.

Table 4-6 presents the summary of gross alpha survey results based upon the individual scoping survey results presented in Appendix F.

Table 4-6. Building Scoping Survey Summary

Property Area	Associated Structure/Building	Appendix Figure	Gross Alpha Results (dpm/100 cm^2)								
			Interior			Exterior			Rooftop		
			Number	Range	Average	Number	Range	Average	Number	Range	Average
Plant 1	Building 3	E-1	18	0-66	37	82	0-1,186	105	25	0-2,195	275
	Building 4	E-1	4	0-49	12	28	0-310	67	6	15-218	92
	Building 5	E-1	3	0-33	16	14	0-39	6	[a]	[a]	[a]
	Building 6	E-1	3	16-16	16	37	0-940	97	24	9-1,136	346
	Building 7	E-1	5	**0-163**	39	35	0-731	184	10	27-1,614	546
	Building 8	E-1	4	0-33	16	61	0-1,254	165	8	91-1,345	519
	Building 10	E-1	10	0-37	12	48	0-1,966	193	14	0-2,009	538
	Building 10A	E-1	6	0-64	20	23	0-646	83	5	29-287	126
	Building 17	E-1	7	0-49	16	52	0-282	35	45	26-2,390	307
	Building 25	E-1	30	0-51	9	101	**0-18,232** [b]	498	45	92-3,056	1,086
	Building 26	E-1	8	**0-236**	111	10	39-117	83	--	--	--
	Building B	E-1	22	0-57	18	25	0-414	51	33	25-1,377	518
	Building C	E-1	20	0-70	26	150	0-1,675	155	33	0-1,292	227
	Building P	E-1	12	0-70	41	42	0-1,205	193	12	221-1,254	656
	Building X	E-1	7	0-66	22	128	0-928	94	43	**0-4,279** [c]	626
	Building Z	E-1	21	0-51	13	336	0-2,833	256	20	24-1,828	578
	Building L	E-1	10	0-57	22	96	0-2,878	118	71	5-2,375	755
	Utility Measurements [d]	E-1	NA	NA	NA	28	15-872	146	NA	NA	NA
	Area between Buildings L and Z	E-1	NA	NA	NA	20	0-152	35	--	--	--
	Tanks and Loading Dock	E-1	NA	NA	NA	22	0-571	145	NA	NA	NA
	Old Retaining Wall Salisbury	E-1	NA	NA	NA	49	18-605	130	NA	NA	NA
Plant 2	Building 40	E-2	6	0-127	58	10	19-91	64	--	--	--
	Building 41	E-2	9	**0-164**	57	28	0-465	56	5	291-1,353	719
	Building 501	E-2	22	0-18	1	94	0-446	60	73	13-1,280	195
	Building 506	E-2	[a]	[a]	[a]	20	27-219	75	--	--	--
	Building 508	E-2	8	**0-164**	57	15	0-220	69	--	--	--
	Building 510	E-2	14	0-53	15	40	0-197	44	--	--	--
	Utility Measurements [d]	E-2	NA	NA	NA	27	0-351	120	NA	NA	NA
Plant 6	Building 100	E-3	10	0-58	16	20	4-597	143	--	--	--
	Building 123	E-3	--	--	--	10	0-171	57	--	--	--
	Utility Measurements [d]	E-3	NA	NA	NA	4	18-163	74	NA	NA	NA
Plant 3	Building 63	E-12	--	--	--	30	0-849	150	22	104-2,599	706
	Building 66	E-12	--	--	--	56	0-263	60	22	5-3,018	880
	Building 62	E-12	--	--	--	30	0-1,016	137	20	26-836	232
	Utility Measurements [d]	E-12	NA	NA	NA	1	75-75	75	NA	NA	NA
Plant 8	Building 90	E-12	--	--	--	70	0-1,636	367	--	--	--
	Building 91	E-12	--	--	--	54	0-1,492	343	--	--	--
	Utility Measurements [d]	E-12	NA	NA	NA	3	22-61	44	NA	NA	NA
Plant 9	Building 96	E-12	--	--	--	146	0-1,052	149	34	0-887	237
	Northeast Corner Building	E-12	--	--	--	5	24-67	44	--	--	--
	Building 90	E-12	--	--	--	70	0-1,636	367	--	--	--

Table 4-6. Building Scoping Survey Summary (Continued)

Property Area	Associated Structure/Building	Appendix Figure	Gross Alpha Results (dpm/100 cm^2)								
			Interior			Exterior			Rooftop		
			Number	Range	Average	Number	Range	Average	Number	Range	Average
Plant 9	Building 96	E-12	--	--	--	146	0-1,052	149	34	0-887	237
	Northeast Corner Building	E-12	--	--	--	5	24-67	44	--	--	--
	Building 90	E-12	--	--	--	70	0-1,636	367	--	--	--
DT-4	Administration/ Warehouse	E-6	30	0-51	17	155	0-372	35	110	10-4,055[c]	224
	South Storage Building	E-6	4	13-97	48	110	0-125	30	19	18-125	52
	North Storage Building	E-6	[f]	[f]	[f]	40	0-618	91	15	18-178	91
	South Salt Dome	E-6	[e]	[e]	[e]	12	5-130	78	--	--	--
	North Salt Dome	E-6	[e]	[e]	[e]	10	5-130	66	--	--	--
	Utility Measurements[d]	E-6	NA	NA	NA	20	0-909	102	NA	NA	NA
DT-6	Storage Building	E-7	11	**0-138**	31	65	0-317	82	13	41-248	116
	Fabrication Building	E-7	10	0-75	18	10	27-74	43	--	--	--
DT-8	Warehouse	E-8	11	0-55	19	15	23-231	87	[f]	[f]	[f]
	Administration Building	E-8	[e]	[e]	[e]	66	0-743	133	16	106-2,128	1,194
	Building A	E-8	[e,f]	[e,f]	[e,f]	11	162-813	589	--	--	--
	Building B	E-8	10	0-51	8	10	0-137	66	--	--	--
	Building C	E-8	17	0-51	25	10	51-203	135	--	--	--
	Building D	E-8	7	0-40	26	12	10-981	497	--	--	--
DT-10	Dry Kiln	E-9	5	0-46	18	7	0-257	142	--	--	--
	Metal Storage Building	E-9	14	**0-330**	39	22	0-686	123	--	--	--
	Planer Building	E-9	5	0-43	17	19	0-614	111	--	--	--
	Saw Building	E-9	24	0-72	26	11	0-429	109	--	--	--
	Storage Structure	E-9	--	--	--	14	5-366	85	--	--	--
	Wood Storage Structure	E-9	29	**0-172**	33	115	**0-22,476**[b]	2,100	32	**68-7,335**[b]	2,172
	Office Building	E-9	16	0-122	33	41	5-965	252	14	62-2,636	519
DT-14	L-Shaped Building	E-13	--	--	--	99	**4-4,760**[b]	378	15	30-3,969[c]	784
DT-21	Building	E-12	--	--	--	10	0-1,271	345	10	0-125	56
	Building	E-12	--	--	--	41	9-1,665	347	22	40-3,427	1,102
DT-22	Buildings	E-12	--	--	--	69	0-1,218	151	21	0-1,339	398
DT-24	Building	E-12	--	--	--	92	0-1,378	144	20	124-3895	1,525
DT-25	Building	E-12	--	--	--	31	9-1,037	141	5	102-3,302	761

[a] Survey not conducted because field evidence indicates building is new construction.

[b] Locations of measurement results that are greater than the screening level are shown in Appendix G.

[c] The natural occurring radioactivity from clay/ceramic brick caps, as discussed in Section 2.2.2, has not been subtracted from the reported results.

[d] Utility measurements included power poles, street signs, fire hydrants, overhead pipe supports, etc.

[e] Interior inaccessible for survey.

[f] Modified from the RI WP based on field conditions.

-- Sampling not proposed in the RI WP (USACE 2009a).

NA = Not applicable, because structure does not have an interior or rooftop.

Values in bold exceed the PRGs (i.e., 130 dpm/100 cm^2 for interior structural surfaces and 3,200 dpm/100 cm^2 for exterior structural surfaces).

Data Summarized from Scoping Screening Measurements Presented in Appendix F.

4.3.1 Comparison to Background Values

No BVs were calculated for structural surfaces; therefore, there is no comparison of the survey results to BVs.

4.3.2 Comparison to Preliminary Remediation Goals

The RI sampling results indicate that 7 buildings exceed the interior PRG and 4 buildings exceed the exterior PRG (includes exterior surfaces and roofs). These 10 buildings will be carried forward into the BRA. Table 4-7 presents the buildings and surfaces exceeding the PRGs.

Table 4-7. Buildings Exceeding the Preliminary Remediation Goals

Property Area	Structure/ Building	Surface Exceeding the PRG
Plant 1	Building 7	Interior
	Building 25	Exterior
	Building 26	Interior
	Building X	Roof
Plant 2	Building 41	Interior
	Building 508	Interior
DT-6	Storage Shed	Interior
DT-10	Metal Storage Shed	Interior
	Wood Storage Building	Interior, Exterior, and Roof
DT-14	L-Shaped Building	Exterior

4.4 NATURE AND EXTENT OF CONTAMINATION ASSOCIATED WITH SEWERS

This section summarizes the results of the RI sampling conducted to investigate contamination associated with sewers. Activities conducted as part of the sewer investigation included collecting sediment samples from manholes and surface drains (grate inlets) and collecting soil samples adjacent to sewer lines. The sampling activities focused on the sewers that were used for MED/AEC operations, as well as sewers that could contain MED/AEC contamination due to receiving runoff from contaminated areas. Sediment samples collected within sewer manholes and drains, and soil samples collected adjacent to sewers as part of the RI, are shown on the figures provided in Appendices H and J. The Appendix H figures also identify locations where PCOC PRGs were exceeded for the sediment and soil samples associated with the sewers. The analytical results and sampling locations for sewer sediment and soil adjacent to sewers are presented in Appendix J. Table 4-8 summarizes the results of the screening of the radiological and metal PCOC data against BVs for sewer sediment and soil adjacent to sewers. In addition, the results of background sediment sampling conducted in manholes located along sewer lines upstream of the Mallinckrodt facility are discussed in Appendix I.

Tables 4-8 and 4-9 present summaries of the concentrations of the radiological PCOCs in sewer sediment and soil adjacent to sewers, respectively, by plant or property area. A summary of the metal concentrations on a property-by-property basis is shown in Tables 4-10 (sewer sediment) and 4-11 (soil adjacent to sewers).

The analytical results for each sewer sample evaluated in this RI are presented in Appendix J.

Table 4-8. Summary of Radiological Concentrations in Sewer Sediment [a,b]

Location	Ac-227						Pa-231						Ra-226						Ra-228						Th-228					
	ISOU PRG = 11.4						ISOU PRG = 1.25						ISOU PRG = 0.0248						ISOU PRG = 0.0538						ISOU PRG = 121					
	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG
Plant 1	0.02	-0.12	0.14	11	0	0	0.13	-0.17	0.97	11	0	0	**1.08**	**0.67**	**2.14**	11	11	11	**0.33**	**0.14**	**0.81**	11	11	11	0.46	0.20	0.86	11	10	0
Plant 2	-0.02	-0.22	0.11	10	0	0	0.02	-0.51	0.95	10	0	0	**0.82**	**0.43**	**1.14**	10	10	10	**0.26**	**0.17**	**0.56**	10	10	10	0.33	0.15	0.54	10	7	0
Plant 6	0.00	-0.05	0.03	3	0	0	0.15	-0.04	0.38	3	0	0	**0.98**	**0.83**	**1.22**	3	3	3	**0.30**	**0.20**	**0.42**	3	3	3	0.40	0.10	0.67	3	2	0
Plant 7	0.06	0.06	0.06	1	0	0	-0.01	-0.01	-0.01	1	0	0	**0.89**	**0.89**	**0.89**	1	1	1	**0.48**	**0.48**	**0.48**	1	1	1	0.59	0.59	0.59	1	1	0
DT-11	-0.02	-0.02	-0.02	1	0	0	0.06	0.06	0.06	1	0	0	**0.61**	**0.61**	**0.61**	1	1	1	**0.27**	**0.27**	**0.27**	1	1	1	0.54	0.54	0.54	1	1	0

Location	Th-230						Th-232						U-235						U-238					
	ISOU PRG = 20						ISOU PRG = 18.9						ISOU PRG = 34.3						ISOU PRG = 1.65					
	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG
Plant 1	0.92	0.40	1.41	11	11	0	0.33	0.03	0.78	11	9	0	0.14	0.03	0.49	11	1	0	**2.41**	0.35	**13.60**	11	7	3
Plant 2	0.92	0.27	2.01	10	10	0	0.33	0.05	0.76	10	8	0	0.06	-0.07	0.20	10	0	0	0.55	-1.46	**2.10**	10	6	1
Plant 6	0.84	0.37	1.08	3	3	0	0.33	0.07	0.50	3	2	0	0.14	-0.02	0.38	3	1	0	**2.62**	0.90	**6.04**	3	2	1
Plant 7	0.78	0.78	0.78	1	1	0	0.26	0.26	0.26	1	1	0	0.19	0.19	0.19	1	0	0	1.02	1.02	1.02	1	1	0
DT-11	0.87	0.87	0.87	1	1	0	0.40	0.40	0.40	1	1	0	0.27	0.27	0.27	1	0	0	0.70	0.70	0.70	1	1	0

[a] This table does not include data for inaccessible soil or soil adjacent to sewer lines.

[b] Appendix J provides the analytical results for each location at the property including summary statistics for each PCOC. Statistics include number of samples, minimum, maximum, average, median, and mode of the parameter concentration.

Units are pCi/g.

Bold values and gray shading indicate samples collected at the property that exceeded the PRG.

Table 4-9. Summary of Radiological Concentrations in Soil Adjacent to Sewers [a,b]

Location	Ac-227						Pa-231						Ra-226						Ra-228						Th-228					
	ISOU PRG = 11.4						ISOU PRG = 1.25						ISOU PRG = 0.0248						ISOU PRG = 0.0538						ISOU PRG = 121					
	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG
Plant 1	0.11	-0.31	2.11	59	4	0	-0.01	-1.01	**1.51**	59	1	3	**1.91**	**1.11**	**5.49**	59	59	59	**0.88**	**0.29**	**1.26**	59	59	59	1.11	0.24	2.12	59	59	0
Plant 2	0.05	-0.47	0.32	23	0	0	0.01	-1.20	**1.26**	23	0	1	**1.64**	**1.05**	**2.26**	23	23	23	**0.86**	**0.21**	**1.41**	23	23	23	1.15	0.06	1.72	23	22	0
Plant 6	2.74	-0.19	**44.80**	18	2	1	**3.06**	-1.12	**56.30**	18	2	2	**6.35**	**1.32**	**58.30**	18	18	18	**0.88**	**0.57**	**1.16**	18	18	18	1.10	0.42	1.64	18	17	0
Plant 7/DT-12	5.49	-0.24	**153.00**	46	3	3	**6.45**	-1.97	**170.00**	46	3	4	**6.06**	**0.86**	**117.00**	46	46	46	**0.85**	**0.10**	**2.56**	46	46	46	1.05	0.10	2.56	46	42	0
DT-2 Levee	6.20	0.57	**11.60**	4	3	1	**7.25**	0.70	**14.10**	4	1	3	**29.44**	**4.35**	**45.20**	4	4	4	**1.18**	**0.89**	**1.55**	4	4	4	1.18	0.89	1.55	4	4	0
DT-8	-0.02	-0.35	0.25	10	0	0	0.11	-0.41	0.92	10	0	0	**1.44**	**0.94**	**2.19**	10	10	10	**0.89**	**0.44**	**1.20**	10	10	10	1.02	0.49	1.82	10	10	0

Location	Th-230						Th-232						U-235						U-238					
	ISOU PRG = 20						ISOU PRG = 18.9						ISOU PRG = 34.3						ISOU PRG = 1.65					
	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG
Plant 1	2.46	0.85	**24.00**	59	59	2	1.02	0.20	1.72	59	59	0	0.17	-0.44	3.69	59	4	0	**3.49**	-2.15	**78.60**	59	30	19
Plant 2	1.48	0.59	2.23	23	23	0	0.93	0.22	1.74	23	22	0	1.41	-0.19	15.00	23	5	0	**25.23**	0.28	**287.00**	23	18	158
Plant 6	**32.79**	1.15	**489.00**	18	18	2	1.07	0.65	1.60	18	18	0	0.28	-0.13	0.93	18	2	0	**3.54**	-0.37	**14.50**	18	11	10
Plant 7/DT-12	**386.61**	0.47	**10180.00**	46	46	4	0.94	-0.03	2.56	46	42	0	0.17	-0.27	1.68	46	2	0	**4.10**	-0.54	**48.70**	46	42	18
DT-2 Levee	**765.58**	**47.30**	**1180.00**	4	4	4	1.18	0.89	1.55	4	4	0	0.79	-0.02	1.31	4	1	0	**20.11**	**3.82**	**35.30**	4	4	4
DT-8	1.27	1.00	1.86	10	10	0	0.84	0.62	1.03	10	10	0	0.06	-0.18	0.28	10	0	0	0.01	-4.71	1.65	10	3	0

[a] This table does not include data for inaccessible soil or sewer sediment.

[b] Appendix J provides the analytical results for each location at the property including summary statistics for each PCOC. Statistics include number of samples, minimum, maximum, average, median, and mode of the parameter concentration.

Units are pCi/g.

Bold values and gray shading indicate samples collected at the property that exceeded the PRG.

Table 4-10. Summary of Metal Concentrations in Sewer Sediment [a,b]

Location	Arsenic						Cadmium						Cobalt						Copper					
	ISOU PRG = 1.6						ISOU PRG = 800						ISOU PRG = 300						ISOU PRG = 41,000					
	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG
Plant 1	**5,72**	1.30	**17.10**	10	1	9	5.09	0.47	17.60	10	0	0	9.61	1.50	38.50	10	6	0	1182.21	11.10	7930.00	10	10	0
Plant 2	**3.09**	**1.70**	**4.30**	8	4	8	2.22	0.96	3.80	8	0	0	3.81	2.30	5.80	8	0	0	271.95	21.60	1640.00	8	8	0
Plant 6	**1.80**	1.00	**2.60**	3	0	2	0.81	0.37	1.30	3	0	0	2.00	1.10	2.80	3	1	0	46.57	3.30	79.50	3	3	0
Plant 7	**4.60**	**4.60**	**4.60**	1	1	1	2.80	2.80	2.80	1	0	0	3.20	3.20	3.20	1	0	0	60.70	60.70	60.70	1	1	0
DT-11	**3.90**	**3.90**	**3.90**	1	0	1	1.00	1.00	1.00	1	0	0	7.10	7.10	7.10	1	0	0	17.60	17.60	17.60	1	1	0

Location	Lead						Manganese						Molybdenum						Nickel					
	ISOU PRG = 800						ISOU PRG = 23,000						ISOU PRG = 5,100						ISOU PRG = 20,000					
	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG
Plant 1	126.15	4.10	438.00	10	9	0	283.03	34.30	772.00	10	10	0	6.11	1.80	16.10	10	1	0	69.23	3.70	344.00	10	9	0
Plant 2	45.45	14.10	96.60	8	1	0	207.50	112.00	308.00	8	8	0	6.04	2.00	12.20	8	0	0	50.05	12.20	152.00	8	0	0
Plant 6	30.10	5.90	72.70	3	0	0	171.07	57.20	308.00	3	3	0	2.00	1.60	2.30	3	0	0	7.60	2.70	12.40	3	1	0
Plant 7	80.70	80.70	80.70	1	0	0	495.00	495.00	495.00	1	1	0	1.70	1.70	1.70	1	0	0	17.70	17.70	17.70	1	0	0
DT-11	59.10	59.10	59.10	1	1	0	152.00	152.00	152.00	1	1	0	2.10	2.10	2.10	1	1	0	20.40	20.40	20.40	1	1	0

Location	Selenium						Uranium						Vanadium						Zinc					
	ISOU PRG = 5,100						ISOU PRG = 3,100						ISOU PRG = 5,200						ISOU PRG = 310,000					
	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG
Plant 1	3.10	0.32	9.00	10	8	0	37.31	5.80	78.00	10	3	0	13.75	8.80	27.90	10	2	0	562.78	50.20	1950.00	10	9	0
Plant 2	2.04	0.31	3.90	8	7	0	12.75	5.60	35.90	8	5	0	12.44	5.40	18.40	8	0	0	550.88	293.00	802.00	8	1	0
Plant 6	0.39	0.34	0.45	3	3	0	6.63	6.20	6.90	3	2	0	8.63	3.70	14.50	3	0	0	153.70	56.10	229.00	3	0	0
Plant 7	4.20	4.20	4.20	1	1	0	7.90	7.90	7.90	1	0	0	15.80	15.80	15.80	1	0	0	551.00	551.00	551.00	1	0	0
DT-11	1.90	1.90	1.90	1	1	0	34.60	34.60	34.60	1	0	0	10.80	10.80	10.80	1	0	0	206.00	206.00	206.00	1	1	0

[a] This table does not include data for inaccessible soil or soil adjacent to sewer lines.

[b] Appendix J provides the analytical results for each location at the property including summary statistics for each PCOC. Statistics include number of samples, minimum, maximum, average, median, and mode of the parameter concentration.

Units are mg/kg.

Bold values and gray shading indicate samples collected at the property that exceeded the PRG.

Table 4-11. Summary of Metal Concentrations in Soil Adjacent to Sewers [a,b]

Location	Arsenic						Cadmium						Cobalt						Copper					
	ISOU PRG = 1.6						ISOU PRG = 800						ISOU PRG = 300						ISOU PRG = 41,000					
	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG
Plant 1	**13.60**	**2.40**	**94.80**	48	8	48	43.70	0.12	**1730.00**	48	10	1	8.69	4.20	19.70	48	0	0	53.85	9.20	537.00	48	9	0
Plant 2	**10.82**	0.38	**67.50**	17	4	13	1.99	0.27	11.10	17	9	0	10.70	1.50	17.60	17	0	0	31.46	3.50	92.90	17	1	0
Plant 6	**5.45**	**2.80**	**11.00**	6	1	6	0.47	0.31	0.63	6	6	0	7.03	6.20	8.30	6	1	0	25.93	10.40	57.80	6	0	0
Plant 7 and DT-12	**5.10**	**3.90**	**7.20**	3	2	3	8.64	0.62	17.20	3	1	0	8.80	6.70	10.30	3	0	0	531.30	16.90	1460.00	3	3	0
DT-8 and DT-11	**4.61**	**3.00**	**9.20**	7	2	7	0.56	0.06	0.84	7	3	0	6.60	4.30	8.70	7	0	0	12.59	3.50	17.60	7	3	0

Location	Lead						Manganese						Molybdenum						Nickel					
	ISOU PRG = 800						ISOU PRG = 23,000						ISOU PRG = 5,100						ISOU PRG = 20,000					
	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG
Plant 1	147.66	8.90	**1260.00**	48	12	3	561.33	136.00	3250.00	48	30	0	1.74	0.39	10.00	48	19	0	34.53	8.70	282.00	48	0	0
Plant 2	619.19	1.50	**9930.00**	17	9	1	611.39	79.60	1410.00	17	10	0	3.00	0.34	14.90	17	7	0	37.44	9.10	150.00	17	1	0
Plant 6	595.48	8.40	**3370.00**	6	1	1	353.83	133.00	557.00	6	3	0	2.48	0.60	6.60	6	3	0	18.02	15.20	20.90	6	0	0
Plant 7 and DT-12	148.47	51.40	264.00	3	3	0	801.00	380.00	1600.00	3	0	0	1.70	0.74	3.40	3	0	0	37.93	18.80	65.50	3	0	0
DT-8 and DT-11	9.86	4.90	13.10	7	3	0	443.57	295.00	675.00	7	3	0	0.43	0.39	0.54	7	6	0	16.11	9.50	20.30	7	2	0

Location	Selenium						Uranium						Vanadium						Zinc					
	ISOU PRG = 5,100						ISOU PRG = 3,100						ISOU PRG = 5,200						ISOU PRG = 310,000					
	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG	Average	Minimum	Maximum	Total # of Samples	# of Detects	# of Samples Exceeding the PRG
Plant 1	1.91	0.36	4.10	48	42	0	15.33	0.60	105.00	48	26	0	26.84	13.10	35.70	48	3	0	1004.83	40.10	8930.00	48	9	0
Plant 2	1.35	0.31	6.90	17	11	0	201.91	5.60	1070.00	17	4	0	46.56	7.10	104.00	17	0	0	131.58	37.80	890.00	17	11	0
Plant 6	1.60	0.36	3.40	6	6	0	29.23	7.90	48.60	6	3	0	28.93	20.30	47.30	6	0	0	89.95	41.50	161.00	6	0	0
Plant 7 and DT-12	1.58	0.36	4.00	3	3	0	13.10	6.50	25.90	3	2	0	30.47	29.60	31.10	3	0	0	1065.20	73.60	2620.00	3	3	0
DT-8 and DT-11	1.71	0.36	6.00	7	4	0	6.73	6.50	7.10	7	7	0	19.51	10.90	25.20	7	0	0	52.30	29.50	66.90	7	0	0

[a] This table does not include data for inaccessible soil or sewer sediment.

[b] Appendix J provides the analytical results for each location at the property including summary statistics for each PCOC. Statistics include number of samples, minimum, maximum, average, median, and mode of the parameter concentration.

Units are mg/kg.

Bold values and gray shading indicate samples collected at the property that exceeded the PRG.

4.4.1 Comparison to Background

Sample results for each PCOC were compared to BVs. As shown in Table 4-12, there were exceedances of BVs for each of the radiological PCOCs in sewer sediment and soil adjacent to sewers. With the exception of lead in sewer sediment and uranium metal in soil adjacent to sewers, all of the metal PCOCs had at least one exceedance of BVs in the sewer sediment samples and soil samples collected adjacent to sewers.

Table 4-12. Number of Samples Associated with Sewers Exceeding Background

PCOC	Number of Samples	Number of Samples Exceeding Background	Percentage of Samples Exceeding Background
Sewer Sediment			
Radiological			
Ac-227	26	3	12%
Pa-231	26	4	15%
Ra-226	26	6	23%
Ra-228	26	4	15%
Th-228	26	9	35%
Th-230	26	7	27%
Th-232	26	4	15%
U-235	26	10	38%
U-238	26	9	35%
Metals			
Arsenic	23	1	4%
Cadmium	23	3	13%
Cobalt	23	2	9%
Copper	23	6	26%
Lead	23	0	0%
Manganese	23	1	4%
Molybdenum	23	5	22%
Nickel	23	21	91%
Selenium	23	7	30%
Uranium Metal	23	12	52%
Vanadium	23	1	4%
Zinc	23	5	22%
Soil Adjacent to Sewers			
Radiological			
Ac-227	160	34	21%
Pa-231	160	10	6%
Ra-226	160	17	11%
Ra-228	160	41	26%
Th-228	160	48	30%
Th-230	160	29	18%
Th-232	160	41	26%
U-235	160	77	48%
U-238	160	64	40%

Table 4-12. Number of Samples Associated with Sewers Exceeding Background (Continued)

PCOC	Number of Samples	Number of Samples Exceeding Background	Percentage of Samples Exceeding Background
Soil Adjacent to Sewers			
Metals			
Arsenic	81	20	25%
Cadmium	81	30	37%
Cobalt	81	40	49%
Copper	81	6	7%
Lead	81	7	9%
Manganese	81	20	25%
Molybdenum	81	16	20%
Nickel	81	27	33%
Selenium	81	67	83%
Uranium Metal	81	0[a]	0%
Vanadium	81	11	14%
Zinc	81	19	23%

[a] There is no BV for uranium metal in soil.

4.4.2 Comparison to Preliminary Remediation Goals

Table 4-13 summarizes the results of the screening of the PCOC data against PRGs in sewer sediment and soil adjacent to 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. These four sediment PCOCs have been carried forward into the BRA. 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 and have been retained for evaluation in the BRA.

Based on the results presented in Table 4-8, the highest concentrations of the radiological PCOCs exceeding PRGs in sewer sediment (Ra-226, Ra-228, and U-238) are associated with samples collected from manholes at Plant 1. The highest concentrations of Ac-227, Pa-231, Ra-226, Ra-228, and Th-230 in soil collected adjacent to sewers were detected in soil samples collected adjacent to the Destrehan Street sewer that runs beneath DT-12 and the Levee at DT-2. The maximum concentration of U-238 was associated with a soil sample collected adjacent to a sewer line in Plant 2 (at location SLD124580, as shown in Appendix J). Because this Plant 2 sewer line was subsequently remediated in calendar year 2011 under the 1998 ROD, this sampling location has not been carried forward to the BRA.

Based on the results presented in Tables 4-10 and 4-11, the highest concentrations of arsenic associated with sewer sediment and soil adjacent to sewer lines were detected in Plant 1. The highest concentration of lead in soil adjacent to sewer lines was detected in Plant 2. The single cadmium exceedance of PRGs was in a soil sample collected adjacent to a sewer line in Plant 1.

Table 4-13. Number of Samples Associated with Sewers Exceeding the Preliminary Remediation Goals

PCOC	PRG	Number of Samples	Number of Samples Exceeding the PRG	Percentage of Samples Exceeding the PRG
Sewer Sediment				
Radiological				
Ac-227	11.4 pCi/g	26	0	0%
Pa-231	1.25 pCi/g	26	0	0%
Ra-226	0.0248 pCi/g	26	26	100%
Ra-228	0.0538 pCi/g	26	26	100%
Th-228	121 pCi/g	26	0	0%
Th-230	20 pCi/g	26	0	0%
Th-232	18.9 pCi/g	26	0	0%
U-235	34.3 pCi/g	26	0	0%
U-238	1.65 pCi/g	26	5	19%
Metals				
Arsenic	1.6 mg/kg	23	21	91%
Cadmium	800 mg/kg	23	0	0%
Cobalt	300 mg/kg	23	0	0%
Copper	41,000 mg/kg	23	0	0%
Lead	800 mg/kg	23	0	0%
Manganese	23,000 mg/kg	23	0	0%
Molybdenum	5,100 mg/kg	23	0	0%
Nickel	20,000 mg/kg	23	0	0%
Selenium	5,100 mg/kg	23	0	0%
Uranium	3,100 mg/kg	23	0	0%
Vanadium	5,200 mg/kg	23	0	0%
Zinc	310,000 mg/kg	23	0	0%
Soil Adjacent to Sewers				
Radiological				
Ac-227	11.4 pCi/g	160	5	3%
Pa-231	1.25 pCi/g	160	10	6%
Ra-226	0.0248 pCi/g	160	158	99%
Ra-228	0.0538 pCi/g	160	160	100%
Th-228	121 pCi/g	160	0	0%
Th-230	20 pCi/g	160	11	7%
Th-232	18.9 pCi/g	160	0	0%
U-235	34.3 pCi/g	160	0	0%
U-238	1.65 pCi/g	160	66	41%
Metals				
Arsenic	1.6 mg/kg	81	77	95%
Cadmium	800 mg/kg	81	1	1%
Cobalt	300 mg/kg	81	0	0%
Copper	41,000 mg/kg	81	0	0%
Lead	800 mg/kg	81	5	6%
Manganese	23,000 mg/kg	81	0	0%
Molybdenum	5,100 mg/kg	81	0	0%
Nickel	20,000 mg/kg	81	0	0%
Selenium	5,100 mg/kg	81	0	0%
Uranium Metal	3,100 mg/kg	81	0	0%
Vanadium	5,200 mg/kg	81	0	0%
Zinc	310,000 mg/kg	81	0	0%

4.5 SUMMARY OF NATURE AND EXTENT OF CONTAMINATION AND IDENTIFICATION OF CONTAMINANTS OF POTENTIAL CONCERN

COPCs were conservatively identified based on a single exceedance of their risk-based PRG and are applied on a sitewide basis. These COPCs are carried forward into the BRA. No COPCs were eliminated from being carried into the BRA based on their results being less than BVs. Based on the conservative inclusion of the COPCs to be carried forward in the BRA, potential impacts for defining the nature and extent of contamination due to deviations from the RI WP, including modification of sampling locations and limiting of sampling depth, are minimal. There is no need for additional sampling of inaccessible soil, sewer sediment, soil adjacent to sewers, or building/structure surfaces to define nature and extent of contamination. All site soil and sediment characterization necessary to perform risk assessment and remedial alternatives has been completed. Additional sampling will not impact the remedy decision-making process. The need for additional sampling for remedial design will be evaluated during the remedial design phase after RGs are developed for the COCs.

The COPCs that will be carried forward for evaluation in the BRA are presented in Table 4-14.

Table 4-14. Contaminants of Potential Concern for the Inaccessible Soil Operable Unit

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.

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:

Interior Surface Exceedances:

- 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.

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)	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.

8.0 REFERENCES

10 *Code of Federal Regulations (CFR)* 20, Subpart E. *Standards for Protection Against Radiation.*

40 *CFR* 192, Subpart A. *Standards for the Control of Residual Radioactive Materials from Inactive Uranium Processing Sites.*

40 *CFR* 300.430, Subpart E. *Remedial Investigation/Feasibility Study and Selection of Remedy.*

Allard, B., U. Olofsson, and B. Torstenfelt 1982. *Sorption of Actinides in Well-Defined Oxidation States on Geologic Media,* Materials Research Society Symposia Proceedings 11:775-782.

ANL (Argonne National Laboratory) 2000. *Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes*, ANL/EAD/TM-98, NUREG/CR-6697, prepared for the U.S. Nuclear Regulatory Commission, November.

ANL 2002. *Technical Basis for Calculating Radiation Doses for the Building Occupancy Scenario Using Probabilistic RESRAD-BUILD 3.0 Code*, ANL/EAD/TM/02-1, NUREG/CR-6755, prepared for the U.S. Nuclear Regulatory Commission, February.

ATSDR (Agency for Toxic Substances and Disease Registry) 1990a. *Toxicological Profile for Thorium,* Atlanta, GA, U.S. Department of Health and Human Services, Public Health Service.

ATSDR 1990b. *Toxicological Profile for Radium,* Atlanta, GA, U.S. Department of Health and Human Services, Public Health Service.

ATSDR 1999. *Toxicological Profile for Uranium,* Atlanta, GA, U.S. Department of Health and Human Services, Public Health Service.

ATSDR 2007. *Toxicological Profile for Lead*, Atlanta, GA, U.S. Department of Health and Human Services, Public Health Service.

Benes, P., P. Strejc, and Z. Lukavec 1984. "Interaction of Radium with Freshwater Sediments and Their Mineral Components: I. Ferric Hydroxide and Quartz," *Journal of Radioanalytical and Nuclear Chemistry* 82:275-285.

Benes, P., Z. Borovec, and P. Strejc 1985. "Interaction of Radium with Freshwater Sediments and their Mineral Components: II. Kaolinite and Montmorillonite," *Journal of Radioanalytical and Nuclear Chemistry* 89:339-351.

Benes, P., Z. Borovec, and P. Strejc 1986. "Interaction of Radium with Freshwater Sediments and their Mineral Components: III. Muscovite and Feldspar," *Journal of Radioanalytical and Nuclear Chemistry* 98:91-103.

Bibler, J. and D. Marson 1992. *Behavior of mercury, lead, cesium, and uranyl ions on four SRS soils (U).* Technical Report, Westinghouse Savannah River Company Savannah River Site, WSR-RP-92-326.

BNI (Bechtel National, Inc.) 1989a. *Report on the Limited Radiological Survey of the McKinley Iron Company Property in St. Louis, Missouri*, DOE/OR/20722-226, September.

BNI 1989b. *Report on the Limited Radiological Survey of the Thomas and Proetz Lumber Company Property in St. Louis Missouri*, DOE/OR/20722-228, September.

BNI 1989c. *Preliminary Radiological Survey Report for the St. Louis Terminal Railroad Property in St. Louis, Missouri,* DOE/OR/20722-230, May.

BNI 1989d. *Preliminary Radiological Survey Report for the Norfolk and Western Railroad Property in St. Louis, Missouri.*

BNI 1989e. *Preliminary Radiological Survey Report for the Chicago, Burlington, and Quincy Railroad Property in St. Louis, Missouri.*

BNI 1989f. *Report on the Limited Radiological Survey of the PVO Foods, Inc. Property in St. Louis, Missouri*, DOE/OR20722-227, September.

BNI 1990a. *Radiological, Chemical, and Hydrogeological Characterization Report for the St. Louis Downtown Site, St. Louis, Missouri*, DOE/OR/20722-258, September.

BNI 1990b. *Assessment of Sewers and Drains at the St. Louis Downtown Site.*

BNI 1994. *Remedial Investigation Report for the St. Louis Site, St. Louis, Missouri*, DOE/OR/21949-280, U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN, January.

Brunskill, G. and P. Wilkinson 1987. "Annual Supply of Uranium-238, Uranium-234, Thorium-230, Radium-226, Lead-210, Polonium-210 and Thorium-232 to Lake 239, Experimental Lakes Area, Ontario, Canada from Terrestrial and Atmospheric Sources," *Canadian Journal of Fisheries and Aquatic Science* 44(Supplement 1):215-230.

City of St. Louis 2005. City Ordinance 66777, effective August 2005.

City of St. Louis 2012a. City of St. Louis Zoning Map. Found on the world-wide web at http://stlcin.missouri.org/zoning/map.cfm.

City of St. Louis 2012b. "Strategic Land Use Plan of the St. Louis Comprehensive Plan." Found on the world-wide web at: http://stlouis-mo.gov/government/departments/planning/planning/adopted-plans/strategic-land-use/.

Connell, D.W. and G.J. Miller 1984. *Chemistry and Ecotoxicology of Pollution*, John Wiley and Sons, Inc.

DOD (U.S. Department of Defense) 2000. U.S. Department of Defense, U.S. Department of Energy, U.S. Environmental Protection Agency, and U.S. Nuclear Regulatory Commission. *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM).* NUREG 1575. USEPA 402-R-97-016. August.

DOD 2006. U.S. Department of Defense, Environmental Data Quality Workgroup. *Department of Defense Quality Systems Manual for Environmental Laboratories.* Final Version 3. January.

DOE (U.S. Department of Energy) 1990. *Federal Facility Agreement in the Matter of: The United States Department of Energy, St. Louis and Hazelwood, Missouri*, Docket No. VII-90-F-0005, June.

DOE 1991. *Engineering Evaluation/Cost Analysis for Decontamination at the St. Louis Downtown Site, St. Louis, Missouri*, DOE/OR/23701-02.2, May.

DOE 1992. *Action Memorandum for the Removal of Contaminated Materials at the St. Louis Downtown Site, St. Louis, Missouri*, Memorandum from L.K. Price (OR-FSRD) to File, CCN 086138 (February 27).

DOE 1993. *Baseline Risk Assessment for Exposure to Contaminants at the St. Louis Site, St. Louis, Missouri*, DOE/OR/23701-41.1, prepared for U.S. Department of Energy, Oak Ridge Operations Office, Formerly Utilized Sites Remedial Action Program, under

Contract W-31-109-Eng-38, prepared by Environmental Assessment Division, Argonne National Laboratory, November.

DOE 1995. *Remedial Investigation Addendum Report for the St. Louis Site, St. Louis, Missouri,* DOE/OR/21950-132, September.

DOE 1999. *Guidance for Conducting Risk Assessments and Related Risk Activities for the DOE-ORO Environmental Management Program,* Department of Energy Oak Ridge Operations (DOE-ORO) Environmental Management Program, Oak Ridge, TN, BJC/OR-271, April.

DOE 2012. Risk Assessment Information System (RAIS), Department of Energy Oak Ridge Operations (DOE-ORO), on-line at http://rais.ornl.gov/.

Erdal, B., W. Daniels, and D. Hoffman 1979. *Sorption and Migration of Radionuclides in Geologic Media,* Materials Research, Scientific Basis for Nuclear Waste Management 423-426.

Garten, C.T. Jr. 1978. "A Review of Parameter Values Used to Assess the Transport of Plutonium, Uranium, and Thorium in Terrestrial Food Chains," *Environmental Research* 17:437-452.

Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring,* Van Nostrand Reinhold, New York, NY.

Harmsen, K. and F. De Haan 1980. "Occurrence and Behaviour of Uranium and Thorium in Soil and Water," *Netherlands Journal of Agricultural Science* 28:40-62.

Hayakawa, O. and N. Watanabe 1982. "Characteristics of Arsenite and Arsenate Adsorption on Soils," *Mem Hokkaido Inst Technol,* 10:179–187.

Hitchon, B., E.H. Perkins, and W.D. Gunter 2002. *Introduction to Ground Water Geochemistry,* Geoscience Publishing Ltd., Alberta, Canada.

IT (IT Corporation) 2001. *Pre-Design Investigation Data Summary Report Gunther Salt North Vicinity Property (DT-4), FUSRAP St. Louis Downtown Site, St. Louis, Missouri,* Rev. 0, May 3.

Korte, Nic. 1999. *A Guide for the Technical Evaluation of Environmental Data,* Technomic Publishing Company, Lancaster, PA.

LaFlamme, B. and J. Murray 1987. "Solid/Solution Interaction: The Effect of Carbonate Alkalinity on Adsorbed Thorium," *Geochimica et Cosmochimica Acta* 51:243-250.

Landa, E.R., and D.F. Reid 1982. "Sorption of Radium-226 from Oil-Production Brine by Sediments and Soils," *Environmental Geology* 5:1-8.

Lide, D.R. 1994. Handbook of Chemistry and Physics, 74th Edition, CRC Press, Boca Raton, FL, pages 31-32.

Mallinckrodt Chemical Works, Inc. 1945. *Shipment Security Survey at Mallinckrodt Chemical Works,* February.

MassDEP (Massachusetts Department of Environmental Protection) 2003. "*Best Management Practices for Controlling Exposure to Soil during the Development of Rail Trails.*" Massachusetts Department of Environmental Protection, Commonwealth of Massachusetts Executive Office of Environmental Affairs. Found on the World Wide Web at: http://www.mass.gov/dep/cleanup/laws/railtrai.pdf

Mason, M.G. 1977. *History and Background Relative to the Radiological Re-monitoring of Mallinckrodt by the Energy Research and Development Administration,* prepared for Mallinckrodt, Inc. St. Louis, MO, August.

McKelvey, V.E., D.L. Everhart, and R.M. Garrels 1955. *Origin of uranium deposits,* Economic Geology (50th Anniversary Volume), pp. 464–533.

MDNR (Missouri Department of Natural Resources) 2010. *Lead in Drinking Water: Important Information on How to Protect Your Health,* Water Protection Program, PUB2409, December.

Moulin, V., E. Ansoborlo, L. Bion, D. Doizi, C. Moulin, G. Cote, C. Madic, and J. Van der Lee, 2005. *Speciation Needs in Relation with Environmental and Biological Purposes*, Radioprotection, Vol. 40, Supplement 1, p. S11-S18, May.

NCRP (National Council on Radiation Protection and Measurements) 1984. *Exposures from the Uranium Series with Emphasis on Radon and its Daughter*, NCRP Report No. 77, Bethesda, MD.

NCRP 1995. *Radiation Exposure of the U.S. Population from Consumer Products and Miscellaneous Sources.* NCRP Report No. 95. Bethesda, MD: National Council on Radiation Protection and Measurements, June.

NIST (National Institute of Standards and Technology) 2000. “Radioactivity Measurements on Glazed Ceramic Surfaces.” *Journal of the National Institute of Standards and Technology* 105, no. 22, 275-283. Bethesda, MD.

NPS (National Park Service) 1997. *Mallinckrodt Chemical Works Historic American Buildings Survey*, Great Plains Support Office, Omaha, NE, August.

NRC (U.S. Nuclear Regulatory Commission) 1998. *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions.* NUREG-1507. June.

NRC 1999. *Residual Radioactive Contamination from Decommissioning – Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent,* NUREG/CR-5512, PNL-7994, Volume 1. Final Report.

NRC 2003. *Consolidated NMSS Decommissioning Guidance – Characterization, Survey, and Determination of Radiological Criteria*, NUREG 1757, Volume 2. Revision 1. September.

ORNL (Oak Ridge National Laboratory) 1981. *Radiological Survey of Mallinckrodt Chemical Works, St. Louis, Missouri,* December.

Platford, R., and S. Joshi 1986. “The Chemistry of Uranium and Related Radionuclides in Lake Ontario (USA, Canada) Waters,” *Journal of Radioanalytical and Nuclear Chemistry* 106:333-344.

PNL (Pacific National Laboratory) 1994. *Residual Radioactive Contamination From Decommissioning*, PNL-7994, NUREG/CR-5512 Volume 1, prepared for the U.S. Nuclear Regulatory Commission, June.

Premuzic, E., A. Francis, and M. Lin 1985. “Induced Formation of Chelating Agents by Pseudomonas Aeruginosa Grown in Presence of Thorium and Uranium,” *Archives of Environmental Contamination and Toxicology* 14:759-768.

SAIC (Science Applications International Corporation) 2006. Science Applications International Corporation. *Data Validation Technical Procedures*, June.

SAIC 2008. Quality Assurance Technical Procedures Volume II: Field Standard Operating Procedures, *FTP-400 Equipment Decontamination*, McLean, VA, Revision 2, November.

Sheppard, M., D. Thibault, and J. Mitchell 1987. "Element Leaching and Capillary Rise in Sandy Soil Cores: Experimental Results," *Journal of Environmental Quality* 16:273-284.

Sheppard, M., and D. Thibault 1990. *Default Soil Solid/Liquid Partition Coefficients, K_ds, For Four Major Soil Types: A Compendium.*, Health Physics 1990, Vol. 59, No. 4 pp. 471-482.

Silva, R., L. Benson, and J. Apps 1979. "Studies of Actinide Sorption on Selected Geologic Materials," *American Chemical Society Symposium Series* 100:215-240.

Smith, Brice and Alexandra Amonette 2006. *The Environmental Transport of Radium and Plutonium: A Review,* Institute for Energy and Environmental Research, Takoma Park, MD, June 23.

Smith, K.S. 1999. *Metal Sorption on Mineral Surfaces: An Overview with Examples Relating to Mineral Deposits, in The Environmental Geochemistry of Mineral Deposits Part A: Processes, Techniques, and Health Issues,* Reviews in Economic Geology, Vol. 6A, Society of Economic Geologists, Inc., Littleton, CO, p. 161-176.

Smith, L.A., J.L. Means, A. Chen, B. Alleman, C. Chapman, J. Tixier, S. Brauning, A. Gavaskar, and M. Royer 1995. *Remedial Options for Metals-Contaminated Sites,* Lewis Publishers, Boca Raton, FL.

SNL (Sandia National Laboratories) 1999. *Residual Radioactive Contamination From Decommissioning*, SAND99-2148, NUREG/CR-5512 Vol. 3, prepared for the U.S. Nuclear Regulatory Commission, June.

State of Illinois 2002. Illinois 92nd General Assembly, The McKinley Bridge Fund, Public Act 92-0679, Springfield, IL, July 16.

Swanson, S.M. 1985. "Food chain transfer of U-Series Radionuclides in Northern Saskatchewan Aquatic System," *Health Physics* 49:747-770.

Ticknor, K.V. 1994. "Uranium Sorption on Geological Materials," *Radiochemica Acta* 64:229-236.

Torstenfelt, B. 1986. "Migration of the Actinides Thorium, Protactinium, Uranium, Neptunium, Plutonium, and Americium in Clay," *Radiochemica Acta* 39:105-112.

URS 2005. *Final Remedial Investigation Report for Midnite Mine, Stevens County, Washington*, Final, Sept. 30, 2005.

USACE (U.S. Army Corps of Engineers) 1998a. *Record of Decision for the St. Louis Downtown Site.* Final, October.

USACE 1998b. *Feasibility Study for the St. Louis Downtown Site.* Final, April.

USACE 1998c. *Quality Assurance Project Plan for the St. Louis Airport and Downtown Sites.* Final. June.

USACE 1999a. *Background Soils Characterization Report for the St. Louis Downtown Site.* March.

USACE 1999b. *Inaccessible Soils at St. Louis Downtown Site*, Letter to Mr. Robert Boland from Sharon R. Cotner, September 2.

USACE 2000. *Sampling and Analysis Guide for the St. Louis Site.* October.

USACE 2002a. *Post-Remedial Action Report for the Accessible Soils within the St. Louis Downtown Site Plant 2 Property.* January.

USACE 2002b. *USACE Kansas City and St. Louis District Radionuclide Data Quality Evaluation Guidance for Alpha and Gamma Spectroscopy.* December.

USACE 2003. *Final Status Survey Plan for Structures and Other Consolidated Material Left in Place at the St. Louis Site*, September 22.

USACE 2004a. *Derivation of Site-Specific DCGLs for North County Structures.* Final. October 18.

USACE 2005a. *Memorandum for Record: Non-Significant Change to the Record of Decision for the St. Louis Downtown Site*, March 31.

USACE 2005b. *Post-Remedial Action Report for the Accessible Soils within the St. Louis Downtown Site, Heintz Steel and Manufacturing Vicinity Property (DT-6), and Midwest Waste Vicinity Property (DT-7).* Rev. 0, September 22.

USACE 2005c. U.S. Army Corps of Engineers, St. Louis District. Memorandum for the Record. *SAG Implementation Guidance for Interpretation of QA Split Program.* Sharon R. Cotner. November 23.

USACE 2006. *Final Status Survey Evaluation for the Accessible Soils within the St. Louis Downtown Site Vicinity Properties West of Broadway, Mallinckrodt Plants 3, 8, 9, and 11 and Parking Lots.* Rev. 0, May 26.

USACE 2009a. *Remedial Investigation Work Plan for the Inaccessible Soil Operable Unit at the St. Louis Downtown Site.* Rev. 0, November 30.

USACE 2009b. *Pre-Design Investigation and Final Status Survey Evaluation for the Accessible Soils within the St. Louis Downtown Site Vicinity Properties DT-35 and DT-36.* Rev. 0, May 7.

USACE 2010a. *Post-Remedial Action Report and Final Status Survey Evaluation for the Accessible Soils within the St. Louis Downtown Site Vicinity Property Thomas and Proetz Lumber Company (DT-10).* Rev. 0, July 12.

USACE 2010b. *Environmental Quality – Risk Assessment Handbook Volume II: Environmental Evaluation.* Engineer Manual. Final. EM 200-1-4. December.

USACE 2011. *St. Louis Downtown Site Annual Environmental Monitoring Data and Analysis Report for Calendar Year 2010.* July 8.

USEPA (U.S. Environmental Protection Agency) 1985. *Chemical, Physical, and Biological Properties of Compounds Present at Hazardous Waste Sites,* Washington, D.C.

USEPA 1988a. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA,* EPA/540/G-89/004, October.

USEPA 1988b. *Guidelines for Ground-Water Classification under the EPA Ground-Water Protection Strategy*, Office of Research and Development, Washington, D.C, June.

USEPA 1989a. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part A,* Office of Solid Waste and Emergency Response, EPA/540/1-89/002, Washington, D.C.

USEPA 1989b. *Risk Assessment Guidance for Superfund, Volume II: Environmental Evaluation Manual,* Interim Final. Office of Emergency and Remedial Response, EPA/540/1-89/001, Washington, D.C. March.

USEPA 1990. National Oil and Hazardous Substances, Pollution Contingency Plan, Final Rule, 40 *CFR* Part 300, 55 Federal Register 8666.

USEPA 1991a. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual: Part B, Development of Risk-Based Preliminary Remediation Goals,* Office of Solid Waste and Emergency Response, EPA/540/R-92/003, Washington, D.C.

USEPA 1991b. *Radionuclides in Drinking Water Fact Sheet,* Office of Ground Water and Drinking Water, EPA-570/9-91-700, June.

USEPA 1991c. *A Guide to Principal Threat and Low Level Threat Wastes*, Office of Solid Waste and Emergency Response, Publication 9380.3-06FS, NTIS Order Number PB92-963345, November.

USEPA 1992a. *Behavior of Metals in Soils,* Groundwater Issue, EPA/540/S-92/018, Office of Research and Development, Office of Solid Waste and Emergency Response, Washington D.C., October.

USEPA 1992b. *Guidance for Data Usability in Risk Assessment (Part A),* Office of Solid Waste and Emergency Response, Publication 9285.7-09.A, Washington, D.C.

USEPA 1993. *Environmental Characteristics of EPA, NRC, and DOE Sites Contaminated with Radioactive Substances.* Publication EPA 402-R-93-011, Washington, D.C., March.

USEPA 1995a. *National Primary Drinking Water Regulations: Contaminant Specific Fact Sheets, Inorganic Chemicals - Technical Version*, EPA 811-F-95-002-T, October.

USEPA 1995b. *Health Effects Assessment Summary Tables, Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors.* Office of Radiation and Indoor Air.

USEPA 1996a. *Soil Screening Guidance: Users Guide,* Office of Solid Waste and Emergency Response, Publication 9355-4-23, Washington, D.C., July.

USEPA 1996b. *Radiation Exposure and Risk Assessment Manual.* EPA 402-R-96-016, Office of Air and Radiation, June.

USEPA 1996c. *Soil Screening Guidance: Technical Background Document,* Office of Solid Waste and Emergency Response, EPA 540-R-95-128, Washington, D.C., May.

USEPA 1997a. *Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination*, Office Solid Waste and Emergency Response, OSWER Directive No. 9200.4-18, Washington, D.C., August.

USEPA 1997b. *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments,* Interim Final, Office Solid Waste and Emergency Response, EPA/540-R-97-006, Washington, D.C., June.

USEPA 1999a. *Understanding Variation in Partition Coefficient, Kd, Values, Volume I: The* K_d *Model of Measurement, and Application of Chemical Reaction Codes*, EPA 402-R-99-004A, August.

USEPA 1999b. *Understanding Variation in Partition Coefficient, Kd, Values. Volume II: Review of Geochemistry and Available Kd Values for Cadmium, Cesium, Chromium, Lead, Plutonium, Radon, Strontium, Thorium, Tritium (3H), and Uranium,* Office of Air and Radiation, EPA/402-R-99-004B, August.

USEPA 1999c. *Cancer Risk Coefficients for Environmental Exposure to Radionuclides, Federal Guidance Report No. 13,* Office of Air and Radiation, EPA 402-R-99-001, Washington, D.C., September.

USEPA 1999d. *Background Report on Fertilizer Use, Contaminants and Regulations*, United States Environmental Protection Agency, January.

USEPA 2000. *Soil Screening Guidance for Radionuclides: User's Guide*, Office of Radiation and Indoor Air, Office of Solid Waste and Emergency Response, 9355.4-16A, EPA/540-R-00-007, PB2000 963307, Washington, D.C., October.

USEPA 2002a. *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites,* Office of Emergency and Remedial Response, OSWER Directive 9285.6-10, Washington, D.C, December.

USEPA 2002b. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites,* Office of Solid Waste and Emergency Response, OSWER 9355.4-24, Washington, D.C.

USEPA 2002c. *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites*, Office of Solid Waste and Emergency Response, OSWER 9285.7-41, Washington, D.C. September.

USEPA 2003a. *Human Health Toxicity Values in Superfund Risk Assessments,* Office of Solid Waste and Emergency Response, OSWER Directive 9285.7-53, Washington, D.C. December 5.

USEPA 2003b. *Recommendations of the Technical Review Workgroup for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil*, EPA-540-R-03-001, OSWER Directive 92857-54, January.

USEPA 2004a. *Understanding Variation in Partition Coefficient, Kd, Values, Volume III: Review of Geochemistry and Available Kd Values for Americium, Arsenic, Curium, Iodine, Neptunium, Radium, and Technetium*, Office of Air and Radiation, EPA 402-R-04-002C, July 2004.

USEPA 2004b. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual: Part E, Supplemental Guidance for Dermal Risk Assessment,* Office of Solid Waste and Emergency Response, EPA/540/R/99/005, Washington, D.C.

USEPA 2005. *Guidelines for Carcinogen Risk Assessment.* EPA/630/P-03/001F. Risk Assessment Forum, Washington, D.C. March.

USEPA 2006. *Guidance on Systematic Planning Using the Data Quality Objectives Process (EPA QA/G-4).*

USEPA 2007. *Framework for Metals Risk Assessment,* EPA/120/R-07/001, Office of the Science Advisor, Washington D.C., March.

USEPA 2008. *Child-Specific Exposure Factors Handbook*, EPA/600/R-06/096F, National Center for Environmental Assessment, Office of Research and Development, Washington, D.C., September.

USEPA 2009a. *Radium,* Radiation Protection, accessed on November 9, found on the World Wide Web at: http://www.epa.gov/rpdweb00/radionuclides/radium.html.

USEPA 2009b. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual: Part F, Supplemental Guidance for Inhalation Risk Assessment, Final,* Office of Solid Waste and Emergency Response, EPA-540-R-070-002, Washington, D.C.

USEPA 2010a. *ProUCL Version 4.0 Technical Guide,* EPA/600/R-07/041. April.

USEPA 2010b. *ProUCL Version 4.0 User Guide,* EPA/600/R-07/038. May.

USEPA 2010c. Preliminary Remediation Goals for Radionuclides, found on the world wide web at: http://epa-prgs.ornl.gov/radionuclides/download.html. Office of Solid Waste and Emergency Response. August 3rd.

USEPA 2011. *Exposure Factors Handbook: 2011 Edition.* National Center for Environmental Assessment, Office of Research and Development, EPA/600/R-09/052F, Washington, D.C.

USEPA 2012a. *Risk-Based Regional Screening Levels,* prepared by Oak Ridge National Laboratory with input from USEPA Regions 3, 6, and 9, May.

USEPA 2012b. *Integrated Risk Information System (IRIS),* National Center for Environmental Assessment, Cincinnati, OH, on-line database.

USFWS (U.S. Fish and Wildlife Service) 2008. *Wetlands Digital Data and Mapping*, accessed on July 23, found on the World Wide Web at: http://wetlandsfws.er.usgs.gov/.

Warren and Van Praag, Inc. 1980. Plants 1 and 2 Sewer System Analysis, M.C.W. Drawing No. 3121-5, 3121-6 and 3121-7, prepared for Mallinckrodt Incorporated, St. Louis, MO, January.

WHO (World Health Organization) 2001. *Arsenic and Arsenic Compounds,* 2nd edition, Environmental Health Criteria 224, Geneva.

WSU (Washington State University) 1999. *Determination of the In Vitro Dissolution Rates of Selected Radionuclides in Soil and Subsequent ICRP 30 Solubility Classification for Dosimetry.* Prepared by Sam Glover, Ph.D., and Steve LaMont, Department of Chemistry, Washington State University. Final Report {Draft}. August 15.

FIGURES

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Figure 1-1 Location Map of the St.mxd

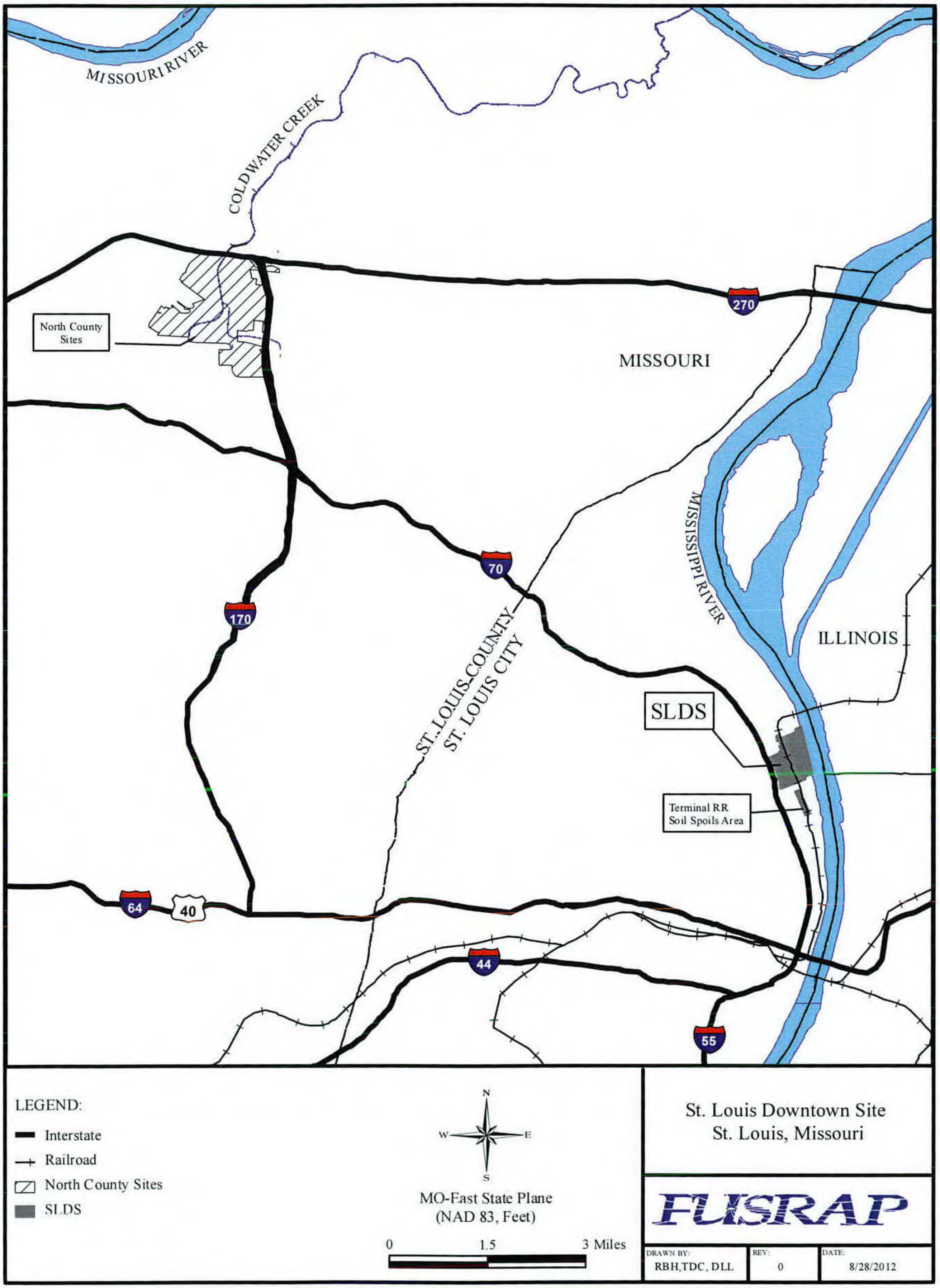
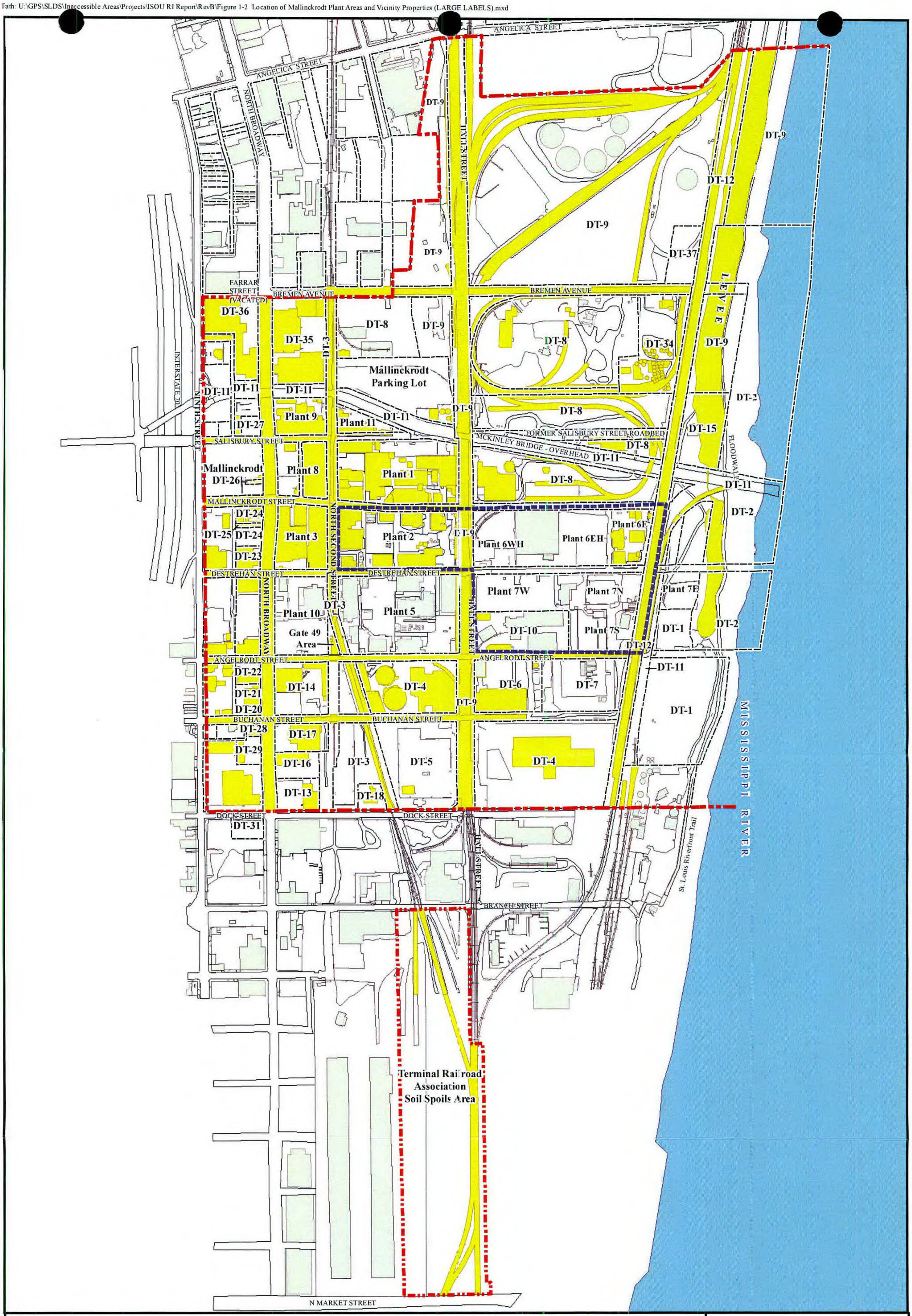


Figure 1-1. Location Map of the St. Louis Sites

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\ISOU RI Report\RevB\Figure 1-2 Location of Mallinckrodt Plant Areas and Vicinity Properties (LARGE LABELS).mxd



LEGEND

🟨	Inaccessible Areas
- - -	Property Boundary
▭	Uranium-Ore Processing Areas as Defined by the 1998 ROD
- - -	SLDS Boundary
🟩	Building or Tank
🟦	River/Stream
—×—	Fence
—+—	Railroad

NOTE: Inaccessible areas are shown for conceptual purposes and do not represent exact boundaries of such areas.

MO-East State Plane
(NAD 83, Feet)

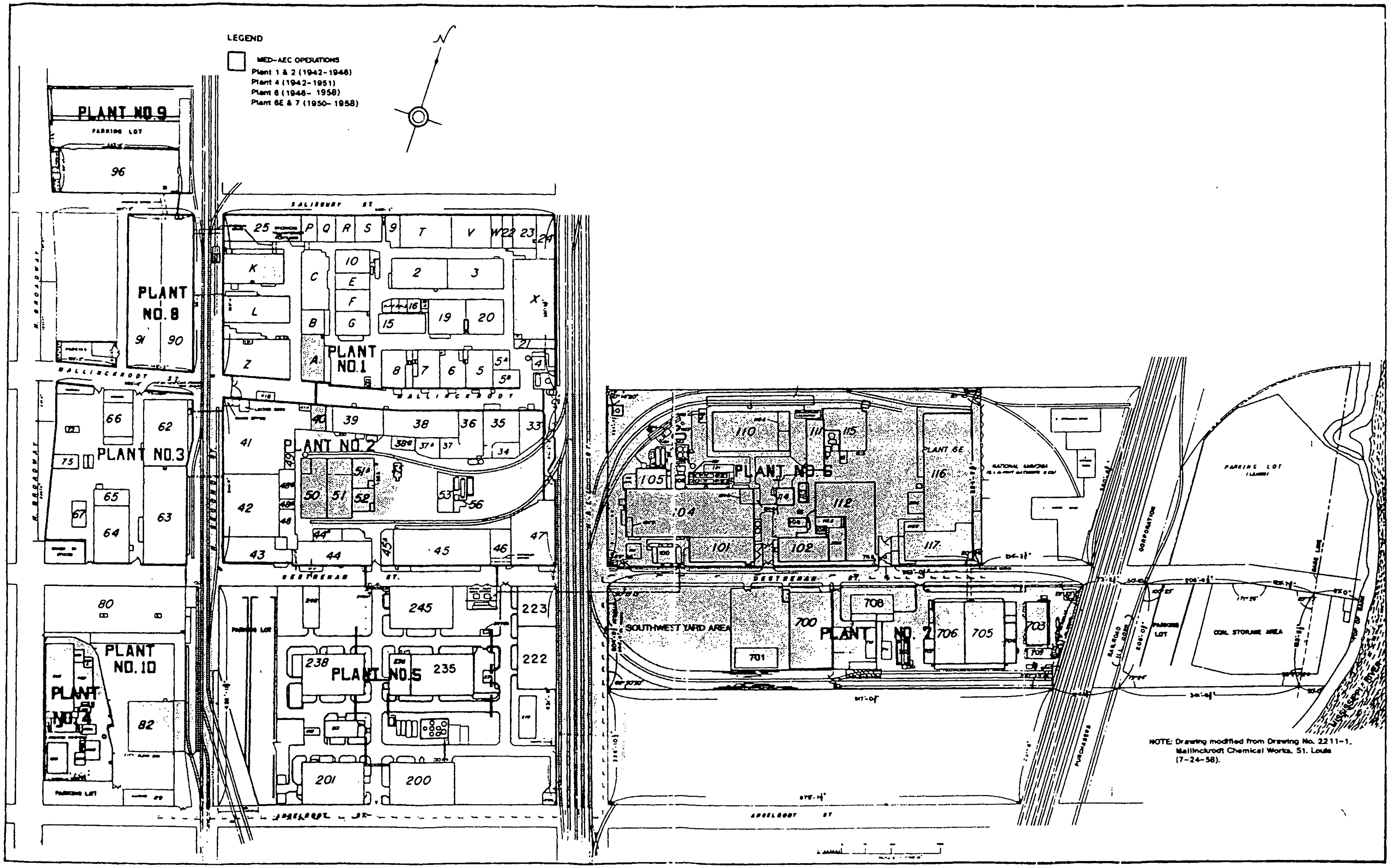
0 260 520 1,040 Feet

St. Louis Downtown Site (SLDS)
St. Louis, Missouri

FUSRAP

DRAWN BY:	REV:	DATE:
KLP, DJH, DLL	2	8/29/12

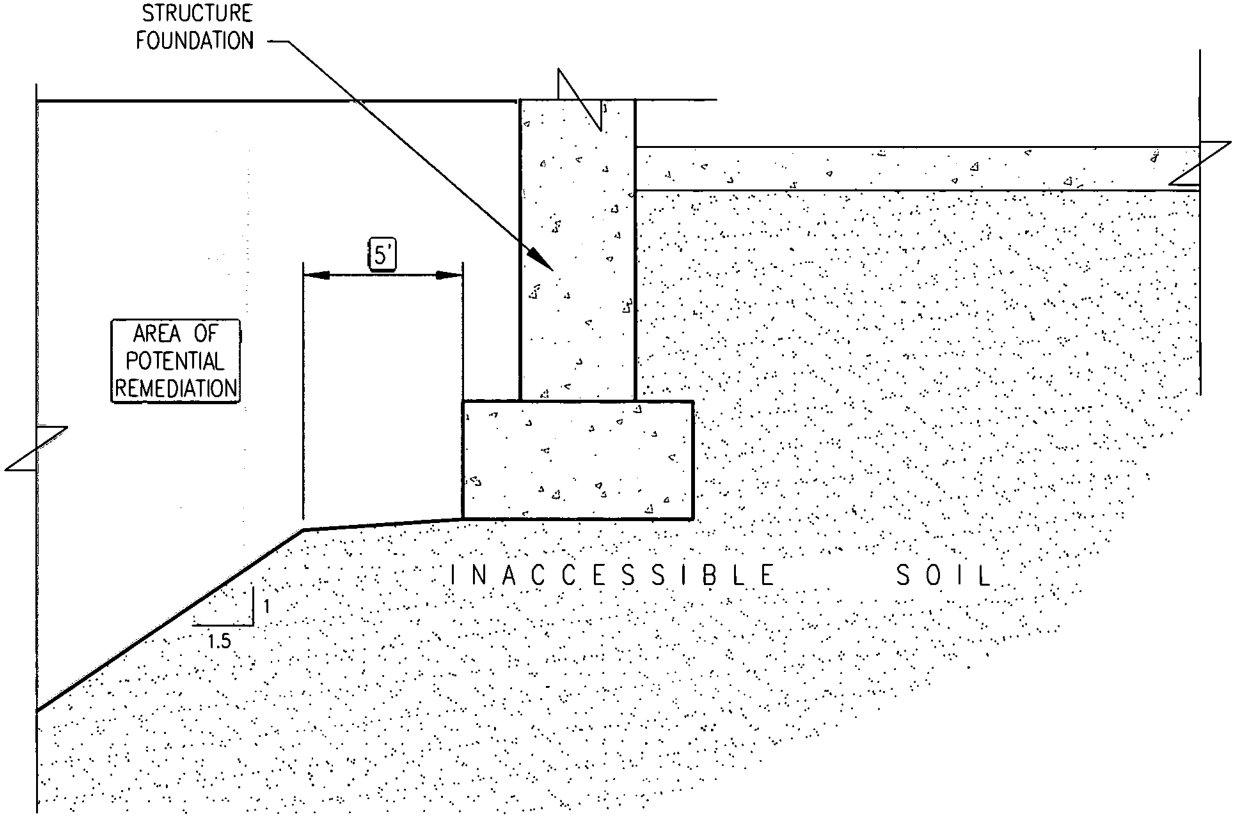
Figure 1-2. Location of Mallinckrodt Plant Areas and Vicinity Properties



NOTE: Drawing modified from Drawing No. 2211-1, Mallinckrodt Chemical Works, St. Louis (7-24-58).

Figure 1-3. Historic Layout (1958) of the MED/AEC and Mallinckrodt Plant Facility

U:\CAD\SLDS\Dwgs\Inaccessible Areas\RI Report\SLDSStructureExcavationDetail.dwg



NOTES:

1. SLOPE SHOWN IS APPROXIMATE. ACTUAL SLOPE WILL DEPEND UPON SOIL PROPERTIES OF AREA IN QUESTION AND ACTUAL DEPTH OF CUT. SHORING WITH SHEETPILING MAY ALSO BE NECESSARY.

FUSRAP

St. Louis Downtown Site

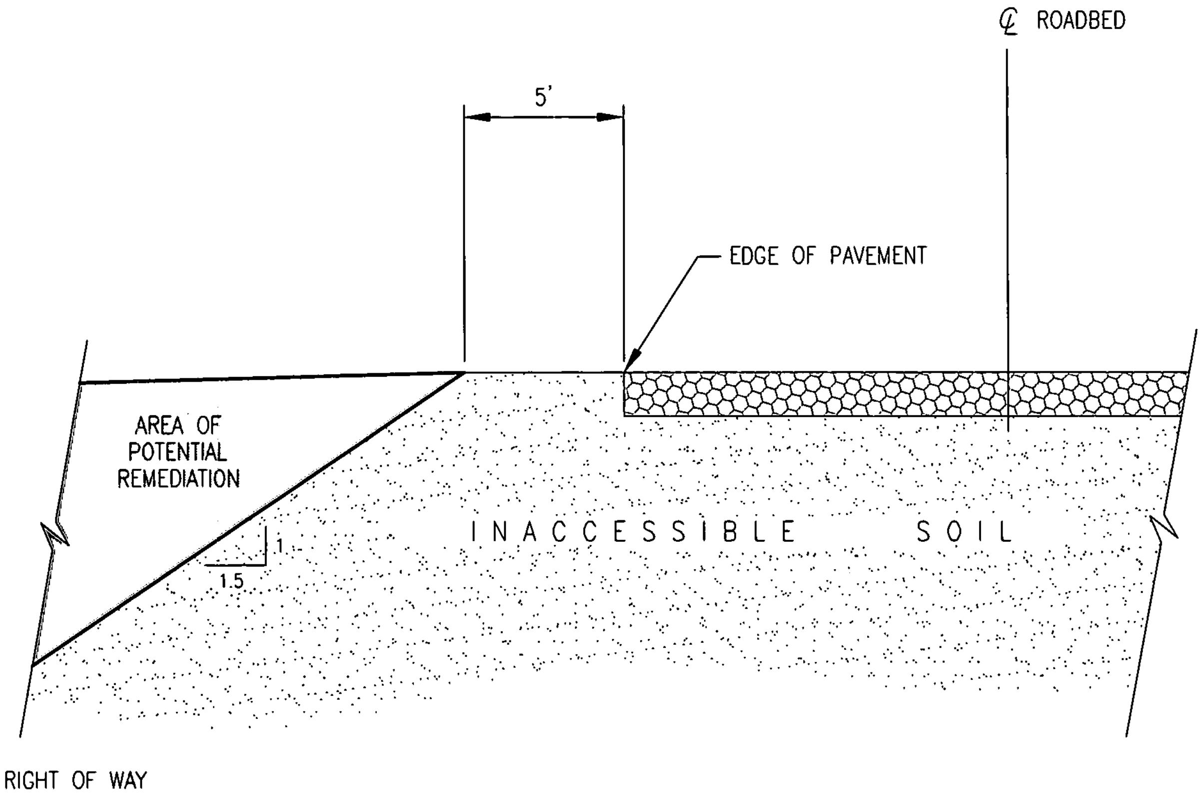
St. Louis, Missouri

DRAWN BY: F. Bauer

REV. NO./DATE: 09/15/11

Figure 2-1. Typical Structure Foundation Inaccessible Soil Profile

U:\CAD\SLDS\Dwgs\Inaccessible Areas\RI Report\SLDSRoadExcavationDetail.dwg



NOTES:

1. SLOPE SHOWN IS APPROXIMATE. ACTUAL SLOPE WILL DEPEND UPON SOIL PROPERTIES OF AREA IN QUESTION AND ACTUAL DEPTH OF CUT. SHORING WITH SHEETPILING MAY ALSO BE NECESSARY.

2. LIMITS OF INACCESSIBLE SOIL ARE SYMMETRICAL ABOUT CENTER LINE OF ROADWAY.

FUSRAP

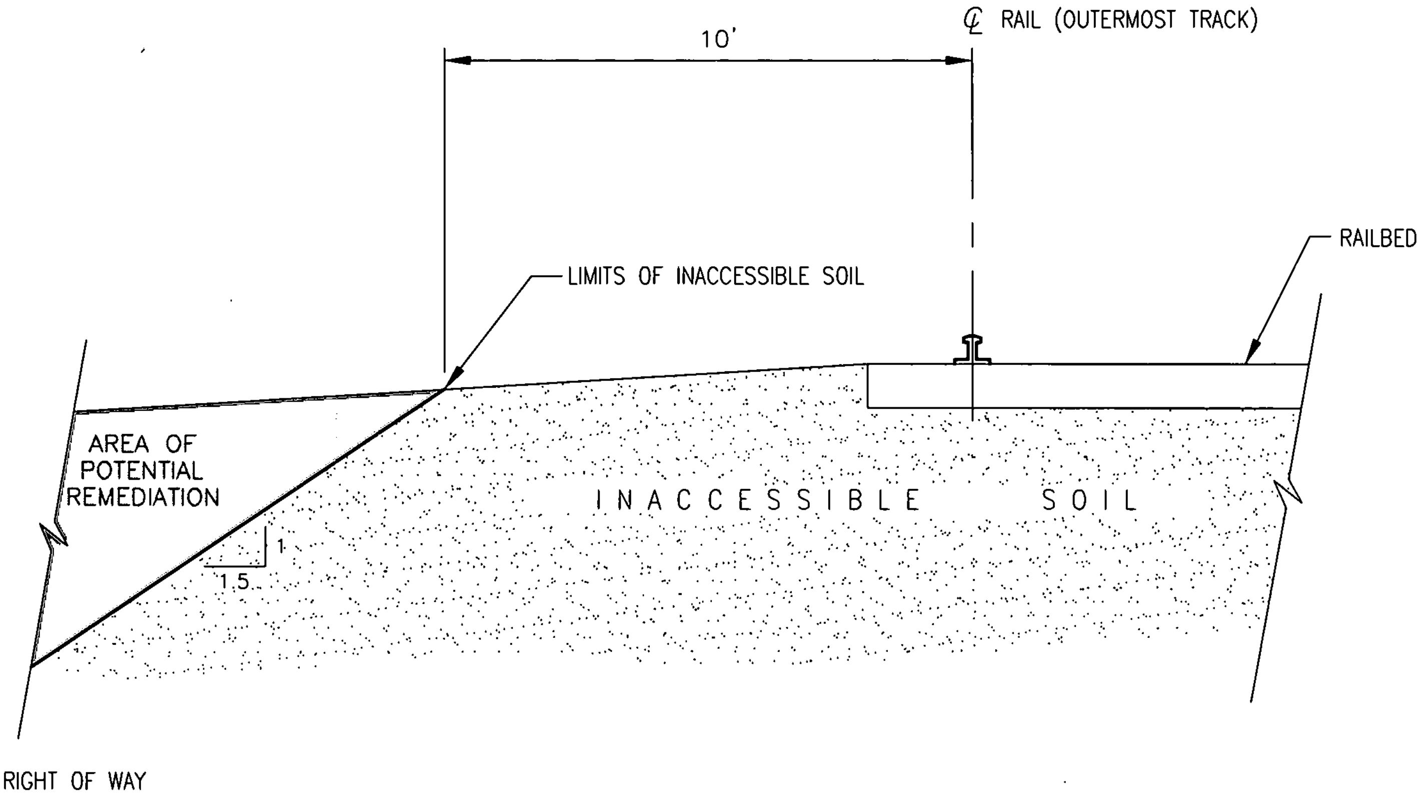
St. Louis Downtown Site

St. Louis, Missouri

DRAWN BY:	REV. NO./DATE:
F. Bauer	09/15/11

Figure 2-2. Typical Roadway Inaccessible Soil Profile

U:\CAD\SLDS\Dwgs\Inaccessible Areas\RI Report\SLDSRailroadExcavationDetail.dwg



NOTES:

1. SLOPE SHOWN IS APPROXIMATE. ACTUAL SLOPE WILL DEPEND UPDN SOIL PROPERTIES OF AREA IN QUESTION AND ACTUAL DEPTH OF CUT. SHORING WITH SHEETPILING MAY ALSO BE NECESSARY.
2. LIMITS OF INACCESSIBLE SOIL ARE TYPICAL ALONG OUTERMOST TRACK.

FUSRAP

St. Louis Downtown Site

St. Louis, Missouri

DRAWN BY:	REV. NO./DATE:
F. Bauer	09/14/11

Figure 2-3. Typical Rail Bed Inaccessible Soil Profile

Unit Designation	Approximate Thickness (ft)	Description
Upper Hydrostratigraphic Unit (HU-A)	0-25	**FILL** Grayish black (N2) to brownish black (5YR2/1). Dry to slightly moist, generally becoming moist at 5 to 6 ft and saturated at 10 to12 ft. Slight cohesion, variable with depth, moisture content and percentage of fines present. Consistency of relative density is unrepresentative due to large rubble fragments. Rubble is concrete, brick, glass, and coal slag. Percentage of fines as silt or clay increases with depth from 5 to 30%. Some weakly cemented aggregations of soil particles. Adhesion of fines to rubble increases with depth and higher moisture content. Degree of compaction is slight to moderate with frequent large voids.
	0-10	**Silty CLAY (CH)** Layers are mostly olive gray (5Y2/1) with some olive black (5Y2/1). Predominantly occurs at contact of undisturbed material or at boundary of material with elevated activity. Abundant dark, decomposed organics. Variable percentages of silt and clay composition.
	0-5	**CLAY (CL)** Layers are light olive gray (5Y5/2) or dark greenish gray (5GY4/1). Slightly moist to moist, moderate cohesion, medium stiff consistency. Tends to have lowest moisture content. Slight to moderate plasticity.
	0-2.5	**Interbedded CLAY, silty CLAY, SILT and Sandy SILT (CL, ML, SM)** Dark greenish gray (5GY4/1) to light olive gray (5Y6/1). Moist to saturated, dependent on percentage of particle size. Contacts are sharp, with structure normal to sampler axis to less than 15 degrees downdip. Layer thicknesses are variable, random in alternation, with no predictable vertical gradiation or lateral continuity. Some very fine-grained, rounded silica sand as stringers. Silt in dark mafic, biotite flakes. Some decomposed organics.
Lower Hydrostratigraphic Unit (HU-B)	0-10	**Sandy SILT (ML)** Olive gray (5Y4/1). Moist with zones of higher sand content saturated. Slight to moderate cohesion, moderate compaction. Stiff to very stiff consistency, rapid dilatancy, nonplastic. Sand is well sorted, very fine, and fine-grained rounded quartz particles.
	0-50	**Silty SAND and SAND (SM, SP, SW)** Olive gray (5Y4/1). Saturated, slight cohesion, becoming noncohesive with decrease of silt particles with depth. Dense, moderate compaction. Moderate to well-graded, mostly fine- and medium-grained with some fine- and coarse-grained particles. Mostly rounded with coarse grains slightly subrounded. Gradual gradation from upper unit, silty sand has abundant dark mafic/biotite flakes. Sand is well-graded, fine gravel to fine sand. Mostly medium-grained, with some fine-grained and few coarse-grained and fine gravel.
Limestone Bedrock Unit (HU-C)	Total thickness not penetrated during drilling	**LIMESTONE** Light olive gray (5Y4/1) with interbedded chert nodules. Generally hard to very hard; difficult to scratch with knife. Slightly weathered, moderately fresh with little to no discoloration or staining. Top 5 ft is moderately fractured with 99% of joints normal to the core axis. Joints are open, planar, and smooth. Some are slightly discolored with trace of hematite staining.

Source: Modified from BNI 1994.

Note: The codes in parentheses following lithologies are the Unified Soil Classification System (USCS) codes.

The codes in parentheses following the colors represent chroma, hue, and value from the Munsell soil color charts.

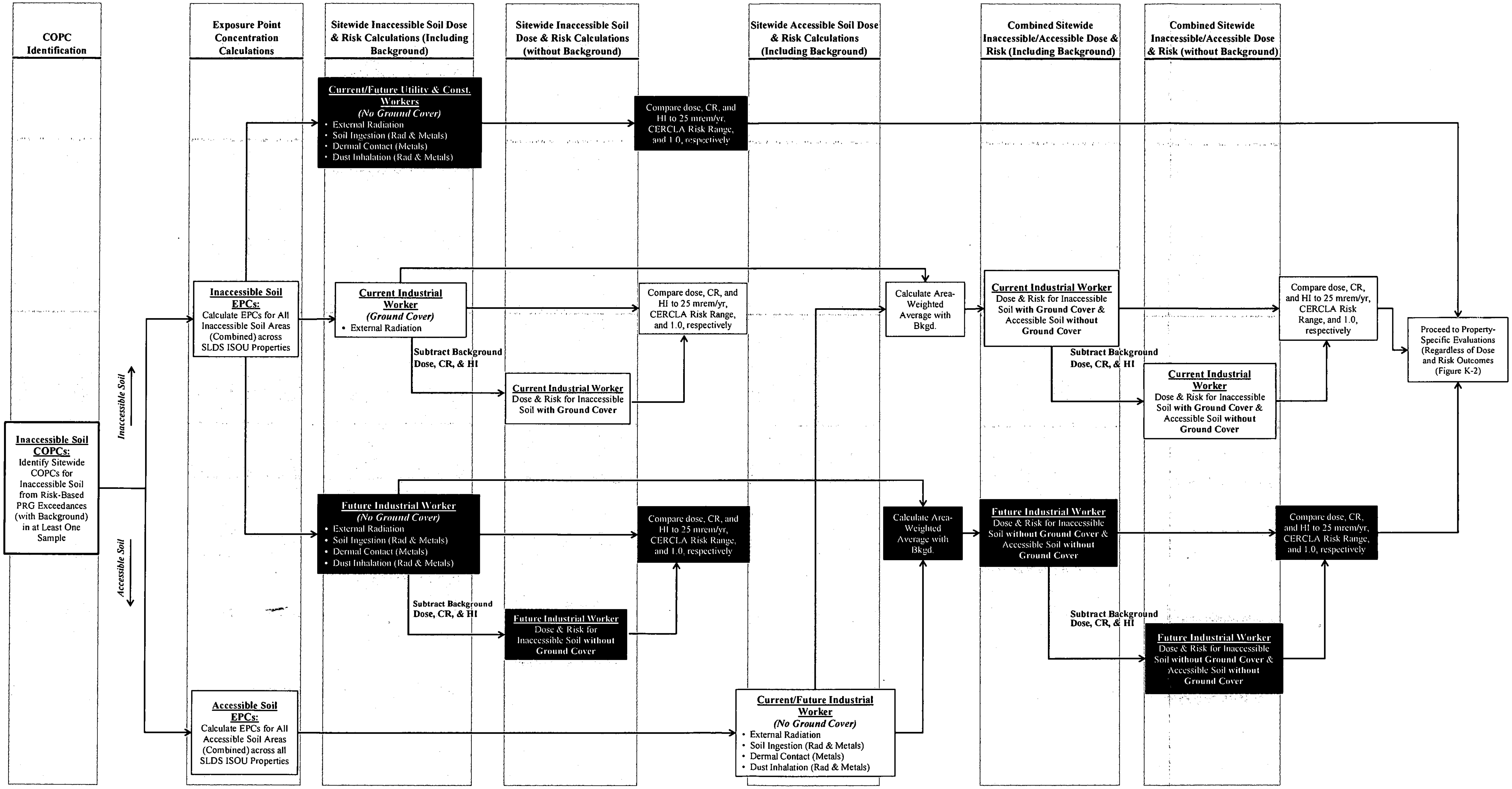
NOT TO SCALE

FUSRAP

St. Louis Downtown Site
St. Louis, Missouri

DRAWN BY:	REV. NO./DATE:	CAD FILE:
C.Kaple	0 - 06/01/00	

Figure 3-1. Generalized Stratigraphic Column for the SLDS



RECEPTOR SCENARIOS:

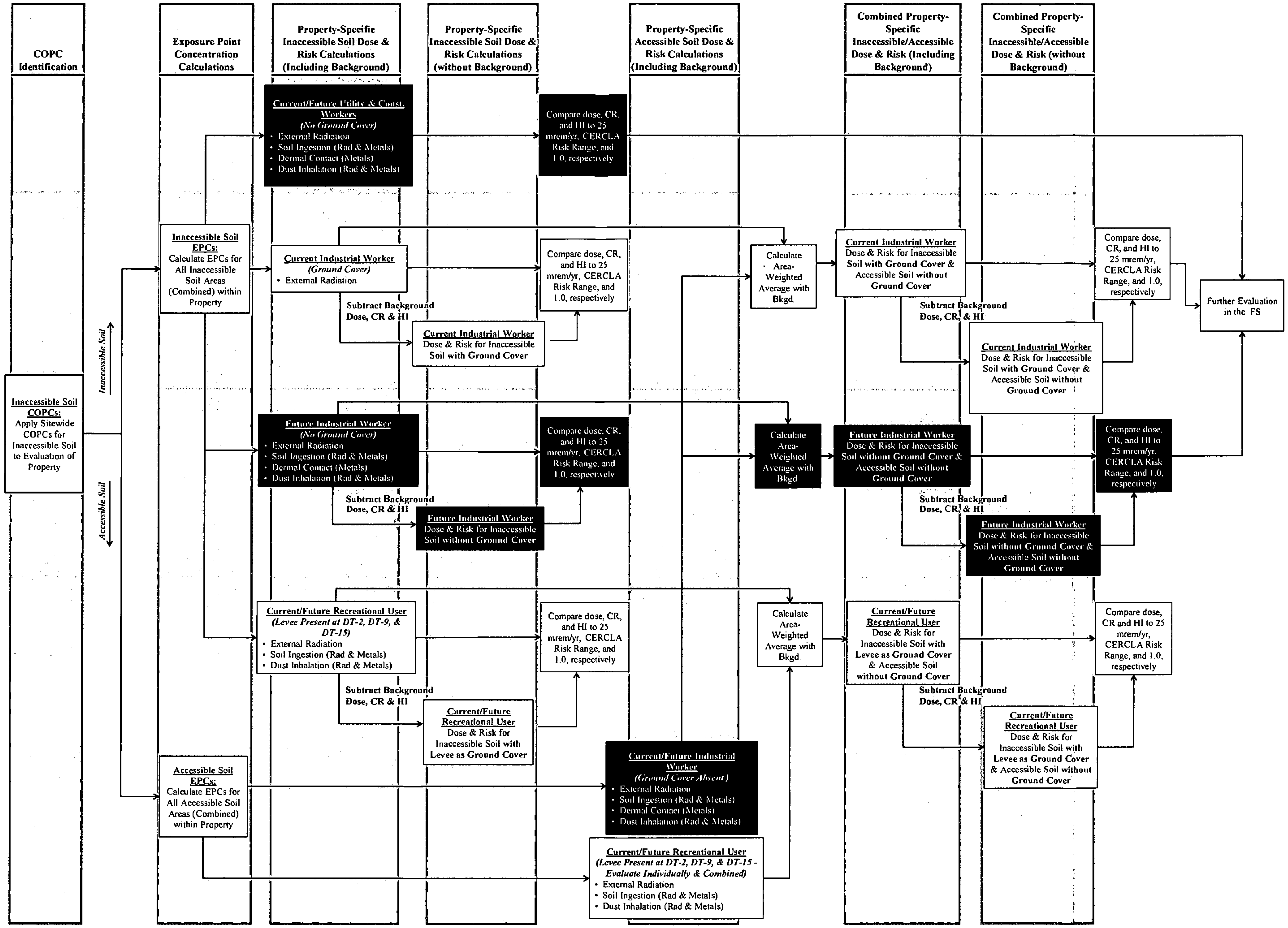
Current/Future Utility & Construction Worker - Inaccessible soil evaluations with no ground cover assumed to be present over excavated

Current Industrial Worker - Inaccessible soil and combined inaccessible/accessible soil evaluations, with ground cover assumed to be present over inaccessible soil areas.

Future Industrial Worker - Inaccessible soil and combined inaccessible/accessible soil evaluations, with no ground cover assumed to be present over inaccessible soil

Current/Future Industrial Worker - Accessible soil evaluations, with no ground cover assumed to be present.

Figure 6-1. Sitewide ISOU Human Health Risk Assessment Process for Soil



RECEPTOR SCENARIOS:

Current/Future Utility & Construction Worker - Inaccessible soil evaluations with no ground cover assumed to be present over excavated inaccessible soil.

Current Industrial Worker - Inaccessible soil and combined inaccessible/occessible soil evaluations, with ground cover assumed to be present over inaccessible soil areas.

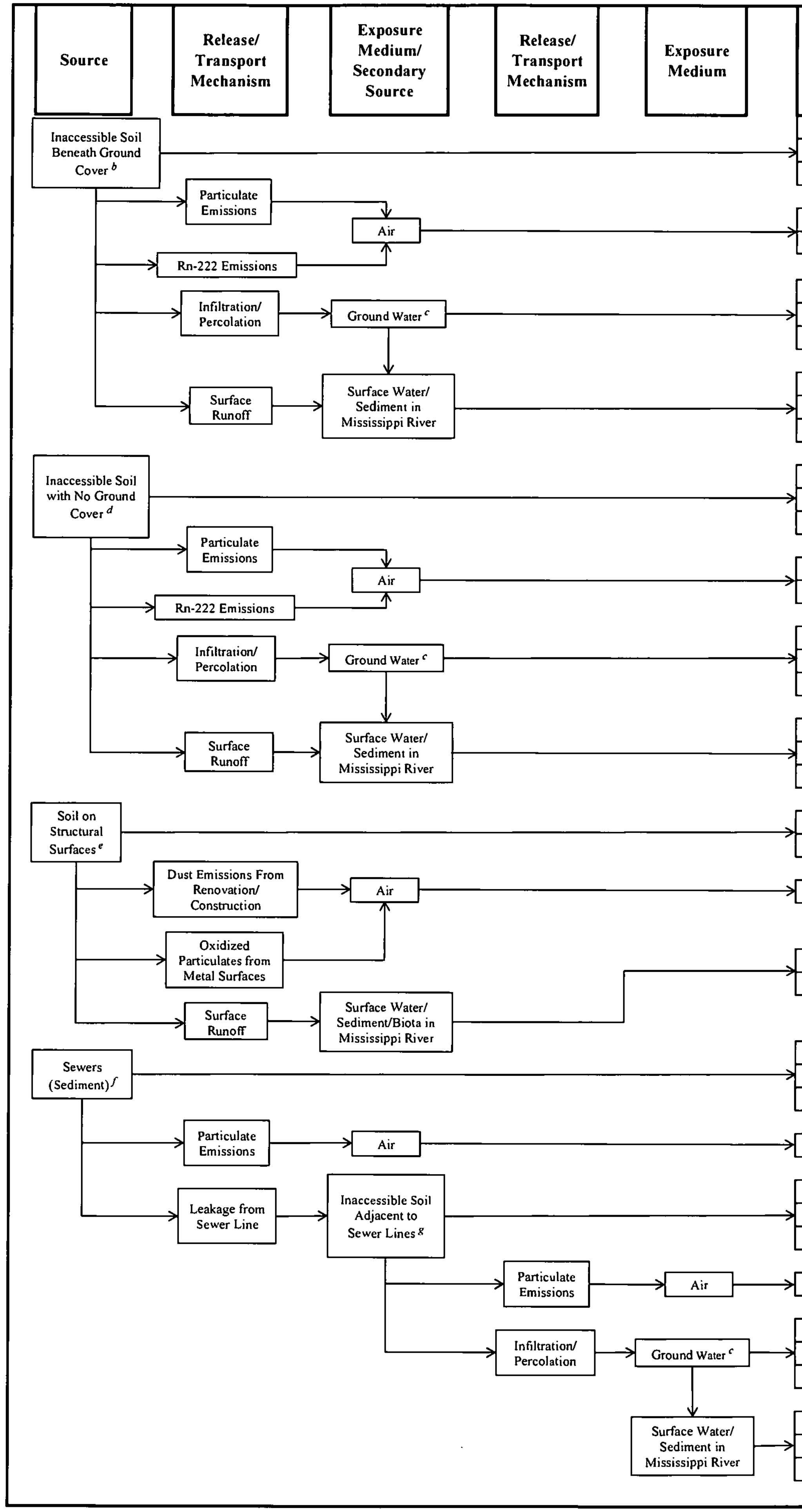
Future Industrial Worker - Inaccessible soil and combined inaccessible/accessible soil evaluations, with no ground cover assumed to be present over inaccessible soil areas.

Current/Future Recreational User of St. Louis Riverfront Trail - Inaccessible soil and combined inaccessible/accessible soil evaluations. Levee assumed to be always present as ground cover over inaccessible soils at DT-2, DT-9, and DT-15.

Current/Future Industrial Worker - Accessible soil evaluations, with no ground cover assumed to be present.

Current/Future Recreational User of the St. Louis Riverfront Trail - Accessible soil evaluations for DT-2, DT-9, and DT-15. No ground cover assumed.

Figure 6-2. SLDS ISOU Property-Specific Human Health Risk Assessment Process for Soil



Exposure Routes	Potential Human Receptors							Ecological Receptors [a]	
	Current Industrial Worker	Future Industrial Worker	Current/Future Construction Worker	Current/Future Utility Worker	Current/Future Sewer Maintenance Worker	Current/Future Recreational User (St. Louis Riding Trail)	Future Resident	Aquatic	Terrestrial
External Radiation	❷					❷			❶
Ingestion (Rad & Metals)									❶
Dermal Contact (Metals)									❶
Dust Inhalation (Rad & Metals)									❶
Rn-222 Inhalation [h]	❶	❶	❶	❶	❶				❶
External Radiation									
Ingestion (Rad & Metals)									
Dermal Contact (Metals)									
External Radiation								❶	❶
Ingestion (Rad & Metals)								❶	❶
Dermal Contact (Metals)								❶	❶
External Radiation		❷	❷	❷					❶
Ingestion (Rad & Metals)		❷	❷	❷					❶
Dermal Contact (Metals)		❷	❷	❷					❶
Dust Inhalation (Metals & Rad)		❷	❷	❷					❶
Rn-222 Inhalation [h]	❶	❶	❶	❶	❶				❶
External Radiation			❶	❶					
Ingestion (Rad & Metals)			❶	❶					
Dermal Contact (Metals)			❶	❶					
External Radiation								❶	❶
Ingestion								❶	❶
Dermal Contact (Metals)								❶	❶
External Radiation	❷	❷	❶						
Ingestion (Rad)	❷	❷	❶						
Dust Inhalation (Rad)	❷	❷	❶						
External Radiation								❶	❶
Ingestion (Rad)								❶	❶
External Radiation				❶	❷				
Ingestion (Rad & Metals)				❶	❷				
Dermal Contact (Metals)				❶	❷				
Dust Inhalation (Rad & Metals)				❶	❶				
External Radiation				❷	❶				
Ingestion (Rad & Metals)				❷	❶				
Dermal Contact (Metals)				❷	❶				
Dust Inhalation (Rad & Metals)				❷	❶				
External Radiation				❶	❶				
Ingestion (Rad & Metals)				❶	❶				
Dermal Contact (Metals)				❶	❶				
External Radiation									
Ingestion (Rad & Metals)									
Dermal Contact (Metals)									

Notes

KEY:

☐ Incomplete exposure pathway. Pathway is not evaluated in the BRA.

❶ Pathway is potentially complete, but is considered unlikely, insignificant, or out of scope for the ISOU. Pathway is not quantitatively evaluated in the BRA. For Rn-222, the pathway is currently indeterminate due to insufficient data.

❷ Potentially complete and significant exposure pathway. Pathway is evaluated in the BRA.

NOTES:

[a] Ecological receptors include animals and plants.

[b] SLDS-wide and property-specific inaccessible soil beneath ground cover is being evaluated under the current industrial land use scenario.

[c] There are no complete or significant human or ecological exposure pathways for ground water.

[d] SLDS-wide and property-specific inaccessible soil with no ground cover is being evaluated under the future industrial worker scenario, as well as for current/future construction and utility worker scenarios.

[e] Includes interior and exterior surfaces containing radiologically contaminated soil. Industrial worker exposures are assumed for interior surfaces, and exposures to industrial workers performing maintenance are assumed for exterior surfaces and roofs. Industrial workers are assumed to be exposed 2,000 hours per year for 25 years. Industrial maintenance workers are assumed to be exposed 80 hours per year for 1 year.

[f] Sewers are considered to be a source, and the first medium assumed to have been impacted by MED/AEC operations is sediment inside of sewer lines. Sewer sediment exposures are assumed to occur infrequently during internal sewer line maintenance activities. Dust inhalation is not evaluated, because the moisture content of the sediment is assumed to preclude dust emissions. Soil adjacent to sewers are also part of this source.

[g] Because radiological and metals contamination in soil adjacent to sewer lines is likely due to sewer line leaks, soil adjacent to sewer lines is considered to be a secondary source.
Pathways are considerd complete and significant due to recent sewer removal/replacement work that has been conducted.

[h] Only Rn-222 emissions from inaccessible soil to indoor air are considered for occupied or habitable buildings. Currently, no indoor air sampling results are available for quantitative BRA evaluations. Rn-222 emissions from inaccessible soil to outdoor air are not considered significant, as explained in Section 5.2.1.2.

Figure 6-3. Human Health and Ecological Conceptual Site Model for St. Louis Downtown Site, Inaccessible Soil Operable Unit

APPENDIX A

Soil Boring Logs and Sewer Sediment Manhole Logs

(On the DVD on the Back Cover of this Report)

APPENDIX B

Quality Control Summary Report

(On the DVD on the Back Cover of this Report)

APPENDIX C

Figures: RI Sampling Locations for Inaccessible Soil Areas and Buildings and Extent of Contamination for Inaccessible Soil Areas

LIST OF FIGURES

Path: \SLDS\Inaccessible Areas\Projects\Risk Ranges\Figure C-1 Extent of Ac-227 Exceeding the PRG.mxd

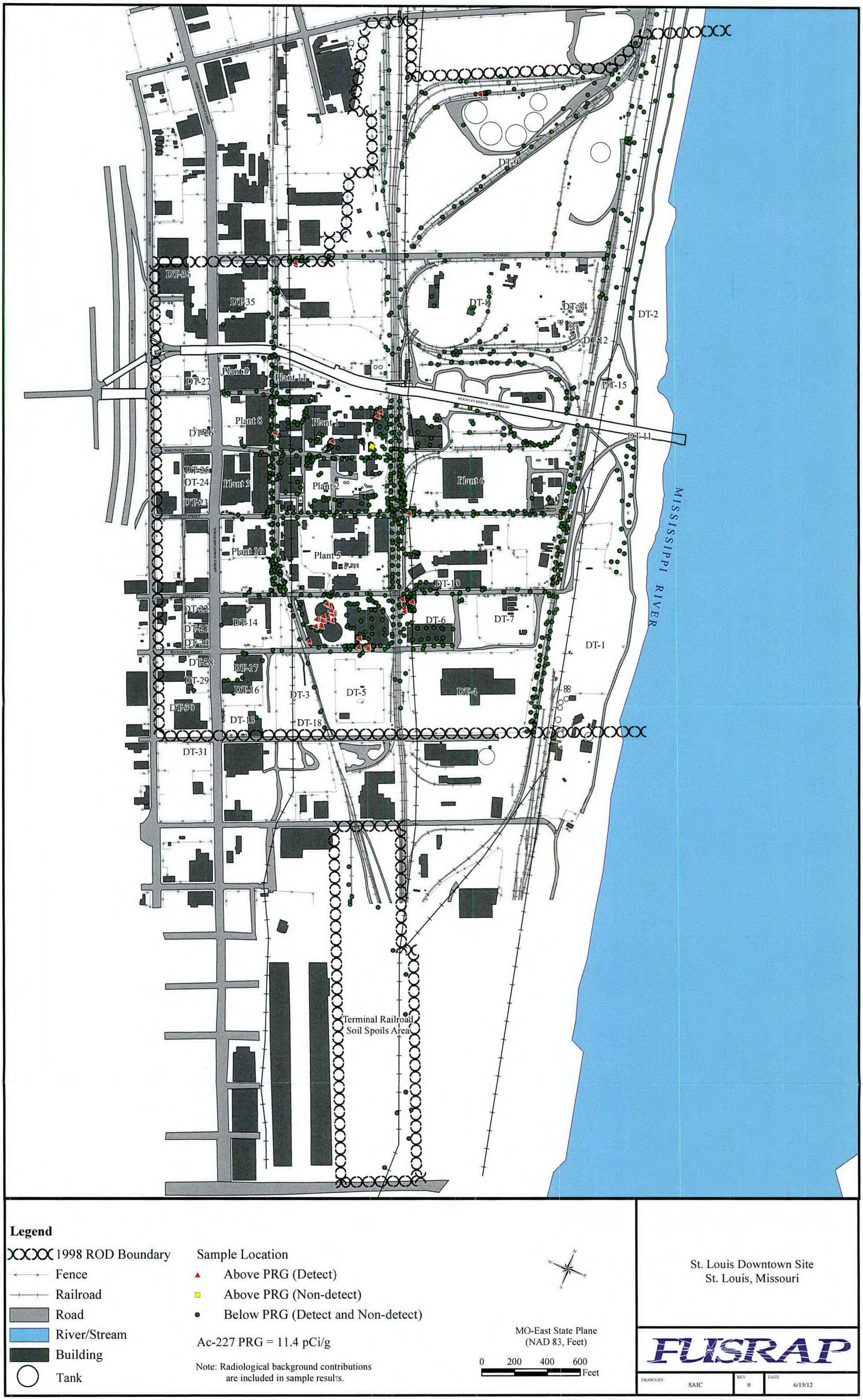


Figure C-1. Distribution of Ac-227 Exceeding the PRG in Inaccessible Soil

Path: SLDS\Inaccessible Areas\Projects\Risk Ranges\Figure C-2 Extent of Pa-231 Exceeding the PRG.mxd

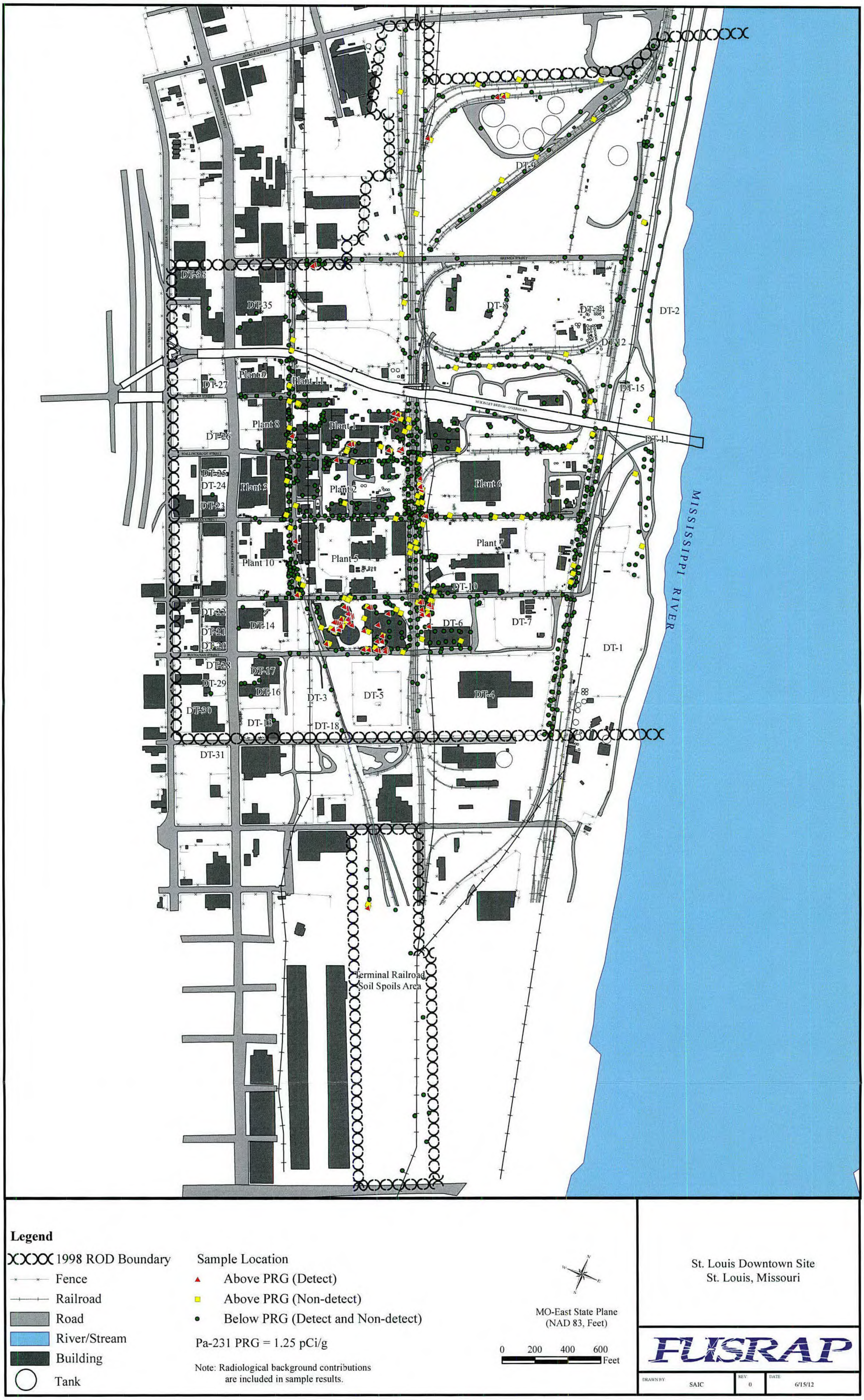
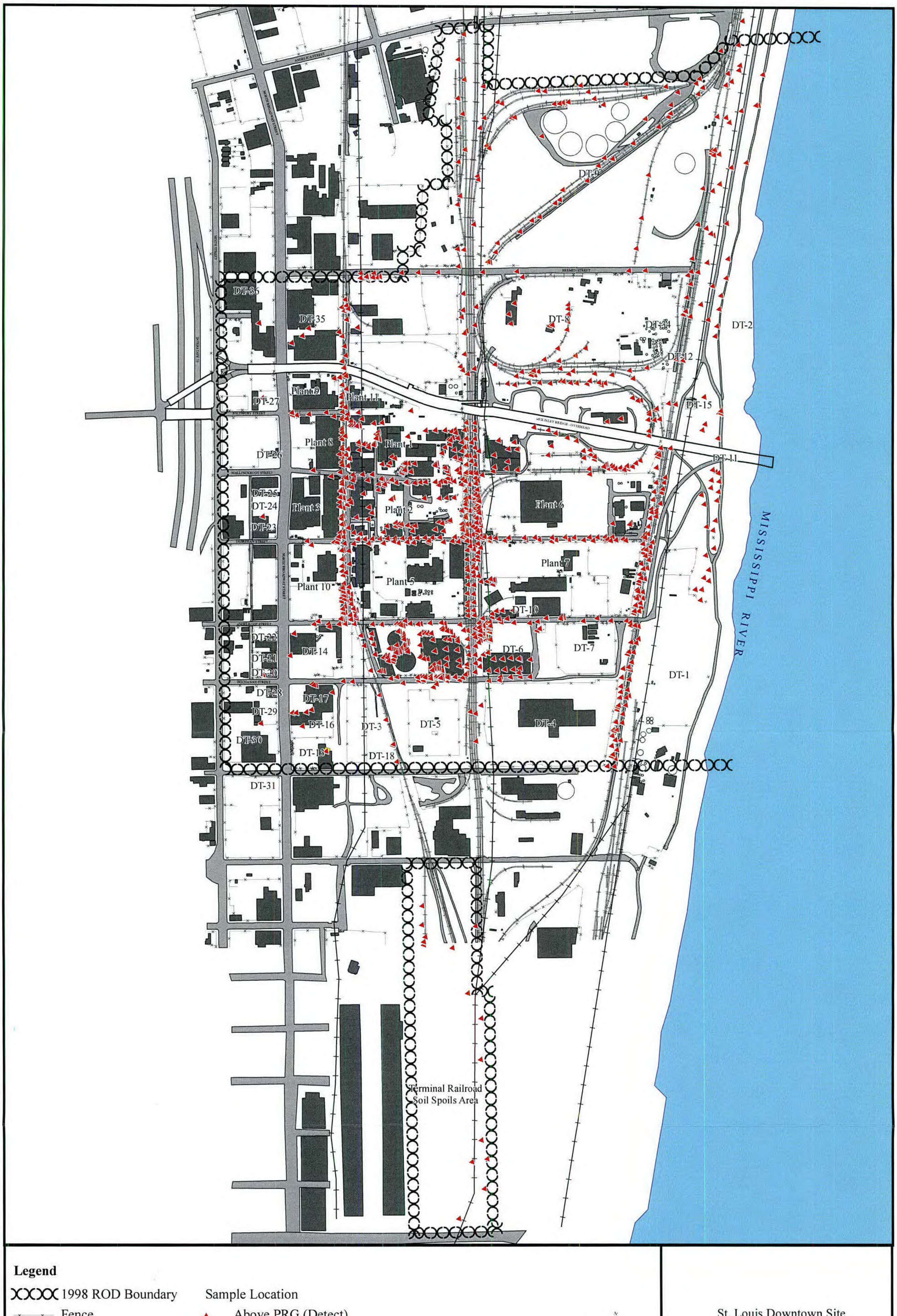


Figure C-2. Distribution of Pa-231 Exceeding the PRG in Inaccessible Soil

Path: SLDS\Inaccessible Areas\Projects\Risk Ranges\Figure C-3 Extent of Ra-226 Exceeding the PRG.mxd



Legend

XXXX 1998 ROD Boundary
-×-×- Fence
-+-+- Railroad
▨ Road
🟦 River/Stream
■ Building
○ Tank

Sample Location
▲ Above PRG (Detect)
🟨 Above PRG (Non-detect)
● Below PRG (Detect and Non-detect)

Ra-226 PRG = 0.02 pCi/g

Note: Radiological background contributions are included in sample results.

MO-East State Plane
(NAD 83, Feet)

0 200 400 600 Feet

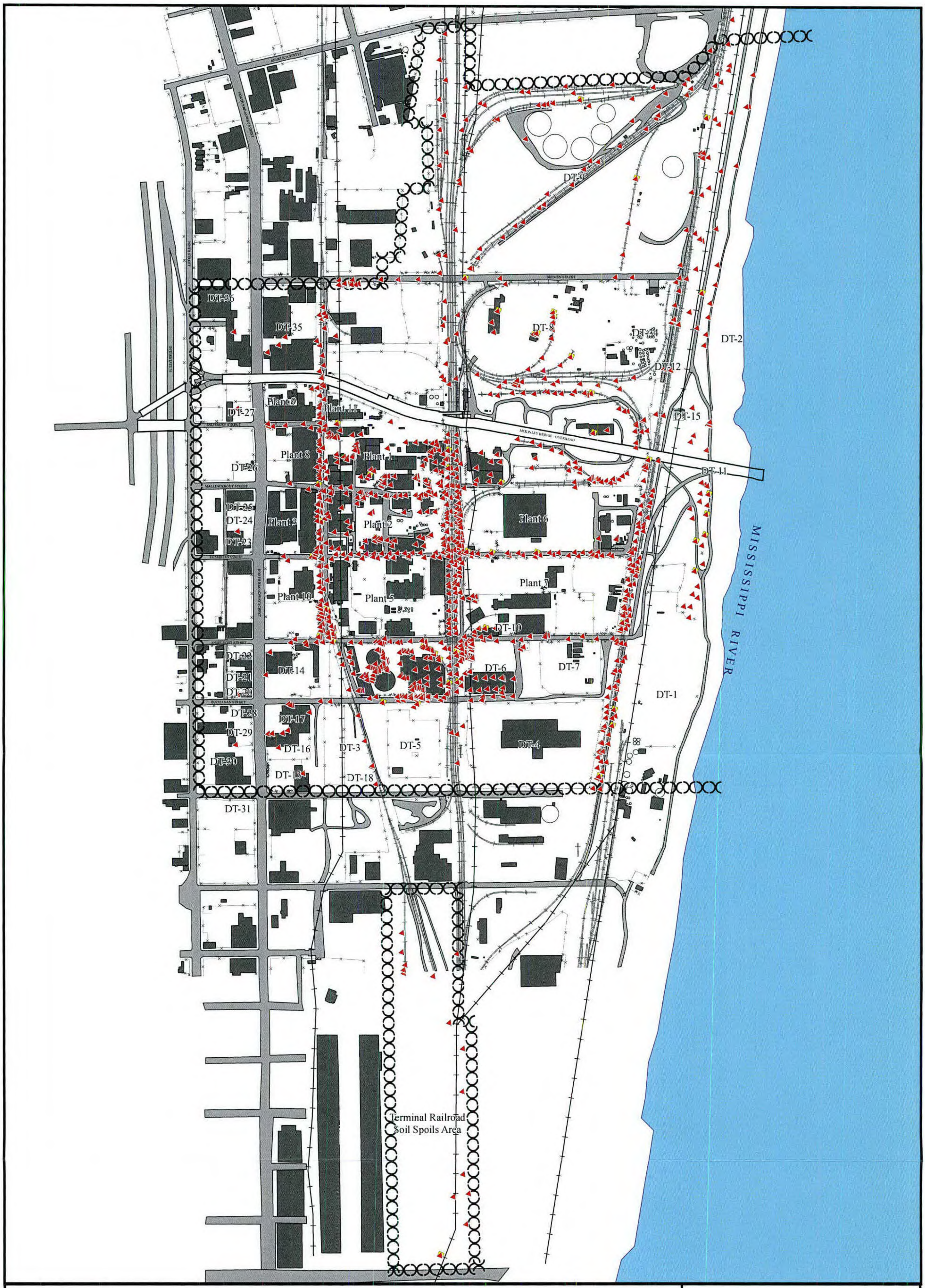
St. Louis Downtown Site
St. Louis, Missouri

FUSRAP

DRAWN BY	REV	DATE
SAIC	0	6/12/12

Figure C-3. Distribution of Ra-226 Exceeding the PRG in Inaccessible Soil

Path: SLDS\Inaccessible Areas\Projects\Risk Ranges\Figure C-4 Extent of Ra-228 Exceeding the PRG.mxd



Legend

- 1998 ROD Boundary
- Fence
- Railroad
- ▨ Road
- 🟦 River/Stream
- ■ Building
- ○ Tank

Sample Location

- ▲ Above PRG (Detect)
- 🟨 Above PRG (Non-detect)
- ● Below PRG (Detect and Non-detect)

Ra-228 PRG = 0.05 pCi/g

Note: Radiological background contributions are included in sample results.

MO-East State Plane
(NAD 83, Feet)

0 200 400 600 Feet

St. Louis Downtown Site
St. Louis, Missouri

FUSRAP

DRAWN BY:	REV:	DATE:
SAIC	0	6/12/12

Figure C-4. Distribution of Ra-228 Exceeding the PRG in Inaccessible Soil

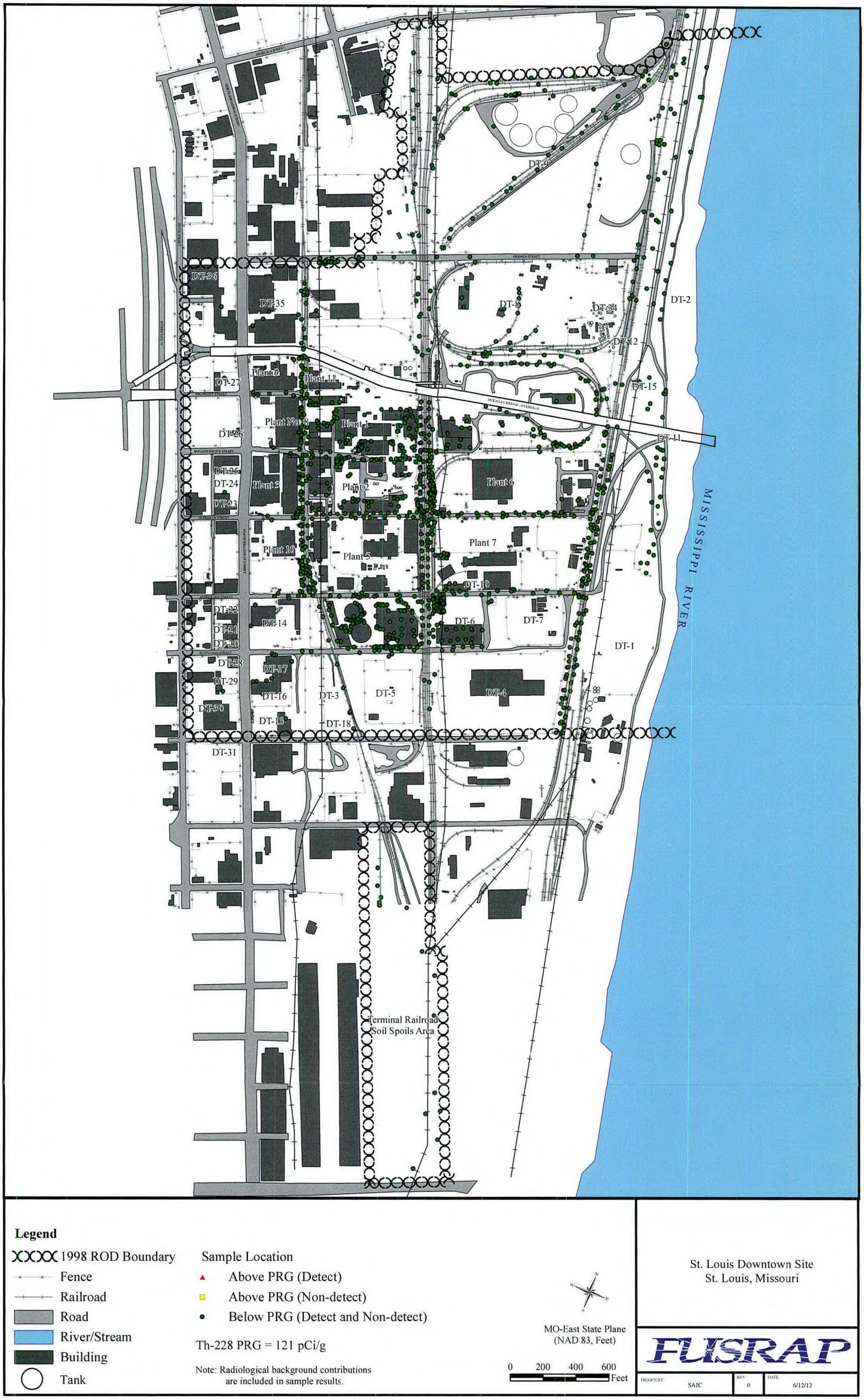
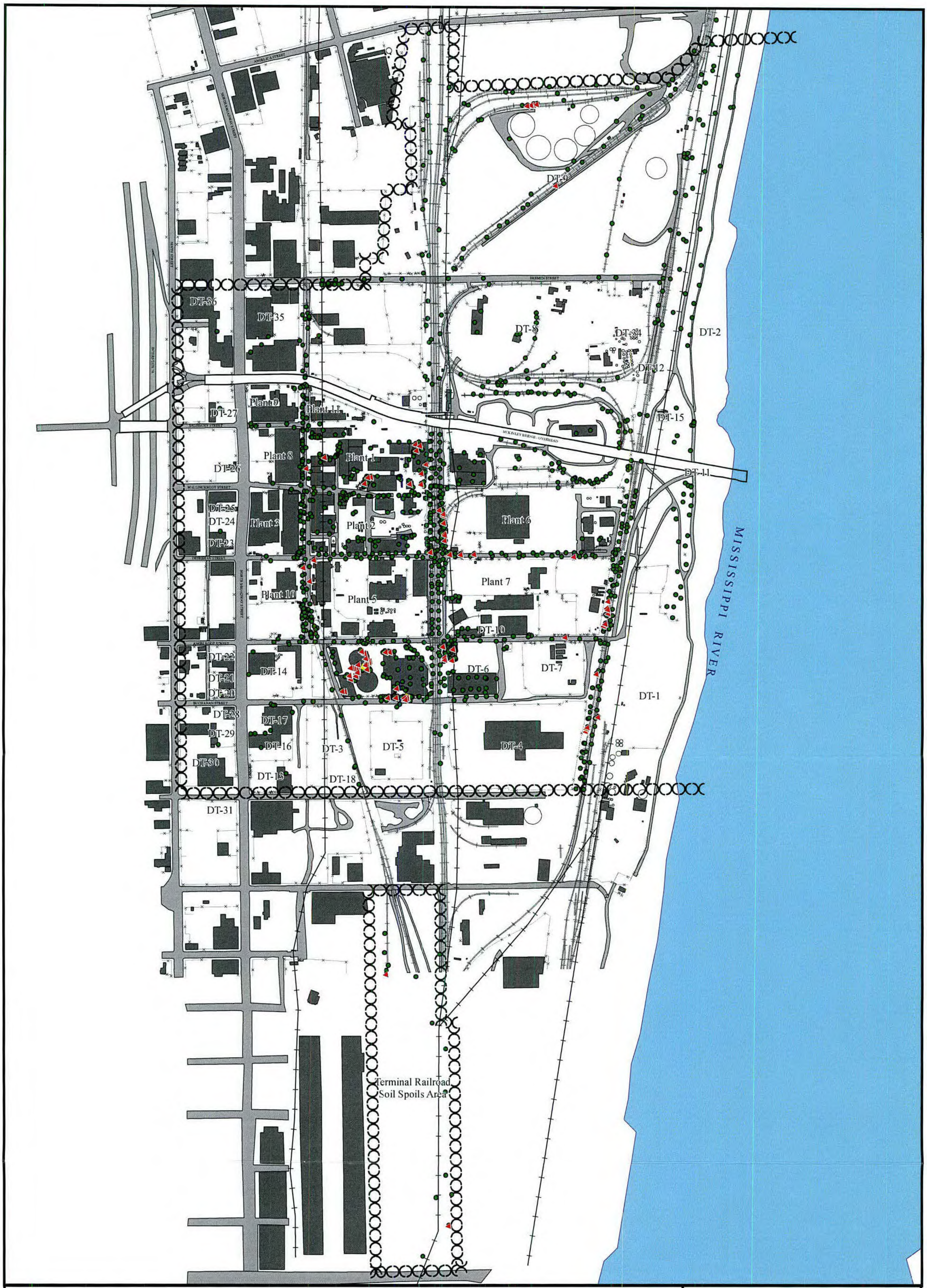


Figure C-5. Distribution of Th-228 Exceeding the PRG in Inaccessible Soil

Path: SLDS\Inaccessible Areas\Projects\Risk Ranges\Figure C-6 Extent of Th-230 Exceeding the PRG.mxd



Legend

XX 1998 ROD Boundary
—×— Fence
—+— Railroad
▨ Road
🟦 River/Stream
■ Building
○ Tank

Sample Location
▲ Above PRG (Detect)
🟨 Above PRG (Non-detect)
● Below PRG (Detect and Non-detect)

Th-230 PRG = 20 pCi/g

Note: Radiological background contributions are included in sample results.

MO-East State Plane
(NAD 83, Feet)

0 200 400 600
Feet

St. Louis Downtown Site
St. Louis, Missouri

FUSRAP

DRAWN BY	REV	DATE
SAIC	0	6/12/12

Figure C-6. Distribution of Th-230 Exceeding the PRG in Inaccessible Soil

Path: SLDS\Inaccessible Areas\Projects\Risk Ranges\Figure C-7 Extent of Th-232 Exceeding the PRG.mxd

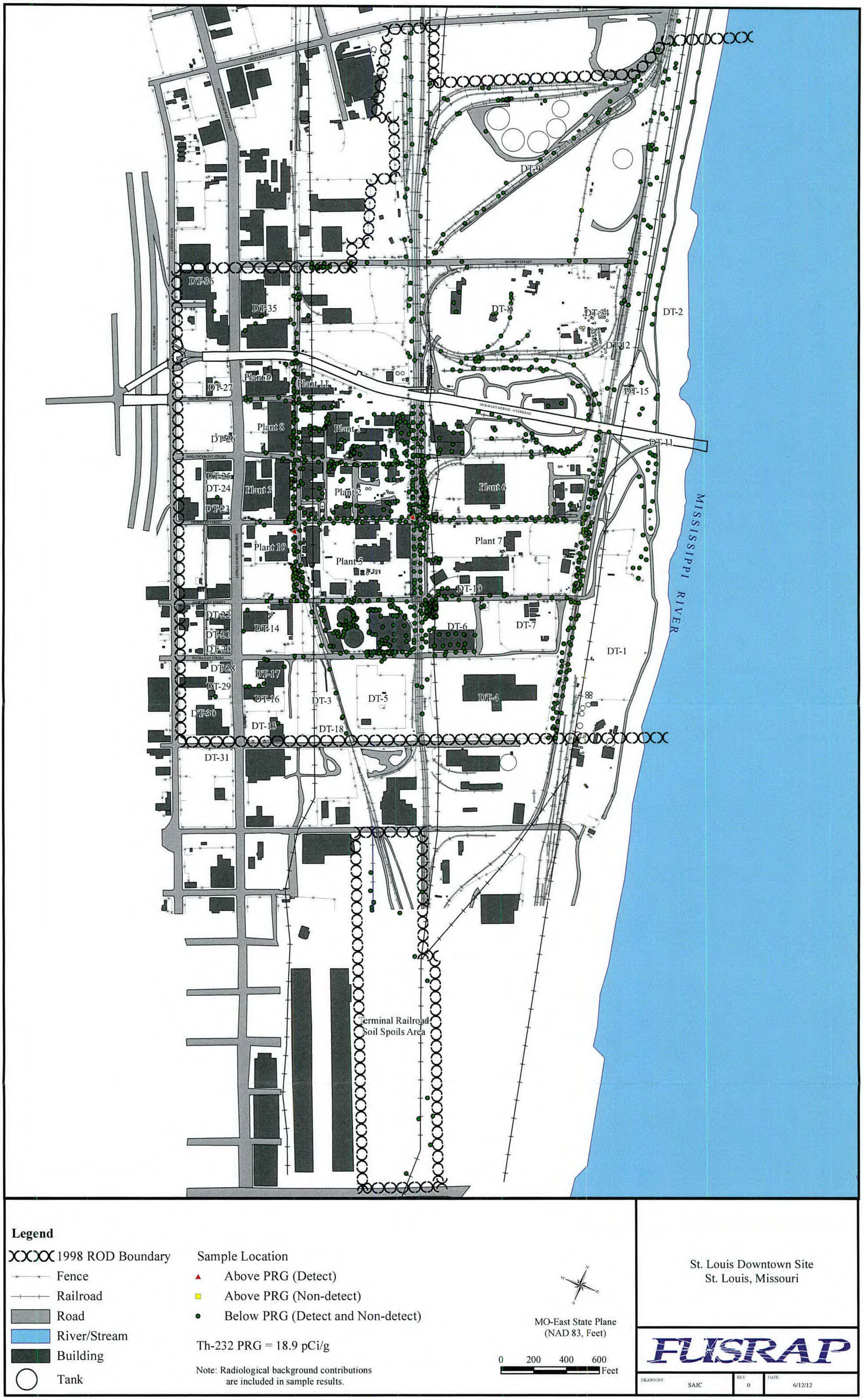
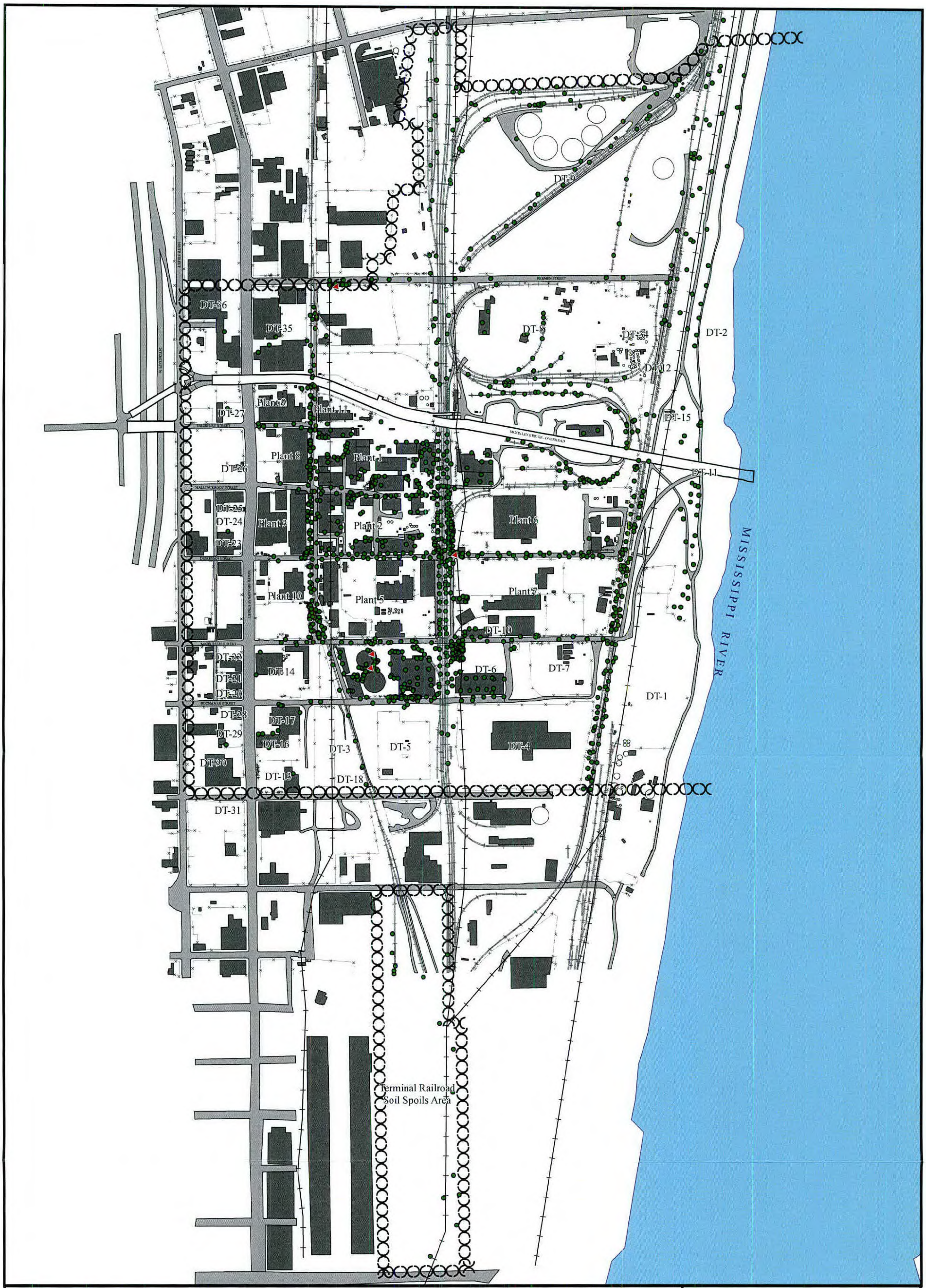


Figure C-7. Distribution of Th-232 Exceeding the PRG in Inaccessible Soil

Path: [illegible]\SLDS\Inaccessible Areas\Projects\Risk Ranges\Figure C-8 Extent of U-235 Exceeding the PRG.mxd



Legend

XXXX 1998 ROD Boundary
-×-×- Fence
-+-+- Railroad
▨ Road
🟦 River/Stream
■ Building
○ Tank

Sample Location
▲ Above PRG (Detect)
🟨 Above PRG (Non-detect)
● Below PRG (Detect and Non-detect)

U-235 PRG = 34.30 pCi/g

Note: Radiological background contributions are included in sample results.

MO-East State Plane
(NAD 83, Feet)

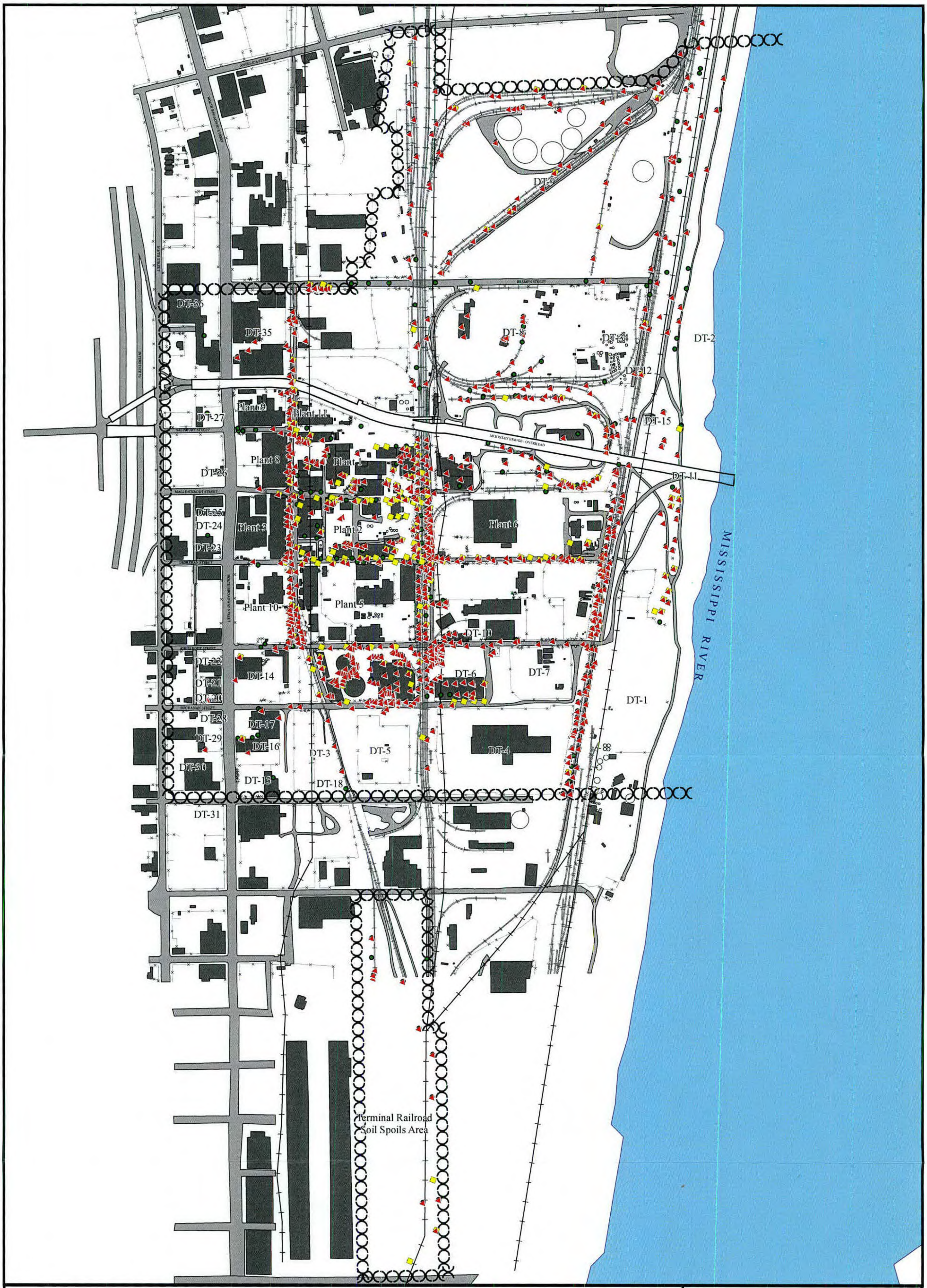
0 200 400 600
Feet

St. Louis Downtown Site
St. Louis, Missouri

FUSRAP

DRAWN BY:	REV:	DATE:
SAIC	0	5/24/12

Figure C-8. Distribution of U-235 Exceeding the PRG in Inaccessible Soil



Legend

XXX 1998 ROD Boundary

-x-x- Fence

-+-+- Railroad

▨ Road

🟦 River/Stream

■ Building

○ Tank

Sample Location

▲ Above PRG (Detect)

🟨 Above PRG (Non-detect)

● Below PRG (Detect and Non-detect)

U-238 PRG = 1.65 pCi/g

Note: Radiological background contributions are included in sample results.

MO-East State Plane
(NAD 83, Feet)

0 200 400 600 Feet

St. Louis Downtown Site
St. Louis, Missouri

FUSRAP

DRAWN BY:	REV:	DATE:
SAIC	0	6/12/12

Figure C-9. Distribution of U-238 Exceeding the PRG in Inaccessible Soil

Path: J:\G[illegible]SLDS\Inaccessible Areas\Projects\Risk Ranges\Figure C-10 Extent of Arsenic Exceeding the PRG mxd

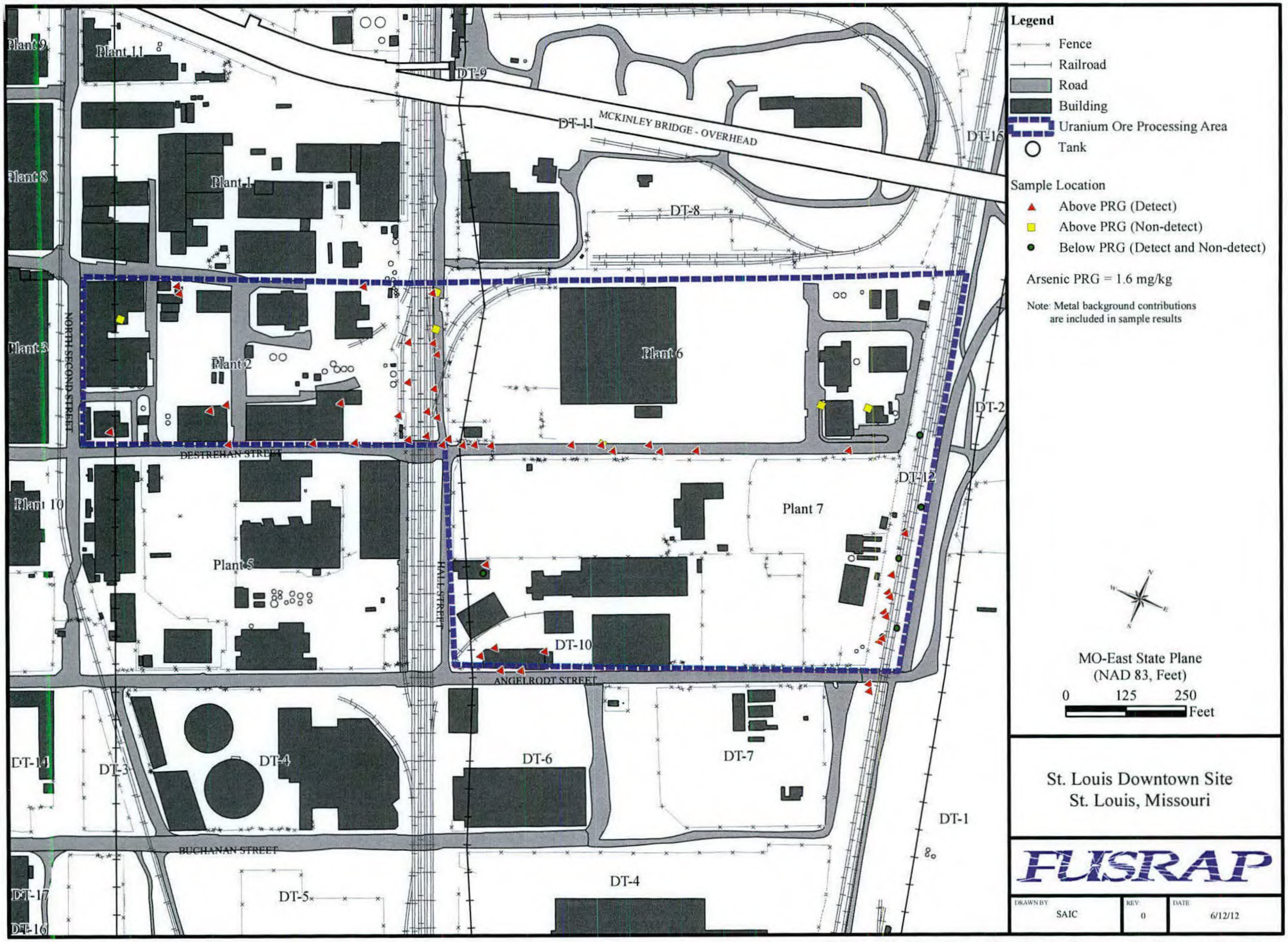


Figure C-10. Distribution of Arsenic Exceeding the PRG in Inaccessible Soil

Path: J:\G[illegible]\SLDS\Inaccessible Areas\Projects\Risk Ranges\Figure C-11 Extent of Cadmium Exceeding the PRG.mxd

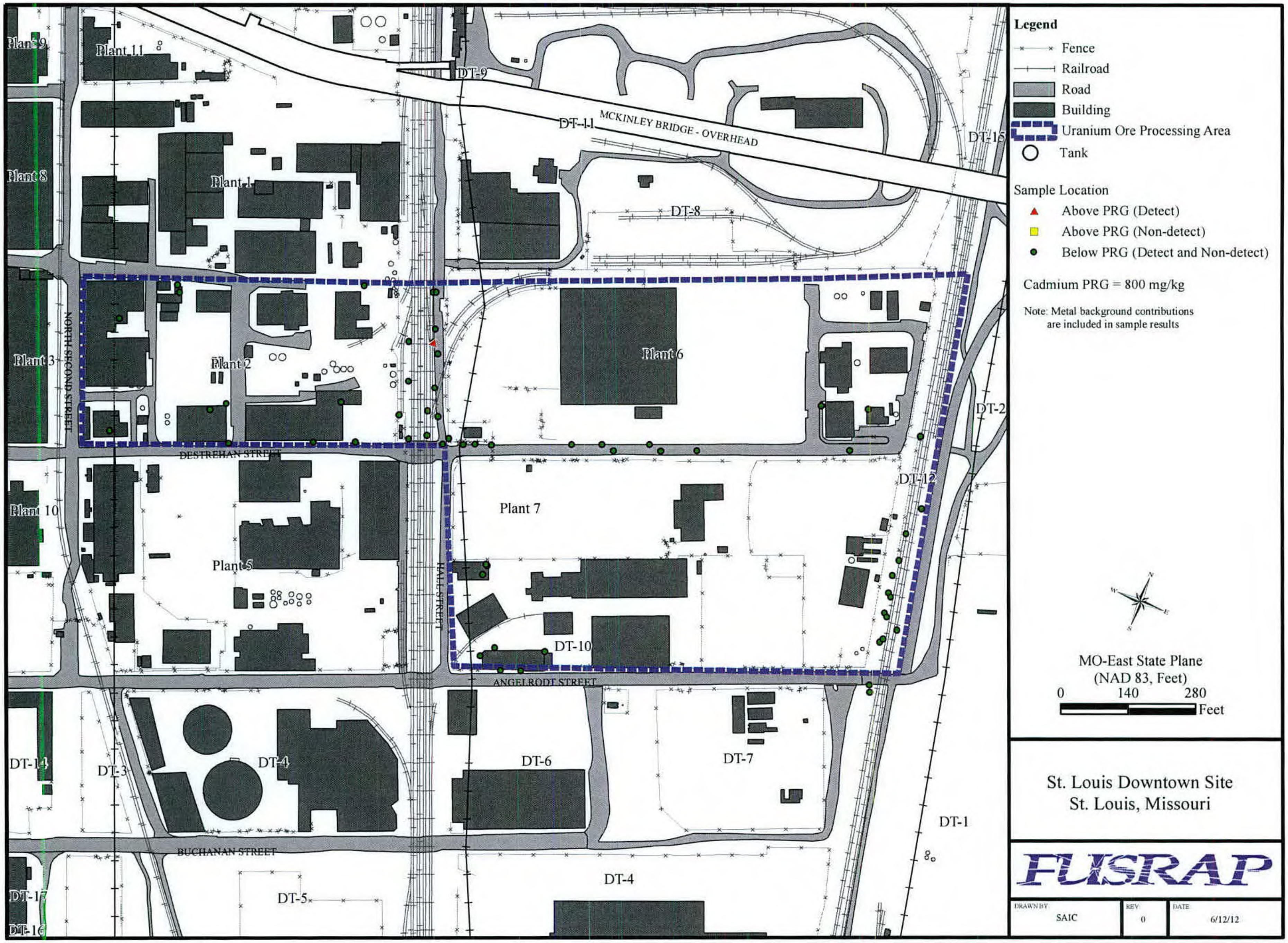


Figure C-11. Distribution of Cadmium Exceeding the PRG in Inaccessible Soil

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Figure C-12 Extent of Uranium Exceeding the PRG.mxd

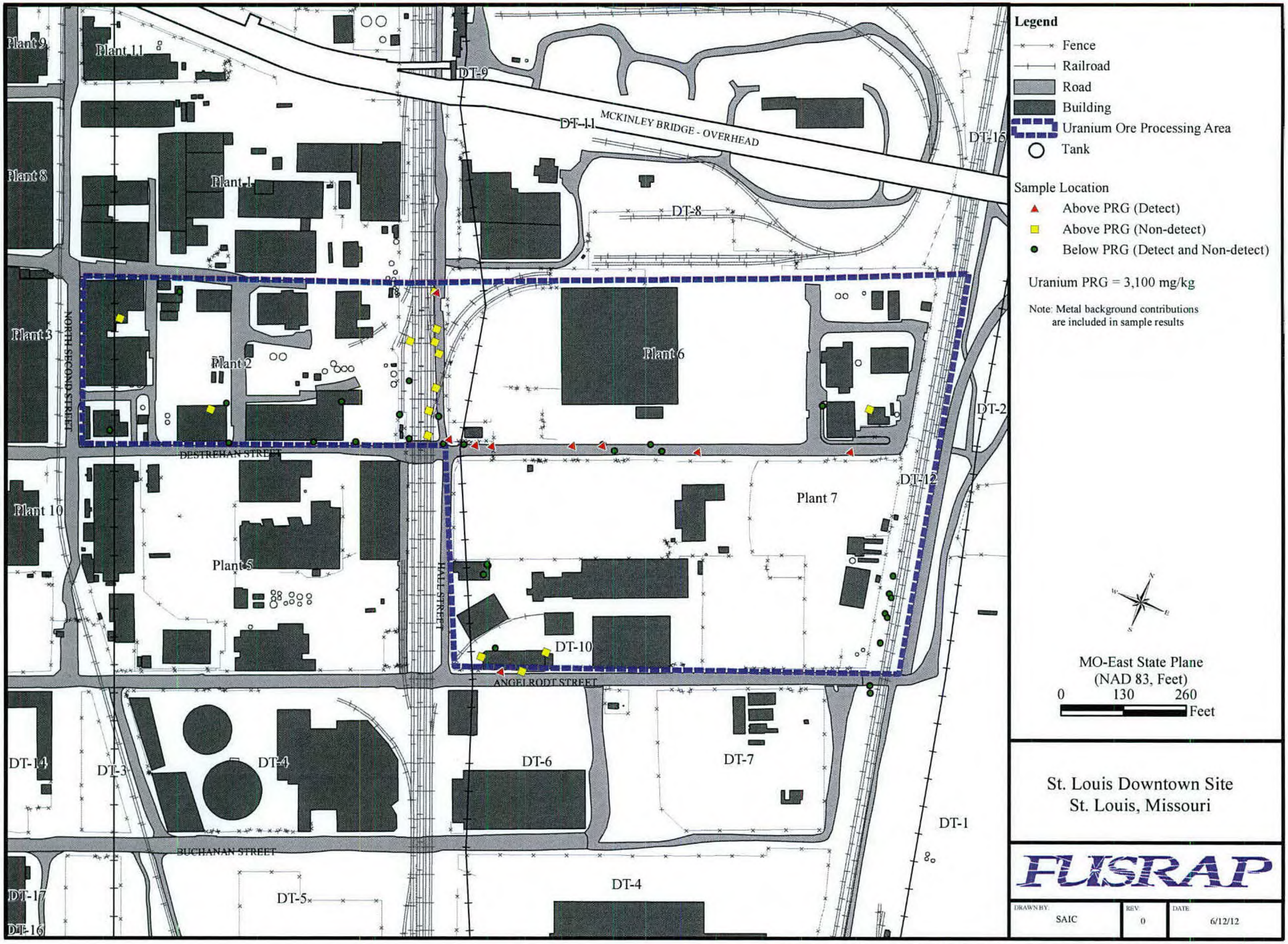


Figure C-12. Distribution of Uranium Metal Exceeding the PRG in Inaccessible Soil

Path [illegible]\SLDS\Inaccessible Areas\Projects\Risk Ranges\Figure C-13 Buildings Structures with Surfaces Exceeding PRGs.mxd

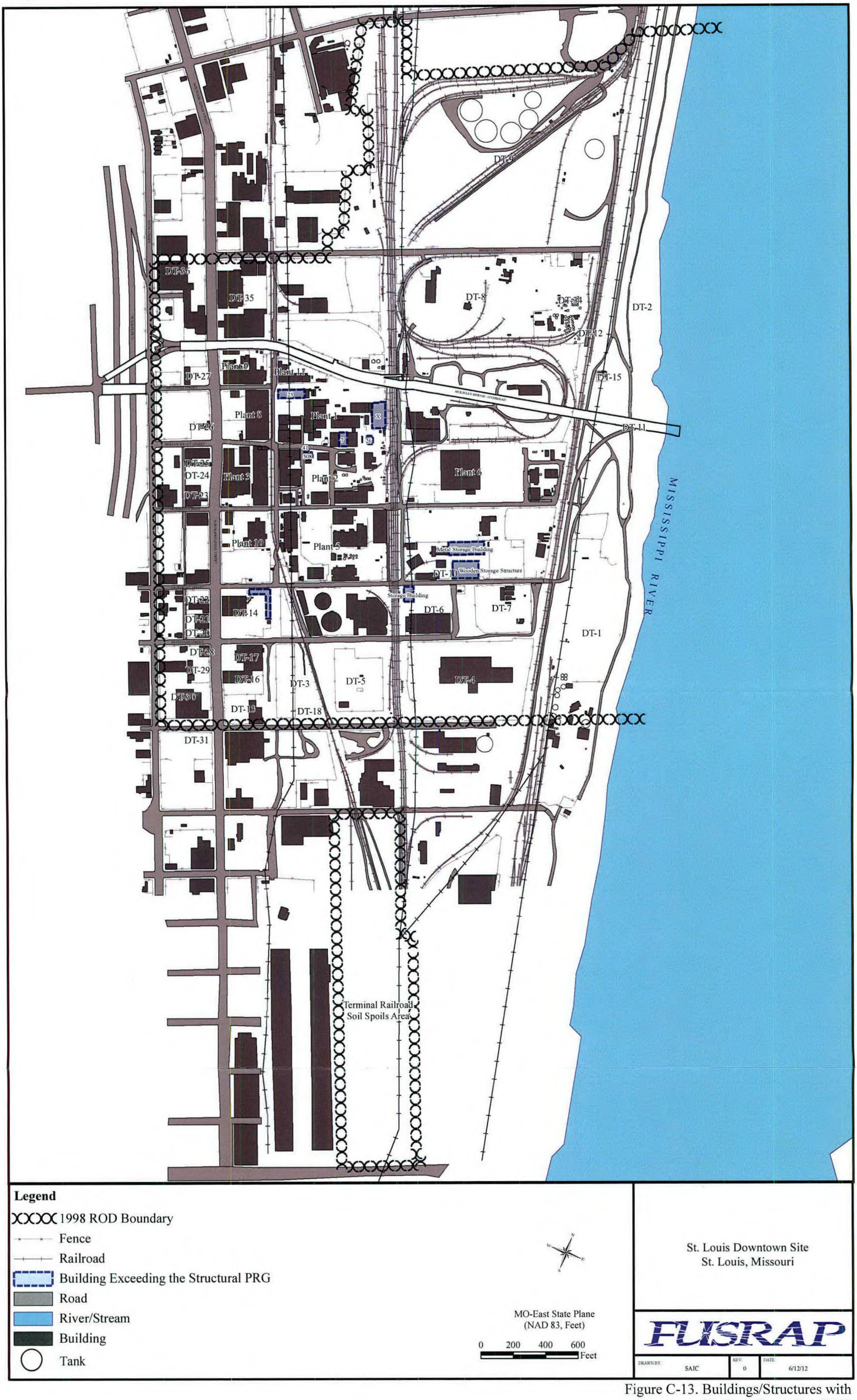


Figure C-13. Buildings/Structures with Surfaces Exceeding PRGs

APPENDIX D

Figures: Gamma Walkover Surveys of Inaccessible Soil Areas

(On the DVD on the Back Cover of this Report)

APPENDIX E

Radiological and Metals Analytical Data Summaries and Figures for Inaccessible Soil and Building Sampling Locations

(On the DVD on the Back Cover of this Report)

APPENDIX F

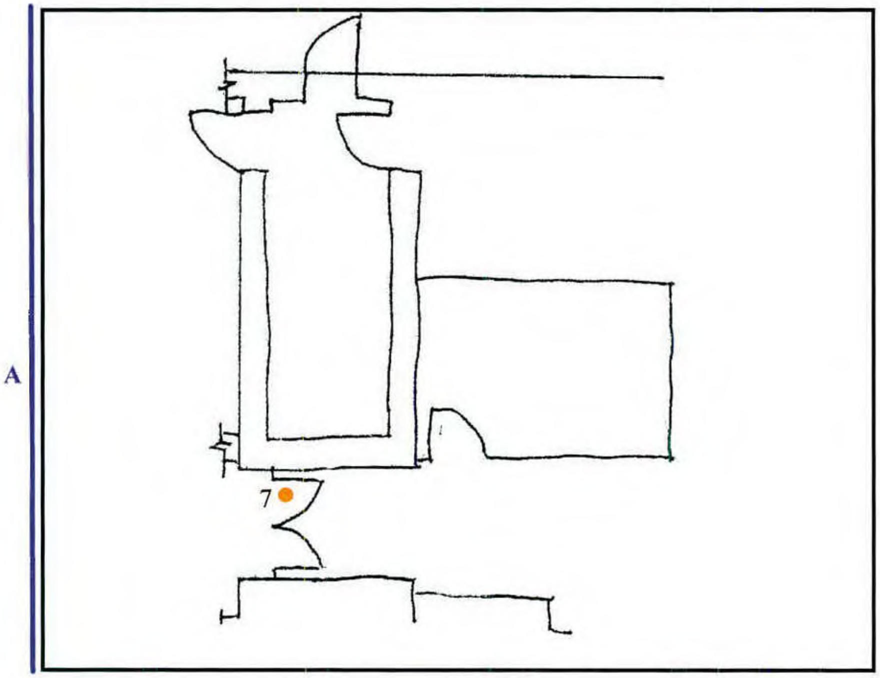
Data: Radiological Building Survey Results by Property and Building

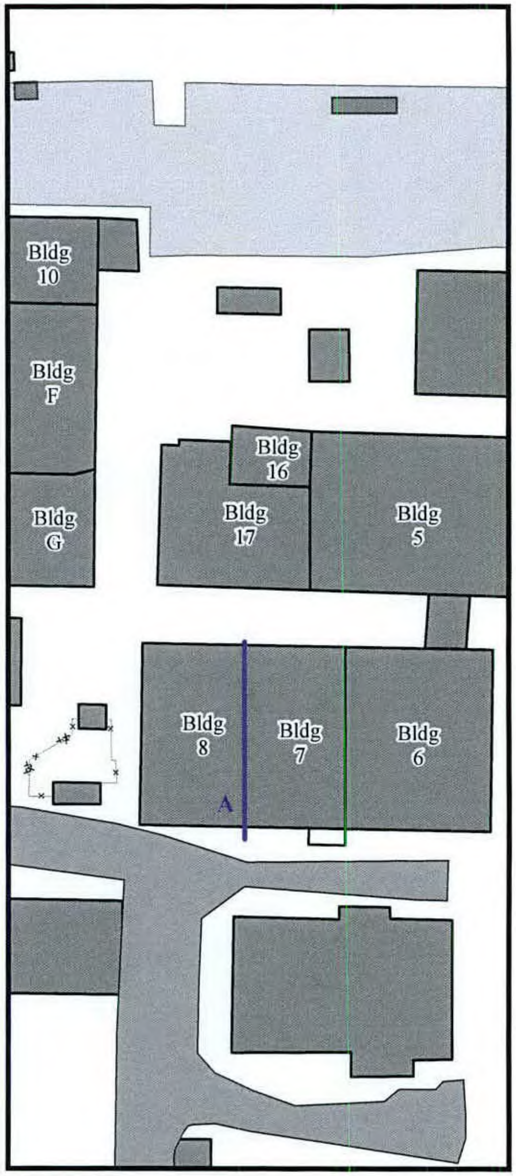
(On the DVD on the Back Cover of this Report)

APPENDIX G

Figures: Extent of Radiological Contamination for Buildings

LIST OF FIGURES





Surface Measurement Results ($dpm/100cm^2$)
#7: 163

● Elevated measurement above interior alpha limit of 130 $dpm/100cm^2$.

FUSRAP

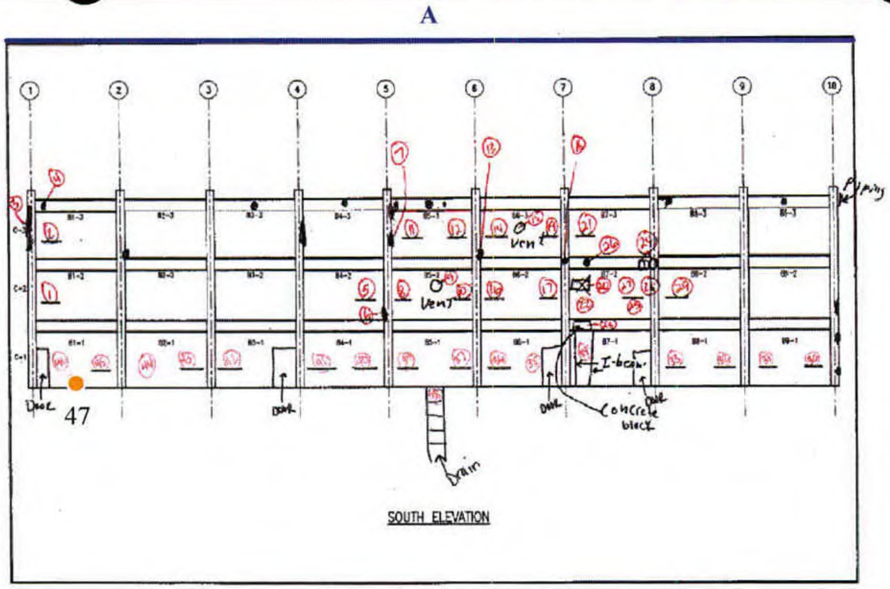
Property:
Mallinckrodt Inc., Plant 1, St. Louis Downtown Site, St. Louis, Missouri

Subject:
Building 7 Elevated Interior Building Scan Location

Drawn By:
DLL

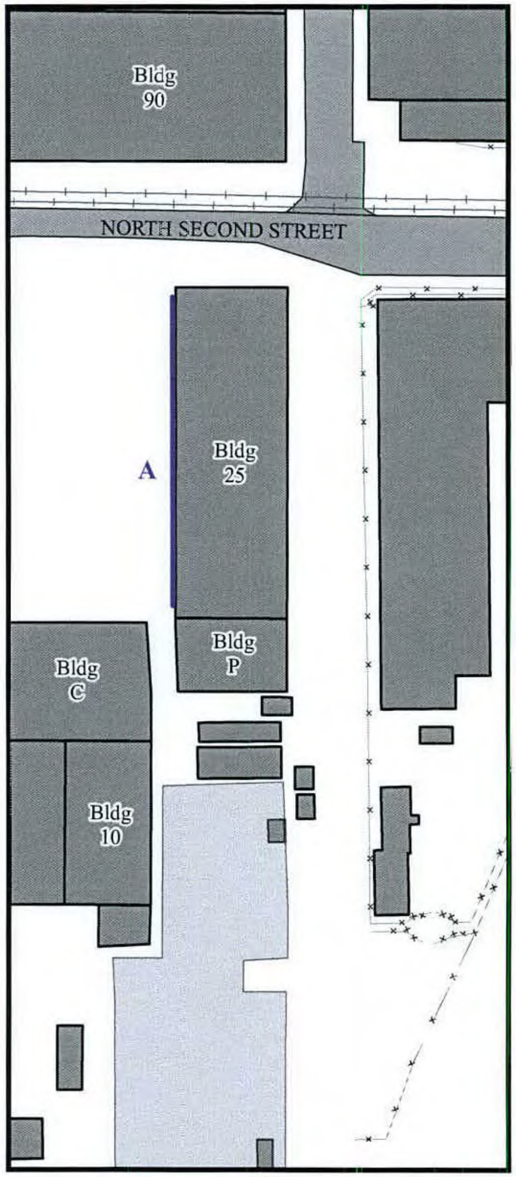
Date:
05/30/2012

G-1



Surface Measurement Results (dpm/100cm^2)
#47: 18,232

Location of Sample #47 obscured by metal shed. (See diagram above)



● Elevated measurement above exterior alpha limit of 3200 dpm/100cm^2.

FUSRAP

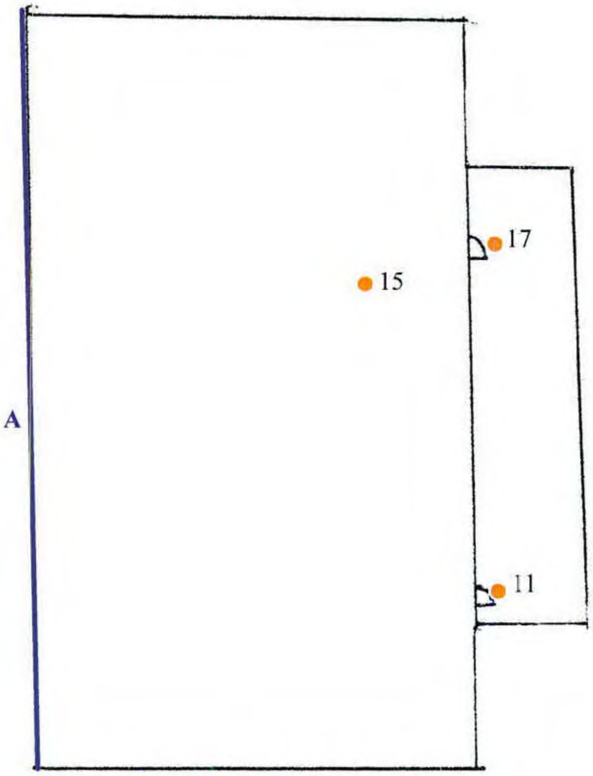
Property:
Mallinckrodt Inc., Plant 1, St. Louis Downtown Site, St. Louis, Missouri

Subject:
Building 25 Elevated Exterior Building Scan Location

Drawn By:
DJH, DLL

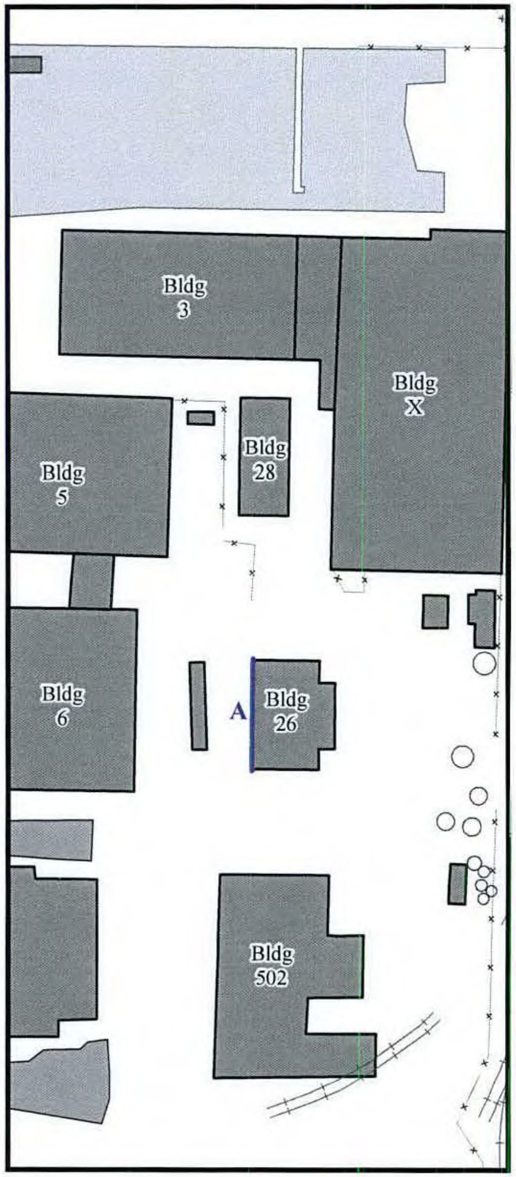
Date:
05/30/2012

G-2



Surface Measurement Results
(dpm/100cm^2)

#11: 200 #15: 236
#17: 182



● Elevated measurement above alpha limit of 130 dpm/100cm^2.

FUSRAP

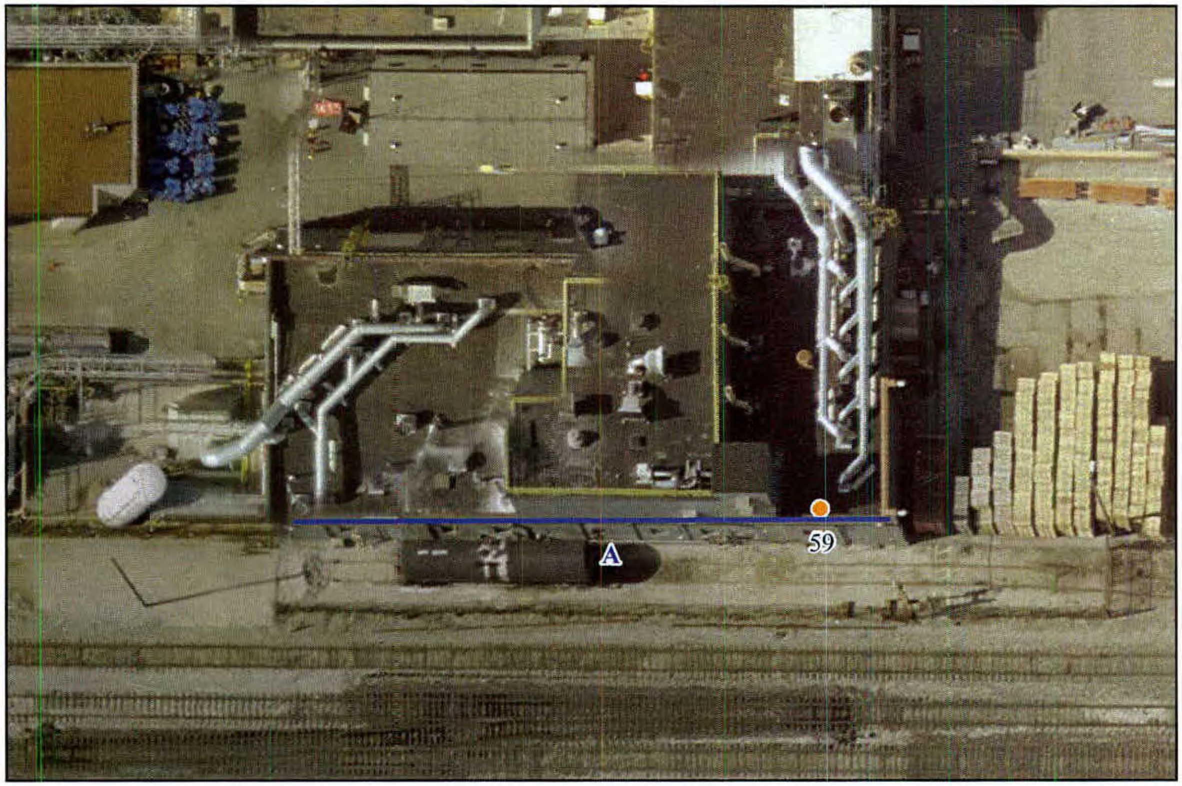
Property:
Mallinckrodt Inc., Plant 1, St. Louis Downtown Site, St. Louis, Missouri

Subject:
Building 26 Elevated Interior Building Scan Locations

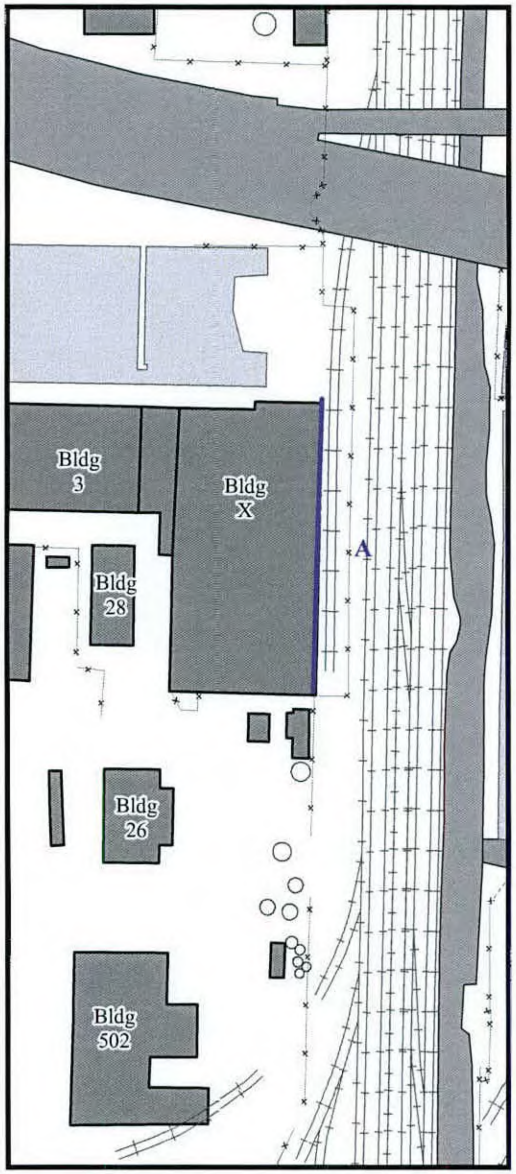
Drawn By:
DLL

Date:
06/01/2012

G-3



Surface Measurement Results (dpm/100cm^2)
#59: 4,279



● Elevated measurement above exterior alpha limit of 3200 dpm/100cm^2.

FUSRAP

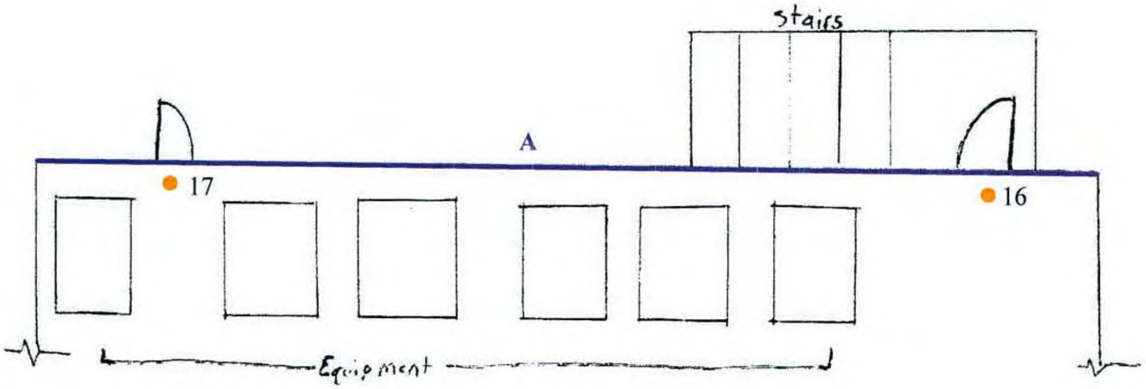
Property:
Mallinckrodt Inc., Plant 1, St. Louis Downtown Site, St. Louis, Missouri

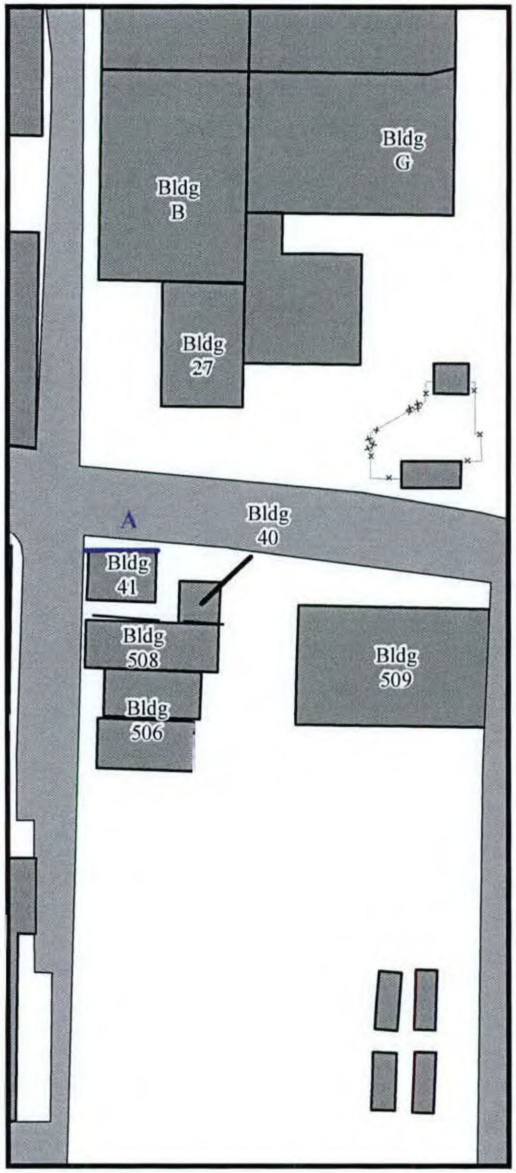
Subject:
Building X Elevated Exterior Building Scan Location

Drawn By:
DLL

Date:
06/01/2012

G-4





Surface Measurement Results
(dpm/100cm^2)

#16: 145
#17: 164

● Elevated measurement above interior alpha limit of 130 dpm/100cm^2.

FUSRAP

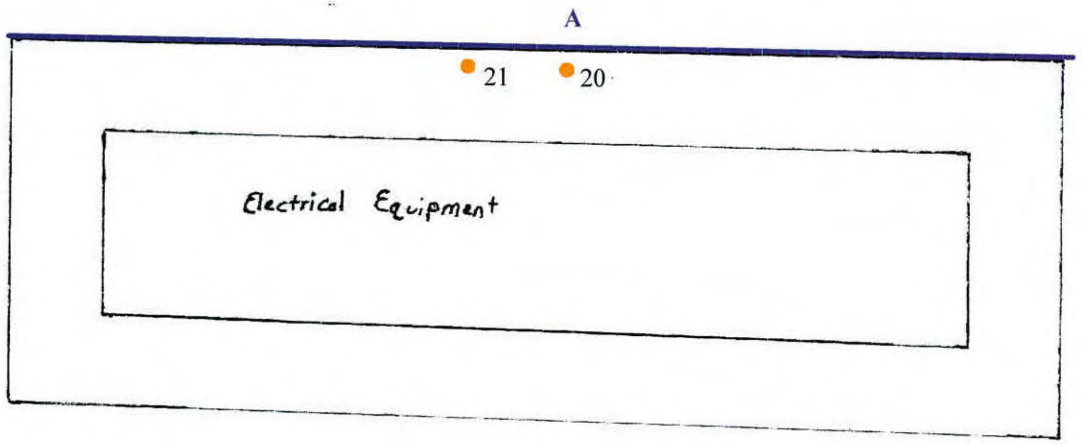
Property:
Mallinckrodt Inc., Plant 2, St. Louis Downtown Site, St. Louis, Missouri

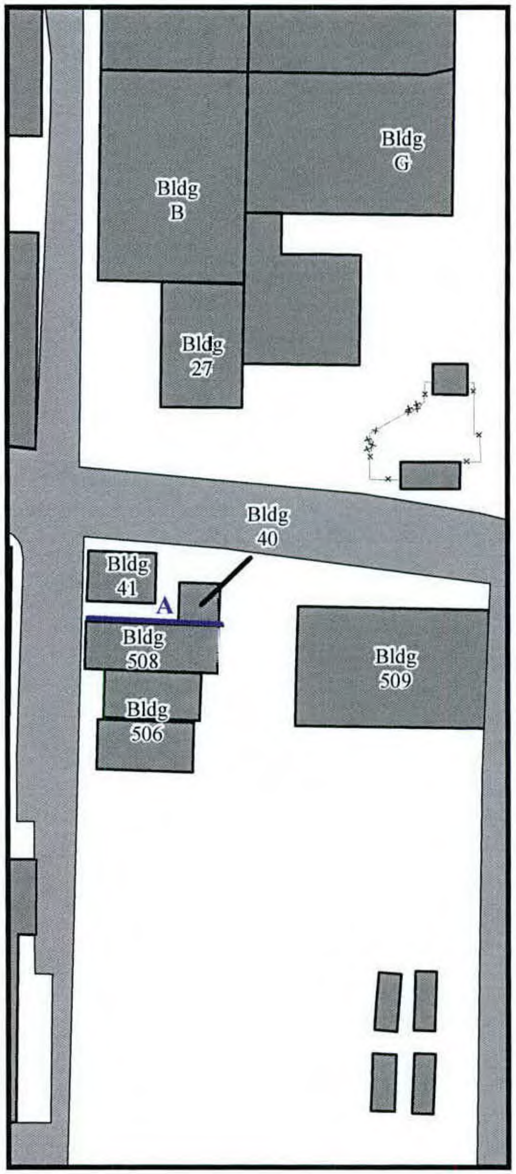
Subject:
Building 41 Elevated Interior Building Scan Locations

Drawn By:
DLL

Date:
05/30/2012

G-5





Surface Measurement Results (dpm/100cm^2)
#20: 164 #21: 145

● Elevated measurement above interior alpha limit of 130 dpm/100cm^2.

FUSRAP

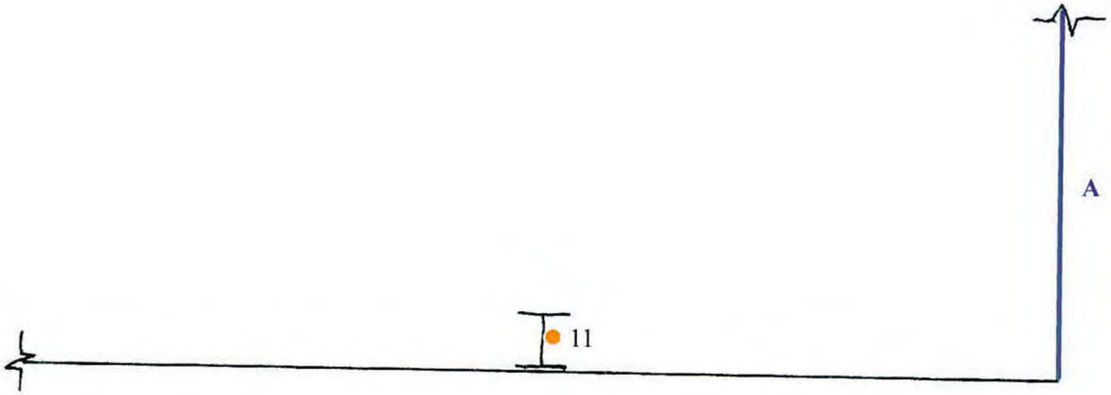
Property:
Mallinckrodt Inc., Plant 2, St. Louis Downtown Site, St. Louis, Missouri

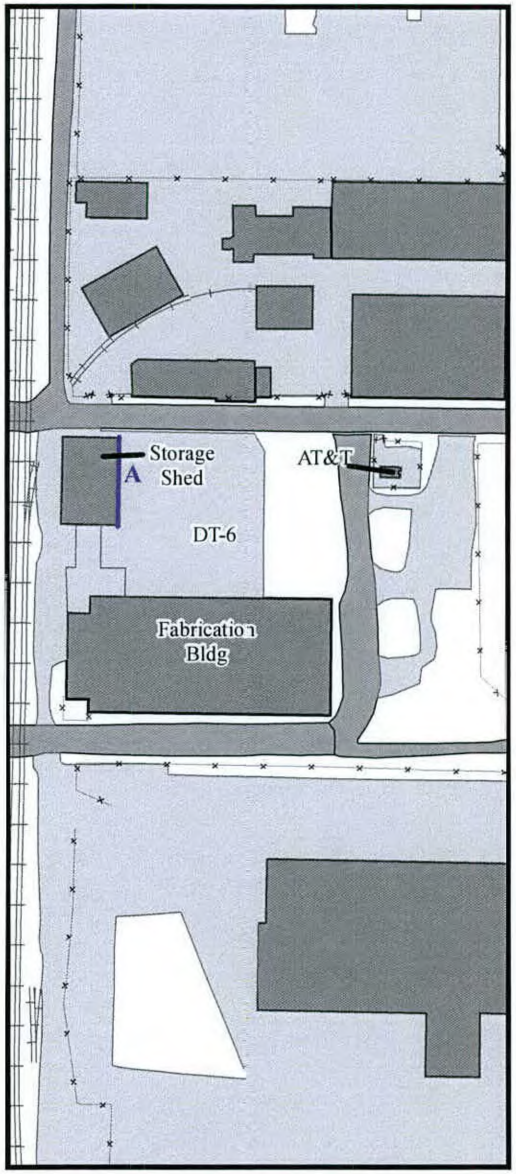
Subject:
Building 508 Elevated Interior Building Scan Locations

Drawn By:
DLL

Date:
06/01/2012

G-6





Surface Measurement Results (dpm/100cm^2)
#11: 138

● Elevated measurement above interior alpha limit of 130 dpm/100cm^2.

FUSRAP

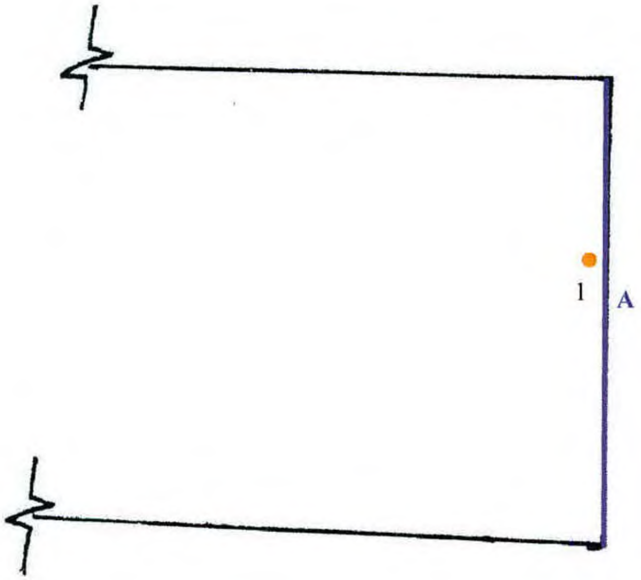
Property:
Heintz Steel and Manufacturing, DT-6, St. Louis Downtown Site, St. Louis, Missouri

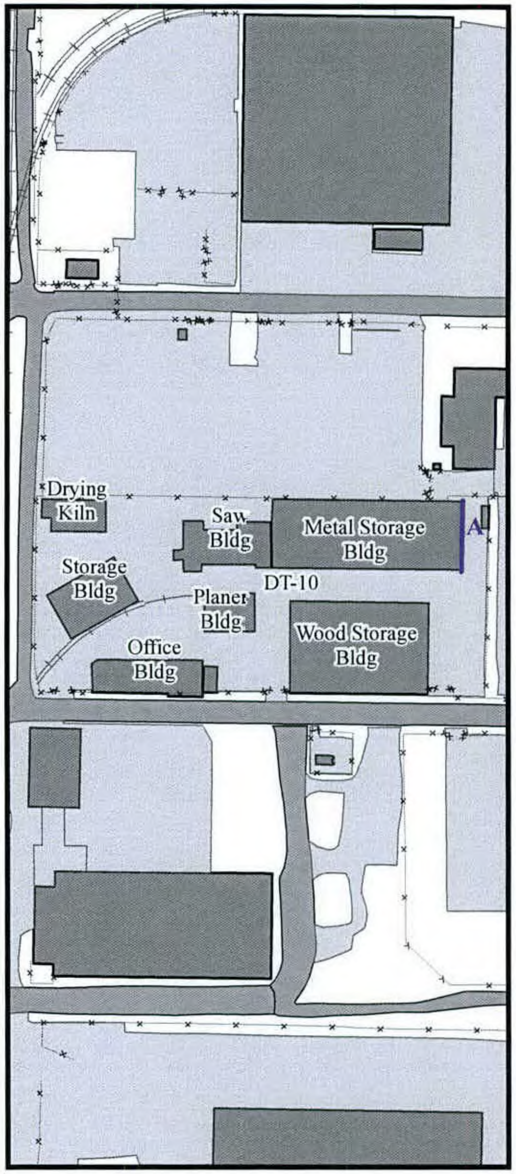
Subject:
Storage Shed Elevated Interior Building Scan Location

Drawn By:
DLL

Date:
06/01/2012

G-7





Surface Measurement Results (dpm/100cm^2)
#1: 330

● Elevated measurement above interior alpha limit of 130 dpm/100cm^2.

FUSRAP

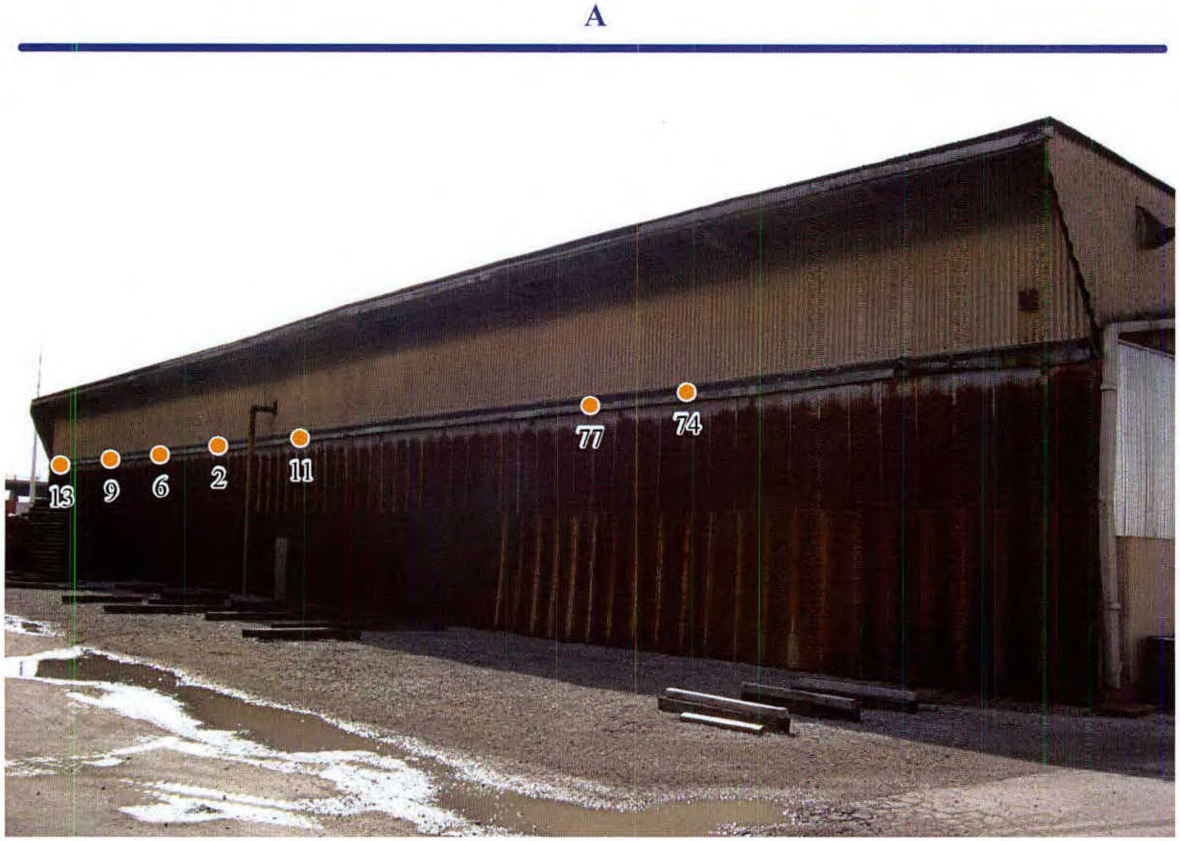
Property:
Thomas and Proetz Lumber Co., DT-10, St. Louis Downtown Site, St. Louis, Missouri

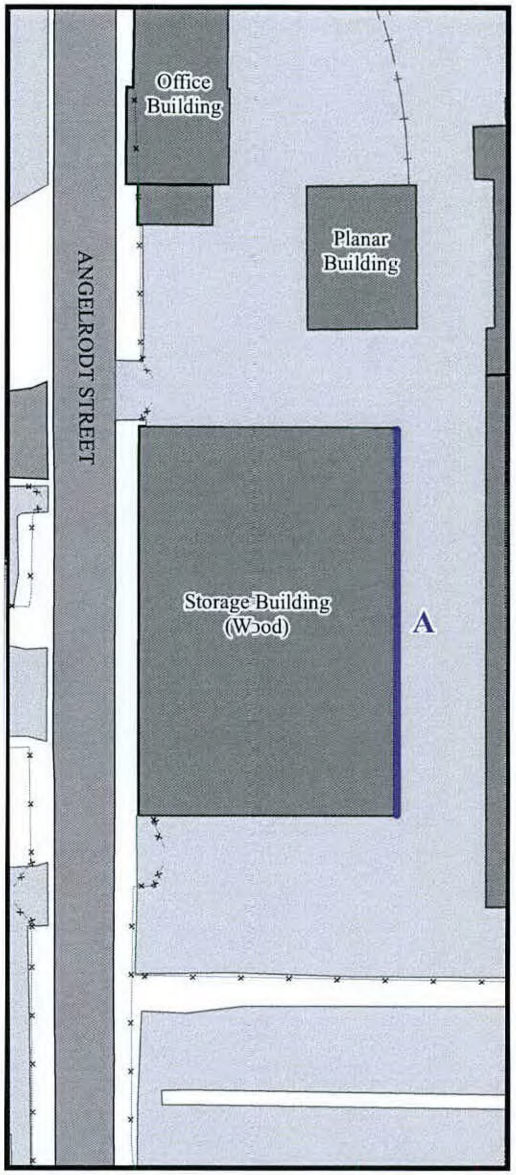
Subject:
Metal Storage Building Elevated Interior Building Scan Location

Drawn By:
DLL

Date:
06/01/2012

G-8





Surface Measurement Results (dpm/100cm^2)

#02: 17,752
#06: 18,728
#09: 16,259
#11: 15,863
#13: 16,792
#74: 22,476
#77: 19,196

● Elevated measurement above exterior alpha limit of 3200 dpm/100cm^2.

FUSRAP

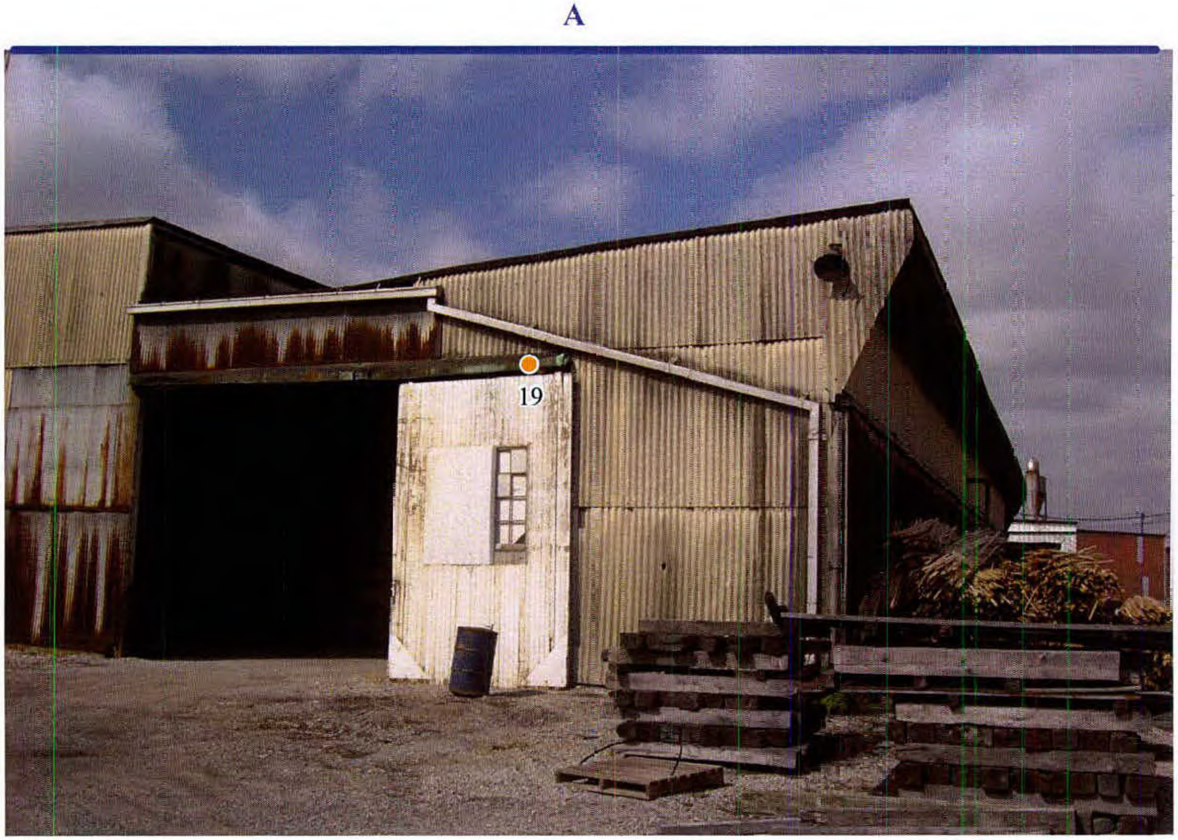
Property:
Thomas and Proetz Lumber Co., DT-10, St. Louis Downtown Site, St. Louis, Missouri

Subject:
Wood Storage Building Elevated Exterior Building Scan Locations - North Wall

Drawn By:
DJH, DLL

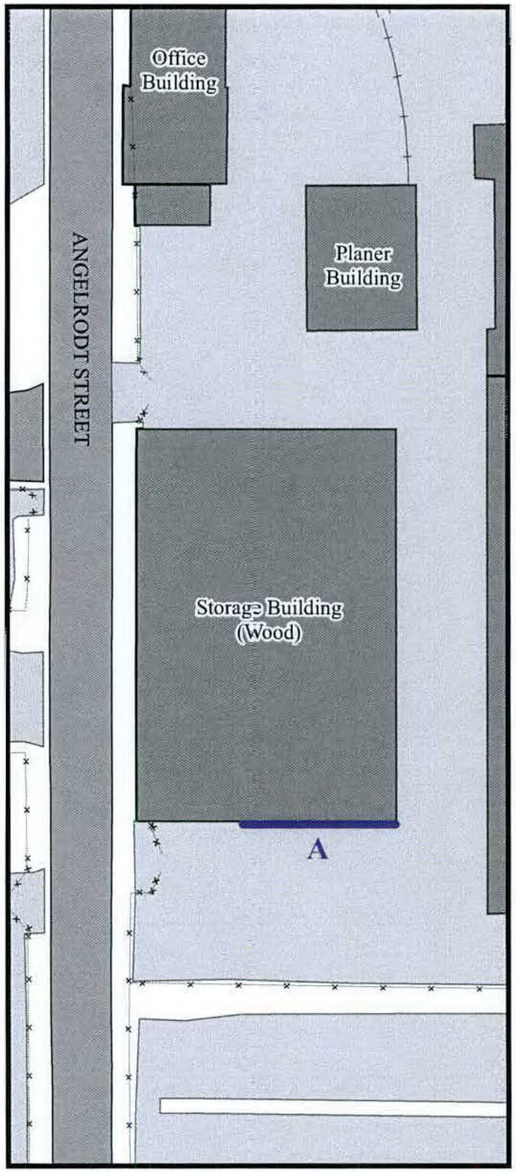
Date:
09/30/10

G-9



● Elevated measurement above exterior alpha limit of 3200 dpm/100cm^2.

Surface Measurement Results (dpm/100cm^2)
#19: 4,419



FUSRAP

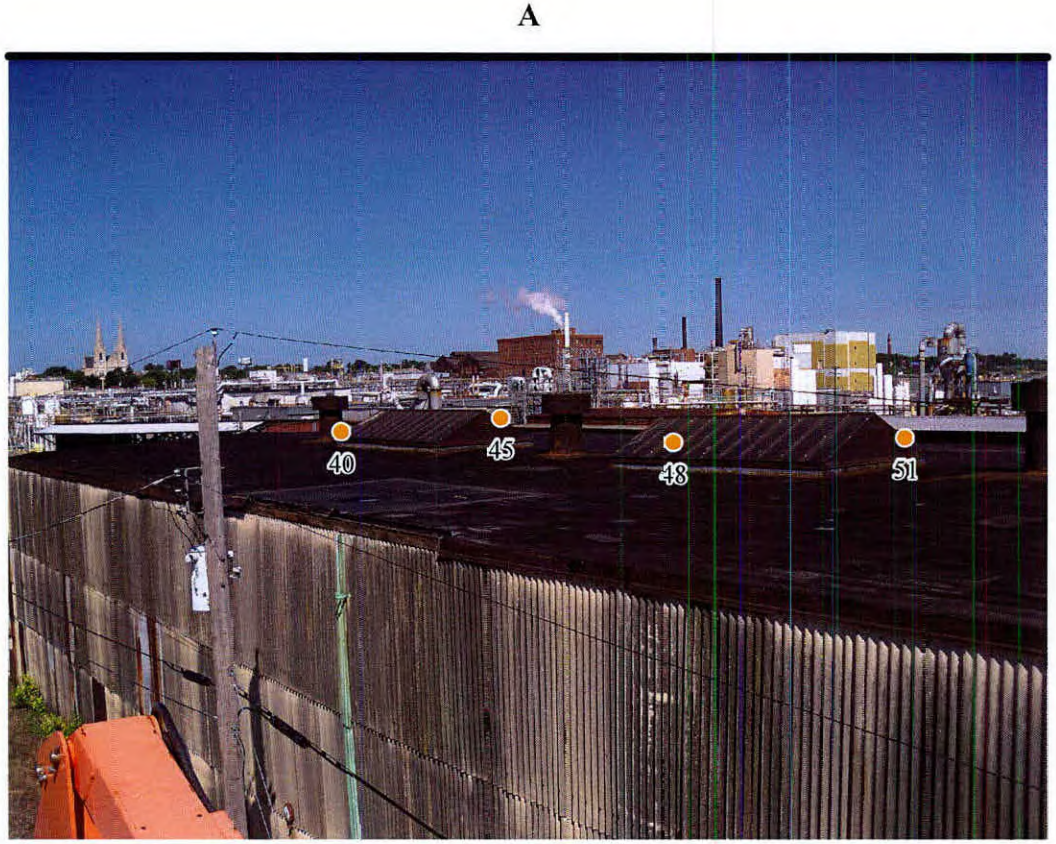
Property:
Thomas and Proetz Lumber Co., DT-10, St. Louis Downtown Site, St. Louis, Missouri

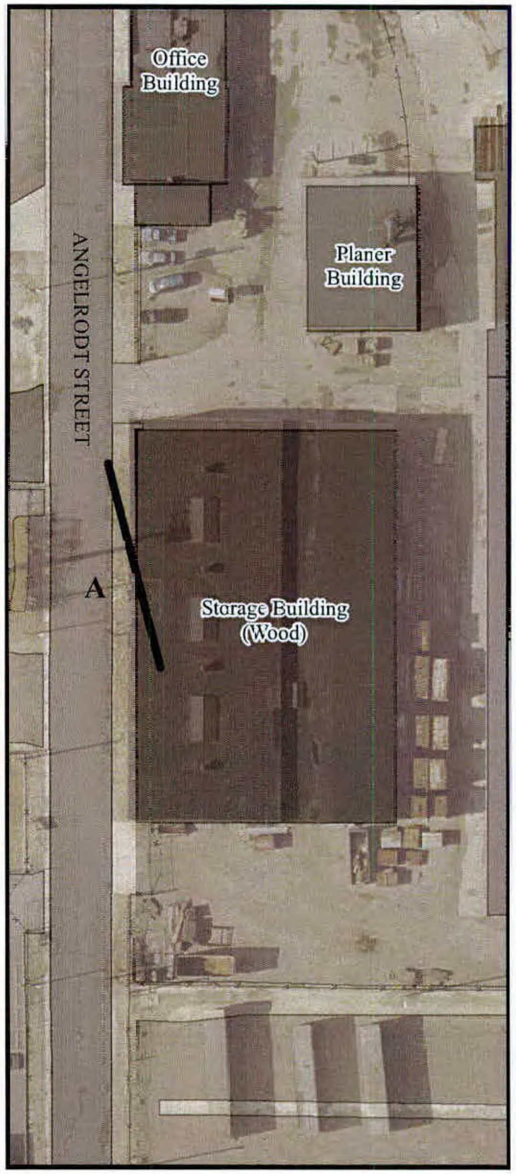
Subject:
Wood Storage Building Elevated Exterior Building Scan Location - East Wall

Drawn By:
DJH, DLL

Date:
09/10/10

G-10





Surface Measurement Results (dpm/100cm^2)	
#40: 5,831	#48: 6,121
#45: 5,557	#51: 5,709

● Elevated measurement above exterior alpha limit of 3200 dpm/100cm^2

FUSRAP

Property:
Thomas and Proetz Lumber Co., DT-10, St. Louis Downtown Site, St. Louis, Missouri

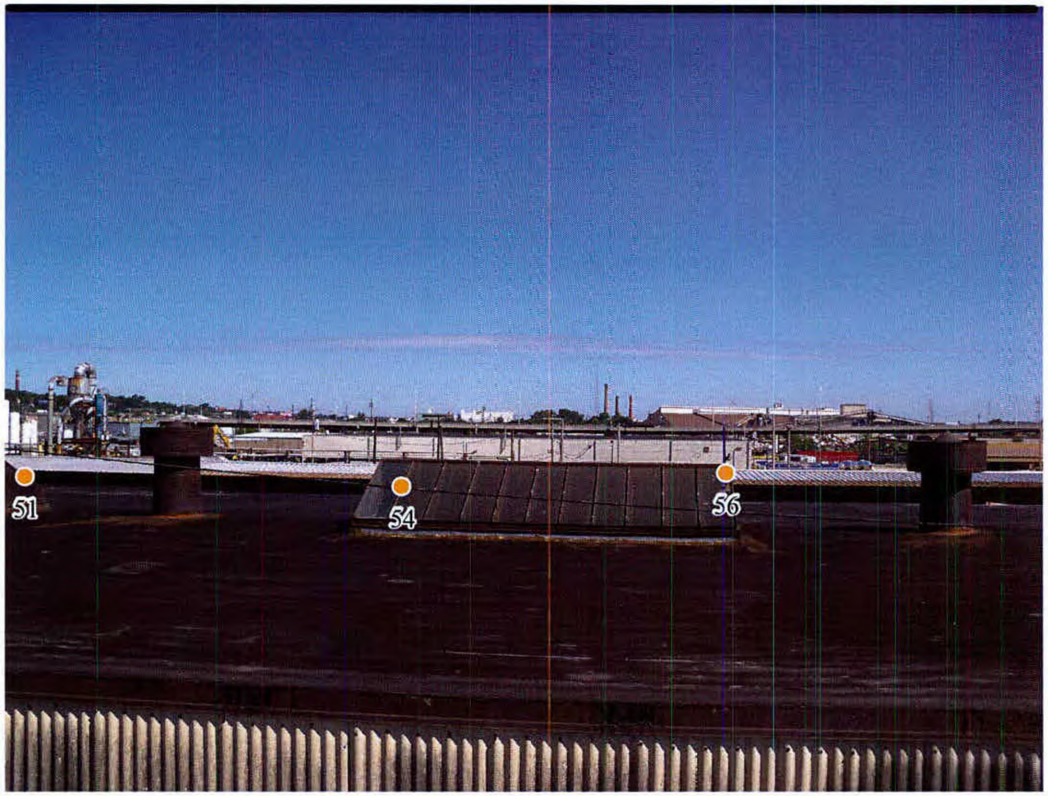
Subject:
Wood Storage Building Elevated Exterior Building Scan Locations - Roof Facing West

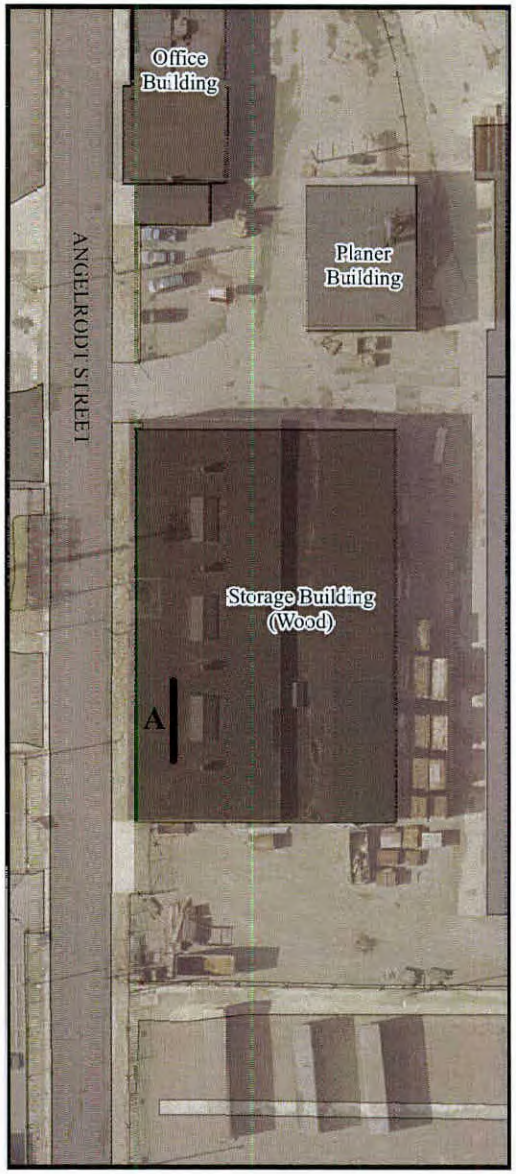
Drawn By:
DJH, DLL

Date:
09/30/10

G-11

A





Surface Measurement Results (dpm/100cm^2)
#51: 5,709 #54: 6,364 #56: 7,050

● Elevated measurement above exterior alpha limit of 3200 dpm/100cm^2.

FUSRAP

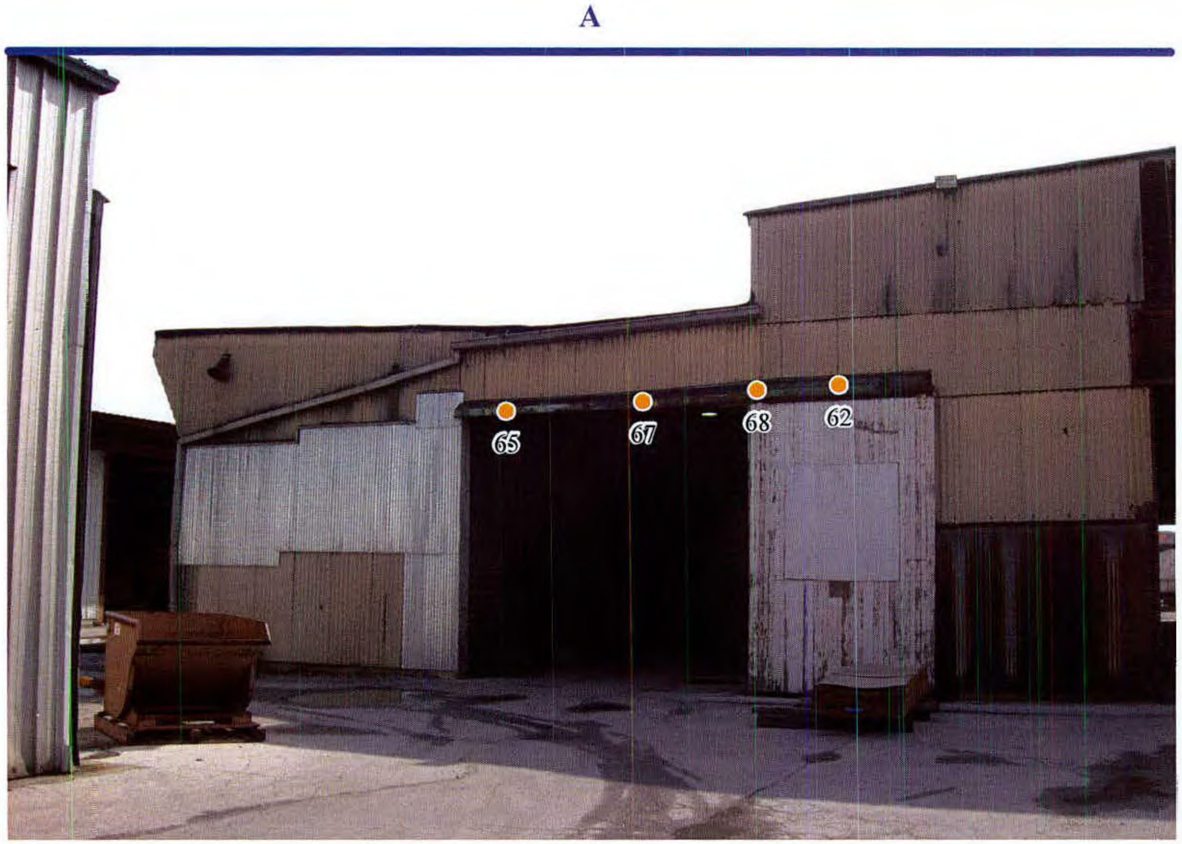
Property:
Thomas and Proetz Lumber Co., DT-10, St. Louis Downtown Site, St. Louis, Missouri

Subject:
Wood Storage Building Elevated Exterior Building Scan Locations - Roof Facing North

Drawn By:
DJH, DLL

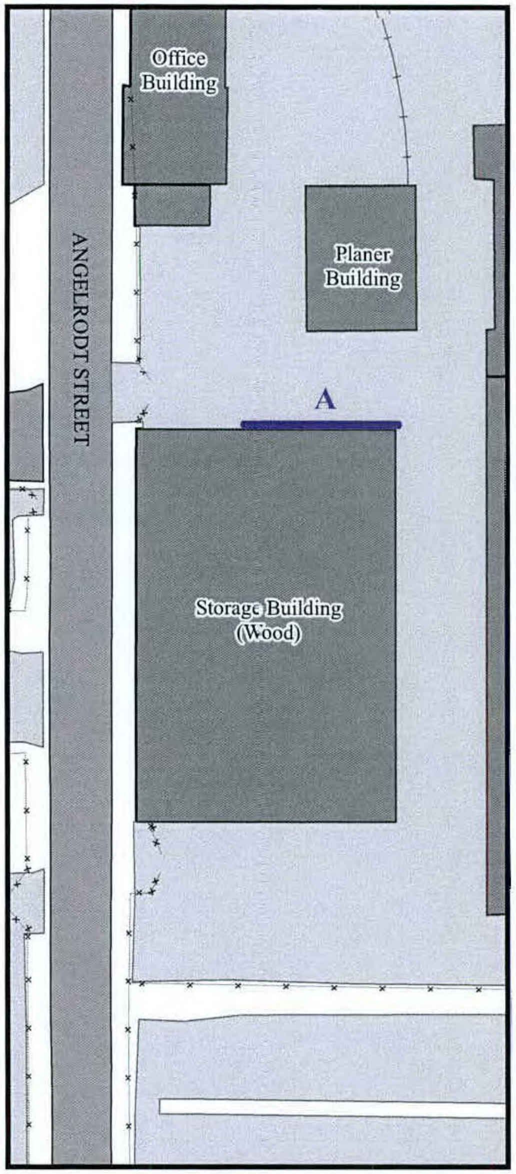
Date:
09/30/10

G-12



● Elevated measurement above exterior alpha limit of 3200 dpm/100cm^2.

Surface Measurement Results (dpm/100cm^2)	
#62: 6,609	#67: 6,329
#65: 4,116	#68: 5,809



FUSRAP

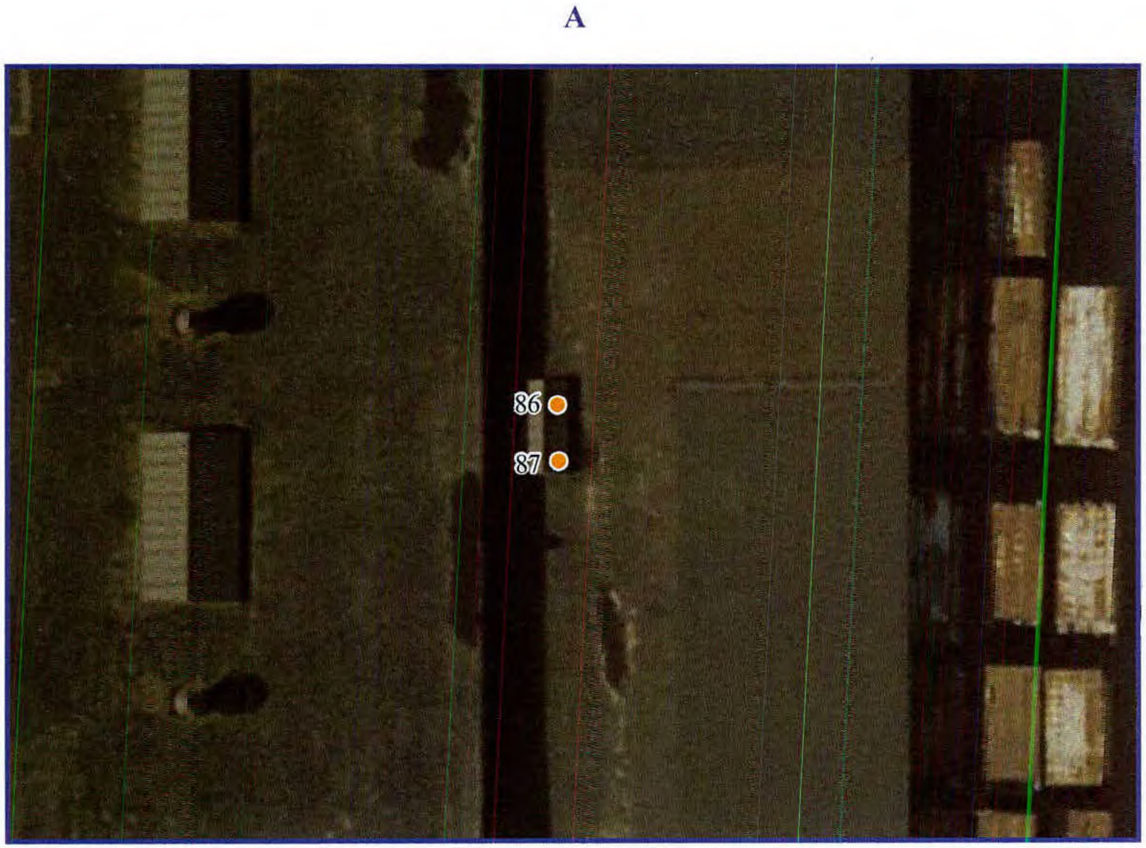
Property:
Thomas and Proetz Lumber Co., DT-10, St. Louis Downtown Site, St. Louis, Missouri

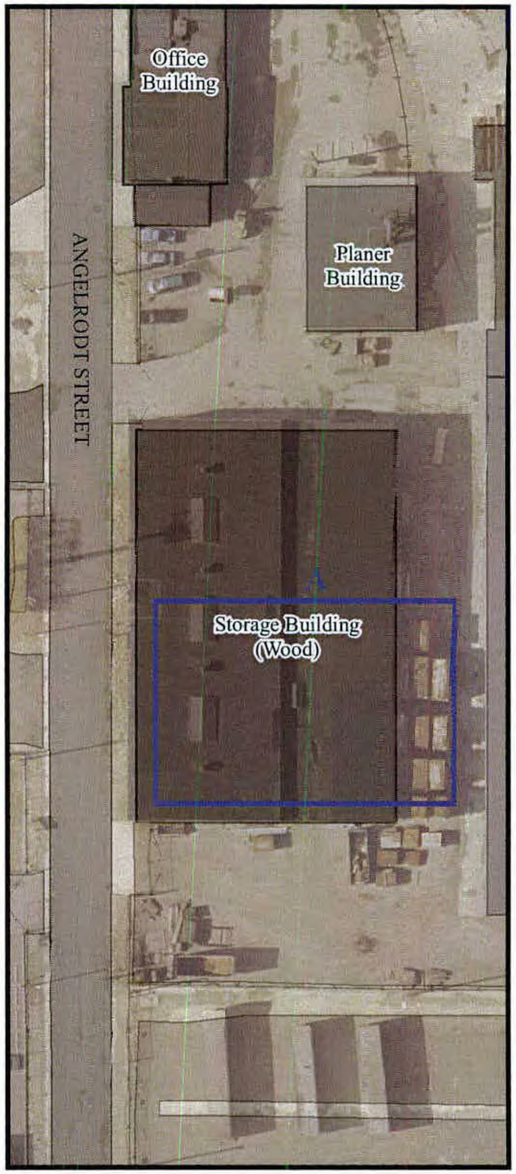
Subject:
Wood Storage Building Elevated Exterior Building Scan Locations - West Wall

Drawn By:
DJH, DLL

Date:
09/30.10

G-13





Surface Measurement Results ($dpm/100cm^2$)
#86: 5,333 #87: 7,335

- ● Elevated measurement above exterior alpha limit of 3200 $dpm/100cm^2$.

FUSRAP

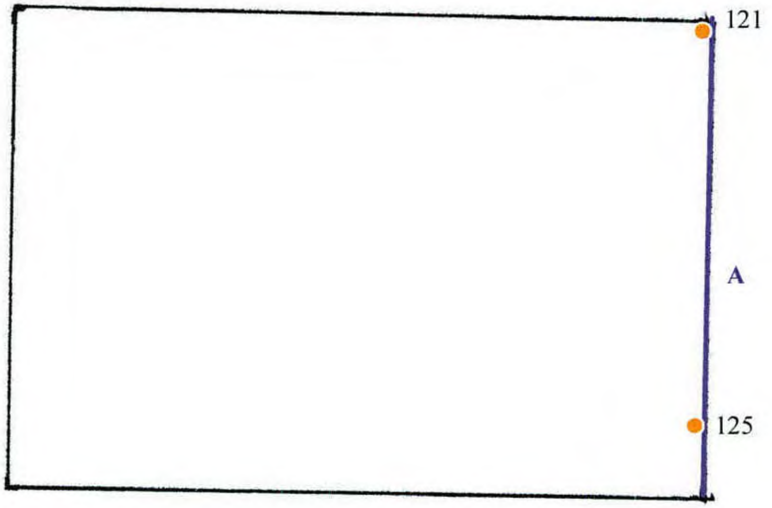
Property:
Thomas and Proetz Lumber Co., DT-10, St. Louis Downtown Site, St. Louis Missouri

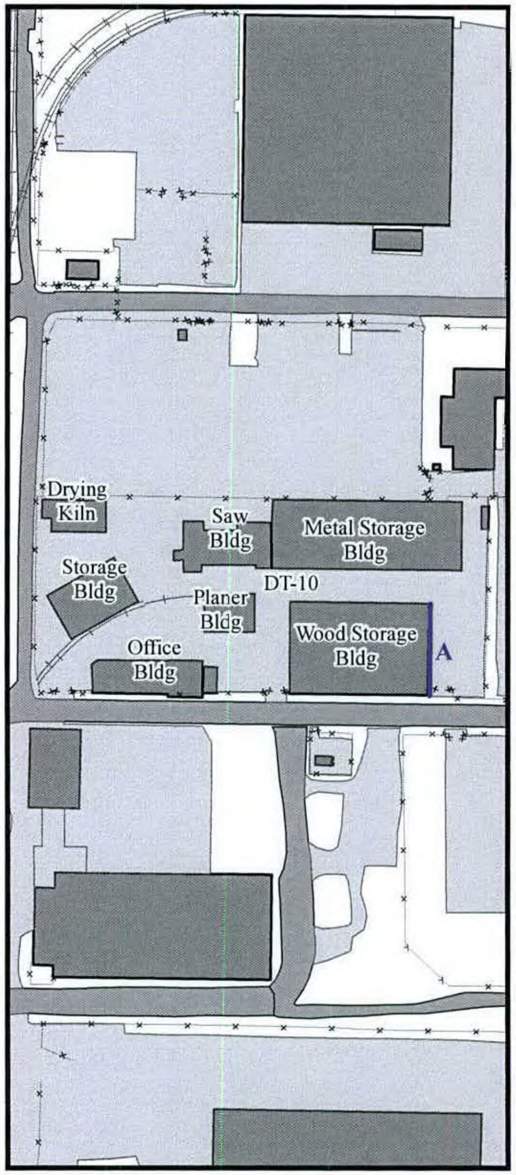
Subject:
Wood Storage Building Elevated Exterior Building Scan Locations - Roof

Drawn By:
DJH, DLL

Date:
09/30/10

G-14





Surface Measurement Results ($dpm/100cm^2$)
#121: 172 #125: 143

● Elevated measurement above interior alpha limit of 130 $dpm/100cm^2$.

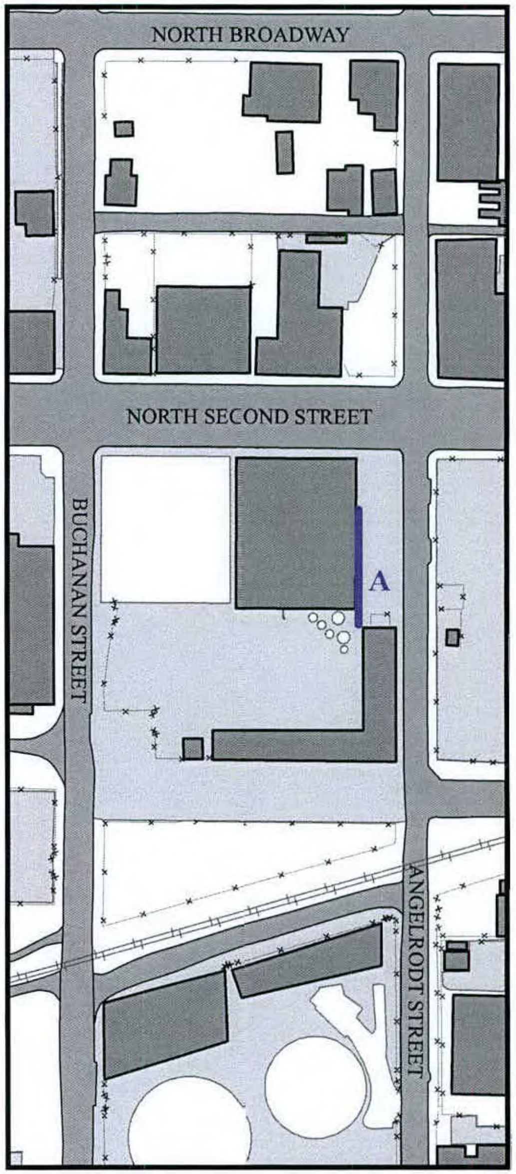
FUSRAP	Property: Thomas and Proetz Lumber Co., DT-10, St. Louis Downtown Site, St. Louis, Missouri	Drawn By: DLL
	Subject: Wood Storage Building Elevated Interior Building Scan Locations	Date: 06/01/2012

G-15

A

● Elevated measurement above exterior alpha limit of 3200 dpm/100cm^2.

Surface Measurement Results (dpm/100cm^2)
#40: 4,760



FUSRAP

Property:
Cotto Waxo, DT-14, St. Louis Downtown Site, St. Louis, Missouri

Subject:
Support Beam Between Buildings Elevated Exterior Scan Location

Drawn By:
DJH, DLL

Date:
09/30/10

G-16

APPENDIX H

Figures: Extent of Contamination for Radiological and Metals Sampling for Sewers

LIST OF FIGURES

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-1 Extent of Ac-227 Exceeding the PRG Sewer Sediment.mxd

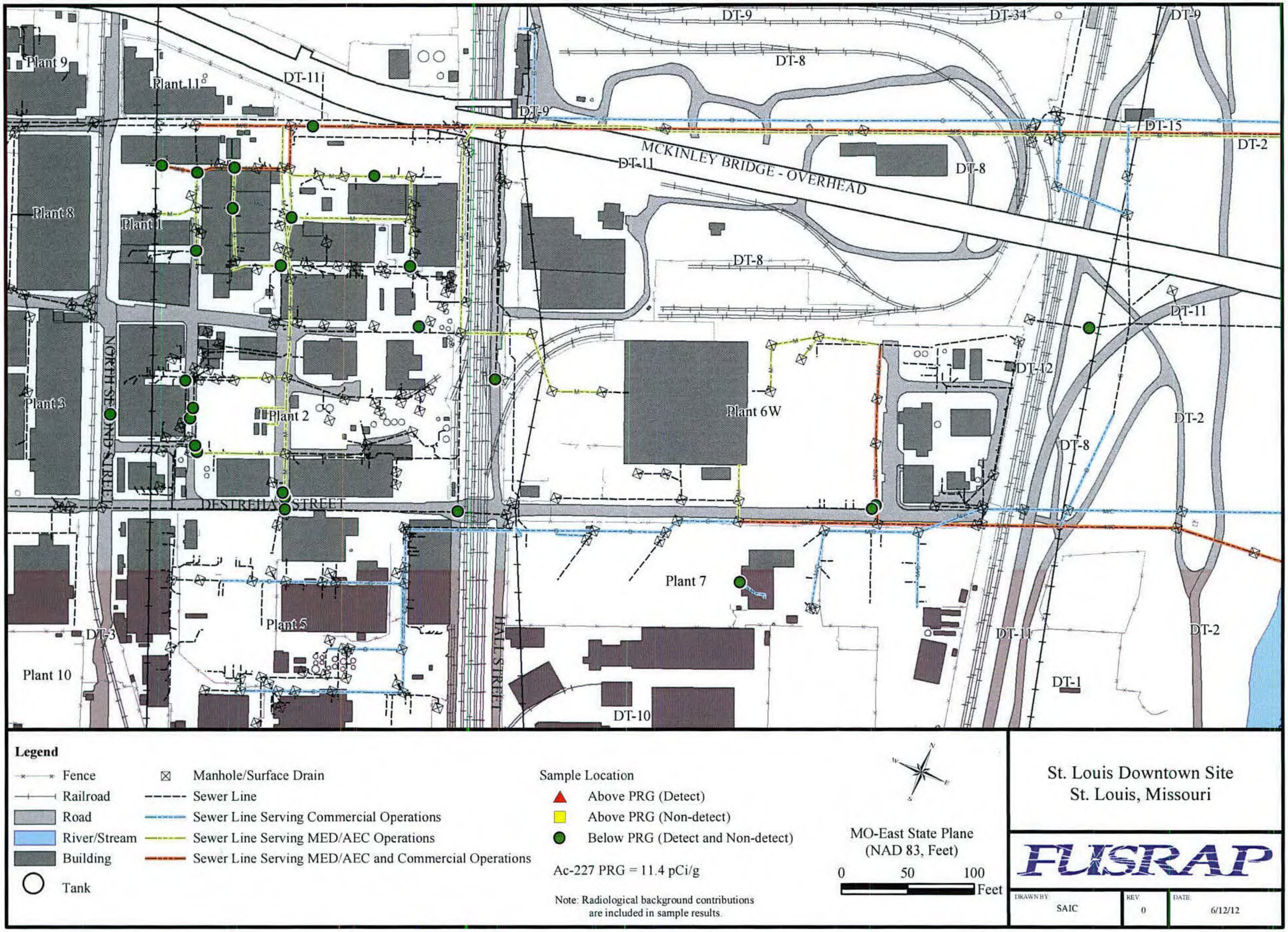
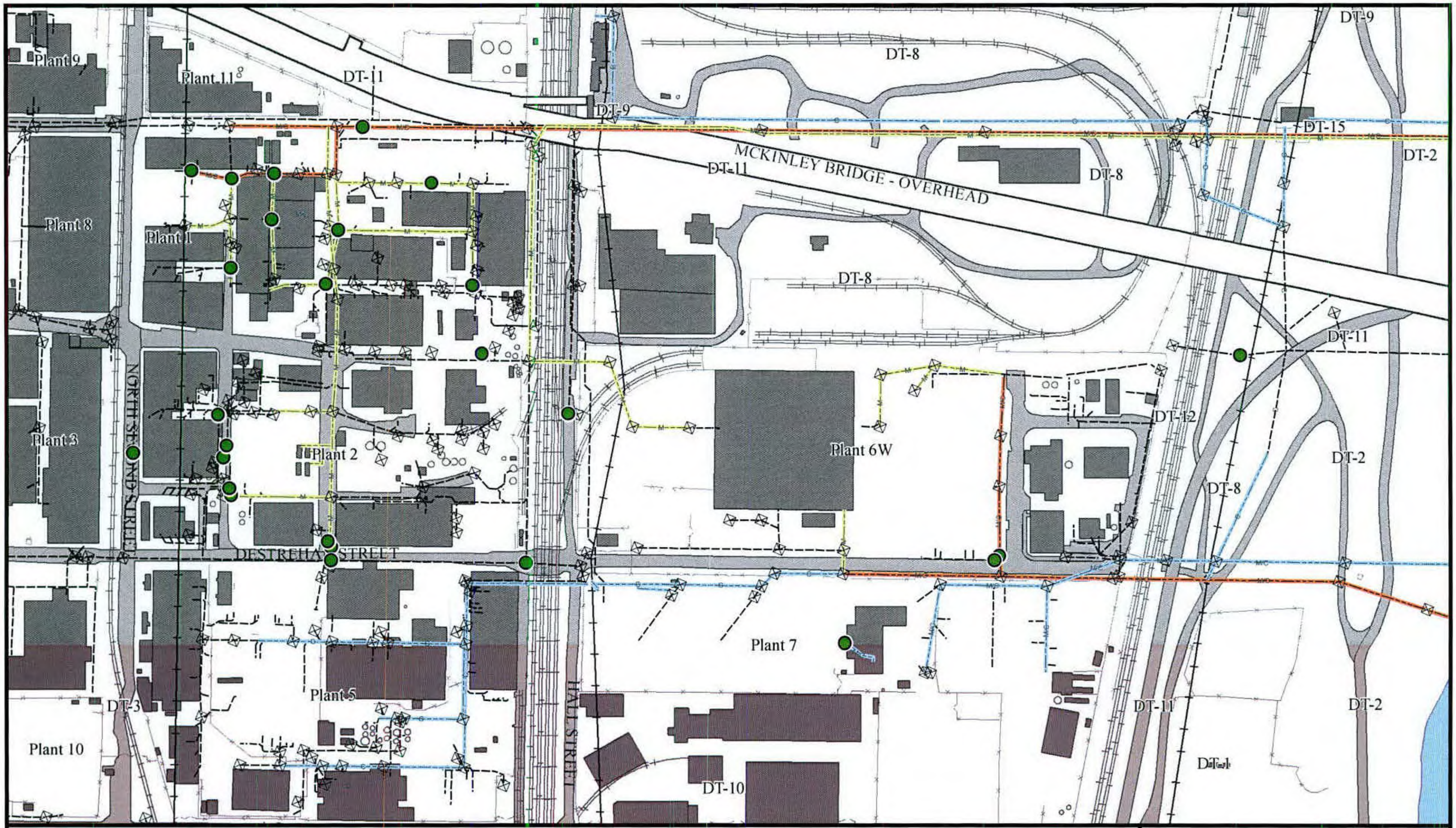


Figure H-1. Distribution of Ac-227 Exceeding the PRG in Sewer Sediment

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-2 Extent of Pa-231 Exceeding the PRG Sewer Sediment.mxd



Legend

- Fence
- Railroad
- 🟫 Road
- 🟦 River/Stream
- ⬛ Building
- ○ Tank
- ☒ Manhole/Surface Drain
- Sewer Line
- Sewer Line Serving Commercial Operations
- Sewer Line Serving MED/AEC Operations
- Sewer Line Serving MED/AEC and Commercial Operations

Sample Location

- ▲ Above PRG (Detect)
- 🟨 Above PRG (Non-detect)
- ● Below PRG (Detect and Non-detect)

Pa-231 PRG = 1.25 pCi/g

Note: Radiological background contributions are included in sample results.

MO-East State Plane
(NAD 83, Feet)

0 50 100 Feet

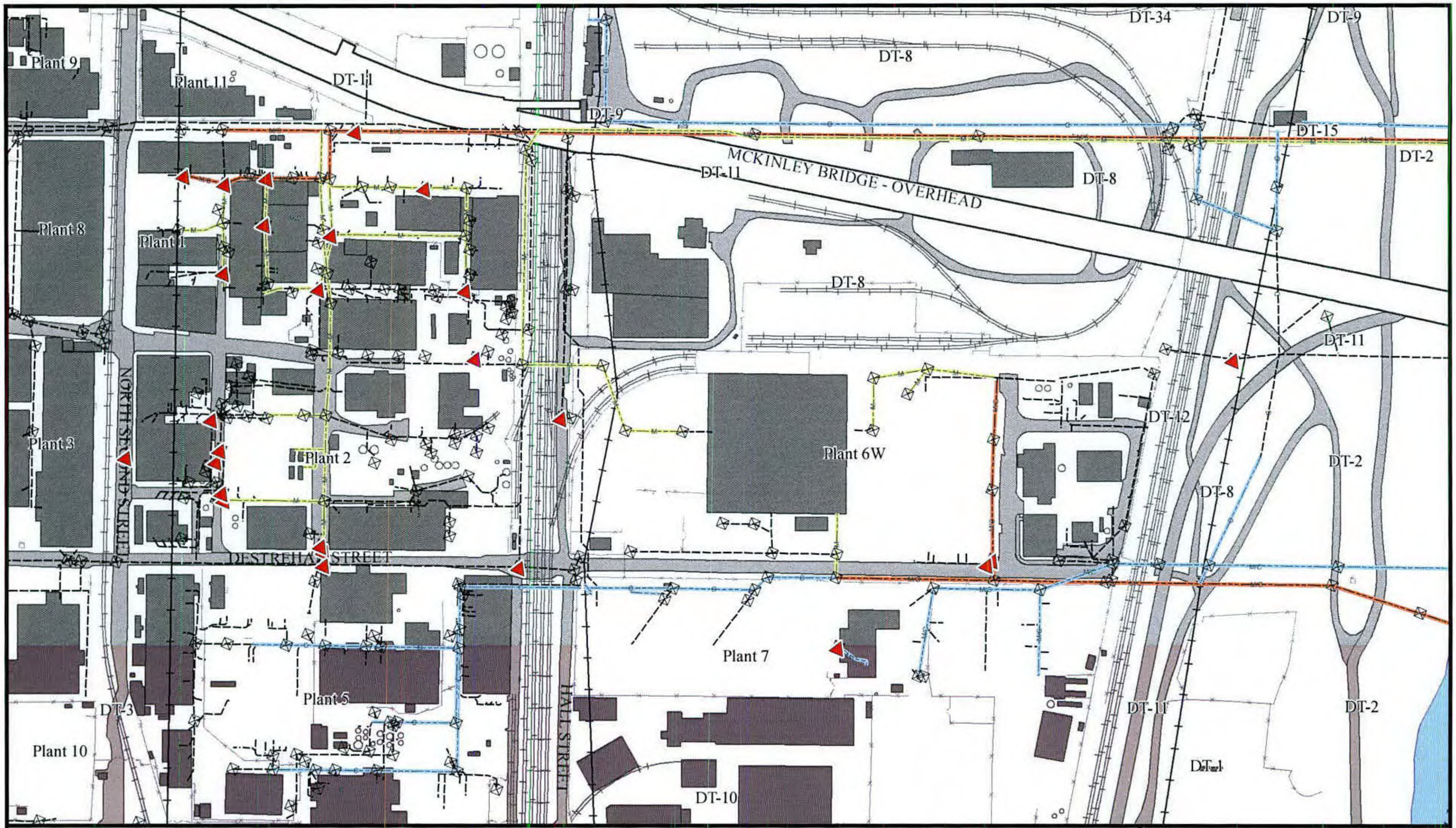
St. Louis Downtown Site
St. Louis, Missouri

FUSRAP

DRAWN BY	REV	DATE
SAIC	0	6/12/12

Figure H-2. Distribution of Pa-231 Exceeding the PRG in Sewer Sediment

Path: U:\GIS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-3 Extent of Ra-226 Exceeding the PRG Sewer Sediment.mxd



Legend

- Fence
- Railroad
- ▨ Road
- ▨ River/Stream
- ▨ Building
- ○ Tank
- ☒ Manhole/Surface Drain
- Sewer Line
- Sewer Line Serving Commercial Operations
- Sewer Line Serving MED/AEC Operations
- Sewer Line Serving MED/AEC and Commercial Operations

Sample Location

- ▲ Above PRG (Detect)
- 🟨 Above PRG (Non-detect)
- ● Below PRG (Detect and Non-detect)

Ra-226 PRG = 0.02 pCi/g

Note: Radiological background contributions are included in sample results.

MO-East State Plane
(NAD 83, Feet)

0 50 100
Feet

St. Louis Downtown Site
St. Louis, Missouri

FUSRAP

DRAWN BY	REV	DATE
SAIC	0	6/12/12

Figure H-3. Distribution of Ra-226 Exceeding the PRG in Sewer Sediment

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-4 Extent of Ra-228 Exceeding the PRG Sewer Sediment.mxd

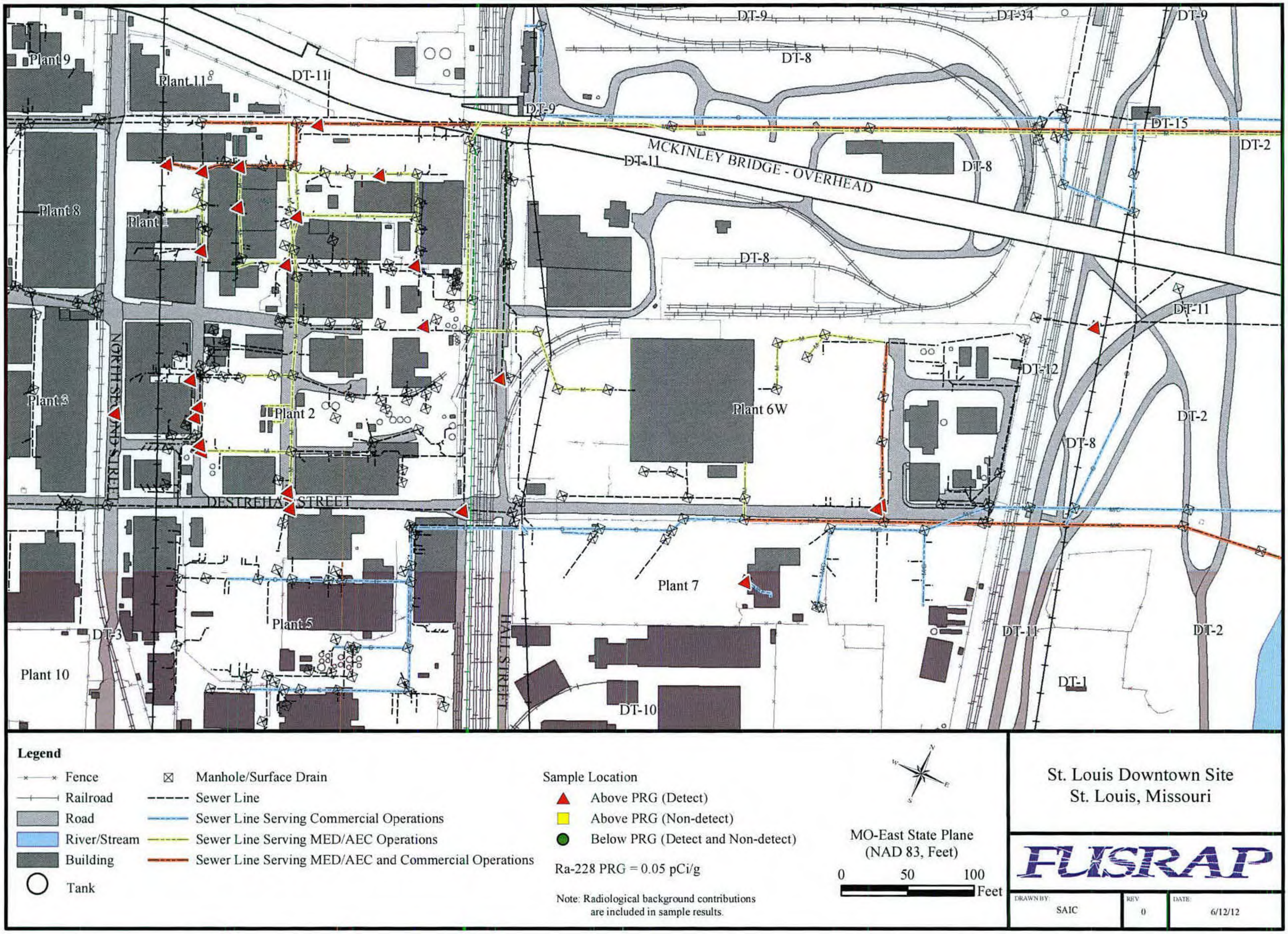


Figure H-4. Distribution of Ra-228 Exceeding the PRG in Sewer Sediment

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-5 Extent of Th-228 Exceeding the PRG Sewer Sediment.mxd

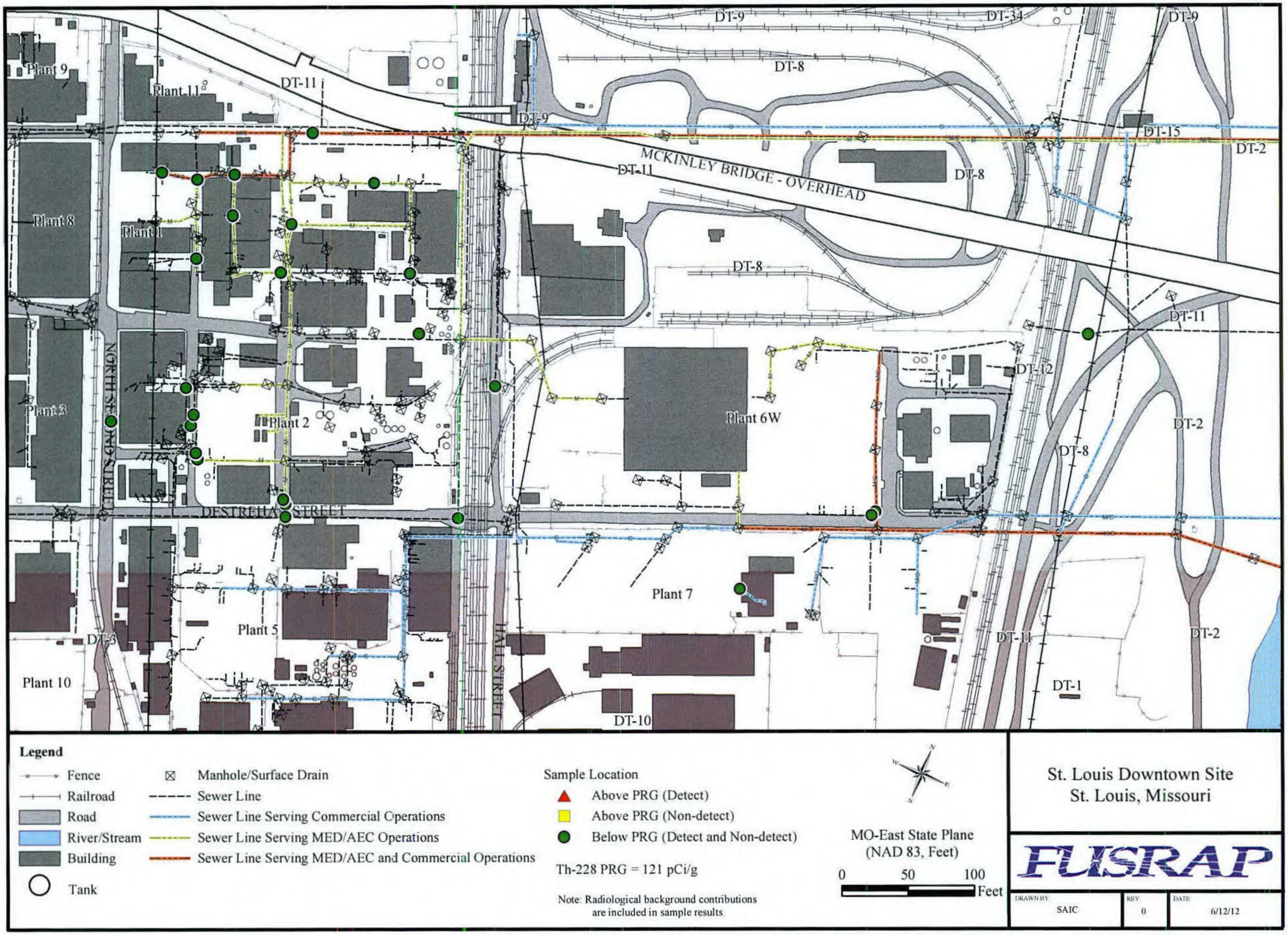


Figure H-5. Distribution of Th-228 Exceeding the PRG in Sewer Sediment

Path: U:\GIS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-6 Extent of Th-230 Exceeding the PRG Sewer Sediment.mxd

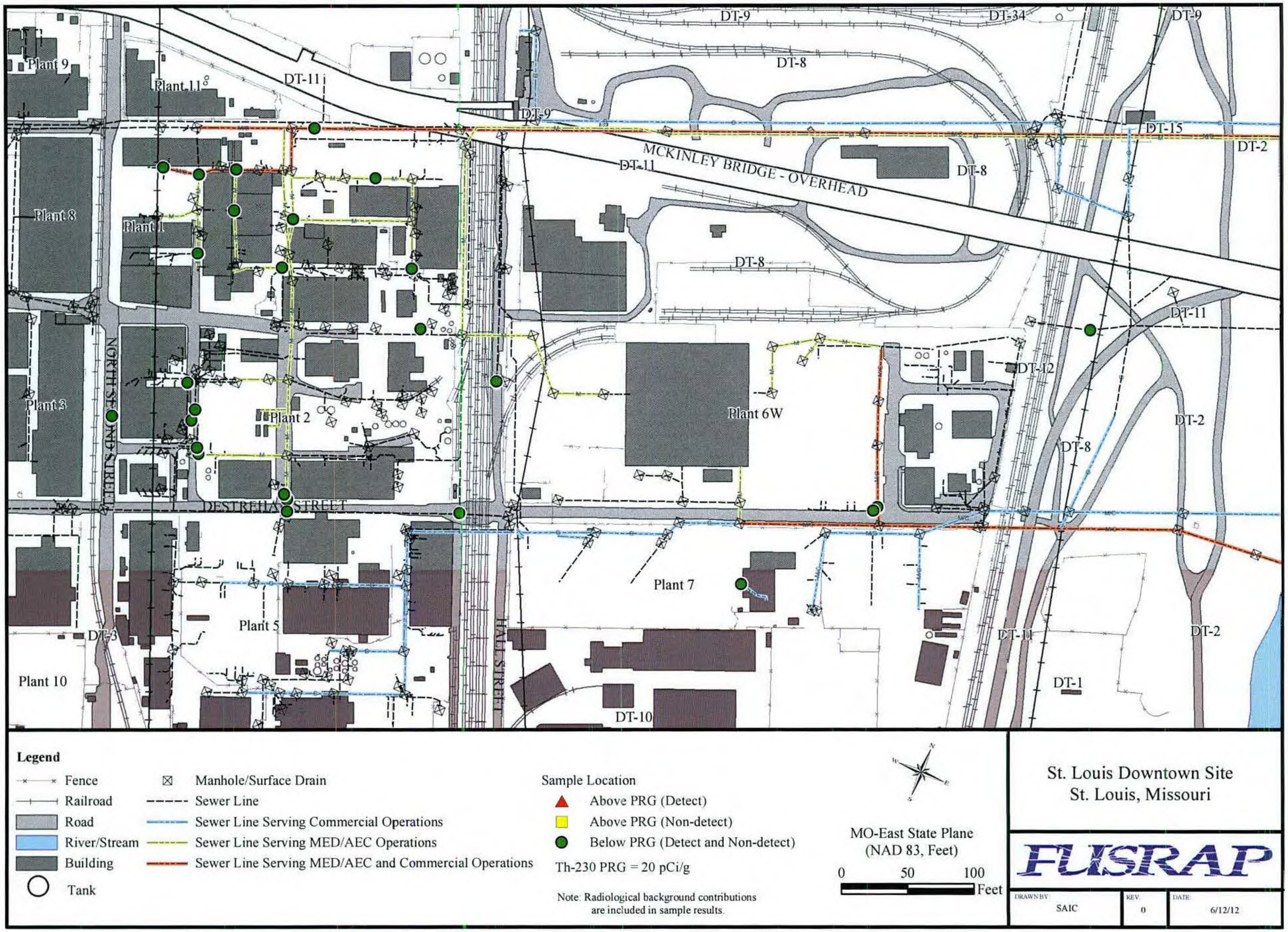


Figure H-6. Distribution of Th-230 Exceeding the PRG in Sewer Sediment

Path: U:\G[illegible]S\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-7 Extent of Th-232 Exceeding the PRG Sewer Sed[illegible].mxd

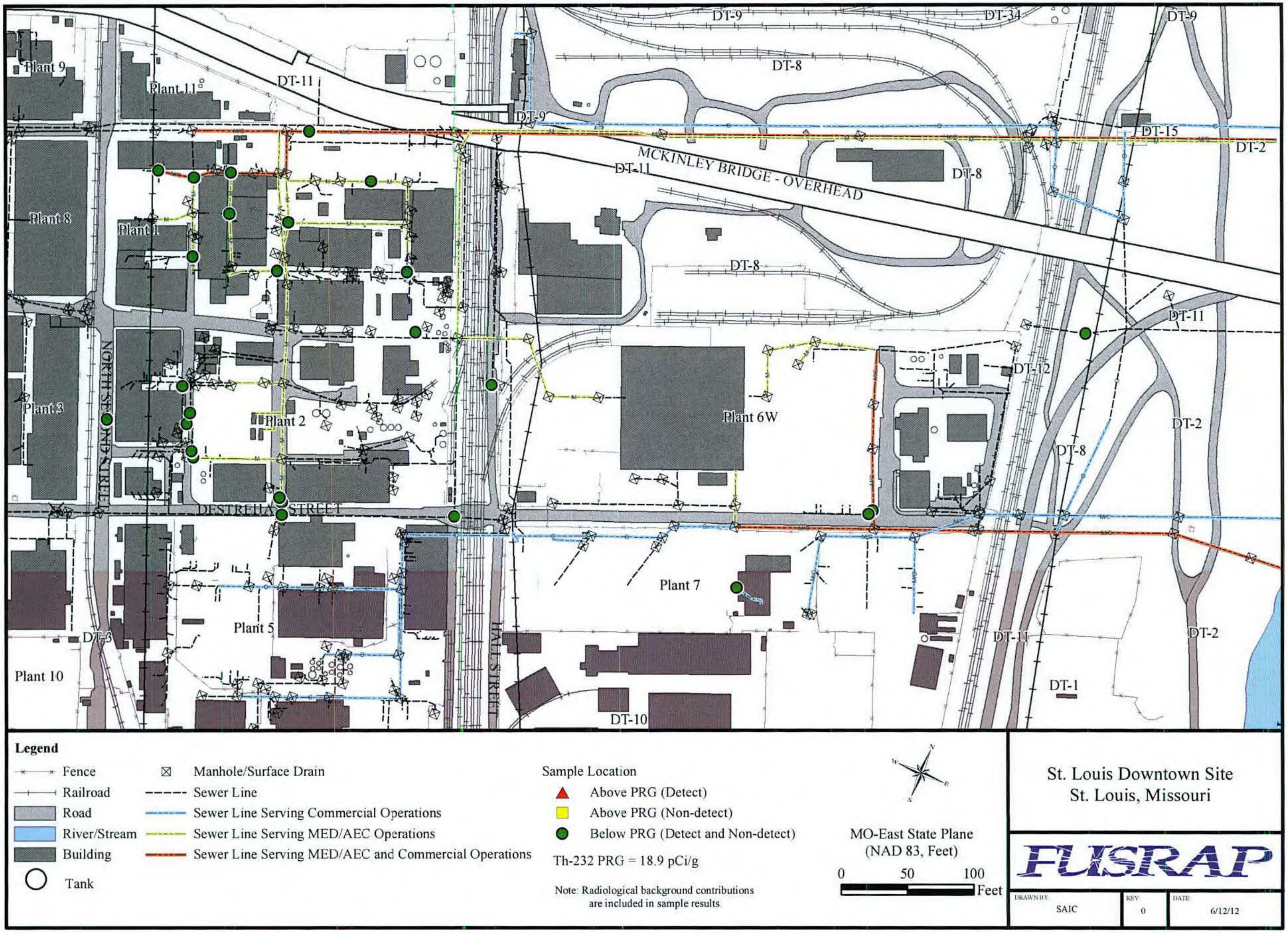


Figure H-7. Distribution of Th-232 Exceeding the PRG in Sewer Sediment

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-8 Extent of U-235 Exceeding the PRG Sewer Sediment.mxd

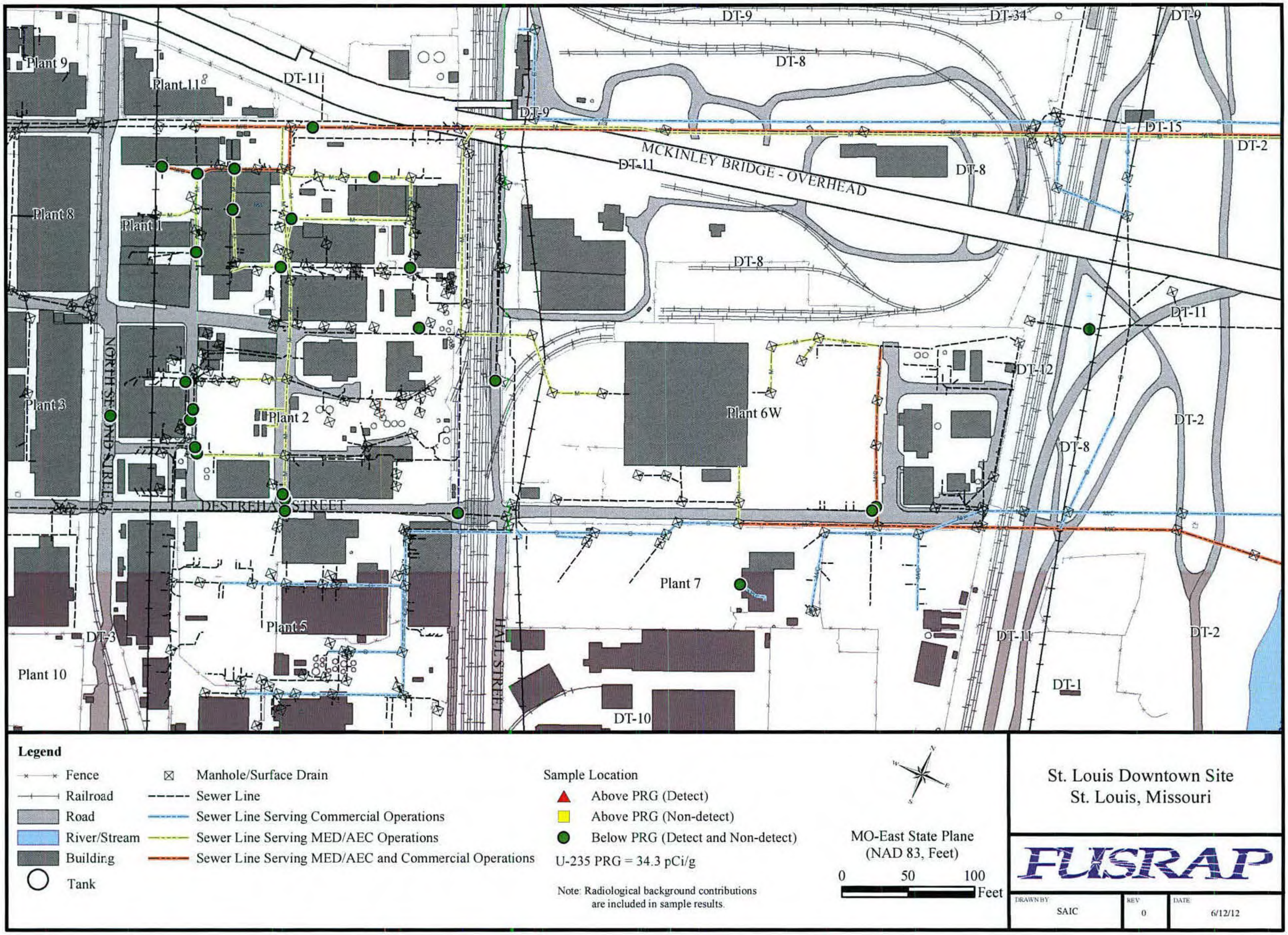


Figure H-8. Distribution of U-235 Exceeding the PRG in Sewer Sediment

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-9 Extent of U-238 Exceeding the PRG Sewer Sediment.mxd

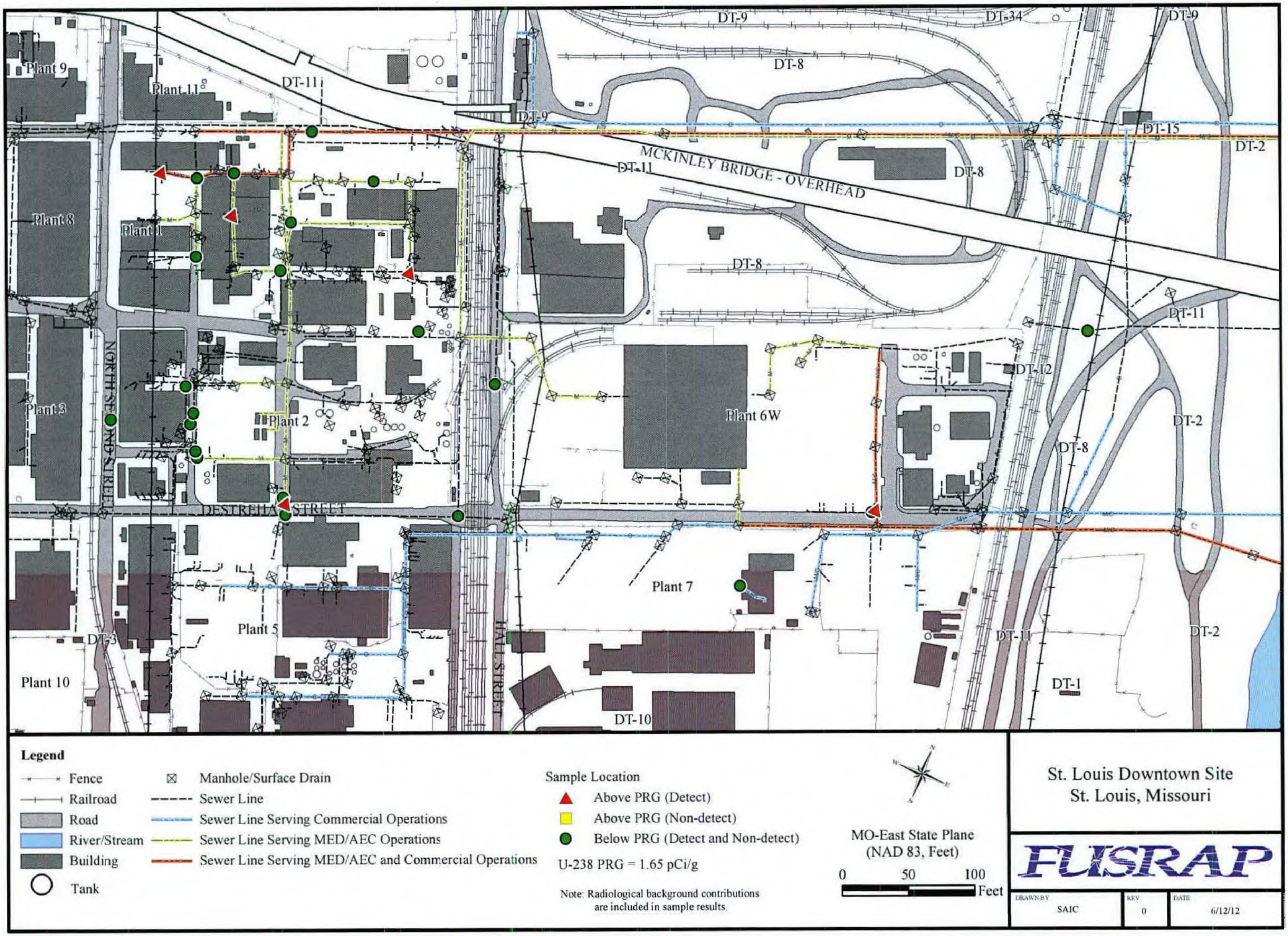


Figure H-9. Distribution of U-238 Exceeding the PRG in Sewer Sediment

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-10 Extent of Arsenic Exceeding the PRG Sewer Sediment.mxd

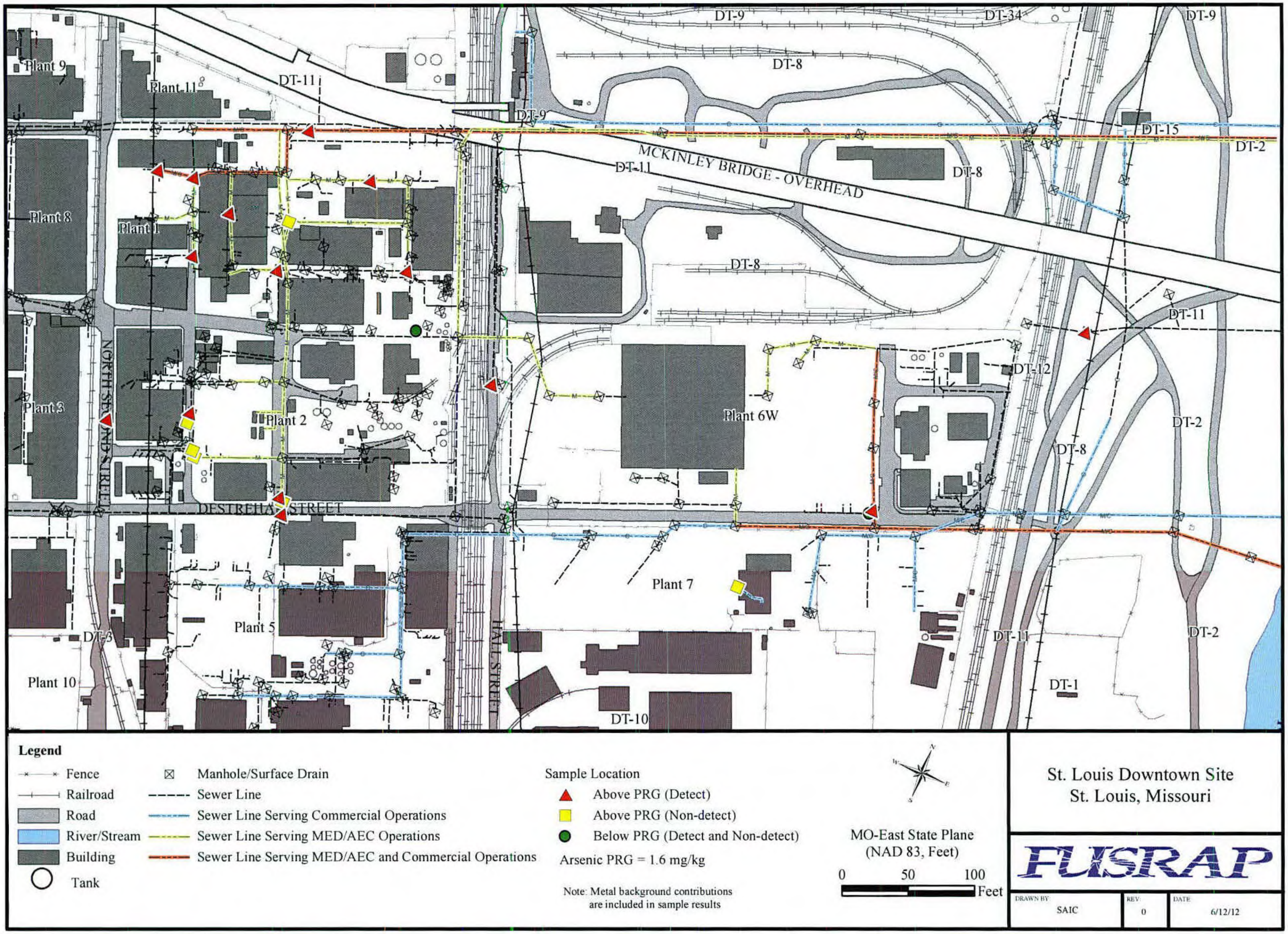


Figure H-10. Distribution of Arsenic Exceeding the PRG in Sewer Sediment

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-11 Extent of Cadmium Exceeding the PRG Sewer Sediment.mxd

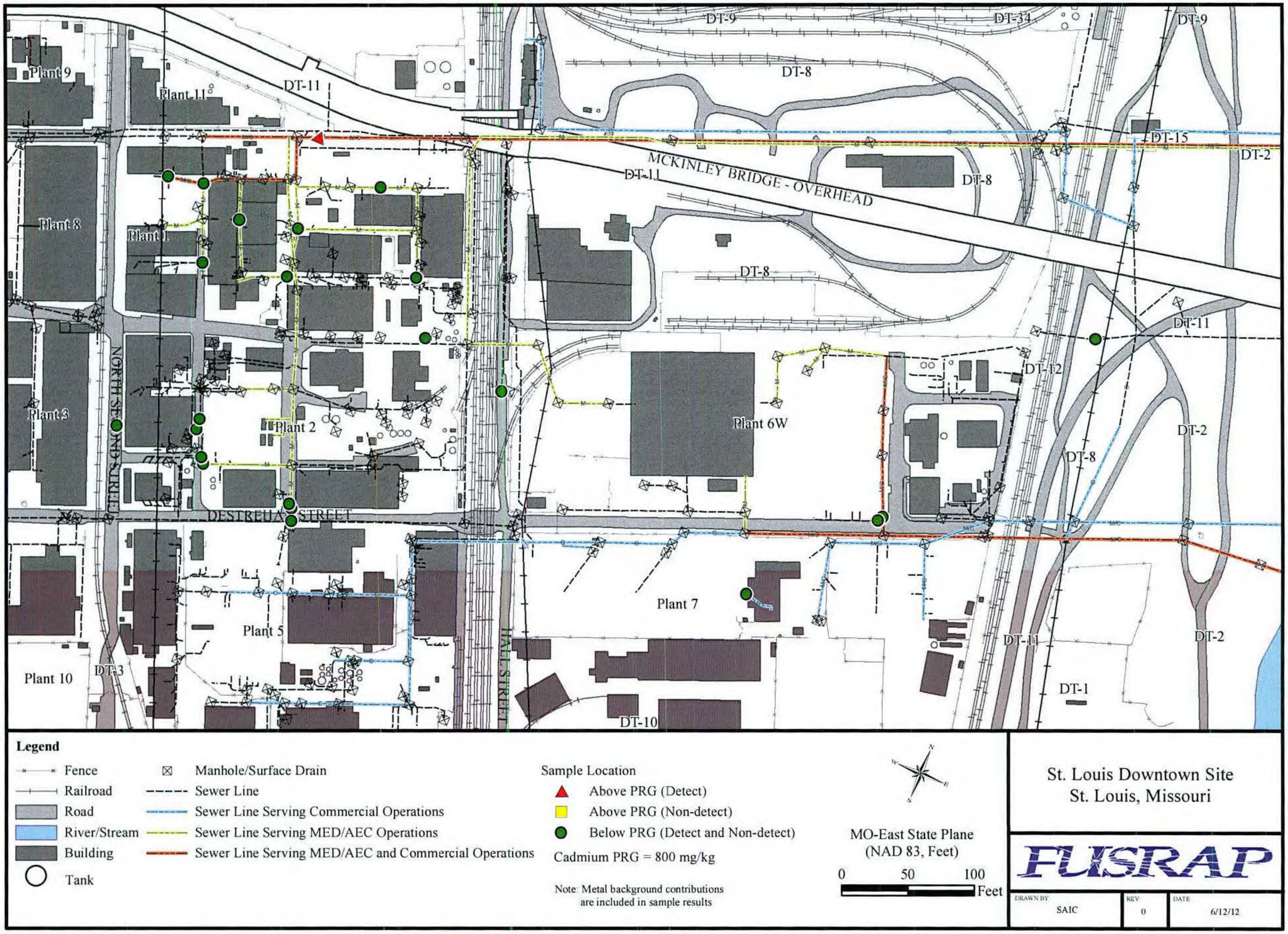


Figure H-11. Distribution of Cadmium Exceeding the PRG in Sewer Sediment

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-12 Extent of Cobalt Exceeding the PRG Sewer Sediment.mxd

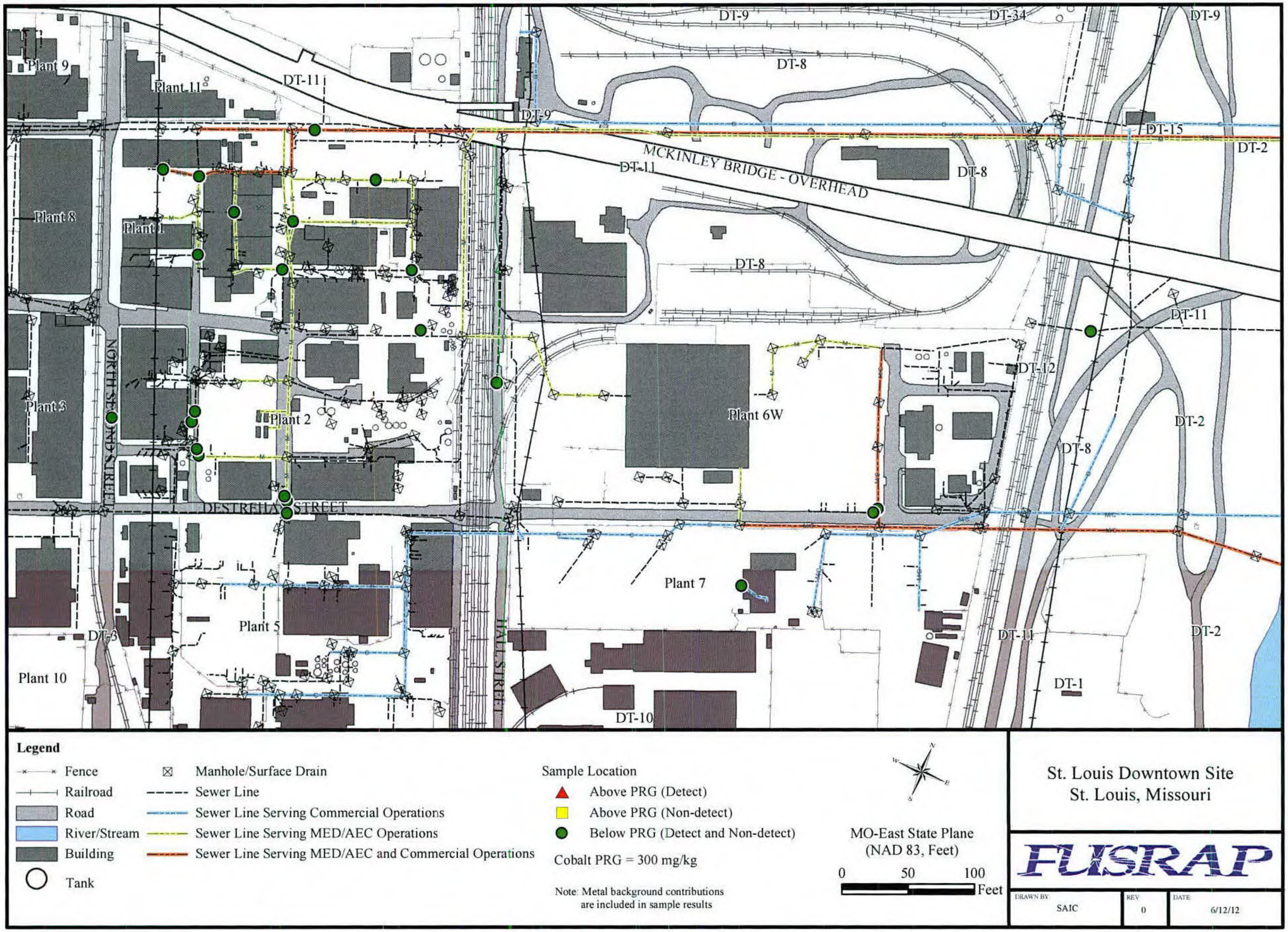


Figure H-12. Distribution of Cobalt Exceeding the PRG in Sewer Sediment

Path: U:\GIS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-13 Extent of Copper Exceeding the PRG Sewer Sediment.mxd

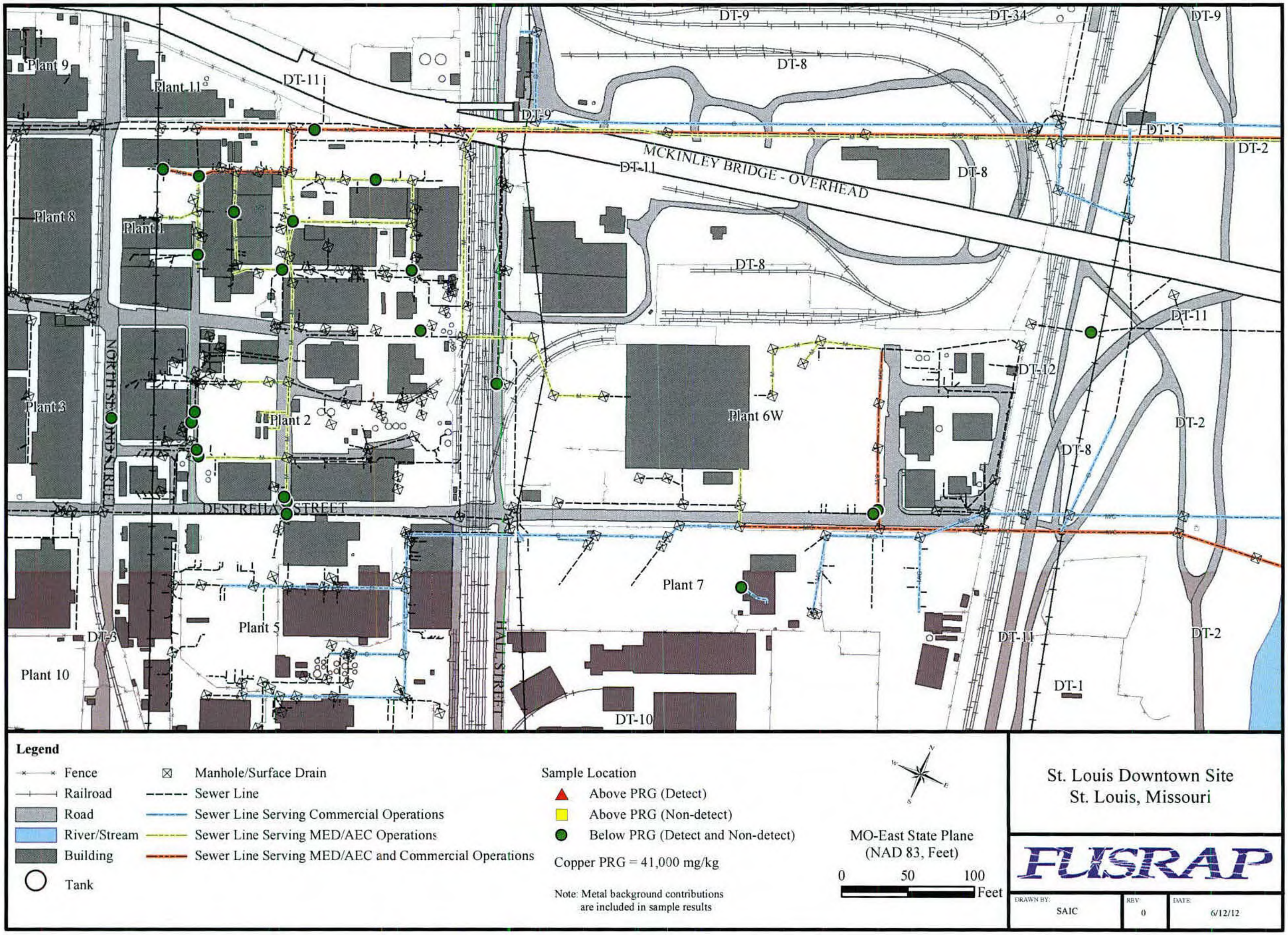


Figure H-13. Distribution of Copper Exceeding the PRG in Sewer Sediment

Path: U:\G[illegible]SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-14 Extent of Lead Exceeding the PRG Sewer Sedim[illegible]mxd

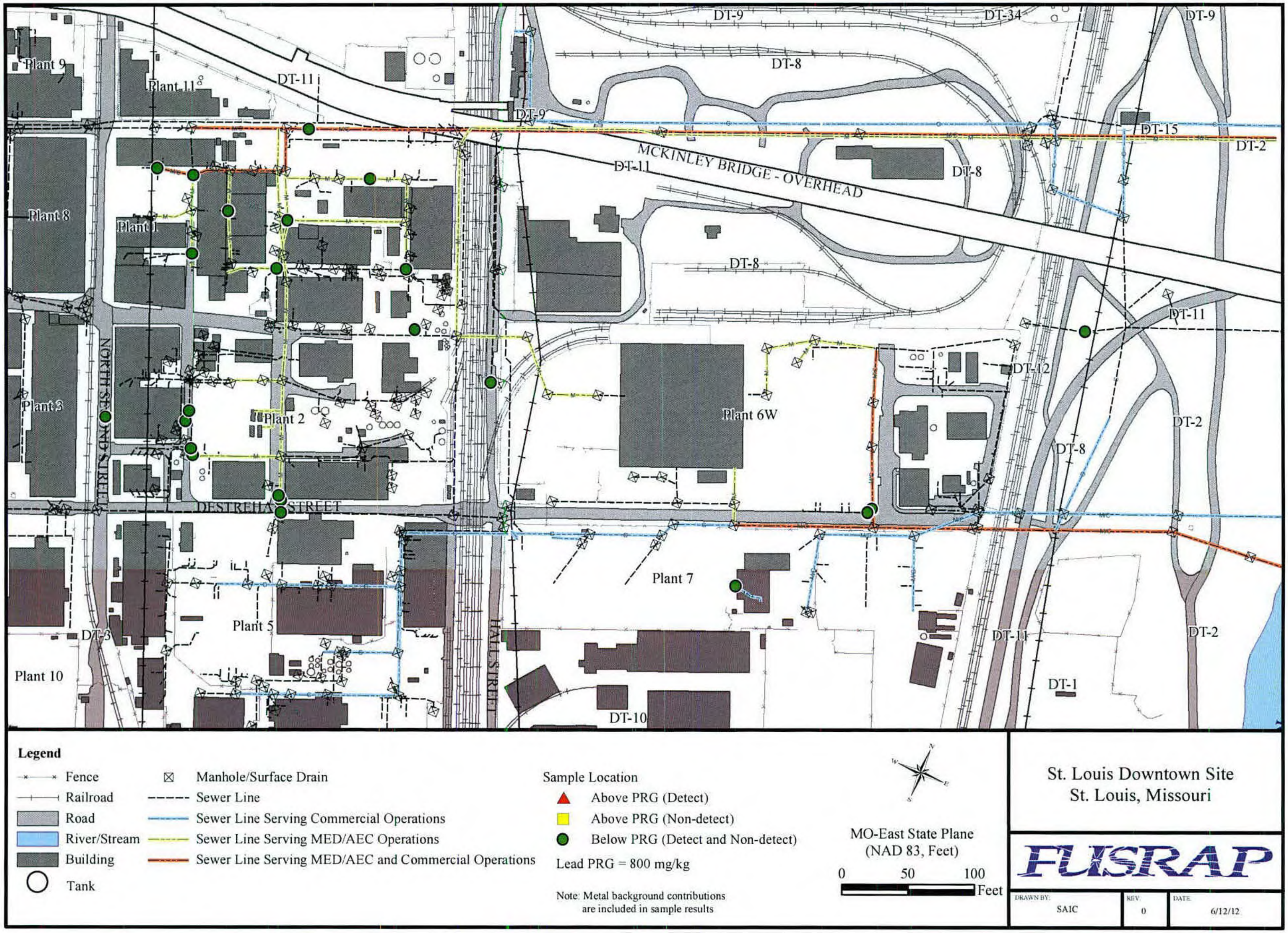


Figure H-14. Distribution of Lead Exceeding the PRG in Sewer Sediment

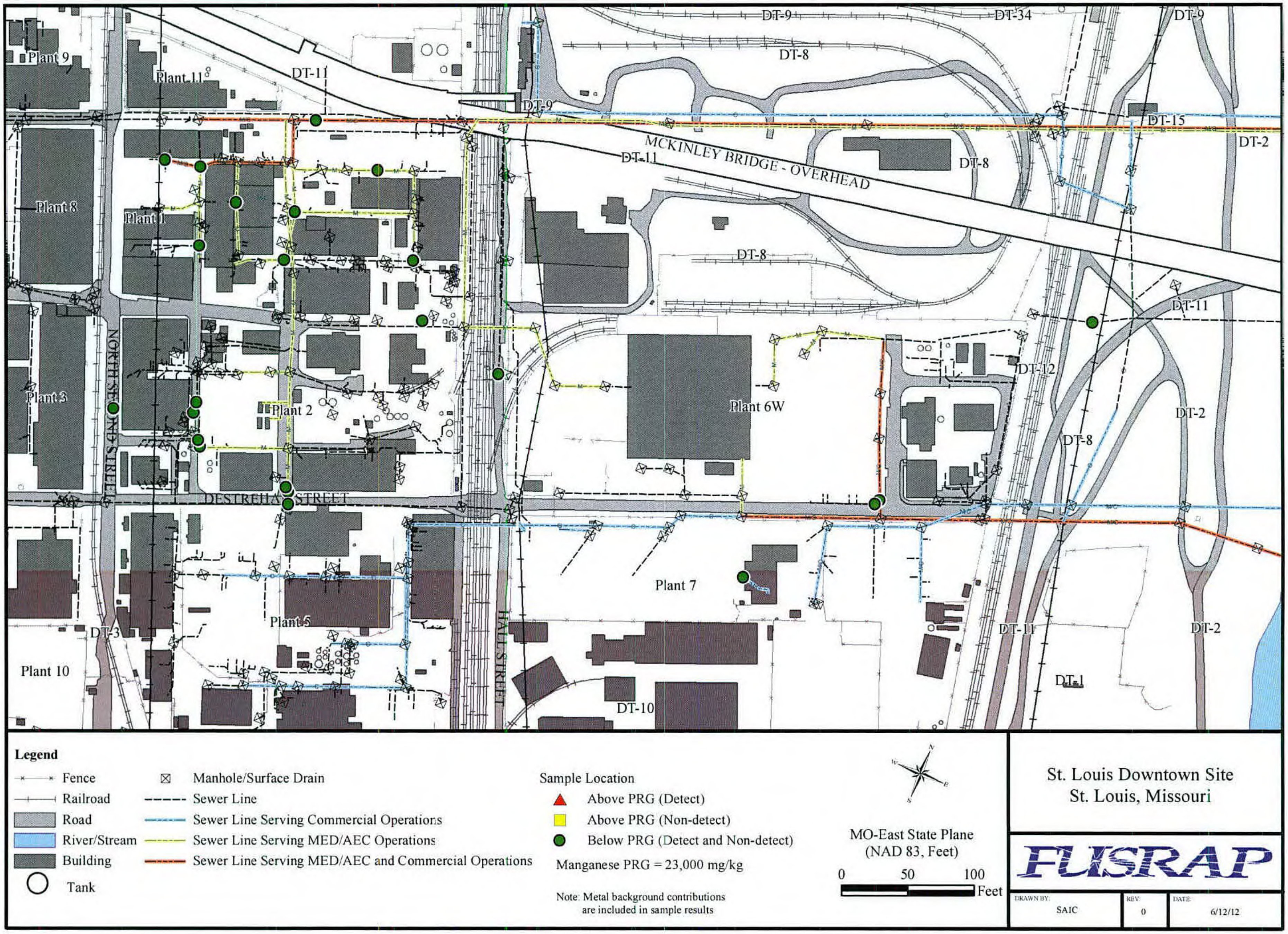


Figure H-15. Distribution of Manganese Exceeding the PRG in Sewer Sediment

Path: U:\GIS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-16 Extent of Molybdenum Exceeding the PRG Sewer Sediment.mxd

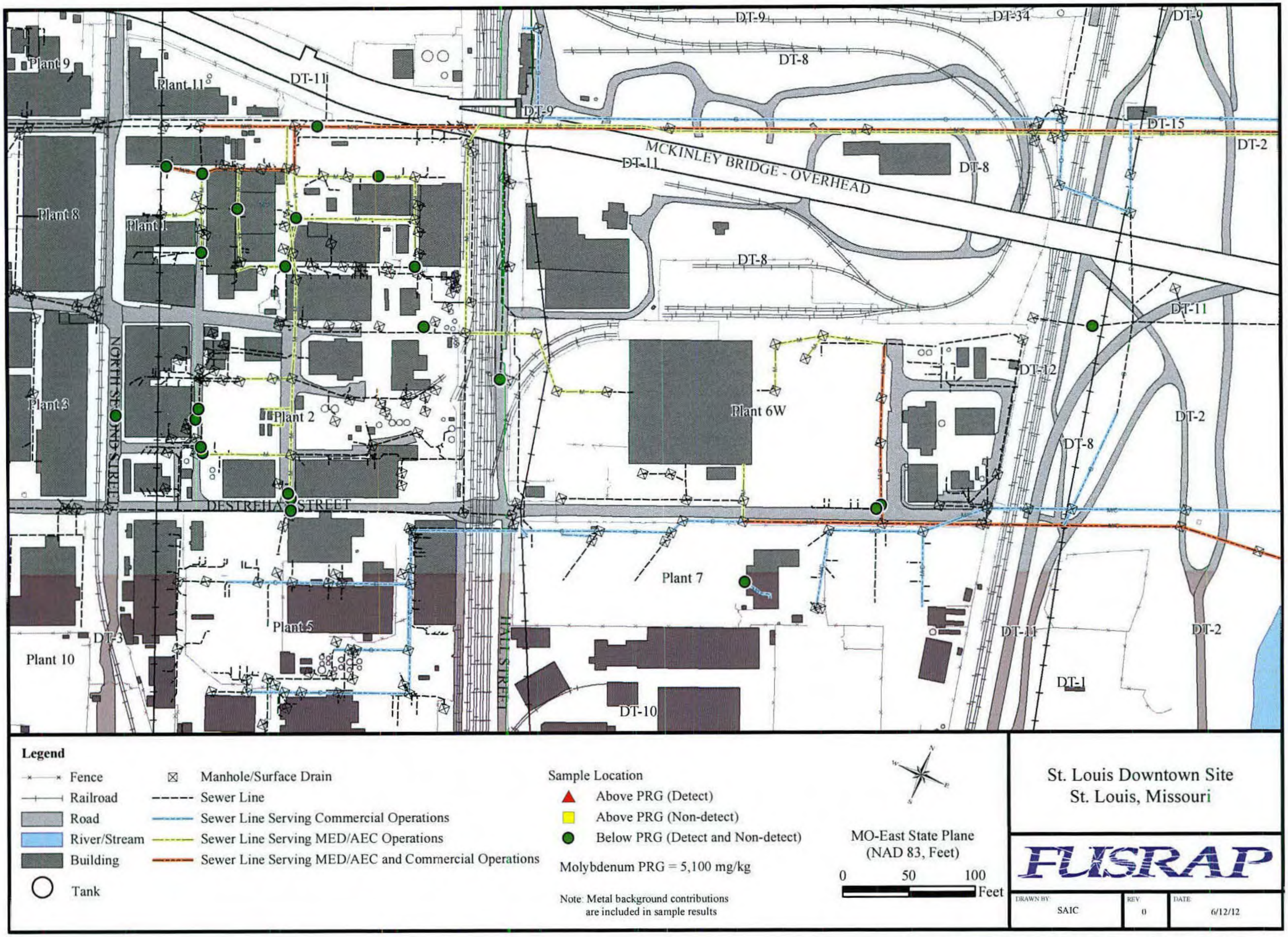


Figure H-16. Distribution of Molybdenum Exceeding the PRG in Sewer Sediment

Path: U:\GIS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-17 Extent of Nickel Exceeding the PRG Sewer Sediment.mxd

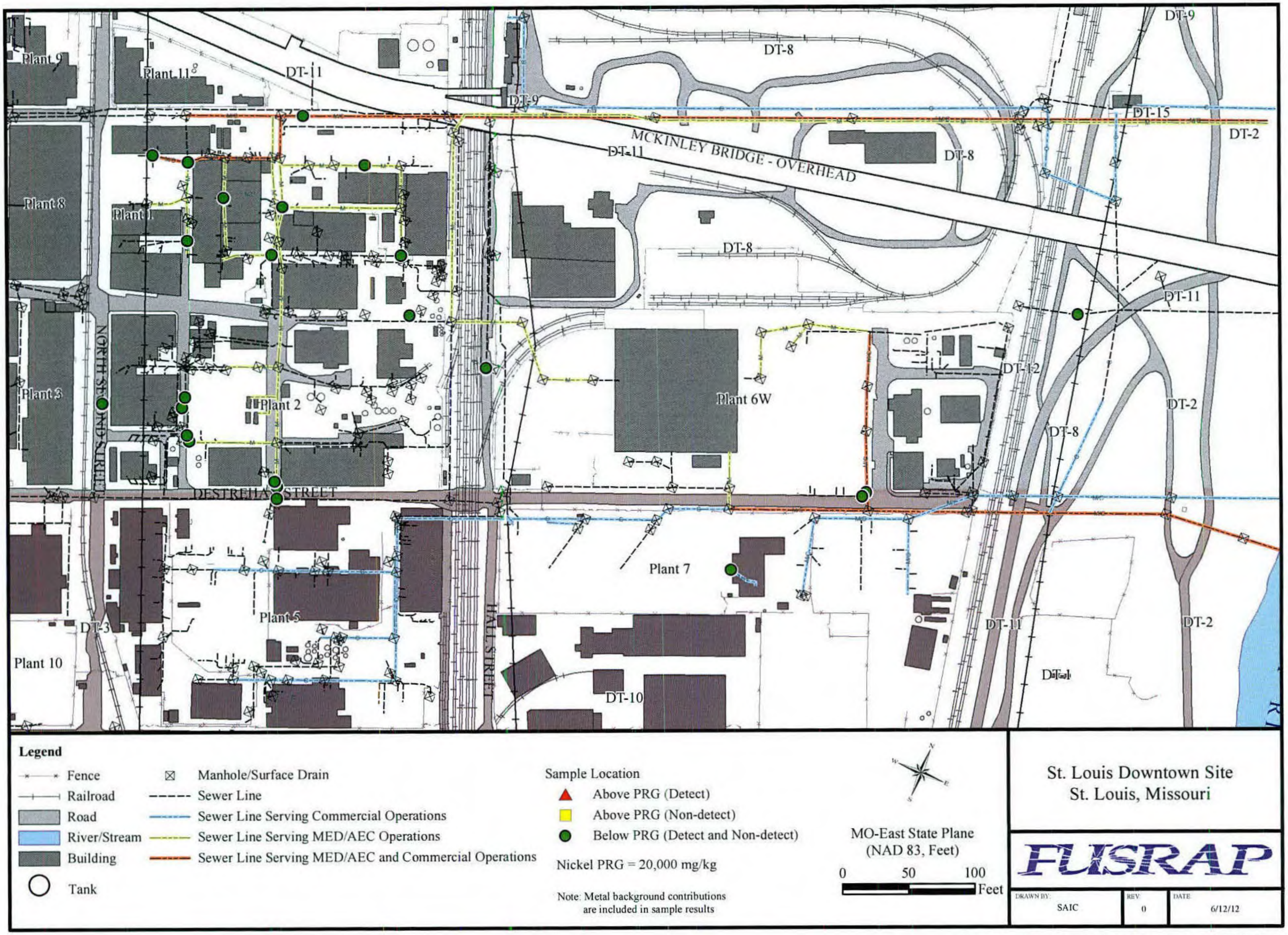
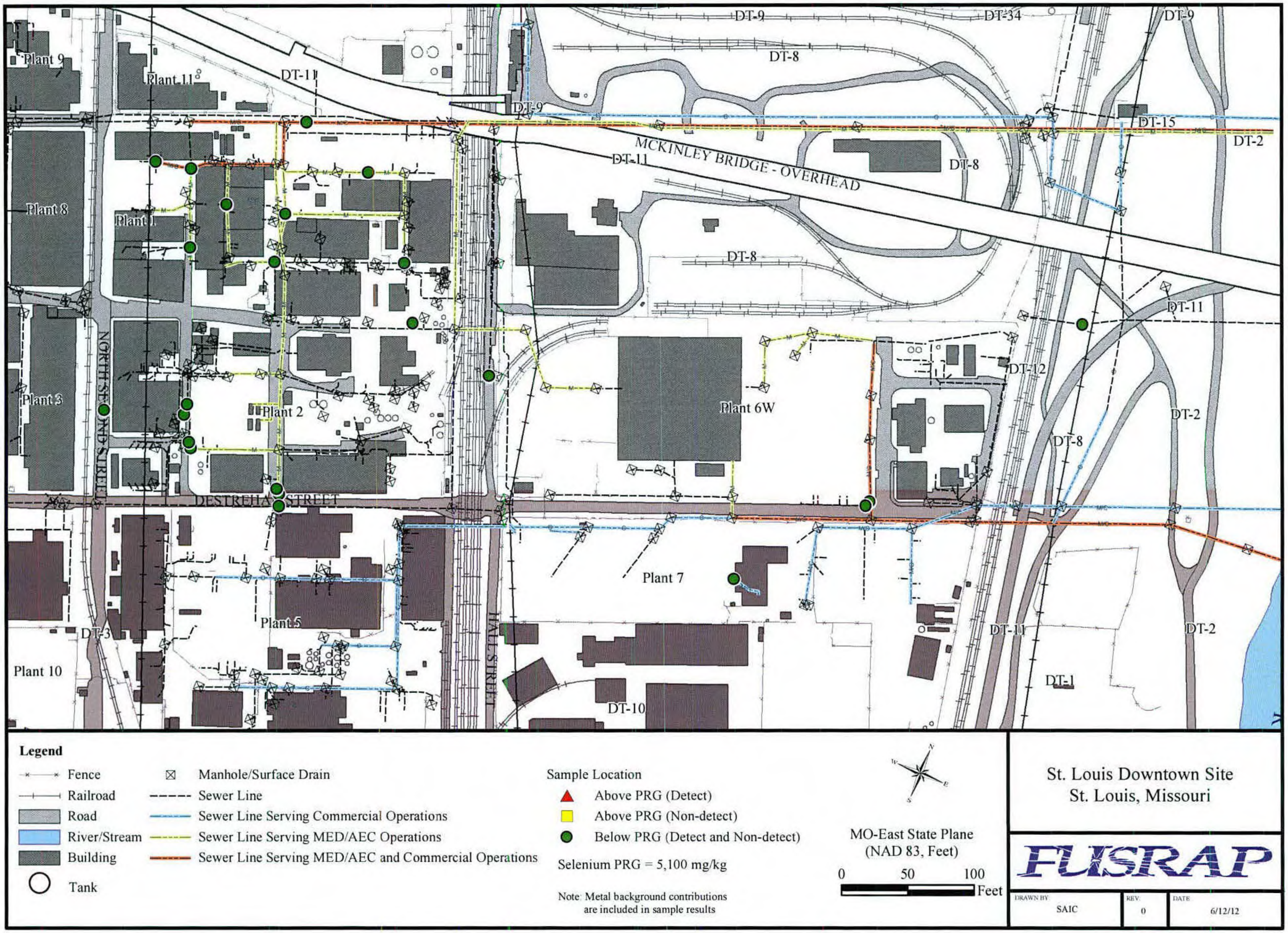


Figure H-17. Distribution of Nickel Exceeding the PRG in Sewer Sediment

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-18 Extent of Selenium Exceeding the PRG Sewer Sediment.mxd



Legend

- Fence
- Railroad
- Road
- River/Stream
- Building
- ○ Tank
- ☒ Manhole/Surface Drain
- Sewer Line
- Sewer Line Serving Commercial Operations
- Sewer Line Serving MED/AEC Operations
- Sewer Line Serving MED/AEC and Commercial Operations

Sample Location

- ▲ Above PRG (Detect)
- 🟨 Above PRG (Non-detect)
- ● Below PRG (Detect and Non-detect)

Selenium PRG = 5,100 mg/kg

Note: Metal background contributions
are included in sample results

MO-East State Plane
(NAD 83, Feet)

0 50 100
Feet

St. Louis Downtown Site
St. Louis, Missouri

FUSRAP

DRAWN BY	REV.	DATE
SAIC	0	6/12/12

Figure H-18. Distribution of Selenium Exceeding the PRG in Sewer Sediment

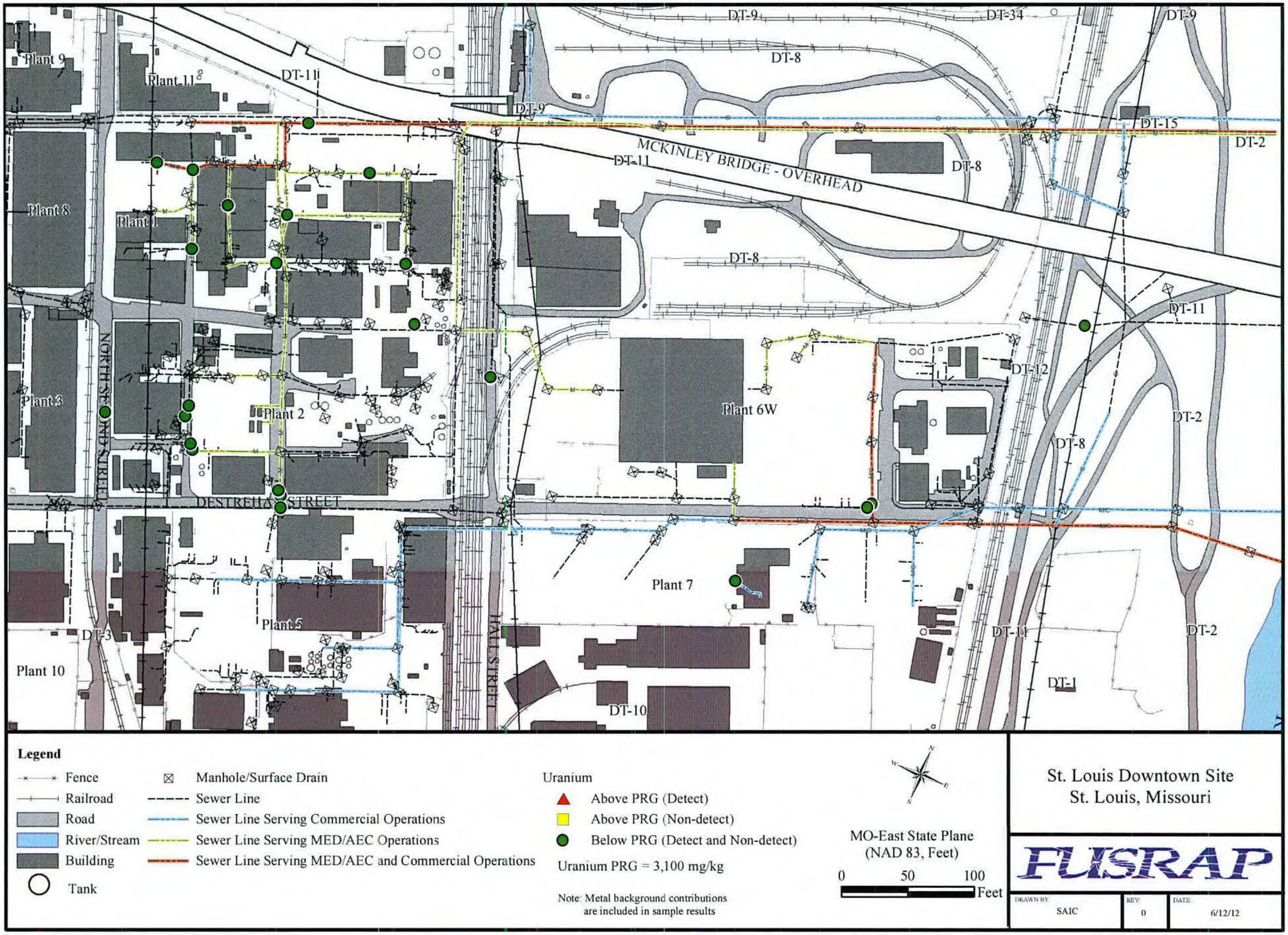


Figure H-19. Distribution of Uranium Metal Exceeding the PRG in Sewer Sediment

Path: U:\GIS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-20 Extent of Vanadium Exceeding the PRG Sewer Sediment.mxd

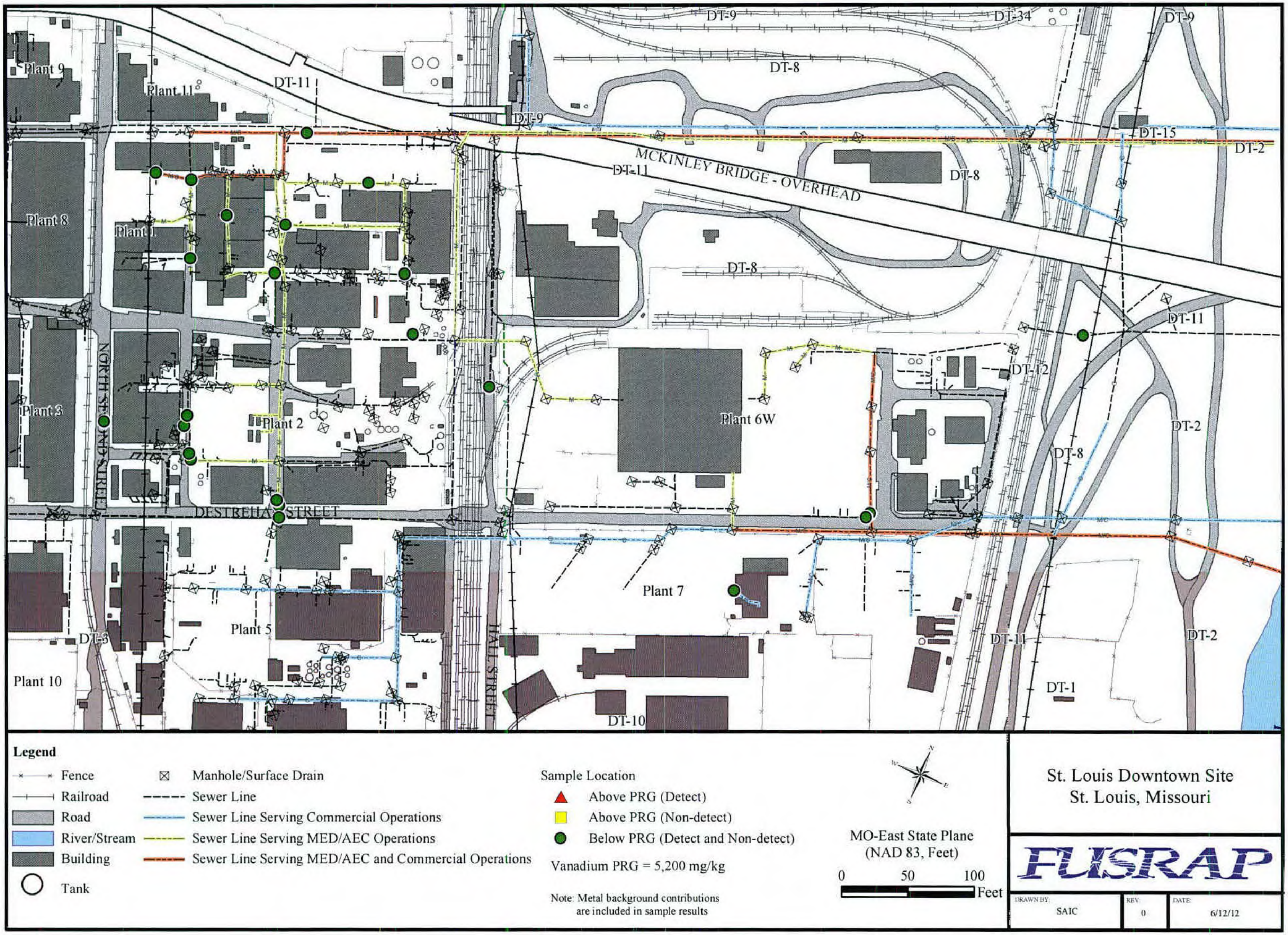


Figure H-20. Distribution of Vanadium Exceeding the PRG in Sewer Sediment

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-21 Extent of Zinc Exceeding the PRG Sewer Sediment.mxd

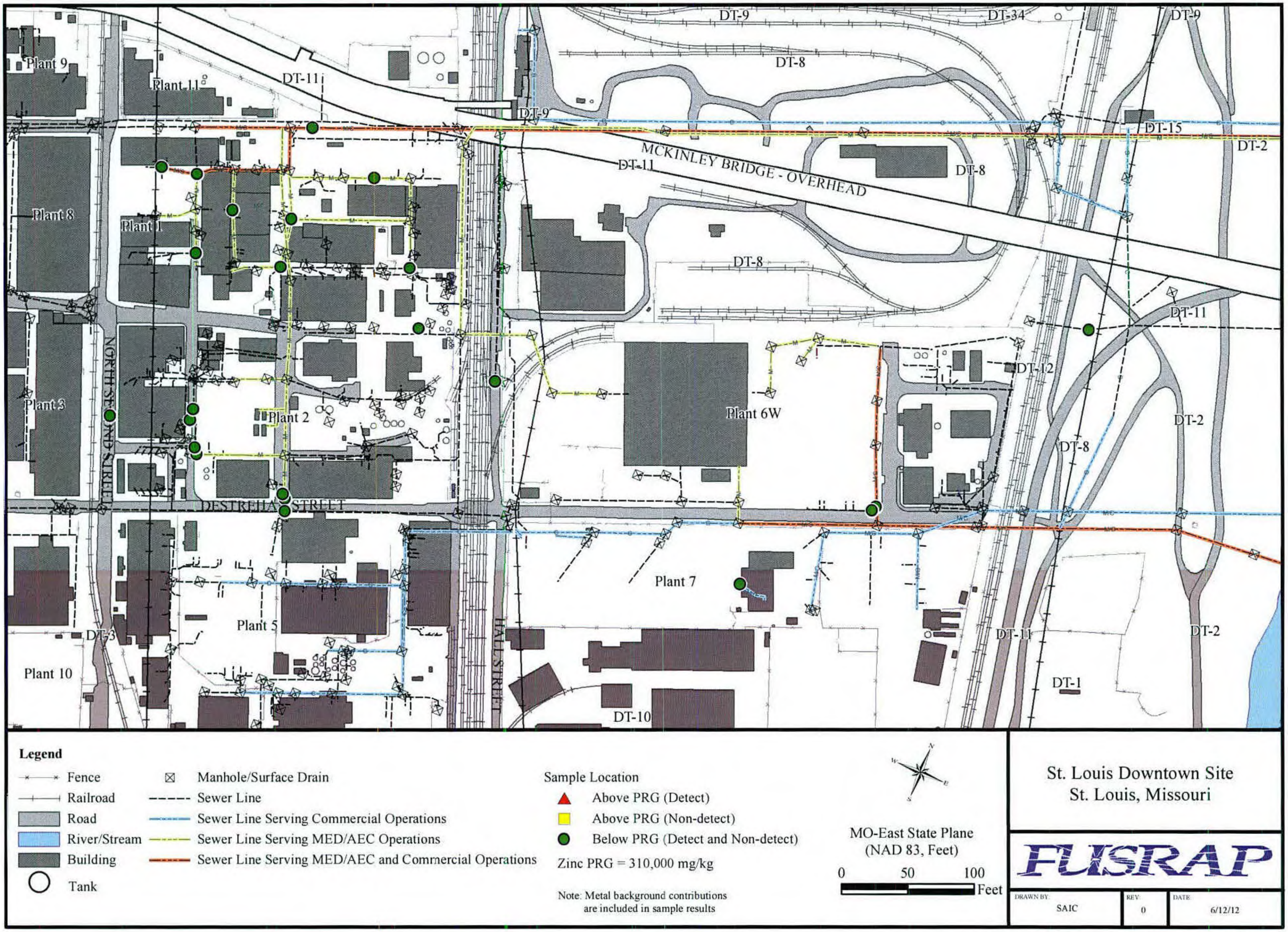
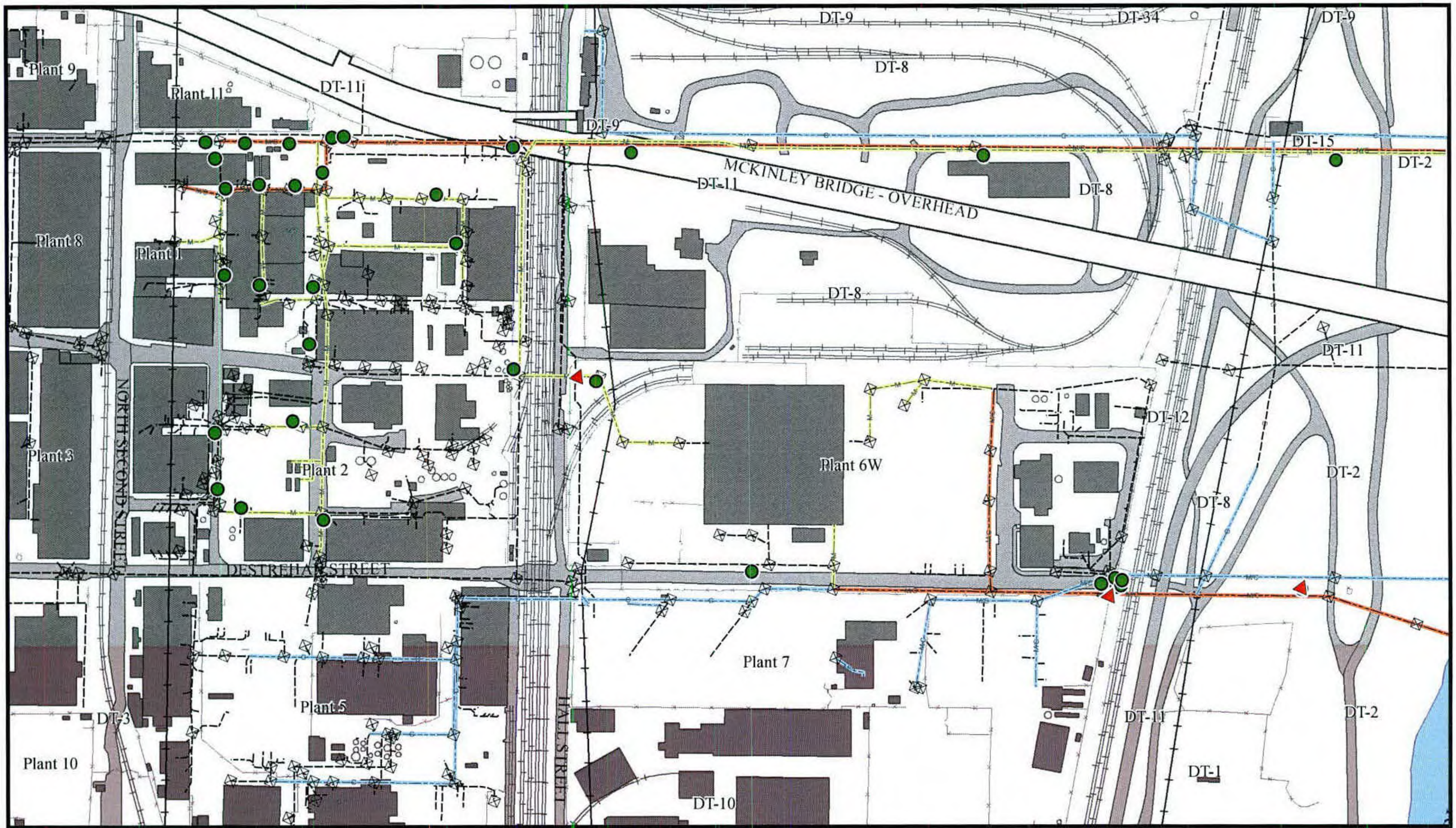


Figure H-21. Distribution of Zinc Exceeding the PRG in Sewer Sediment

Path: U:\GIS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-22 Extent of Ac-227 Exceeding the PRG Sewer Soil.mxd



Legend

Fence	☒	Manhole/Surface Drain
Railroad	- - - -	Sewer Line
Road		Sewer Line Serving Commercial Operations
River/Stream		Sewer Line Serving MED/AEC Operations
Building		Sewer Line Serving MED/AEC and Commercial Operations
○ Tank		

Sample Location

- ▲ Above PRG (Detect)
- 🟨 Above PRG (Non-detect)
- ● Below PRG (Detect and Non-detect)

Ac-227 PRG = 11.4 pCi/g

Note: Radiological background contributions are included in sample results.

MO-East State Plane
(NAD 83, Feet)

0 50 100 Feet

St. Louis Downtown Site
St. Louis, Missouri

FUSRAP

DRAWN BY:	REV:	DATE:
SAIC	0	6/12/12

Figure H-22. Distribution of Ac-227 Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\G S\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-23 Extent of Pa-231 Exceeding the PRG Sewer Soil.mxd

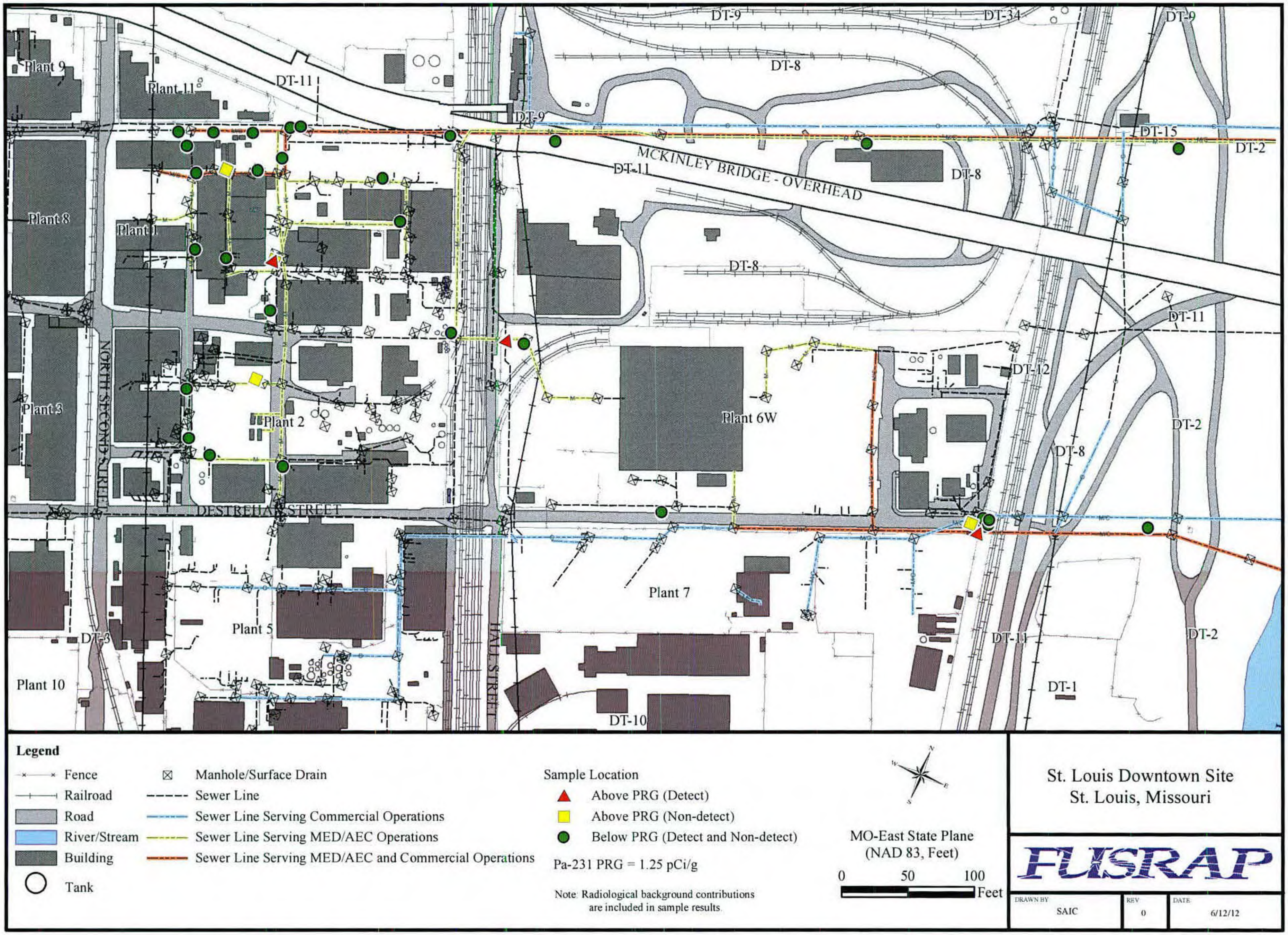


Figure H-23. Distribution of Pa-231 Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\GIS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-24 Extent of Ra-226 Exceeding the PRG Sewer Soil.mxd

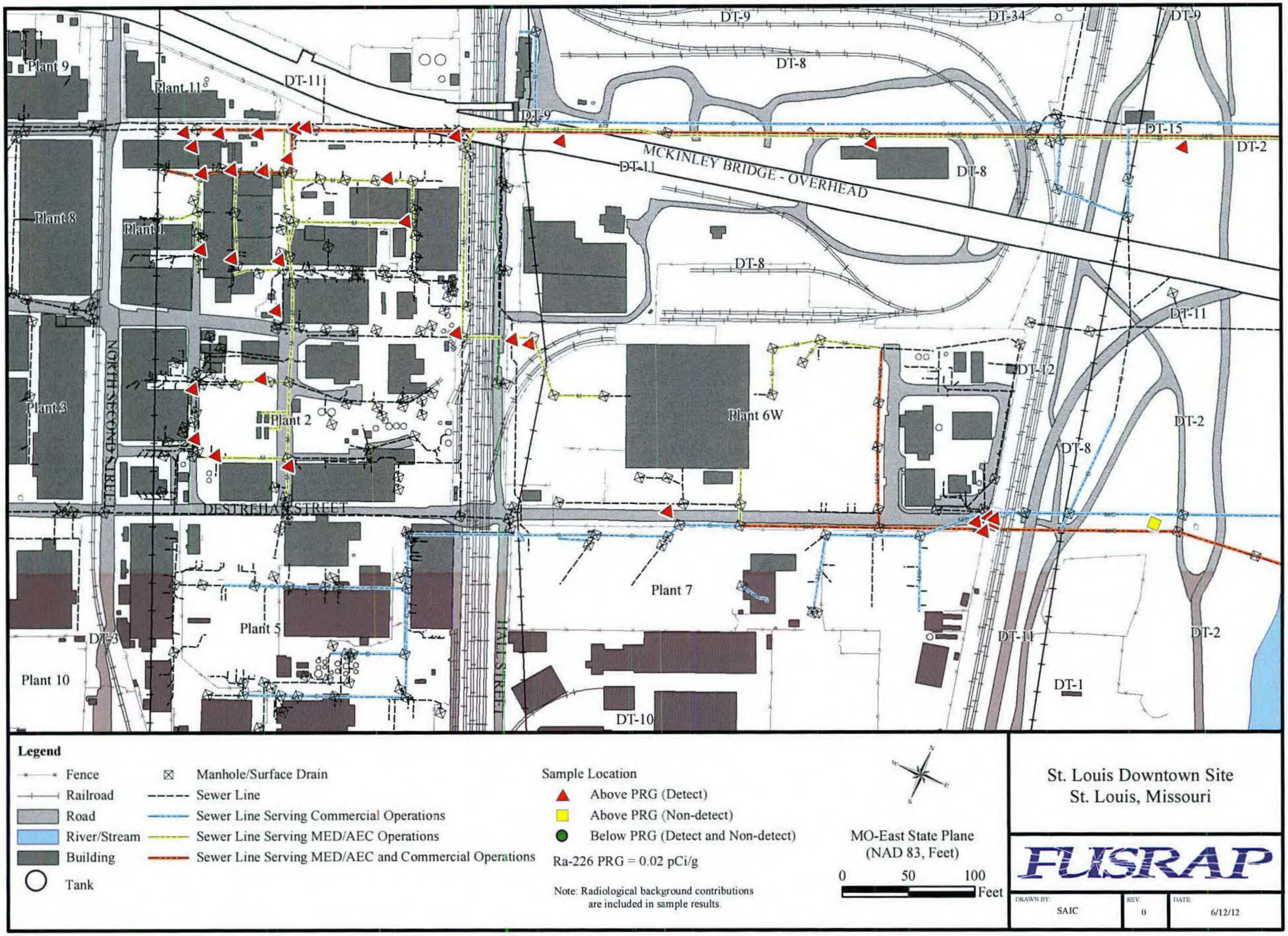
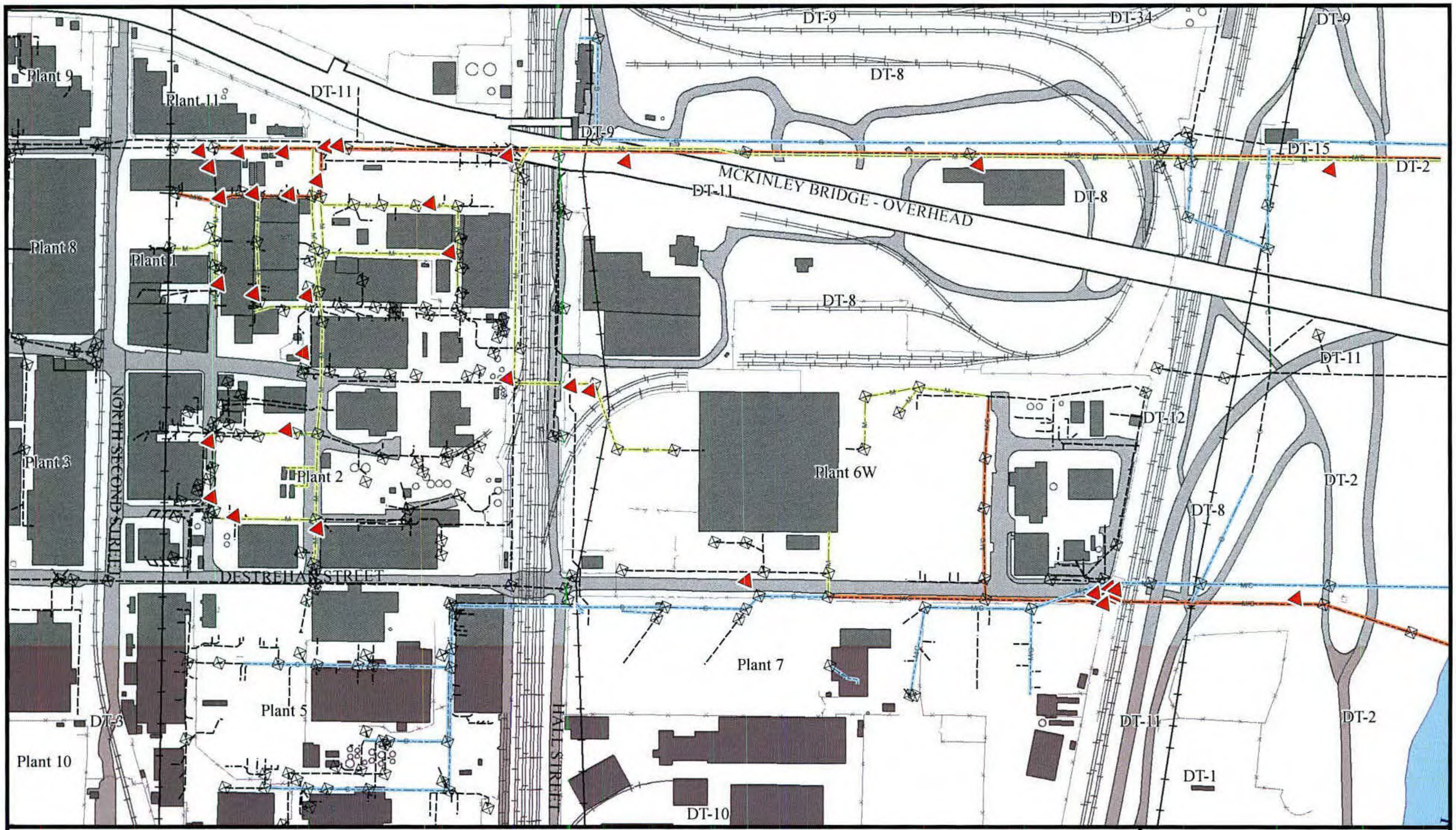


Figure H-24. Distribution of Ra-226 Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\G S\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-25 Extent of Ra-228 Exceeding the PRG Sewer Soil.mxd



Legend

⨯ Fence
┼ Railroad
▨ Road
🟦 River/Stream
■ Building
○ Tank
☒ Manhole/Surface Drain
- - - - Sewer Line
Sewer Line Serving Commercial Operations
Sewer Line Serving MED/AEC Operations
Sewer Line Serving MED/AEC and Commercial Operations

Sample Location
🔺 Above PRG (Detect)
🟨 Above PRG (Non-detect)
● Below PRG (Detect and Non-detect)

Ra-228 PRG = 0.05 pCi/g

Note: Radiological background contributions are included in sample results.

MO-East State Plane
(NAD 83, Feet)

0 50 100 Feet

St. Louis Downtown Site
St. Louis, Missouri

FUSRAP

DRAWN BY:	REV:	DATE:
SAIC	0	6/12/12

Figure H-25. Distribution of Ra-228 Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-26 Extent of Th-228 Exceeding the PRG Sewer Soil.mxd

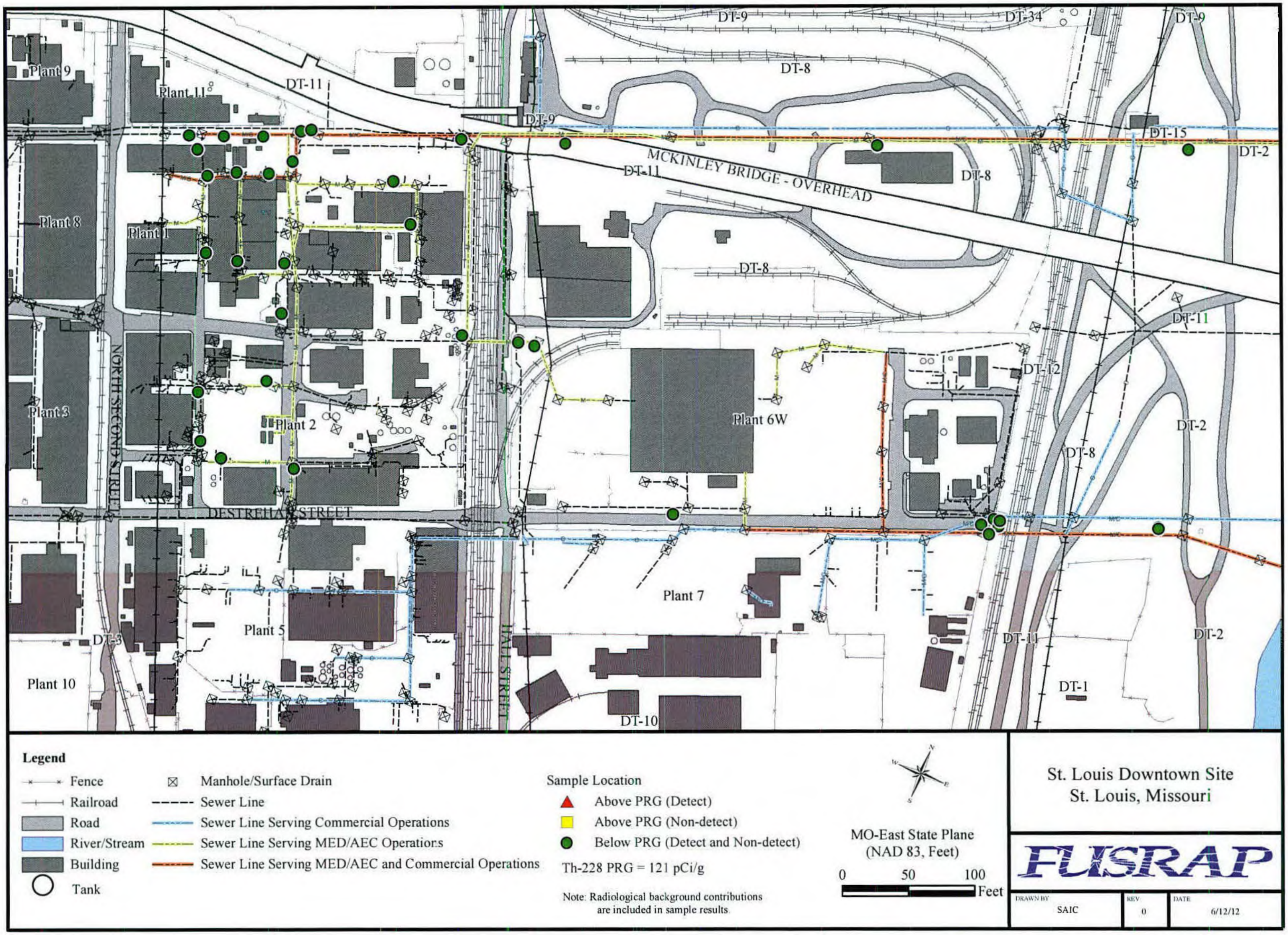


Figure H-26. Distribution of Th-228 Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-27 Extent of Th-230 Exceeding the PRG Sewer Soil.mxd

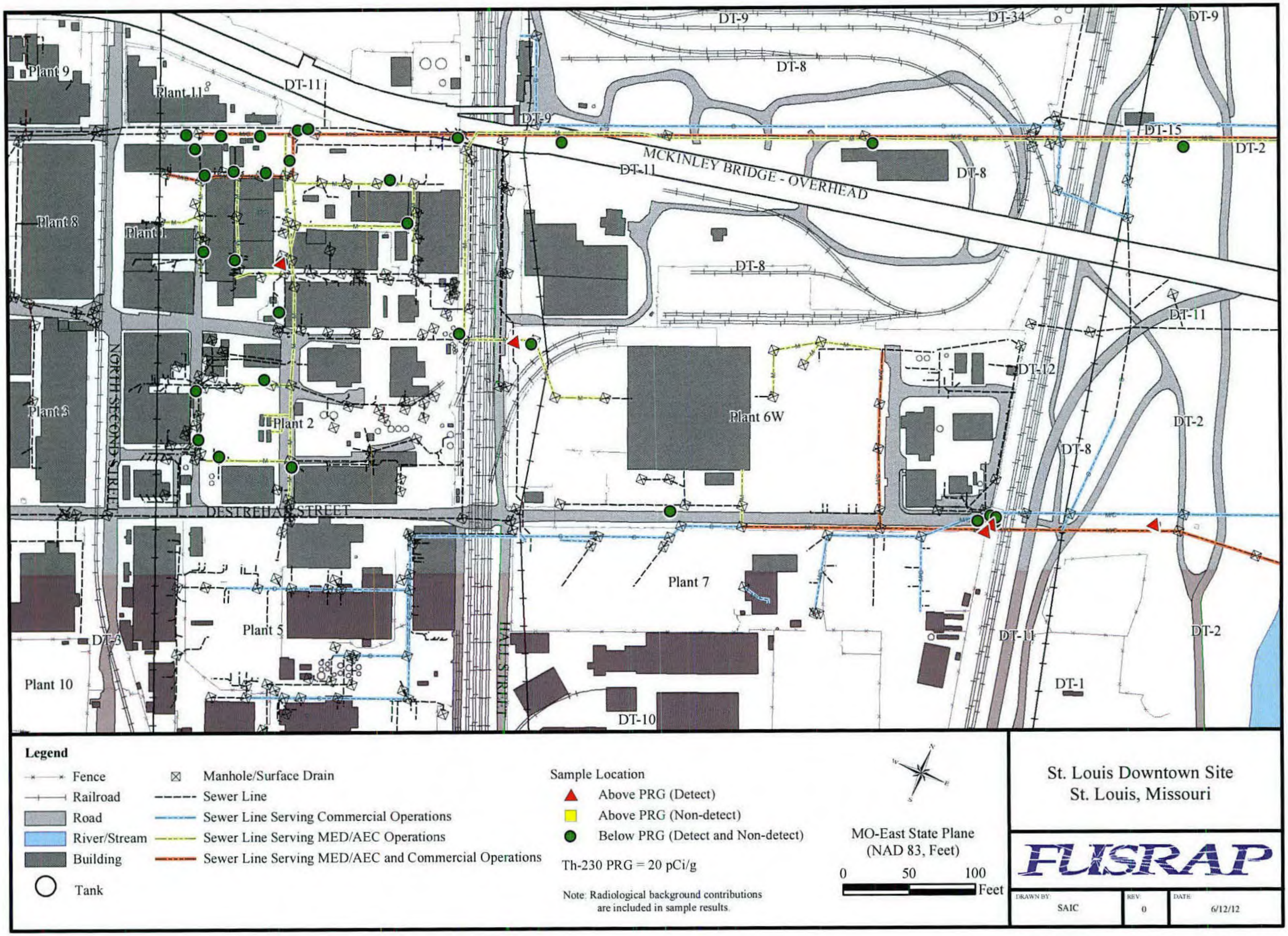


Figure H-27. Distribution of Th-230 Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-28 Extent of Th-232 Exceeding the PRG Sewer Soil.mxd

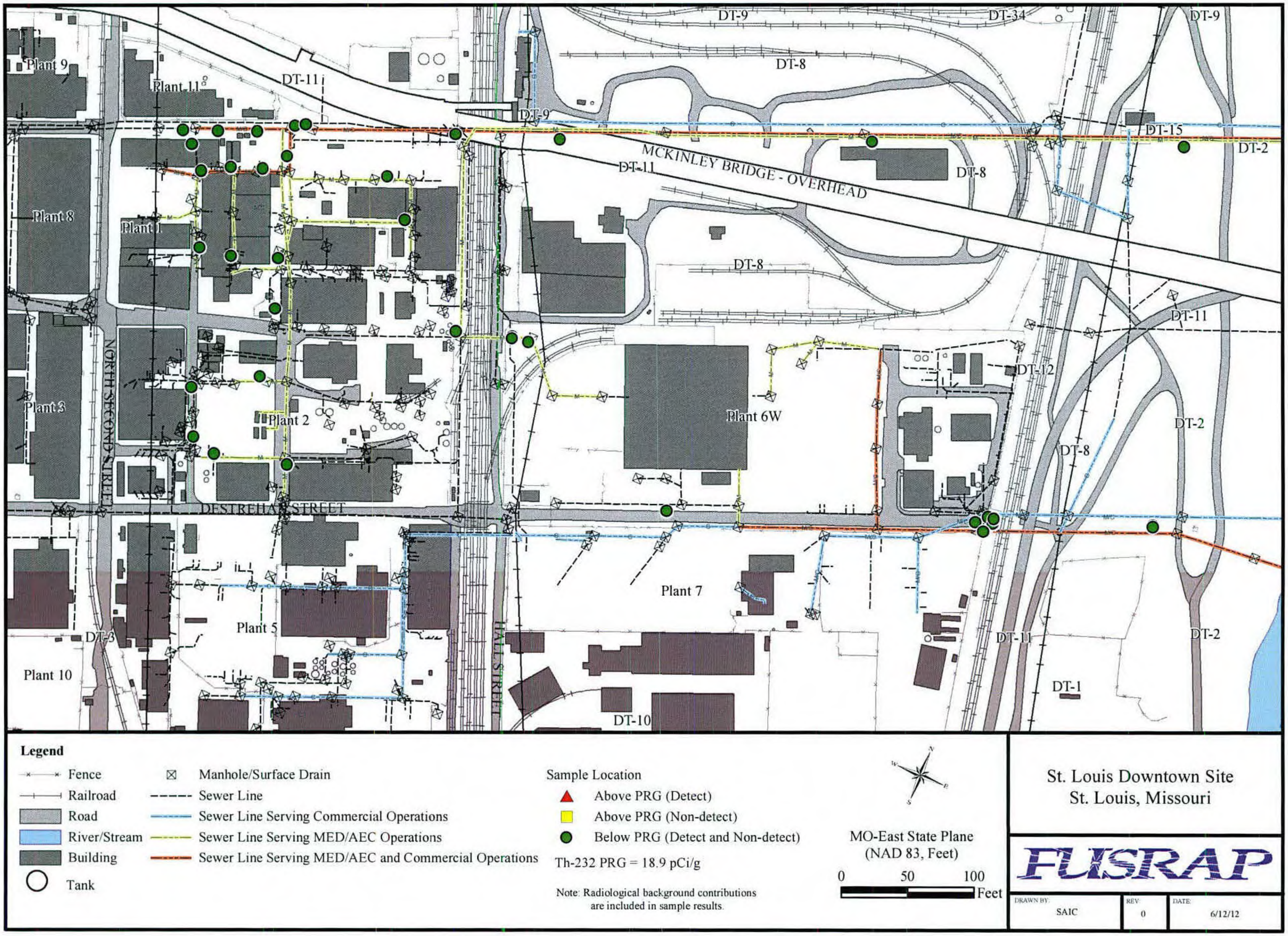


Figure H-28. Distribution of Th-232 Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-29 Extent of U-235 Exceeding the PRG Sewer Soil.mxd

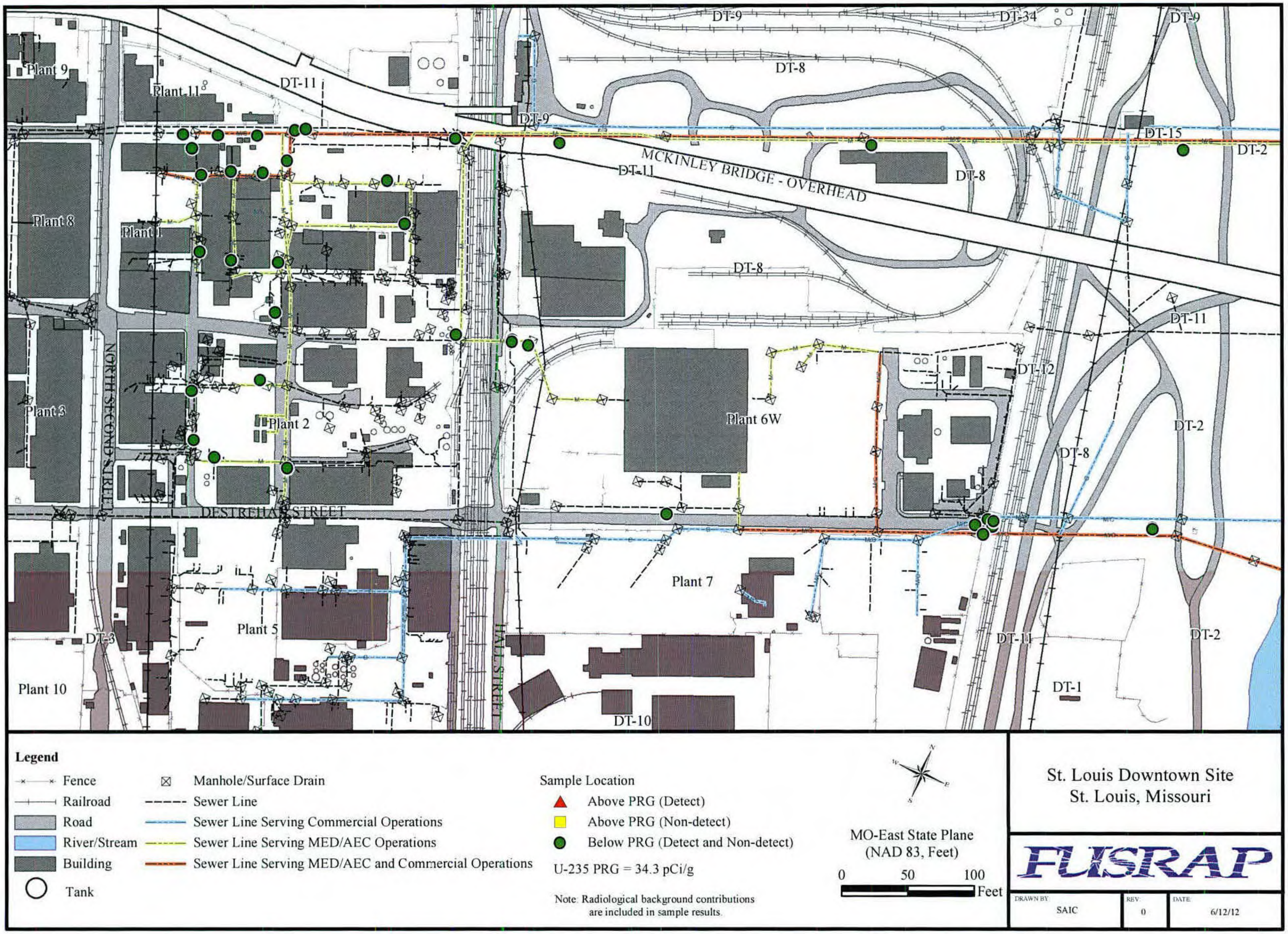


Figure H-29. Distribution of U-235 Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\GIS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-30 Extent of U-238 Exceeding the PRG Sewer Soil.mxd

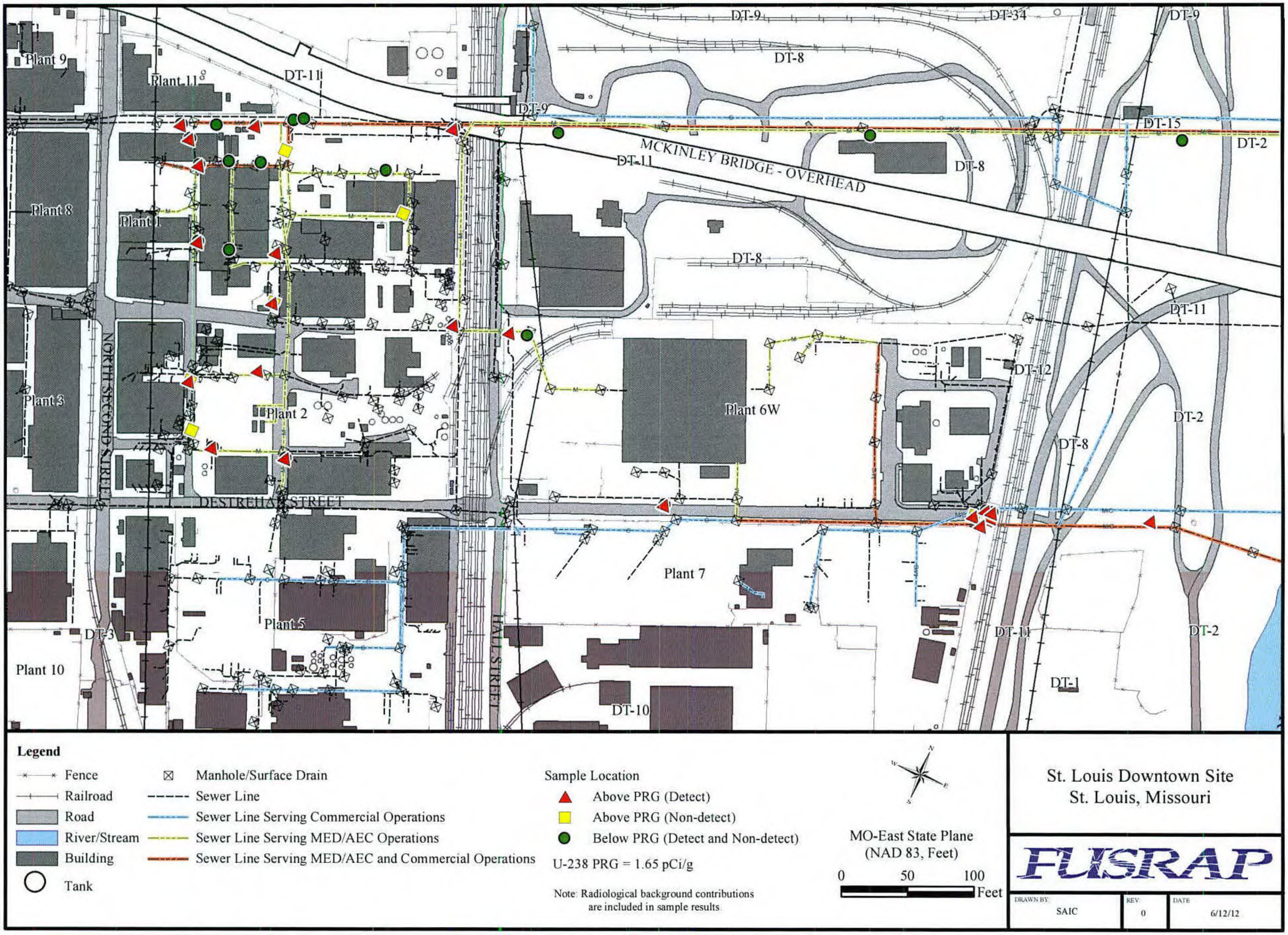


Figure H-30. Distribution of U-238 Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-31 Extent of Arsenic Exceeding the PRG Sewer Soil.mxd

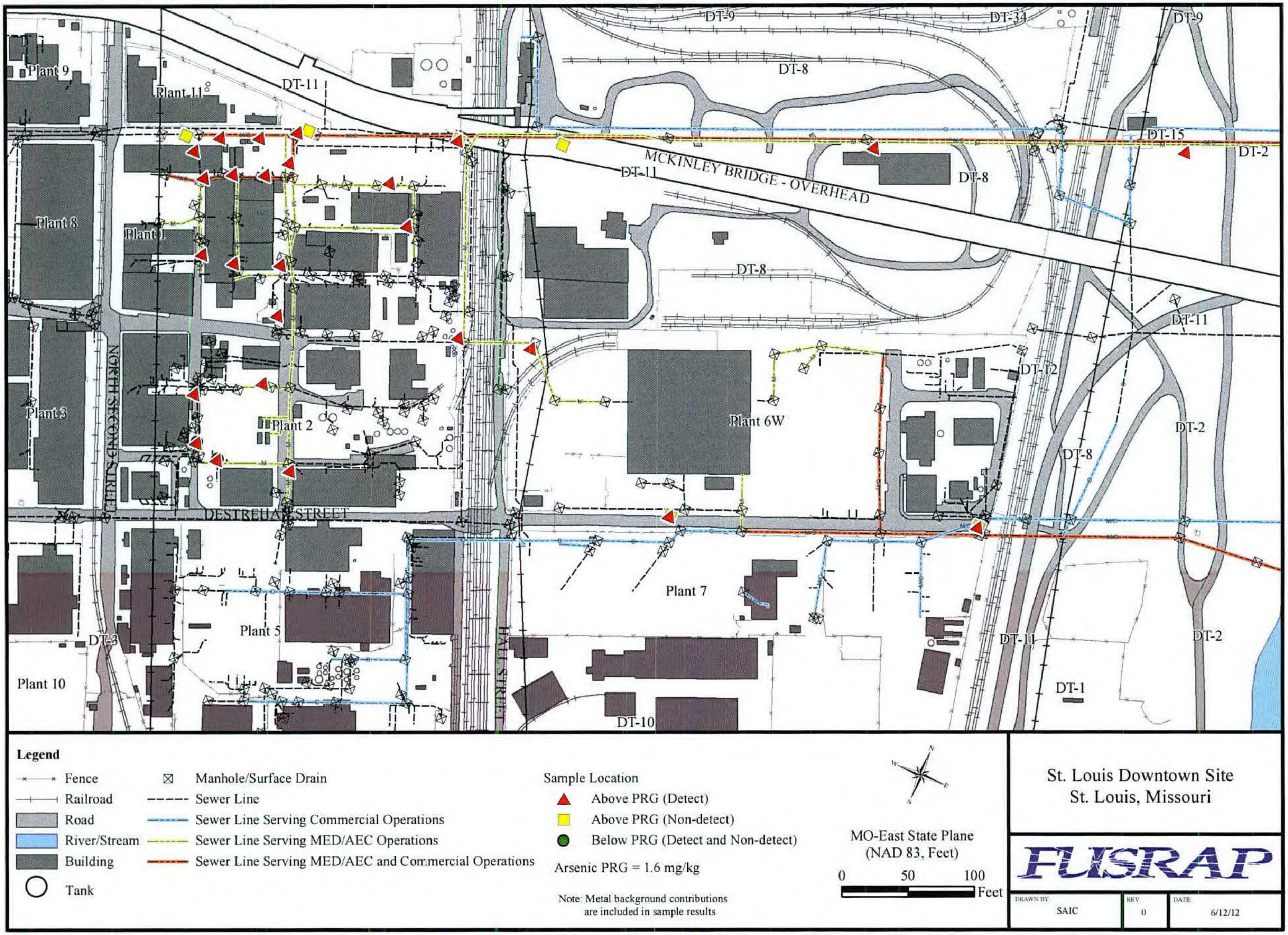


Figure H-31. Distribution of Arsenic Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-32 Extent of Cadmium Exceeding the PRG Sewer Soil.mxd

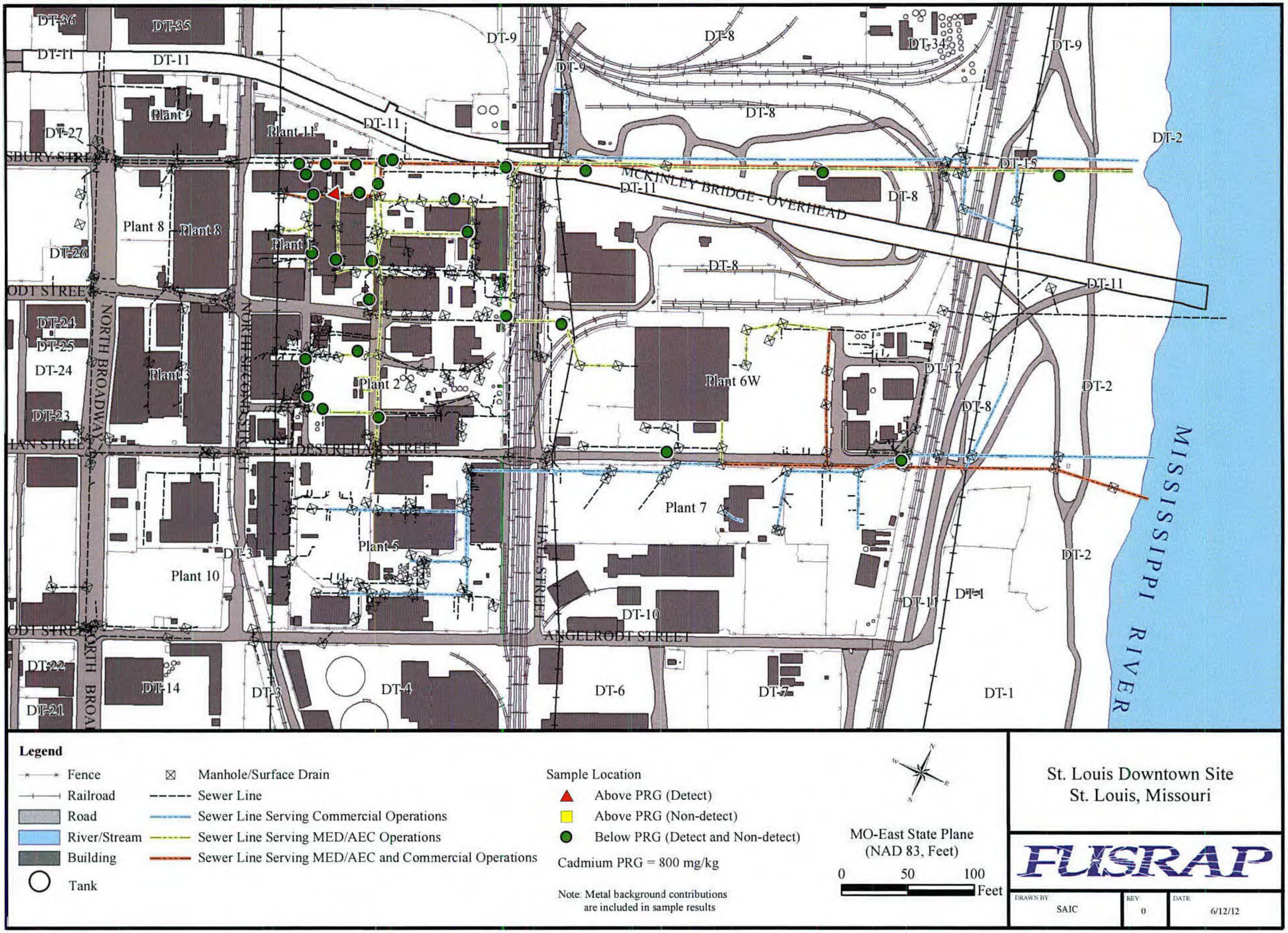


Figure H-32. Distribution of Cadmium Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\GIS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-33 Extent of Cobalt Exceeding the PRG Sewer Soil.mxd

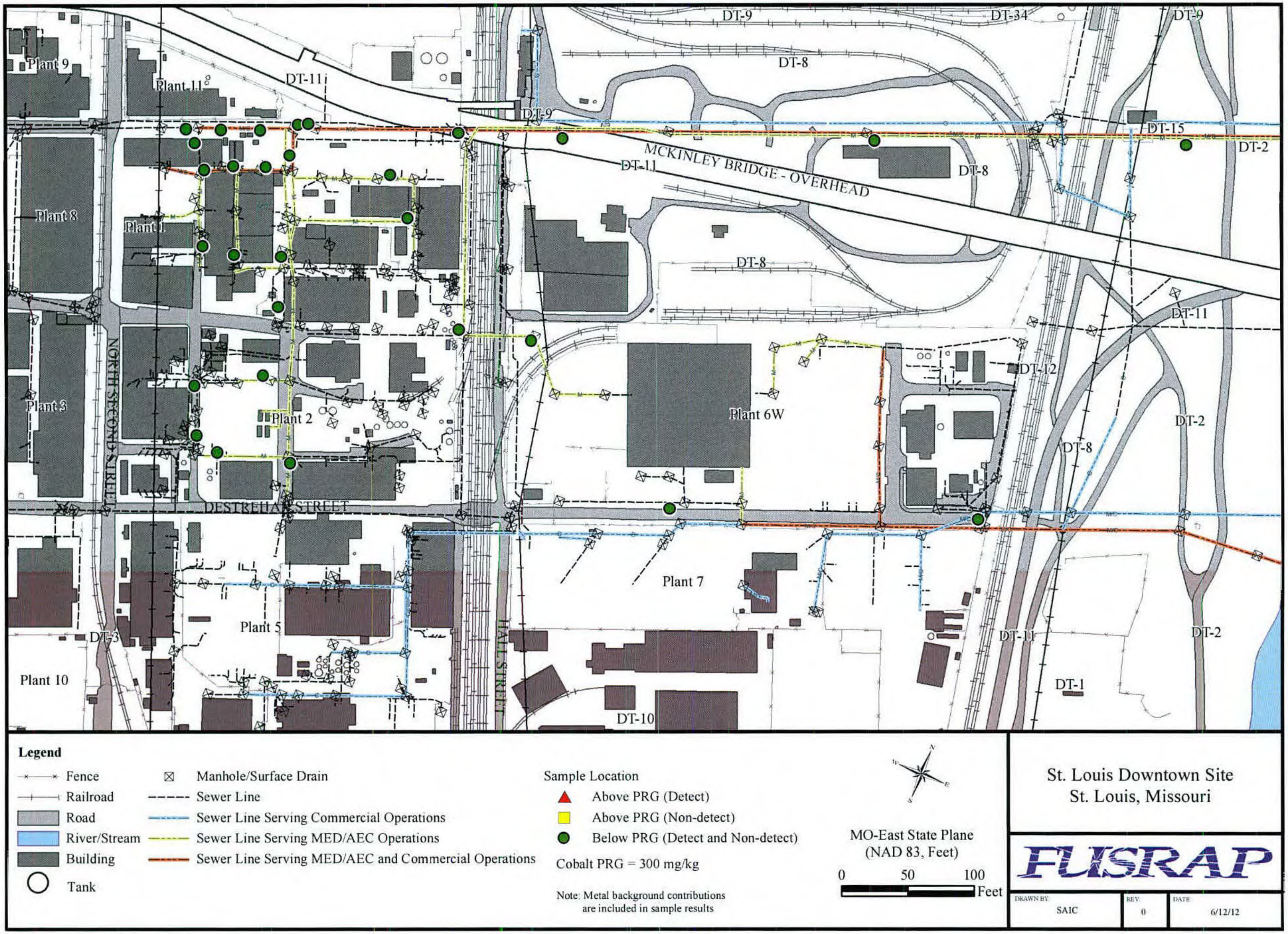


Figure H-33. Distribution of Cobalt Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\GIS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-34 Extent of Copper Exceeding the PRG Sewer Soil.mxd

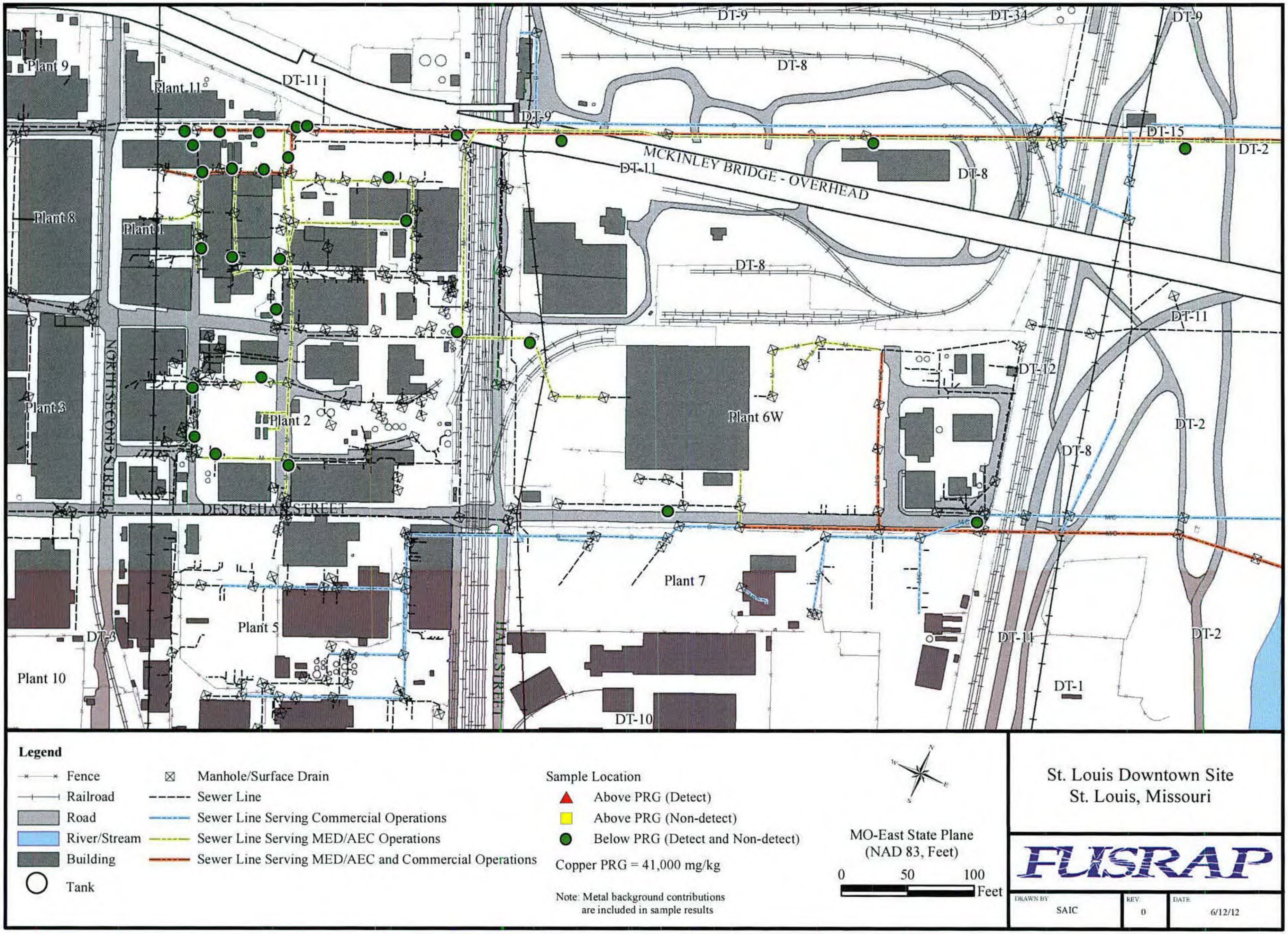


Figure H-34. Distribution of Copper Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-35 Extent of Lead Exceeding the PRG Sewer Soil.mxd

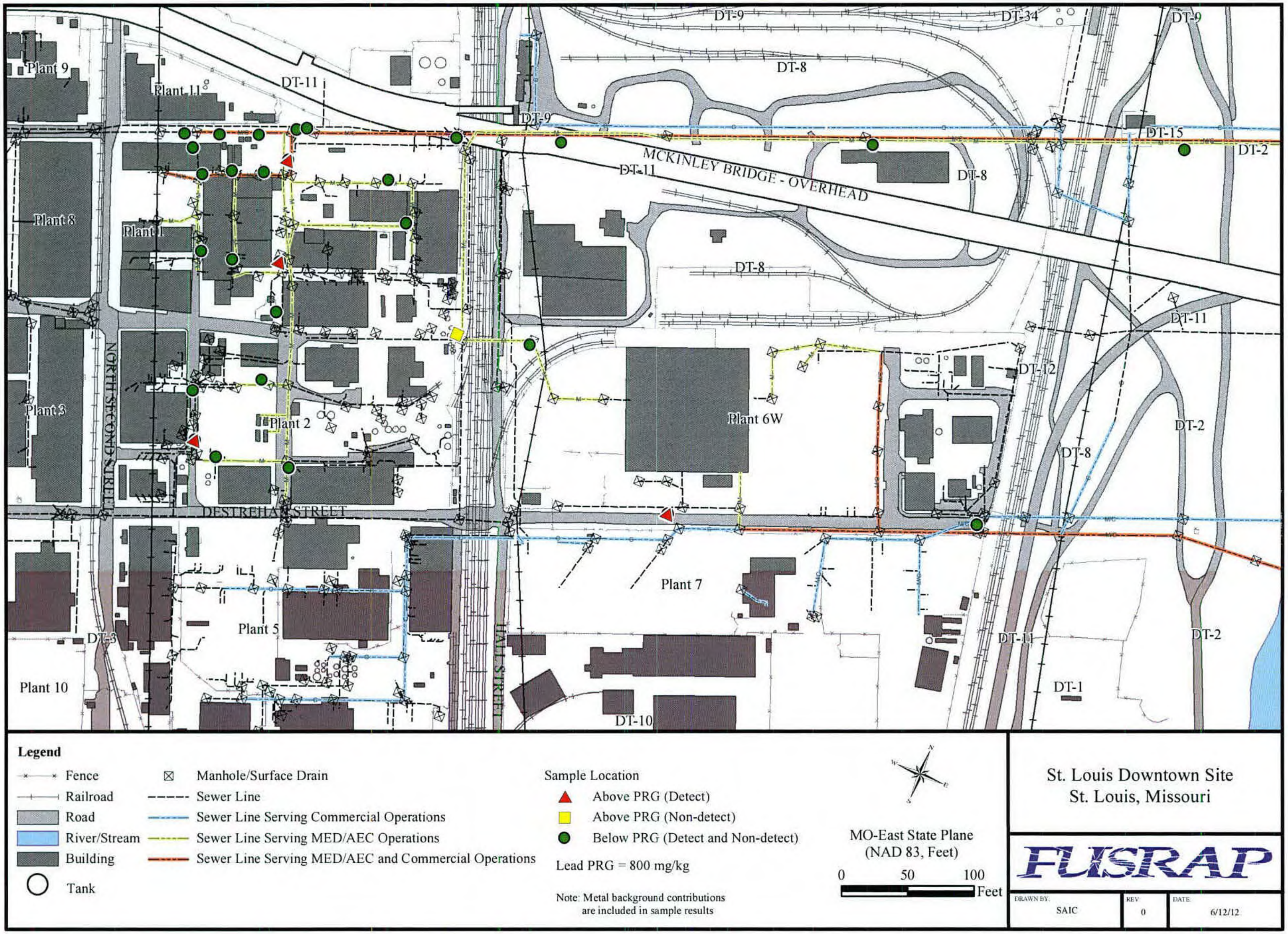


Figure H-35. Distribution of Lead Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\GIS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-36 Extent of Manganese Exceeding the PRG Sewer Soil.mxd

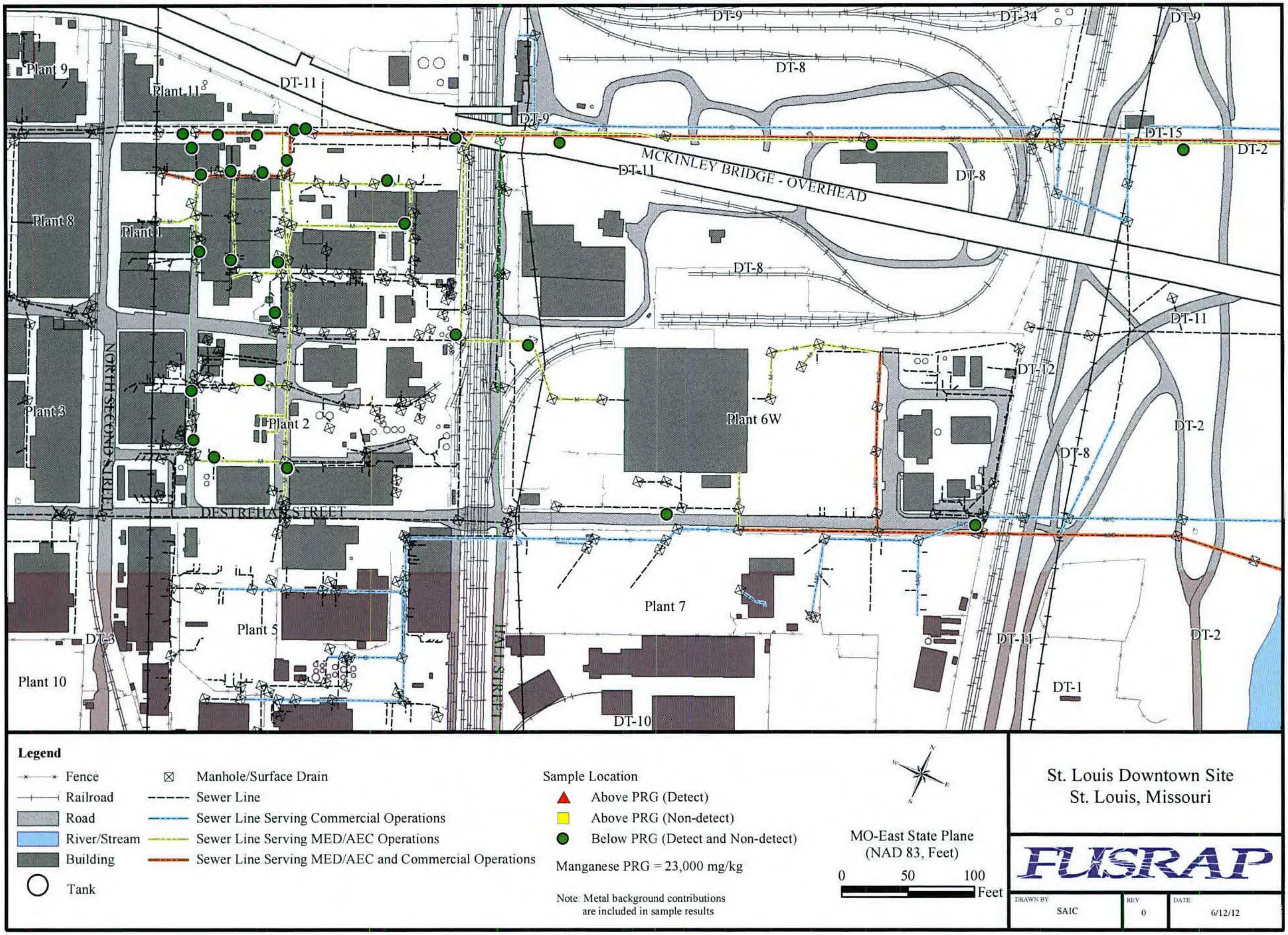


Figure H-36. Distribution of Manganese Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-37 Extent of Molybdenum Exceeding the PRG Sewer Soil.mxd

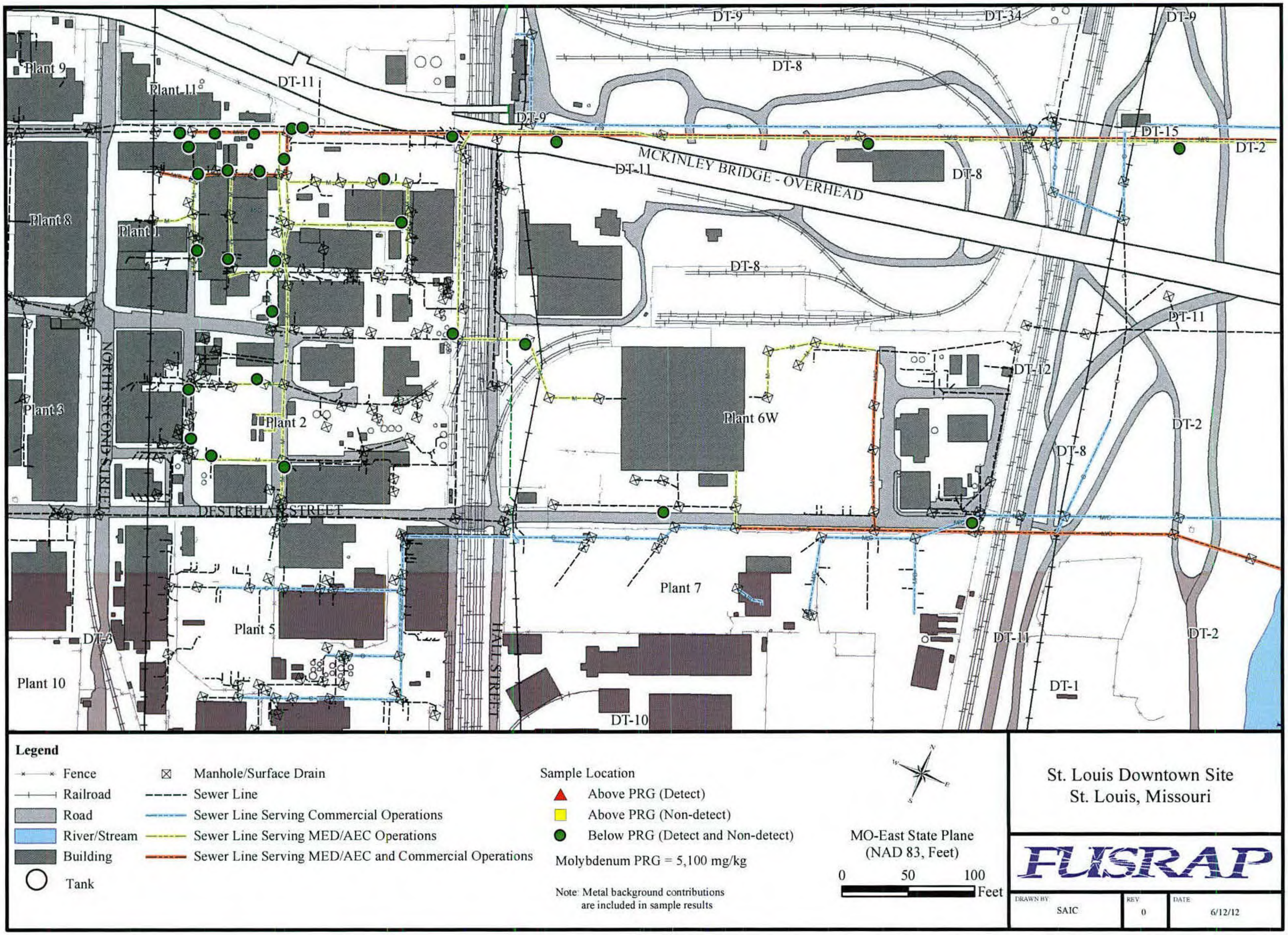


Figure H-37. Distribution of Molybdenum Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-38 Extent of Nickel Exceeding the PRG Sewer Soil.mxd

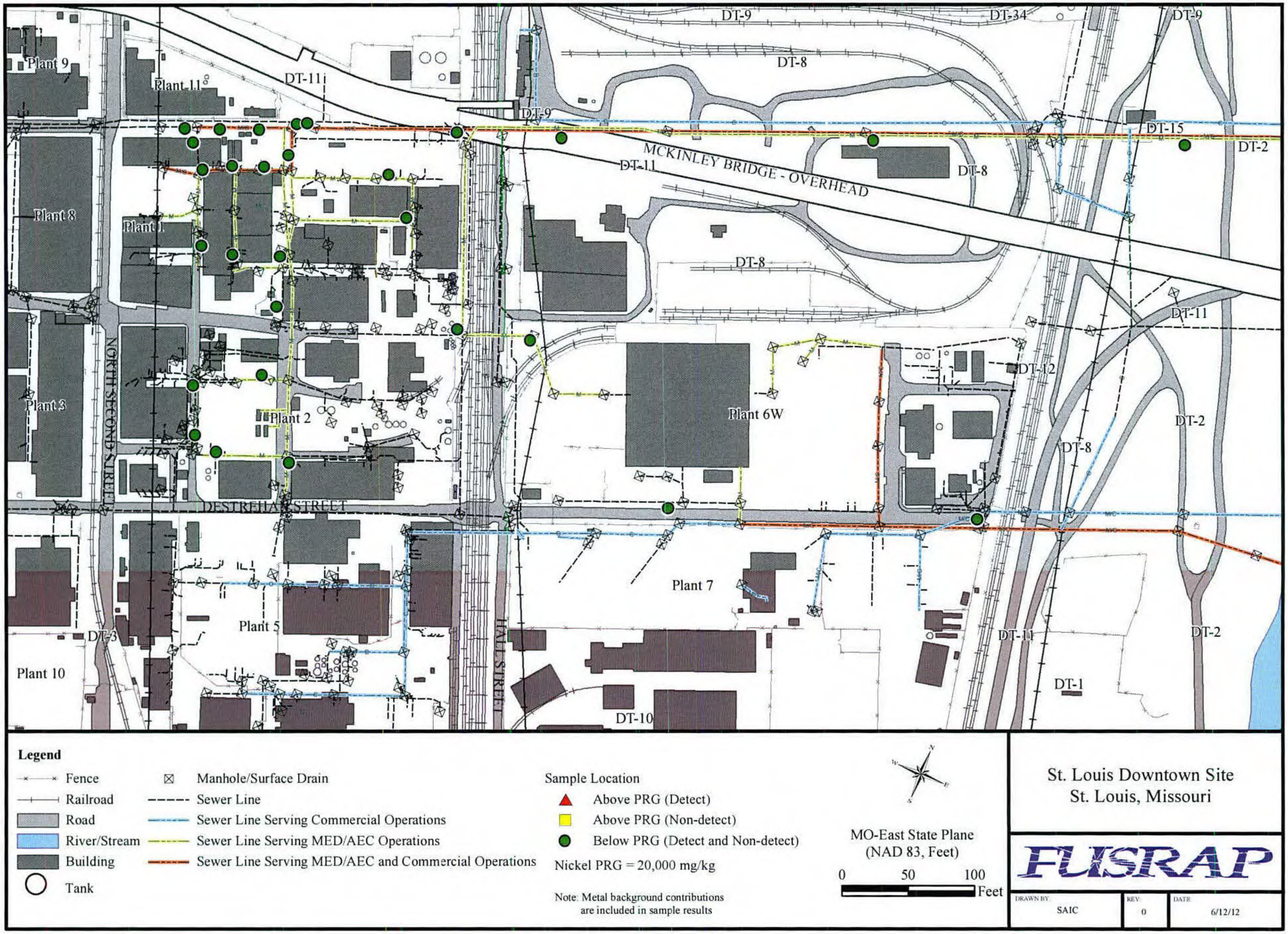


Figure H-38. Distribution of Nickel Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-39 Extent of Selenium Exceeding the PRG Sewer Soil.mxd

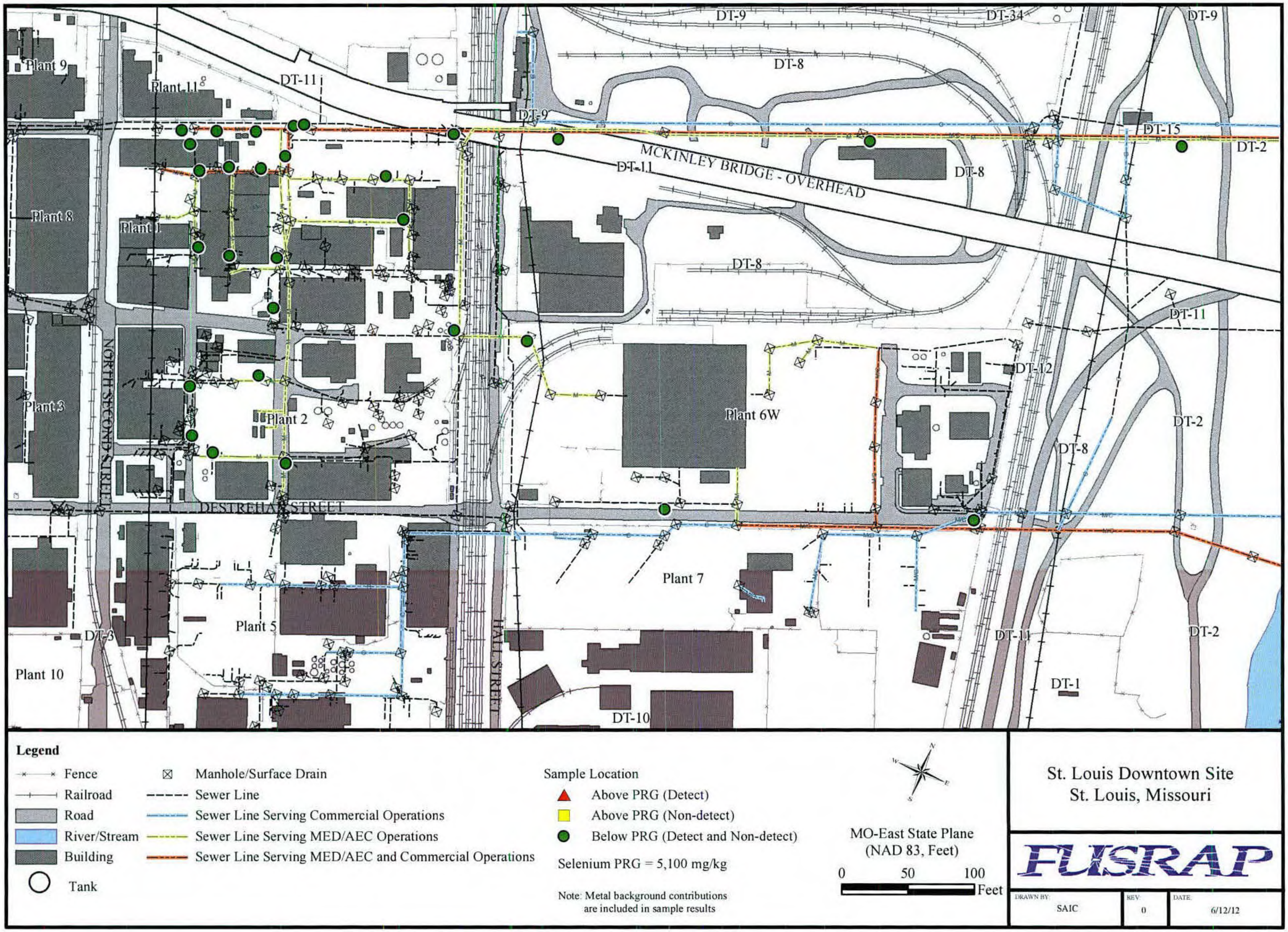


Figure H-39. Distribution of Selenium Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-40 Extent of Uranium Exceeding the PRG Sewer Soil.mxd

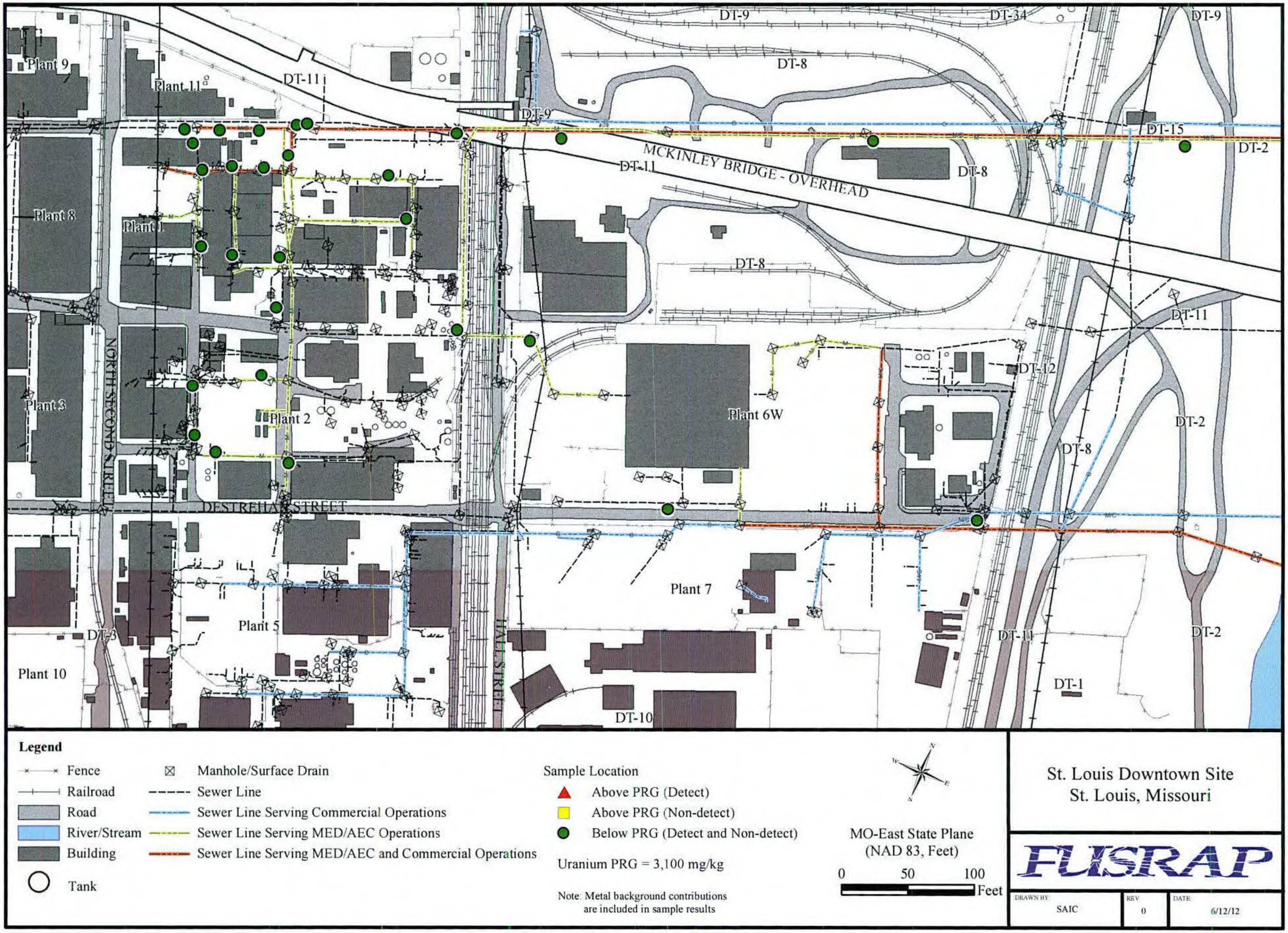


Figure H-40. Distribution of Uranium Metal Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-41 Extent of Vanadium Exceeding the PRG Sewer Soil.mxd

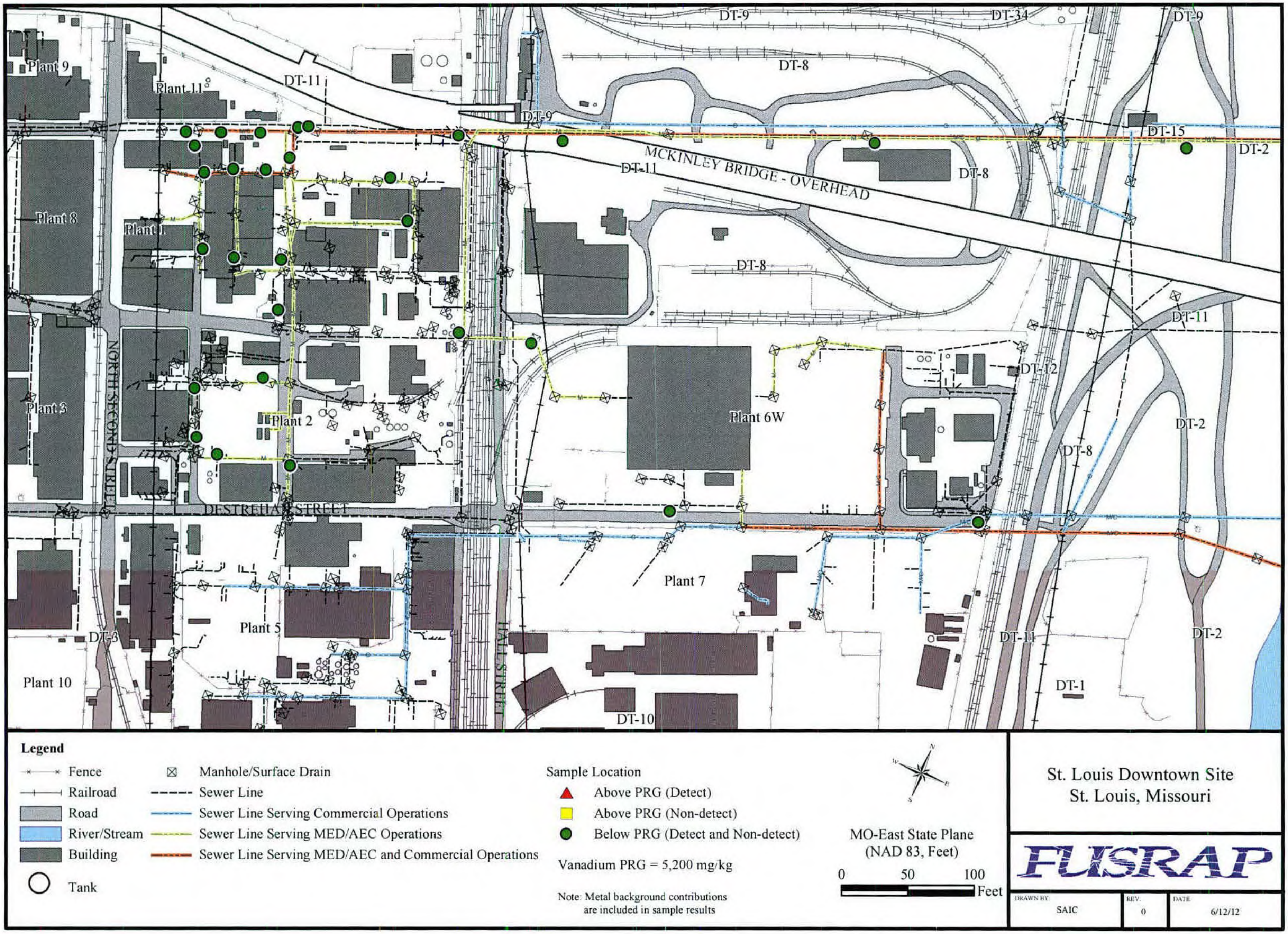


Figure H-41. Distribution of Vanadium Exceeding the PRG in Soil Adjacent to Sewers

Path: U:\GIS\SLDS\Inaccessible Areas\Projects\Risk Ranges\Appendix H\Figure H-42 Extent of Zinc Exceeding the PRG Sewer Soil

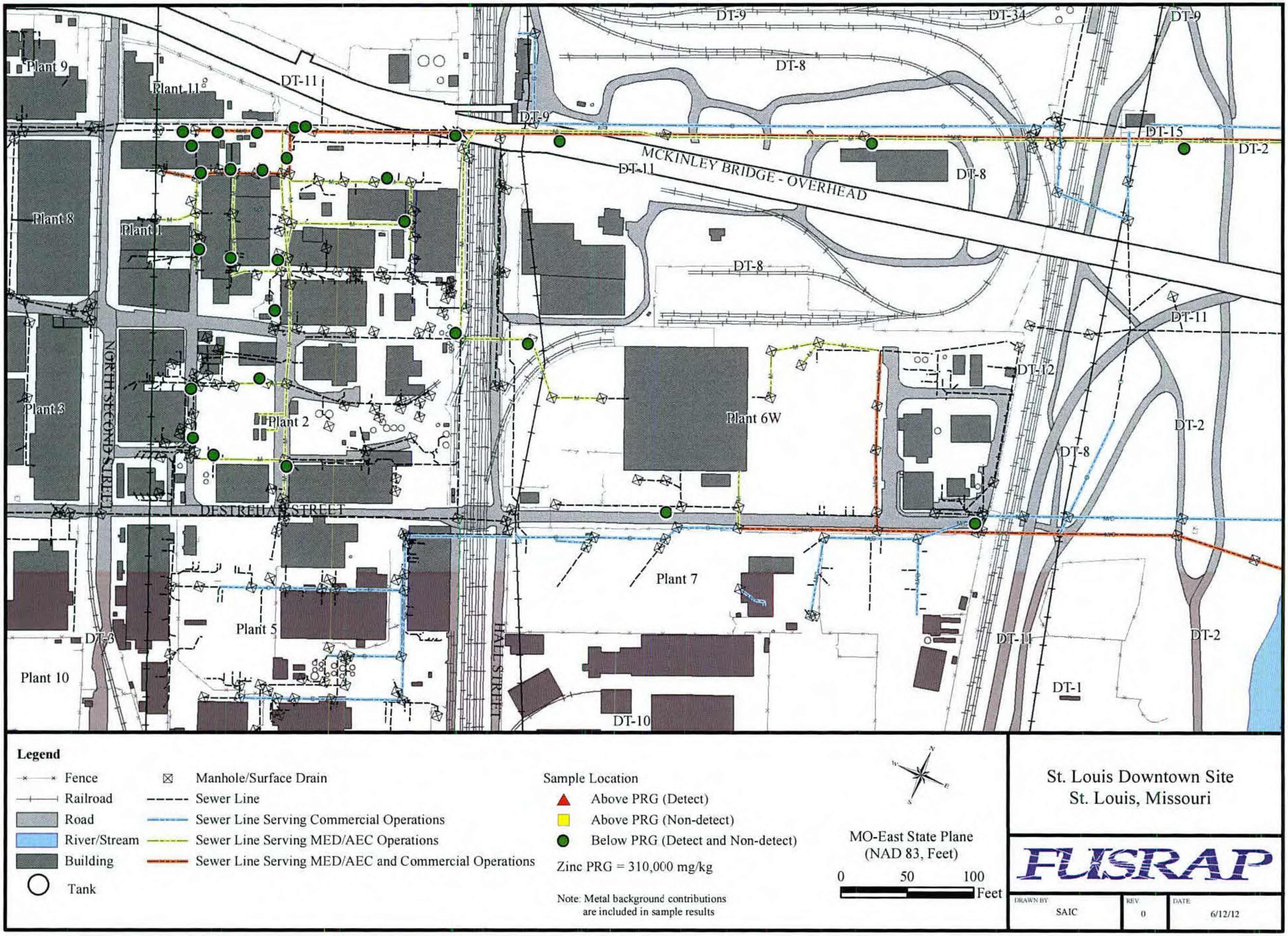


Figure H-42. Distribution of Zinc Exceeding the PRG in Soil Adjacent to Sewers

APPENDIX I

Background Sewer Sediment Evaluation

(On the DVD on the Back Cover of this Report)

APPENDIX J

Radiological and Metals Analytical Data Summaries and Figures for Sewers and Inaccessible Soil Associated with Sewers by Plant or Property Area

(On the DVD on the Back Cover of this Report)

APPENDIX K

Baseline Risk Assessment

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF ATTACHMENTS

Attachment K-1*	Evaluations of Hypothetical Resident Gardener Exposures at the St. Louis Downtown Site Inaccessible Soil Operable Unit
Attachment K-2*	Data Comparisons with Residential Preliminary Remediation Goals

BACK COVER

*DVD	Attachments K-1 and K-2

K1.0 BASELINE RISK ASSESSMENT

The SLDS is one of two separate geographical areas collectively referred to as the SLS. These two areas are comprised of multiple properties and are located in two distinct areas: downtown St. Louis City and NC (Figure 1-1). These two areas are designated as the SLDS and the NC sites, respectively. The SLDS is located in an industrial area in the eastern portion of the City of St. Louis, just west of the Mississippi River. The SLDS is comprised of approximately 210 acres of land, which includes the former Mallinckrodt property and 38 surrounding VPs. The former Mallinckrodt property and the surrounding VPs have the potential for radiological and chemical contamination as a result of the historical MED/AEC operations and/or subsequent transportation, storage, or migration of MED/AEC-related residues.

Descriptions of all of the VPs are provided in Table 1-1. The SLDS is divided into two OUs. One OU addresses accessible soil and ground water, which are covered by the 1998 ROD. The other OU addresses the inaccessible soil (i.e., the ISOU), which includes all media at the SLDS not covered by the 1998 ROD that may have become contaminated as a result of the deposition or migration of MED/AEC-related contaminated media. Specifically, the ISOU media of concern include inaccessible soil, soil on building/structural surfaces, sewer sediment, and soil adjacent to sewers. ISOU media do not include surface water or sediment in the Mississippi River. A conceptual view of the inaccessible areas is shown on Figure 1-2.

This ISOU BRA was conducted primarily to estimate and characterize baseline doses and risks to the most likely human receptors identified at the SLDS as a result of potential current and future exposures to radiological and metal COPCs identified in ISOU media (Section 4.0). As previously discussed in Section 1.1.1, radiological and metal COPCs that were determined to be present in ISOU media above corresponding human health risk-based PRGs, as a result of former MED/AEC operations, are being evaluated and considered for further actions. Only metal COPCs located within the boundary of the former uranium-ore processing area, as identified in Figure 1-2, or those that are associated with the sewers, are considered for further actions. Additionally, this BRA includes a SLERA, which follows guidance provided in the USEPA's *Ecological Risk Assessment Guidance for Superfund* [ERAGS]: *Process for Designing and Conducting Ecological Risk Assessments* (USEPA 1997b) and USACE's *Environmental Quality – Risk Assessment Handbook, Volume II: Environmental Evaluation* (USACE 2010b). Thus, the BRA consists of two main components: the HHRA (Section K2.0) and the SLERA (Section K3.0). Scction K4.0 provides a high-level summary of both the HHRA and SLERA.

Supporting analytical data, information, and calculations to this BRA are provided in the following appendices:

- Appendix E – Radiological and Metals Analytical Data Summaries and Figures for Inaccessible Soil by Property;
- Appendix F – Data: Radiological Building Survey Results by Property and Building;
- Appendix J – Radiological and Metals Analytical Data Summaries and Figures for Sewers and Inaccessible Soil Associated with Sewers by Plant or Property Area;
- Appendix L – Radiological and Metals Analytical Data Summaries and Figures for Accessible Soil by Property;
- Appendix M – Exposure Point Concentration Calculations for Radiological COPCs;
- Appendix N – Exposure Point Concentration Calculations for Metal COPCs;

- Appendix O – RESRAD Model Outputs: Radiological Dose and Risk Calculations for Inaccessible Soil and Sewer Soil Borehole Locations;
- Appendix P – RESRAD-BUILD Model Outputs: Radiological Dose and Risk Calculations for Exterior Building Surfaces;
- Appendix Q – Dose and Risk Calculations for Exposures to Metal COPCs in Inaccessible Soil, Sewer Sediment, and Soil Adjacent to Sewer Lines;
- Appendix R – Ecological Checklist for the SLDS ISOU; and
- Appendix S – Derivation of Gross Activity Derived Concentration Guideline Levels for the St. Louis Downtown Site.

K2.0 HUMAN HEALTH RISK ASSESSMENT

The scope of the HHRA includes an evaluation of dose and risk of all media not covered by the 1998 ROD (USACE 1998a), as previously described in detail in Section 1.1.2, that may have become contaminated as a result of the deposition or migration of MED/AEC-related contaminated media, and that exceed the health-based PRGs presented in Section 4.0. These media include inaccessible soil, soil on interior and exterior building surfaces, sewer sediment, and soil adjacent to sewer lines. Additionally, dose and risk were also characterized for radiological and metal COPCs in SLDS background soil and sewer sediment in an effort to assess background contributions to ISOU dose and risk. No background data are available for building surfaces. In order to evaluate ISOU media, this HHRA was prepared using analytical data acquired primarily during the ISOU RI, as well as other select data from USACE investigations at the SLDS. Potential risk and dose to individuals from assumed exposures to radiological and metal COPCs are assessed under sitewide and property-specific scenarios. 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. The evaluated receptor scenarios for ISOU media include the following:

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

In addition to the previously listed receptors evaluated under current and future industrial land use scenarios, a hypothetical, future, resident gardener scenario was evaluated separately for the ISOU. Because current land use is predominantly industrial/commercial, and land use is expected to remain as such for the foreseeable future, it is recommended that scenarios assuming industrial land use be used as the basis for determining future actions at the ISOU. The hypothetical resident gardener was evaluated as an unlimited use and unrestricted exposure scenario for only informational purposes to facilitate future decision making as needed. It is for these reasons that the evaluation methodologies and results of the residential HHRA are presented separately, in Attachment K-1 to this appendix.

The HHRA facilitates the identification of those SLDS properties that should be retained for further evaluation in the FS. COPCs that result in target dose or risk criteria being exceeded are also being further evaluated in the FS.

Although the focus of the HHRA is the ISOU media, sitewide and property-specific evaluations are also performed that consider risk and dose status inclusive of both inaccessible and accessible soil areas. These evaluations 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 process for evaluating soil in this HHRA is described in later sections of the HHRA, and is also presented schematically, for sitewide and property-specific scenarios in Figures K-1 and K-2, respectively. The following paragraphs briefly describe the results of the HHRA for ISOU media. All properties/locations and media exceeding target dose and risk criteria are being retained for further evaluations in the FS.

Summary of HHRA Results

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 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.

K2.1 INTRODUCTION

The SLDS is comprised of numerous former Mallinckrodt plant areas and VPs. Each property quantitatively evaluated in this HHRA, along with specific buildings and locations within each property, is considered an exposure area. The ISOU media being evaluated on a sitewide basis (all media except for building surfaces), as well as on a property-specific or sampling location-specific basis, consist of the following, for which receptor scenarios have been developed:

- Soil that is inaccessible due to the presence of buildings and other permanent structures, including the subsoil within the footprint of a structure of which remediation would reasonably be expected to affect the stability of the structure;
- Soil located under active RRs, including the supporting soil in the associated ROW;
- Soil located under roadways, including the supporting soil in the associated ROW;
- Soil on the exteriors and interiors of buildings and permanent structures (e.g., tanks, bridges, sheds, loading docks, utility poles, traffic signals, piping, rail tracks, and equipment boxes);
- Sewers (e.g., structures and interior sediment) not directly encountered within an excavation area during the remedial action conducted under the 1998 ROD; and

- Soil adjacent to sewers located beneath buildings, permanent structures, RRs, and/or roadways.

This HHRA presents human health dose and risk information specific to each receptor scenario, along with an overall analysis of uncertainty, as an aid in the decision-making process. Characterizing baseline human health dose and risks, both sitewide and at each property, provides stakeholders with information that will be helpful to make decisions to protect human health and the environment, if necessary. The expected end-use of these dose and risk estimates is the recommendation of ISOU media, properties, buildings, and/or locations for further evaluation in the FS.

Both current and expected future land uses at the SLDS have been considered in developing exposure scenarios for each property or building associated with past MED/AEC operations, as well as for those that have been potentially impacted by those operations. Given the current land use and the long history of the SLDS as a heavily industrial and urban setting for more than 100 years, it is expected that the land use will remain as such for the foreseeable future; therefore, evaluations in this HHRA focus on current and future exposure scenarios consistent with this land use. The distinction between current and future exposures is applied mainly to evaluations of inaccessible soil exposures, as opposed to the other ISOU media, which consider no real distinction between current and future exposures. Inaccessible soils are being evaluated under sitewide and property-specific evaluations. Additionally, for the industrial worker (i.e., the limiting receptor) and recreational users of the St. Louis Riverfront Trail, combined inaccessible and accessible soil evaluations are conducted on both a sitewide and property-specific basis to determine overall risk and dose status of the SLDS and each property.

Under current land configurations, various types of ground cover are present across the SLDS ISOU study area in the forms of buildings/structures, RRs, roadways, the levee, and pavement, which affect the significance and completeness of the direct contact exposure pathways (i.e., exposures via ingestion, dermal contact, and dust inhalation). These covers are comprised of consolidated and unconsolidated materials. Examples of consolidated materials include asphalt and concrete. Unconsolidated materials include soil and gravel. Of all of these materials, soil as a form of ground cover is the least dense and, therefore, provides the least protection for individuals from external radiological exposures. Therefore, for the purpose of presenting health-conservative evaluations in the HHRA, radiological exposure evaluations of all inaccessible soil areas under the current scenario conservatively assume a 0.3048-m-thick soil cover. However, for the properties in which the levee exists (DT-2, DT-9 Levee, and DT-15), a minimal thickness of 1 m is assumed. All evaluations of the levee for the non-soil-intrusive scenarios (industrial worker and recreational user) assume that the levee is always present in both the current and future timeframes. In the FS, the health protectiveness of the actual existing cover material present in each area will be evaluated to support development of remediation goals and remedial alternatives. For evaluations of future scenarios, the degradation or complete loss of ground cover in the inaccessible soil areas is assumed to estimate reasonable worst case exposures. Under both current and future scenarios, sitewide and property-specific evaluations of combined inaccessible and accessible soil exposures to the industrial worker and recreational user assume no ground cover present in the accessible soil areas.

Radiological doses and CRs are estimated using the DOE's RESRAD and RESRAD-BUILD computer codes for soil/sediment and structural surfaces, respectively. Human health risks are characterized herein for metal COPCs as estimates of excess lifetime CRs for carcinogenic effects and non-carcinogenic HIs for systemic effects. CRs and non-carcinogenic hazards are estimated for metal exposures using mathematical algorithms presented in various USEPA risk assessment guidance documents. The ALM was used to estimate the risk of elevated fetal blood lead levels in a pregnant female worker following assumed exposures to lead in soil adjacent to sewer lines (USEPA 2003b). This HHRA has been conducted based on the methodology presented in Appendix A of the RI WP (USACE 2009a) and has applied methods from the following USEPA guidance documents:

- *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual: Part A* (USEPA 1989a);
- *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual: Part B, Development of Risk-Based Preliminary Remediation Goals* (USEPA 1991a);
- *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual: Part E, Supplemental Guidance for Dermal Risk Assessment* (USEPA 2004b);
- *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual: Part F, Supplemental Guidance for Inhalation Risk Assessment* (USEPA 2009b);
- *Exposure Factors Handbook: 2011 Edition* (USEPA 2011);
- *Child-Specific Exposure Factors Handbook* (USEPA 2008);
- *Guidance for Data Usability in Risk Assessment (Part A)* (USEPA 1992b);
- *Regional Screening Levels* Tables (USEPA 2012a);
- *Guidance for the Data Quality Objective Process* (USEPA 2000);
- *Soil Screening Guidance: User's Guide* (USEPA 1996a);
- *Radiation Exposure and Risk Assessment Manual* (USEPA 1996b);
- *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (USEPA 2002a);
- *Supplemental Guidance for Developing Soil Screening Levels at Superfund Sites* (USEPA 2002b); and
- *Recommendations of the Technical Review Workgroup for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil* (USEPA 2003b).

For all ISOU media, the HHRA itself is comprised of several significant steps (identification of COPCs, exposure assessment toxicity assessment, and dose and risk characterization). Thus, the main components of this HHRA are as follows:

- **Section K2.2 – Summary of Data Evaluation and Identification of COPCs:** Briefly summarizes the validity of data acquired during the RI for use in the risk assessment and the identification of COPCs, buildings, and properties, being evaluated in this HHRA, as previously presented in Section 4.0.
- **Section K2.3 – Exposure Assessment:** Presents potentially exposed populations and exposure routes/pathways for the industrial land use CSM, methodology for estimating EPCs, pathway intake equations for metal exposures, and input values for radiological and metal exposure parameters, including overviews of the RESRAD and RESRAD-BUILD computer models used for evaluating radiological exposures to soil/sediment and structures, respectively.
- **Section K2.4 – Toxicity Assessment:** Describes the approach used to evaluate carcinogenic effects from radiological and metal exposures in terms of CRs and non-

carcinogenic effects from metal exposures in terms of hazards, as well as quantitative indices of toxicity used for estimating both potential risks and hazards. The USEPA's ALM for evaluating exposures to lead in soil is also discussed.

- **Section K2.5 – Dose and Risk Characterization:** Describes the methodology used for the estimation of doses and CRs for radiological exposures and CRs and non-carcinogenic HIs for exposures to metals by integrating the results of the exposure and toxicity assessments. Radionuclides and metals contributing predominantly to doses, CRs, and HIs (i.e., as risk drivers), by exceeding target criteria, will be identified as COCs for consideration of future actions.
- **Section K2.6 – Uncertainties Analysis:** Discusses sources and implications of uncertainty in the risk assessment process, including ISOU-specific factors and model-specific factors contributing to the overall uncertainty of the HHRA results.

All figures and tables for Appendix K that are mentioned in the text are presented after the text.

K2.2 SUMMARY OF DATA EVALUATION AND IDENTIFICATION OF CONTAMINANTS OF POTENTIAL CONCERN

All ISOU RI data underwent data validation to determine its usability for risk assessment purposes. Data were qualified accordingly with regard to usability. All RI data were found to be usable and are incorporated into the risk assessment. A detailed evaluation of the data is presented in the QCSR (see Appendix B).

COPCs in ISOU media (inaccessible soil, soil on building surfaces, sewer sediment and soil adjacent to sewer lines) being retained for radiological and/or metals dose/risk evaluations were identified in Section 4.0 through data comparisons with risk-based PRGs.

Both radiological and metals PRGs used for comparisons with concentrations detected in ISOU media are presented in Table 4-1. Descriptions of the risk basis of the PRGs being used to evaluate radiological and metals data are provided in Sections 4.1.1 and 4.1.2, respectively. Identifications of COPCs for each ISOU medium were done on a sitewide basis such that if at least one sample result for a PCOC in a medium exceeded the corresponding PRG, then that PCOC was retained as a COPC for that medium, across all SLDS properties, for quantitative dose and risk evaluation in the BRA. The sections below summarize the sitewide COPCs retained for each ISOU medium.

K2.2.1 Inaccessible Soil Contaminants of Potential Concern

Attachment E-2 of Appendix E presents exceedances of radiological and metal PRGs by individual sample concentrations measured in inaccessible soil. Attachment E-2 of Appendix E also presents summary statistics for each inaccessible soil dataset. The total numbers of inaccessible soil samples collected and analyzed for each of the radiological and metal PCOCs, along with the total numbers of soil PRG exceedances by each PCOC are presented in Table 4-3. As previously stated, one PRG exceedance by at least one sample result throughout SLDS caused the PCOC to be retained as a COPC for the HHRA. Therefore, the following have been identified as sitewide radiological COPCs in inaccessible soil: Ac-227, Pa-231, Ra-226, Ra-228, Th-230, Th-232, U-235, and U-238. Th-228 is not a COPC, because none of the samples collected across any of the SLDS properties had detected concentrations greater than 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. Therefore, arsenic was identified as the only metal COPC in inaccessible soil within the former uranium-ore processing area.

For the combined inaccessible and accessible soil dose and risk evaluations, the above list of radiological COPCs and arsenic are evaluated for the inaccessible soil areas of each property; whereas, the accessible soil COCs identified in the 1998 ROD and evaluated within the associated PRARs are evaluated for the accessible soil areas of each property. The 1998 ROD identified the following as soil COCs: Ac-227, Pa-231, Ra-226, Ra-228, Th-228, Th-230, Th-232, U-235, U-238, arsenic, cadmium, and uranium metal.

K2.2.2 Soil Contaminants of Potential Concern on Building Surfaces

Appendix F shows gross alpha and beta results obtained during from radiological surveys of fixed-point locations on interior and exterior surfaces of buildings. The results of gross alpha surface data comparisons were compared with the interior and exterior surface PRGs presented in Table 4-1. Table 4-6 shows that interior and exterior PRGs were exceeded by surfaces on or within 10 buildings at Plant 1, Plant 2, DT-6, DT-10, and DT-14. The radiological soil COCs that were identified in the 1998 ROD have been retained as the COPCs for soil on building surfaces. This is because it is assumed that the soil on surfaces originated predominantly from accessible soil areas. Therefore, the sitewide radiological COPCs for soil on building surfaces 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.

K2.2.3 Contaminants of Potential Concern in Sewer Sediment and Soil Adjacent to Sewer Lines

Sewer sediment and soil adjacent to sewer lines were sampled and analyzed for radiological and metal PCOCs that were identified in the RI WP. Because sediment present in the drains, manholes, and sewers used for MED/AEC operations had not been analyzed for metals during past investigations, metals associated with formerly used pitchblende and domestic ores (i.e., arsenic, cadmium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, vanadium, zinc, and uranium metal) were identified as PCOCs in the RI WP for sampling and analysis of sewer sediment, as well as for soil adjacent to sewers.

Attachment J-2 of Appendix J shows radiological and metal data summaries for sewer sediment and soil adjacent to sewer lines, including individual sample results that exceed corresponding soil PRGs, and their summary statistics. Metals in sewer line sediments and in soil adjacent to sewer lines that serviced plants and buildings within the boundary of the former uranium-ore processing area were evaluated as COPCs, even if the sampling locations were outside of the boundary. The total numbers of sewer sediment samples collected and analyzed for each of the radiological and metal PCOCs, along with the total numbers of sediment PRG exceedances by each PCOC, are presented in Tables 4-9 and 4-10. Based on these exceedances, the following radiological and metal PCOCs were retained as COPCs for evaluation of sewer sediment: Ra-226, Ra-228, U-238, and arsenic.

Likewise, the total numbers of soil samples collected adjacent to sewer lines and analyzed for each of the radiological and metal PCOCs, along with the total numbers of PRG exceedances by each PCOC, are presented in Tables 4-11, 4-12, and 4-13. Based on the PRG exceedances, the following radiological and metal PCOCs were retained as COPCs for evaluation of soil adjacent to sewer lines: Ac-227, Pa-231, Ra-226, Ra-228, Th-230, U-238, arsenic, cadmium, and lead.

K2.2.4 Summary of Contaminants of Potential Concern Identified in ISOU Media

The following items summarize the COPCs identified in each of the ISOU media that are being 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 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.

K2.3 EXPOSURE ASSESSMENT

To assess potential risks to human health at a given site, exposure must first be evaluated and quantified. At the ISOU, a radiological exposure occurs when there is physical contact between a human receptor and a radiological COPC in the environment, or between a human and the external radiation emitted from the radiological COPC. A metal exposure occurs when there is contact between a human and a metal COPC in the environment. The exposure assessment estimates the magnitude, frequency, duration, and routes of potential exposure to human receptors from COPCs present in ISOU media. An exposure assessment consists of the following elements:

- description of the site setting (previously discussed in Section 3.0);
- identification of the current and future land use and potentially exposed people (receptors);
- identification of pathways through which people may be exposed;
- calculations of EPCs for each COPC; and
- presentation of intake equations, including exposure factors used to estimate intake for each COPC, exposure pathway, and receptor.

A CSM (Figure K-3) has been developed for the ISOU that presents and discusses complete and incomplete exposure pathways identified for ISOU media and receptors under current and future land use scenarios. The current land use scenario assumes that the existing physical configurations at the SLDS remain in place-particularly, the ground cover currently present throughout most of the ISOU areas in the form of buildings, RRs, roadways, and pavement. The future land use scenario assumes that these ground cover features are either completely removed or are allowed to degrade to a point that renders contamination in inaccessible soils physically available for receptor exposures.

Figure K-3 identifies the following types of potential exposure pathways assumed for current and expected future land use scenarios: (1) complete and potentially significant pathways, (2) potentially complete but insignificant pathways, and (3) incomplete pathways. A complete exposure pathway is comprised of each of the following elements:

- a source,
- a mechanism of contaminant release and transport process/medium (e.g., soil),

- an exposure medium and point where humans could contact the contaminated medium, and
- an exposure route (i.e., ingestion, dermal contact, inhalation, or external radiation).

Complete pathways are retained for quantitative evaluations in the BRA. Potentially "complete but insignificant" pathways are considered unlikely, insignificant, or out of scope for the ISOU. Potentially complete but insignificant exposure pathways and incomplete exposure pathways are not quantitatively evaluated in the HHRA. CSM discussions focusing on potential contaminant sources and environmental release/transport mechanisms were provided in Sections 5.1 and 5.2, respectively. Under current configurations (i.e., under ground cover), the only potentially complete exposure pathway for contaminants in inaccessible soil is via the route of external radiation. This HHRA assumes that in the future all inaccessible soil has become accessible and that no ground cover is present to prevent direct contact exposures to radiological and metal COPCs, via the routes of ingestion, dermal contact, or dust inhalation. For soil in inaccessible areas that is not beneath any ground cover, ingestion, dermal contact, inhalation of dust, and external radiation exposures 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, following excavation.

Exposure scenarios evaluated in this HHRA are based on land use, identification of potentially exposed individuals, and human exposure routes, which are described in Section K2.3.1. The proper development of EPCs is important in the evaluation of each scenario. Therefore, prior to discussing exposure scenarios in Section K2.3.2, the general methodology for calculating EPCs is presented in Section K2.3.1.

K2.3.1 Quantification of Exposure Point Concentrations

To calculate a CR for radiological and metal COPCs or a non-cancer hazard for metal COPCs, an estimate must be made of the COPC concentration in the environmental medium to which an individual may be exposed. To quantify exposure for each receptor, an EPC, or an upper-bound estimate of the constituent concentration a receptor is likely to come in contact with over the duration of exposure, is calculated. The EPC is used to estimate the dose and intake for each radiological and metal COPC, respectively, by individual receptors, via all complete pathways and media identified in the CSM (Figure K-3). Sections K2.3.1.1, K2.3.1.2 and K2.3.2.3 discuss the general methodologies for calculating property-/receptor-specific EPCs for the following media: inaccessible and combined inaccessible and accessible soil (Section K2.3.1.1), soil on building surfaces (Section K2.3.1.2), and sewer sediment and soil adjacent to sewer lines (Section K2.3.1.3). Table K-1 summarizes the property-specific receptor scenarios evaluated in the HHRA, for which EPCs were determined. The radiological EPCs are presented in Tables K-2A, K-3A, K-3B, K-3C, K-4A, and K-5A. Likewise, EPCs for metal COPCs are presented in Tables K-2B, K-4B, and K-5B. Data inputs and calculation outputs for radiological and metal EPCs are presented in Appendices M and N, respectively. All locations and sample IDs associated with each set of EPC calculations are also presented in Appendices M and N.

An EPC was calculated for each COPC identified within each ISOU medium and is specific to the property, building, or location for which it was applied. If no COPCs were identified, then no EPC was calculated, because the scenario does not require quantitative dose/risk evaluations. Radiological and metal EPCs were determined for inaccessible soil, sewer sediment, and soil adjacent to sewer lines. Although SLDS soil and sediment background data are available for radiological and metal COPCs, background concentrations were not subtracted from sample results prior to, or during, EPC calculations.

In accordance with USEPA guidance (USACE 2002a), the EPC should be the estimate of the average concentration measured over the area to which an individual receptor would be exposed for the duration of the exposure. Because of the uncertainty associated with estimating the true average concentration at a site, the USEPA recommends that the lower of the 95 percent UCL or the maximum detected concentration be used to estimate the average site concentration for a reasonable maximum exposure scenario. Essentially, the 95 percent UCL is a conservative, upper-bound estimate of the mean concentration and, by using the 95 percent UCL, the probability of underestimating the true mean is less than 5 percent. The 95 percent UCL also accounts for uncertainties resulting from limited sampling (Gilbert 1987). Under certain situations (e.g., small sample sizes), the 95 percent UCL may be greater than the maximum detected concentration. For this reason, the USEPA recommends the selection of the lower of the two values as the appropriate EPC, which was applied for both radiological and metal COPCs.

The 95 percent UCL was calculated using the ProUCL statistical software package. Before calculating the 95 percent UCL, the distribution of the dataset was determined (e.g., normal, lognormal, non-parametric). Subsequently, the 95 percent UCL was calculated based on the distribution determined for the dataset. To simplify this calculation process, the USEPA's ProUCL software was used to determine both data distributions and the corresponding 95 percent UCLs for each set of data. For non-detect metals results (i.e., qualified "U" or "UJ"), the 95 percent UCL cannot be estimated unless numerical values are assigned. ProUCL has goodness-of-fit tests for normal, lognormal, and gamma distributed data sets with or without non-detect results. For consistency with past and ongoing evaluations of non-detects being conducted in support of remedial actions under the 1998 ROD, the USEPA's methodology (USEPA 2002a) is implemented for evaluating non-detects in metals datasets. In other words, for the purposes of calculating 95 percent UCLs, as well as descriptive statistics (i.e., mean, standard deviation, etc.) for metals evaluated in this HHRA, non-detect results were replaced with proxy values equivalent to one-half the detection limit, prior to application of ProUCL.

For this HHRA, the greater of the two results obtained for a COPC from analysis of a field duplicate pair was used in the calculation of EPCs to avoid the "double-counting" of data from any one soil sampling location/depth. Split samples were not included in datasets used to calculate EPCs. Split sample data are used only for QA purposes, the results of which are reported and discussed in the QCSR (Appendix B), because the field duplicate pair and split sample are analyzed at different laboratories. For risk assessment purposes, it is preferred that data generated from one laboratory (i.e., the primary laboratory) be used to calculate EPCs, unless the dataset must also include historical data generated by a different laboratory. Using RI data generated from only the primary laboratory eliminates uncertainties that can result from inter-laboratory variability.

K2.3.1.1 Exposure Point Concentrations for Inaccessible Soil and Combined Inaccessible Soil and Accessible Soil

For all sitewide and property-specific inaccessible soil and combined inaccessible/accessible soil dose and risk evaluations, EPCs were first calculated separately for inaccessible soil and accessible soil, each of which are based on the lesser of the 95 percent UCL or maximum detection. As described in Section K2.5.3, the resulting EPCs are used to determine risks and doses for inaccessible and accessible soil areas separately for each sitewide and property-specific scenario. Afterward, for any given property, or for SLDS (sitewide), the combined inaccessible/accessible soil doses and risks are finally determined as the area-weighted average of the doses and risks determined separately for the inaccessible and accessible soil areas. Therefore, combined inaccessible/accessible soil EPCs are never actually calculated. For metals, sitewide and property-specific EPCs for inaccessible and accessible soil areas are determined using data from only those properties within the boundary of the former uranium ore processing area. For properties through which the levee and St. Louis Riverfront Trail runs, only radiological data from DT-2 , DT-9 Levee, and DT-15 are used for calculating EPCs for inaccessible and accessible soil areas.

K2.3.1.2 Radiological Exposure Point Concentrations for Soil on Building Surfaces

According to the CSM, industrial workers and maintenance workers at the SLDS plant properties and VPs are being evaluated for exposures to radiological COPCs on interior and exterior building surfaces, respectively. All radiological survey measurements for buildings were analyzed as gross alpha activities. If at least one sample result for building surfaces exceeded the gross alpha DCGL, then the gross alpha results (either all exterior or all interior) from the survey were inserted into the USEPA-designed software, ProUCL, to calculate the 95 percent UCL. The lesser of the ProUCL-recommended 95 percent UCL or the maximum gross alpha measurement was then converted from dpm/100 cm^2 to pCi/m^2 as follows:

$$gross\ alpha\ \left({}^{pCi}/_{m^2}\right) = gross\ alpha\ \left({}^{dpm}/_{100\ cm^2}\right) \times 10{,}000\ {}^{cm^2}/_{m^2} \times \left({}^{1\ pCi}/_{2.22\ dpm}\right)$$

This conversion was conducted to adjust the gross alpha units into those units required for the RESRAD-BUILD parameter input.

Because survey instrumentation could not distinguish between individual radionuclide activities (i.e., instruments only provide a gross alpha value), it was assumed that any areas exceeding PRGs must have been contaminated from the surrounding contaminated soil and, therefore, would have the same activity fractions as the soil at the SLDS. Individual radionuclide-specific EPCs were calculated by multiplying the gross alpha value (lesser of the 95 percent UCL and maximum gross alpha) by the radionuclide-specific activity fraction. Activity fractions were calculated by dividing individual radionuclide soil concentration values by the sum of soil concentration values for all COCs. Soil concentration values used for this calculation were selected from Table 3.9 of the 1993 BRA (DOE 1993). SLDS-specific activity fractions were calculated as needed to appropriately assign portions of the average gross alpha 95 percent UCL value into radionuclide-specific EPCs required for RESRAD-BUILD parameter inputs. SLDS-specific soil activity fractions are presented in Table K-3A.

Interior surfaces at seven buildings exceeded the gross alpha PRG for interior surfaces:

- Plant 1 Building 7,
- Plant 1 Building 26,
- Plant 2 Building 41,
- Plant 2 Building 508,
- DT-6 Storage Building,
- DT-10 Metal Storage Building, and
- DT-10 Wood Storage Building.

Exterior surfaces at four buildings/locations exceeded the gross alpha PRG for exterior surfaces:

- Plant 1 Building 25,
- Plant 1 Building X,
- DT-10 Wood Storage Building, and
- DT-14 Horizontal Beam between the L-Shaped Building and Brick Building.

Surface EPCs were calculated for each radiological COPC. All interior data were used to calculate the interior EPC for each COPC in that building. All interior surface EPCs are presented in Table K-3B. Likewise, all exterior data were used to calculate the exterior EPC for each COPC for that building. All exterior surface EPCs are presented in Table K-3C.

K2.3.1.3 Exposure Point Concentrations for Sewer Sediment and Soil Adjacent to Sewer Lines

For sewer sediment and soil adjacent to sewer lines, sitewide and sample location-specific EPCs were calculated. The sitewide EPCs for each sewer medium were determined to be the lesser of the 95 percent UCL or maximum detection for all sample locations across the SLDS for the medium. Location-specific, rather than property-specific, EPCs were determined for each sewer sediment location and soil location adjacent to sewer lines, because of the large distances between individual sewer sediment locations and soil boreholes. The location-specific sewer sediment EPCs are simply the reported concentrations at each location, because only one sample was collected per location. However, because soil samples adjacent to sewer lines were collected at a frequency of two or three depth intervals per location, the location-specific EPCs for radiological COPCs, arsenic and cadmium were determined to be the maximum detection of the soil samples collected from within each borehole location adjacent to a sewer line. Because 95 percent UCLs cannot be reliably determined for only two or three samples, the location-specific EPCs for all boreholes were the maximum detected concentrations. Because only one sample was collected from each location, with 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. 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.

K2.3.2 Identification of Land Use and Potential Exposure Scenarios

The SLDS is located in a heavily industrial/urban setting. Current land use is predominantly industrial and commercial and is expected to remain as such for the foreseeable future. According to the City of St. Louis Strategic Land Use Map, which was adopted by the City of St. Louis' Planning Commission on January 5, 2005, all SLDS properties are listed as "Business and Industrial Preservation and Development Area" or "Business and Industrial Development Area" (City of St. Louis 2012a). The long-term plans by the City of St. Louis for the SLDS area are to retain the industrial uses, encourage the wholesale produce district, and phase out the remaining marginal residential uses. Therefore, this HHRA focuses on receptors that are likely to be exposed to contaminated inaccessible soil, soil on building surfaces, sewer sediment, and soil adjacent to sewer lines under current and future industrial land use scenarios.

The main distinction between current and future scenarios pertains to ground cover assumptions applied during evaluations of exposures to inaccessible soil. There is no real distinction assumed between current and future potential human exposures to the ISOU media. Future land use of the SLDS is expected to be heavily industrial; therefore, this HHRA does not assume that the properties are redeveloped for land uses other than industrial/commercial use. This approach ensures that a reasonable maximum risk will be characterized under existing land use patterns and that all potential receptors will be adequately protected.

- *Current Industrial Worker (Ground Cover Present) and Future Industrial Worker (Ground Cover Absent)* – The current industrial worker evaluation assumes existing ground cover remains intact so that the only potentially complete exposure pathway for this receptor is external radiation. In the future, ground cover is assumed to be absent or degraded sufficiently so that a future industrial worker could be exposed via external radiation, soil ingestion, dermal contact with soil, and dust inhalation. Industrial workers are individuals working mainly indoors with some outdoor activities at the plants, industrial/commercial VPs, RRs, and roadways. This group includes site workers performing daily job activities specific to the SLDS property/VP at which they are employed (e.g., working at various plant processes and industrial/commercial work activities at the SLDS and VPs, office workers, and building maintenance employees). Industrial worker exposures to inaccessible soil are assumed to occur property-wide and are not limited to any particular area of a property. Based on the industrial worker soil exposure frequencies and durations, this receptor is assumed to be the maximally exposed individual (i.e., limiting receptor) at the ISOU. Therefore, this receptor is evaluated at all ISOU properties for exposures to inaccessible soil and to combined inaccessible/ accessible soil.
- *Current/Future Recreational User* – Recreational users are assumed to use the St. Louis Riverfront Trail along DT-2, DT-9 Levee, and DT-15 for walking, jogging, and biking.
- *Current/Future Construction Worker* – The construction worker is assumed to be a contractor (i.e., not a SLDS/VP employee) who performs one-time, deep excavation and construction activities at the ISOU. This receptor group is assumed to be exposed at all SLDS plants, industrial/commercial VPs, RRs, and roadways. Because this scenario assumes work in excavations, ground cover is assumed to absent under both current and future exposure scenarios. Because construction can occur anywhere within the SLDS study area or within any given property at the SLDS, this scenario is evaluated for sitewide and property-specific inaccessible soil exposures.
- *Current/Future Utility Worker* – In a manner consistent with the 1998 ROD, a utility worker is assumed to perform one-time work on utilities (i.e., repairing, maintaining, and replacing subsurface utilities), within a deep excavation, for a short time duration with an equal probability of performing this work at any location across each individual property, as well as across all of the SLDS. Because this scenario assumes work in excavations, ground cover is assumed to absent under both current and future exposure scenarios. This receptor is evaluated for exposures to COPCs in inaccessible soil areas across each property and all of the SLDS.
- *Current/Future Industrial Worker* – Industrial workers may be exposed to contaminated soil on interior and exterior building surfaces in either the current or future timeframes. Exposures to exterior surfaces are assumed to occur during exterior building or structural maintenance work; therefore, industrial workers exposed to exterior surfaces are being evaluated as maintenance workers. Exposures to contaminated soil on surfaces are assumed to be specific to the building to which the exposures occur; therefore, sitewide evaluations of buildings are not considered in the HHRA.

- *Current/Future Sewer Maintenance Worker* – Sewer maintenance workers are assumed to perform infrequent work inside of sewers and manholes. Sewer sediment exposures for this receptor are evaluated on a sitewide and sampling location-specific basis.
- *Current/Future Sewer Utility Worker* – This receptor is assumed to perform work specifically on the outside of lines, usually within a deep excavation and for a short duration. During this time, exposures are likely to occur to the soil adjacent to the outside of the sewer lines. In an effort to evaluate possible contamination specifically from the sewers, this receptor is evaluated separately from the current utility worker described in the fourth bullet in this list.

In addition to the above receptors evaluated under current and future industrial land use scenarios, a hypothetical, future, resident gardener scenario was evaluated for the ISOU. Because current land use is predominantly industrial/commercial, and land use is expected to remain as such for the foreseeable future, it is recommended that scenarios assuming industrial land use be used as the basis for determining future actions at the ISOU. The hypothetical resident gardener was evaluated as an unlimited use and unrestricted exposure scenario for only informational purposes to facilitate future decision making as needed. It is for these reasons that the evaluation methodologies and results of the residential HHRA are presented separately, in Attachment K-1 to this appendix. Attachment K-2 presents inaccessible soil data comparisons with USEPA risk-based residential PRGs for the purpose of determining COPCs for the residential scenario.

The following subsections (K2.3.2.1 through K2.3.2.5) summarize the exposure scenarios as they relate to each ISOU medium under industrial land use considerations, with more specific information regarding receptor-specific exposure routes being quantitatively evaluated for dose and risk.

K2.3.2.1 Inaccessible Soil

For the sitewide and property-specific scenarios, the evaluation of inaccessible soil beneath buildings, permanent structures, RRs, and roadways includes all inaccessible soil areas within SLDS and within each individual property, respectively. However, for the industrial worker and recreational user, this HHRA determines the sitewide and property-wide dose/risk status of all soil (i.e., inaccessible and accessible soil combined).

As previously stated, different assumptions apply to the evaluations of inaccessible soil under current and future scenarios. This distinction 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, roadways, RRs, 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.

The recreational user is applied 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. 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.

Construction and utility worker exposures to inaccessible soil always assume that excavation is required 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 current industrial worker, future industrial worker, current/future construction worker, and the current/future utility worker are evaluated for sitewide exposures, as well as for property-specific exposures, to inaccessible soil; therefore, sitewide and property-specific EPCs are calculated for these receptors across all properties. Inaccessible soil EPCs for the recreational user are calculated for each of the three properties through which the St. Louis Riverfront Trail runs: DT-2, DT-9 Levee, and DT-15. Additionally, the recreational user is being evaluated for inaccessible soil across all three properties combined (i.e., the "St. Louis Riverfront Trail properties"). The industrial workers and the recreational users are evaluated for both 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 SLDS evaluation and for each property evaluation, separate EPCs are calculated for inaccessible and accessible soils. Inaccessible soil dose and risk is determined using the inaccessible soil EPC, while 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 no ground cover over accessible soil areas when evaluating the current industrial worker and the current/future recreational user scenarios. This evaluation would not be possible if area weighting was applied to EPCs rather than to 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.

The following items summarize the inaccessible soil and combined inaccessible/accessible soil exposure scenarios. These scenarios are also reflected by property in Table K-1. Tables presenting the EPCs associated with each scenario are presented in parentheses.

Current Industrial Worker Exposures to Radiological COPCs: Sitewide and Property-Specific Evaluations across All Properties (EPC Table K-2A) 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 contaminated 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) 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) (metals only),
- dermal contact with accessible soil (ground cover absent) (metals only),
- 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, DT-9, and DT-15) (EPC Table K-2A) 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 [levee] cover 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) include:

- incidental ingestion of inaccessible soil (ground cover absent),

- dermal contact with inaccessible soil (ground cover absent) (metals only),
- 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) include:

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

Table K-1 shows that the industrial worker scenario was applied to a total of 28 properties. In the current scenario, the HHRA assumes ground cover consisting of soil, the cover depth (i.e., the thickness of ground cover between the receptor and the top of the contaminated zone) of which is assumed to be 0.3048 m. In the future scenario, the HHRA assumes that property-wide inaccessible soil has become accessible, and that the cover depth is assumed to be 0 m. The current and future industrial workers are SLDS plant/VP employees assumed to work indoors 1,600 hours per year (200 days per year) and also perform 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. Exposures to metal COPCs in inaccessible soil via ingestion, dermal contact, and inhalation of dusts can only occur during the fraction of time spent outdoors, or 50 days per year for 25 years for an industrial worker. Because of the levee material present at DT-2, DT-9, and DT-15, ground cover over inaccessible soil at these properties is assumed to be comprised of soil to a depth of 1 m for the industrial worker and recreational user, based on the shallowest radiological PRG exceedance. It is further assumed that the recreational user spends approximately 75 hours per year (i.e., 1 hour per day for 75 days), for 9 years, engaged in recreational activities at the St. Louis Riverfront Trail.

The assumption of 0 m for a cover depth is also assumed for the current/future construction worker and utility worker, because these receptors are exposed to inaccessible soil in open excavations. The durations assumed for the contact-intensive soil exposures for the construction worker and utility worker are 90 days and 10 days, respectively, for 1 year.

Soil exposure assumptions for the industrial worker, recreational user, construction worker, and utility worker are presented for radiological and metals evaluations in Tables K-6 and K-8, respectively.

K2.3.2.2 Soil on Surfaces of Buildings and Structures

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

The HHRA scenarios for evaluating current/future industrial and maintenance worker exposures to radiological COPCs in soil on contaminated interior and exterior building surfaces is summarized in the following list.

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

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

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

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

Radiological dose and risk for buildings 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.

K2.3.2.3 Sediment in Sewer Lines

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 sewer maintenance workers to COPCs in sediment. Inhalation exposures to sediments are not likely to occur via the generation of particulate emissions from mechanical disturbance of the sediment during inside maintenance work activities because of 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 radiological and metal COPCs in sewer sediment is summarized in the following list.

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

- incidental ingestion of sediment in sewers,
- dermal contact with contaminated sediment in sewers, and
- external gamma exposures.

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

K2.3.2.4 Soil Adjacent to Sewer Lines

The exposure scenario used for evaluating soil adjacent to sewer lines assumes that direct contact with this medium can occur to individuals only when excavation is performed (e.g., 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. This receptor is assumed to perform work specifically on the outside of lines, usually within a deep excavation, for a short duration (80 hours or 8 hours per day for 10 days). 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) 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.

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. Lead in inaccessible soil adjacent to sewer lines was assessed using the ALM. The ALM is a biokinetic model that predicts the relative increase in PbB that might result from an environmental exposure. The ALM is used in this HHRA to predict the risk of elevated PbBs in non-residential settings (adult exposure to soil; ultimate receptor is fetus). In accordance with the USEPA's ALM methodology (USEPA 2003b), the mean soil concentration was used as the EPC for input into the ALM. Further explanation of the ALM and the results are presented in Sections K2.4.2.5 and K2.5.3.9, respectively.

K2.3.3 Methodology for Quantifying Dose

The magnitude of human exposure to contaminants in environmental media is usually described in terms of a dose. Radiological dose is a measure of the radiation absorbed by the body based on radionuclide concentrations and different intake pathways (ingestion, inhalation, and external radiation) and is expressed as mrem/yr. Chemical dose (also referred to as "intake") is a measure of exposure expressed as the concentration of a constituent that has come in contact (via ingestion and dermal contact) with a receptor per unit body weight per unit of time (milligrams of chemical per kilogram body weight per day [mg/kg-day]). For quantifying exposures via inhalation of dusts, an exposure concentration (EC) is determined as the time-weighted average concentration ($\mu g/m^3$) derived from measured or modeled contaminant concentrations in air, adjusted based on the characteristics of the exposure scenario being evaluated (USEPA 2009b). Sections K2.3.3.1 and K2.3.3.2 describe the methodologies used for calculating dose and risk for radiological COPCs and chemical dose (i.e., intake) for metal COPCs.

K2.3.3.1 Estimation of Radiological Dose and Risk

RESRAD was used to calculate dose and risk to potential ISOU receptors from exposures to soil and sewer sediment. RESRAD-BUILD was used for determining risk and dose from exposures to contaminated building surfaces. RESRAD and RESRAD-BUILD are computer codes developed at Argonne National Laboratory (ANL) for the DOE to determine site-specific residual radiation guidelines and dose to on-site receptors at sites that are contaminated with radioactive materials. The use of RESRAD codes for modeling dose and risk has become an acceptable industry practice among prominent federal agencies, including the following examples:

- The USEPA used RESRAD in its "Reassessment of Radium and Thorium Soil Concentrations and Annual Dose Rates," which demonstrated the protectiveness of Uranium Mill Tailings Radiation Control Act soil criteria, and in its rulemaking for cleanup of sites contaminated with radioactivity.
- Seven U.S. Cabinet-level agencies including the USEPA, the DOE, the NRC, and the U.S. Department of Defense (DOD), functioning as the Interagency Steering Committee on Radiation Standards, formally accepted RESRAD-BIOTA.
- The USEPA was also a signatory to the 1998 ROD (USACE 1998a), which incorporated RESRAD evaluations, and is a participant in many other CERCLA actions utilizing RESRAD.

In accordance with Title 40 *CFR* Part 192, Subpart A, control of residual radioactive materials from inactive uranium processing sites shall be designed to be effective for up to 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. Therefore, for inaccessible soils, radiological risk in this HHRA, as well as dose, has been assessed over a 1,000-year period. Tables K-6 and K-7 present values assigned to all relevant non-default RESRAD and RESRAD-BUILD input parameters, respectively.

K2.3.3.2 Pathway-Specific Dose Calculations for Exposures to Metal Contaminants of Potential Concern

Chemical dose is the amount of chemical that comes into contact with an exchange surface (e.g., skin, lungs, and gastrointestinal [GI] tract) and is absorbed into the body, averaged over the duration of exposure (for non-carcinogens) or a lifetime (for carcinogens). The magnitude of the dose is dependent on the body weight of the receptor. All doses determined for metal COPCs were based on chronic exposures (as opposed to subchronic exposures) or exposures that occur on a daily basis for at least 90 days. For ingestion exposures to contaminants in any environmental medium, dose is referred to as the chronic daily intake (CDI) (USEPA 1989a). For dermal exposures to contaminants, dose is referred to as the dermally absorbed dose (DAD) (USEPA 2004b). For inhalation exposures, recent USEPA RAGS, Volume I, Part F, methodology (USEPA 2009b) has been used in calculating time-weighted average concentrations, referred to as ECs, for contaminants adsorbed onto soil, and released into the air as airborne particulates (i.e., from wind-blown action or mechanical disturbance).

Based on the metal COPCs identified in inaccessible soil, sewer sediment, and inaccessible soil adjacent to sewer lines, as well as the receptor information discussed in Section K2.3.2, CDIs, DADs, and ECs were determined for metal COPCs in these media for the following receptor scenarios:

- Future industrial worker (SLDS/VP employee) exposed to metal COPCs in inaccessible soil across all of the SLDS, as well as at Plant 2, Plant 6, DT-10, the DT-9 Main Tracks, DT-12, Hall Street, Mallinckrodt Street, and Destrehan Street (the current industrial worker scenario is not applicable due to incomplete exposure pathways from the presence of ground cover);
- Current/future construction worker exposed to metal COPCs in inaccessible soil across all of the SLDS, as well as at Plant 2, Plant 6, DT-10, the DT-9 Main Tracks, DT-12, Hall Street, Mallinckrodt Street, and Destrehan Street;
- Current/future utility worker exposed to metal COPCs in inaccessible soil across all of the SLDS, as well as at Plant 2, Plant 6, DT-10, the DT-9 Main Tracks, DT-12, Hall Street, Mallinckrodt Street, and Destrehan Street;
- Current/future sewer maintenance worker exposed to metal COPCs in sediment inside of sewer lines across all of the SLDS, as well as at Plants 1, 2, and 6 and DT-8; and
- Current/future sewer utility worker exposed to metal COPCs in soil adjacent to sewer lines across all of SLDS, as well as at Plants 1, 2, and 6, Plant 7N/DT-12, and DT-8/DT-11.

The following sections present general dose equations used to evaluate receptor exposures to metal COPCs in inaccessible soil, sewer sediment, and soil adjacent to sewer lines. The following inhalation equations are applicable to soil only, as this pathway is considered to be incomplete for sediment, because releases of sediment particulates into the air are prevented by the high percent moisture content of the sediment. Table K-8 summarizes all receptor-specific exposure parameters used as input values into the dose equations, which includes parameter descriptions, units, numerical values assigned to the parameters, and sources/rationale for the numerical values. Additional subscripting is applied in Table K-8 to the general parameters presented in the equations below to correlate inputs with receptor-specific scenarios.

The following equations are not applicable to exposures to lead in soil adjacent to sewer lines, because this was assessed, as previously stated, using the USEPA's ALM.

<u>Non-Carcinogenic Exposures to Soil or Sewer Sediment via Incidental Ingestion</u>

The CDI for a worker exposed to non-carcinogenic metal COPCs via the incidental ingestion of soil or sediment (CDI_{nc}) was calculated with the following formula (USEPA 1989a)

$$CDI_{nc} = \frac{C_s \times IR \times CF \times FI \times EF \times ED}{BW \times AT_{nc-ing}}$$

where:

CDI_{nc} = chronic daily intake for worker exposures to non-carcinogenic metals in soil or sediment (mg/kg-day),

C_s = metal concentration in soil or sediment (mg/kg),

IR = soil or sediment ingestion rate (mg/day),

CF = conversion factor (1.0E-06 kilograms per milligram [kg/mg]),

FI = fraction of soil or sediment ingested from contaminated source (unitless),

EF = soil or sediment exposure frequency (days/year),

ED = exposure duration (years),

BW_a = adult body weight (kg),

AT_{nc-ing} = non-carcinogenic averaging time for soil or sediment ingestion exposures (days).

<u>Non-Carcinogenic Exposures to Soil or Sewer Sediment via Dermal Contact</u>

The DAD for a worker exposed to non-carcinogenic metal COPCs via dermal contact (DAD_{nc}) with soil or sediment was calculated with the following formula (USEPA 2004b)

$$DAD_{nc} = \frac{C_s \times CF \times SA \times AF \times ABS \times EF \times ED \times EV}{BW \times AT_{nc-derm}}$$

where:

DAD_{nc} = dermally absorbed dose for worker exposures to non-carcinogenic metals in soil or sediment via dermal contact (mg/kg-day),

C_s = metal concentration in soil or sediment (mg/kg),

CF = conversion factor (1.0E-06 kg/mg),

SA = skin surface area available for soil or sediment contact (cm^2),

AF = skin adherence factor for soil or sediment contact (milligrams of chemical per square centimeter per event [mg/cm^2-event]),

$ABS =$ absorption factor (unitless),

$EF =$ soil or sediment exposure frequency (days per year),

$ED =$ exposure duration (years),

$EV =$ event frequency for soil contact (events per day),

$BW_a =$ adult body weight (kg),

$AT_{nc-derm} =$ non-carcinogenic averaging time for dermal exposures to soil or sediment (days).

Non-Carcinogenic Exposures to Soil via Dust Inhalation

The EC for a worker exposed to non-carcinogenic soil COPCs via the inhalation of airborne particulates emanating from inaccessible soil areas (EC_{nc}) was calculated with the following equation (USEPA 2009b)

$$EC_{nc} = \frac{C_s \times (PEF)^{-1} \times ET \times EF \times ED}{AT_{nc-inh}}$$

where:

$EC_{nc} =$ air exposure concentration for worker exposures to non-carcinogenic metals in soil particulates/dusts (micrograms per cubic meter [$\mu g/m^3$]),

$C_s =$ metal concentration in soil ($\mu g/m^3$),

$PEF =$ particulate emission factor (kilograms per cubic meter [kg/m^3]),

$ET =$ soil exposure time (hours per day),

$EF =$ soil exposure frequency (days per year),

$ED =$ exposure duration (years),

$AT_{nc-inh} =$ non-carcinogenic averaging time for inhalation exposures to airborne soil particulates/dusts (hours).

Carcinogenic Exposures to Soil or Sewer Sediment via Incidental Ingestion

The CDI for a worker exposed to carcinogenic metal COPCs via the incidental ingestion of soil or sediment (CDI_c) was calculated with the following formula (USEPA 1989a)

$$CDI_c = \frac{C_s \times IR \times CF \times FI \times EF \times ED}{BW \times AT_{c-ing}}$$

where:

$CDI_c =$ chronic daily intake for worker exposures to carcinogenic metals in soil or sediment (mg/kg-day),

$C_s =$ metal concentration in soil or sediment (mg/kg),

$IR =$ soil or sediment ingestion rate (mg/day),

$CF =$ conversion factor (1.0E-06 kg/mg),

$FI =$ fraction of soil or sediment ingested from contaminated source (unitless),

$EF =$ soil or sediment exposure frequency (days per year),

$ED =$ exposure duration (years),

$BW_a =$ adult body weight (kg),

$AT_{c-ing} =$ carcinogenic averaging time for soil or sediment ingestion exposures (days).

Carcinogenic Exposures to Soil or Sewer Sediment via Dermal Contact

The DAD for a worker exposed to carcinogenic metal COPCs via dermal contact with soil or sediment (DAD_c) was calculated with the following formula (USEPA 2004b)

$$DAD_c = \frac{C_s \times CF \times SA \times AF \times ABS \times EF \times ED \times EV}{BW \times AT_{c-derm}}$$

where:

$DAD_c =$ dermally absorbed dose for worker exposures to carcinogenic metals in soil or sediment via dermal contact (mg/kg-day),

$C_{sl} =$ metal concentration in soil or sediment (mg/kg),

$CF =$ conversion factor (1.0E-06 kg/mg),

$SA =$ skin surface area available for soil or sediment contact (cm^2),

$AF =$ skin adherence factor for soil or sediment contact (mg/cm^2-event),

$ABS =$ absorption factor (unitless),

$EF =$ soil or sediment exposure frequency (days per year),

$ED =$ exposure duration (years),

$EV =$ event frequency for soil or sediment contact (events per day),

$BW_a =$ adult body weight (kg),

$AT_{c-derm} =$ carcinogenic averaging time for dermal exposures to soil or sediment (days).

Carcinogenic Exposures to Soil via Dust Inhalation

The EC for a worker exposed to carcinogenic soil COPCs via the inhalation of airborne particulates emanating from inaccessible soil areas (EC_c) was calculated with the following equation (USEPA 2009b)

$$EC_c = \frac{C_s \times (PEF)^{-1} \times ET \times EF \times ED}{AT_{c-inh}}$$

where

$EC_c =$ air exposure concentration for worker exposures to non-carcinogenic metals in soil particulates/dusts ($\mu g/m^3$),

$C_s =$ metal concentration in soil (μg/m^3),
$PEF =$ particulate emission factor (kg/m^3),
$ET =$ soil exposure time (hours per day),
$EF =$ soil exposure frequency (days per year),
$ED =$ exposure duration (years),
$AT_{c-inh} =$ carcinogenic averaging time for inhalation exposures to airborne soil particulates/dusts (hours).

K2.4 TOXICITY ASSESSMENT

The toxicity assessment identifies the chemical-specific toxicity values (e.g., cancer slope factors [CSFs] and reference doses [RfDs]) for COPCs identified in ISOU media. These toxicity values were applied to the estimated doses (intakes) to quantify carcinogenic and non-carcinogenic risks. For radiological evaluations, the source of slope factors (SFs) used in the RESRAD and RESRAD-BUILD evaluations is Federal Guidance Report (FGR) 13 (USEPA 1999c).

In accordance with the hierarchy of sources established by the USEPA for obtaining chemical toxicity values for metal COPCs (USEPA 2003a), USEPA's *Integrated Risk Information System* (IRIS) (USEPA 2012b) was used as the preferred source. The IRIS website is continuously updated to reflect the latest toxicological information that is currently available and derived from the results of studies recognized by the USEPA as being of a sufficient degree of confidence for use in risk assessments. The USEPA recommends the following three-tiered hierarchy of toxicological data sources from which to select toxicity criteria:

- Tier 1 – USEPA's on-line IRIS database;
- Tier 2 – Provisional Peer-Reviewed Toxicity Values derived by USEPA's Superfund Health Risk Technical Support Center for the Superfund program; and
- Tier 3 – Other toxicity criteria as recommended by USEPA's National Center for Environmental Assessment, such as the California Environmental Protection Agency, the Agency for Toxic Substances and Disease Registry, or the *Health Effects Assessment Summary Tables* (USEPA 1995b).

K2.4.1 Radiological Toxicity Assessment

Health impacts from exposure to radiation and radionuclides are expressed as the risk of developing cancer and have been determined using the RESRAD computer code. Because radiological exposures may result in cancer, CRs from exposures to ISOU radiological PCOCs have been estimated using USEPA SFs developed for inhalation, ingestion, and external radiation exposure routes. The radiological SFs specific to each exposure route are used to convert exposure to CR.

All radiological SFs used in this ISOU BRA are presented in Table K-9. SFs for radionuclides are defined differently than SFs for metals. The USEPA outlines these differences in the *Radiation Exposure and Risk Assessment Manual* (USEPA 1996b). Major differences include the following:

- The SFs for radiological COPC are based on the endpoint of morbidity – the endpoint for metal exposures is tumorigenic cancer or non-carcinogenic risk.

- Radiological risk estimates are based primarily on human data – metals risk estimates are based primarily on animal studies and extrapolated to the human population.
- Radiological risk estimates are based on the central estimate of the mean – metals risk estimates are based on the 95 percent UCL of the mean.

A dose conversion factor for radiological exposures was used to calculate lifetime committed effective dose equivalents. Radiological doses were calculated to ensure compliance with ARARs to be identified for radiological contamination. For a site to be released for unrestricted use, Title 10 *CFR* Part 20, Subpart E, requires the radiological dose to be less than 25 mrem/yr, which is approximately equivalent to a CR of 5.0E-04 (USEPA 1997a). The appropriate dose limit will be determined during ARARs development in the FS.

K2.4.2 Toxicity Assessment for Metals

The following sections discuss and present information relevant to the evaluation of toxicities of the metal COPCs identified in ISOU media. All numerical toxicity criteria and information for metal COPCs are presented in Tables K-10A through K-10C, with the following information being presented for each PCOC, as appropriate: weight-of-evidence classification, tumor site(s), unit risk values, uncertainty factors, modifying factors, and non-carcinogenic target organs/critical effects.

K2.4.2.1 Cancer Toxicity Assessment for Metal Contaminants of Potential Concern

USEPA SFs used for estimating CRs for metal compounds are upper 95th percentile confidence limits of the probability of response per unit intake (by oral or inhalation routes) over a lifetime. SFs for metals are based on mathematical extrapolation from experimental animal data and epidemiological studies, when available. SFs are expressed in units of risk per milligrams per kilogram body weight per day ($[\text{mg/kg-day}]^{-1}$). Because SFs are upper-bound estimates, actual cancer potency of PCOCs are likely lower than estimated (USEPA 1989a).

K2.4.2.2 Non-cancer Toxicity Assessment for Metal Contaminants of Potential Concern

The RfD is an exposure route-specific estimate of a daily intake per unit body weight that is likely to be without deleterious effects (USEPA 1989a). The USEPA derives RfDs to protect sensitive populations, such as children, and has developed many chronic RfDs to evaluate long-term exposures (7 years to a lifetime) and a few subchronic RfDs to evaluate exposures of shorter duration (2 weeks to 7 years).

K2.4.2.3 Dermal Toxicity Assessment for Metal Contaminants of Potential Concern

There are no toxicity values specific to dermal exposure; therefore, the USEPA recommends that oral toxicity values be adjusted to assess risks from dermal exposure. The approach is described in the USEPA guidance document RAGS, Volume 1, Part E (USEPA 2004b). The oral toxicity factor for a metal relates toxic response to an administered dose of only some metals, which may be absorbed by the body; whereas, intake from dermal contact is estimated as an absorbed dose using chemical-specific permeability constants for absorption from water and dermal-absorbed fraction from soil (USEPA 2004b). To ensure that dermal toxicity is not underestimated, the USEPA recommends adjusting oral toxicity factors by chemical-specific GI absorption fractions (GIABS) to evaluate toxic effects of a DAD (USEPA 2004b). Oral RfDs (RfD_o) are adjusted to derive dermal RfDs (RfD_d) using the following equation:

$$RfD_d = RfD_o \times GIABS$$

Oral SFs (SF_o) are adjusted to derive dermal SFs (SF_d) using the following equation:

$$SF_d = \frac{SF_o}{GIABS}$$

GI absorption efficiencies vary widely for inorganic compounds. Of the metal COPCs identified at the SLDS, GI absorption efficiencies are available for arsenic and cadmium. The GI absorption efficiency for arsenic is estimated to be 95 percent, so no adjustment of the toxicity factor is recommended. The GI absorption efficiency for cadmium is estimated to be between 2.5 and 5 percent, so adjustment of the toxicity factor is recommended. Lead it was assessed using the ALM, so no adjustment was needed.

K2.4.2.4 Inhalation Toxicity Assessment for Metal Contaminants of Potential Concern

USEPA guidance for evaluating the inhalation exposure pathway (RAGS, Volume I, Part F [USEPA 2009b]) recommends the use of carcinogenic inhalation unit risk (IUR) and non-carcinogenic reference concentration (RfC) values.

The IUR is defined as the upper-bound excess lifetime CR estimated to result from continuous exposure to an agent at a concentration of 1 micrograms/meter cubed ($\mu g/m^3$) in air. IURs are expressed in units of cubic meters per milligram of chemical $(mg/m^3)^{-1}$.

The inhalation RfC is defined as an estimate of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to not result in a significant risk of systemic effects during a lifetime. Estimates of RfCs are associated with uncertainty spanning approximately an order of magnitude. The RfC can be derived from a no observed adverse effects level (NOAEL), a lowest observed adverse effects level (LOAEL), or benchmark concentration. Various types of RfCs are available depending on the type of critical effect and the length of exposure being evaluated (chronic or subchronic).

K2.4.2.5 Toxicity Assessment for Lead

Lead is classified as a B2 carcinogen, and it has known non-carcinogenic effects; however, no toxicity values have been established for lead. The USEPA regulates lead exposure using a biomarker (PbB), which can be estimated using the 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 (adult exposure to soil; ultimate receptor is 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 µg Pb/dL blood. The CDC established 10 µg Pb/dL blood as the federal level of concern in 1991, and the USEPA's OSWER risk reduction policy calls for no child to have greater than a 5 percent probability of having a PbB >10 µg/dL. The basis for the ALM PRG calculation is the relationship between the soil lead concentration and the PbB in the developing fetus of adult women who have site exposures. The ALM describes the estimated relationship between the PbB in adult women and the corresponding 95th percentile fetal PbB, assuming that PbBs in women of child-bearing age reflect the geometric mean of a lognormal distribution.

Default values for the ALM input parameters were originally derived from an analysis of blood lead data for U.S. women 17 to 45 years of age, from Phase I (1988 to 1991) of the Third National Health and Nutrition Examination Survey (NHANES III) as well as consideration of available site-specific data on PbBs. For the SLDS, the ALM used updated estimates for the geometric standard deviation of blood level (GSD_i) and baseline PbB based on data from the NHANES surveys that were conducted from 1999 to 2004. In addition to soil lead concentrations, site-specific values incorporated into the ALM runs include soil ingestion rate and frequency of exposure. The ALM default value for soil ingestion is 50 mg/day. Because soil adjacent to sewers is most likely to be disturbed by a utility worker with fairly high exposure to soil, the ALM was run with a soil ingestion rate of 480 mg/day. Utility workers are likely to have fairly high exposure to soil; however, their frequency of exposure was assumed to be intermittent, 10 days per year, as opposed to the default exposure frequency of 219 days per year for an industrial worker.

K2.5 DOSE AND RISK CHARACTERIZATION

The objective of risk characterization is to integrate the information developed in the exposure assessment and the toxicity assessment into an evaluation of the potential current and future health risks associated with radiological and metal COPCs. In this step, the toxicity factors (SFs and RfDs) are applied in conjunction with dose to estimate potential carcinogenic health risks (radiological and metal COPCs) and non-carcinogenic hazards (metal COPCs). Sections K2.5.1 and K2.5.2 describe how the carcinogenic and non-carcinogenic risk calculations were performed, respectively. Determination of CR from exposures to radiological contamination in inaccessible soil and on building surfaces was performed using the RESRAD (Version 6.5) and RESRAD-BUILD (Version 3.5) models, respectively. Attachment O-1 of Appendix O and Appendix P present RESRAD and RESRAD-BUILD output files, respectively, from the radiological dose and risk evaluations of all receptors under the assumptions of industrial land use. Attachment Q-1 of Appendix Q presents risk calculation spreadsheets for evaluating exposures to arsenic and cadmium in soil for all receptors under the assumptions of industrial land use. Attachment Q-2 of Appendix Q presents ALM spreadsheets for evaluating adult worker exposures to lead in soil adjacent to sewers.

K2.5.1 Estimation of Carcinogenic Risk from Radiological and Metal Exposures

The potential for carcinogenic effects was characterized in terms of the incremental probability of an individual developing cancer over a lifetime as a result of site-related exposure to a potential carcinogen. CRs for radiological COPCs were estimated based on SFs that reflect morbidity. For metals, excess lifetime CRs were estimated from the projected lifetime daily average intake and the carcinogenic SF or IUR, which represents an upper-bound estimate of the dose-response relationship.

Generally, excess lifetime CR for carcinogenic effects is calculated by multiplying the estimated dose (i.e., lifetime-averaged daily intake for metals, and average annual dose for radionuclides) via an exposure route by the exposure route-specific (oral, inhalation, dermal, or external radiation) carcinogenic SF or IUR, as described as follows

$$CR = Dose \times Toxicity\ Value$$

where:

CR = Cancer risk (unitless);
$Dose$ = Oral CDI (mg/kg-day), DAD (mg/kg-day), or air EC ($\mu g/m^3$) for inhalation; and
$Toxicity\ Value$ = Oral or dermally adjusted cancer SF_o or SF_d, ($[mg/kg\text{-}day]^{-1}$) or IUR ($\mu g/m^3$).

The CRs resulting from exposure to multiple carcinogens are assumed to be additive. However, because SFs and IURs for radionuclides and metals are specific to distinct models that incorporate different assumptions (as indicated previously), the USEPA's RAGS, Volume I, Part A, guidance cautions against combining (i.e., summing) radiological CRs with metal CRs (USEPA 1989a). In addition, natural background radiation is ubiquitous at levels exceeding typical risk targets, and natural variability may preclude the ability to quantify small incremental CRs due to contamination. Therefore, total CRs to be calculated for radiological and metal COPCs are assessed separately and are not summed together for estimation of cumulative CRs.

USEPA policy must be considered to interpret the significance of the CR estimates. In the NCP (USEPA 1990), the USEPA states that for known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper-bound lifetime CR of between 1.0E-06 and 1.0E-04 (i.e., USEPA's target CR range).

K2.5.2 Estimation of Non-Carcinogenic Hazard for Metal Exposures

The potential for non-carcinogenic health effects resulting from exposures to individual metal COPCs was evaluated by the calculation of an HQ. An HQ is the ratio of the exposure duration-averaged estimated daily intake through a given exposure route, to the chemical and route-specific (i.e., oral, inhalation, or dermal) RfD or RfC, calculated as follows

$$HQ = \frac{Dose}{Toxicity\ Value}$$

where:

HQ = hazard quotient (unitless);
$Dose$ = Oral CDI (mg/kg-day), or DAD (mg/kg-day), or air EC ($\mu g/m^3$) for inhalation;
$Toxicity\ Value$ = Oral or dermally adjusted RfD_o or RfD_d, (microgram of chemical per kilogram body weight per day [μg/kg-day]) or inhalation RfC (mg/m^3).

Use of the RfD or RfC assumes that there is a level of intake (the RfD or RfC) below which it is unlikely that even sensitive individuals, such as children, will experience adverse health effects over the period of exposure. If the average daily intake exceeds the RfD or RfC (i.e., if the HQ exceeds 1.0), then there may be cause for concern for potential non-cancer, systemic effects (USEPA 1989a). It should be noted, however, that the level of concern does not increase linearly as the RfD or RfC is approached or exceeded. Because the HQ does not define a dose-response relationship, its numerical value cannot be construed as a direct estimate of risk (USEPA 1989a). Rather, an HQ greater than 1.0 indicates a potential cause for concern for non-cancer health effects, which might indicate the need for re-evaluating actual exposure conditions or concentrations or consideration of risk management alternatives.

To assess pathway-specific exposures to multiple metals, the HQs over all metal COPCs are summed to yield an HI. The assumption of additive effects reflected in the HI is most properly applied to substances that induce the same effect by the same biological mechanism (USEPA 1989a). Consequently, summing HQs for substances that are not expected to induce the same type of toxic effect will overestimate the potential for adverse health effects. The HI provides a measure of the potential for adverse effects, but it is conservative and dependent on the quality of experimental evidence.

If a receptor is exposed by multiple pathways, then the HIs from all relevant pathways are summed to obtain the total HI for that receptor. If the total HI is less than or equal to 1.0, then multiple-pathway exposures to COPCs at the site will be judged unlikely to result in an adverse effect. If the total HI is greater than 1.0 then further evaluation of exposure assumptions and toxicity, including consideration of specific target organs affected and mechanisms of toxic actions of COPCs, are warranted to ascertain if the cumulative exposure would, in fact, be likely to harm exposed individuals. However, given that arsenic and cadmium are the only two metal COPCs being evaluated, and they affect different target organs, the evaluation of target organs and critical effects was not necessary in this HHRA.

K2.5.3 Determination of Area-Weighted Average Doses and Risks for Combined Inaccessible and Accessible Soil Evaluations

Combined inaccessible and accessible soil evaluations of dose and risk are conducted for the sitewide and property-specific industrial worker scenarios. Similarly, combined inaccessible and accessible soil evaluations of dose and risk are conducted for the recreational user scenarios, though the evaluations are limited to the three properties (DT-2, DT-9 Levee and DT-15) containing the St. Louis Riverfront Trail, which runs along the levee. The recreational user is evaluated for dose and risk under property-specific scenarios as well as for dose and risk for all three properties combined.

For both the industrial worker and recreational user, dose and risk are each calculated as the weighted average between the inaccessible soil area and the accessible soil area for each sitewide and property-specific evaluation. Area-weighted averaging is being applied to dose and risk, rather than to EPCs, because the area-weighting of EPCs does not allow for a means by which ground cover can be applied to inaccessible area soils, while not applying it to accessible area soils, in the RESRAD model. The inaccessible and accessible sampling locations and data for all properties evaluated are presented in figures and tables in Appendices E and L, respectively. In all figures within both appendices, the inaccessible soil areas are presented as the cross-hatched areas. The following equation is used for calculating area-weighted averages of radiological dose for each sitewide and property-specific scenario:

$$Dose_{AW} = \frac{(Dose_I \times Area_I) + (Dose_A \times Area_A)}{Area_T}$$

where:

$Dose_{AW}$ = area-weighted average radiological dose (mrem/yr);
$Dose_I$ = radiological dose for inaccessible area (mrem/yr);
$Dose_A$ = radiological dose for accessible area (mrem/yr);
$Area_I$ = size of inaccessible area (m^2);
$Area_A$ = size of accessible area (m^2); and
$Area_T$ = size of total area (sum of inaccessible and accessible areas) (m^2);

The following equation is used for calculating area-weighted averages of risk (i.e., radiological CR, metal CR, or metal HI) for each sitewide and property-specific scenario:

$$Risk_{AW} = \frac{(Risk_I \times Area_I) + (Risk_A \times Area_A)}{Area_T}$$

where:

$Risk_{AW}$ = area-weighted average of radiological CR, metal CR or metal HI (unitless)

$Risk_I$ = radiological CR, metal CR or metal HI for inaccessible area (unitless);
$Risk_A$ = radiological CR, metal CR or metal HI for accessible area (unitless);
$Area_I$ = size of inaccessible area (m^2);
$Area_A$ = size of accessible area (m^2); and
$Area_T$ = size of total area (sum of inaccessible and accessible areas) (m^2);

K2.5.4 Risk and Dose Characterization of the Inaccessible Soil Operable Unit

Sections K2.5.4.1 through K2.5.4.9 describe the medium- and property-specific radiological and metal dose and risk results, estimated by receptor scenario, which have been determined for the SLDS ISOU. 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 Sections K2.5.4.1 through K2.5.4.9 (no exceedances of the target HI occur for any of the evaluated scenarios).

All radiological and metals doses and risks estimated for SLDS background soil and sewer sediment are presented for each receptor scenario in Tables K-11A and K-11B, respectively. 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 K-12, K-13A, K-14, K-15A, K-16A, K-17, K-18, K-19A, and K-20A. 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 K2.5.4.1 through K2.5.4.9, all discussions of dose pertain to dose above 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 risks estimated as being within or less than the corresponding background doses and risks, 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.

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 K-13B, K-15B, K-16B, K-19B, K-20B, and K-20C. 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 model results). All SLDS doses and risks below corresponding background doses and risks are also noted in the tables.

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.

Finally, as discussed previously, a hypothetical resident gardener scenario was evaluated but is presented separately, in Attachments K-1 and K-2 to this appendix. This is because current land use is predominantly industrial/commercial, and land use is expected to remain as such for the foreseeable future; therefore, it is recommended that scenarios assuming industrial land use be used as the basis for determining future actions at the ISOU. The hypothetical resident gardener was evaluated as an unlimited use and unrestricted exposure scenario for only informational purposes to facilitate future decision making as needed. As discussed in Attachment K-1, weight-of-evidence considerations generally suggest that doses and risks estimated for a resident gardener scenario represent overestimations of actual doses and risks associated with inaccessible soil.

K2.5.4.1 Current Industrial Worker Exposures to Radiological COPCs in Inaccessible Soil and Combined Inaccessible and Accessible Soil at All Properties

Table K-12 presents the maximum total radiological dose and CR results, estimated to occur over the 1,000-year evaluation period, for sitewide and property-specific inaccessible soil exposures to current industrial workers. Property-specific scenarios were evaluated over 28 SLDS properties (4 plant properties, 10 industrial/commercial VPs, 6 RR VPs, and 8 roadways). Inaccessible soil dose and risk were calculated assuming a 0.3-m-thick soil cover is in place. Additionally, combined inaccessible and accessible soil dose and risk were calculated under the assumption of ground cover being present in all inaccessible soil areas and no ground cover being present in the accessible soil areas. The risk and dose for the combined inaccessible and accessible soil areas were calculated as area-weighted averages of the risks and doses estimated for the inaccessible and accessible areas, in order to calculate property-wide risk estimates. The current industrial worker was not evaluated for health risks associated with metal COPCs in inaccessible soil, because there are no complete exposure pathways for metal COPCs due to the presence of ground cover.

For inaccessible soil, the maximum total radiological sitewide dose, as well as the maximum total dose estimates for all 28 properties, are less than the target criterion of 25 mrem/yr. The maximum total radiological CRs estimated for inaccessible soil sitewide, as well as for 25 of the total 28 properties evaluated, are either within or exceed the USEPA's target CR range. The St. Louis Riverfront Trail properties (DT-2, DT-9 Levee, and DT-15) are the only three properties for which CRs are estimated to be less than USEPA's target CR range. CR estimates for inaccessible soil are greatly reduced when considering only CRs above background. Most inaccessible soil CRs above background are within USEPA's target range. However, the inaccessible soil CRs above background estimated for Plant 2 and DT-34 are less than the target CR range for the current industrial worker.

Radiological dose and risk for combined inaccessible and accessible soil was assessed both sitewide and at 20 properties. The eight roadways were not evaluated for combined inaccessible and accessible soil exposures because these areas consist only of inaccessible soil. The maximum total sitewide dose and the maximum total dose estimates for all 20 properties, are less than the target criterion of 25 mrem/yr. The maximum total CRs estimated for combined inaccessible and accessible soil for the sitewide scenario, as well as for the CRs estimated for all 20 of the evaluated property-specific scenarios, are either within or exceed the USEPA's target CR range. CR estimates for combined inaccessible and accessible soil are reduced when considering only CRs above background, with all CRs above background estimated as being 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.

In summary, radiological maximum total dose estimates 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.

K2.5.4.2 Future Industrial Worker Exposures to Radiological and Metal COPCs in Inaccessible Soil and Combined Inaccessible and Accessible Soil at All Properties

Table K-13A presents the maximum total radiological dose and CR results, estimated to occur over the 1,000-year evaluation period, for the sitewide and property-specific inaccessible soil exposures to current industrial workers. Property-specific scenarios were evaluated over 28 SLDS properties (4 plant properties, 10 industrial/commercial VPs, 6 RR VPs, and 8 roadways). For the future scenario, inaccessible soil dose and risk were calculated assuming that no ground cover is present. Additionally, combined inaccessible and accessible soil dose and risk were calculated under the assumption that ground cover is absent from both the inaccessible soil and accessible soil areas. The risk and dose for the combined inaccessible and accessible soil areas were calculated as area-weighted averages of the risks and doses estimated for the inaccessible and accessible areas, in order to calculate property-wide risk estimates.

For inaccessible soil, the maximum total radiological doses above background for Plant 1 (29 mrem/yr) and DT-4 North (45 mrem/yr) exceed the target criterion of 25 mrem/yr. The maximum total radiological CRs estimated for inaccessible soil for the sitewide scenario, as well as for 23 of the total 28 property-specific scenarios evaluated, exceed USEPA's target CR range. The inaccessible soil CRs for Mallinckrodt Security Gate 49 (8.4E-05) and DT-29 (9.4E-05) are within USEPA's target CR range. The inaccessible soil CRs for the 3 St. Louis Riverfront Trail properties are less than the target CR range.

Radiological dose and risk for combined inaccessible and accessible soil were assessed both sitewide and at 20 properties. None of the doses for these properties exceed 25 mrem/yr; for the future industrial worker, but the dose for one property (DT-4 North) is approximately equal to 25 mrem/yr. Of the 20 properties evaluated, the maximum total CR estimated for combined inaccessible and accessible soil for the sitewide scenario, as well as for the CRs estimated for 19 of the evaluated property-specific scenarios, exceed USEPA's target CR range. The combined inaccessible and accessible CR for DT-15 is within the target CR range. When considering combined inaccessible and accessible soil CRs above background, 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 range.

Table K-13B presents total CRs and non-carcinogenic HIs estimated for future industrial worker exposures to metal COPCs in inaccessible soil for the sitewide and 9 property-specific scenarios within the former uranium-ore processing boundary. The total CRs for all inaccessible soil scenarios are within USEPA's target CR range due to future industrial worker ingestion exposures to arsenic. The inaccessible soil CRs for Plant 2, Plant 6, DT-9 Main Tracks, and Hall Street are within the range of background. The HI values estimated for all future industrial worker exposures to inaccessible soil are less than the USEPA's target value of 1.0.

Total CRs and non-carcinogenic HIs were also estimated for future industrial worker exposures to metal COPCs in combined inaccessible and accessible soil sitewide and 6 property-specific scenarios (excluding the roadways) within the former uranium-ore processing boundary. The total CRs for all combined inaccessible/accessible soil scenarios are within USEPA's target CR range due to future industrial worker ingestion exposures to arsenic. All combined inaccessible/accessible soil CRs for the sitewide scenario and 6 property scenarios exceed background. The HI values estimated for all future industrial worker exposures to all combined inaccessible/accessible soil scenarios are less than the USEPA's target value of 1.0.

In summary, maximum total radiological dose estimates 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 are within USEPA's target CR range due to future industrial worker ingestion exposures to arsenic. The total CRs for 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.

K2.5.4.3 Current/Future Recreational User Exposures to Radiological COPCs in Inaccessible Soil and Combined Inaccessible and Accessible Soil at DT-2, DT-9 Levee, and DT-15

The current/future recreational user was evaluated for radiological exposures assumed to occur in three properties (DT-2, DT-9 Levee, and DT-15) containing the St. Louis Riverfront Trail both combined and individually. Table K-14 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 three properties. For the purpose of evaluating this receptor in the HHRA, the levee is assumed to be the ground cover that is always present in the inaccessible soil areas of these properties, at an assumed minimal thickness of 1 m. Accessible soil dose and risks are calculated under the assumption of no ground cover.

The maximum total radiological dose estimates for recreational user exposures to inaccessible soil at the three properties containing the St. Louis Riverfront Trail, both individually and combined, are all below the target criterion of 25 mrem/yr. The maximum total radiological CRs and the CRs above background estimated for inaccessible soil along the St. Louis Riverfront Trail within the three properties, both individually and combined, are all less than the USEPA's target CR range.

The maximum total radiological dose estimates for combined inaccessible/accessible soil for the three properties containing the St. Louis Riverfront Trail, both individually and combined, are all below the target criterion of 25 mrem/yr. However, the maximum total radiological CRs estimated for combined inaccessible/accessible soil for the combined three properties and for DT-2 and DT-9 Levee are within USEPA's target CR range. All estimates of CR above background for combined inaccessible/accessible soil for all property scenarios are less the target CR range.

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 three properties containing the St. Louis Riverfront Trail.

In summary, maximum total radiological dose estimates 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 three properties evaluated, both separately and combined, that contain the St. Louis Riverfront Trail. All maximum total 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.

K2.5.4.4 Current/Future Construction Worker Exposures to Radiological and Metal COPCs in Inaccessible Soil at All Properties

Table K-15A presents the maximum total radiological dose and CR results, estimated to occur over the 1,000-year evaluation period, for inaccessible soil exposures to current/future construction workers. The dose and risk evaluations were conducted for a sitewide scenario, as well as for property-specific scenarios. For the property-specific scenarios, a total of 28 SLDS properties were evaluated, (4 plant properties, 10 industrial/commercial VPs, 6 RR VPs, and 8 roadways). It was assumed that ground cover currently in place over inaccessible soil is absent due to excavation/construction activities. This receptor is assumed to have one-time exposures to inaccessible soil at all investigated depths.

All total maximum radiological dose estimates for inaccessible soil exposures to the current/future construction worker are below the target criterion of 25 mrem/yr for the sitewide scenario and property-specific scenarios. The maximum total CRs for the sitewide and all 28 evaluated property-specific scenarios for the current/future construction worker are within USEPA's target CR range. However, when CRs above background are considered for inaccessible soil, only the CRs for Plant 1, Plant 6, DT-4 North, DT-6, DT-9 Rail Yard, Terminal RR Soil Spoils Area, Buchanan Street, and Hall Street are within the target CR range. All other CRs are less than the target CR range and/or background.

Table K-15B presents potential health risks estimated for current/future construction workers associated with exposures to metal COPCs in a sitewide inaccessible soil scenario and eight property-specific inaccessible soil scenarios. Both the sitewide and property-specific scenarios evaluated exposures within the former uranium-ore processing boundary. Total CRs for construction workers are within USEPA's target CR range for the sitewide scenario and two of the eight property-specific scenarios (DT-10 and DT-12). 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.

In summary, evaluation of total 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 total 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.

K2.5.4.5 Current/Future Utility Worker Exposures to Radiological and Metal COPCs in Inaccessible Soil at All Properties

Table K-16A presents the maximum total radiological dose and CR results, estimated to occur over the 1,000-year evaluation period, for inaccessible soil exposures to current/future utility workers. The dose and risk evaluations were conducted for a sitewide scenario, as well as for property-specific scenarios. For the property-specific scenarios, a total of 28 SLDS properties were evaluated. It was assumed that ground cover currently in place over inaccessible soil is absent due to excavation. This receptor is assumed to have one-time exposures to inaccessible soil at all investigated depths where utilities could be present.

All total maximum radiological dose estimates for inaccessible soil exposures to the current/future utility worker are below the target criterion of 25 mrem/yr and/or background for both the sitewide scenario and the property-specific scenarios. The maximum total CRs estimated for the following property-specific utility worker scenarios are within USEPA's target CR range: Plant 1, DT-4 North, and DT-9 Rail Yard. The sitewide and all remaining property-specific scenarios are less than the target CR range. Consideration of CR above background results in only Plant 1 and DT-4 North being within the target CR range, with all remaining sitewide and property-specific scenarios being less than the target CR range and/or background.

Table K-16B presents potential health risks estimated for current/future utility workers associated with exposures to metal COPCs in a sitewide inaccessible soil scenario and eight property-specific inaccessible soil scenarios. 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.

In summary, total 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 total radiological CRs above background estimated for utility worker exposures are within the USEPA's target range for Plant 1 and DT-4, 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.

K2.5.4.6 Current/Future Industrial Worker Exposures to Radiological COPCs in Soil on Interior Surfaces of Buildings

Table K-17 presents the maximum total radiological dose and CR results, estimated to occur over the 1,000-year evaluation period, for industrial worker exposures to radiological COPCs on interior surfaces of building. Radionuclide-specific COPCs were identified for interior surfaces for which gross alpha survey measurements were found to exceed the PRG of 130 dpm/100 cm^2. EPCs were determined from the gross alpha measurements and were subsequently converted to radionuclide-specific surface concentrations (pCi/m^2) through unit conversions and applications of SLDS-specific soil activity fractions. The resulting radionuclide-specific EPCs were then entered into the RESRAD-BUILD model to calculate total maximum doses and risks associated with interior radiation exposures to industrial workers who labor mainly indoors. Site-specific soil activity fractions used to generate radionuclide-specific EPCs are presented in Table K-3A, and interior building surface EPCs are presented in Table K-3B. As shown in Table K-3B, interior surface EPCs were determined for seven buildings located on four properties (Plant 1, Plant 2, DT-6, and DT-10).

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.

K2.5.4.7 Current/Future Maintenance Worker Exposures to Radiological COPCs in Soil on Exterior Surfaces of Buildings

Table K-18 presents the maximum total radiological dose and CR results, estimated to occur over the 1,000-year evaluation period, for maintenance worker exposures to radiological COPCs on exterior surfaces of building/structures. Radionuclide-specific COPCs were identified for exterior surfaces for which gross alpha survey measurements were found to exceed the PRG of 3,200 dpm/100 cm^2. EPCs for exterior surfaces were determined using the same methodology used for interior surfaces, and then subsequently entered into the RESRAD-BUILD model to calculate total maximum doses and risks associated with maintenance workers who perform repair/maintenance or renovation work on building exteriors. As shown in Table K-3C, exterior surface EPCs were determined for three buildings located on two properties (Plant 1 and DT-10), and at DT-14 on a horizontal beam between the L-shaped building and brick warehouse.

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.

K2.5.4.8 Current/Future Sewer Maintenance Worker Exposures to Radiological and Metal COPCs in Sewer Sediment

Table K-19A presents the maximum total radiological dose and CR results, estimated to occur over the 1,000-year evaluation period, for current/future sewer maintenance worker exposures to sewer sediment. This receptor is evaluated for sitewide sewer sediment exposures to radiological COPCs, as well as for sewer sediment exposures to radiological COPCs at 26 individual manhole/surface drain locations within Plants 1, 2, 6, and 7 and near DT-11. All maximum total radiological doses and CRs estimated for this receptor are less than the target value of 25 mrem/yr and USEPA's target CR range, respectively.

Table K-19B presents health risks for current/future sewer maintenance workers associated with metal COPCs in sewer sediment inside of sewer lines. 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.

K2.5.4.9 Current/Future Utility Worker Exposures to Radiological and Metal COPCs in Soil Adjacent to Sewers

Table K-20A 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. For radiological COPCs, this receptor is evaluated for sitewide exposures to soil adjacent to sewer lines and for radiological exposures at 41 individual soil borings locations and sewer line excavations.

Of the sitewide and 40 individual locations evaluated, the maximum total radiological doses estimated for the following five locations exceeded the target value of 25 mrem/yr:

- 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).

The maximum total radiological CRs estimated for the following location exceeds the USEPA's target CR range:

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

The maximum total radiological CRs estimated for the following locations are within the USEPA's target CR range:

- 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.

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.

Potential health risks for current/future utility workers were estimated for exposures to the metal COPCs arsenic, cadmium, and lead in soil adjacent to sewer lines. Table K-20B 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 K-20C presents potential health risks for pregnant utility workers exposed to lead in soil adjacent to sewer lines. Lead is classified as a B2 carcinogen, and it has known non-carcinogenic effects; however, no toxicity values have been established for lead. The USEPA regulates lead exposure using a biomarker (PbB), which can be estimated using the ALM.

As previously discussed in Section K2.4.2.5, 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. The ALM assesses risk due to lead by predicting PbBs and comparing them to probability that a child will have a PbB greater than 10 µg/dL. This benchmark is used as the standard for evaluating risk from lead exposures.

Table K-20C presents the sitewide EPC for lead estimated across all samples collected from a total of 27 individual sampling locations. Additionally, the mean concentration of lead, calculated over all sampled depth intervals within each of the boring locations, is presented and used as the EPC for evaluating potential health risk to the utility worker at each boring location. Table K-20C also presents the predicted 95th percentile lead concentrations among fetuses of utility workers and the probability that fetal PbBs will exceed the established target of 10 µg/dL blood. 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.

K2.6 UNCERTAINTIES ANALYSIS

There are a number of factors that contribute uncertainty to the estimates of dose and risk presented in Section K2.5. These uncertainties are inherent to each of the main components of the risk assessment process, as described in the following subsections for the industrial land use scenarios.

K2.6.1 Sampling and Dataset Uncertainties

To reduce uncertainties associated with characterizing SLDS ISOU media that could be impacted, either directly or indirectly, from past MED/AEC operations, a combination of biased and random sampling strategies were employed. The objective of media characterization was to develop a health-conservative risk assessment that would not underestimate actual risks to potentially exposed populations. The criteria used for determining locations of biased samples in ISOU media are presented in the RI WP (USACE 2009a).

Because of limited access to some ISOU media, contamination was characterized but not fully delineated in all cases. It is unknown whether media characterization over- or underestimated potential human health risks to likely ISOU receptors. Certainly, datasets of limited size that were generated around elevated measurement areas could have resulted in overestimations of risks due to relatively large standard deviations for the data set, elevating the 95 percent UCLs and, consequently, the EPCs. In some cases, the 95 percent UCLs were greater than the maximum detected concentration, and in these cases, the maximum detected concentration was used as the default EPC. Although a health-conservative risk assessment is desired in the CERCLA process, a lack of sample coverage results in uncertainty, because it does not adequately represent the probability of exposures as a receptor moves randomly about the evaluated area/building.

K2.6.2 Analytical Data Quality

Some unavoidable uncertainty is associated with the contaminant concentrations detected and reported by the analytical laboratory. The quality of the analytical data used in the risk assessment depends on the adequacy of the set of procedures that specifies how samples are selected and handled and how strictly these procedures are followed. QA/QC procedures within the laboratories are used to minimize uncertainties; however, sampling errors, laboratory analysis errors, and data analysis errors can occur.

Some current analytical methods are limited in their ability to achieve detection limits at or below risk-based PRGs. Under these circumstances, it is uncertain whether the true concentration is above or below the PRGs, which are protective of human health. Analytes identified as COPCs associated with datasets consisting of a mixture of detected and non-detected concentrations and risk calculations may be affected by the reported detection limits. Risks may be overestimated as a result of some sample concentrations being reported as non-detected at the maximum detected concentration or MDL, which may be greater than the PRG (when the actual concentration may be much smaller than the maximum detected concentration or MDL). Risks also may be underestimated, because some analytes that are not detected in any sample are removed from the COPC list. If the concentrations of these analytes are below the maximum detected concentration or MDL but are above the PRGs, then the risk from these analytes would not be included in the risk assessment results. However, for the ISOU, COPCs were selected based on exceedances of industrial risk-based PRGs. In most cases, industrial risk-based PRGs are sufficiently elevated so that they were not generally exceeded by detection limits. Screening COPCs using strictly risk-based PRGs introduces uncertainty when the PRG is below site-specific background values, as is the case for Ra-226, Ra-228, U-238, and arsenic. If one of these analytes were detected at a concentration above the PRG but below the background value, then risk from these analytes would be included in the risk assessment results even though it is present at below background concentrations. The aforementioned uncertainties regarding PRGs and detection limits did not result in significant uncertainties in COPC selection and subsequent risk evaluations.

K2.6.3 Selection of Contaminants of Potential Concern

The list of COPCs evaluated for the ISOU media is based on the list of radionuclides and metals associated with past MED/AEC operations and on those constituents that were identified as COCs in the 1998 ROD (USACE 1998a). During the 1993 BRA (DOE 1993), other constituents, including VOCs, PAHs, and other metals (antimony, beryllium, cobalt, copper, and nickel), were detected in the soil but either did not significantly contribute risk (e.g., VOCs) or did contribute risk but were not included on the COC list in the 1998 FS (USACE 1998b) and subsequent 1998

ROD, because they were determined to not be MED/AEC-related constituents (e.g., antimony, copper, nickel, and PAHs). For consistency with the June 1990 FFA, constituents not directly associated with former MED/AEC operations, or constituents that are not mixed or commingled in the investigated ISOU media with MED/AEC-related constituents, were not evaluated in this HHRA even if CRs or HIs were determined to be above the USEPA target criteria during the 1993 BRA. Although it is agreed that non-MED/AEC contaminants can contribute to the overall dose/risk for a receptor, the scope of the FUSRAP ISOU, is all media not covered by the 1998 ROD that may have become contaminated as a result of the deposition or migration of MED/AEC-related contaminated media. Therefore, RI data were collected to support characterization and delineation of the likely sources of MED/AEC-related contamination. For metals, the area of sampling and dose and risk characterization was the former uranium-ore processing area. The actual source(s) of metals in each soil sample collected cannot be reasonably discerned because of the wide-spread distribution and prevalence of metals throughout the uranium-ore processing area.

Besides having been associated with MED/AEC operations, COPCs were identified in ISOU media as those radiological and metal constituents detected at concentrations exceeding the PRGs presented in Table 4-1. For interior and exterior building surfaces, all gross alpha measurements were compared to PRGs of 130 dpm/100 cm^2 and 3,200 dpm/100 cm^2, respectively, which were derived based on interior industrial worker and exterior maintenance worker scenarios as part of this RI/BRA report (See Appendix S). A building surface was retained for further risk evaluation if a gross alpha result exceeded the corresponding surface PRG. The uncertainty analysis for the use of RESRAD-BUILD in the derivation of surface PRGs is presented in Appendix S, Section S3.0.

K2.6.4 Exposure Assessment

Quantification of exposure provides an estimate of the chemical intake for various exposure pathways identified at the site. For the ISOU HHRA, uncertainties associated with the various components of the exposure assessment include those related to representative EPCs and exposure parameters.

K2.6.4.1 Soil Exposure Areas and Exposure Point Concentrations

For the SLDS HHRA, inaccessible and accessible soil exposure areas were determined for each property/receptor scenario. Obtaining adequate sample coverage in inaccessible areas was largely a function of field conditions during sampling events. Inaccessible areas with low sample coverage introduced uncertainty. The lack of sample coverage in some inaccessible areas affects EPCs, dose and risk characterization of those areas, as well as property-wide dose and risk characterization. For example, most of the inaccessible soil data used for the Plant 6 HHRA exist at the southwestern corner and western boundary (i.e., Hall Street). Little sample coverage was achieved beneath existing buildings in the eastern portion of the Plant 6 property. Therefore, the EPC calculated for all inaccessible areas (collectively) at Plant 6 mainly reflects the western and southwestern portions of the property. Combining all inaccessible and accessible soil data into one dataset to calculate EPCs would result in giving equal weight across all accessible and inaccessible samples at a property. This in turn could potentially "dilute out" the impacts of elevated inaccessible areas, or hotspots, given that many of the accessible areas have been remediated. For this reason, area weighting was conducted for dose and risk rather than for EPCs, realizing the possibility exists that inaccessible soil might be over-represented in the combined inaccessible/accessible calculations for the property, which could result in an overestimation of actual dose and risk for Plant 6 and other properties.

When performing calculations of inaccessible and accessible soil area fractions for each property with and existing PRAR/FSSE, the size of the accessible area used is the area established by the combined survey unit areas presented in the PRAR/FSSE. Because some survey units cross property boundaries, and may include samples outside of the property boundary, the size of the combined accessible area for the property could be overestimated. Because the estimated size of inaccessible areas is calculated as the difference between the total property area and the PRAR accessible area, the inaccessible area could be slightly underestimated. The actual impacts to dose and risk estimation as a result of overestimated accessible area fractions, along with the inclusion of sample locations just outside of the property boundary, vary with each property and are dependent on other factors, such as sample coverage and the presence of hotspots. For properties without a PRAR/FSSE, accessible and inaccessible areas were both estimated. The overall inaccessible area for a property was estimated based on RI sample coverage, and the overall accessible area was generally calculated to be the difference between the total property area and the estimated inaccessible area. This could result in either an over- or underestimation of dose and risk results, and could be subject to change as additional future actions may be conducted at those properties. All uncertainties associated with property-wide evaluations will become minimized in the FS, as the focus narrows more to the evaluations of individual elevated measurement areas, including those areas beneath buildings that are driving overall property dose and risk.

Analytical results are used to calculate a mean concentration and the 95 percent UCL on the mean concentration. The lesser of the maximum detected concentration or the 95 percent UCL was used as the EPC for the HHRA. For the data sets containing a small number of samples with high sample variability resulting in high standard deviations, the maximum detected concentration was used as the EPC, representing a worst-case scenario. Therefore, doses and risks generated for elevated measurement areas are likely to have been overestimated.

Uncertainty that can be introduced by the data aggregation process was minimized by utilizing the USEPA's ProUCL program. ProUCL applied statistical tests to determine the distribution that best describes the dataset for each chemical within the area of concern. For each COPC, ProUCL reports the 95 percent UCL associated with the distribution type that best describes the dataset of interest. In many instances, 95 percent UCLs are calculated using both detected values and samples reported as non-detected. For data sets with non-detected results, ProUCL creates extrapolated values for non-detected results obtained using regression on order statistics. The EPC was determined to be the lesser of the maximum detected concentration versus the calculated 95 percent UCL. This method may moderately overestimate the EPC. In addition, when the resulting individual contaminant risks are summed to provide a total CR or HI, the compounding conservatism of this method for estimating EPCs likely has resulted in an overestimation of the total risk.

Additionally, it is conservatively assumed that chemical concentrations detected under current site conditions will remain constant for evaluations of future exposure scenarios. In other words, the measured concentrations (and resulting EPCs) are not reduced by loss due to natural removal processes such as volatilization, leaching, and/or biodegradation. This assumption is a source of uncertainty that tends to overestimate future exposure concentrations.

K2.6.4.2 Exposure Assumptions

For each exposure pathway chosen for analysis in the HHRA, assumptions are made concerning the exposure parameters (e.g., amount of contaminated media a receptor can be exposed to and intake rates for different routes of exposure) and the routes of exposure. The assumptions used are consistent with USEPA-approved default values, which are assumed to be representative of potentially exposed populations. However, in some cases, rather than apply default values, professional judgment was applied to allow for more realistic estimates. Examples of this are the exposure frequencies of 10 days for the duration of a small project involving utility work, and the assumption that a sewer maintenance worker will only work at each location one day per year.

For RESRAD evaluations, exposure parameters were selected to provide a conservative yet reasonable estimate of potential risks to each receptor. Site-specific measurements and data were used, as appropriate, to describe site conditions as accurately as possible. Where site-specific data were not available, standard default values were used or parameter values recommended by the USEPA's *Exposure Factors Handbook: 2011 Edition* (2011b) were chosen to provide reasonably conservative estimates of risk. For all scenarios, the RESRAD model assumes that contamination is always uniformly spread over the area assessed and is never covered in either the inaccessible or accessible soil areas. Assuming no cover over the contaminated zone, while applying the most reasonably maximum exposure scenario (i.e., the industrial worker), allows for a consistent assessment of dose and risk across all areas and provides a starting point for the dose and risk-based evaluations in the FS to support development of remedial alternatives.

Another area of uncertainty due to exposure assumptions is the application of direct contact exposure assumptions to inaccessible soils. This HHRA evaluates property-wide dose and risk for inaccessible soil, and for combined inaccessible and accessible soil at each property. For future exposure scenarios, the HHRA assumes that inaccessible soil has become accessible due to degradation or complete loss of ground cover. The types of ground cover that exist at the SLDS under current configurations includes, but may not be limited to, buildings, RRs, roadways, and pavement. Assuming direct contact with soils located beneath buildings or other permanent structures is highly conservative and tends to overestimate risk due to direct contact with inaccessible soils.

For the indoor and outdoor building occupancy scenario, actual areas of elevated activity were spotty, small, and non-removable compared to the uniform, partially removable contaminated area assumed in the model. Because the primary pathway for risk for the building occupancy scenario is inhalation, which is dependent on the level of removable contamination, assuming a higher-than-actual level of removable contamination results in overestimation of risk. Additionally, for these scenarios, gross alpha survey data were multiplied by SLDS COC activity fractions to get individual COC concentration values needed to estimate risk. This assumes that MED/AEC-related COC contamination on structures was at the same fraction of activity as that found in the soil. Because individual COC SFs vary, actual risk may vary depending on actual activity fractions.

The accuracy of exposure calculations is ultimately limited to the accuracy of the site data and RESRAD models. The data used in the assessment include results from several characterization efforts and include different target analytes, analysis methods, and reporting requirements. The data in this assessment are used assuming the best knowledge of the distribution of contaminants in site soil, with the goal of providing conservative yet reasonable estimates of risk. The models used to calculate risk and dose are approved by the USEPA and are designed to provide a reasonable prediction of site exposures that would not underestimate actual risks to potentially exposed populations.

K2.6.5 Toxicity Assessment

Uncertainties are inherent in the toxicity factors used to determine CRs for both radiological and metal COPCs, as well as for RfDs and RfCs used to determine HIs for metal COPCs.

K2.6.5.1 Toxicity Assessment for Radiological Contaminants of Potential Concern

In October 1999, Washington State University, under contract to the USACE, published a report titled *Determination of the In Vitro Dissolution Rates of Selected Radionuclides in Soil and Subsequent ICRP 30 Solubility Classification for Dosimetry* (WSU 1999). This report was used to support radiological dose and risk estimates for the HHRA. In vitro dissolution rates are broken into three classes: D, W, and Y (day, week, and year). Class D, W, and Y refer to retention time in the respiratory system and not necessarily retention time/exposure to the target organ. Sometimes the Class D or W is more limiting than the Class Y. Generally, RESRAD uses the most limiting dose conversion factor (whether it is Class D, W, or Y) for all COPCs.

Lifetime CR estimates are provided for exposure to chemical contaminants and are compared to the lower boundary of the CERCLA target risk range of 1.0E-06 to 1.0E-04. Although cancerous effects have only been detected at doses several orders of magnitude larger than those estimated at the SLDS, it is assumed that the SFs apply to both large and small radiological doses. Metal SFs are developed mostly from animal studies, and SFs for radionuclides and metal constituents incorporate several differences that may result in incompatibility. The USEPA, therefore, acknowledges a large (undefined) uncertainty in risk estimates and recommends that radiological and metal risks be presented separately (USEPA 1996b).

Radiological risk SFs have been developed primarily using data from groups such as the Japanese atomic bomb survivors. These individuals received large doses of radiation over a short period of time. By contrast, potential receptors in this assessment receive relatively small radiological doses over a long period of time. In addition, the calculations of SFs are based on radium dial painter studies, atomic bomb survivor studies, etc., each considering doses many orders of magnitude higher than those received at environmental levels.

A series of reports published by the National Research Council's Committee on the Biological Effects of Ionizing Radiation lists additional uncertainties resulting from the use of CSFs for radionuclides. The National Research Council's Committee on the Biological Effects of Ionizing Radiation report points out that CRs from exposure to radionuclides at ambient environmental levels (typical background radiation produces approximately 300 mrem/yr) are very difficult to distinguish from background cancer rates. The applicability of the linear no-threshold model has been debated by many professional societies. However, the linear no-threshold model (i.e., assuming risk is linear with exposure and is possible for even the smallest doses) has been adopted by all relevant U.S. regulating agencies. Using this model, risks at environmental levels are calculated even at dose levels a small fraction of background.

The determination of background at the SLDS may have been complicated by the presence of surficial fill consisting of brick, concrete, organic material, and coal slag with minor sand, coal ash, coal cinders, and silt that was used throughout the SLDS. A generalized stratigraphic column for the surficial fill present at SLDS is shown on Figure 3-1. BVs of some radionuclides and metals at the SLDS may be influenced by the presence of mixed fill materials.

K2.6.5.2 Toxicity Assessment for Metal Contaminants of Potential Concern

The methodology used to develop a non-carcinogenic toxicity value (RfD or RfC) involves identifying a threshold level below which adverse health effects are not expected to occur. The RfD and RfC values are based on studies of the most sensitive animal species tested (unless adequate human data are available) and the most sensitive endpoint measured. Uncertainties exist in the experimental dataset for such animal studies. These studies are used to derive the experimental exposure representing the highest dose level tested at which no NOAEL is demonstrated; however, only an LOAEL is available. The RfD and/or RfC is derived from the NOAEL (or LOAEL) for the critical toxic effect by dividing the NOAEL (or LOAEL) by uncertainty factors. These factors usually are in multipliers of 10, with each factor representing a specific area of uncertainty in the extrapolation of the data. For example, an uncertainty factor of 100 is typically used when extrapolating animal studies to humans. Additional uncertainty factors are sometimes necessary when other experimental data limitations are found. Because of the large uncertainties (10 to 10,000) associated with some RfD or RfC toxicity values, exact safe levels of exposure for humans are not known. For non-carcinogenic effects, the amount of human variability in physical characteristics is important in determining the risks that can be expected at low exposures and in determining the NOAEL (USEPA 1989a).

The toxicological data (SFs and RfDs) for dose-response relationships of metals are frequently updated and revised, which can lead to over- or underestimation of risks. These values are often extrapolations from animals to humans, and this can also cause uncertainties in toxicity values, because differences can exist in metal absorption, metabolism, excretion, and toxic response between animals and humans.

The USEPA considers differences in body weight, surface area, and pharmacokinetic relationships between animals and humans to minimize the potential to underestimate the dose-response relationship; as a result, more conservatism is usually incorporated into these steps. In particular, toxicity factors that have high uncertainties may change as new information is evaluated. Therefore, COPCs associated with high uncertainties in toxicity studies may be subject to regulatory change in the future. Finally, the toxicity of a contaminant may vary significantly with the metal form present in the exposure medium. For example, risks from metals may be overestimated, because they are conservatively assumed to be in their most toxic forms.

The carcinogenic potential of a metal can be estimated through a two-part evaluation involving: (1) a weight-of-evidence assessment to determine the likelihood that a metal is a human carcinogen, and (2) an SF assessment to determine the quantitative dose-response relationship. Uncertainties occur with both assessments. With respect to the likelihood that a chemical is a carcinogen, chemicals are categorized into 1 of 5 groups on the basis of weight-of-evidence studies of humans and laboratory animals (USEPA 2005): (1) Group A – known human carcinogen; (2) Group B – probable human carcinogen based on limited human data or sufficient evidence in animals, but inadequate or no evidence in humans; (3) Group C – possible human carcinogens; (4) Group D – not classified as to human carcinogenicity; and (5) Group E – evidence of no carcinogenic effects in humans.

The SF for a chemical is a plausible upper-bound estimate of the probability of a response per unit intake of a metal over a lifetime. It is used to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen. The SF is derived by applying a mathematical model to extrapolate from a relatively high, administered dose to animals to the lower exposure levels expected for humans. The SF represents the 95 percent UCL on the linear component of the slope (generally the low-dose region) of the tumorigenic dose-response curve. A number of low-dose extrapolation models have been developed, and the USEPA uses the linearized multi-stage model in the absence of adequate information to support other models. Therefore, methods used to derive SFs result in an overestimation of CRs in the HHRA.

Although the HHRA shows arsenic to be the only metal to exceed target risk levels, lead was also identified as a COPC in soil adjacent to sewers. Lead is classified as a B2 carcinogen, and it has known non-carcinogenic effects; however, no toxicity values have been established for lead. In comparison to most other environmental contaminants, the degree of uncertainty about the health effects of lead is quite low. Some of these effects, particularly changes in the levels of certain blood enzymes and in aspects of children's neurobehavioral development, may occur at PbBs so low as to be essentially without a threshold. For the SLDS, the ALM was used to associate environmental exposures with risk and inform cleanup decisions (relative to OSWER's risk reduction goal). The ALM was used to calculate both the probability that fetal PbBs would exceed the target level of 10 μg Pb/dL blood and to derive cleanup levels.

Based on recommendations of the Technical Review Workgroup for Lead, the ALM was run using updated ranges for the baseline PbB and GSD_i. However, recent scientific evidence has demonstrated adverse health effects at blood lead concentrations below 10 μg/dL down to 5 μg/dL, and possibly below. The USEPA is developing a new soil lead policy to address this new information. Uncertainty does exist regarding the adverse health effects for blood lead, however, until USEPA's new soil lead policy is finalized, the ALM run for the SLDS ISOU BRA is consistent with current guidance.

K2.6.6 Risk Characterization

Uncertainties inherent in risk characterization reflect the uncertainties inherent in all risk assessment elements leading up to the calculation of doses, CRs, and HIs. Uncertainties specific to the risk characterization of ISOU media are discussed below.

K2.6.6.1 Summation of Cancer Risks Across Radiological and Metal Contaminants of Potential Concern

Doses and CRs were estimated for both radiological and metal COPCs in inaccessible soil, accessible soil, sewer sediment, and soil adjacent to sewers. Gross alpha activity was evaluated for interior and exterior building surfaces. In areas where both radiological and metal CRs were estimated for inaccessible soil, the radiological and metal CRs are presented separately and were not summed together for the purpose of determining a total cumulative CR. The USEPA's RAGS, Volume I, Part A, (USEPA 1989a) cautions against combining radiological and chemical risks, because the derivations of SFs for radionuclides and metals are specific to distinct models incorporating different assumptions. USEPA outlines these differences in the *Radiation Exposure and Risk Assessment Manual* (USEPA 1996b). The major differences include the following.

- The radiological endpoint is fatal cancer – the endpoint for metals exposures is tumorigenic cancer or non-carcinogenic risk.
- Radiological risk estimates are based primarily on human data – metals risk estimates are based primarily on animal studies.
- Radiological risk estimates are based on the central estimate of the mean – metals risk estimates are based on 95 percent UCL of the mean.

Additionally, background radiation is ubiquitous at levels exceeding typical risk targets and natural variability may preclude the ability to quantify small incremental risks due to radiological contamination (USEPA 1996b). Therefore, risks calculated for radionuclides and metals were assessed separately and not summed together for the estimation of cumulative CRs.

K2.6.6.2 Summation of Non-Carcinogenic Hazard Indices

Uncertainties related to the summation of HQs and CRs across chemicals and pathways are generally a primary uncertainty in the risk characterization. In the absence of information on the toxicity of specific chemical mixtures, it is assumed that CRs and HQs are additive (i.e., cumulative) (USEPA 1989a). The limitations of this approach for non-carcinogens are: (1) the effects of a mixture of chemicals are generally unknown – it is possible that the interactions could be synergistic, antagonistic, or additive; (2) the RfDs have different accuracy and precision and are not based on the same severity or effect; and (3) HQ or intake summation is most properly applied to compounds that induce the same effects by the same mechanism. Therefore, the potential for occurrence of non-carcinogenic effects can be overestimated for chemicals that act by different mechanisms and on different target organs. In the HHRA, the metal COPCs exhibiting carcinogenic effects were arsenic and cadmium. Table K-10C shows that these metals affect different target organs and induce different systemic effects; therefore, summation results in an overestimation of the HIs calculated for each receptor.

K2.6.6.3 Risk Characterization of Lead Detected in Sewer Soil Boreholes

Lead concentrations were detected at several sewer soil locations at Plants 1, 2, 6, and Plant 7N/DT-12, as well as at DT-11, that exceed the 800-mg/kg industrial PRG. Although lead is classified as a B2 carcinogen and has known non-carcinogenic effects, no toxicity values have been established for lead. For the HHRA, the ALM was used to calculate both the probability that fetal PbBs would exceed the target level of 10 µg Pb/dL blood and to derive cleanup levels. This evaluation will be used to assess the need for further remediation during the FS. Results of the ALM model runs are presented in Appendix Q.

K2.6.6.4 Risk Characterization Including Background Levels

In the HHRA, SLDS background values are not subtracted from site concentrations or added to PRGs in order to reflect concentrations above SLDS background. Background is not subtracted from PRGs or concentration values used to develop EPCs prior to quantifying risk. Rather, background is used only for characterization purposes. Property dose and risk calculated without subtracting background may be grossly overestimated. This is a highly conservative assumption that tends to overestimate site risk.

K3.0 SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT

The SLERA for the SLDS ISOU has been conducted documenting the process for evaluating the likelihood that the presence of radiological and metal PCOCs identified in ISOU media may adversely affect ecological receptors. The ISOU SLERA follows guidance provided in the USEPA's ERAGS (USEPA 1997b) and the USACE's *Environmental Quality – Risk Assessment Handbook, Volume II: Environmental Evaluation* (USACE 2010b). The entirety of the USEPA's SLERA process is comprised of the following eight steps:

- Step 1: Screening-Level Problem Formulation and Ecological Effects Evaluation
- Step 2: Screening-Level Preliminary Exposure Estimate and Risk Calculation
- Step 3: Baseline Risk Assessment Problem Formulation
- Step 4: Study Design and Data Quality Objectives
- Step 5: Field Verification of Sampling Design
- Step 6: Site Investigation and Analysis of Exposure and Effects
- Step 7: Risk Characterization
- Step 8: Risk Management.

In order to determine those steps that are most appropriate for the ISOU, the USACE reviewed the 1993 BRA, which evaluated potential receptor exposures to soil (mostly accessible), sediment, and surface water at the accessible soils OU. No field/laboratory investigations were conducted to determine the extent to which biota had been affected from past MED/AEC operations at the SLDS. The 1993 BRA primarily consisted of comparisons of contaminant concentrations reported for accessible environmental media with toxicity-based radiological and chemical threshold values available in literature. These comparisons were conducted in conjunction with in-depth toxicity assessments of radiological and chemical contaminants identified during the 1993 BRA and evaluations of other weights-of-evidence (e.g., actual contaminant fate and transport characteristics, exposure pathways, site characteristics, receptor characteristics, etc.) to assess if significant adverse ecological effects could be occurring at the SLDS.

The 1993 BRA concluded that the significance of contaminated media at the SLDS in regard to ecological resources is minimal due to the urban environment, limited wildlife habitat, and biotic diversity, and stated the following:

> *"...the significance of the St. Louis Site with regard to ecological resources is minimal, and intensive field analysis for possible impacts to biota from site contaminants is not warranted. Therefore, future efforts should emphasize concerns that related to human health effects, especially because radiological risks at the St. Louis Site are generally higher than chemical risks to humans by one order of magnitude"* (DOE 1993).

Therefore, all subsequent investigative and remediation activities conducted under the 1998 ROD focused on protection of human health. However, remedial actions being undertaken at the SLDS accessible OU are expected to be protective of both human health and the environment upon completion and to have reduced the likelihood that ISOU media will be impacted by accessible soil contamination.

Based on the results of the 1993 BRA, in conjunction with the results of a site visit to the ISOU in September 2010, only the completion of a portion of the Step 1 Problem Formulation was required for the ISOU in order to make one of three possible decisions at the end of the SLERA (USEPA 1997b): (1) there is adequate information to conclude that ecological risks are negligible, (2) the information is not adequate to make a decision, and the ecological risk assessment process moves to Step 3 (Baseline Ecological Risk Assessment), or (3) the information indicates a potential for adverse ecological effects, and more thorough assessment is warranted.

The following sections present the applicable portions of the Problem Formulation used to complete the ISOU SLERA.

K3.1 SLERA STEP 1 – SCREENING LEVEL PROBLEM FORMULATION

The first step of USEPA's approach to the SLERA process, Problem Formulation, includes:

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

K3.1.1 Environmental Setting and Contaminants at the Site

K3.1.1.1 Environmental Setting

A site visit was conducted on September 10, 2010, to gather information necessary for completing the USEPA's Ecological Checklist (see Appendix R) regarding current environmental conditions at the ISOU relative to potential receptors. The SLDS is located in downtown St. Louis, Missouri, in an industrial land use area situated north of the city's center. The ground surface across the site is relatively flat, with a surface elevation of approximately 430 ft amsl in the southwestern part of the site to 420 ft amsl near the Mississippi River. Figure R-1 in Appendix R presents the topographic characteristics of the SLDS.

The SLDS has been continuously occupied since the 1800s and contains a number of industrial facilities. These facilities include the former Mallinckrodt facilities used in the production of nuclear fuel, a large metal recycling facility, a salt production facility, and several railway lines. The entire site, which encompasses approximately 210 acres of land, is highly disturbed, with areas containing several feet of fill material common throughout the site. A 500-year levee and floodwall separate the Mississippi River and the St. Louis Riverfront Trail from the industrial portions of the site.

The SLDS occupies the Oak-Hickory-Bluestem Parkland section of the Prairie Parkland Province. Pre-settlement vegetation is characterized by deciduous woodlands intermixed with open prairie. Today, the ecological resources at the SLDS are limited because of the site's location within an urban area of concentrated industrial and commercial developments (DOE 1993).

Of the 210 acres of total SLDS area, approximately 86 acres comprise the ISOU land area. There are no natural flowing or non-flowing water bodies at the ISOU with surface water or sediment. Any surface drainage from the ISOU (rain water, SLDS-generated, etc.) is directed by combined sanitary and sewer lines off-site to the MSD treatment plant (i.e., the Bissell Plant).

No wetlands occur within the ISOU, although according to the USFWS's National Wetlands Inventory (USFWS 2008), a portion of the SLDS area directly north of the McKinley Bridge and east of the Mississippi River levee is classified as palustrine wetlands (i.e., non-tidal wetlands that are substantially covered with emergent vegetation), which are commonly found along the Mississippi River. However, this area is not part of the ISOU, and based on the "Environmental

Assessment for Biota" presented in the 1993 BRA, no potentially sensitive habitats for biota occur either on or adjacent to the SLDS (DOE 1993).

There is limited ecological habitat at the ISOU. There are buildings, roads, sidewalks, and parking lots in active use, along with strips of disturbance-tolerant vegetation. Of the approximately 86 acres of ISOU land area, almost 6 acres contain vegetation. Therefore, the total ISOU land area covered by vegetation is approximately 7 percent of the ISOU land area and 3 percent of the SLDS land area. The limited vegetation, lack of suitable cover, and high level of disturbance is unattractive to wildlife. Only the hardiest urban receptors would use the site. No federal or Missouri threatened and endangered (T&E) species exist at the SLDS including the ISOU. Additional information addressing the overall environmental setting of the SLDS, including (1) topography, drainage, and surface water, (2) site geology and hydrogeology, and (3) ecological resources is presented in Sections 3.2, 3.3, and 3.4, respectively. The vegetation, wildlife, and habitats observed during the site visit are described in the Ecological Checklist (Appendix R).

K3.1.1.2 Contaminants in Inaccessible Soil and Soil on Buildings

As discussed in detail in Section 2.1, the inaccessible soil PCOCs selected in the RI WP as the starting point for the ISOU RI were those radionuclides and metals identified as COCs in the 1998 ROD (i.e., the primary radioactive contaminants in soil and sediment at the SLDS, including Ac-227, Pa-231, Ra-226, Ra-228, Th-228, Th-230, Th-232, U-235, and U-238, and the metal contaminants including arsenic, cadmium, and uranium metal) (USACE 1998a).

The derivation of chemical contaminants potentially attributable to MED/AEC operations indicated that chemical contamination consists primarily of elemental metal compounds resulting from uranium-ore processing operations in specific areas of the SLDS (USACE 1998b). The plant properties within the boundary where the uranium-ore processing was conducted by MED/AEC are Plant 2, Plant 6, and Plants 7N and 7S (Figure 1-2). Some VPs that are adjacent to these plant areas were also included in the MED/AEC uranium-ore processing area due to potential migration of contaminants. These VPs include DT-10, portions of DT-9 between Plants 2 and 6, portions of DT-12 adjacent to Plants 6 and 7, portions of Destrehan Street adjacent to Plant 2, Plant 6, Plants 7N and 7S, Hall Street between Plants 2 and 6, and portions of Mallinckrodt Street adjacent to Plant 2 (Figure 1-2). All other plant properties and VPs are outside of the uranium-ore processing area and, therefore, only have radiological PCOCs.

The same radiological PCOCs for soils are being evaluated for the building and structural surfaces. The 1993 BRA stated that chemical contaminants were not applicable to building surfaces; therefore, there are no metals PCOCs for building and structural surfaces (DOE 1993).

The list of PCOCs for the ISOU soil was defined as those radiological and chemical contaminants identified as being attributable to MED/AEC contamination, as shown in Table K-21.

K3.1.1.3 Contaminants in Sewer Sediment and Soil

The same radiological PCOCs for soils are being evaluated for sediment in sewers used for MED/AEC operations, as well as the soil adjacent to those sewers. Additionally, sewer sediment and soil adjacent to sewers used for MED/AEC operations were not analyzed for metals during past investigations; therefore, all metals associated with formerly used pitchblende and domestic ores were identified as PCOCs for sampling and analysis of sediment and soil adjacent to sewers

(See Table K-22). These metals include arsenic, cadmium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, thorium-metal, uranium-metal, vanadium, and zinc.

The list of PCOCs for the ISOU sewer sediment and soil adjacent to sewers was defined as those radiological and chemical contaminants identified as being attributable to MED/AEC contamination, as shown in Table K-22.

K3.1.2 Contaminant Fate and Transport

As discussed in Section 4.0, exceedances of human health PRGs were noted for inaccessible soil, sewer sediment, soil adjacent to sewers and building surfaces within the ISOU. However, the majority of the inaccessible soil is beneath ground cover present in the forms of buildings/structures, the levee, RRs, and roadways. As discussed in Section 5.0, the presence of the ground cover greatly reduces or mitigates surface release and transport mechanisms such as volatilization, fugitive dust, erosion, runoff, and leaching. Likewise, ground cover greatly reduces or mitigates subsurface release and transport mechanisms such as vertical leaching processes and horizontal migration in ground water because of the lack of infiltration from precipitation. There is currently no evidence of significant contaminant transport via ground water to more sensitive aquatic habitats offsite. However, further evaluation of potential risks to the environment from site ground water will be conducted as part of the Ground-Water Remedial Action Alternative Assessment initiated under the 1998 ROD. The information discussed previously concerning contaminant fate and transport was used in Section K3.1.2.2 to facilitate development of the CSM, which is presented schematically for both human health and ecological receptors in Figure K-3.

K3.1.2.1 Ecotoxicity and Potential Receptors

The next step of the Problem Formulation typically focuses on ecotoxicity and potential receptors. Knowing the toxic mechanism of a PCOC helps to determine the importance of potential exposure pathways and to focus the selection of assessment endpoints. However, because there are few complete exposure pathways, and those that are complete are insignificant at the ISOU (Section K3.1.2.2), there is limited usefulness in discussing the ecotoxicity of the PCOCs. Furthermore, no assessment and measurement endpoints have been selected based on the exposure pathway analysis. Instead, this section focuses solely on the potential receptors in order to provide useful supporting information for Section K3.1.2.2.

K3.1.2.1.1 Potential Receptors at the Inaccessible Soil Operable Unit

The SLDS is located within an industrial urban area with no potential for sensitive environmental areas and no natural ecological habitat. The Missouri Department of Conservation's Natural Heritage database indicated that no T&E species are known to occur in the City of St. Louis. The only habitat present at the ISOU consists of small wooded areas and barren/field habitats. The wooded areas are located at three main areas (DT-2, DT-5, and DT-9) as shown in Figure R-2 of Appendix R. Open field areas are located along the levee (DT-9), at DT-1, and the Terminal RR Soil Spoils Area as shown in Figures R-2 and R-3 of Appendix R.

Vegetation

Site vegetation consists of a mixture of prairie species, disturbance-related aggressive species, and species typical of old fields. The largest vegetated area on the site is the area adjacent to the Mississippi River along the levee. This area is maintained as mowed turf grass. A highly disturbed, linear forested area is located immediately adjacent to the Mississippi River. This approximately 4.5-acre fragmented woodland, which includes a portion of the ISOU, is dominated by disturbance-tolerant species such as mulberry (*Morus* sp.), eastern cottonwood (*Populus deltoides*), Amur honeysuckle (*Lonicera maackii*), and Japanese honeysuckle (*Lonicera japonica*). A few American sycamore (*Platanus occidentalis*) and silver maple (*Acer saccharinum*) trees are also present. There is almost no understory present in the woodland.

Other large, vegetated areas at the SLDS that are not part of the ISOU land area include a small wooded area adjacent to the Terminal RR tracks, a wooded area adjacent to the Ameren UE electrical station (DT-5), and a former building site (DT-1). All of these areas are characterized by disturbance-tolerant species such as tree of heaven (*Ailanthus altissma*), Amur honeysuckle, Johnson grass (*Sorghum halepense*), and ragweed (*Ambrosia artemisiifolia, A. trifida*). These areas are described in more detail in Sections IIIA1 and IIIA3 of Appendix R.

Other vegetation observed at the site include black locust, as well as annual and perennial weed species, such as common sunflowers, spotted spurge, and foxtail. The 1993 BRA noted the presence of wild carrot, aster, clover, dandelion, milkweed, ragweed, and various grasses.

Terrestrial Receptors

Few terrestrial receptors are likely to inhabit the site, because the patchiness of the vegetation, lack of vegetative cover and water, and high level of disturbance are unattractive to wildlife. The only receptors likely to use the site would be urban-adapted species. Wildlife observations during the September 2010 site visit included several bird species (swallow, sparrow, robin, cardinal, mourning dove, and mockingbird), an eastern cottontail rabbit, as well as a groundhog den, raccoon tracks, and beaver cuttings.

The 1993 BRA noted that vertebrate fauna of the St. Louis area consist of species that have adapted to urban encroachment, including mammals (e.g., mice, opossum, eastern cottontail rabbit, gray squirrel, and eastern mole). Birds that inhabit the urban environment include the Canada goose, rock dove, mourning dove, American crow, American robin, and Northern cardinal (DOE 1993).

Aquatic Receptors

The only flowing or non-flowing water systems that exist at the SLDS are associated with surface runoff following precipitation events and the subsurface sewer system. All flow from surface runoff is captured by the sewer system and is subsequently directed to a local treatment facility. There are no open and natural flowing or non-flowing water systems at the SLDS capable of sustaining sensitive aquatic species, and no aquatic species or habitats were observed at the SLDS throughout the RI and the September 2010 site visit. There are no off-site surface water discharges from the ISOU to the Mississippi River that could directly impact riparian or aquatic species. In summary, based on these observations and the findings presented in the 1993 BRA, there is currently no evidence of sensitive on-site or off-site aquatic receptors with the potential for being adversely exposed to contaminants identified in ISOU media.

K3.1.2.2 Complete Exposure Pathways

The CSM for human health and ecological receptors, as presented in Figure K-3, indicates that exposure pathways are either incomplete, or are complete but insignificant for aquatic and terrestrial receptors. Site concentrations were not compared to ecological screening levels, because there are no complete and significant exposure pathways, as explained in the following items.

- There are no streams, ponds, or surface water bodies at the SLDS, and the potential for off-site contaminant migration via surface water is low due to run-off collection in sewers.

- There are no significant migration pathways for sediment in sewer lines, except through possible leaks or breaks in the lines, which could result in impact to adjacent and underlying soil. However, this soil is largely inaccessible to ecological receptors and not expected to result in adverse effects.
- Ground water at the SLDS is encountered around 7 to 32 ft bgs depending on the location within the site. Even burrowing mammals are unlikely to be exposed to environmental media this far below the ground surface. Ecological receptors are, therefore, not directly exposed to ground water at the SLDS. There is currently no evidence of significant contaminant transport via ground water to more sensitive aquatic habitats off site. However, further evaluation of potential risks to the environment from site ground water will be conducted as part of the Ground-Water Remedial Action Alternative Assessment initiated under the 1998 ROD.
- Radiological contamination on exterior building surfaces has been determined to be fixed, with very limited potential for removal via natural weathering processes; therefore, there is no likelihood for impacts to ecological receptors.
- The largest vegetated area at the ISOU is the area adjacent to the Mississippi River along the levee. The uptake of site contaminants by trees along the levee is limited, because this area is maintained so that large trees do not grow and potentially affect the structural integrity of the levee. The majority of this area is maintained as mowed turf grass. As a result, the number of trees that could potentially be exposed to contaminants through root uptake would be limited.
- While burrowing animals could be exposed to contaminants via ingestion and inhalation of soil if they burrowed into the inaccessible soils area, these exposures are expected to be insignificant due to the limited number of such animals expected to occur in the ISOU areas. Worms and insects would have limited exposure to the inaccessible soils, which are typically beneath ground cover (e.g., buildings, asphalt). With limited exposure to prey items that had been exposed to inaccessible soils, birds would not be at risk from consuming these invertebrates.

Given the information discussed previously, and based on the results noted in the Ecological Checklist in Appendix R, it is concluded that there are no complete or significant exposure pathways for ecological receptors at the ISOU. This is primarily because the majority of the site is covered by sidewalks, roads, buildings, and parking lots, which inhibit contaminant mobility, especially in the subsurface. In addition, most of the samples collected from ISOU media were collected from areas of the site not readily accessible to wildlife, limiting direct contact between contaminants and ecological receptors.

Based on the findings of the Ecological Checklist (Appendix R), as well as the results of the 1993 BRA ("Environmental Assessment for Biota"), no potentially important habitats for biota occur either on site or adjacent to the SLDS (DOE 1993). Lastly, there are no sensitive or unique ecological receptors located within the site.

K3.1.3 Summary and Recommendations

The 1993 ecological evaluation determined that potential impacts to ecological receptors from accessible environmental media at the SLDS are likely to be insignificant, because the SLDS is a heavily urbanized area not suitable for habitation of sensitive and T&E species. In comparison to the accessible media evaluated in the 1993 BRA, the potential for impacts to ecological receptors from ISOU media evaluated in this SLERA is significantly less for the following reasons. First, based on the lack of suitable habitat, the potential for direct contact exposures to ISOU media is reduced for terrestrial or aquatic ecological receptors. Second, the presence of buildings and consolidated cover (e.g. asphalt and concrete pavement) over inaccessible soil acts as a physical barrier to direct contact exposures by terrestrial receptors. Third, the potential for subsurface migration to sensitive terrestrial or aquatic habitats (although none have been found to exist, per the Ecological Checklist in Appendix R,) from inaccessible soil is not significant. Thus, it is concluded that there are no complete or significant exposure pathways for ecological receptors at the ISOU. Finally, remedial actions conducted at the SLDS under the 1998 ROD have reduced the likelihood that ISOU media will be impacted by accessible soil contamination. It is for the aforementioned reasons that contaminant screening was not conducted in the ISOU SLERA and no further action was recommended from an ecological perspective.

THIS PAGE INTENTIONALLY LEFT BLANK

K4.0 SUMMARY OF THE BASELINE RISK ASSESSMENT

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 that were not addressed in the 1998 ROD (USACE 1998a). The BRA consists primarily of two components: a quantitative HHRA and a SLERA, the summaries and findings of which are discussed in the following subsections.

K4.1 HUMAN HEALTH RISK ASSESSMENT

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 sediment inside of sewer lines, and
- current/future sewer utility worker exposures to soil adjacent to sewer lines.

The previously listed 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 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 surfaces; and sampling location-specific dose and risk evaluations were conducted for sewer sediment and soil adjacent to sewer lines.

A hypothetical resident gardener scenario was evaluated but is presented separately, in Attachments K-1 and K-2 to this appendix. This is because current land use is predominantly industrial/commercial, and land use is expected to remain as such for the foreseeable future; therefore, it is recommended that scenarios assuming industrial land use be used as the basis for determining future actions at the ISOU. The hypothetical resident gardener was evaluated as an unlimited use and unrestricted exposure scenario for only informational purposes to facilitate future decision making as needed. As discussed in Attachment K-1, weight-of-evidence considerations generally suggest that doses and risks estimated for a resident gardener scenario represent overestimations of actual doses and risks associated with inaccessible soil.

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 K-2, K-3A, K-4, K-5A, K-6A, K-7, K-8, K-9A, and K-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 K-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 K-3B, K-5B, K-6B, K-9B, K-10B, and K-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 K-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 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 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.

K4.2 SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT

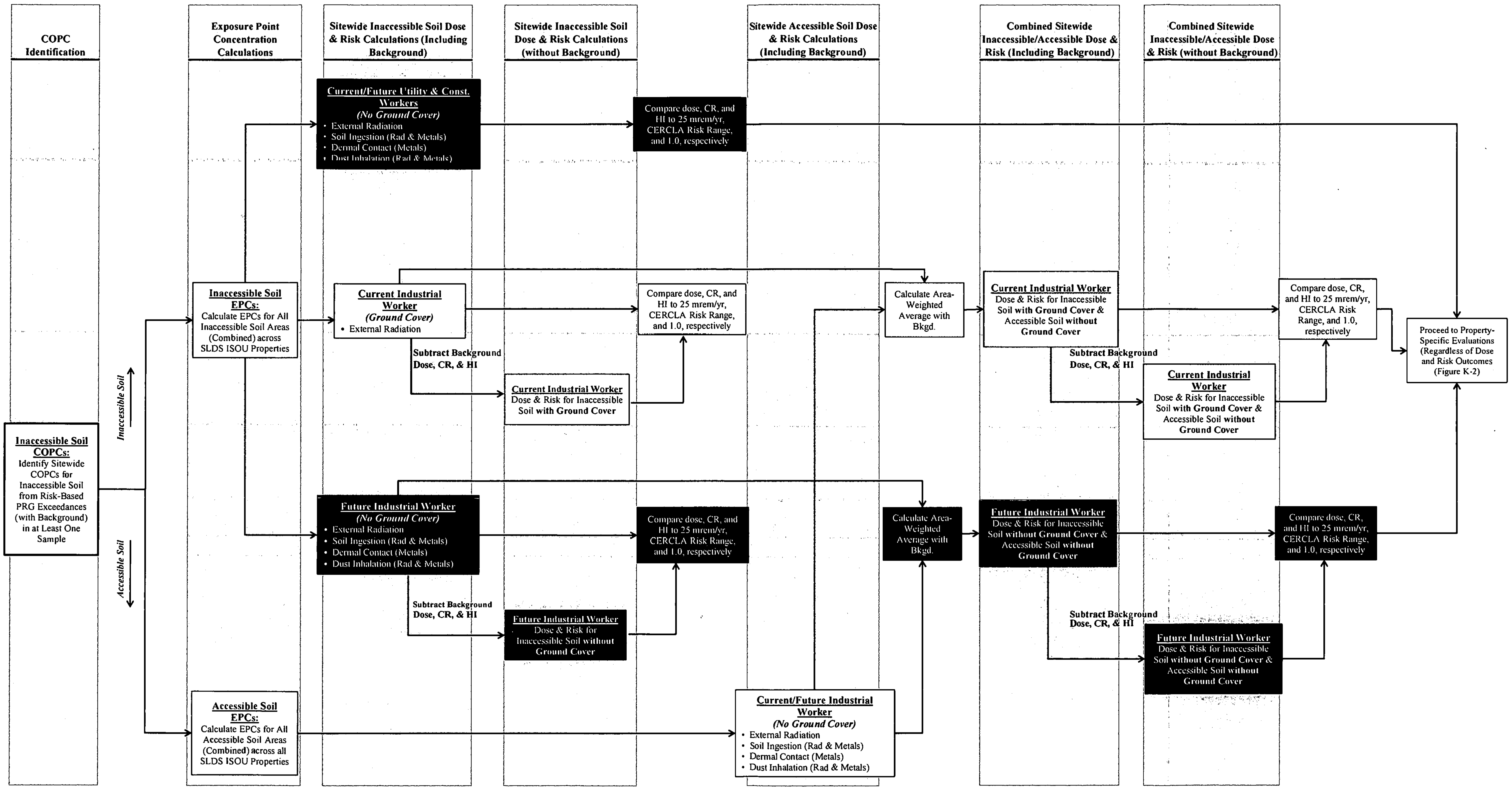
A SLERA was conducted for the ISOU that followed the USEPA's approach for the first step of the SLERA process, Problem Formulation, which included:

- 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, 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.

THIS PAGE INTENTIONALLY LEFT BLANK

FIGURES



RECEPTOR SCENARIOS:

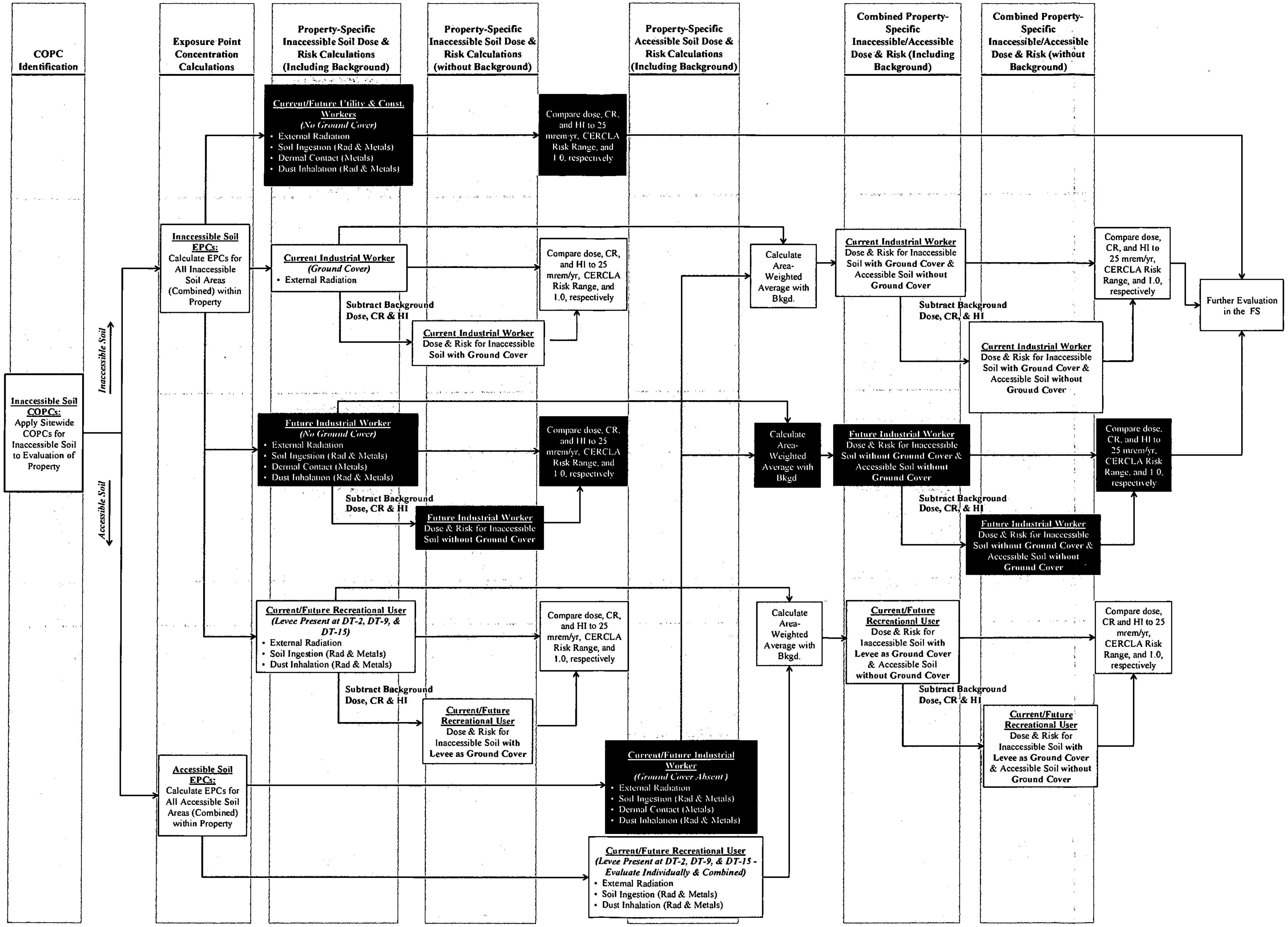
Current/Future Utility & Construction Worker - Inaccessible soil evaluations with no ground cover assumed to be present over excavated

Current Industrial Worker - Inaccessible soil and combined inaccessible/accessible soil evaluations, with ground cover assumed to be present over inaccessible soil areas.

Future Industrial Worker - Inaccessible soil and combined inaccessible/accessible soil evaluations, with no ground cover assumed to be present over inaccessible soil

Current/Future Industrial Worker - Accessible soil evaluations, with no ground cover assumed to be present.

Figure K-1. Sitewide ISOU Human Health Risk Assessment Process for Soil



RECEPTOR SCENARIOS:

Current/Future Utility & Construction Worker - Inaccessible soil evaluations with no ground cover assumed to be present over excavated inaccessible soil.

Current Industrial Worker - Inaccessible soil and combined inaccessible/accessible soil evaluations, with ground cover assumed to be present over inaccessible soil areas.

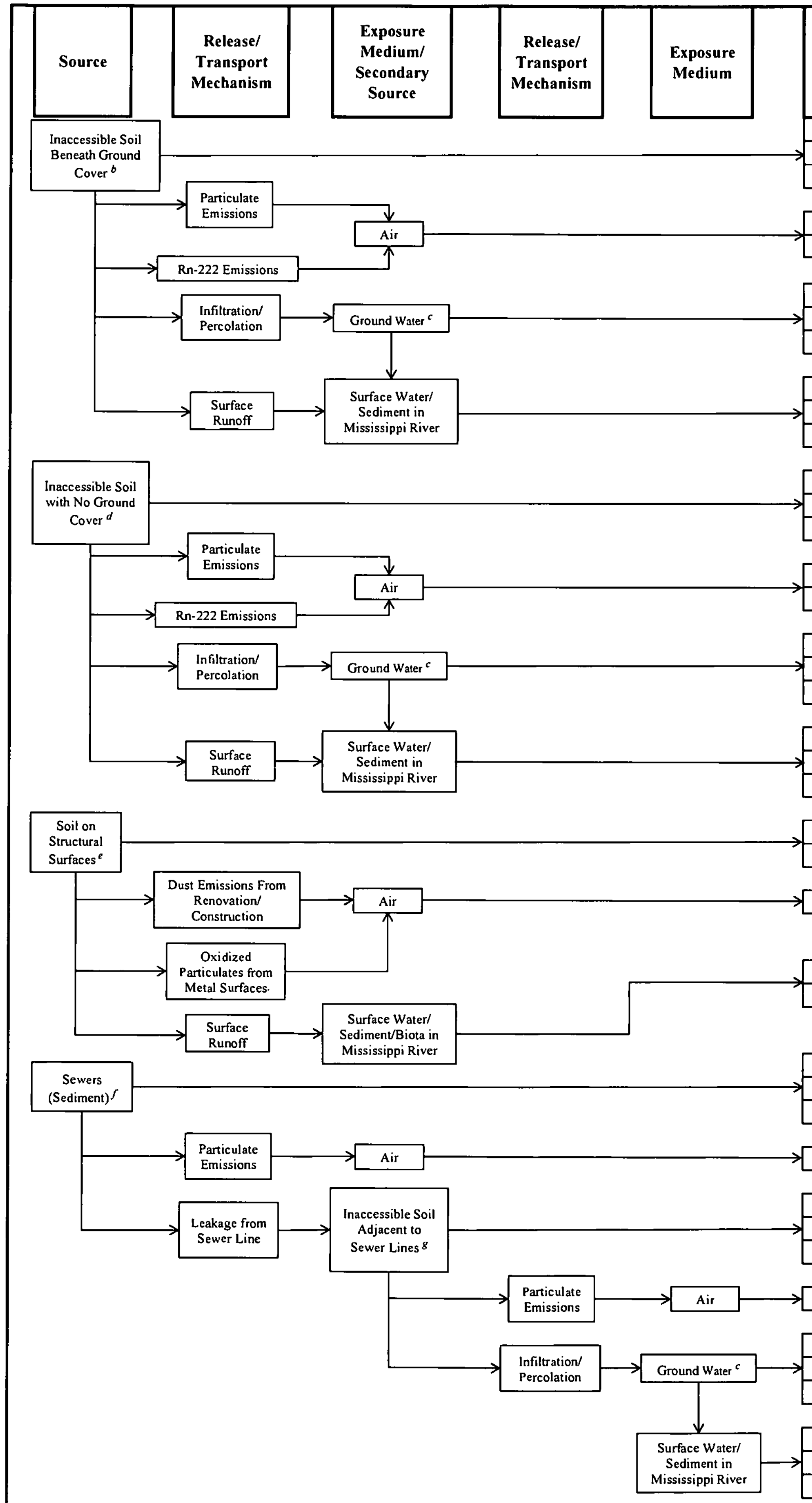
Future Industrial Worker - Inaccessible soil and combined inaccessible/accessible soil evaluations, with no ground cover assumed to be present over inaccessible soil areas.

Current/Future Recreational User of St. Louis Riverfront Trail - Inaccessible soil and combined inaccessible/accessible soil evaluations. Levee assumed to be always present as ground cover over inaccessible soils at DT-2, DT-9, and DT-15.

Current/Future Industrial Worker - Accessible soil evaluations, with no ground cover assumed to be present.

Current/Future Recreational User of the St. Louis Riverfront Trail - Accessible soil evaluations for DT-2, DT-9, and DT-15. No ground cover assumed.

Figure K-2. SLDS ISOU Property-Specific Human Health Risk Assessment Process for Soil



Exposure Routes	Potential Human Receptors							Ecological Receptors[a]	
	Current Industrial Worker	Future Industrial Worker	Current/Future Construction Worker	Current/Future Utility Worker	Current/Future Sewer Maintenance Worker	Current/Future Recreational User (St. Louis Riding Trail)	Future Resident	Aquatic	Terrestrial
External Radiation	❷					❷			❶
Ingestion (Rad & Metals)									❶
Dermal Contact (Metals)									❶
Dust Inhalation (Rad & Metals)									❶
Rn-222 Inhalation[h]	❶	❶	❶	❶	❶				❶
External Radiation									
Ingestion (Rad & Metals)									
Dermal Contact (Metals)									
External Radiation								❶	❶
Ingestion (Rad & Metals)								❶	❶
Dermal Contact (Metals)								❶	❶
External Radiation		❷	❷	❷					❶
Ingestion (Rad & Metals)		❷	❷	❷					❶
Dermal Contact (Metals)		❷	❷	❷					❶
Dust Inhalation (Metals & Rad)		❷	❷	❷					❶
Rn-222 Inhalation[h]	❶	❶	❶	❶	❶				❶
External Radiation			❶	❶					
Ingestion (Rad & Metals)			❶	❶					
Dermal Contact (Metals)			❶	❶					
External Radiation								❶	❶
Ingestion								❶	❶
Dermal Contact (Metals)								❶	❶
External Radiation	❷	❷	❶						
Ingestion (Rad)	❷	❷	❶						
Dust Inhalation (Rad)	❷	❷	❶						
External Radiation								❶	❶
Ingestion (Rad)								❶	❶
External Radiation				❶	❷				
Ingestion (Rad & Metals)				❶	❷				
Dermal Contact (Metals)				❶	❷				
Dust Inhalation (Rad & Metals)				❶	❶				
External Radiation				❷	❶				
Ingestion (Rad & Metals)				❷	❶				
Dermal Contact (Metals)				❷	❶				
Dust Inhalation (Rad & Metals)				❷	❶				
External Radiation				❶	❶				
Ingestion (Rad & Metals)				❶	❶				
Dermal Contact (Metals)				❶	❶				
External Radiation									
Ingestion (Rad & Metals)									
Dermal Contact (Metals)									

Notes

KEY:

☐	Incomplete exposure pathway. Pathway is not evaluated in the BRA.
❶	Pathway is potentially complete, but is considered unlikely, insignificant, or out of scope for the ISOU. Pathway is not quantitatively evaluated in the BRA. For Rn-222, the pathway is currently indeterminate due to insufficient data.
❷	Potentially complete and significant exposure pathway. Pathway is evaluated in the BRA.

NOTES:

[a] Ecological receptors include animals and plants.

[b] SLDS-wide and property-specific inaccessible soil beneath ground cover is being evaluated under the current industrial land use scenario.

[c] There are no complete or significant human or ecological exposure pathways for ground water.

[d] SLDS-wide and property-specific inaccessible soil with no ground cover is being evaluated under the future industrial worker scenario, as well as for current/future construction and utility worker scenarios.

[e] Includes interior and exterior surfaces containing radiologically contaminated soil. Industrial worker exposures are assumed for interior surfaces, and exposures to industrial workers performing maintenance are assumed for exterior surfaces and roofs. Industrial workers are assumed to be exposed 2,000 hours per year for 25 years. Industrial maintenance workers are assumed to be exposed 80 hours per year for 1 year.

[f] Sewers are considered to be a source, and the first medium assumed to have been impacted by MED/AEC operations is sediment inside of sewer lines. Sewer sediment exposures are assumed to occur infrequently during internal sewer line maintenance activities. Dust inhalation is not evaluated, because the moisture content of the sediment is assumed to preclude dust emissions. Soil adjacent to sewers are also part of this source.

[g] Because radiological and metals contamination in soil adjacent to sewer lines is likely due to sewer line leaks, soil adjacent to sewer lines is considered to be a secondary source.
Pathways are considerd complete and significant due to recent sewer removal/replacement work that has been conducted.

[h] Only Rn-222 emissions from inaccessible soil to indoor air are considered for occupied or habitable buildings. Rn-222 emissions from inaccessible soil to outdoor air are not considered significant, as explained in Section 5.2.1.2.

Figure K-3. Human Health and Ecological Conceptual Site Model for St. Louis Downtown Site, Inaccessible Soil Operable Unit

TABLES

Table K-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	---	---	---	---	---	---	---

Table K-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)
Mallinckrodt Street	Radiological	---	Radiological + As	Radiological + As	Radiological + As	---	---	---	---	---	---	---
Destrehan Street	Radiological	---	Radiological + As	Radiological + As	Radiological + As	---	---	---	---	---	---	---
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 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 evaluate

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 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 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 North 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.

As - Arsenic; Cd - Cadmium; Pb - Lead

Table K-2A. Property-Wide Exposure Point Concentrations for Radiological Contaminants of Potential Concern for Inaccessible and Accessible Soil at Plant Properties, Industrial/Commercial Vicinity Properties, Railroad Properties, and Roadways

Property	Area (m^2)	Statistic	EPCs for Radiological COPC (pCi/g)										
			Ac-227	Pa-231	Pb-210 [a]	Ra-226	Ra-228	Th-228	Th-230	Th-232	U-234 [a]	U-235	U-238
Sitewide													
Background[b]	10,000	ISOU EPC	0.18	1.12	N/A	3.04	1.00	N/A	2.18	1.18	N/A	0.10	1.67
	10,000	Accessible EPC	0.18	1.12	N/A	3.04	1.00	1.26	2.18	1.18	N/A	0.10	1.67
SLDS (Sitewide)	381,357	ISOU EPC	0.81	0.83	4.97	3.82	0.90	N/A	7.33	1.00	11.72	0.64	11.72
	776,844	Accessible EPC	0.17	0.22	3.42	2.63	0.84	1.16	3.18	0.97	6.58	0.37	6.58
St. Louis Riverfront Trail	103,089	ISOU EPC	0.06	0.11	4.21	3.24	0.93	N/A	2.36	1.04	2.29	0.16	2.29
	269,387	Accessible EPC	0.21	0.23	3.41	2.62	0.87	1.18	4.01	1.01	2.55	0.16	2.55
Mallinckrodt Properties													
Plant 1	10,500	ISOU EPC	1.32	1.27	21.53	16.56	0.91	N/A	18.23	0.99	23.97	1.28	23.97
	11,700	Accessible EPC	0.20	0.90	3.72	2.86	0.95	1.26	3.17	1.37	4.49	0.31	4.49
Plant 2	3,563	ISOU EPC	0.12	0.18	2.94	2.26	1.12	N/A	3.22	1.28	23.45	2.08	23.45
	16,531	Accessible EPC	0.14	1.03	3.74	2.88	0.95	1.3	1.94	1.09	3.45	0.08	3.45
Plant 6	2,370	ISOU EPC	1.33	1.31	10.79	8.30	0.80	N/A	5.93	0.96	171.40	11.28	171.40
	29,965	Accessible EPC	0.39	0.40	3.87	2.98	0.89	1.29	4.27	1.08	17.49	0.95	17.49
Mallinckrodt Security Gate 49	5	ISOU EPC	0.21	0.38	6.97	5.36	0.96	N/A	4.9	1.13	8.54	0.40	8.54
	435	Accessible EPC	0.44	0.54	3.86	2.97	0.75	1.04	3.52	0.92	5.59	0.44	5.59
Industrial/Commercial Vicinity Properties													
DT-2	12,665	ISOU EPC	0.09	0.14	5.67	4.36	0.96	N/A	2.84	1.07	2.89	0.22	2.89
	77,475	Accessible EPC	0.29	0.24	3.63	2.79	0.89	1.24	4.88	1.07	2.92	0.18	2.92
DT-4	7,962	ISOU EPC	9.54	9.94	12.51	9.62	1.07	N/A	65.42	1.23	83.46	4.62	83.46
	6,178	Accessible EPC	0.29	0.57	4.13	3.18	0.90	1.22	3.91	0.99	12.30	0.70	12.30
DT-6	3,582	ISOU EPC	6.86	7.19	6.57	5.05	0.87	N/A	25.30	1.03	26.11	1.86	26.11
	6,686	Accessible EPC	0.22	0.34	3.67	2.83	0.93	1.53	3.93	1.12	4.14	0.34	4.14
DT-8	20,471	ISOU EPC	0.12	0.15	3.46	2.66	0.81	N/A	2.23	0.88	3.22	0.20	3.22
	85,560	Accessible EPC	0.13	0.23	4.03	3.10	0.87	1.14	3.01	0.98	5.27	0.29	5.27
DT-10	726	ISOU EPC	0.28	0.15	5.77	4.44	1.00	N/A	4.18	0.97	7.55	0.66	7.55
	10,479	Accessible EPC	0.24	0.37	5.72	4.40	1.13	1.48	4.37	1.20	8.28	0.49	8.28
DT-29	533	ISOU EPC	0.01	0.25	1.47	1.13	0.81	N/A	1.45	1.05	1.76	0.26	1.76
	1,345	Accessible EPC	1.19	0.87	4.04	3.11	0.85	1.27	3.30	0.95	20.07	1.16	20.07
DT-34	4,780	ISOU EPC	0.07	0.16	3.08	2.37	0.93	N/A	2.86	1.46	1.87	0.06	1.87
	9,846	Accessible EPC	0.01	0.10	2.31	1.78	0.83	0.95	1.79	0.86	1.66	0.14	1.66
West of Broadway	33,043	ISOU EPC	0.12	0.34	2.82	2.17	0.78	N/A	2.34	0.88	2.42	0.19	2.42
	50,847	Accessible EPC	0.12	0.27	3.03	2.33	0.94	1.3	3.16	1.02	2.41	0.17	2.41
South of Angelrodt	6,508	ISOU EPC	0.19	0.26	3.68	2.83	0.89	N/A	2.81	0.93	3.38	0.22	3.38
	34,159	Accessible EPC	0.14	0.25	3.32	2.55	0.80	1.04	2.66	0.91	3.15	0.20	3.15

Table K-2A. Property-Wide Exposure Point Concentrations for Radiological Contaminants of Potential Concern for Inaccessible and Accessible Soil at Plant Properties, Industrial/Commercial Vicinity Properties, Railroad Properties, and Roadways

Property	Area (m^2)	Statistic	EPCs for Radiological COPC (pCi/g)										
			Ac-227	Pa-231	Pb-210 [a]	Ra-226	Ra-228	Th-228	Th-230	Th-232	U-234 [a]	U-235	U-238
Railroad Properties													
DT-3	6,363	ISOU EPC	0.12	0.16	3.74	2.88	1.57	N/A	3.23	1.43	4.32	0.27	4.32
	13,562	Accessible EPC	0.48	0.54	4.15	3.19	0.84	1.09	4.11	0.93	7.33	0.47	7.33
DT-9 Rail Yard	24,384	ISOU EPC	0.53	0.66	14.34	11.03	1.03	N/A	12.27	1.11	10.16	0.67	10.16
	131,791	Accessible EPC	0.07	0.20	4.13	3.18	0.89	1.27	3.01	1.07	2.93	0.18	2.93
DT-9 Levee	84,920	ISOU EPC	0.05	0.07	1.90	1.46	0.91	N/A	1.52	1.02	1.59	0.10	1.59
	188,158	Accessible EPC	0.08	0.34	3.67	2.82	0.86	1.13	2.25	0.94	2.14	0.17	2.14
DT-9 Main Line	36,630	ISOU EPC	0.08	0.17	3.29	2.53	1.46	N/A	3.19	1.59	2.43	0.16	2.43
	16,803	Accessible EPC	0.09	0.17	3.29	2.53	0.76	1.06	2.66	0.94	2.37	0.17	2.37
DT-9 Soil Spoils	10,636	ISOU EPC	1.02	1.31	5.63	4.33	0.80	N/A	30.13	0.86	20.93	1.05	20.93
	68,803	Accessible EPC	0.01	0.39	3.59	2.76	0.87	1.13	2.59	0.98	2.49	0.20	2.49
DT-12	23,009	ISOU EPC	0.08	0.08	2.95	2.27	0 67	N/A	4.59	0.76	3.45	0.21	3.45
	13,730	Accessible EPC	0.09	0.28	3.63	2.79	0.86	1.12	4.43	1.01	4.89	0.30	4.89
DT-15	5,505	ISOU EPC	0.05	0.42	2.91	2.24	0.95	N/A	2.29	1.09	2.17	0.19	2.17
	3,754	Accessible EPC	0.05	0.20	2.33	1.79	0.72	0.91	1.87	0.76	1.38	0.03	1.38
Roadways													
Angelrodt Street	7,696	ISOU EPC	0.16	0.44	4.06	3.12	0.79	N/A	3.28	0.92	3.20	0.22	3.20
Bremen Avenue	10,920	ISOU EPC	1.93	2.15	1.92	1.48	1.02	N/A	8.70	1.02	111.60	5.63	111.60
Buchanan Street	7,193	ISOU EPC	2.11	2.21	4.54	3.49	0.95	N/A	8.12	0.99	36.79	2.02	36.79
Destrehan Street	4,772	ISOU EPC	0.12	0.17	4.17	3.21	0.85	N/A	11.03	1.16	6.49	0.34	6.49
Hall Street	33,810	ISOU EPC	0.77	0.79	5.82	4.48	0.82	N/A	6.05	0.95	8.40	0.50	8.40
Mallinckrodt Street	5,391	ISOU EPC	0.26	0.56	2.08	1.60	0.77	N/A	3.15	1.25	6.38	0.35	6.38
North Second Street	10,552	ISOU EPC	0.48	0.57	3.82	2.94	0.86	N/A	5.17	1.05	6.11	0.38	6.11
Salisbury Street	2,207	ISOU EPC	0.10	0.08	2.02	1.55	0.73	N/A	1.56	0.87	1.33	0.08	1.33

[a] EPC was determined based upon Table 2.15 of the 1993 BRA (DOE 1993).

[b] EPCs for background soil were determined based upon 95% UCL values in Table 3-2 of the *Background Soils Characterization Report for the St. Louis Downtown Site* (USACE 1999a).

N/A - Not Available

Table K-2B. Sitewide and Property-Specific Exposure Point Concentrations for Metal Contaminants of Potential Concern in Inaccessible Soil and Accessible Soil within the Former Uranium-Ore Processing Area

Property	Inaccessible Soil EPCs (mg/kg)	Accessible Soil EPCs (mg/kg)		
	Arsenic	Arsenic	Cadmium	Uranium [a]
Background	10.6	10.6	1.03	NA
SLDS (Sitewide)	93.99	14.93	1.019	NA
Mallinckrodt Properties				
Plant 2 [b]	8.49	16.57	4.554	NA
Plant 6 [c]	9.578	15.36	1.071	NA
Industrial/Commercial Vicinity Properties				
DT-10 [d]	162.5	46.7	1.4	NA
Railroad Vicinity Properties				
DT-9 Main Line	8.17	NA	NA	NA
DT-12	166.8	NA	NA	NA
Roadway Vicinity Properties				
Hall Street	12.56	NA	NA	NA
Mallinckrodt Street	14.8	NA	NA	NA
Destrehan Street	16.98	NA	NA	NA

[a] Uranium metal was not retained as a COPC in inaccessible soil and was not evaluated in the PRARs for the properties shown in the above table; therefore, uranium metal is not being evaluated for inaccessible and accessible soil dose and risk, even though it was identified as a COC in the 1998 ROD.

[b] No Accessible soil EPCs or risks were calculated in the Plant 2 PRAR (USACE 2002) for arsenic or cadmium; however, EPCs and risks for these metals in accessible soil are being calcualted in this BRA to determine property-wide risks.

[c] Accessible soil EPCs for arsenic and cadmium were 18.02 and 1.04 mg/kg, respectively, in the Plant 6 PRAR. The differences between the the above arsenic and cadmium EPCs versus those in the PRAR are due to the incorporation of data into the calculations of the above EPCs that became available after the PRAR was developed. The accessible soil EPC calculated for uranium metal is 21.02 mg/kg; however, because uranium metal was not identified as an inaccessible soil COPC, and no accessible soil EPCs were calculated for uranium metal in the Plant 6 PRAR, uranium metal is not being evaluated for combined inaccessible/accessible soil dose and risk.

[d] The accessible soil EPCs for arsenic and cadmium in the table are the same as those used in the DT-10 PRAR (USACE 2008).

NA - No accessible soil areas exist on RR or roadway VPs.

Table K-3A. St. Louis Downtown Site-Specific Soil Activity Fractions

Radiological COPC	Soil Concentration [a] (pCi/g)	Activity Fraction
Ac-227	15	0.022
Pa-231	14	0.021
Pb-210	50	0.074
Ra-226	38	0.056
Ra-228	4.7	0.007
Th-228	5.8	0.009
Th-230	90	0.134
Th-232	5.8	0.009
U-234	220	0.327
U-235	10	0.015
U-238	220	0.327
TOTAL	**673.3**	**1**

[a] Soil concentrations used to determine activity fractions are from Table 3.9 of the 1993 BRA (DOE 1993).

Table K-3B. Exposure Point Concentrations for Radiological Contaminants of Potential Concern on Interior Building Surfaces

Property	**EPCs for Radiological COPC (pCi/m^2)**										
	Ac-227	**Pa-231**	**Pb-210** [a]	**Ra-226**	**Ra-228**	**Th-228**	**Th-230**	**Th-232**	**U-234** [a]	**U-235**	**U-238**
Sitewide											
Plant 1 Building 7	164	153	546	415	51	63	983	63	2404	109	2404
Plant 1 Building 26	173	162	577	439	54	67	1039	67	2540	115	2540
Plant 2 Building 41	165	165	549	417	52	64	987	64	2414	110	2414
Plant 2 Building 508	155	145	516	393	49	60	930	60	2273	103	2273
DT-6 Storage Building	84	79	281	213	26	33	506	33	1236	56	1236
DT-10 Metal Storage Building	140	131	467	355	44	54	841	54	2055	93	2055
DT-10 Wood Storage Building	68	64	227	173	21	26	409	26	1001	45	1001

[a] EPC was determined based upon Table 2.15 of the 1993 BRA (DOE 1993).

A conservative estimation of 180 m^2 of contaminated surfaces was used for each structure to determine the risk and dose.

Table K-3C. Exposure Point Concentrations for Radiological Contaminants of Potential Concern on Exterior Building Surfaces

Property	EPCs for Radiological COPC (pCi/m^2)										
	Ac-227	Pa-231	Pb-210 [a]	Ra-226	Ra-228	Th-228	Th-230	Th-232	U-234 [a]	U-235	U-238
Sitewide											
Plant 1 Building 25	1,113	1,039	3,710	2,819	349	430	6,677	430	16,323	742	16,323
Plantt 1 Building X	426	398	1,421	1,080	134	165	2,557	165	6,251	284	6,251
DT-10 Wood Storage Building	3,973	3,708	13,243	10,065	1,245	1,536	23,838	1,536	58,270	2,649	58,270
DT-14	563	525	1,887	1,877	176	218	3,378	218	8,257	375	8,257

[a] EPC was determined based upon Table 2.15 of the 1993 BRA (DOE 1993).

A conservative estimation of 180 m^2 of contaminated surfaces was used for each structure to determine the risk and dose.

Table K-4A. Exposure Point Concentrations for Radiological Contaminants of Potential Concern Identified in Sewer Sediment by Sampling Location

Property	Station ID	EPCs for Radiological COPCs (pCi/g)		
		Ra-226	Ra-228	U-238
Background [a]	N/A	1.007	0.466	1.378
SLDS (Sitewide)	N/A	**1.06**	**0.35**	**3.95**
Plant 1	SLD123489	0.97	0.37	1.56
	SLD123490	0.81	0.50	0.85
	SLD123491	1.63	0.81	0.84
	SLD123492	1.05	0.40	1.53
	SLD123493	0.74	0.26	1.90
	SLD123494	2.14	0.23	0.87
	SLD123495	0.67	0.14	1.10
	SLD123496	0.88	0.28	13.60
	SLD123497	1.45	0.28	1.50
	SLD123498	0.77	0.20	2.40
Plant 2	SLD123503	0.43	0.23	0.79
	SLD123504	0.84	0.25	-1.46
	SLD123505	0.84	0.17	0.79
	SLD123740	0.82	0.21	0.59
	SLD123741	0.60	0.36	-0.02
	SLD123742	1.14	0.56	2.10
	SLD123743	0.92	0.19	0.62
	SLD123744	0.92	0.18	0.76
	SLD123749	0.80	0.16	0.35
	SLD123750	0.87	0.24	0.59
	SLD123751	0.85	0.19	0.79
Plant 6	SLD123746	1.22	0.42	6.04
	SLD123747	0.83	0.27	0.90
	SLD123748	0.90	0.20	0.93
Plant 7	SLD123745	0.89	0.48	1.02
DT-11	SLD123488	0.61	0.27	0.70

[a] EPCs for background sediment were determined based upon 95% UCL values in Table I-4 of Appendix I.

N/A - Not Applicable

Table K-4B. Exposure Point Concentrations for Arsenic Identified in Sewer Sediment by Sampling Location

Property	Sewer Sediment Location	EPC [a] (mg/kg)
Background	All Locations Combined	11.84
SLDS (Sitewide)	All Locations Combined	4.846
Plant 1	SLD123489	5.90
	SLD123490	9.10
	SLD123492	5.10
	SLD123493	6.80
	SLD123494	4.20
	SLD123495	2.70
	SLD123496	17.10
	SLD123497	2.20
	SLD123498	2.80
Plant 2	SLD123503	4.30
	SLD123504	3.80
	SLD123505	4.20
	SLD123740	1.90
	SLD123742	3.90
	SLD123743	1.70
	SLD123744	2.10
	SLD123749	1.30
	SLD123750	2.80
Plant 6	SLD123746	1.80
	SLD123747	1.00
	SLD123748	2.60
Plant 7	SLD123745	4.60
DT-11	SLD123488	3.90

[a] The arsenic EPC for each individual location is the concentration reported at each location. All arsenic concentrations are detected concentrations.

Table K-5A. Exposure Point Concentrations for Radiological Contaminants of Potential Concern Identified in Soil Adjacent to Sewer Lines by Property/Borehole Location

Property	Station ID	EPCs for Radiological COPCs (pCi/g)					
		Ac-227	Pa-231	Ra-226	Ra-228	Th-230	U-238
Background[a]	N/A	0.18	1.12	3.04	1.00	2.18	1.67
SLDS (Sitewide)	N/A	**7.01**	**8.11**	**8.43**	**0.91**	**456.50**	**14.23**
Plant 1	SLD124538	0.13	-0.02	1.61	1.26	1.98	2.70
	SLD124540	2.11	1.50	4.66	1.08	24.00	78.60
	SLD124542	-0.03	0.12	1.68	0.96	1.53	1.69
	SLD124544	0.27	0.47	2.97	0.98	2.84	16.30
	SLD124546	0.27	0.05	1.70	1.23	1.89	1.20
	SLD124548	-0.02	1.51	2.31	0.98	1.76	1.61
	SLD124550	0.20	0.12	2.15	0.97	1.73	2.94
	SLD124552	0.15	0.42	1.37	1.09	1.23	1.81
	SLD124554	0.13	0.03	1.33	0.96	1.75	1.24
	SLD124556	0.01	0.02	1.98	0.57	1.20	1.56
	SLD124558	-0.07	0.40	1.64	0.91	1.51	1.49
	SLD124560	0.11	0.51	2.20	1.02	1.88	2.27
	SLD124564	0.31	0.73	1.77	1.07	1.16	1.02
	SLD124566	0.15	0.55	2.41	1.08	2.13	2.92
	SLD124568	0.18	1.03	1.44	1.02	1.40	1.94
	SLD124570	0.27	0.00	2.29	1.03	2.33	2.33
	SLD125283	0.09	0.24	2.24	0.96	2.64	1.38
	SLD125521	0.39	-0.12	5.49	0.98	3.55	4.22
Plant 2	SLD124574	0.20	0.45	1.79	1.28	1.64	3.68
	SLD124576	0.27	-0.13	1.87	0.85	1.56	1.96
	SLD124578	-0.09	0.16	1.60	0.71	1.63	8.42
	SLD125385	0.32	0.61	2.26	1.41	2.23	26.90
Plant 6	HTZ88929	44.80	56.30	58.30	1.16	489.00	3.69
	HTZ88930	3.94	3.14	20.20	0.87	72.60	2.69
	SLD127572	0.30	0.65	9.02	1.09	5.25	14.50
Plant 7/DT-12	SLD124586	0.09	1.70	1.95	1.21	2.57	20.40
	SLD131146	0.22	0.54	5.14	1.06	33.50	13.40
	SLD131156	0.12	0.23	3.62	1.07	7.13	7.97
	SLD131166	0.24	0.38	1.93	1.09	2.12	2.35
	SLD131176	0.24	0.14	4.65	1.12	3.75	3.16
	SLD93275	153.00	170.00	117.00	2.56	10180.00	48.70
	SLD93276	21.40	23.70	32.60	1.13	2961.00	16.10
	SLD93277	76.90	102.00	44.70	0.76	4533.00	13.40
DT-2 Levee	SLD120945	11.60	14.10	45.20	1.55	1097.00	22.40
	SLD120946	6.93	7.12	35.30	1.19	738.00	18.90
	SLD120947	5.68	7.09	32.90	1.09	1180.00	35.30
	SLD120948	0.57	0.70	4.35	0.89	47.30	3.82
DT-8 and DT-11	SLD124590	0.25	0.40	2.19	1.01	1.86	0.56
	SLD124592	-0.03	0.24	1.12	0.73	1.24	1.65
	SLD124594	0.08	0.92	1.59	1.20	1.57	1.08

[a] EPCs for background soil were determined based upon 95% UCL values in Table 3-2 of the *Background Soils Characterization Report for the St. Louis Downtown Site* (USACE 1999a).

N/A - Not Applicable

Table K-5B. Exposure Point Concentrations for Metal Contaminants of Potential Concern Identified in Soil Adjacent to Sewer Lines by Property/Borehole Location

Property	Station Name	Sewer Soil EPCs (mg/kg) [a]		
		Arsenic	Cadmium	Lead
Background	All Locations Combined	10.6	1.03	209
SLDS (Sitewide) [b]	All Locations Combined	19.3	122	271
Plant 1	SLD124538	4.4 [c]	1	18.7
	SLD124540	94.8	33.8	715
	SLD124542	5	0.26	49.2
	SLD124544	10.7	1.3	41.1
	SLD124546	60.9	2.7	16.2
	SLD124548	20.9	1,730	176
	SLD124550	13.2	1.3	102
	SLD124552	18.3	1	17
	SLD124554	8	28.8	23.5
	SLD124556	10.1	6.4	125
	SLD124558	15.1	0.78	36.8
	SLD124560	22.1	5.6	352
	SLD124564	6.4	2.5	12.7
	SLD124566	17.3	0.63 [c]	39.8
	SLD124568	8.1	0.83	13.7
	SLD124570	41.9	0.84	476
	SLD125283	4.2 [c]	0.83	14.3
	SLD125521	31.8	28.9	345
Plant 2	SLD124574	7.6	2.2	13.1
	SLD124576	2.5	1.2 [c]	3,380
	SLD124578	9.3	0.65 [c]	14.0
	SLD125385	17.3	1.6	61.7
Plant 6	SLD124572	11	0.63 [c]	595
Plant 7N/BNSF RR	SLD124586	7.2	17.2	148
DT-8 & DT-11	SLD124590	4 [c]	0.84	12.1
	SLD124592	3.4	0.49	6
	SLD124594	9.2	0.67 [c]	10.9

[a] Each EPC for arsenic and cadmium is the lesser of the maximum detection and the 95% UCL. Each EPC for lead is the mean concentration per USEPA (2003b).

[b] Start and end depths for sitewide evaluation are the shallowest and deepest depth intervals, respectively, that were sampled across all soil boreholes adjacent to sewers at SLDS.

[c] Value is a non-detect result, but is being used to determine risk at the level of the reported detection limit.

Table K-6. Input Values for Non-Default Residual Radioactivity Model Parameters

Parameter	Unit	RESRAD Default [a]	Current & Future Industrial Worker	Construction/ Utility Worker/Sewer Maintenance Worker	Recreational User
Soil Concentrations/Transport Factors					
Soil Concentrations	pCi/g	NA	Table K-2A	Table K-2A	Table K-2A
Contaminated Zone Parameters					
Area of Contaminated Zone	m^2	10,000	Property-specific	Property-Specific/180 [b]	Property-specific
Thickness of Contaminated Zone (All Properties)	m	2	2	2	2
Cover/Hydrological Data					
Cover Depth	m	0	0.3048/1.0/0 [c]	0	1.0/0 [d]
Density of Cover Material	g/cm^3	1.5	1.5/Not used [c]	Not used	1.5/Not used [d]
Cover Erosion Rate	m/year	0.001	0.00006/Not used [c]	Not used	0.00006/Not used [d]
Density of Contaminated Zone	g/cm^3	1.5	1.28	1.28	1.5
Contaminated Zone Erosion Rate	m/year	0.001	0.00006	0.00006	0.00006
Contaminated Zone Total Porosity	unitless	0.40	0.42	0.42	0.40
Contaminated Zone Field Capacity	unitless	0.20	0.36	0.36	0.20
Contaminated Zone Hydraulic Conductivity	m/yr	10.00	3.048	3.048	10.00
Contaminated Zone B Parameter	unitless	5.30	10.40	10.40	5.30
Wind Speed	m/sec	2.00	4.17	4.17	2.00
Precipitation	m/yr	1.00	0.92	0.92	1.00
Irrigation	m/yr	0.20	0.00	0.00	0.20
Runoff Coefficient	unitless	0.20	0.80	0.80	0.20
Occupancy Data					
Inhalation Rate	m^3/year	8,400	10,550	10,550	9,326
Mass Loading for Inhalation	g/m^2	0.0001	0.0002	0.0002	0.0001
Indoor Dust Filtration Factor	unitless	0.4	0.5	0.5	0.4
Exposure Duration	year	30	25	1	9
Indoor Time Fraction	unitless	0.5	0.1969	0	0
Outdoor Time Fraction	unitless	0.25	0.04566	0.082/0.0091/ 0.00091 [e]	0.0086
Ingestion Dietary Data					
Soil Ingestion Rate	g/year	36.5	49.64	175.2	18.25
Pathways					
External Gamma	unitless	Active	Active	Active	Active
Inhalation	unitless	Active	Active	Active [f]	Active
Plant Ingestion	unitless	Active	Suppressed	Suppressed	Suppressed
Meat Ingestion	unitless	Active	Suppressed	Suppressed	Suppressed
Milk Ingestion	unitless	Active	Suppressed	Suppressed	Suppressed
Aquatic Foods	unitless	Active	Suppressed	Suppressed	Suppressed
Drinking Water	unitless	Active	Suppressed	Suppressed	Suppressed
Soil Ingestion	unitless	Active	Active	Active	Active
Radon	unitless	Suppressed	Suppressed	Suppressed	Suppressed

[a] Where possible, input values for the RESRAD models equate to USEPA assumptions applied to the metals evaluations.

[b] Area of contaminated zone is assumed to be 180 m^2 for a sewer maintenance worker and utility worker working adjacent to sewer lines, and is property-specific for all other construction worker and utility worker receptor scenarios

[c] The current industrial worker scenario for the SLDS ISOU assumes a 1-foot thick soil cover is in place, with the exception of levee properties DT-2, DT-9 Levee, and DT-15 where the levee is represented by assuming a 1-meter thick soil cover is in place. The future industrial worker scenario for the SLDS ISOU and for the accessible soil scenario assumes no cover is in place.

[d] The current and future recreational user for the SLDS ISOU assumes a 1-meter thick soil cover is present, representing the levee. Dose and risk for the accessible soil recreational user scenario assumes no ground cover.

[e] Outdoor time fraction is 0.082 for a construction worker (720 hours/year) and 0.0091 for a utility worker exposed to soil adjacent to sewers (80 hours/year) and 0.00091 for a sewer maintenance worker exposed to sediment inside of sewers (8 hours/year).

[f] Inhalation is not active for evaluating sewer maintenance worker exposures to sewer sediment because it's assumed that the moisture content of the sediment will prevent emissions into the air and subsequent inhalation.

NA = Parameter is not applicable to receptor scenario.

Table K-7. Input Values for Non-Default Residual Radioactivity-Build Model Parameters

Parameter	Unit	RESRAD-Build Default	Industrial Worker	Maintenance Worker
Case				
Dose/Risk Library	NA	FGR 11	FGR 11	FGR 11
Time Parameters				
Exposure Duration	days	365	9125	9125
Indoor Fraction	unitless	0.5	0.23	0.0091
Building Parameters				
Number of Rooms	NA	1	1	1
Area	m^2	36	100	100
Receptor Parameters				
Number of Receptors	unitless	1	1	1
Time Fraction	unitless	1	1	1
Breathing Rate	m^3/day	18	33.6	33.6
Location (x,y,z)	m	1,1,1	5, 5, 1	5, 5, 1
Shielding Parameters				
Source Parameters				
Number of Sources	unitless	1	5	5
Type	unitless	Volume	Area	Area
Direction	unitless	X	Floor (z), four walls (x,y,x,y)	Floor (z), four walls (x,y,x,y)
Location (x,y,z)	m	0,0,0	Floor: 5, 5, 0;	Floor: 5, 5, 0;
			Walls: 10, 5, 1	Walls: 10, 5, 1
			5, 10, 1	5, 10, 1
			0, 5, 1;	0, 5, 1;
			5, 0, 1	5, 0, 1
Geometry (circular or rectangle)	NA	Circular	Circular	Circular
Area (volume, area, point source)	m^2	36	100, 20, 20, 20, 20	100, 20, 20, 20, 20
Release				
Air Fraction (all sources)	NA	0.1	0.07	0.07
Direct Ingestion (all sources)	1/h	0	0	0
Removable Fraction (area, line, point source)	unitless	0.5	0.2	0.2
Lifetime (area, line, point source)	days	365	10,000	10,000
Pathways				
External	NA	Active	Active	Active
Inhalation	NA	Active	Active	Active
Ingestion	NA	Active	Active	Active

FGR = Federal Guidance Report.

Table K-8. Input Values for Pathway Dose Equations: Exposures to Metal Contaminants of Potential Concern

Exposure Pathway	Exposure Parameter	Exposure Parameter Description	Units	Exposure Parameter Value	Source/Comments
General Assumptions - All Pathways	BW_a	Adult Body Weight	kg	71.8	USEPA (1997a)
	ED_{cw}	Exposure Duration for Construction Worker	years	1	USEPA (1997a)
	ED_{iw}	Exposure Duration for Industrial Worker	years	25	USEPA (1997a)
	ED_{mw}	Exposure Duration for Sewer Maintenance Worker	years	25	USEPA (1997a)
	ED_{uw}	Exposure Duration for Utility Worker	years	1	USEPA (1989a)
	EF_{cw-sl}	Soil Exposure Frequency for Construction Worker	days/year	90	Exposure frequency applied to road workers at North St. Louis County FUSRAP sites.
	EF_{iw-sl}	Soil Exposure Frequency for Industrial Worker	days/year	50	USACE (1998b). Exposure frequency corresponds to 400 hours assumed for time spent outdoors.
	EF_{mw-sd}	Sediment Exposure Frequency for Sewer Maintenance Worker	days/year	1	Conservative estimate of exposure frequency for a City sewer worker at one manhole location.
	EF_{uw-sl}	Exposure Frequency for Utility Worker	days/year	10	USACE (1998b) exposure frequency assumed to be a one-time 80-hour exposure.
Soil/Sediment Ingestion	FI_{cw-sl}	Fraction Contaminated Soil Ingested by Construction Worker	unitless	1	USEPA (1989a)
	FI_{iw-sl}	Fraction Contaminated Soil Ingested by Industrial Worker	unitless	1	USEPA (1989a)
	FI_{mw-sd}	Fraction Contaminated Sediment Ingested by Sewer Maintenance Worker	unitless	1	USEPA (1989a)
	FI_{uw-sl}	Fraction Contaminated Soil Ingested by Utility Worker	unitless	1	USEPA (1989a)
	IR_{cw-sl}	Soil Ingestion Rate for Construction Worker	mg/day	480	USEPA (1996a, 2002b)
	IR_{iw-sl}	Soil Ingestion Rate for Industrial Worker	mg/day	136	USACE (1998b)
	IR_{mw-sd}	Sediment Ingestion Rate for Sewer Maintenance Worker	mg/day	330	USACE (1996a, 2002b)
	IR_{uw-sl}	Soil Ingestion Rate for Utility Worker	mg/day	480	USEPA (1996a, 2002b)
	AT_{c-ing}	Carcinogenic Averaging Time for All Receptors	days	25,550	Calculated value per USEPA (1989a): $AT_{c-ing} = 70\ years \times 365 \frac{days}{year}$
	$AT_{cw-nc-ing}$	Noncarcinogenic Averaging Time for Construction Worker	days	365	Calculated value per USEPA (1989a): $AT_{cw-nc-ing} = ED_{uw} \times 365 \frac{days}{year}$
	$AT_{iw-nc-ing}$	Noncarcinogenic Averaging Time for Industrial Worker	days	9,125	Calculated value per USEPA (1989a): $AT_{iw-nc-ing} = ED_{iw} \times 365 \frac{days}{year}$
	$AT_{mw-nc-ing}$	Noncarcinogenic Averaging Time for Sewer Maintenance Worker	days	9,125	Calculated value per USEPA (1989a): $AT_{mw-nc-ing} = ED_{mw} \times 365 \frac{days}{year}$
	$AT_{uw-nc-ing}$	Noncarcinogenic Averaging Time for Utility Worker	days	365	Calculated value per USEPA (1989a): $AT_{uw-nc-ing} = ED_{uw} \times 365 \frac{days}{year}$

Table K-8. Input Values for Pathway Dose Equations: Exposures to Metal Contaminants of Potential Concern

Exposure Pathway	Exposure Parameter	Exposure Parameter Description	Units	Exposure Parameter Value	Source/Comments
Soil/Sediment - Dermal Absorption	ABS	Dermal Absorption Factors (ABS) for All Receptors Being Evaluated:			
		Arsenic	unitless	0.03	USEPA (2004)
		Cadmium	unitless	0.001	USEPA (2004)
	AF_{cw-sl}	Soil-Skin Adherence Factor for Construction Worker	mg/cm^2-event	0.3	USEPA (2004)
	AF_{iw-sl}	Soil-Skin Adherence Factor for Industrial Worker	mg/cm^2-event	0.3	USEPA (2004)
	AF_{mw-sd}	Sediment-Skin Adherence Factor for Sewer Maintenance Worker	mg/cm^2-event	13	USEPA (2004)
	AF_{uw-sl}	Soil-Skin Adherence Factor for Utility Worker	mg/cm^2-event	0.3	USEPA (2004)
	EV_{cw-sl}	Soil Contact Event Frequency – Construction Worker	events/day	1	USEPA (2004)
	EV_{iw-sl}	Soil Contact Event Frequency – Industrial Worker	events/day	1	USEPA (2004)
	EV_{mw-sd}	Sediment Contact Event Frequency – Sewer Maintenance Worker	events/day	1	USEPA (2004)
	EV_{uw-sl}	Soil Contact Event Frequency Contact for Utility Worker	events/day	1	USEPA (2004)
	SA_{cw-sl}	Skin Surface Area Available for Soil Contact for Construction Worker	cm^2/day	3,890	Calculated value for outdoor worker per USEPA (2011), Table 7-12 - sum of 50th percentile values for head, forearms, and hands for a male worker.
	SA_{iw-sl}	Skin Surface Area Available for Soil Contact for Industrial Worker	cm^2/day	3,890	Calculated value for outdoor worker per USEPA (2011), Table 7-12 - sum of 50th percentile values for head, forearms, and hands for a male worker.
	SA_{mw-sd}	Skin Surface Area Available for Sediment Contact for Sewer Maintenance Worker	cm^2/day	3,890	Calculated value for outdoor worker per USEPA (2011), Table 7-12 - sum of 50th percentile values for head, forearms, and hands for a male worker.
	SA_{uw-sl}	Skin Surface Area Available for Sediment Contact for Utility Worker	cm^2/day	3,890	Calculated value for outdoor worker per USEPA (2011), Table 7-12 - sum of 50th percentile values for head, forearms, and hands for a male worker.
	AT_{c-derm}	Carcinogenic Averaging Time for All Receptors	days	25,550	Calculated value per USEPA (1989a): $AT_{c-derm} = 70\ years \times 365\ \frac{days}{year}$
	$AT_{cw-nc-derm}$	Noncarcinogenic Averaging Time for Construction Worker	days	365	Calculated value per USEPA (1989a): $AT_{cw-nc-ing} = ED_{uw} \times 365 \frac{days}{year}$
	$AT_{iw-nc-derm}$	Noncarcinogenic Averaging Time for Industrial Worker	days	9,125	Calculated value per USEPA (1989a): $AT_{iw-nc-derm} = ED_{iw} \times 365 \frac{days}{year}$
	$AT_{mw-nc-derm}$	Noncarcinogenic Averaging Time for Sewer Maintenance Worker	days	9,125	Calculated value per USEPA (1989a): $AT_{mw-nc-derm} = ED_{mw} \times 365 \frac{days}{year}$
	$AT_{uw-nc-derm}$	Noncarcinogenic Averaging Time for Utility Worker	days	365	Calculated value per USEPA (1989a): $AT_{uw-nc-derm} = ED_{uw} \times 365 \frac{days}{year}$
Soil - Inhalation	$ET_{cw-sl-inh}$	Soil Exposure Time for Construction Worker	hr/day	8	RAIS (DOE 2011), assumption based on length of work day
	$ET_{iw-sl-inh}$	Soil Exposure Time for Industrial Worker	hr/day	8	RAIS (DOE 2011), assumption based on length of work day
	$ET_{uw-sl-inh}$	Soil Exposure Time for Utility Worker	hr/day	8	RAIS (DOE 2011), assumption based on length of work day
	PEF_{cw}	Particulate Emission Factor for Construction Worker	m^3/kg	6.58×10^8	Calculated value per USEPA (2002b). Value assumes 0% vegetative cover of the site
	PEF_{iw}	Particulate Emission Factor for Industrial Worker	m^3/kg	1.36×10^9	USEPA (2002b). Default value for industrial worker.
	PEF_{uw}	Particulate Emission Factor for Utility Worker	m^3/kg	6.58×10^8	Calculated value per USEPA (2002b). Value assumes 0% vegetative cover of the site
	AT_{c-inh}	Carcinogenic Averaging Time for All Receptors	hr	613,200	Calculated value per USEPA (2009b): $AT_{c-inh} = 70\ years \times 365 \frac{days}{year} \times 24 \frac{hr}{day}$
	$AT_{cw-nc-inh}$	Noncarcinogenic Averaging Time for Construction Worker	hr	8,760	Calculated value per USEPA (2009b): $AT_{iw-nc-inh} = ED_{iw} \times 365 \frac{days}{year} \times 24 \frac{hr}{day}$
	$AT_{iw-nc-inh}$	Noncarcinogenic Averaging Time for Industrial Worker	hr	219,000	Calculated value per USEPA (2009b): $AT_{iw-nc-inh} = ED_{iw} \times 365 \frac{days}{year} \times 24 \frac{hr}{day}$
	$AT_{uw-nc-inh}$	Noncarcinogenic Averaging Time for Utility Worker	hr	8,760	Calculated value per USEPA (2009b): $AT_{uw-nc-inh} = ED_{uw} \times 365 \frac{days}{year} \times 24 \frac{hr}{day}$

Table K-9. Cancer Slope Factors for Radiological Contaminants of Potential Concern

CAS Number	Isotope	Radioactive Half-Life	ICRP Lung Type	GI Absorption Fraction	Water Ingestion	Food Ingestion	Soil Ingestion	Inhalation	External Exposure	Source
		years		Risk/pCi					Risk/yr per pCi/g	
14952-40-0	Ac-227+D	2.18E+01	S	5.00E-04	4.86E-10	6.53E-10	1.16E-09	2.09E-07	1.47E-06	FGR-13 Morbidity [a]
14331-85-2	Pa-231	3.28E+04	S	5.00E-04	1.73E-10	2.26E-10	3.74E-10	4.55E-08	1.39E-07	FGR-13 Morbidity [a]
14255-04-0	Pb-210+D	2.23E+01	M	2.00E-01	1.27E-09	3.44E-09	2.66E-09	1.39E-08	4.21E-09	FGR-13 Morbidity [a]
13982-63-3	Ra-226+D	1.60E+03	M	2.00E-01	3.86E-10	5.15E-10	7.30E-10	1.16E-08	8.49E-06	FGR-13 Morbidity [a]
15262-20-1	Ra-228+D	5.75E+00	M	2.00E-01	1.04E-09	1.43E-09	2.29E-09	5.23E-09	4.53E-06	FGR-13 Morbidity [a]
14274-82-9	Th-228+D	1.91E+00	S	5.00E-04	3.00E-10	4.22E-10	8.09E-10	1.43E-07	7.76E-06	FGR-13 Morbidity [a]
14269-63-7	Th-230	7.70E+04	S	5.00E-04	9.10E-11	1.19E-10	2.02E-10	2.85E-08	8.19E-10	FGR-13 Morbidity [a]
7440-29-1	Th-232	1.41E+10	S	5.00E-04	1.01E-10	1.33E-10	2.31E-10	4.33E-08	3.42E-10	FGR-13 Morbidity [a]
13966-29-5	U-234	2.45E+05	M	2.00E-02	7.07E-11	9.55E-11	1.58E-10	1.14E-08	2.52E-10	FGR-13 Morbidity [a]
15117-96-1	U-235+D	7.04E+08	M	2.00E-02	7.18E-11	9.76E-11	1.63E-10	1.01E-08	5.43E-07	FGR-13 Morbidity [a]
7440-61-1	U-238	4.47E+09	M	2.00E-02	6.40E-11	8.66E-11	1.43E-10	9.32E-09	4.99E-11	FGR-13 Morbidity [a]
7440-61-1	U-238+D	4.47E+09	M	2.00E-02	8.71E-11	1.21E-10	2.10E-10	9.35E-09	1.14E-07	FGR-13 Morbidity [a]

[a] USEPA 1999b.

Table K-10A. Toxicity Criteria for Metal Contaminants of Potential Concern: Carcinogenic Effects

COPC:	**Arsenic**	**Cadmium** [a]	**Lead** [b]
CAS Number:	7440-38-2	7440-43-9	7439-92-1
Weight of Evidence Classification [c]	A	B1	B2
Oral Exposure Route			
SF_o, $(mg/kg/day)^{-1}$	1.5E+00	NA	NA
Type of Cancer	Organ (liver, kidney, lung, and bladder); Skin	NA	Kidneys (renal tumors); genetic expression
SF_o Basis	Drinking Water	NA	Dietary/subcutaneous exposures to rats/mice
SF_o Source	USEPA (2011b)	USEPA (2011b)	USEPA (2011b)
Dermal Exposure Route			
SF_d, $(mg/kg/day)^{-1}$ [d]	1.6E+00	NA	NA
ABS, unitless [e]	0.03	0.001	NA
GIABS, % [e]	95	0.025	100
SF_d Source	Calculated from SF_o	NA	NA
Inhalation Exposure Route			
IUR, $(\mu g/m^3)^{-1}$	4.3E-03	1.8E-03	NA
Type of Cancer	Lung	Lung, trachea, bronchial	NA
IUR Basis	Inhalation	Inhalation & injection studies on rats and mice	NA
IUR Source	USEPA (2011b)	USEPA (2011b)	USEPA (2011b)

[a] The SF_o, ABS, and GIABS values for cadmium are based on diet.

[b] No toxicity criteria are established for determining risk due to lead exposures.

[c] Weight of Evidence (WOE) Classifications:

A - Human carcinogen

B1 - Probable human carcinogen - based on limited evidence of carcinogenicity in humans

B2 - Probable human carcinogen - based on sufficient evidence of carcinogenicity in animals

[d] Calculated using the following equation: $SF_d = SF_o \div GIABS\ (\%)$.

[e] ABS (dermal absorption fraction from soil) and GIABS (gastrointestinal absorption efficiencies) obtained from RAGS Part E (USEPA 2004) and USEPA's (2011a) most recent Regional Screening Levels Table. Default GIABS value of 100% is assumed for COPCs that lack available published data (USEPA 2004).

IUR - Inhalation unit risk.

SF_d - Dermal cancer slope factor.

SF_o - Oral cancer slope factor.

NA - No published oral slope factor is available.

Table K-10B. Toxicity Criteria for Metal Contaminants of Potential Concern: Non-Carcinogenic Effects

COPC:	**Arsenic**	**Cadmium** [a]	**Lead** [b]
CAS Number:	7440-38-2	7440-43-9	7439-92-1
		Oral Exposure Route	
RfD_O, mg/kg/day	3.0E-04	1.0E-03	*c*
RfDo Basis	Human chronic oral studies	Human studies	*c*
Critical Effect(s)	Skin/hyperpigmentation, keratosis: Cardiovascular/possible vascular complications, congestive heart failure	Kidney/Significant proteinuria	Anemia, hypertension, developmental effects
Confidence Level	Medium	High	*c*
Uncertainty Factor, unitless	3	10	*c*
RfD_o Source	USEPA (2011b)	USEPA (2011b)	ATSDR (2007)
		Dermal Exposure Route	
RfD_d, mg/kg/day [d]	2.9E-04	*c*	*c*
ABS, unitless [e]	0.03	0.001	*c*
GIABS, % [e]	95	0.025	100
RfD_d Source	Calculated from RfD_O	*c*	*c*
		Inhalation Exposure Route	
RfC, mg/m^3	1.5E-05	1.0E-05	*c*
RfC Basis	*c*	*c*	*c*
Critical Effect(s)	Development effects, cardiovascular system, nervous system	Respiratory/pulmonary effects	Anemia, hypertension, developmental effects
Confidence Level	*c*	*c*	*c*
Uncertainty Factor, unitless	*c*	*c*	*c*
RfC Source	CalEPA (2011)	USEPA (2011a)	ATSDR (2007)

Table K-10B. Toxicity Criteria for Metal Contaminants of Potential Concern: Non-Carcinogenic Effects

COPC:	**Arsenic**	**Cadmium** [a]	**Lead** [b]
Target Organs			
Blood Chemistry/Erythrocytes			X
Cardiovascular System	X		X
Central Nervous System/Neurotoxicity	X		
Fetus (Development)	X		X
Kidneys		X[f]	
Pulmonary/Respiratory System		X[f]	
Skin	X		

[a] The RfD_o, ABS, and GIABS values for cadmium are based on diet.

[b] No toxicity criteria are established for determining risk due to lead exposures.

[c] Information is currently not available.

[d] Calculated using the following equation: Dermal RfD = Oral RfD x GIABS (%).

[e] ABS (dermal absorption fraction from soil) and GIABS (gastrointestinal absorption efficiencies) obtained from RAGS Part E (USEPA 2004) and USEPA's (2011a) most recent Regional Screening Levels Table. Default GIABS value of 100% is assumed for COPCs that lack available published data (USEPA, 2004).

[f] Target organs are applicable to cadmium exposures via diet and water ingestion.

RfC - Inhalation reference concentration.

SF_d - Dermal cancer slope factor.

SF_o - Oral cancer slope factor.

X - Indicates target organ/organ system for COPC.

Table K-10C. Summary of Target Organs and Critical Effects for Non-Carcinogenic Exposures to Metal Contaminants of Potential Concern

CAS No.	COPC	Target Organ/Critical Effect [a]						
		Blood Chemistry/ Erythrocytes	Cardiovascular	Central Nervous System/ Neurotoxicity	Developmental (Including Fetal) Effects	Kidneys	Pulmonary/ Respiratory System	Skin
7440-38-2	Arsenic		X	X	X			X
7440-43-9	Cadmium (Diet)					X	X	
7440-43-9	Cadmium (Water)					X	X	
7439-92-1	Lead	X	X		X			

[a] Sources for target organs/critical effects are the same as those cited in Table K-13B.

Table K-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)	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 background value (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 presentd 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 K-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		Noncarcinogenic 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 background value (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 presentd 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).

Table K-12. 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
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

Table K-12. 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)
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
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

Table K-12. 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)
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 DT-15), 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.

NA - Not applicable.

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

Table K-13A. 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]	726	2.1E-04	1.3	3.2E-05
	Accessible [d]	10,479	1.8E-04	3.3	<BKGD
	Property-Wide [e]	11,205	1.8E-04	3.2	2.0E-06

Table K-13A. 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)
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	9.4E-05	<BKGD	<BKGD
	Accessible [d]	1,345	1.8E-04	0.7	3.3E-06
	Property-Wide [e]	1,878	1.6E-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

Table K-13A. 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)
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
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 K-13B. 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
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 K-14. Combined and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil and Accessible Soil within Properties Encompassing the St. Louis Riverfront Trail (DT-2, DT-9 Levee, and DT-15): 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
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 K-15A. 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 [b]	
	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
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 K-15B. 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 K-16A. 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 [b]**	
	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 K-16B. 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 K-17. 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
Plant 1	Building 26	0.4	1.3E-06
Plant 2	Building 41	0.4	1.2E-06
Plant 2	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
DT-10	Wood Storage Building	0.2	5.0E-07

Table K-18. Radiological Dose and Risk Characterization for Exterior Building Surfaces: MaintenanceWorker

Property	Building	Dose (mrem/year)	CR
Plant 1	Building 25	0.1	3.2E-07
Plant 1	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 K-19A. 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 K-19B. 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 K-20A. 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 ^{b}	
		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

Table K-20A. 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 [b]	
		Max. CR (unitless)	Max. Dose (mrem/yr)	Max. CR (unitless)
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
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 sewer 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 K-20B. 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
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 K-20C. 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 Blood Lead 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%
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.

Table K-21. Potential Contaminants of Concern for Soil in the Inaccessible Soil Operable Unit

Chemical Constituents [a]	Radiological Constituents
Arsenic	Ac-227
Cadmium	Pa-231
Uranium metal	Ra-226
	Ra-228
	Th-228
	Th-230
	Th-232
	U-235
	U-238

[a] Applicable to soil in the uranium-ore processing area: Plants 2, 6, and 7; DT-10; and portions of DT-9, DT-12, Hall Street, Mallinckrodt Street, and Destrehan Street (USACE 1998a).

Table K-22. Potential Contaminants of Concern for Sewer Sediment and Soil Adjacent to Sewers in the Inaccessible Soil Operable Unit

Chemical Constituents	Radiological Constituents
Arsenic	Ac-227
Cadmium	Pa-231
Cobalt	Ra-226
Copper	Ra-228
Lead	Th-228
Manganese	Th-230
Molybdenum	Th-232
Nickel	U-235
Selenium	U-238
Thorium metal	
Uranium metal	
Vanadium	
Zinc	

Note: Sewer sediment and soil adjacent to sewers had not been characterized for metals; therefore, all metals associated with pitchblende and domestic ores used in the former MED/AEC uranium-ore processing operations (DOE 1993) were identified as PCOCs in sewer sediment and soil adjacent to sewers.

ATTACHMENT K-1

Evaluation of Hypothetical Resident Gardener Exposures at the St. Louis Downtown Site Inaccessible Soil Operable Unit

(On the DVD on the Back Cover of this Report)

ATTACHMENT K-2

Data Comparisons with Residential Preliminary Remediation Goals

(On the DVD on the Back Cover of this Report)

APPENDIX L

Radiological and Metals Analytical Data Summaries and Figures for Accessible Soil by Property

(On the DVD on the Back Cover of this Report)

APPENDIX M

Exposure Point Concentration Calculations for Radiological COPCs

(On the DVD on the Back Cover of this Report)

APPENDIX N

Exposure Point Concentration Calculations for Metal COPCs

(On the DVD on the Back Cover of this Report)

APPENDIX O

RESRAD Model Outputs: Radiological Dose and Risk Calculations for Inaccessible Soil and Sewer Soil Borehole Locations

(On the DVD on the Back Cover of this Report)

APPENDIX P

RESRAD-BUILD Model Outputs: Radiological Dose and Risk Calculations for Exterior Building Surfaces

(On the DVD on the Back Cover of this Report)

APPENDIX Q

Dose and Risk Calculations for Exposures to Metals COPCs in Inaccessible Soil, Sewer Sediment, and Soil Adjacent to Sewer Lines

(On the DVD on the Back Cover of this Report)

APPENDIX R

Ecological Checklist for the SLDS ISOU

Checklist for Ecological Assessment/Sampling

I. SITE DESCRIPTION

1. **Site Name:** Inaccessible Soil Operable Unit (ISOU) at the St. Louis Downtown Site (SLDS)

U.S. EPA ID Number: MOD980633176

Location: Site is roughly bounded by Dock Street, Ninth Street, Angelica Street, and the Mississippi River.

County: NA **City:** St. Louis **State:** Missouri

2. **Latitude:** 38-39-44 N **Longitude:** 90-11-21 W

3. **Attach site maps, including a topographical map, a diagram which illustrates the layout of the facility (e.g. site boundaries, structures, etc.), and maps showing all habitat areas identified in Section III of the checklist. Also, include maps which illustrate known and suspected release area, sampling location and any other important features, if available.** See Figures R-1,R-2, and R-3.

II. SITE CHARACTERIZATION

1. **What is the approximate area of the site?**

Site is approximately 210 acres.

2. **Is this the first site visit?** ☒ **Yes** ☐ **No**
If no, attach trip report of previous site visit(s), if available.

Date(s) of previous site visit(s):

3. **Are aerial or other site photographs available?** ☒ **Yes** ☐ **No**
If yes, please attach any available photo(s) to the site map at the conclusion of this section.
See attached photographs.

4. **The land use on the site is:**

50 **% Heavy Industrial**	48 **% Light Industrial**	**% Urban**
% Residential	**% Rural**	**% Agricultural**[b]
2 **% Recreational**[a]	**% Undisturbed**	**% Other**[c]

[a]**For recreational areas, please describe the use of the area (e.g., park, playing field, etc.).**
The Riverfront Bike trail extends along the east side of the property. The bike trail is a paved trail that is located on a levee in the northern portion of the site and then drops into the floodplain area located between the levee and the Mississippi River in the southern portion of the site (See Photos 34 and 35).

[b]**For agricultural areas, please list the crops and/or livestock which are present.**

[c]**For areas designated as "other," please describe the use of the area.**

5. **Provide an approximate breakdown of land uses in the areas surrounding the site. Indicate the radius (in miles) of the area described:** 1- mile radius from the approximate center of the Mallinckrodt property.

40 **% Heavy Industrial**	28 **% Light Industrial**	**% Urban**
7 **% Residential**	**% Rural**	**% Agricultural**[b]
% Recreational[a]	**% Undisturbed**	25 **% Other**[c]

[a]**For recreational areas, please describe the use of the area (e.g., park, playing field, etc.).**

[b]**For agricultural areas, please list the crops and /or livestock which are present.**

[c]**For areas designated as "other," please describe the use of the area.** Mississippi River

6. **Has any movement of soil taken place at the site?** ☒ **Yes** ☐ **No**
If yes, please identify the most likely cause of this disturbance:

☐ Agricultural Use ☐ Heavy Equipment ☐ Mining ☐ Erosion ☐ Natural Events ☒ Other
Please describe: The project site has been continuously occupied since the early 1800s. Construction and land alteration has occurred throughout the history of site as a variety of structures have been built and then demolished. The construction of the levees involved a large addition of fill material to the site. In addition, numerous remediation activities have occurred at the site, removing contaminated soils and replacing those soils with clean fill.

7. **Do any potentially sensitive environmental areas exist adjacent to or in proximity to the site (e.g., federal and state parks, national and state monuments, wetlands, prairie potholes)?** ***Remember, flood plains and wetlands are not always obvious; do not answer "no" without confirming information.*** No. The Mississippi River is located adjacent to the site. The river is channelized at this location, and flow is primarily confined to the navigation channel. A small area of the site is located with the 100-year floodplain of the Mississippi River. The majority of the site is protected by a levee along the eastern edge of the site. National Wetland Inventory Maps from the 1980s indicate that a small forested wetland is located along the river just north of the McKinley Bridge. This wetland was not observed during the field reconnaissance. No other wetlands were observed at the site.

Please provide the source(s) of information used to identify these sensitive areas, and indicate their general location on the site map.

8. **What type of facility is located at the site?**

☒ Chemical ☒ Manufacturing ☐ Mixing ☐ Waste disposal

☒ Other (specify): The primary site is the Mallinckrodt property, which began in 1867 with the construction of a chemical plant. Operations have continued at this site since 1867. From 1942 to 1957, Mallinckrodt processed uranium feed materials in support of the nation's early nuclear program.

9. **What are the suspected contaminants of concern (COCs) at the site? If known, what are the maximum concentration levels? Please cite the source of data cited (e.g. RFI, confirmatory sampling, etc.).**
Contaminants of concern include: arsenic, cadmium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, thorium, uranium, vanadium, and zinc. Radiological constituents include Ra-226, Ra-228, Th-230, Th-232, U-234, U-235, U-238, Ac-227, Pb-210, and Pa-231. Additional details for COCs can be found in the Remedial Investigation (RI) Report.

10. **Check any potential routes of off-site migration of contaminants observed at the site:**

☐ Swales ☐ Depressions ☐ Drainage ditches

☐ Runoff ☐ Windblown particulates ☐ Vehicular traffic

☒ Other (specify): There appears to be very little opportunity for off-site migration through surface water. The majority of the site is covered by buildings, parking lots, or other pavement. Storm water at the site is collected by storm sewers and discharges to a sanitary sewer. Because most of the soils at the site are covered windblown contamination is also unlikely.

11. **If known, what is the approximate depth to the water table?**
7-32' below ground surface (bgs)

12. **Indicate the direction of ground-water flow.**
Ground-water flow is generally to the east.

13. **Is the direction of surface runoff apparent from site observations? ☒ Yes ☐ No**
If yes, to which of the following does the surface runoff discharge? Indicate all that apply.

☐ Surface water ☐ Ground water ☒ Sewer ☐ Collection impoundment

Storm water on the site is collected in a series of swales and curb and drop inlets and then conveyed offsite to waste water treatment facilities.

14. **Is there a navigable water body or tributary to a navigable water body? ☒ Yes ☐ No**
The Mississippi River is located adjacent to the site.

15. **Is there a water body on or in the vicinity of the site? If yes, also complete Section III.B.1: Aquatic Habitat Checklist -- Non-Flowing Systems and/or Section III.B.2: Aquatic Habitat Checklist -- Flowing Systems.**

☐ Yes ☒ No

16. **Is there evidence of flooding? ☐ Yes ☒ No**
Wetlands and flood plains are not always obvious; do not answer "no" without confirming information. **If yes, complete Section V: Wetland Habitat Checklist.** No visible evidence of flooding or wetlands was observed at the site. The eastern portion of the site is located within the 100-year floodplain of the Mississippi River; however, it does not appear that floodwaters have reached the site in some time. The lack of potential wetlands and floodplains was confirmed by an SAIC wetland scientist during the site visit.

17. **If a field guide was used to aid any of the identifications, please provide a reference. Also, estimate the time spent identifying fauna. (Use a blank sheet if additional space is needed for text.)** Not applicable

18. **Are any threatened and/or endangered species (plant or animal) known to inhabit the area of the site?**
☐ Yes ☒ No
If yes, you are required to verify this information with the U.S. Fish and Wildlife Service (USFWS). **If species' identities are known, please list them next.**

19. **Record weather conditions at the time this checklist was prepared:**

Date: 09/10/2010

Temperature: 80° F

Normal daily high temperature: 83° F

Wind (direction/speed): None

Precipitation (rain, snow): <0.1 inches

Cloud cover: Overcast, occasional light rain

20. **Describe reasonable and likely future land and/or water use(s) at the site.**
The project site is located within a highly industrialized portion of the City of St. Louis. There are no known plans to discontinue the use of the Mallinckrodt facility. Therefore, the site is anticipated to remain as industrial land use.

No surface water is located at the site. As noted in the 1998 ROD (USACE 1998a), the Mississippi Alluvial Aquifer (HU-B) qualifies as a potential source of drinking water under the "Guidelines for Groundwater Classification under the USEPA Groundwater Protection Strategy" (USEPA 1988). However, the City of St. Louis explicitly forbids the installation of wells into the subsurface for the purposes of using the ground water as a potable water supply (Ordinance 66777, City of St. Louis 2005).

21. **Describe the historical uses of the site. Include information on chemical releases that may have occurred as a result of previous land uses. For each chemical release, provide information on the form of the chemical released (i.e., solid, liquid, vapor) and the known or suspected causes or mechanism of the release (i.e., spills, leaks, material disposal, dumping, explosion, etc.).**
Detailed information concerning site history may be found in the Remedial Investigation Report.

22. **Identify the media (e.g., soil [surface or subsurface], surface water, air, ground water) that are known or suspected to contain COCs.**
Contamination is suspected in inaccessible soil and sediments associated with buildings and sewers, roadways, and RRs.

IIA. SUMMARY OF OBSERVATIONS AND SITE SETTING

Include information on significant source areas and migration pathways that are likely to constitute complete exposure pathways.

The site visit began at approximately 0930 on 09/10/2010 with overcast skies and a temperature of 80° F. Observations were made within the boundaries of the SLDS property. Areas adjacent to the SLDS were observed from the public roadways.

The SLDS is predominantly an industrialized area, and the only habitat present at the site consists of small wooded areas and barren/field habitats. The wooded areas are located at three main areas (DT-2, DT-5, and DT-9) as shown in Figure R-2. Open field areas are located along the levee (DT-9), at DT-1, and the Terminal Railroad Spoil Area. The largest vegetated area on the site is the area adjacent to the Mississippi River along the levee. The majority of this area is maintained as mowed turfgrass. A highly disturbed, linear forested area is located immediately adjacent to the Mississippi River. This approximately 4.5-acre fragmented woodland is dominated by disturbance-tolerant species such as mulberry (*Morus* sp.), eastern cottonwood (*Populus deltoides*), Amur honeysuckle (*Lonicera maackii*), and Japanese honeysuckle (*Lonicera japonica*). A few American sycamore (*Platanus occidentalis*) and silver maple (*Acer saccharinum*) trees are also present. There is almost no understory present in the woodland.

Other large, vegetated areas at the site include a small wooded area adjacent to the Terminal railroad tracks, a wooded area adjacent to the Ameren UE electrical station (DT-5), and a former building site (DT-1). All of these areas are characterized by disturbance-tolerant species such as tree of heaven (*Ailanthus altissma*), Amur honeysuckle, Johnson grass (*Sorghum halepense*), and ragweed (*Ambrosia artemisiifolia, A. trifida*). These areas are described in more detail in Sections IIIA1 and IIIA3.

Wildlife observations during the site visit included several bird species (swallow, sparrow, robin, cardinal, mourning dove, and mockingbird), as well as a groundhog den, raccoon tracks, and beaver cuttings.

There are no complete significant exposure pathways to ISOU media being evaluated in the ISOU RI Report (inaccessible soil, storm-sewer sediment, and structural surfaces) at the site. There is no natural ecological habitat at the site. Few terrestrial receptors are likely to inhabit the site, because the patchiness of the vegetation, lack of cover and water, and high level of disturbance are unattractive to wildlife. The only receptors likely to use the site would be urban-adapted species. Finally, there is currently no evidence of significant contaminant transport via ground water to more sensitive aquatic habitats offsite. However, further evaluation of potential risks to the environment from site ground water will be conducted as part of the Ground-water Remedial Action Alternative Assessment initiated under the 1998 ROD.

Completed by: Brian W. Tutterow **Affiliation:** SAIC

Date: 09/10/2010

III. HABITAT EVALUATION

IIIA. Terrestrial Habitat Checklist

IIIA1. WOODED

1. **Are there any wooded areas at the site?** ☒ **Yes** ☐ **No**
If no, go to Section IIB: Shrub/Scrub.

Wooded Area Questions

☒ Onsite ☐ Offsite

Name or Designation: Wooded Area 1 (DT-2); Figure R-2, Photographs 1-4

1. **Estimate the approximate size of the wooded area.** 4.5 acres
Please identify what information was used to determine the wooded area of the site (e.g., direct observation, photos, etc.). Aerial photography and direct observation

2. **Indicate the dominant type of vegetation in the wooded area. Provide photographs, if available.**

☐ Evergreen
☒ Deciduous
☐ Mixed

Dominant plant species, if known: Species underlined were dominant
Tree and Shrub Layer: Mulberry, cottonwood, Amur honeysuckle, sumac, (*Rhus* sp.), silver maple, black willow (*Salix nigra*), black locust (*Robinia pseudoacacia*), Siberian elm (*Ulmus pumila*).

3. **Estimate the vegetation density of the wooded area.**

☒ **Dense (i.e., greater than 75% vegetation)**
☐ **Moderate (i.e., 25% to 75% vegetation)**
☐ **Sparse (i.e., less than 25% vegetation)**

4. **Indicate the predominant size of the trees at the site. Use diameter at breast height.**

☐ **0-6 inches**
☒ **6-12 inches**
☐ **>12 inches**
☐ **No single size range is predominant**

5. **Specify type of understory present, if known. Provide a photograph, if available.**
Honeysuckle was the only understory species present. The following species were present in the unmowed areas adjacent to the woods: Johnson grass, foxtail (*Setaria glauca*), goldenrod (*Solidago* sp.), late-flowering thoroughwort (*Eupatorium serotinum*), elderberry (*Sambucus canadensis*).

Name or Designation: Wooded Area 2 (DT-5); Figure R-2, Photographs 4-8

Estimate the approximate size of the wooded area. 0.5 acres

Please identify what information was used to determine the wooded area of the site (e.g., direct observation, photos, etc.). Aerial photography and direct observation

1. **Indicate the dominant type of vegetation in the wooded area. Provide photographs, if available.**

   ☐ Evergreen
   ☒ Deciduous
   ☐ Mixed

   Dominant plant species are underlined: cottonwood, tree of heaven, sycamore, black locust, Catalpa (*Catalpa speciosa*)

2. **Estimate the vegetation density of the wooded area.**

   ☒ **Dense (i.e., greater than 75% vegetation)**
   ☐ **Moderate (i.e., 25% to 75% vegetation)**
   ☐ **Sparse (i.e., less than 25% vegetation)**

3. **Indicate the predominant size of the trees at the site. Use diameter at breast height.**

   ☒ **0-6 inches**
   ☐ **6-12 inches**
   ☐ **>12 inches**
   ☐ **No single size range is predominant**

4. **Specify type of understory present, if known. Provide a photograph, if available.**
   Understory was limited to Amur honeysuckle with some horseweed (*Conyza canadensis*), ragweed, and late-flowering thoroughwort along the edges of the woods.

Name or Designation: Wooded Area 3 (DT-9); Figure R-3, Photographs 9-12

1. **Estimate the approximate size of the wooded area.** 1.0 acres
   Please identify what information was used to determine the wooded area of the site (e.g., direct observation, photos, etc.). Aerial photography and direct observation

2. **Indicate the dominant type of vegetation in the wooded area. Provide photographs, if available.**

   ☐ Evergreen
   ☒ Deciduous
   ☐ Mixed

   Dominant plant species are underlined: Mulberry, Siberian elm, tree of heaven, sycamore, wild grape, cottonwood, hackberry

3. **Estimate the vegetation density of the wooded area.**

   ☒ **Dense (i.e., greater than 75% vegetation)**
   ☐ **Moderate (i.e., 25% to 75% vegetation)**
   ☐ **Sparse (i.e., less than 25% vegetation)**

4. **Indicate the predominant size of the trees at the site. Use diameter at breast height.**

   ☒ **0-6 inches**
   ☐ **6-12 inches**
   ☐ **>12 inches**
   ☐ **No single size range is predominant**

5. **Specify type of understory present, if known. Provide a photograph, if available.**
The understory was limited to Amur honeysuckle. Some scattered camphorweed (*Heterotheca subaxillaris*) and annual sunflower (*Helianthus annuus*), as well as a few large clusters of Johnson grass, were present in the gravel area adjacent to the woods.

IIIA2. SHRUB/SCRUB

1. **Is shrub/scrub vegetation present at the site?** ☐ **Yes** ☒ **No**
If no, go to Section IIC: Open Field.
The remainder of Section IIIA2 is not applicable

IIIA3. OPEN FIELD

1. **Are there open (bare, barren) field areas present at the site?** ☒ **Yes** ☐ **No**
If yes, please answer the questions below:

Open Field Area Questions

☒ Onsite ☐ Offsite

Name or Designation: Field 1 (Plant 7E, DT-1); Photographs 13-20

1. **Estimate the approximate size of the open field area.** 7.0 acres
Please identify what information was used to determine the open field area of the site. Aerial photography and direct observation.

2. **List the vegetation: (dominant vegetation is underlined).**
Field 1A: Johnson grass, common ragweed, common sunflower, evening primrose (*Oenothera biennis*), purple top (*Tridens flavus*), foxtail, partridge pea (*Chamaecrista fasiculata*), common mullein (*Verbascum thapsus*), cottonwood
Field 1B: Johnson grass, foxtail, common ragweed, late-flowering thoroughwort, cottonwood, common sunflower, spotted spurge (*Euphorbia maculate*), goldenrod, common mullein, horseweed

3. **Estimate the vegetation density of the area.**

☐ **Dense (i.e., greater than 75% vegetation)**
☒ **Moderate (i.e., 25% to 75% vegetation)**
☐ **Sparse (i.e., less than 25% vegetation)**

4. **Indicate the approximate average height of the dominant plant:** Cottonwoods on the edge of the Field 1A were approximately 8-10 ft tall, several cottonwoods were that tall in Field 1B, and a single tree near the center of the site was approximately 25 ft tall. Sunflowers in the interior of both sites were approximately 3 ft tall.

Name or Designation: Field 2 (DT-9); Photographs 21-24

1. **Estimate the approximate size of the open field area.** 13 acres
Please identify what information was used to determine the open field area of the site. Aerial photographs and site observation.

2. **List the vegetation: (dominant vegetation is underlined).**
Common ragweed, foxtail, Johnson grass, wormwood (*Artemisia* sp.), spiny amaranth (*Amaranthus spinosus*), chicory (*Cichorium intybus*), red clover (*Trifolium pretense*)

3. **Estimate the vegetation density of the area.**

   ☐ **Dense (i.e., greater than 75% vegetation)**
   ☒ **Moderate (i.e., 25% to 75% vegetation)**
   ☐ **Sparse (i.e., less than 25% vegetation)**

4. **Indicate the approximate average height of the dominant plant:** 5-6 feet

Name or Designation: Field 3 (Terminal Railroad Spoil Area); Photographs 25-27

1. **Estimate the approximate size of the open field area.** 5.75 acres
   Please identify what information was used to determine the open field area of the site.

2. **List the vegetation: (dominant vegetation is underlined).**

   Common sunflower, late-flowering thoroughwort, camphorweed, Johnson grass, horseweed, mulberry, common mullein, goldenrod, Chinese lespedeza, (*Lespedeza cuneata*), Queen Anne's lace (*Daucus carota*), common ragweed.

3. **Estimate the vegetation density of the area.**

   ☐ **Dense (i.e., greater than 75% vegetation)**
   ☒ **Moderate (i.e., 25% to 75% vegetation)**
   ☐ **Sparse (i.e., less than 25% vegetation)**

4. **Indicate the approximate average height of the dominant plant.** 3-4 ft

IIIA4. MISCELLANEOUS

1. **Are other types of terrestrial habitats present at the site, other than woods, scrub/shrub, and open field?**
   ☒ **Yes** ☐ **No**
   If yes, identify and describe them below.

2. **Describe the terrestrial miscellaneous habitat(s) and identify these area(s) on the site map.**
   Areas of vegetation less than 0.1 acre in size are scattered throughout the SLDS along fence lines and in the corners of unused lots. In total, it is estimated that these sites total less than 1.5 acres of additional habitat. Vegetation in these areas is characterized by noxious and invasive species, such as Johnson grass, ragweed, mulberry, Amur honeysuckle, and tree of heaven. A few sites contained cottonwoods and sumac. See photographs 32-33.

3. **What observations, if any, were made at the site regarding the presence and/or absence of insects, fish, birds, mammals, etc.?**
   Several species of birds were observed at the site, including swallow, mourning dove, mockingbird, robin, cardinal, American goldfinch, and sparrows. Raccoon tracks were observed along the Mississippi River, and a ground hog den was observed in Wooded Area 2. Evidence of beaver cuts on trees was also observed in the wooded area adjacent to the river. An eastern cottontail rabbit was observed in Field 3.

4. **Review the questions in Section I to determine if any additional habitat checklists should be completed for this site.**
   No other habitat type is applicable.

III.B AQUATIC HABITAT

III.B1 NON-FLOWING SYSTEMS

1. **What type of open-water, non-flowing system is present at the site?** None

The remainder of Section IIIB1 is not applicable.

III.B2 FLOWING SYSTEMS

1. **What type(s) of flowing water system(s) is (are) present at the site?** The Mississippi River is located adjacent to the site.

Flowing Aquatic Systems Questions

☐ Onsite ☒ Offsite

Name or Designation: Mississippi River – The river is not considered part of the site, although it is possible that during a 100-year flood event, portions of the site east of the levee (DT-2, DT-9, DT-15) would be flooded. See Photographs 28-31.

Indicate the type of flowing aquatic feature present. River

1. **For natural systems, are there any indicators of physical alteration (e.g., channeling, debris, etc.)?**
☐ Yes ☒ No
If yes, please describe the indicators observed.
The river has been extensively modified through the use of dams, dredging, levees, wing dams, and rip-rap. Most of the river bank adjacent to the site has at least some remaining rip-rap structure.

2. **Indicate the general composition of the bottom substrate.**

☐ **Bedrock**
☐ **Boulder (>10 inches)**
☐ **Cobble (2.5 - 10 inches)**
☐ **Gravel (0.1 - 2.5 inches)**
☐ **Sand (course)**
☒ **Silt (fine)**
☐ **Clay (slick)**
☒ **Muck (fine/black)**
☐ **Concrete**
☒ **Debris**
☒ **Detritus**
☐ **Marl (Shells)**
☐ **Other (please specify):**______________________________

3. **Describe the condition of the bank (e.g., height, slope, extent of vegetative cover).**
The bank is generally steep and at the time of the survey extended approximately 15-20 ft above the water level of the river. The bank was un-vegetated and consisted of a mix of rip-rap and silt.

4. **Is the system influenced by tides?** ☐ **Yes** ☒ **No**
What information was used to make this determination?

5. **Is the flow intermittent?** ☐ **Yes** ☒ **No**
If yes, please note the information used to make this determination.

6. **Is there a discharge from the site to the water body?** ☐ **Yes** ☒ **No**
If yes, describe the origin of each discharge and its migration path.

7. **Indicate the discharge point of the water body. Specify name of the discharge, if known.**

8. **Identify any field measurements and observations of water quality that were made. Provide the measurement and the units of measure in the appropriate space below:**
No water quality measurements were made.

9. **Describe observed color and area of coloration.**
No color observations were made.

10. **Is any aquatic vegetation present?** ☐ **Yes** ☒ **No**
If yes, please identify the type of vegetation present, if known.

☐ **Emergent** ☐ **Submergent** ☐ **Floating**

11. **Mark the flowing water system on the attached site map.**
See attached Figures R-1 and R-2.

12. **What observations were made at the water body regarding the presence and/or absence of benthic macroinvertebrates, fish, birds, mammals, etc?** Evidence of birds (swallow, mourning dove), beaver, and raccoon were observed at the site.

IIIC. WETLAND HABITAT CHECKLIST

1. Are any wetland[1] areas such as marshes or swamps on or adjacent to the site?
☐ **Yes** ☒ **No**

Identify the sources of the observations and information (e.g., National Wetland Inventory, federal or state agency, U.S. Geological Survey [USGS] topographic maps) used to make the determination whether or not wetland areas are present.
The lack of wetlands on site determination was made after a review of National Wetland Inventory maps, aerial photographs, and an on-site visit by an SAIC wetland scientist.

If no wetland areas are present, proceed to Section III.D: Sensitive Environments and Receptors.

III.D Sensitive Environments and Receptors

1. **Do any other potentially sensitive environmental areas[2] exist adjacent to or within one-half mile of the site? If yes, list these areas and provide the source(s) of information used to identify sensitive areas. Do not answer "no" without confirmation from the USFWS and other appropriate agencies. See Table 1 for a list of contacts.**
No. The project is located within an industrial urban area with no potential for sensitive environmental areas. The Missouri Department of Conservation's Natural Heritage database indicated that no threatened or endangered species are known to occur in the City of St. Louis.

2. **Are any areas on or near (i.e., within one-half mile) the site owned or used by local tribes? If yes, describe.**
No

---

[1] Wetlands are defined in 40 *CFR* §232.2 as " Areas inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances does support, a prevalence of vegetation typically adapted for life in saturated soil conditions." Examples of typical wetlands plants include: cattails, cordgrass, willows, and cypress trees. National wetland inventory maps may be available at http:\\nwi.fws.gov. Additional information on wetland delineation criteria is also available from the USACE.

[2] Areas that provide unique and often protected habitat for wildlife species. These areas are typically used during critical life stages such as breeding, hatching, rearing of young and overwintering. Refer to Table 2 at the end of this document for examples of sensitive environments.

3. **Does the site serve or potentially serve as a habitat, foraging area, or refuge by rare, threatened, endangered, candidate and/or proposed species (plants or animals), or any otherwise protected species? If yes, identify species. This information should be obtained from the USFWS and other appropriate agencies. See Table 1 for a list of contacts.**
   No suitable habitat is present on site.

4. **Is the site potentially used as a breeding, roosting or feeding area by migratory bird species? If yes, identify which species.**
   The site could provide limited habitat to urban-adapted migratory bird species such as robins or killdeer.

5. **Is the site used by any ecologically[3], recreationally, or commercially important species? If yes, explain.**
   No, the limited habitat quality and quantity on the site would only be suitable for species adapted to urban habitat.

IV. EXPOSURE PATHWAY EVALUATION

Do existing data provide sufficient information on the nature, rate, and extent of contamination at the site?

[✓ Yes]
No
Uncertain

1. **Please provide an explanation for your answer.** Numerous studies have been conducted on site, including the 1977 radiological survey, the 1987 to 1990 Phase 1 and Phase 2 site characterization, an RI addendum in 1992 and 1993, the 1998 background soil survey, and the ongoing pre-design investigations (PDIs) and final status survey evaluations (FSSEs). Details of these investigations are included in the *Remedial Investigation Work Plan for the Inaccessible Soil Operable Unit at the St. Louis Downtown Site.*

2. **Do existing data provide sufficient information on the nature, rate, and extent of contamination in off-site affected areas?**

   Yes
   No
   Uncertain
   [✓ No offsite contamination]

   Please provide an explanation for your answer: Observation of site conditions, including ground-water flow and the impervious nature of the majority of the site surface, limit potential for offsite contamination.

3. **Do existing data address potential migration pathways of contaminants at the site?**

   [✓ Yes]
   No
   Uncertain

   Please provide an explanation for your answer. The majority of potential site contaminants occur within accessible soils at the site that are under remediation. Migration of contaminants from inaccessible soil is limited, because most of these soils are covered by buildings, pavement, or other impervious materials.

---

[3] Ecologically important species include populations of species, which provide a critical (i.e., not replaceable) food resource for higher organisms. These species' functions would not be replaced by more tolerant species or perform a critical ecological function (such as organic matter decomposition) and will not be replaced by other species. Ecologically important species include pests and opportunistic species that populate an area if they serve as a food source for other species, but do not include domesticated animals (e.g., pets and livestock) or plants/animals whose existence is maintained by continuous human interventions (e.g., fish hatcheries, agricultural crops, etc).

4. **Do existing data address potential migration pathways of contaminants in off-site affected areas?**

Yes
No
Uncertain
[✓ No offsite contamination]

Please provide an explanation for your answer. See response to question 2 above.

5. **Are there visible indications of stressed habitats or receptors on or near (i.e., within one-half mile) the site that may be the result of a chemical release? If yes, explain. Attach photographs if available.** No

6. **Is the location of the contamination such that receptors might be reasonably expected to come into contact with it? For soil, this means contamination in the soil 0 to 1 ft bgs. If yes, explain.**
Contamination may be present within the inaccessible soil at the site. The potential that receptors could come in contact with this soil is unlikely due to the presence of buildings, roadways, etc. acting as cover material. Additionally, the presence of potential receptors is limited by the quality and quantity of available habitat on site.

7. **Are receptors located in or using habitats where chemicals exist in air, soil, sediment, or surface water? If yes, explain.**
Chemicals present on site are limited to the inaccessible soil.

8. **Could chemicals reach receptors via ground water? Can chemicals leach or dissolve to ground water? Are chemicals mobile in ground water? Does ground water discharge into receptor habitats? If yes, explain.**
No. While it is possible that chemicals found on the site could leach or dissolve into the ground water, there is no open pathway for ecological receptors due to the depth to ground water and the general lack of sensitive receptors.

9. **Could chemicals reach receptors through runoff or erosion?** Unlikely. The majority of the site is covered by impervious surfaces such as parking lots, buildings, and walkways. The portions of the site not covered by impervious surfaces are protected by landscape plants, mulch, and turf grass.

Answer the following questions.

What is the approximate distance from the contaminated area to the nearest watercourse?

0 feet (i.e., contamination has reached a watercourse)
1-10 ft
11-20 ft
21-50 ft
51-100 ft
[✓ 101-200 ft]
> 200 ft
> 500 ft
> 1000 ft

What is the slope of the ground in the contaminated area?

[✓ 0-10%]
10-30%
> 30%

What is the approximate amount of ground and canopy vegetative cover in the contaminated area?

< 25%
25-75%
[✓ > 75%]

Is there visible evidence of erosion (e.g., a rill or gully) in or near the contaminated area?

Yes
[✓ **No**]
Do not know

Do any structures, pavement, or natural drainage features direct run-on flow (i.e., surface flows originating upstream or uphill from the area of concern) into the contaminated area?

Yes
[✓ **No**]
Do not know

10. **Could chemicals reach receptors through the dispersion of contaminants in air (e.g., volatilization, vapors, fugitive dust)? If yes, explain.**
No

11. **Could chemicals reach receptors through migration of non-aqueous phase liquids (NAPLs)? Is a NAPL present at the site that might be migrating toward receptors or habitats? Could NAPL discharge contact receptors or their habitat?** No

Conclusion

Given the environmental setting/nature of the potential contamination in the inaccessible soils at the SLDS, the results of this Ecological Risk Checklist concur with the findings of the 1993 ecological evaluation that the ISOU evaluations should focus on the protection of human health for the following reasons: (1) the SLDS is a heavily urbanized area not suitable for habitation of sensitive and threatened and endangered (T&E) species, (2) it is highly unlikely that potential ecological impacts from the ISOU are greater than those from accessible media, (3) the potential for direct exposures to ISOU media is greater for humans than for terrestrial or aquatic species, and (4) the potential for subsurface migration beneath structures to sensitive terrestrial or aquatic habitats (although none are likely to exist) is unlikely. Also, given that some remediation at the SLDS has since been conducted, potential impacts to ecological resources from the ISOU contaminated media are likely to be even less significant than those determined during the 1993 BRA. Therefore, no comprehensive ecological risk assessment will be performed as part of the ISOU RI.

FIGURES

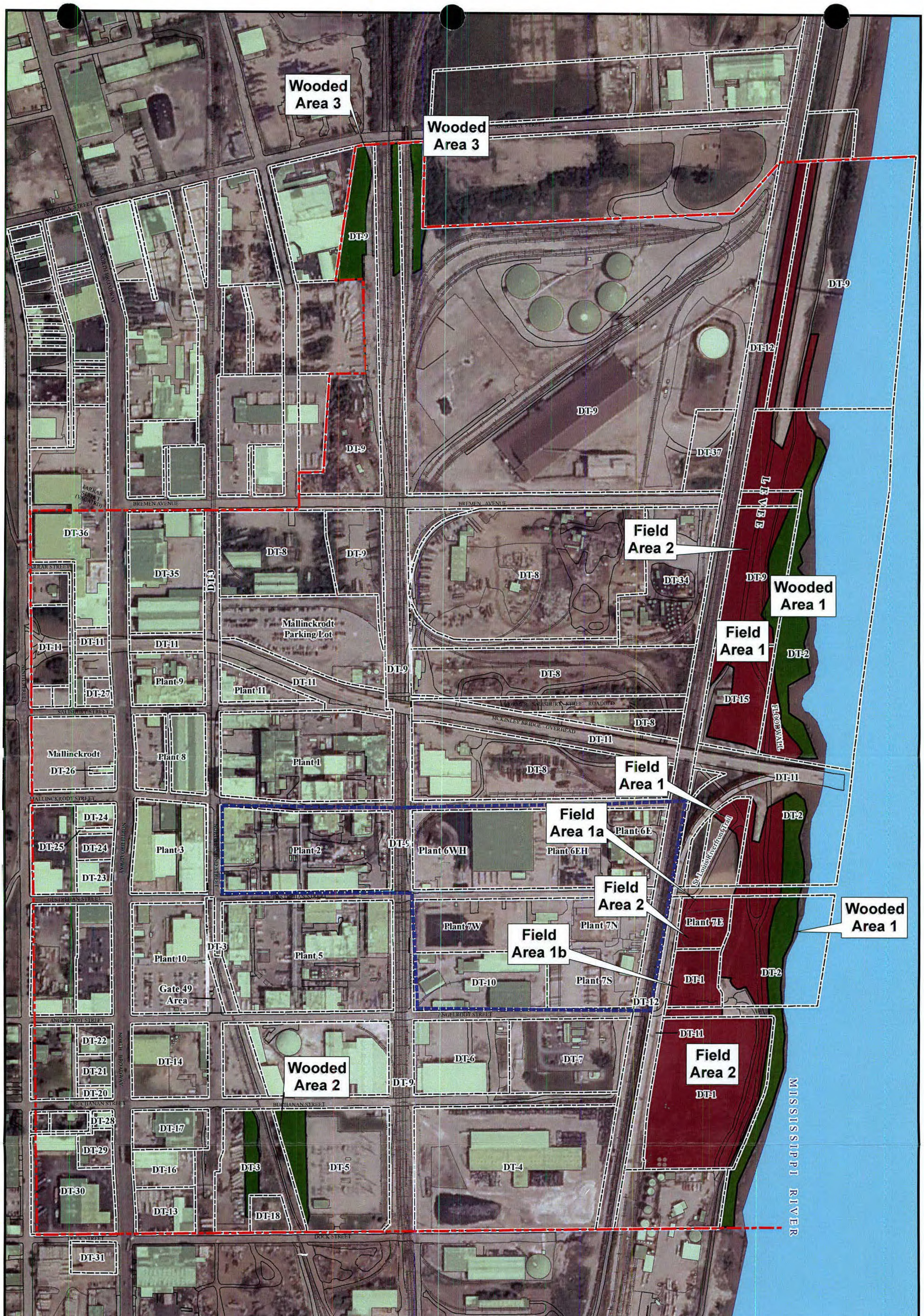
U:\GPS\SLDS\Inaccessible Areas\Projects\ISOU RI Report\RevB\Figure R-1 SLDS Inaccessible Topo.mxd

St. Louis Downtown Site (SLDS)
St. Louis, Missouri

FUSRAP

DRAWN BY:	REV:	DATE:
DLL	B	10/24/11

R-1. Topographic Map



LEGEND

--- Property Boundary

▭ Uranium-Ore Processing Areas as Defined by the 1998 ROD

--- SLDS Boundary

🟩 Building or Tank

🟦 River/Stream

-x- Fence

-+- Railroad

🟥 Field Area

🟩 Wooded Area

MO-East State Plane
(NAD 83, Feet)

0 165 330 660
Feet

St. Louis Downtown Site (SLDS)
St. Louis, Missouri

FUSRAP

DRAWN BY:	REV:	DATE:
DLL	2	10/24/11

R-2. Ecological Checklist Habitat Areas

Path: U:\GPS\SLDS\Inaccessible Areas\Projects\ISOU RI Report\RevB\Figure R-3 Terminal RR Spoils Area.mxd

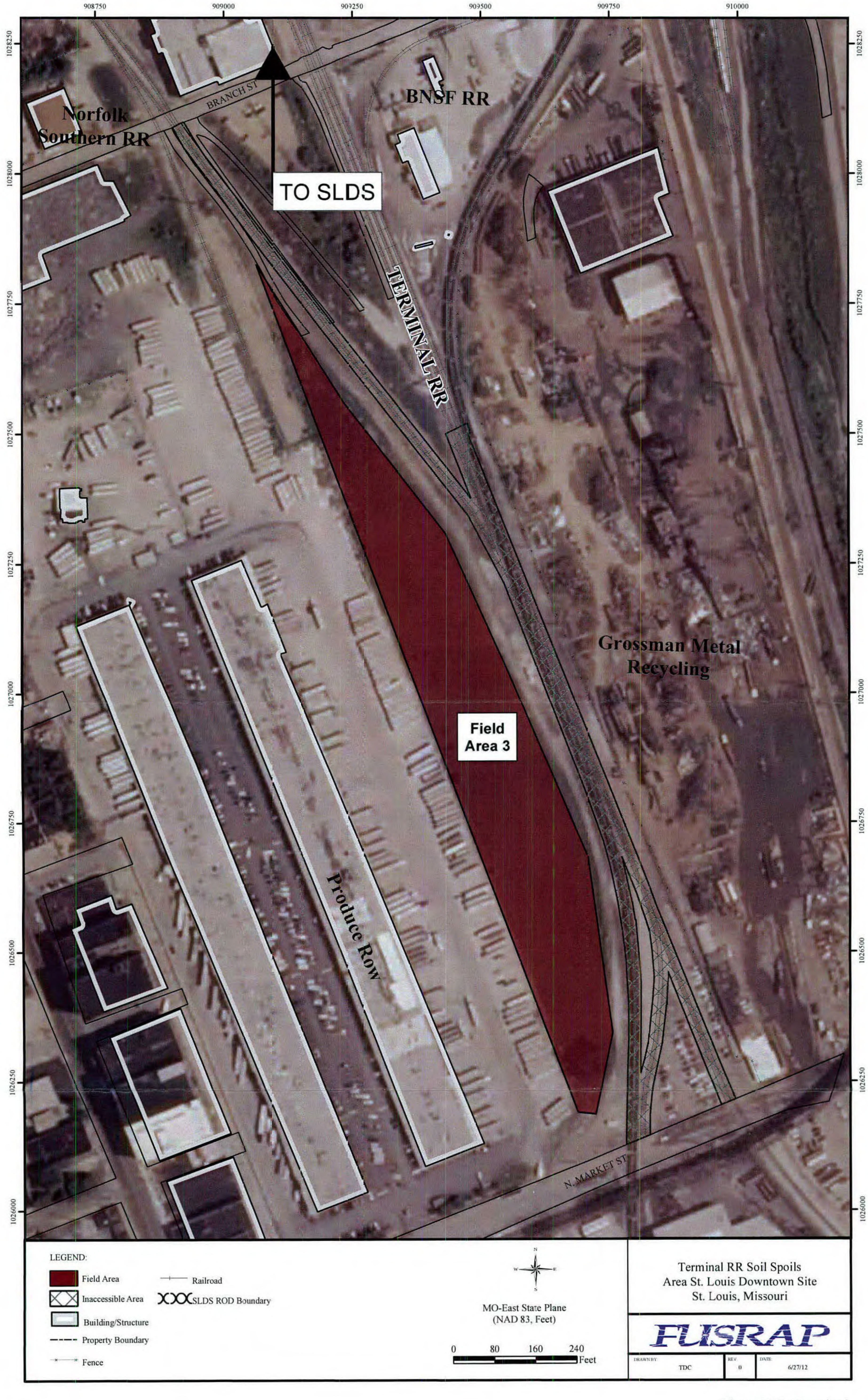


Figure R-3. Terminal RR Soil Spoils Area

PHOTOGRAPHS

Wooded Area 1 (DT-2)

Photo 1. View looking south at the northern edge of the wooded area. McKinley Bridge is visible in the background.

Photo 2. View facing east from the top of the levee at wooded area 1 and field area 1.

Photo 3. View of wooded area facing southeast.

Photo 4. View of understory within the wooded area.

Wooded Area 2 (DT-5)

Photo 5. View facing southeast at the edge of the Ameren UE substation. Bradford pears are located to the left with the wooded area to the right. Ragweed and late-flowering thoroughwort are visible in the foreground.

Photo 6. View of wooded area from the railroad tracks. Tree of heaven and late-flowering thoroughwort are the most visible species. Goldenrod and honeysuckle are also present at this location.

Photo 7. View southeast along the southwest edge of Wooded Area 2.

Photo 8. Groundhog den within Wooded Area 2.

Wooded Area 3 (DT-9)

Photo 9. View from the intersection of Angelica railroad crossing. View is facing southwest at woodland on the southwest edge of the railroad tracks.

Photo 10. View facing south.

Photo 11. View facing southeast with both strips of woods visible at the edge of the photographs.

Photo 12. View of honeysuckle understory.

Field Area 1a (Plant 7E)

Photo 13. View of DT-1 facing south.

Photo 14. View of DT-1 inside the fenceline facing southeast.

Photo 15. View of DT-1 facing south.

Photo 16. Additional view of DT-1 facing south.

Field Area 1b (DT-1)

Photo 17. View of DT-1 facing east.

Photo 18. View facing east southeast.

Photo 19. View facing east northeast.

Photo 20. View facing north northeast.

Field Area 2 (DT-9)

Photo 21. View looking south along the levee. Photograph was taken near the northern boundary of the site. McKinley Bridge is visible in the background.

Photo 22. View facing north at the toe of the levee. Photograph shows Johnson grass to the right with several cottonwoods visible in the background.

Photo 23. View facing north from the top of the levee. Johnson grass, ragweed, wormwood species are visible along the top and toe of the levee.

Photo 24. Mowed portion of the levee near McKinley Bridge.

Field Area 3 (Railroad Spoil Area)

Photo 25. View facing southeast of railroad spoil area.

Photo 26. View facing northwest.

Photo 27. View facing southwest into vegetation portion of site. Eastern cottontail rabbit is highlighted within the red circle.

Mississippi River

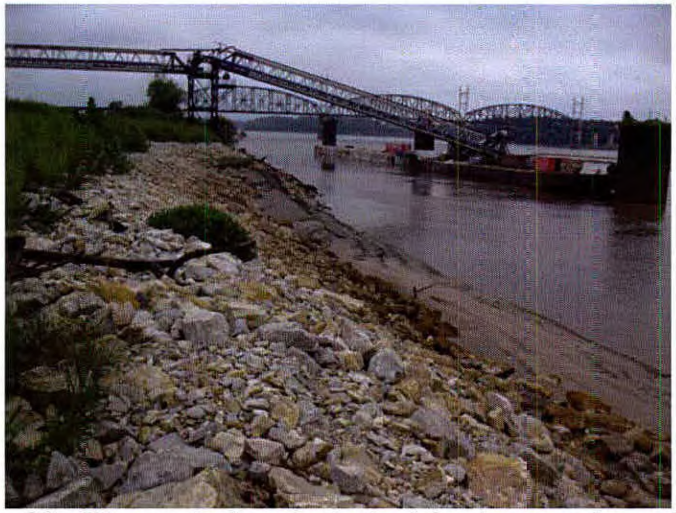


Photo 28. View north along the bank of the river near the northern boundary of SLDS.

Photo 29. View facing south along the riverbank.

Photo 30. View of the riverbank in the vicinity of McKinley Bridge.

Photo 31. View facing east across the river.

Miscellaneous Photographs

Photo 32. View facing southwest along rail line. Gunther Salt (DT-4) is visible to the right. Note the vegetation along the fence line and underneath the elevated walkway.

Photo 33. View facing southwest along Buchanan Street at the fenceline next to DT-4 and at the mowed turfgrass adjacent to the USACE trailers.

Photo 34. View facing north at the Riverfront Trail. This photograph was taken near the north end of SLDS across from DT-9.

Photo 35. Entrance to the Riverfront Trail at the end of Branch Street just south of the SLDS boundary.

APPENDIX S

Derivation of Building Surface Preliminary Remediation Goals

(On the DVD on the Back Cover of this Report)

AR-021