099641

SL-1283

DOE/OR/23701-41.1

Baseline Risk Assessment for Exposure to Contaminants at the St. Louis Site, St. Louis, Missouri

November 1993

prepared by

Environmental Assessment Division, Argonne National Laboratory

prepared for

U.S. Department of Energy, Oak Ridge Operations Office, Formerly Utilized Sites Remedial Action Program, under Contract W-31-109-Eng-38

CONTENTS

LIST OF FIGURES vi

LIST OF TABLES x

NOTATION xviii

ENGLISH/METRIC AND METRIC/ENGLISH EQUIVALENTS xx

1 INTRODUCTION 1-1

1.1 Site Overview 1-1
1.1.1 Environmental Compliance Process 1-2
1.1.2 Objectives of the Baseline Risk Assessment 1-5
1.2 Site Background 1-5
1.2.1 General Site Description and History 1-5
1.2.2 Summary of Site Contamination 1-11
1.3 Scope of Risk Assessment 1-12
1.3.1 Time Period 1-13
1.3.2 Institutional Control and Exposure Scenarios 1-13
1.4 Report Organization 1-14

2 IDENTIFICATION OF CONTAMINANTS OF CONCERN 2-1

2.1 Origin of Contamination 2-1
2.2 Data Collection 2-2
2.2.1 Objectives 2-2
2.2.2 Sampling Program 2-3
2.2.3 Analytical Scheme 2-5
2.3 Radiological Characterization Results 2-9
2.3.1 Soil 2-9
2.3.2 Groundwater 2-13
2.3.3 Surface Water and Sediment 2-13
2.3.4 Air 2-13
2.3.5 Building Surfaces and Other Structures 2-14
2.4 Chemical Characterization Results 2-14
2.4.1 Soil and Sediment 2-15
2.4.2 Groundwater 2-15
2.4.3 Air 2-16
2.4.4 Comparison of Site Contaminant Levels with Regulatory Standards 2-16
2.5 Data Evaluation 2-16
2.5.1 Radiological Data 2-17
2.5.2 Chemical Data 2-18
2.6 Summary of Contaminants of Concern 2-21

CONTENTS (Cont.)

3 EXPOSURE ASSESSMENT 3-1

3.1 Characterization of Exposure Setting 3-1
  3.1.1 Environmental Setting 3-1
  3.1.2 Land Use and Demography 3-5
3.2 Identification of Exposure Pathways 3-7
  3.2.1 Source Areas 3-8
  3.2.2 Contaminant Fate and Transport 3-8
  3.2.3 Exposure Points, Exposure Routes, and Receptors 3-10
  3.2.4 Summary of Exposure Pathways 3-13
3.3 Estimation of Exposure Point Concentrations 3-13
  3.3.1 Soil 3-15
  3.3.2 Groundwater 3-20
  3.3.3 Exposure to Contaminated Drains 3-22
  3.3.4 Exposure to Contaminated Building Surfaces 3-23
  3.3.5 Exposure from Ingestion of Fish 3-24
3.4 Estimation of Contaminant Dose and Intake 3-24
  3.4.1 Scenario-Specific Assumptions and Intake Parameters 3-26
  3.4.2 Equations for Exposure to Soil 3-29
  3.4.3 Equations for Exposure to Groundwater 3-35
  3.4.4 Equations for Exposure to External Gamma Radiation and Radioactive Contaminants from Incidental Ingestion of Sediment in Drains 3-38
  3.4.5 Equations for Contaminated Building Surfaces 3-38
  3.4.6 Equations for Ingestion of Fish 3-38

4 TOXICITY ASSESSMENT 4-1

4.1 Radiation Toxicity 4-1
  4.1.1 Radiation Toxicity Related to the St. Louis Site 4-2
  4.1.2 Methods of Evaluating Radiation Toxicity 4-3
4.2 Chemical Toxicity 4-4
  4.2.1 General Data Related to the St. Louis Site 4-4
  4.2.2 Methods of Evaluating Chemical Toxicity 4-5

5 RISK CHARACTERIZATION 5-1

5.1 Risk Characterization Methodology 5-1
  5.1.1 Radiological Risks 5-1
  5.1.2 Chemical Risks and Hazard Quotients 5-2
5.2 Risk Estimates for the St. Louis Site 5-3
  5.2.1 Current Site Use 5-4
  5.2.2 Hypothetical Future Site Use 5-8
5.3 Uncertainties Related to Risk Estimates 5-10
  5.3.1 Identification of the Contaminants of Concern 5-10
  5.3.2 Exposure Assessment 5-11
  5.3.3 Toxicity Assessment 5-13

CONTENTS (Cont.)

5.3.4 Risk Characterization 5-14
5.3.5 Assessment of Lead Toxicity 5-16
5.4 Summary of the Risk Characterization 5-17
5.4.1 Radiological Risks 5-17
5.4.2 Chemical Risks 5-17
5.4.3 Overall Risks 5-18

6 ENVIRONMENTAL ASSESSMENT FOR BIOTA 6-1

6.1 Radiological Toxicity 6-2
6.2 Chemical Toxicity 6-3
6.3 Summary 6-4

7 SUMMARY 7-1

7.1 Background 7-1
7.2 Characterization of Site Contamination 7-1
7.2.1 Radioactive Contamination 7-3
7.2.2 Chemical Contamination 7-4
7.2.3 Contaminants of Concern 7-4
7.3 Exposure Assessment 7-5
7.3.1 Contaminant Fate and Transport 7-5
7.3.2 Potential Receptors and Routes of Exposure 7-6
7.3.3 Exposure Point Concentrations, Doses, and Intakes 7-7
7.4 Toxicity Assessment 7-7
7.5 Risk Characterization 7-7
7.5.1 Risk Estimates for Current Site Use 7-8
7.5.2 Risk Estimates for Hypothetical Future Site Use 7-8
7.5.3 Uncertainties Related to Risk Estimates 7-13
7.6 Summary and Recommendations 7-15

8 REFERENCES 8-1

9 LIST OF CONTRIBUTORS 9-1

APPENDIX A: Figures Showing Areas and Depths of Contamination at the St. Louis Site A-1

APPENDIX B: Toxicity Assessment for Individual Contaminants of Concern at the St. Louis Site B-1

APPENDIX C: Parameters Determined in Samples Collected at the St. Louis Site C-1

APPENDIX D: Risk Estimates for the Ingestion of Homegrown Produce Pathway D-1

FIGURES

1.1 Locations of FUSRAP Properties in the St. Louis, Missouri, Area 1-2

1.2 Locations of the SLDS and Vicinity Properties 1-6

1.3 Locations of SLAPS and Vicinity Properties 1-9

1.4 Locations of the Latty Avenue Properties 1-10

2.1 Uranium-238 Radioactive Decay Series 2-22

2.2 Thorium-232 Radioactive Decay Series 2-23

2.3 Uranium-235 Radioactive Decay Series 2-24

3.1 Conceptual Site Model for SLDS, SLDS Vicinity Properties, and City Property 3-40

3.2 Conceptual Site Model for SLAPS, HISS, and Other Properties 3-41

7.1 Total Carcinogenic Risks for Current Receptors from Radiological and Chemical Exposures 7-9

7.2 Total Radiological Carcinogenic Risks for Current Receptors from Radon and Nonradon Exposures 7-10

7.3 Hazard Indexes for Current Receptors from the Ingestion of Chemical Contaminants 7-11

7.4 Total Carcinogenic Risks for Future Receptors from Radiological and Chemical Exposures 7-11

7.5 Total Radiological Carcinogenic Risks for Future Receptors from Radon and Nonradon Exposures 7-12

7.6 Total Chemical Carcinogenic Risks for Future Receptors from Alternative Pathways 7-12

7.7 Hazard Indexes for Future Receptors from Alternative Pathways of Chemical Contaminants 7-14

A.1 Areas of Radioactive Contamination at SLDS A-3

A.2 Areas and Depths of Radioactive Contamination at SLAPS A-4

A.3 Areas and Depths of Radioactive Contamination at the St. Louis Airport Authority Property A-5

FIGURES (Cont.)

A.4 Areas and Depths of Radioactive Contamination at Banshee Road A-6

A.5 Areas and Depths of Radioactive Contamination at the Ditches to the North and South of SLAPS A-7

A.6 Areas and Depths of Radioactive Contamination at the Ballfield Area A-8

A.7 Areas and Depths of Radioactive Contamination at Latty Avenue A-9

A.8 Areas and Depths of Radioactive Contamination at McDonnell Boulevard A-10

A.9 Areas and Depths of Radioactive Contamination along Pershall Road A-11

A.10 Areas and Depths of Radioactive Contamination along Hazelwood Avenue A-12

A.11 General Areas of Contamination along the Haul Roads A-13

A.12 Radioactive Contamination at the Vicinity Properties A-14

A.13 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 5 .... A-15

A.14 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 7 .... A-15

A.15 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 9 .... A-16

A.16 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 10 .... A-16

A.17 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 11 .... A-17

A.18 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 14 .... A-17

A.19 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 15 .... A-18

A.20 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 16 .... A-18

FIGURES (Cont.)

A.21 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 19 . . . . A-19

A.22 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 20 . . . . A-20

A.23 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 21 . . . . A-21

A.24 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 22 . . . . A-21

A.25 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 23 . . . . A-22

A.26 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 24 . . . . A-22

A.27 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 26 . . . . A-23

A.28 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 27 . . . . A-23

A.29 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 30 . . . . A-24

A.30 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 32 . . . . A-25

A.31 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 33 . . . . A-25

A.32 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 34 . . . . A-26

A.33 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 35 . . . . A-27

A.34 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 37 . . . . A-27

A.35 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 38 . . . . A-28

A.36 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 39 . . . . A-28

FIGURES (Cont.)

A.37 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 40 . . . . A-29

A.38 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 41 . . . . A-29

A.39 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 42 . . . . A-30

A.40 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 43 . . . . A-30

A.41 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 44 . . . . A-31

A.42 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 45 . . . . A-32

A.43 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 47 . . . . A-33

A.44 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 48 . . . . A-33

A.45 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 53 . . . . A-34

A.46 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 58 . . . . A-35

A.47 Areas and Depths of Radioactive Contamination at Property 2 on Coldwater Creek A-35

A.48 Areas and Depths of Radioactive Contamination at the Norfolk & Western Railroad Property Adjacent to 9200 Latty Avenue A-36

A.49 Areas and Depths of Radioactive Contamination at the Norfolk & Western Railroad Property South of SLAPS A-37

A.50 Areas and Depths of Radioactive Contamination at the Norfolk & Western Railroad Property Adjacent to Hazelwood Avenue and South of Latty Avenue A-38

A.51 Areas and Depths of Radioactive Contamination at the Norfolk & Western Railroad Property Adjacent to Eva Avenue A-39

FIGURES (Cont.)

A.52 Areas and Depths of Radioactive Contamination at the Futura Coatings Site A-40

A.53 Areas and Depths of Radioactive Contamination at HISS A-40

A.54 Areas and Depths of Radioactive Contamination at Property 1 on Latty Avenue A-41

A.55 Areas and Depths of Radioactive Contamination at Property 2 on Latty Avenue A-42

A.56 Areas and Depths of Radioactive Contamination at Property 3 on Latty Avenue A-42

A.57 Areas and Depths of Radioactive Contamination at Property 4 on Latty Avenue A-43

A.58 Areas and Depths of Radioactive Contamination at Property 5 on Latty Avenue A-43

A.59 Areas and Depths of Radioactive Contamination at Property 6 on Seeger Industrial Drive A-44

TABLES

1.1 Properties Comprising the St. Louis Site 1-3

2.1 Summary of Data Collection Activities at the St. Louis Site 2-25

2.2 Background Radiation Levels at the St. Louis Site 2-32

2.3 Summary of Soil Characterization Results for Radionuclides 2-33

2.4 Radionuclide Concentrations in Composite Samples from the HISS Pile 2-38

2.5 Concentration of Radionuclides in Groundwater at SLDS, SLAPS, and HISS 2-38

2.6 Radiological Measurements in Selected SLDS Buildings 2-39

2.7 Concentrations of Radionuclides in Samples Collected from 50 Manholes at SLDS 2-39

TABLES (Cont.)

2.8 Characterization Results for Metals and Mobile Anions in Soil at the St. Louis Site 2-40

2.9 Characterization Results for Organic Compounds in Soil at the St. Louis Site 2-44

2.10 Chemical Characterization Results for Coldwater Creek Sediment 2-46

2.11 Summary of Chemical Data for Groundwater at the St. Louis Site: Inorganics 2-48

2.12 Summary of Chemical Data for Groundwater at the St. Louis Site: Organic Compounds 2-49

2.13 Chemicals in Groundwater at the St. Louis Site that Exceed Regulatory Standards 2-49

2.14 Groupings of Radionuclides 2-50

2.15 Derived Concentrations from the Source Term Analysis 2-51

2.16 Concentration-Toxicity Screening Procedure for St. Louis Site Soil and Sediment: Oral Reference Doses 2-52

2.17 Concentration-Toxicity Screening Procedure for St. Louis Site Soil and Sediment: Oral Slope Factors 2-57

2.18 Concentration-Toxicity Screening Procedure for St. Louis Site Soil and Sediment: Inhalation Slope Factors 2-62

2.19 Chemical Contaminants in Soil and Sediment Deleted from the Risk Assessment 2-67

2.20 Chemical Contaminants in Groundwater Deleted from the Risk Assessment for All Properties 2-74

2.21 Chemical Contaminants of Concern in Soil and Sediment at the St. Louis Site 2-74

3.1 Property Groups and Corresponding Receptors Assumed for Current and Future Land-Use Scenarios at the St. Louis Site 3-42

3.2 Environmental Transport Media and Exposure Pathways Assessed for Current Receptors at the St. Louis Site 3-43

TABLES (Cont.)

3.3 Environmental Transport Media and Exposure Pathways Assessed for Future Receptors at the St. Louis Site 3-44

3.4 Statistical Parameters for Derivation of Soil UL_{95} Values for Radionuclides 3-45

3.5 Statistical Parameters for Derivation of Soil UL_{95} Values for Chemical Contaminants 3-47

3.6 Radionuclide Exposure Point Concentrations and Estimated External Gamma Doses for Current Receptors at the St. Louis Site 3-49

3.7 Exposure Point Concentrations and Estimated Doses for Employees in SLDS Buildings 3-52

3.8 Indoor Radionuclide Exposure Point Concentrations and Estimated Doses for Construction Workers at SLDS 3-53

3.9 Outdoor Radionuclide Exposure Point Concentrations and Estimated Doses for Construction Workers at SLDS 3-54

3.10 Radionuclide Exposure Point Concentrations and Estimated Doses for Incidental Ingestion of Soil by Current Receptors at the St. Louis Site 3-55

3.11 Radionuclide Exposure Point Concentrations and Estimated External Gamma Doses for Future Receptors at the St. Louis Site 3-58

3.12 Radionuclide Exposure Point Concentrations and Estimated Doses for Incidental Ingestion of Soil by Future Receptors at the St. Louis Site 3-60

3.13 Radionuclide Exposure Point Concentrations and Estimated Doses for Future Receptors from Contaminants in the HISS Storage Pile 3-62

3.14 Chemical Exposure Point Concentrations for Incidental Ingestion of Soil by Current Receptors at the St. Louis Site 3-63

3.15 Chemical Exposure Point Concentrations for Incidental Ingestion of Soil by Future Receptors at the St. Louis Site 3-64

3.16 Exposure Point Concentrations and Estimated Doses for Inhalation of Radon-222 and Its Decay Products by Current Receptors at the St. Louis Site 3-65

TABLES (Cont.)

3.17 Exposure Point Concentrations and Estimated Doses for Inhalation of Radon-222 and Its Decay Products by Future Receptors at the St. Louis Site 3-66

3.18 Radionuclide Exposure Point Concentrations and Estimated Doses for Inhalation of Particulates by Current Receptors at the St. Louis Site 3-67

3.19 Radionuclide Exposure Point Concentrations and Estimated Doses for Inhalation of Particulates by Future Receptors at the St. Louis Site 3-70

3.20 Chemical Exposure Point Concentrations for Inhalation of Particulates by Current Receptors at the St. Louis Site 3-72

3.21 Chemical Exposure Point Concentrations for Inhalation of Particulates by Future Receptors at the St. Louis Site 3-73

3.22 Radionuclide Exposure Point Concentrations and Estimated Doses for Ingestion of Groundwater by Future Receptors at the St. Louis Site 3-73

23 Exposure Point Concentrations of Chemicals for Ingestion of Groundwater by Future Receptors at the St. Louis Site 3-74

3.24 Exposure Point Concentrations of Chemicals for Inhalation of Groundwater by Future Receptors at the St. Louis Site 3-75

3.25 Dose Conversion Factors Used for Calculating Doses from External Exposure, Ingestion, and Inhalation 3-75

3.26 Summary of Estimated Doses to Current Receptors from Radionuclide Exposure at the St. Louis Site 3-76

3.27 Summary of Estimated Doses to Future Receptors from Radionuclide Exposure at the St. Louis Site 3-77

3.28 Values Assumed for Scenario Parameters 3-78

3.29 Estimated Daily Intake of Chemicals from Incidental Ingestion of Soil by Current Receptors at the St. Louis Site 3-82

3.30 Estimated Daily Intake of Chemicals from Incidental Ingestion of Soil by Future Receptors at the St. Louis Site 3-84

31 Estimated Daily Intake of Chemicals from Inhalation of Particulates by Current Receptors at the St. Louis Site 3-85

TABLES (Cont.)

3.32 Estimated Daily Intake of Chemicals from Inhalation of Particulates by Future Receptors at the St. Louis Site 3-86

3.33 Estimated Daily Intake of Chemicals from Ingestion of Groundwater by Future Receptors at the St. Louis Site 3-87

3.34 Estimated Daily Intake of Chemicals from Inhalation of Groundwater by Future Receptors at the St. Louis Site 3-89

4.1 Toxicity Values for Chemical Contaminants of Concern for Oral and Inhalation Exposure: Potential Noncarcinogenic Effects 4-7

4.2 Toxicity Values for Chemical Contaminants of Concern for Oral and Inhalation Exposure: Potential Carcinogenic Effects 4-9

5.1 Radiological Carcinogenic Risk from External Gamma Irradiation for Current Receptors at the St. Louis Site 5-19

5.2 Radiological Carcinogenic Risk for Employees in SLDS Buildings 5-21

5.3 Radiological Carcinogenic Risk for Indoor Construction Workers at SLDS 5-22

5.4 Radiological Carcinogenic Risk for Outdoor Construction Workers at SLDS 5-23

5.5 Radiological Carcinogenic Risk from Incidental Ingestion of Soil for Current Receptors at the St. Louis Site 5-24

5.6 Radiological Carcinogenic Risk from Inhalation of Radon-222 and Its Decay Products for Current Receptors at the St. Louis Site 5-26

5.7 Radiological Carcinogenic Risk from Inhalation of Particulates for Current Receptors at the St. Louis Site 5-27

5.8 Summary of Estimated Radiological Carcinogenic Risk for Current Receptors at the St. Louis Site 5-29

5.9 Chemical Carcinogenic Risk from Ingestion of Soil for Current Receptors at the St. Louis Site 5-30

5.10 Chemical Hazard Quotients for Ingestion of Soil by Current Receptors at the St. Louis Site 5-31

5.11 Chemical Carcinogenic Risk from Inhalation of Particulates for Current Receptors at the St. Louis Site 5-32

TABLES (Cont.)

5.12 Chemical Carcinogenic Risk across Pathways for Current Receptors at the St. Louis Site 5-33

5.13 Chemical Hazard Index across Pathways for Current Receptors at the St. Louis Site 5-33

5.14 Radiological Carcinogenic Risk from External Gamma Irradiation for Future Receptors at the St. Louis Site 5-34

5.15 Radiological Carcinogenic Risk from Incidental Ingestion of Soil for Future Receptors at the St. Louis Site 5-35

5.16 Radiological Carcinogenic Risk from Inhalation of Radon-222 and Its Decay Products for Future Receptors at the St. Louis Site 5-36

5.17 Radiological Carcinogenic Risk from Inhalation of Particulates for Future Receptors at the St. Louis Site 5-37

5.18 Radiological Carcinogenic Risk from Ingestion of Groundwater for Future Receptors at the St. Louis Site 5-38

5.19 Radiological Carcinogenic Risk for a Future Resident from Contaminants in the HISS Storage Pile 5-38

5.20 Summary of Estimated Radiological Carcinogenic Risk for Future Receptors at the St. Louis Site 5-39

5.21 Chemical Carcinogenic Risk from Incidental Ingestion of Soil for Future Receptors at the St. Louis Site 5-40

5.22 Chemical Hazard Quotients for Incidental Ingestion of Soil by Future Receptors at the St. Louis Site 5-41

5.23 Chemical Carcinogenic Risk from Inhalation of Particulates for Future Receptors at the St. Louis Site 5-42

5.24 Chemical Carcinogenic Risk from Ingestion of Groundwater for Future Residents at the St. Louis Site 5-43

5.25 Chemical Hazard Quotients for Ingestion of Groundwater by Future Residents at the St. Louis Site 5-44

5.26 Chemical Carcinogenic Risk for Inhalation of Groundwater by Future Residents at the St. Louis Site 5-45

5.27 Chemical Hazard Quotients for Inhalation of Groundwater by Future Residents at the St. Louis Site 5-46

TABLES (Cont.)

5.28 Chemical Carcinogenic Risk across Pathways for Future Receptors at the St. Louis Site 5-47

5.29 Chemical Hazard Indexes across Pathways for Future Receptors at the St. Louis Site 5-47

5.30 Correlation of Lead Concentrations in Soil, Air, and Groundwater at the St. Louis Site with Blood Lead Concentrations 5-48

5.31 Total Estimated Carcinogenic Risk from All Exposures for Current Receptors at the St. Louis Site 5-49

5.32 Total Estimated Carcinogenic Risk from All Exposures for Future Receptors at the St. Louis Site 5-50

7.1 Contaminants of Concern for the Human Health Assessment 7-5

B.1 Primary Human Health Toxicology References for Contaminants of Potential Concern at the St. Louis Site B-10

C.1 Metals Analyzed in Samples from the St. Louis Site C-3

C.2 Volatile Organic Compounds Analyzed in St. Louis Site Soils C-4

C.3 Semivolatile Organic Compounds Analyzed in St. Louis Site Soils C-5

C.4 Methods of Analysis for Soil C-7

C.5 Methods of Analysis for Water C-8

D.1 Soil-to-Plant Transfer Factors for Contaminants of Concern at the St. Louis Site D-8

D.2 Radionuclide Exposure Point Concentrations and Estimated Doses from Ingestion of Homegrown Produce by Current and Future Residents at the St. Louis Site D-9

D.3 Chemical Exposure Point Concentrations for Ingestion of Homegrown Produce by Future Residents at the St. Louis Site D-11

D.4 Estimated Daily Intake of Chemicals from Ingestion of Homegrown Produce by Future Residents at the St. Louis Site D-12

D.5 Radionuclide Carcinogenic Risk from Ingestion of Homegrown Produce by Current and Future Residents at the St. Louis Site D-13

TABLES (Cont.)

D.6 Estimated Dose and Risk from the HISS Pile D-14

D.7 Chemical Carcinogenic Risk from Ingestion of Homegrown Produce by Future Residents at the St. Louis Site D-14

D.8 Chemical Hazard Quotients for Ingestion of Homegrown Produce by Future Residents at the St. Louis Site D-15

D.9 Radiological and Chemical Carcinogenic Risk from Ingestion of Homegrown Produce D-15

NOTATION

The following is a list of the acronyms, initialisms, and abbreviations (including units of measure) used in this document. Some acronyms used in tables or equations only are defined in the respective tables or equations.

ACRONYMS, INITIALISMS, AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
ANL	Argonne National Laboratory
ARAR	applicable or relevant and appropriate requirement
ATSDR	Agency for Toxic Substances and Disease Registry
BEIR	Biological Effects of Ionizing Radiations (Committee)
BNI	Bechtel National, Inc.
BRA	baseline risk assessment
CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended
CFR	Code of Federal Regulations
DCF	dose conversion factor
DCG	derived concentration guide
4,4′-DDT	4,4′-dichlorodiphenyltrichloroethane
DOE	U.S. Department of Energy
EDE	effective dose equivalent
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
FS	feasibility study
FUSRAP	Formerly Utilized Sites Remedial Action Program
HEAST	*Health Effects Assessment Summary Tables*
HISS	Hazelwood Interim Storage Site
ICRP	International Commission on Radiological Protection
IRIS	*Integrated Risk Information System*
LC_{50}	concentration lethal to 50% of the exposed population
LD_{50}	dose lethal to 50% of the exposed population
LOAEL	lowest-observed-adverse-effect level
MCL	maximum contaminant level
MDA	minimum detectable activity
MED	Manhattan Engineer District
NCRP	National Council on Radiation Protection and Measurements
NEPA	National Environmental Policy Act of 1969, as amended
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NOAEL	no-observed-adverse-effect level
NPL	National Priorities List
ORNL	Oak Ridge National Laboratory
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
pH	negative logarithm of the hydrogen ion concentration
QA	quality assurance

NOTATION (Cont.)

QC	quality control
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RI	Remedial Investigation
RME	reasonable maximum exposure
SLAPS	St. Louis Airport Storage Site
SLDS	St. Louis Downtown Site
SMCL	secondary maximum contaminant level
TDS	total dissolved solids
TL_{50}	level toxic to 50% of the exposed population
TL_M	median tolerance level
TMA/E	Thermoanalytical/Eberline Laboratory
TOC	total organic carbon
TOX	total organic halides
UL_{95}	95% upper confidence limit
VOC	volatile organic compound

UNITS OF MEASURE

°C	degrees Celsius
°F	degrees fahrenheit
cm	centimeter(s)
cm^2	square centimeter(s)
cm^3	cubic centimeter(s)
d	day(s)
dL	decaliter(s)
dpm	disintegration(s) per minute
ft	foot (feet)
g	gram(s)
gal	gallon(s)
gpm	gallon(s) per minute
h	hour(s)
ha	hectare(s)
in.	inch(es)
$in.^2$	square inch(es)
kg	kilogram(s)
km	kilometer(s)
km^2	square kilometer(s)
L	liter(s)
µg	microgram(s)
µR	microroentgen(s)
m	meter(s)
m^2	square meter(s)
m^3	cubic meter(s)
MeV	million electron volt(s)
mg	milligram(s)
mi	mile(s)
mi^2	square mile(s)
min	minute(s)
mo	month(s)
mph	mile(s) per hour
mR	milliroentgen(s)
mrem	millirem(s)
oz	ounce(s)
pCi	picocurie(s)
ppb	part(s) per billion
ppm	part(s) per million
rem	roentgen equivalent man
s	second(s)
t	metric ton(s)
WL	working level(s)
WLM	working-level month(s)
yd^3	cubic yard(s)
yr	year(s)

ENGLISH/METRIC AND METRIC/ENGLISH EQUIVALENTS

In this document, units of measure are presented with the metric equivalent first, followed by the measured English unit in parentheses. In cases where the measurement was originally made in metric units, the values were not converted back to English units; in tables, the data are generally in English or metric units only. The following table lists the appropriate equivalents for English and metric units.

Multiply	By	To Obtain
English/Metric Equivalents		
acres	0.4047	hectares (ha)
cubic feet (ft^3)	0.02832	cubic meters (m^3)
cubic yards (yd^3)	0.7646	cubic meters (m^3)
degrees Fahrenheit (°F) -32	0.5555	degrees Celsius (°C)
feet (ft)	0.3048	meters (m)
gallons (gal)	3.785	liters (L)
gallons (gal)	0.003785	cubic meters (m^3)
inches (in.)	2.540	centimeters (cm)
miles (mi)	1.609	kilometers (km)
pounds (lb)	0.4536	kilograms (kg)
short tons (tons)	907.2	kilograms (kg)
short tons (tons)	0.0972	metric tons (t)
square feet (ft^2)	0.09290	square meters (m^2)
square yards (yd^2)	0.8361	square meters (m^2)
square miles (mi^2)	2.590	square kilometers (km^2)
yards (yd)	0.9144	meters (m)
Metric/English Equivalents		
centimeters (cm)	0.3937	inches (in.)
cubic meters (m^3)	35.31	cubic feet (ft^3)
cubic meters (m^3)	1.308	cubic yards (yd^3)
cubic meters (m^3)	264.2	gallons (gal)
degrees Celsius (°C) +17.78	1.8	degrees Fahrenheit (°F)
hectares (ha)	2.471	acres
kilograms (kg)	2.205	pounds (lb)
kilograms (kg)	0.001102	short tons (tons)
kilometers (km)	0.6214	miles (mi)
liters (L)	0.2642	gallons (gal)
meters (m)	3.281	feet (ft)
meters (m)	1.094	yards (yd)
metric tons (t)	1.102	short tons (tons)
square kilometers (km^2)	0.3861	square miles (mi^2)
square meters (m^2)	10.76	square feet (ft^2)
square meters (m^2)	1.196	square yards (yd^2)

BASELINE RISK ASSESSMENT FOR EXPOSURE TO CONTAMINANTS AT THE ST. LOUIS SITE, ST. LOUIS, MISSOURI

1 INTRODUCTION

1.1 SITE OVERVIEW

The St. Louis Site comprises three noncontiguous areas in and near St. Louis, Missouri: (1) the St. Louis Downtown Site (SLDS), (2) the St. Louis Airport Storage Site (SLAPS), and (3) the Latty Avenue Properties (Figure 1.1). In addition to the main sites, numerous vicinity properties are also included as part of these three subareas. The main site of the Latty Avenue Properties includes the Hazelwood Interim Storage Site (HISS) and the Futura Coatings property, which are located at 9200 Latty Avenue. The three major areas of the St. Louis Site and their associated vicinity properties are listed in Table 1.1; references containing background information and characterization data for these properties are also listed.

Contamination at the St. Louis Site is the result of uranium processing and disposal activities that took place from the 1940s through the 1970s. Uranium processing took place at the SLDS from 1942 through 1957. From the 1940s through the 1960s, SLAPS was used as a storage area for residues from the manufacturing operations at SLDS. The materials stored at SLAPS were bought by Continental Mining and Milling Company of Chicago, Illinois, in 1966, and moved to the HISS/Futura Coatings property at 9200 Latty Avenue. Vicinity properties became contaminated as a result of transport and movement of the contaminated material among SLDS, SLAPS, and the 9200 Latty Avenue property. This contamination led to the SLAPS, HISS, and Futura Coatings properties being placed on the National Priorities List (NPL) of the U.S. Environmental Protection Agency (EPA).

The U.S. Department of Energy (DOE) is responsible for cleanup activities at the St. Louis Site under its Formerly Utilized Sites Remedial Action Program (FUSRAP). The primary goal of FUSRAP is the elimination of potential hazards to human health and the environment at former Manhattan Engineer District/Atomic Energy Commission (MED/AEC) sites so that, to the extent possible, these properties can be released for use without restrictions. To determine and establish cleanup goals for the St. Louis Site, DOE is currently preparing a remedial investigation/feasibility study-environmental impact statement (RI/FS-EIS), as required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended, and the National Environmental Policy Act (NEPA) of 1969. Details of the RI/FS-EIS process are described in the project work plan (DOE 1993). This baseline risk assessment (BRA) is a component of the process; it addresses potential risks to human health and the environment associated with contamination present at the various properties comprising the St. Louis Site.

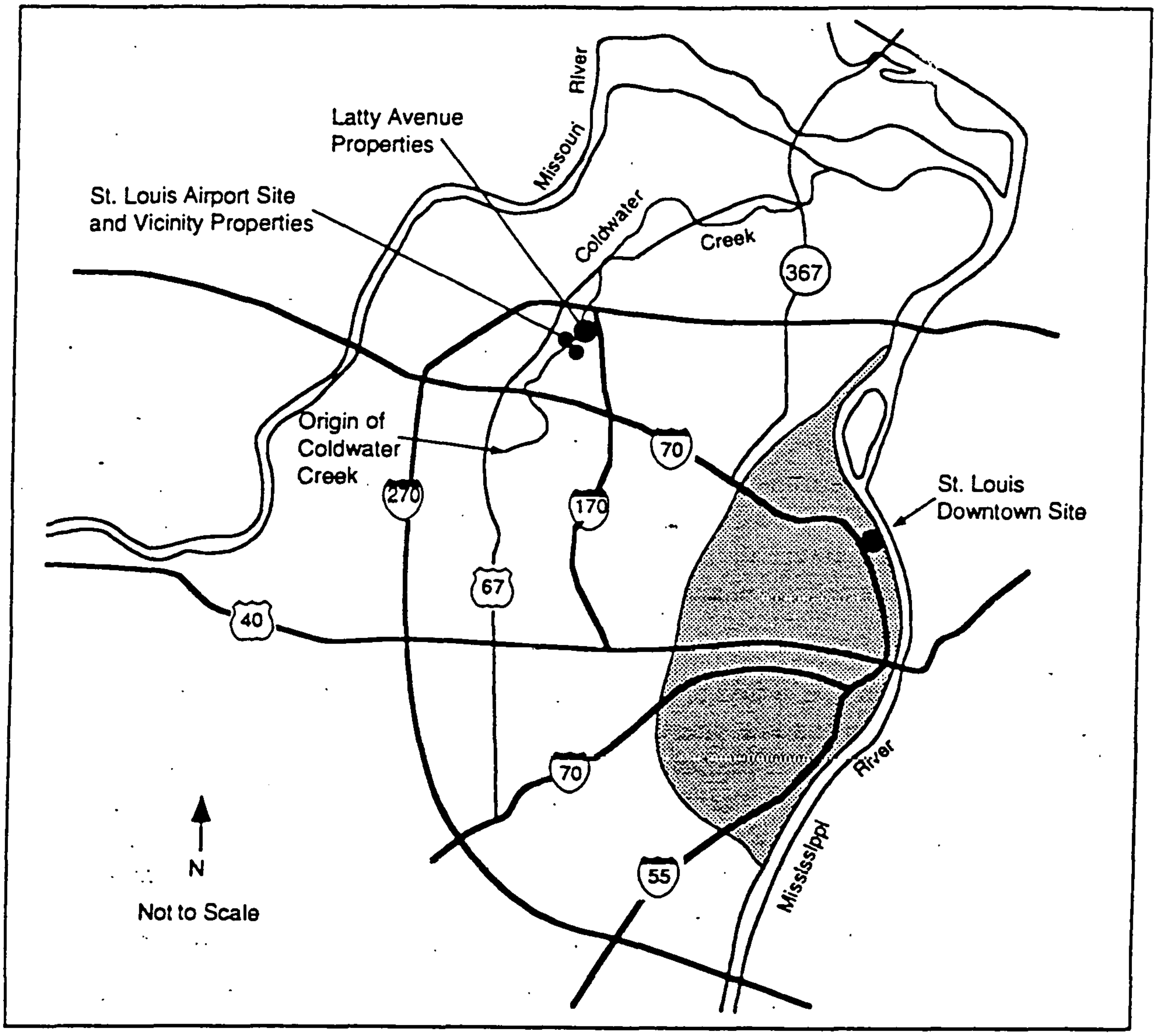


FIGURE 1.1 Locations of FUSRAP Properties in the St. Louis, Missouri, Area (Source: Modified from DOE 1993)

1.1.1 Environmental Compliance Process

The assessment of potential baseline health risks and environmental impacts associated with a contaminated site is an important component of the RI/FS process, which is the framework developed by the EPA for evaluating response alternatives for hazardous waste sites under CERCLA. For the St. Louis Site, NEPA values have been integrated with those of CERCLA. Hence, the primary evaluation documents of an RI/FS under CERCLA have been supplemented to incorporate elements of an EIS under NEPA; the resultant document package is therefore referred to as the RI/FS-EIS. In integrating NEPA values into CERCLA documentation, the RI generally incorporates the affected environment portion of an EIS, the BRA provides information for evaluation of the no-action alternative, and the FS

TABLE 1.1 Properties Comprising the St. Louis Site

Property	Type of Property	References[a]
St. Louis Downtown Site (SLDS) and Vicinity Properties		
Main site (Mallinckrodt, Inc.)	Industrial	ORNL (1981); BNI (1990d); DOE (1994)
City property	Municipal	BNI (1990d); DOE (1994)
SLDS vicinity properties		
McKinley Iron Company	Industrial	DOE (1993)
Thomas & Proetz Lumber Company	Commercial	DOE (1993)
PVO Foods, Inc.	Commercial	DOE (1993)
Norfolk & Western Railroad	Industrial	DOE (1993)
St. Louis Terminal Railroad Association	Industrial	DOE (1993)
Chicago, Burlington & Quincy Railroad	Industrial	DOE (1993)
St. Louis Airport Site (SLAPS) and Vicinity Properties		
Main site	Municipal	BNI (1985b, 1986b, 1987c, 1987e, 1988b, 1989c, 1990a, 1990e, 1991b); ORNL (1979); DOE (1994)
SLAPS vicinity properties		
St. Louis Airport Authority Property	Municipal	BNI (1990c); DOE (1994)
Banshee Road	Municipal	BNI (1990c); DOE (1994)
Ditches north and south of SLAPS	Municipal	BNI (1983, 1990c); DOE (1994)
Ballfield area	Municipal	BNI (1989b, 1990c); DOE (1994)
Haul roads (Latty Avenue, McDonnell Boulevard, Hazelwood Avenue, Pershall Road, Eva Avenue, and Frost Avenue)	Municipal	ORNL (1986); BNI (1990c); DOE (1994)
Haul roads vicinity properties (68)	58 commercial/ industrial; 5 municipal; 5 residential	BNI (1990c); DOE (1994)

TABLE 1.1 (Cont.)

Property	Type of Property	References[a]
St. Louis Airport Site (SLAPS) and Vicinity Properties (Cont.)		
SLAPS vicinity properties (cont.)		
Coldwater Creek	Municipal	U.S. Army Corps of Engineers (1987); BNI (1990c); DOE (1994)
Coldwater Creek vicinity properties (10)	Municipal	BNI (1990c); DOE (1994)
Railroad properties (7)	Commercial/ Industrial	BNI (1990c); DOE (1994)
Latty Avenue Properties		
Futura Coatings, Inc.	Commercial/ Industrial	BNI (1987d, 1990c); DOE (1994)
Hazelwood Interim Storage Site	Municipal	BNI (1985a, 1986a, 1987a, 1987b, 1988a, 1989a, 1990a, 1990b, 1991a); ORNL (1986); DOE (1994)
Latty Avenue vicinity properties (6)	Commercial/ Industrial	BNI (1990c); DOE (1994)

[a] BNI = Bechtel National, Inc.; ORNL = Oak Ridge National Laboratory.

provides detailed evaluation of the alternatives. The environmental compliance documents for the St. Louis Site are being developed in coordination with EPA Region VII and the state of Missouri.

The results of the RI/FS-EIS documents will be presented in a proposed plan, which also identifies the preferred alternative for site remediation. The documents will be issued for public comment, and public involvement is considered an important component of the decision-making process for site remediation. Responses to public comments on the RI/FS-EIS and proposed plan will be incorporated into a responsiveness summary and a record of decision. Following the record of decision, remedial design and remedial action activities will be planned and implemented at the site.

1.1.2 Objectives of the Baseline Risk Assessment

The specific objectives of this BRA are as follows:

- Estimating potential human health risks and environmental impacts associated with the St. Louis Site if no remedial action is taken;
- Establishing a framework for developing preliminary cleanup criteria to support the identification of specific concentration levels for the primary risk-driving contaminants that will be part of upcoming cleanup decisions;
- Indicating areas that pose little or no threat to human health or the environment and, hence, for which risk-based remediation may not be required;
- Providing a baseline for comparing the protectiveness of cleanup alternatives in the FS relative to potential human health and environmental impacts; and
- Focusing the future remedy selection process for site cleanup, e.g., by identifying the areas and contaminants that pose the primary health and environmental concerns.

1.2 SITE BACKGROUND

A general description and history of each of the three major subareas comprising the St. Louis Site is provided in Section 1.2.1. Site contamination is summarized in Section 1.2.2 and described in more detail in Chapter 2.

1.2.1 General Site Description and History

1.2.1.1 St. Louis Downtown Site and Vicinity Properties

The 18-ha (45-acre) SLDS is a chemical plant located in a highly industrialized area on the eastern border of the city of St. Louis, Missouri (BNI 1990d). It is 90 m (300 ft) west of the Mississippi River and approximately 18 km (10.7 mi) southeast of Lambert-St. Louis International Airport. The plant is currently owned by Mallinckrodt, Inc., and numerous buildings and facilities comprise various plant areas that are currently used for the production of specialty chemicals (Figure 1.2). Buildings cover a large portion of the site, and most of the remainder of the site is covered with asphalt or concrete (BNI 1990d). The property is fenced, and access is currently limited to about 900 employees, 200 subcontracting

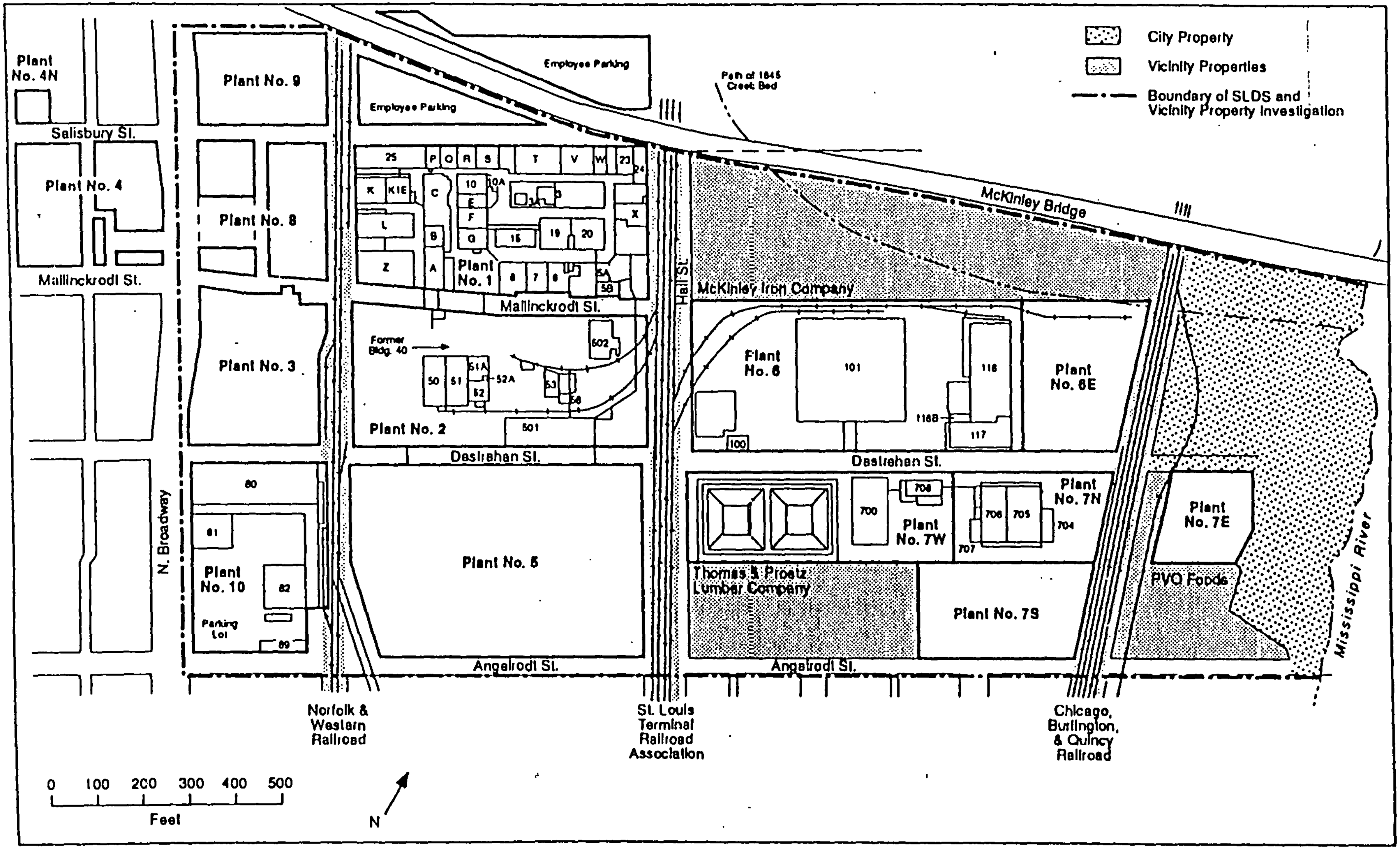


FIGURE 1.2 Locations of the SLDS and Vicinity Properties (Source: Modified from DOE 1994)

construction workers, and escorted visitors. Land use within a 1.6-km (1-mi) radius of the SLDS is largely a mixture of public, industrial, and commercial activities along with limited residential use (BNI 1990d).

Past operations at the SLDS under MED/AEC programs involved the processing and production of various forms of uranium compounds. Uranium ores (mainly African Congo pitchblende) were processed at the site from 1942 through 1957 (BNI 1990d). The process involved several steps. First, the ore was digested in nitric acid to form uranyl nitrate, $U(NO_3)_6$. The uranyl nitrate was then extracted with ether and water and denitrated by heating to form uranium oxide (first uranium trioxide, UO_3, and then uranium dioxide, UO_2, by reduction with hydrogen). The uranium oxide was fluorinated with hydrogen fluoride to produce green salt (uranium tetrafluoride, UF_4), which was then reduced with magnesium to produce uranium metal.

Plants 1, 2, 6, 6E, 7, and 10 were involved in this process. Plants 1 and 2 were used for refining pitchblende (a uranium-containing ore) in the initial plant operations from 1942 to 1945. Nitration and fluorination were conducted in Plant 6. Green salt production was also conducted in Plants 7 and 10. During the processing operations, naturally occurring radionuclides in the ores were also concentrated.

Although not part of MED/AEC activities, columbium-tantalum ores were processed in Plant 5 under a U.S. Nuclear Regulatory Commission license (BNI 1990d). These ores contain natural uranium, thorium, and actinium decay series radionuclides but at levels that are generally lower than those in pitchblende ores. To some degree, residual contamination in Plant 5 may be due to these operations.

A portion of a city property is located between the SLDS and the Mississippi River (Figure 1.2). This property contains no buildings, it is not fenced, and it is accessible to the general public, although apparently not often used by the public. Contamination similar to that found at SLDS has been identified on this property (BNI 1990d).

Six vicinity properties are also associated with SLDS (Table 1.1): three are railroad properties running north and south through SLDS, and three are industrial and commercial properties that border SLDS on the north and south (Figure 1.2). It is unknown whether the three railroad properties were used for past MED/AEC operations at SLDS. A portion of one of the industrial and commercial vicinity properties (i.e., the Thomas & Proetz Lumber Company) was formerly used as part of the MED/AEC activities, but past use of the other industrial and commercial vicinity properties is unknown. Contaminants from the SLDS may have migrated to the city property and these six vicinity properties via wind, runoff, direct transport, or other unknown mechanisms.

1.2.1.2 St. Louis Airport Site and Vicinity Properties

The SLAPS is an 8.8-ha (21.7-acre) property approximately 24 km (15 mi) from downtown St. Louis (Figure 1.1); SLAPS lies immediately north of Lambert-St. Louis

International Airport (BNI 1987c). Ditches directly adjoin the north and south property boundaries. Beyond these ditches, SLAPS is bounded on the south by the Norfolk & Western Railroad, Banshee Road, and the airport; on the west by Coldwater Creek; and on the north and east by a ballfield area and McDonnell Boulevard. The area is zoned for industrial use, and the nearest residential areas are located approximately 0.8 km (0.5 mi) west, 1.6 km (1 mi) northwest, and 2.4 km (1.5 mi) north of the site (BNI 1990c). The property is currently owned by the city of St. Louis and is controlled by the St. Louis Airport Authority. From 1946 until 1966, SLAPS was used by the MED/AEC as a storage area for residues from the manufacturing operations at SLDS. In the mid 1960s, most of the residues were removed from the property and transported to 9200 Latty Avenue; in 1969, buildings were demolished and buried on-site, and the whole area was covered with 0.3 to 1 m (1 to 3 ft) of clean fill material (BNI 1990c). Additional fill material and rubble were placed at SLAPS in 1971, 1977, and 1978. Currently, the site contains a pile of miscellaneous contaminated debris and an office trailer. The entire site is fenced to restrict public access, and maintenance and routine environmental monitoring are the only activities taking place at the property.

The SLAPS vicinity properties include the ditches to the north and south of the property, an adjacent ballfield, six local transportation routes known as haul roads, Coldwater Creek, and the areas along transportation routes and Coldwater Creek that have been identified as containing radioactive contamination above DOE guidelines (Figure 1.3; Table 1.1). Seventy-eight properties along the haul roads and Coldwater Creek have been identified as having contamination and have been designated as part of FUSRAP; five of these properties are zoned residential, and the rest are zoned commercial or municipal (BNI 1990c). Banshee Road on the southern border of SLAPS, a 30-m (100-ft) strip of St. Louis Airport Authority property south of and parallel to Banshee Road, and seven railroad properties in the area of SLAPS are also considered SLAPS vicinity properties. Any of a variety of mechanisms may have contaminated these properties, including direct deposition, wind movement, surface runoff, and losses off transportation vehicles during transfer of material from SLAPS.

1.2.1.3 Latty Avenue Properties

The Latty Avenue Properties consist of the HISS and Futura Coatings properties located at 9200 Latty Avenue, and six commercial or industrial vicinity properties along Latty Avenue (Figure 1.4). These properties are located in northern St. Louis County within the city limits of Hazelwood and Berkeley, Missouri, approximately 1.2 km (0.75 mi) northeast of SLAPS. The HISS occupies the eastern half of the 9200 Latty Avenue property and is separated by a chain-link fence from the Futura Coatings property, which is located on the western half. The property at 9200 Latty Avenue was used to store contaminated material from SLAPS between 1966 and 1973.

The HISS and Futura Coatings properties are completely fenced to restrict public access. The Latty Avenue Properties are located in an area that is primarily commercial/ industrial; the nearest residential area is approximately 0.5 km (0.3 mi) to the east

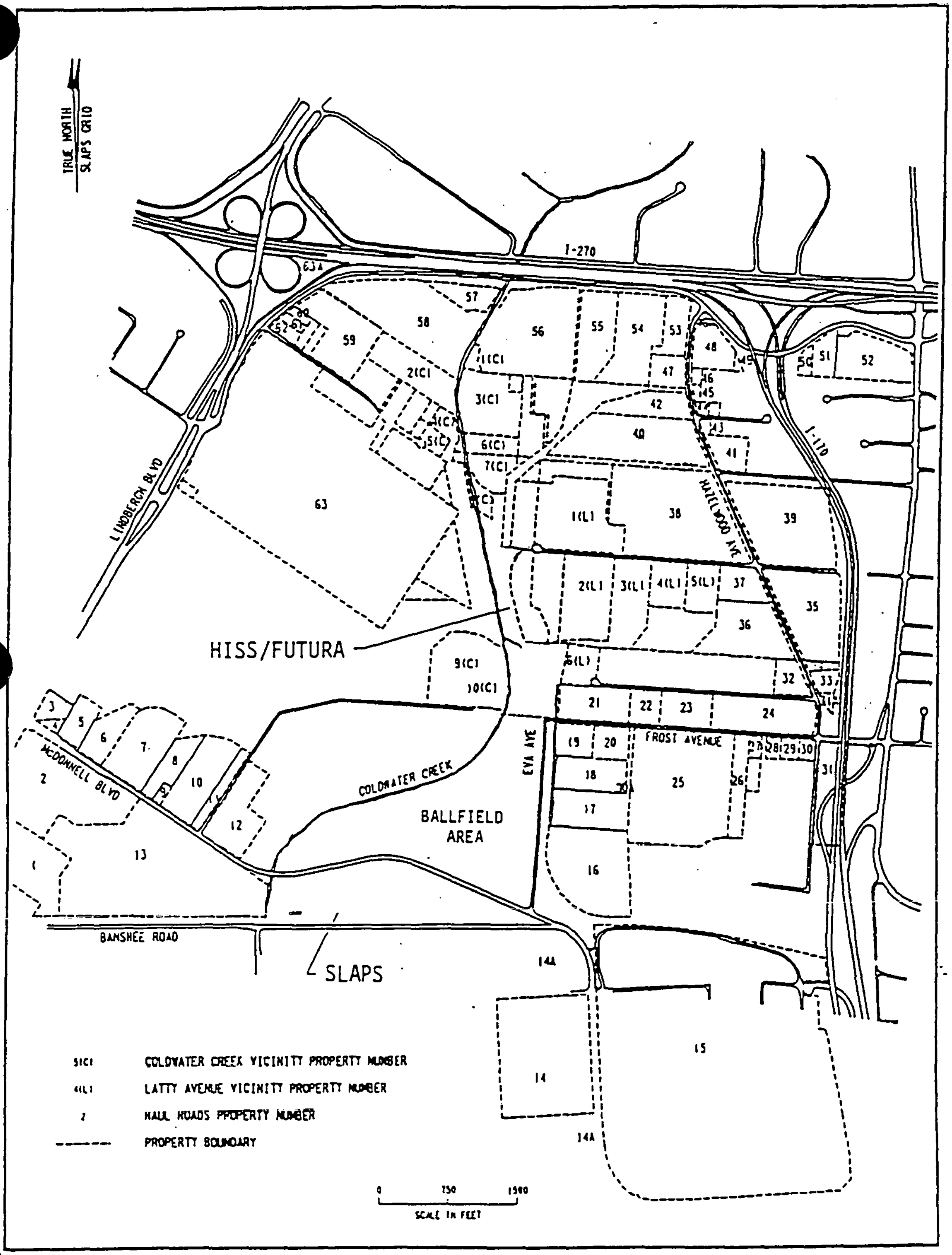


FIGURE 1.3 Locations of SLAPS and Vicinity Properties (Source: Modified from DOE 1993)

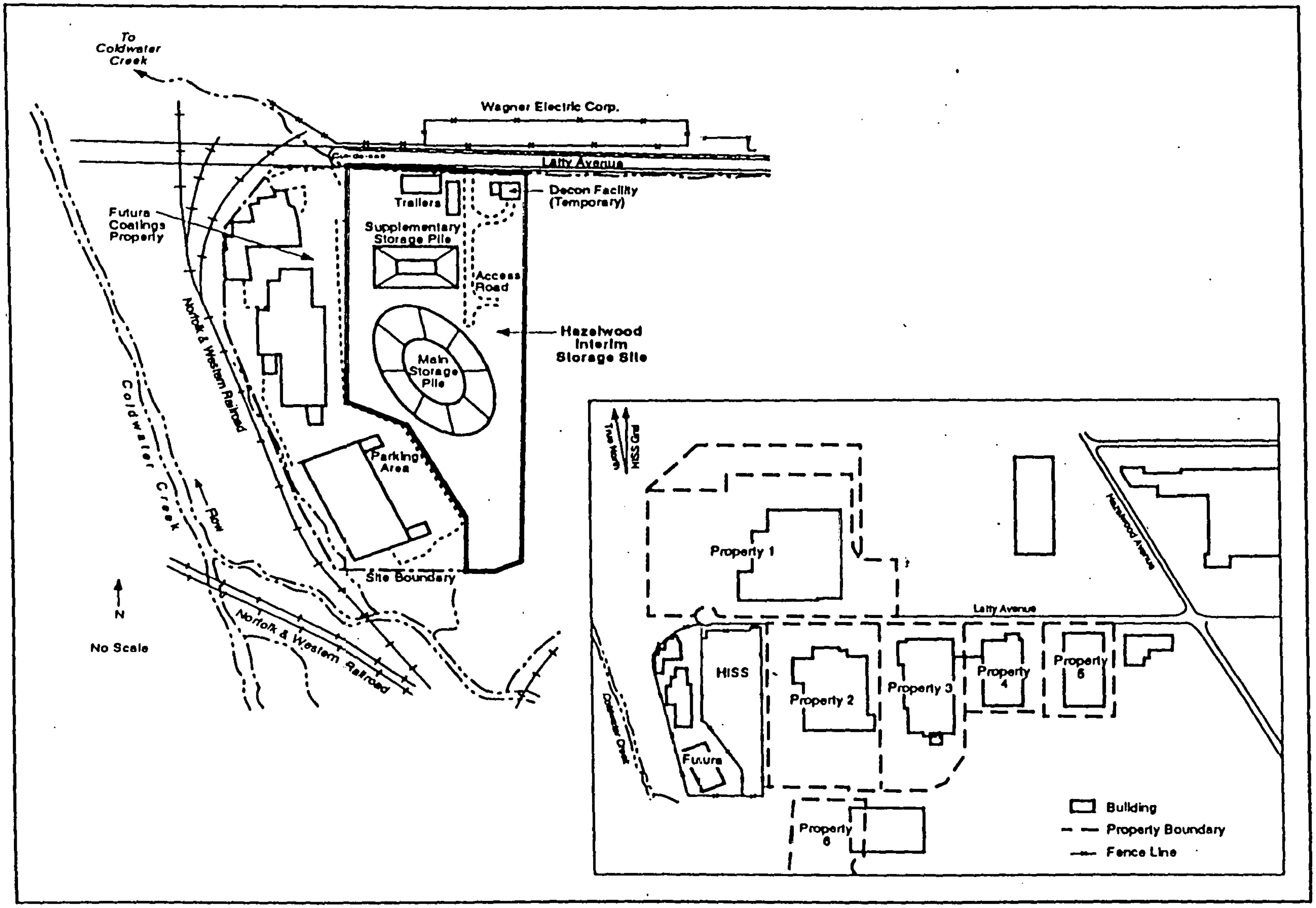


FIGURE 1.4 Locations of the Latty Avenue Properties (Source: Modified from DOE 1993)

(BNI 1989a). Storm-water runoff from the Latty Avenue Properties flows into ditches and a storm sewer that drain to Coldwater Creek, which passes to the west of the properties. The HISS property, which is currently leased by DOE, contains a vehicle decontamination (decon) facility, a trailer used by the caretaker for maintenance of the property, a DOE information office trailer, and two covered surface storage piles containing approximately 27,700 m^3 (32,000 yd^3) of radioactive material (DOE 1993). The Futura Coatings property is owned by Jarboe Realty and Investment Company and is leased to Futura Coatings, Inc., which currently manufactures plastic coating products on the property. Three buildings are located on the property.

Wastes containing uranium and radium were stored at SLAPS by the AEC; in 1966, these wastes were bought by Continental Mining and Milling Company of Chicago, Illinois, and moved to 9200 Latty Avenue. All these wastes were deposited directly on the ground. During 1967 and 1970, the residues were dried and shipped to Canon City, Colorado, by the Commercial Discount Corporation and Cotter Corporation. In 1973, the remaining residues were removed, and 30 to 40 cm (12 to 18 in.) of topsoil was transported to the West Lake Landfill in Bridgeton, Missouri.

The material currently stored in two covered piles at the HISS originated from a 1979 demolition and excavation activity on the Futura Coatings property and from remedial action and construction activities on and around the Latty Avenue vicinity properties that took place in 1984 and 1986.

1.2.2 Summary of Site Contamination

Information available to date includes characterization and monitoring data obtained from soil, groundwater, surface water, sediment, air, and structures. Additional information continues to be collected through an ongoing environmental monitoring program. The results of site sampling efforts have confirmed the presence of several sources of process-related contamination on the St. Louis Site, as follows:

- Widespread radioactive contamination (e.g., uranium-238, thorium-230, and radium-226) of surface and subsurface soil at the SLDS, city property adjacent to SLDS, SLAPS, ballfield area, HISS, and Futura Coatings property; and chemical contamination of soil in the form of metals and inorganic anions at these same properties;
- Primarily isolated radioactive contamination of surface soil at the edges of the other properties comprising the St. Louis Site;
- Low-level contamination of bank soil and sediment at Coldwater Creek;
- Radioactive contamination of groundwater at the HISS (elevated levels of uranium and irregularly elevated levels of thorium-230), SLAPS

(uranium), and SLDS (uranium); and detectable concentrations of metals in groundwater at the SLDS, SLAPS, and HISS areas;

- Two piles of radioactively contaminated materials at the HISS;
- Beta-gamma and alpha surface contamination, primarily fixed, within SLDS buildings;
- Elevated concentrations of radon-222 gas and its decay products within SLDS buildings; and
- Residual radioactive contamination in outdoor drains at the SLDS.

In addition, several organic compounds that are commonly found in areas utilized for industrial purposes have been detected in samples of site soil and groundwater (e.g., volatile and semivolatile organic compounds, particularly polycyclic aromatic hydrocarbons [PAHs]). The contamination by these organic compounds is not believed to be related to uranium-processing activities.

1.3 SCOPE OF RISK ASSESSMENT

This BRA evaluates potential risks to human health and the environment from contaminants that DOE is responsible for remediating under FUSRAP in the absence of remedial action. These responsibilities are explicitly defined in the Federal Facility Agreement for the St. Louis Site, as summarized in the project work plan (DOE 1993). Such responsibilities are limited to all radioactive and nonradioactive contamination at the SLDS, 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. This BRA includes an evaluation of the potential risks to human health and the environment associated with no action regarding the contamination at the St. Louis Site for which DOE has responsibility, and the BRA is considered to satisfy the requirement for evaluating the no-action alternative under the integrated CERCLA/NEPA process.

This assessment considers potential risks to human health and the environment from contaminants found in the various site media and follows the procedure for evaluating these risks that is presented in EPA's guidance for human health and ecological evaluation at hazardous waste sites (EPA 1989c, 1989d). Estimated human health risks were calculated for reasonably maximally exposed individuals (receptors) for both current and future land-use scenarios at the site properties. Future risk estimates were calculated for hypothetical persons who are assumed to establish residence at the various site properties, except Coldwater Creek; potential risks from exposure to contaminants at Coldwater Creek were estimated assuming a recreational use scenario for both current and future conditions. The estimated risks for the hypothetical future scenario are considered to be reasonable worst-case scenarios for future exposure to contaminants at the various site properties.

The ecological assessment for the St. Louis Site was conducted at a level appropriate to current site conditions; because of the industrial nature of the site, the potentially affected biota is limited. Consequently, the ecological assessment is limited in scope and is qualitative in nature (see Chapter 6).

1.3.1 Time Period

The scope of the "future condition" scenario in a BRA can extend into the long term for a Superfund site for which no party has taken cleanup responsibility. This scope is based on uncertainty regarding the initiation of remedial action, and the BRA then serves to conservatively bound potential impacts if no action is taken in order to justify the use of enforcement actions or the expenditure of EPA funds for site cleanup. The DOE has responsibility for cleanup of this site and is committed to pursuing a timely response. Nevertheless, to focus the decision-making process for site cleanup, this BRA hypothetically assumes that institutional controls are lost over an extended time period. The time period considered as the extended future in this assessment of risks for the no-action alternative is 100 years and beyond. Ingrowth of radionuclides and potential future groundwater contamination have been considered in this BRA. The determination of final cleanup criteria will be addressed in the FS for the site.

1.3.2 Institutional Control and Exposure Scenarios

Under the CERCLA process, a BRA typically considers impacts that could occur if remedial action were not performed at a site. It assesses impacts under both current conditions, which can include institutional controls, and projected future conditions, under which no institutional controls are assumed. Under the NEPA process, the impact assessment for the no-action alternative typically addresses the status quo at the site, which includes the retention of existing institutional controls (e.g., access restrictions and monitoring) up to the next 100 years. Although loss of access restrictions at the SLDS, HISS, and SLAPS is, in fact, implausible in the future (i.e., short term of 50 years), loss of access restrictions for future exposure scenarios at the St. Louis Site has been assumed to address that element of the CERCLA baseline assessment process. The exposure assessments presented in Chapter 3 of this document address, in detail, the potential receptors and locations selected to assess baseline impacts for the St. Louis Site.

1.4 REPORT ORGANIZATION

This BRA serves as the combined baseline (i.e., no-action) assessment of potential human health and ecological impacts for the St. Louis Site. The document is organized as follows:

- Chapter 1 presents background site information, current conditions, and the general approach to risk assessment;
- Chapter 2 outlines the data collection effort and identifies the contaminants of concern for the site;
- Chapter 3 describes the human exposure assessment, including fate and transport, potential receptors, and exposure routes;
- Chapter 4 provides human toxicity information for the contaminants of concern;
- Chapter 5 presents the methodology and results of risk characterization;
- Chapter 6 evaluates the environmental impacts of site contamination; and
- Chapter 7 summarizes the contaminants of concern, exposure and toxicity assessments, and risk characterization for the site.

Additional information regarding site contamination, contaminant toxicity, data evaluation, and alternative pathway evaluation is presented in Appendixes A, B, C, and D.

2 IDENTIFICATION OF CONTAMINANTS OF CONCERN

The data used in this assessment are primarily those obtained by BNI and are generally summarized in the RI report prepared for the St. Louis Site (DOE 1994). More detailed information can also be found in other reports, which are cited as appropriate.

2.1 ORIGIN OF CONTAMINATION

Contamination at the St. Louis Site originated from the processing of over 45,000 t (50,000 tons) of natural uranium products between 1942 and 1957 at the SLDS (DOE 1993). The main ore processed was African Congo pitchblende, although some domestic ores were also processed. The pitchblende feedstock, which contained high concentrations of radium, was separated into a residue fraction containing radium-226 and its decay products and other impurities. The residue fraction, termed K-65 residue, was transported to DOE facilities in Ohio and New York where it is currently in storage. The remaining process waste was transported to SLAPS; most of this waste was stored on open ground, although some was buried at the western end of the property. Process materials sent to SLAPS included pitchblende raffinate residue, radium-bearing residue, barium sulfate cake, Colorado raffinate residue, and contaminated scrap material.

Although the removal of the K-65 residue fraction decreased the level of radium-226 contamination at the St. Louis Site, radium-226 levels above current DOE guidelines have been detected at the various properties comprising the site. In addition to radium-226, other radionuclides — primarily from the uranium-238 decay series (e.g., uranium-238 and thorium-230) — are also expected to be present at the St. Louis Site because of the composition of the ores processed and the nature of the processing operations that took place at SLDS. Actinium (uranium-235) decay series radionuclides are expected to be present because uranium-235 comprises about 0.72% (by weight) of natural uranium. In addition, thorium-232 is often a coincidental component of uranium ores, and isotopes in the thorium-232 decay series are also potential contaminants.

Chemical contaminants potentially attributable to past processing activities at SLDS are primarily metal elements or compounds. In addition to uranium, pitchblende ores generally contain arsenic, lead, manganese, and thorium (Stokinger 1981), whereas domestic ores may be enriched in arsenic, cobalt, copper, molybdenum, nickel, selenium, vanadium, and zinc (Dreesen et al. 1982).

The processes used for the manufacture of uranium dioxide, uranium trioxide, uranium tetrafluoride, uranyl fluoride, and uranium metal involved the use of inorganic compounds such as hydrofluoric, nitric, and sulfuric acids. These acids would likely remain in the site environment as anions (e.g., fluorides, nitrates, and sulfates). Also, because the site is located mostly in an industrialized area, it is likely that organic compounds (e.g., PAHs) are present at the site at levels typically resulting from human activities such as the use of coal-fired burners.

Contamination of vicinity properties probably resulted from movement of materials during underground utility, road, or other construction activities in the area and from spillage or fugitive dust associated with truck or train transport — particularly on haul roads, railroads, and adjacent properties between the main processing sites and the storage sites. The results of preliminary surveys at various properties comprising the St. Louis Site have indicated the presence of radioactive contamination and of inorganic metals and anions that may be attributable to SLDS operations. In addition, because of the industrial nature of the site location, some organic compounds typically found in areas similar to the St. Louis Site are expected to be present and may be commingled with process-related radioactively contaminated material.

2.2 DATA COLLECTION

To fulfill the primary goal of FUSRAP — i.e., to protect human health and the environment — a comprehensive site characterization regime was planned and characterization objectives were formulated. Available historical information and results of preliminary surveys were reviewed, evaluated, and incorporated into the characterization regime.

2.2.1 Objectives

The objectives of characterization activities included (1) identifying the nature and levels of contamination; (2) determining the horizontal and vertical extent of radioactive contamination; (3) determining the nature and levels of chemical contamination commingled with the radioactively contaminated areas; (4) wherever chemical contamination was identified in soil contaminated with radionuclides, determining if such waste could be classified as hazardous under the Resource Conservation and Recovery Act (RCRA); and (5) determining health and safety measures necessary for the protection of remedial action workers. To meet these objectives, the various site media that were indicated as radioactively contaminated by preliminary surveys were sampled, including surface and subsurface soil, surface water, sediment, groundwater, air, and structures. Field measurements were taken to survey radioactivity levels, and laboratory analyses were performed on samples collected from the site media to determine individual radionuclide levels and the nature and levels of commingled chemical contamination.

In addition to site sampling, background samples were also collected to determine levels of naturally occurring radionuclides in soil (Section 2.2.2.1). No samples were collected to determine background levels of metals in soil and groundwater at the St. Louis Site, but data on background levels of metals and an anion (fluoride) in Missouri surface soil are available in the literature (Tidball 1984) and are presented in Table 2.8. Because organic compounds do not occur naturally in soil, background levels were assumed to be zero, although some organic compounds — like the PAHs found at SLDS — are widespread in soils in industrial areas (Agency for Toxic Substances and Disease Registry [ATSDR] 1990b).

2.2.2 Sampling Program

The sampling program for the various site media is described in Sections 2.2.2.1 through 2.2.2.5. A summary of the comprehensive characterization effort conducted for DOE at the site is presented in Table 2.1.* The results obtained from the sampling program are discussed in Sections 2.3 and 2.4.

2.2.2.1 Soil

In general, the soil sampling scheme conducted at the SLDS, city property, SLAPS, Futura Coatings property, and HISS involved establishing a 15-m (50-ft) grid system and performing walkover gamma scans to identify areas of elevated gamma radiation. Next, near-surface gamma measurements were taken at 4-m (12.5-ft) intervals in the areas identified as containing elevated levels of radioactivity during the walkover gamma scan. Initial surface and subsurface soil samples were collected from areas where gamma levels were two or more times background levels (Table 2.2). At the vicinity properties, soil samples were collected in 0.3-m (1-ft) increments to a depth of 1 m (3 ft). The samples were collected either at 15-m (50-ft) grid intersections, 15 m (50 ft) onto the vicinity properties from the edges of the haul roads; or at 31-m (100-ft) grid intersections, 46 m (150 ft) onto the properties from the edges of the roads.

During sampling, the guideline levels for residual radioactivity provided in DOE Order 5400.5 were used as the basis for determining the horizontal and vertical boundaries of contamination at the various properties comprising the site. Limits for residual concentrations of radium and thorium in soil are 5 pCi/g averaged over a 100-m^2 area for the surface 15 cm of soil and 15 pCi/g averaged over 15-cm-thick layers of soil more than 15 cm below the surface. Although a residual concentration guideline for uranium-238 in soil has not been established for the St. Louis Site, 50 pCi/g was assumed to be the uranium-238 guideline for this characterization effort. This value was obtained from preliminary calculations with data specific to the St. Louis Site, and it results in an estimated dose of less than 100 mrem/yr. The extent of contamination (vertical and horizontal boundaries) was established by selecting samples in which the concentrations of radionuclides exceeded DOE guidelines. Samples were then collected at locations beyond the established boundaries of contamination to ensure that the extent of contamination was adequately defined. Although these preliminary results were used for the analysis in this BRA, the identification of final cleanup values for the St. Louis Site will be determined in coordination with EPA Region VII and the state of Missouri.

Surface and subsurface soil samples were also collected for chemical analysis at known radioactively contaminated areas at the SLDS, city property, SLAPS, ballfield area, Futura Coatings property, and HISS. In this BRA, these chemical results were used as

---

*For readability, all tables and figures in this chapter are presented in sequence at the end of the text of the chapter.

indicators of the potential risks that might be incurred by a receptor from this class of contaminants at the other properties comprising the St. Louis Site where chemical analysis of soil samples has not been carried out.

Levels of naturally occurring radionuclides in soil in the vicinity of the St. Louis Site were determined by sampling at locations that were considered to be nonindustrialized, undisturbed, and within a reasonable proximity of the site. Background samples were collected at 2.8 km (1.8 mi) northwest, 2.8 km (1.8 mi) southeast, and 17.2 km (10.7 mi) southeast of the airport. The first two locations were open grassy areas, and the third location was an open area with some grass and trees. Although these locations were chosen for their proximity to SLAPS and HISS, the results were used to denote typical background radionuclide levels for the entire St. Louis Site (including SLDS). A summary of these results is presented in Table 2.2.

2.2.2.2 Groundwater

At SLDS, quarterly groundwater monitoring was performed from July 1988 to April 1989 at eight monitoring wells to evaluate groundwater quality and determine groundwater flow directions. These groundwater samples were analyzed for radiological and chemical parameters, i.e., metals, anions, volatile organic compounds (VOCs), and semivolatile organic compounds.

As part of the environmental monitoring programs at SLAPS and HISS, groundwater samples have been collected quarterly to monitor radiological and chemical parameters (i.e., metals, total organic carbon, total organic halides, and specific conductance). In addition, VOCs and semivolatile organic compounds were analyzed during one quarter. Samples were collected and analyzed from a system of 16 monitoring wells at SLAPS and 15 monitoring wells at HISS. A well canvass was conducted in March 1989 to identify and investigate wells within a 4.8-km (3-mi) radius of SLAPS and HISS (Pais 1989). The canvass identified eight wells in the area, but none of these wells is currently used as a source of drinking water. Three wells are used for irrigation (e.g., watering), one is used for industrial purposes, and two are capped and not operating. Two of the wells have not been used by their owners in 10 years or more.

2.2.2.3 Surface Water and Sediment

Surface water samples have also been collected quarterly at the HISS area to determine potential contaminant migration and discharge routes from HISS. Sludge and/or sediment samples have been collected from the drainage pathways at SLDS, SLAPS, and HISS. In addition, 84 manholes at SLDS were surveyed for residual radioactivity, and sediment samples were collected from the 50 manholes that were accessible. Also included in the characterization for SLDS were 3 sediment/bank soil samples that were collected from the Mississippi River.

At Coldwater Creek, surface sediment samples have been collected for radiological analysis from the sides and center of the creek, beginning at SLAPS and continuing downstream to HISS. Further characterization at Coldwater Creek has also involved the collection of four sediment samples for chemical analysis. These samples were collected north of Banshee Road, north of McDonnell Boulevard, south of the Latty Avenue Properties, and downstream of the Latty Avenue Properties (DOE 1993).

2.2.2.4 Air

Air samples have been collected to determine the levels of radon and external gamma radiation. At SLDS, radon and external gamma measurements have been taken in the buildings (approximately 19) that were associated with MED/AEC activities.

The environmental monitoring programs at SLAPS and HISS include continual monitoring of the respective site boundaries for radon. Three additional detectors are maintained off-site of SLAPS and HISS to measure background levels. External gamma radiation levels are measured at locations corresponding to the radon monitors at SLAPS and HISS, and gamma exposure rates from the HISS storage piles are also monitored. In addition to the routine environmental monitoring, charcoal canisters were placed in the two trailers at HISS for a one-time measurement of radon in October 1990.

At Futura, four track-etch radon detectors were installed in September 1986; these detectors were then recovered and analyzed in January 1987. In addition, gross alpha concentrations were measured inside the Futura buildings.

2.2.2.5 Building Surfaces and Other Structures

Structures at the St. Louis Site have been sampled primarily for radioactive contamination. Buildings at SLDS were investigated to determine whether radioactivity exceeding DOE guidelines existed on building surfaces. Floors, walls, ceilings, and roofs were surveyed; the average density of sampling in the SLDS building survey was one reading at every grid intersection at 1-m (3-ft) intervals for floors and one reading at every grid intersection at 5-m (15-ft) intervals for ceilings, walls, and roofs. Wipe samples of surface areas of about 100 cm^2 (15.5 $in.^2$) were collected with smear cloths.

At the Futura Coatings property, the interior and exterior surfaces of the buildings (now demolished) were surveyed by spot checking for nonremovable and removable alpha and beta-gamma contamination.

2.2.3 Analytical Scheme

The analytical methods used to determine site-related parameters from various site media are discussed in Sections 2.2.3.1 and 2.2.3.2. A radiological source term analysis was performed to confirm and augment characterization results; this analysis is discussed in

Section 2.2.3.3. Quality assurance/quality control (QA/QC) features that were required and implemented are presented in Section 2.2.3.4.

2.2.3.1 Radiological Methods and Parameters

The radiological parameters analyzed for this BRA were selected on the basis of preliminary surveys and historical information available for the St. Louis Site. This information indicated that radionuclides in the uranium-238 decay series — particularly, uranium-238, radium-226, and thorium-230 — are the dominant radionuclides contributing to potential human health risks from radioactive contamination of the various media at the site.

For soil and sediment samples, the laboratory methods used to determine radium-226, thorium-230, and thorium-232 have quantitation limits or minimum detectable activities (MDAs) that are sufficient to delineate the presence of these radionuclides at levels below their naturally occurring background levels in the environment (see Appendix C, Table C.4). Thus, the results obtained through the application of these methods are considered suitable for risk assessment purposes because they allow for the delineation of elevated levels (i.e., those exceeding background). An alpha spectrometry method was used for the thorium-230 determinations, and a gamma spectroscopy method was used for the uranium-238, radium-226, and thorium-232 determinations (see Appendix C, Table C.4). The MDA for uranium-238 via gamma spectroscopy is higher than the background concentration at the St. Louis Site (i.e., 5 pCi/g compared with 1.1 pCi/g). For purposes of conservatism in this assessment, data points for these samples were generally retained at values equivalent to the detection limits. Implications of analytical method sensitivity are discussed further in Section 2.5 (data evaluation) and Chapter 3 (exposure assessment).

For groundwater and surface water samples, total uranium and thorium-230 were determined in the laboratory by alpha spectroscopy; radium-226 was determined with an emanation/scintillation type analysis. The MDAs of these methods are adequate for use in this risk assessment because they are lower than the maximum contaminant levels (MCLs) currently proposed by the EPA (1991c). In addition, the MDAs for radionuclides in water samples are much lower than available derived concentration guides (DCGs). The DCGs are used as reference values to indicate the radionuclide levels that result in a dose of 100 mrem/yr.

Direct alpha, direct beta-gamma, and removable contamination were determined from building surfaces. Direct alpha measurements were taken with an AC-3 detector coupled to a PRS-1 scaler, and direct beta-gamma measurements were taken with an HP-210 detector coupled to a PRS-1 scaler. Wipe samples were analyzed to determine removable contamination.

Radon levels in air were measured with charcoal canisters and track-etch monitors. External gamma radiation levels were measured with thermoluminescent dosimeters, and gamma exposure rates were measured with a pressurized ionization chamber.

2.2.3.2 Chemical Methods and Parameters

The chemical parameters for soil, sediment, and groundwater samples from the St. Louis Site were selected primarily to determine the constituents potentially traceable to processing activities at SLDS, to identify chemicals commingled with identified radioactive waste, and to formulate appropriate health and safety measures for remedial action workers during their handling of the identified contamination. Consequently, in addition to analyses for metals and anions, samples collected from the SLDS, SLAPS, HISS, Futura Coatings property, ballfield area, and Coldwater Creek were analyzed for organic constituents because it was anticipated that organic compounds would be present due to the urban location and industrial land use of these properties. The list of chemical constituents for which these samples were analyzed consists of parameters potentially attributable to processing activities (i.e., metals and anions) and other parameters generally determined by the EPA for sites in the Superfund program. The analytical parameters and their corresponding method detection limits are presented in Appendix C, Tables C.1, C.2, and C.3.

The analytical methods and corresponding method detection limits used to qualitatively and quantitatively identify these chemical parameters are summarized in Appendix C, Tables C.4 and C.5. In general, the laboratory methods used for analysis of soil or sediment and water samples are based on procedures developed by the EPA for use in the Superfund and RCRA programs, and the results generated from these methods are considered adequate for use in risk assessment with regard to data QA/QC. However, in cases (e.g., some metals) where the method sensitivity is not adequate because the detection limits for the parameters are either higher than background (soil) or MCLs (water), the incremental risk potentially due to site levels of these chemicals cannot be delineated. For purposes of conservatism in this assessment, data points for these samples were retained at values equivalent to the detection limits for groundwater data and equivalent to half the detection limit for soil data (see Section 3.3.1.1 for further discussion); an exception is groundwater data for lead, which was retained at a value equivalent to half the detection limit (see Section 5.3.5). Implications of analytical method sensitivity are discussed further in Section 2.5 (data evaluation) and Chapter 3 (exposure assessment).

2.2.3.3 Source Term Analysis

In addition to radiological results obtained through the main characterization effort (Section 2.2.3.1), information is available from additional analyses of archived samples from the SLDS and city property, SLAPS, Futura Coatings property, and HISS. These samples were analyzed for radionuclides in the uranium-238, thorium-232, and uranium-235 decay series (Figures 2.1, 2.2, and 2.3[*]). This particular set of analyses is referred to in this report as the "source term analysis." For this effort, the properties comprising the St. Louis Site were treated as follows. Seven of the plants at SLDS were considered as individual units

---

[*] For readability, all figures and tables in this chapter are presented in sequence at the end of the text of the chapter.

because a different uranium-processing step was performed in each plant. The SLAPS was divided into five units because different types of residues and wastes from uranium processing at SLDS were stored in different areas at SLAPS. The Latty Avenue Properties, which include HISS and Futura Coatings, were considered one unit. Thus, a total of 13 units were analyzed in the source term analysis.

Thirteen composite samples representing at least 10% of the boreholes from each of seven plant areas at SLDS and the city property (included with one of the plant areas), the five units at SLAPS, and the combined area of HISS and Futura were created from the archived samples to determine the average radionuclide concentration for each of the 13 subareas. The composite samples were prepared by taking equal aliquots of soil, ranging from 15 to 60 g, from each depth region within the boreholes. These aliquots were mixed and sorted to 100 mesh, and one sample was pulled from each composite. The samples were analyzed for actinium-227, lead-210, polonium-210, radium-224, radium-226, radium-228, thorium-227, thorium-230, thorium-232, uranium-234, uranium-235, and uranium-238. Protactinium-231 activity concentrations were derived from actinium-227 and thorium-227 levels.

Results of the source term analysis confirm that site radionuclide contaminants are primarily those in the uranium-238 decay series (i.e., uranium-238, radium-226, and thorium-230); elevated levels of radionuclides in the uranium-235 decay series are also present — in particular, actinium-227 and, through inference, protactinium-231. In general, the levels of radionuclides in the thorium-232 decay series were at approximately background; the highest concentration identified was 6.1 times background. For this BRA, the results of the source term analysis were incorporated with the available characterization data so that the analysis of site contaminants would be as complete as possible. Ratios from the source term analysis were used to estimate activity concentrations of pertinent radionuclides not directly measured in the main database (see Section 2.3.1 for further discussion.)

2.2.3.4 Quality Assurance/Quality Control

A QA program is maintained for the sampling, analysis, and data management performed for the St. Louis Site. This QA program meets the requirements of DOE Order 5700.6B and American National Standards Institute/American Society of Mechanical Engineers Nuclear Quality Assurance (ANSI/ASME NQA-1). The quality of field activities is established through implementation of standard operating procedures; control samples — such as trip blanks, field blanks, and duplicate samples — are collected along with the site samples to ensure the maintenance of data quality at the field level. In addition, for chemical samples, chain-of-custody procedures are implemented to maintain traceability of samples to corresponding analytical results.

Radiochemical analyses were performed by the Thermoanalytical/Eberline (TMA/E) Laboratory in Albuquerque, New Mexico, and chemical analyses were performed under subcontract by Weston Analytical Laboratory in Lionsville, Pennsylvania. Both TMA/E and Weston maintain internal QA programs that have been reviewed by BNI.

The TMA/E internal QA program includes routine calibration of counting instruments, source and background counts, routine yield determinations of radiochemical procedures, and replicate analyses to check precision. The accuracy of radionuclide results was determined through the use of standards traceable to the National Institute of Standards and Technology, when available; when these standards were not available, standards from the New Brunswick Laboratory were used. The TMA/E Laboratory participates in EPA's *Laboratory Intercomparison Studies Program*, in which samples of different environmental media — such as water, milk, air filters, soil, food, and tissue ash — containing one or more radionuclides in known amounts are prepared and distributed to participating laboratories. Results of the analyses are forwarded to EPA for comparison with known values and with results from other laboratories. The participation of TMA/E in this EPA program serves as a measure and check of the accuracy of their analyses. Results from past participation indicate that TMA/E has consistently been successful at meeting required accuracy. In addition, TMA/E is also a participant in DOE's *Laboratory Quality Assessment Program for Radioactive Materials*, coordinated by the DOE Environmental Laboratory in New York City.

In support of the chemical analyses for the St. Louis Site, Weston maintains an internal QA program which ensures that data obtained for both inorganic and organic analyses are of established quality. The following controls are routinely implemented in conjunction with inorganic analyses: initial calibration and calibration verification, continuing calibration verification, reagent blank analyses, matrix spike analyses, duplicate sample analyses, and laboratory control analyses. The quality of results obtained from organic analyses are ensured through initial multilevel calibration for the compounds analyzed, continuing calibration for each of the compounds analyzed, method blank analyses, surrogate spike analyses, matrix spike analyses, and duplicate sample analyses. Weston participates in drinking water, wastewater, and/or hazardous waste certification programs. Continued certification is contingent on the laboratory's ability to maintain a consistently acceptable quality of performance. All data are reviewed by Weston's QA coordinator before transmittal of the results to BNI.

2.3 RADIOLOGICAL CHARACTERIZATION RESULTS

2.3.1 Soil

Radiological analyses have identified elevated levels (i.e., exceeding naturally occurring background levels [Table 2.2]) of primarily uranium-238, radium-226, and thorium-230 in soil at the site properties. Although the vertical extent of contamination varies from property to property (see Appendix A), contamination generally tends to be concentrated near the surface (upper 15 cm). The results of radiological characterization of soil at the St. Louis Site are presented in Table 2.3.

2.3.1.1 SLDS, SLDS Vicinity Properties, and City Property

The results of the extensive investigation at SLDS confirmed the presence [illegible] radioactive contamination at the various plant areas comprising the site. Soil contamination was found primarily underneath buildings or paved areas, and the level of contamination varied from plant to plant (see Appendix A, Figure A.1).

At the Plant 1 area, a majority of the samples contained radionuclides at above background levels. Most of the elevated soil radioactivity was found near Building K1E, and radium-226 levels were the highest of the four radionuclides measured (uranium-238, thorium-230, thorium-232, and radium-226). The maximum measured concentration of radium-226 at Plant 1 was 5,400 pCi/g. Building K1E is currently used primarily for storage. At Plant 2, contamination was concentrated near or beneath Buildings 51, 51A, 52, and 52A. Uranium-238 and thorium-230 were present at the highest levels of 33,000 and 14,000 pCi/g, respectively. The Plant 5 area also contained radioactivity exceeding background levels, with thorium-230 measured at the highest levels. The maximum concentration reported was 1,000 pCi/g. In general, soil contamination was distributed across the entire Plant 6 and 7 areas, as shown by the detection frequencies and concentrations of the radionuclides measured in these plants (Table 2.3). The maximum concentrations of uranium-238, radium-226, thorium-230, and thorium-232 were 15,000, 2,800, 3,000, and 440 pCi/g, respectively, at Plant 6; and 310, 490, 670, and 210 pCi/g, respectively, at Plant 7. Overall, the levels of radioactive contamination found at the Plant 1 area are the most significant of all plant areas because of the high levels of radium-226 identified near Building K1E.

The source term analysis of samples obtained from SLDS confirms the results of the characterization effort. The source term results also indicated that, aside from the main radionuclides in the uranium-238 decay series (for which direct measurements are available), several radionuclides in the uranium-235 decay series were present at levels above background (e.g., actinium-227 and protactinium-231).

Surficial radioactive contamination at above background levels was found in soil at the six SLDS vicinity properties. In addition, subsurface soil contamination was indicated by the radium-226 level in a soil sample collected at the Thomas & Proetz Lumber Company.

Contamination was deepest at the city property adjacent to SLDS. Widespread contamination was indicated at this property and, of the four radionuclides measured, uranium-238 levels were the highest; the maximum concentration was reported at 20,000 pCi/g.

2.3.1.2 SLAPS and Vicinity Properties

SLAPS. Characterization results showed that radioactive contamination of soil at SLAPS extended to a depth of approximately 5.5 m (18 ft). Most of the contamination was between 1.2 and 2.4 m (4 and 8 ft). Analytical results indicated that the majority of uranium-238, radium-226, thorium-230, and thorium-232 levels in soil samples exceeded background levels. Maximum concentrations reported for these radionuclides were 1,600, 5,600, 2,600, and 63 pCi/g, respectively.

SLAPS Vicinity Properties. At the St. Louis Airport Authority property, which is adjacent to SLAPS on the south, contamination was generally shallow (i.e., top 0.6 m [2 ft]) and extended the length of SLAPS. Contamination extended to a depth of 1.2 m (4 ft) at two locations. Of the four radionuclides measured, thorium-230 levels were the most elevated compared with naturally occurring background levels.

At Banshee Road, two small areas contained elevated levels of thorium-230 (i.e., maximum concentration of 34 pCi/g) to a depth of 0.3 m (1 ft). Essentially the whole area of the ditches north and south of SLAPS is contaminated; a maximum contamination depth of 4.3 m (14 ft) occurred at one location. The predominant radioactive contaminant was thorium-230, with concentrations ranging from 0.9 to 15,000 pCi/g.

At the ballfield area, where sampling was relatively extensive (approximately 680 soil samples were collected), both surface and subsurface samples had elevated radionuclide concentrations. Radioactive contamination averaged 0.3 m (1 ft) in depth over the first 45.7 to 61 m (150 to 200 ft) along the northern edge of McDonnell Boulevard (see Appendix A, Figure A.6). Maximum concentrations measured for uranium-238, radium-226, and thorium-230 were 42, 190, and 2,300 pCi/g, respectively.

Radioactive contamination at the haul roads and associated vicinity properties was identified in some areas under Latty Avenue, McDonnell Boulevard, and Pershall Road and along the sides of Hazelwood Avenue and Pershall Road. Properties 1 through 14A border McDonnell Boulevard, and contamination was generally shallow and confined to areas immediately adjacent to the boulevard. Properties 12, 13, and 15 had the highest concentrations of thorium-230. Concentrations of radium-226 and thorium-232 at property 12 were also above background levels. Properties 16, 17, and 19 near Eva Avenue generally had levels of thorium-230 slightly above background; the highest concentrations measured at these properties were 6.6, 1.4, and 11 pCi/g, respectively. Contamination at properties 20 through 31 along Frost Avenue tended to be at shallow depths and on the northern side of the avenue; maximum thorium-230 concentrations at properties 21, 22, 23, and 24 were 230, 110, 710, and 710 pCi/g, respectively. Properties 32 through 48 bordering Hazelwood Avenue had contamination at less than 0.7 m (2 ft); the maximum thorium-230 concentrations occurred at property 32. Contamination at properties 49 through 63A tended to be spotty, shallow, and immediately adjacent to the road.

Of the approximately 70 vicinity properties in the vicinity of the haul roads, five are currently zoned as residential. The remaining vicinity properties near the haul roads are mostly used for commercial/municipal/industrial purposes. The contamination identified at the residential properties was generally surficial and located near the edges of the roads adjacent to the properties. Of the five residential properties (i.e., 19, 20, 41, 43, and 44), property 44 contained the highest concentration of thorium-230 at 91 pCi/g.

The 10 properties adjacent to Coldwater Creek contained radionuclide concentrations in excess of background levels. However, contamination was generally in the first 0.3 m (1 ft) of soil, and levels of thorium-230 were highest of the four radionuclides measured. A thorium-230 level as high as 79 pCi/g was measured at property 3; the concentrations of the other three radionuclides were only slightly above background levels.

Although the seven Norfolk & Western railroad properties characterized in the vicinity of SLAPS contained levels of radionuclides elevated above background, samples from the property adjacent to Hanley Road and Hazelwood Avenue, north of Latty Avenue, had levels only slightly above background (e.g., the thorium-230 level of 3.8 pCi/g was the highest level measured).

2.3.1.3 Latty Avenue Properties

Futura Coatings Property. Characterization of the Futura Coatings Property by BNI began in 1986. Analytical results have indicated elevated levels of uranium-238, radium-226, thorium-230, and thorium-232; maximum concentrations for these four radionuclides were reported at 2,500, 2,300, 2,000, and 26 pCi/g, respectively. Contamination was found at depths ranging from the surface to more than 4.6 m (15 ft) below the surface.

HISS. An earlier characterization of HISS performed in 1981 by Oak Ridge Associated Universities included sampling of the single storage pile then existing and a radiological survey of the northern and eastern boundaries. The results of the storage pile characterization indicated the presence of radionuclides from the uranium-238, uranium-235, and thorium-232 decay series (Table 2.4). Contamination was also found along the boundaries surveyed, and the results indicated that thorium-230 was present at levels exceeding background. The characterization performed by BNI in 1986 indicated that the majority of the ground surface at HISS contained levels of radionuclides exceeding background. Maximum concentrations for uranium-238, radium-226, and thorium-232 were 800, 700, and 5 pCi/g, respectively. The level of thorium-230 contamination was estimated to be at least as high as 790 pCi/g. Contamination was found to a depth of 1.8 m (6 ft); the average depth was about 1 m (3 ft).

Latty Avenue Vicinity Properties. Contamination has been identified at all six Latty Avenue vicinity properties. The depths of contamination ranged from 0 to 4.3 m (0 to 14 ft) at one location on Property 1, but contamination was typically confined to the top 1 m (3 ft) of soil. The ranges of radionuclides detected at each of these properties are presented in Table 2.3. The maximum concentrations of uranium-238, radium-226, thorium-230, and thorium-232 at any of these properties were 100, 89, 5,700, and 7 pCi/g, respectively.

2.3.2 Groundwater

Groundwater data, primarily from environmental monitoring efforts, are available for the SLDS, SLAPS, and HISS areas. Results show that, at SLDS, the level of uranium (190 pCi/L) has exceeded the recently proposed EPA guideline for drinking water. This proposed guideline is 20 µg/L, which corresponds to 14 pCi/L for situations in which the uranium isotopes in water are present in their naturally occurring ratios. Results of groundwater analyses at SLAPS and at HISS also indicate that uranium levels have exceeded the proposed guideline for drinking water. The results are summarized in Table 2.5.

2.3.3 Surface Water and Sediment

The results from the three sediment/bank soil samples collected from the Mississippi River indicated primarily elevated concentrations of radium-226 and uranium-238, at averages of 370 and 26 pCi/g, respectively. The results from samples collected during the 1986 and 1987 characterization at Coldwater Creek indicated spotty contamination over the entire distance sampled, typically in the first 15 cm (6 in.) of sediment. Levels of uranium-238, radium-226, and thorium-232 were lower than those detected for thorium-230 (Table 2.3). In addition, results obtained from sediment sampling locations in the creek that are included in the environmental monitoring program for SLAPS indicate consistent results from year to year (BNI 1985b, 1986b, 1987e, 1988b, 1989c, 1990e, 1991b). The measurements reported in the environmental monitoring reports, however, have been typically lower than those measured during the 1986 and 1987 characterization effort. Measured levels of radionuclides in monitored surface water from Coldwater Creek were consistent with background levels and lower than proposed guidelines. At HISS, environmental monitoring results for sediment and surface water samples generally indicate that the levels of radionuclides measured were slightly elevated above background.

2.3.4 Air

Radon measurements taken inside SLDS buildings indicated levels exceeding the DOE guideline of 3 pCi/L in only 2 of 17 buildings measured, i.e., Building K1E and Building 101; results are summarized in Table 2.6. Both floors of two-story Building K1E are currently being used for storage of laboratory equipment and chemicals, and access by site personnel is restricted. External gamma exposure rates were also measured at the SLDS buildings and were found to exceed background rates at 11 of 20 buildings; the highest levels were again measured at Building K1E (Table 2.6).

At SLAPS, external gamma radiation levels have remained consistently low since 1984, although measurements taken at several locations surveyed were above background levels. The averages in 1990 for eight of the nine sampling locations ranged from 32 to 132 mR/yr; the average for the ninth sampling location was 1,970 mR/yr, which can be attributed to spotty high concentrations of radionuclides in the ditches along McDonnell

Boulevard. The 1990 averages for the three background locations were 60, 60, and 51 mR/yr. Radon levels at SLAPS have been consistently low and within the DOE guideline of 3 pCi/L at all nine sampling locations; measurements in 1990 ranged from 0.4 to 0.9 pCi/L, compared with background readings of 0.4 to 0.6 pCi/L.

At the Futura Coatings property, radon measurements taken inside buildings in 1986 were between 0.3 and 0.7 pCi/L, with an average of 0.6 pCi/L (DOE 1993). At HISS, external gamma radiation levels have been decreasing since 1984 for most monitoring locations because of cleanup activities that took place in 1984 at the site; the generated contaminated materials were added to the pile. However, the most recent measurements taken at several locations have exceeded background levels. Radon levels at HISS have remained consistently stable and are within the DOE guideline of 3 pCi/L (e.g., the maximum radon level measured at HISS in 1990 was 0.9 pCi/L). Radon measurements taken inside the trailers at HISS were also within the DOE guideline of 3 pCi/L, with readings at 1.21, 1.25, and 1.19 pCi/L.

2.3.5 Building Surfaces and Other Structures

The removable alpha or beta measurements taken in buildings at SLDS were at or near background levels. However, the nonremovable alpha and beta-gamma contamination was elevated above background levels on walls and floors in most of the buildings. In general, the nonremovable beta-gamma measurements were higher than the alpha measurements (DOE 1994). Roof contamination was identified at four of the buildings surveyed.

Eighty-four manholes have been surveyed for residual radioactivity. Sediments from 50 manholes were directly sampled, and the results are summarized in Table 2.7. Thirty-five of the 50 manhole sludge or sidewall samples collected had residual radioactivity exceeding the uranium-238 reference level of 50 pCi/g, which is being used for the St. Louis Site project activities to indicate surface soil contamination with uranium.

2.4 CHEMICAL CHARACTERIZATION RESULTS

Chemical characterization data for soil in various site areas are primarily summarized in three studies: (1) the Phase I and Phase II characterization of SLDS (BNI 1990d); (2) a chemical characterization study of the SLAPS, HISS, and Futura Coatings areas (BNI 1990a), and (3) a chemical characterization of the ballfield area (BNI 1989b). Limited additional chemical data are available from a preliminary study of SLAPS soil (BNI 1987c) and from four sediment samples taken at Coldwater Creek (DOE 1993). Chemical characterization data for groundwater are from the SLDS characterization effort (BNI 1990d) and various annual environmental monitoring reports (BNI 1990b, 1990e). Results of chemical measurements from soil and groundwater samples at the various site properties indicate contamination primarily in the form of metals, some of which may be attributable to the process conducted at SLDS. The results of analyses for soil and sediment, groundwater, and air are discussed in Sections 2.4.1 through 2.4.3. Site contaminant levels are compared to available regulatory standards in Section 2.4.4.

2.4.1 Soil and Sediment

The results of analyses for metals and anions in soil at the various site areas are summarized in Table 2.8. Data for uranium are also presented because, of the four radionuclides measured, uranium was found to be prevalent at the site and because the toxicity of soluble uranium is primarily due to its chemical properties rather than its radiological hazard. Uranium levels were measured as part of the radiological site investigation, so the number and location of samples differ from those of the other metals. The results of analyses for organic compounds in soil are summarized in Table 2.9. Only those compounds detected at least once in any of the site areas are included in the table. Samples were analyzed for compounds on the EPA Target Compound List (TCL); the complete list of compounds tested for is given in Appendix C, Tables C.2 and C.3.

Metals consistently detected above background levels at the properties evaluated include antimony, arsenic, beryllium, cadmium, cobalt, lead, and thallium. At SLDS, SLAPS, and HISS, higher concentrations of metals were found in surficial soil, whereas elevated contamination levels were detected at lower depths at the ballfield area and Futura Coatings property.

The VOC detected at the greatest frequency was toluene. Twenty-seven semivolatile organic compounds were detected in SLDS soil. No semivolatile compounds were detected at SLAPS, the ballfield area, HISS, or the Futura Coatings property; however, mass spectral characterization of the soil samples yielded tentative identification of several nonstandardized organic compounds.

The results of Coldwater Creek sediment analyses are presented in Table 2.10. Metal concentrations were compared with background levels in soil because background levels were not available for sediment. Several metals were detected at levels greater than background. Several volatile and semivolatile organic compounds were also detected, but many were detected in only one sample at a low level or were also detected in associated blanks.

2.4.2 Groundwater

The results of groundwater monitoring for metals and organic compounds are summarized in Tables 2.11 and 2.12. For organic compounds, only compounds that were detected in at least one sample are reported in the table. Maximum uranium levels are also included, as reported in the site work plan for SLDS (DOE 1993) and in annual environmental reports for SLAPS (BNI 1987e) and HISS (BNI 1990b).

At SLDS, most of the organic compounds were detected in one well. Seven of the 10 organic compounds detected were found in one well whereas only one or two organics were detected in each of five other site wells. No organics were detected in two of the eight site monitoring wells.

At SLAPS, organic compounds were detected in 11 of 16 wells. The only organic contaminant detected in a HISS well was bis(2-ethylhexyl)phthalate. The maximum levels of contaminants detected in SLDS, SLAPS and HISS wells were scattered among the various wells.

2.4.3 Air

The level of particulates in air at the St. Louis Site has not been measured. However, data available for the level of particulates in the St. Louis area (Trijonis et al. 1980) can be used to estimate metal levels in airborne particulates on the basis of site soil data (see Section 3.3.1.3). This procedure is likely to overestimate airborne contaminant levels somewhat because buildings, pavement, and vegetative cover at each of the properties will limit resuspension of particulates to some degree.

2.4.4 Comparison of Site Contaminant Levels with Regulatory Standards

Regulatory standards do not exist for contaminants in soil or sediment. Federal ambient water quality criteria exist for the evaluation of chemicals in surface water (EPA 1986), but no chemical data are available for the surface water associated with the St. Louis Site (i.e., Coldwater Creek and the Mississippi River). Therefore, a comparison with federal criteria could not be conducted. For groundwater contaminants, primary and secondary maximum contaminant levels (MCLs and SMCLs) for chemicals in public water supplies are specified in the Clean Water Act, which would be applicable if the site groundwater were used as a public water supply in the future. Additionally, the EPA considers MCLs to be potential applicable or relevant and appropriate requirements (ARARs) for CERCLA actions.

Some contaminants detected in groundwater at one or more of the St. Louis Site properties (i.e., SLDS, SLAPS, or HISS) exceed MCLs or SMCLs. These contaminants are listed in Table 2.13. In the case of lead, the detection limit of 100 µg/L exceeds the MCL of 50 µg/L. Although lead has not been detected in groundwater at the St. Louis Site, the high detection limit makes it impossible to determine whether the concentration of lead is less than the MCL. Chemical contaminant levels in air have not been compared with regulatory standards in this analysis because only estimated levels are available.

2.5 DATA EVALUATION

The results gathered from the site characterization activities were evaluated for appropriateness of use in this risk assessment. The EPA guidelines for data evaluation (EPA 1989c) and data usability in risk assessment (EPA 1990c) were followed in determining the final list of contaminants of concern for the St. Louis Site and in gathering the subset of data ecessary to estimate the risks to human health and the environment in the absence of remedial action.

In accordance with EPA (1989c) guidance, the following data evaluation steps were applied to identify the contaminants of concern from site media (e.g., soil and groundwater) and to gather the subset of data for exposure quantification:

- Evaluation of analytical methods used; consideration of data qualifiers, results of control blank samples, sample quantitation limits, and detection frequency;

- Evaluation of the significance of all detected compounds;

- Comparison of potential site-related contamination with background levels;

- Screening of certain chemicals classified as essential nutrients on the basis of their concentration and potential toxicity; and

- If a large number of contaminants remain after screening, performance of a concentration-toxicity screen to limit the number of contaminants carried through the risk assessment.

The evaluation steps used to determine the radioactive and chemical contaminants of concern for the St. Louis Site are summarized in Section 2.5.1 and 2.5.2, respectively.

2.5.1 Radiological Data

The methods used for the analysis of radionuclides have adequate sensitivity to delineate levels that exceed background. Therefore, risks attributable to site levels over background can be estimated. Radionuclides in the uranium-238, thorium-232, and uranium-235 decay series (Figures 2.1, 2.2, and 2.3) that are expected to significantly contribute to site risk can be identified in a preliminary screening. However, for completeness, all radionuclides in these three decay series were considered in the risk assessment for this BRA. In addition, on the basis of the source term analysis results, the radiological hazards of the various radionuclides in the uranium-238 decay series can be determined from the activity concentrations of uranium-238, thorium-230, radium-226, and lead-210. Activities of radionuclides from uranium-238 through uranium-234 can be assumed to be equal in nature, and thorium-234 and protactinium-234 have short half-lives. Also, the activities of each individual radionuclide from radium-226 through polonium-214 can be assumed to be equal to that of radium-226. The latter assumption is based on measured concentrations of lead-210 reported in the source term analysis where lead-210 concentrations were higher than those of radium-226 in some samples (by a factor of about 2); therefore, to be conservative, the activities of each individual radionuclide from lead-210 through lead-206 were assumed to be equal to that of lead-210.

Results of the source term analysis also indicated the presence of radionuclides in the uranium-235 series, principally protactinium-231 and actinium-227. Furthermore, on the basis of these results, it can be assumed that these two radionuclides and all subsequent decay products below actinium-227 through lead-207 are in secular equilibrium, in which the activity of each radionuclide is equal to that of protactinium-231. This assumption is considered to be valid on the basis of the half-lives of the radionuclides (i.e., protactinium-231, 32,000 years; actinium-227, 22 years) and the length of time since processing activities ceased (about 33 years). The source term analysis also indicated that the radionuclides in the thorium-232 decay series were present at the site in concentrations that are slightly above background levels and that the activity of each individual radionuclide in this decay series can be assumed to be equal to that of thorium-232.

On the basis of the above discussion, the doses and risks from radioactive contaminants at the St. Louis Site are expected to be related to the activities of all radionuclides in the three decay series. In this assessment, the radionuclides were grouped as shown in Table 2.14 on the basis of the groupings used in the *res*idual *rad*ioactive material guideline computer code, RESRAD. The dose contributions from decay product nuclides with half-lives of less than 1 year have been incorporated into the dose conversion factor for the parent radionuclide (see Section 3.4).

The database generally consists of measured concentrations for uranium-238, radium-226, thorium-230, and thorium-232. The reported values for these four radionuclides were used in this assessment to estimate potential risks resulting from these radionuclides. However, concentrations of the remaining radionuclides in the three decay series were derived from the source term analysis results, which confirmed that uranium-238, uranium-234, and uranium-235 are present in their natural activity concentration ratio of 1:1:0.046. Therefore, the concentrations of uranium-234 and uranium-235 were derived from the concentration of uranium-238 at that ratio. Actual concentrations of the remaining radionuclides in the uranium-238 and uranium-235 decay series were compared with the radium-226 concentrations reported in the source term analysis to derive a ratio; thorium-232 decay series radionuclides were compared with thorium-232. These ratios were then applied to radium-226 or thorium-232, as appropriate, to determine the concentrations of the remaining radionuclides. This information is presented in Table 2.15.

2.5.2 Chemical Data

The evaluation procedure summarized in Section 2.5 was applied to determine chemical contaminants of concern in site soil, sediment, and groundwater. Samples were analyzed according to EPA methods considered to yield qualitative and quantitative results suitable for risk assessment purposes. Data qualifiers were used by the analytical laboratory in reporting the results to provide an indication/interpretation of the data from an analytical standpoint; however, as a conservative approach for this analysis, all data were considered regardless of any accompanying qualifiers so that the accuracy, adequacy, or appropriateness of the qualifiers used would not have any effect on risk results. For example, EPA guidance recommends the procedure of eliminating a chemical as a contaminant of concern in a particular sample or group of samples if the chemical is present at a level no more than 0 times the level of a common laboratory contaminant in the associated control blank sample(s). In the preparation of this BRA, no chemical constituent was eliminated from further consideration as a contaminant of concern on the basis of its presence in blank samples.

The quantitation limits provided by the methods used for the analysis of the St. Louis Site samples are those that generally meet the objectives set for the St. Louis Site. An exception was the quantitation limits for a few metals that were higher than the background levels in soil samples or higher than the MCLs in water samples. Consequently, for soil samples, other than retaining any parameter that had at least one result over the corresponding detection limit, the metals with detection limits higher than the respective background levels were also retained, even if their detection frequency was zero. For groundwater samples, several inorganic parameters had a zero detection frequency at SLDS, SLAPS and HISS (e.g., lead was not detected at any of the properties [Table 2.11]). However, because the groundwater data were more limited than the soil data, and because some of the detection limits were higher than the MCLs, no inorganic groundwater parameters were deleted from further evaluation on the basis of a zero detection frequency.

The next data evaluation step (comparison with background) was performed only for soil and sediment data because site-specific background data for groundwater are currently unavailable. The mean soil or sediment levels of all detected compounds were compared with mean background levels, as reported for Missouri agricultural soil. For each site property, norganics with mean soil levels less than mean background levels were not considered further as contaminants of concern. Because background values for nitrate and sulfate could not be obtained, these anions were not screened by this process. In addition, because organic compounds are not naturally occurring, they were also not screened by comparison with background levels.

The essentiality and toxicity to humans of the various contaminants were also considered. Several of the metals — including calcium, iron, magnesium, potassium, and sodium — are essential human nutrients. Although the mean calcium and magnesium levels in soil and sediment were above the Missouri background levels at all of the site properties for which chemical data were available, and the mean iron level was above background at SLDS, the maximum site levels were not elevated above maximum background levels measured in the United States (Shacklette and Boerngen 1984). Therefore, in accordance with EPA guidance on essential elements, these metals were not considered further as ontaminants of concern. For groundwater, these same five metals were screened from further consideration on the basis of their widespread natural occurrence in groundwater and because they are essential human nutrients. Aluminum was also screened from further consideration in soil, sediment, and groundwater because it is a normal dietary constituent of low toxicity. Furthermore, aluminum levels in soil and sediment were below background evels at all properties.

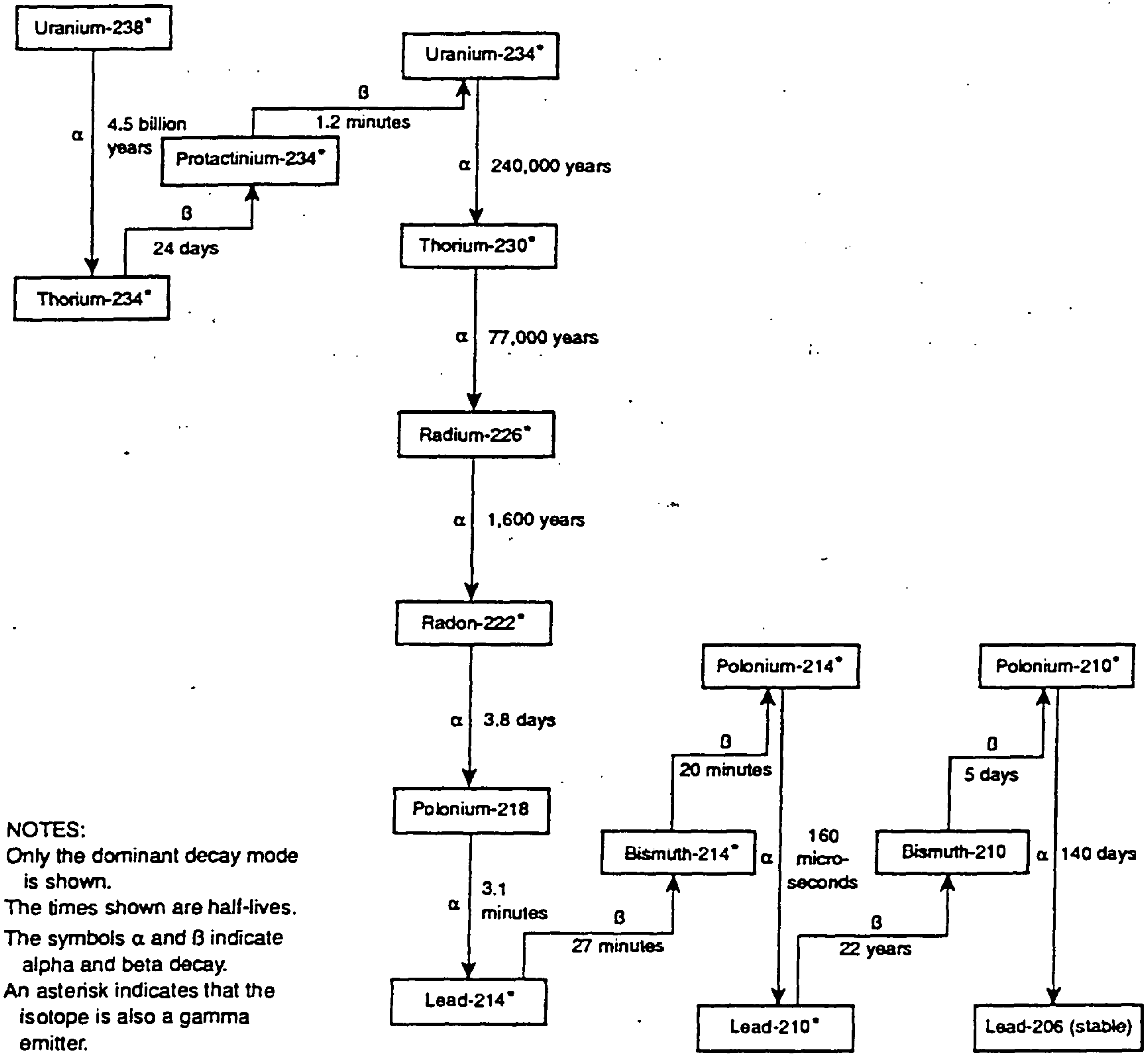
Lithium and sulfate were also screened from consideration as contaminants of concern in soil and sediment on the basis of their low toxicity, moderate site concentrations, and ubiquitous presence in plant and animal food products. The mean concentration of lithium was slightly higher than background at SLAPS. A background value for sulfate in soil was not available. However, neither lithium nor sulfate would be considered toxic at the levels detected in site soil and sediment. Lithium is present in the daily human diet at a level of about 2 mg (Venugopal and Luckey 1978) and is safely used as a psychiatric drug at concentrations of approximately 1 g/d. Sulfate exhibits low toxicity in humans but has been shown to have laxative effects at water levels of 630 mg/L or greater (Chien et al. 1968). The possible lithium and sulfate intakes from exposure to site soil and sediment are considerably below these levels.

Finally, a concentration-toxicity screening procedure was conducted with available chemical soil and sediment data for the remaining potential contaminants of concern at each site property. As a conservative approach, this step was not performed for available groundwater data because of the limited amount of information available to date. The screening of soil and sediment data involved calculating a ratio of the maximum concentration detected for each substance to a toxicity value and summing the ratios; this methodology was developed by the EPA (1989c). Each property with available chemical data was evaluated individually, and three screenings were conducted for each property: one based on oral or inhalation noncarcinogenic toxicity values (reference doses, RfDs), one based on oral carcinogenic toxicity values (oral slope factors), and one based on inhalation slope factors. Both oral and inhalation toxicity were considered because of the possibility of either soil ingestion or inhalation of resuspended particulates at the site. Few inhalation RfDs were available for the contaminants considered; where available and lower than the oral RfDs, these values were used in the screening process. For each property, any contaminant contributing less than 1% to the total risk ratio for each screening was excluded from further evaluation for that property. The results of the chemical concentration-toxicity screening procedure for the various site properties are presented in Tables 2.16, 2.17, and 2.18.

The following potential contaminants of concern for soil and sediment did not have available toxicity values: cobalt, lead, 4-chloro-3-methylphenol, 2-propanol-1,3-dichlorophosphate, dibenzofuran, and several PAH compounds not classified as carcinogenic by the EPA — i.e., acenaphthylene, benzo(g,h,i)perylene, 2-methylnaphthalene, and phenanthrene. The organic contaminants were detected either in SLDS soil or Coldwater Creek sediment. Except for the PAHs, the organic contaminants were eliminated from further consideration as contaminants of concern on the basis of low detection frequency and/or low site concentrations. The noncarcinogenic PAHs were included in the toxicity screening by assuming the RfD values to be equal to that of naphthalene. Cobalt and lead were detected in soil samples from all site properties; they were retained as contaminants of concern because they were present at elevated levels at all site properties and because of their potential toxic effects. Soil samples from the city property adjacent to SLDS were not analyzed for organic compounds. It was assumed that any organic compounds identified as contaminants of concern for SLDS would also be contaminants of concern for the city property.

2.6 SUMMARY OF CONTAMINANTS OF CONCERN

In summary, the radionuclides of concern at all properties comprising the St. Louis Site are those found in the uranium-238, thorium-232, and uranium-235 decay series — primarily uranium-238, radium-226, thorium-230, lead-210, actinium-227, and protactinium-231. The chemical contaminants deleted as a result of the screening procedure are presented in Tables 2.19 and 2.20. The chemical contaminants of concern for site soil and sediment that were retained for evaluation are listed in Table 2.21. All inorganic parameters for which groundwater samples were analyzed (except for the constituents listed in Table 2.20) were retained as contaminants of concern. Also, any organic contaminants detected in groundwater were retained for further analysis; these contaminants of concern are listed in Table 2.12. The radioactive and chemical contaminants of concern were assessed in more detail to determine their contribution to site risk; this assessment is presented in Chapters 3 through 6.



NOTES:

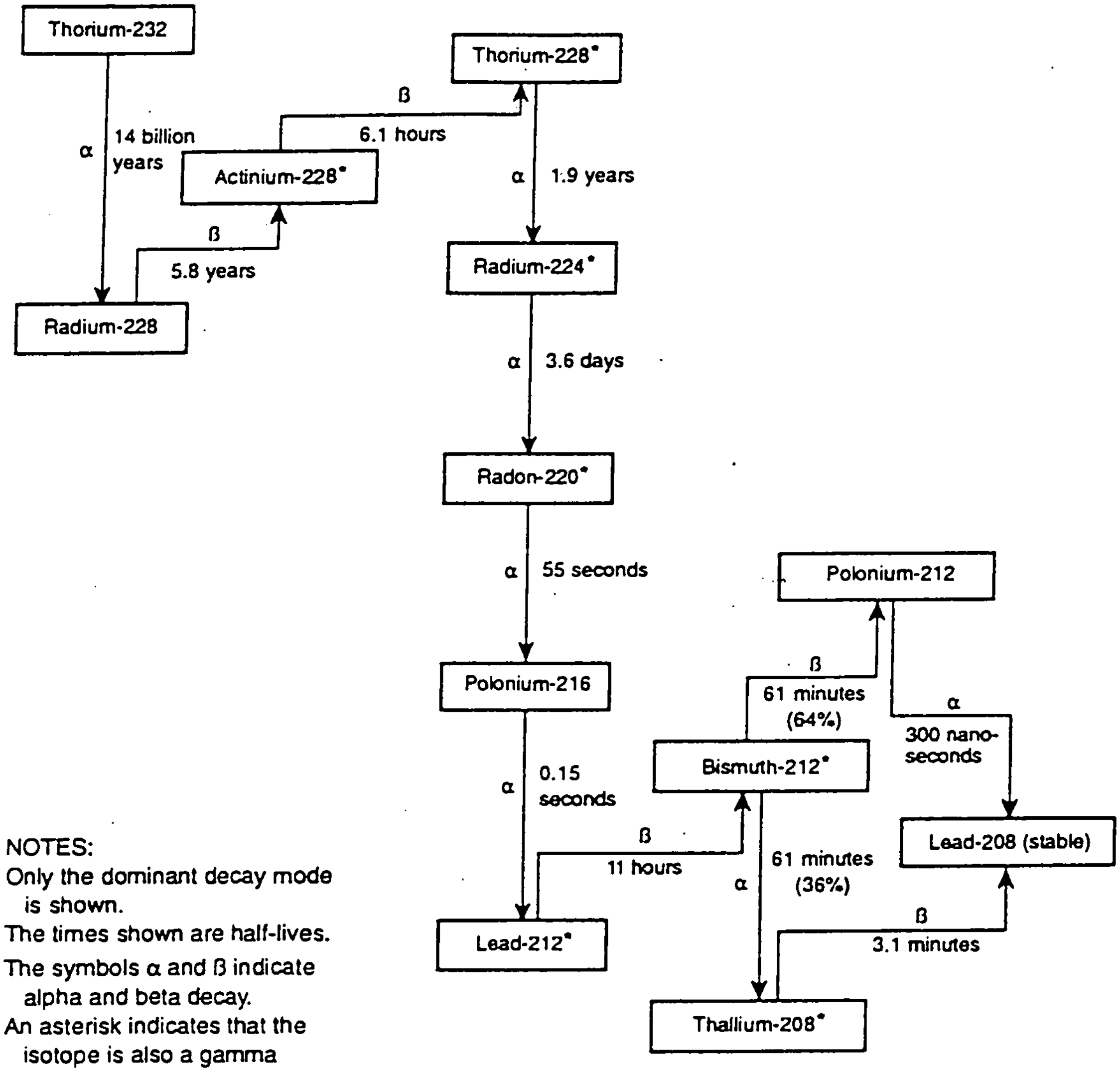
Only the dominant decay mode is shown.

The times shown are half-lives.

The symbols α and β indicate alpha and beta decay.

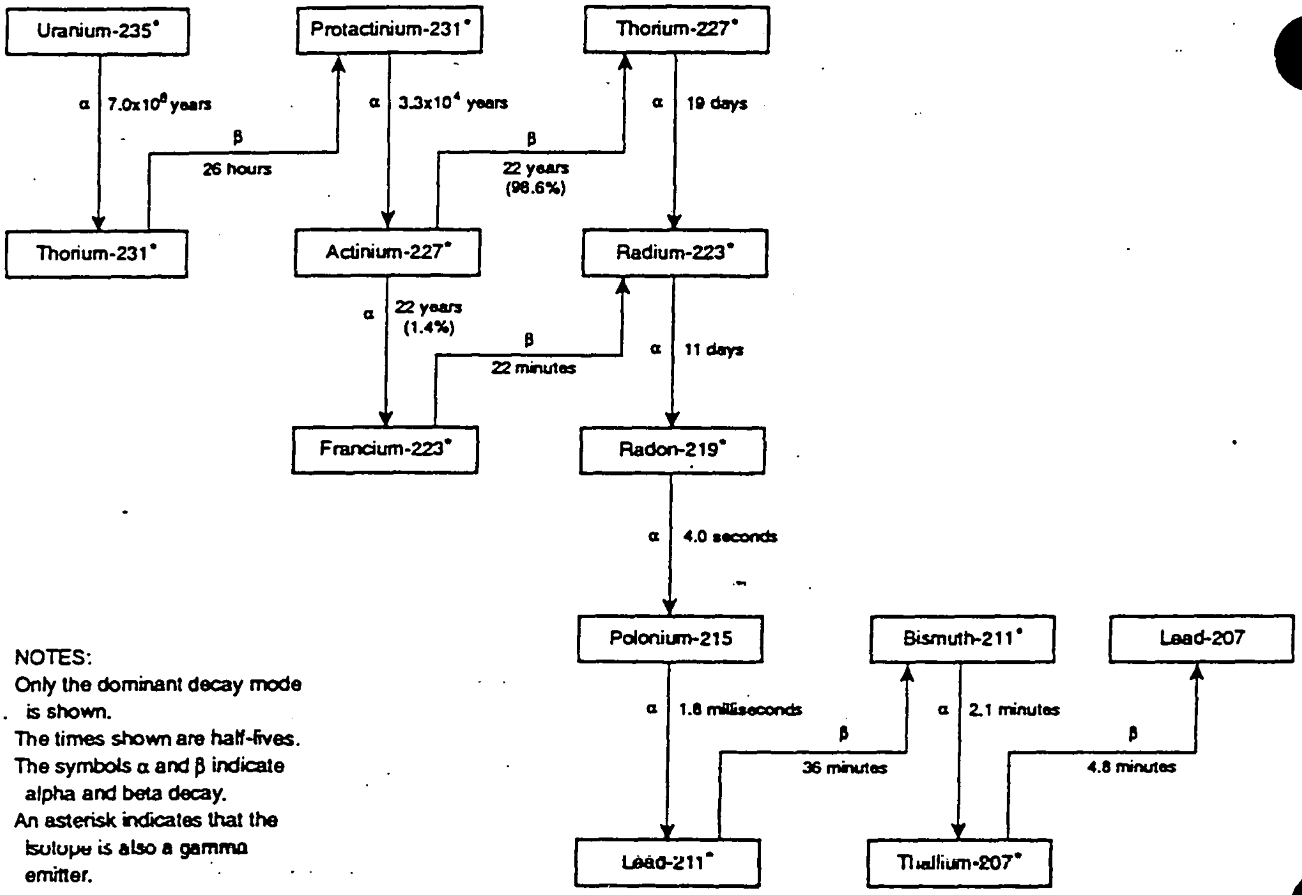
An asterisk indicates that the isotope is also a gamma emitter.

FIGURE 2.1 Uranium-238 Radioactive Decay Series



NOTES:
Only the dominant decay mode is shown.
The times shown are half-lives.
The symbols α and ß indicate alpha and beta decay.
An asterisk indicates that the isotope is also a gamma emitter.

FIGURE 2.2 Thorium-232 Radioactive Decay Series



NOTES:
Only the dominant decay mode is shown.
The times shown are half-lives.
The symbols α and β indicate alpha and beta decay.
An asterisk indicates that the isotope is also a gamma emitter.

FIGURE 2.3 Uranium-235 Radioactive Decay Series

[illegible] Summary of Data Collection Activities at the S[illegible]uis Site[a]

Property	Medium	Radiological Characterization		Chemical Characterization		References
		Sampling Program	Analytical Parameters	Sampling Program	Analytical Parameters[b]	
SLDS and Vicinity Properties						
SLDS and city property	Soil	Walkover gamma scans and gamma logging	Count rates	Composite samples from 69 boreholes	Metals, VOCs, semivolatiles, and RCRA characteristics	BNI (1990d)
		297 surface samples and samples from 218 boreholes	Uranium-236, radium-226, thorium-230, and thorium-232	Discrete samples from another 61 boreholes	Metals and RCRA characteristics	BNI (1990d)
	Groundwater	Quarterly sampling of 8 wells in 1988	Total uranium, radium-226, thorium-230, and thorium-232	Quarterly sampling of 6 wells in 1988	VOCs, semivolatiles, PCBs/pesticides, metals, pH, specific conductance, TOX, and TOC	BNI (1990d)
	Air	Two-time charcoal canister sampling in 19 buildings[c] (March and Sept. 1990)	Radon	Not applicable	Not applicable	DOE (1993)
		One-time Terradex cup sampling in 18 buildings[d] (Sept. 1990)	Radon			
	Surface water and sediment	84 manholes surveyed with gamma logging instrumentation	Gamma count rate	Not applicable	Not applicable	BNI (1990d)
		Sludge and sediment samples from 60 of the 84 manholes	Uranium-236, radium-226, thorium-230, and thorium-232			
	Buildings	Spot surveys of floors, walls, ceilings, and roofs of buildings[e]	Direct alpha, direct beta-gamma, and removable contamination; uranium-238, radium-226, thorium-230, and thorium-232	Not applicable	Not applicable	BNI (1990d)

TABLE 2.1 (Cont.)

		Radiological Characterization		Chemical Characterization		
Property	**Medium**	**Sampling Program**	**Analytical Parameters**	**Sampling Program**	**Analytical Parameters**[b]	**References**
SLDS and Vicinity Properties (Cont.)						
Vicinity properties						
McKinley Iron Company	Soil	42 samples from 39 locations	Uranium-238, radium-226, thorium-230, and thorium-232	Not applicable	Not applicable	DOE (1993)
PVO Foods, Inc.	Soil	13 samples from 9 locations	Uranium-238, radium-226, thorium-230, and thorium-232	Not applicable	Not applicable	DOE (1993)
Thomas & Proetz Lumber Company	Soil	65 samples from 48 locations	Uranium-238, radium-226, thorium-230, and thorium-232	Not applicable	Not applicable	DOE (1993)
St. Louis Terminal Railroad Association	Soil	32 samples from 29 locations	Uranium-238, radium-226, thorium-230, and thorium-232	Not applicable	Not applicable	DOE (1993)
Norfolk & Western Railroad	Soil	34 samples from 24 locations	Uranium-238, radium-226, thorium-230, and thorium-232	Not applicable	Not applicable	DOE (1993)
Chicago, Burlington, & Quincy Railroad	Soil	40 samples from 26 locations	Uranium-238, radium-226, thorium-230, and thorium-232	Not applicable	Not applicable	DOE (1993)
SLAPS and Vicinity Properties						
SLAPS	Soil	Walkover gamma scan, near-surface gamma measurements, and gamma logging	Count rates	33 samples from 11 boreholes	Metals, TOC, and TOX	BNI (1887c, 1990a, 1990e)
		Surface samples from 21 locations along SLAPS boundary and subsurface samples from 102 boreholes	Uranium-238, radium-226, thorium-230, and thorium-232	109 samples from 30 boreholes	Metals, VOCs, semivolatiles, mobile ions, and RCRA characteristics	

TABLE 2.1 (Cont.)

Property	Medium	Radiological Characterization: Sampling Program	Radiological Characterization: Analytical Parameters	Chemical Characterization: Sampling Program	Chemical Characterization: Analytical Parameters[b]	References
SLAPS and Vicinity Properties (Cont.)						
SLAPS (cont.)	Groundwater	Quarterly environmental monitoring of 19 wells	Total uranium, radium-226, thorium-230, and thorium-232	Quarterly environmental monitoring since 1987; one quarter only in 1989	pH, specific conductance, TOC, and TOX; metals and VOCs (1988-1989)	BNI (1987c, 1990a, 1990e); DOE (1993)
	Sediment	5 locations	Total uranium, radium-226, and thorium-230	Not applicable	Not applicable	BNI (1990e)
	Surface water	Quarterly environmental monitoring at 7 locations	Total uranium, radium-226, and thorium-230	Not applicable	Not applicable	BNI (1990e)
	Air	Year-round monitoring at 9 locations with track-etch monitors; sampling with thermoluminescent dosimeters and a pressurized ionization chamber	Radon, external gamma radiation, and gamma exposure rates	Not applicable	Not applicable	BNI (1990e)
Vicinity properties St. Louis Airport Authority	Soil	Near-surface gamma measurements and gamma logging	Count rates	Not applicable	Not applicable	BNI (1990c)
		Samples from 66 boreholes	Uranium-238, radium-226, thorium-230, and thorium-232			
Banshee Road	Soil	Gamma logging in 47 boreholes	Count rates	Not applicable	Not applicable	BNI (1990c)
		Samples from 48 boreholes	Uranium-238, radium-226, thorium-230, and thorium-232			

TABLE 2.1 (Cont.)

		Radiological Characterization		Chemical Characterization		
Property	Medium	Sampling Program	Analytical Parameters	Sampling Program[a]	Analytical Parameters[b]	References
SLDS and Vicinity Properties (Cont.)						
Vicinity properties (cont.)						
Ditches north and south of SLAPS	Soil	Near-surface gamma measurements and gamma logging	Count rates	Not applicable	Not applicable	BNI (1990c)
		Surface and subsurface samples from 87 boreholes	Uranium-238, radium-226, thorium-230, and thorium-232			
Ballfield	Soil	Near-surface gamma measurements and gamma logging	Count rates	Samples from 11 boreholes	Metals, mobile ions, VOCs, semivolatiles, PCBs/pesticides, and RCRA characteristics	BNI (1989b, 1990c)
		680 samples	Uranium-238, radium-226, thorium-230, and thorium-232			
Haul roads and haul roads vicinity properties	Soil	3,000 samples	Thorium-230	Not applicable	Not applicable	BNI (1990c)
		240 samples	Uranium-238, radium-226, thorium-230, and thorium-232			
Coldwater Creek	Soil	Walkover gamma scan and gamma logging	Count rates	Not applicable	Not applicable	BNI (1990c)
		Samples from 519 boreholes from SLAPS to HISS	Uranium-238, radium-226, thorium-230, and thorium-232			
	Sediment	Surface samples from sides and center of creek (1986)	Radioactive contamination	4 samples from 4 locations	Metals, mobile ions, VOCs, and semivolatiles	DOE (1993)
Coldwater Creek vicinity properties	Soil	Walkover gamma scan and gamma logging	Count rates	Not applicable	Not applicable	BNI (1990c)
		120 samples	Uranium-238, radium-226, thorium-230, and thorium-232			

TABLE 2.1 (Cont.)

Property	Medium	Radiological Characterization: Sampling Program	Radiological Characterization: Analytical Parameters	Chemical Characterization: Sampling Program	Chemical Characterization: Analytical Parameters[b]	References
SLAPS and Vicinity Properties (Cont.)						
Vicinity properties (cont.) Norfolk & Western Railroad	Soil	Gamma scan and gamma logging	Gamma exposure and count rates	Not applicable	Not applicable	BNI (1990c)
		Samples from 200 boreholes	Uranium-238, radium-228, thorium-230, and thorium-232			
Latty Avenue Properties						
Futura Coatings, Inc.	Soil	Walkover gamma scans, near-surface gamma measurements, and gamma logging	Count rates	Samples from 3 random boreholes and 3 biased boreholes	Metals, mobile ions, VOCs, semivolatiles, and RCRA characteristics	BNI (1987d, 1990a)
		Samples from 48 exterior boreholes and 10 boreholes beneath the building	Selected exterior borehole samples analyzed for uranium-238, radium-226, thorium-230, and thorium-232; all borehole samples from beneath the building analyzed for uranium-238, radium-226, thorium-230, and thorium-232			
	Buildings	Environmental monitoring	Radon, gamma levels, and gross alpha concentrations	Not applicable	Not applicable	BNI (1987d)

TABLE 2.1 (Cont.)

		Radiological Characterization		Chemical Characterization		
Property	Medium	Sampling Program	Analytical Parameters	Sampling Program	Analytical Parameters[b]	References
Latty Avenue Properties (Cont.)						
HISS	Soil	Walkover gamma scans, near-surface gamma measurements, and gamma logging in all boreholes	Count rates	15 samples from 3 random boreholes and 3 biased boreholes	Metals, mobile ions, VOCs, semivolatiles, and RCRA characteristics	BNI (1987a, 1990a, 1990b)
		Samples at 1-ft increments in each of 36 boreholes	All samples analyzed for uranium-238, radium-226, and thorium-232; selected samples analyzed for thorium-230			
	Groundwater	Quarterly environmental monitoring since 1984	Total uranium, radium-226, thorium-230, external gamma radiation, and radon	Quarterly environmental monitoring since 1984	pH, specific conductance, TOX, and TOC	BNI (1987a, 1990a, 1990b)
				Quarterly environmental monitoring since 1984; only one quarter in 1989	Metals, VOCs, and semivolatiles	
	Surface water and sediment	Quarterly environmental monitoring of drainage pathways at 4 locations; composite sediment samples	Total uranium, radium-228, and thorium-230	Not applicable	Not applicable	BNI (1987a, 1990a, 1990b)
	Air	Monitoring at 11 locations; charcoal canister sampling in the 2 trailers (Oct. 1990)	Radon	Not applicable	Not applicable	BNI (1987a, 1990a, 1990b)
		Measurements with thermoluminescent dosimeters at the HISS boundary and storage piles	External gamma radiation			

TABLE 2.1 (Cont.)

Property	Medium	Radiological Characterization: Sampling Program	Radiological Characterization: Analytical Parameters	Chemical Characterization: Sampling Program	Chemical Characterization: Analytical Parameters[b]	References
Latty Avenue Properties (Cont.)						
Vicinity properties	Soil	Surface and subsurface samples	Uranium-238, radium-226, thorium-230, and thorium-232	Not applicable	Not applicable	BNI (1990c)

[a] A summary of activities performed or supervised by Bechtel National, Inc.

[b] Notation: PCB = polychlorinated biphenyl; RCRA = Resource Conservation and Recovery Act; TOC = total organic carbon; TOX = total organic halides; VOC = volatile organic compound.

[c] Includes Buildings K1E, 25, 50, 51, 51A, 52, 52A, 81, 82, 100, 101, 116, 117, 700, 704, 705, 706, 707, and 708.

[d] Includes Buildings K1E, 25, 50, 51, 51A, 52A, 81, 82, 100, 101, 116, 117, 700, 704, 705, 706, 707, and 708.

[e] Includes Buildings K1E, 25, 50, 51, 51A, 52, 52A, 81, 82, 100, 101, 116, 116B, 117, 700, 704, 705, 706, 707, and 708.

TABLE 2.2 Background Radiation Levels at the St. Louis Site

Type of Radiation Measurement	Unit	Average Radiation Level or Radionuclide Concentration
Gamma exposure rate at 1 m (3 ft) above ground surface[a]	μR/h	10
Radionuclide concentrations in soil[a]	pCi/g	
Uranium-238 decay series		1.1
Thorium-232 decay series		1.1
Outdoor radon[b]	pCi/L	0.3
Radon flux[b]	pCi/m^2-s	0.08
Ambient air concentrations[b]	pCi/m^3	
Actinium-227		0.0003
Lead-210		0.01
Radium-226		<0.005
Thorium-230		0.004
Uranium-238		0.003

[a] Source: BNI (1990c).

[b] Source: ORNL (1979).

TABLE 2.3 Summary of Soil Characterization Results for Radionuclides[a]

Property	Uranium-238		Radium-226		Thorium-230		Thorium-232	
	Concentration Range (pCi/g)	Detection Frequency	Concentration Range (pCi/g)	Detection Frequency	Concentration Range (pCi/g)	Detection Frequency	Concentration Range (pCi/g)	Detection Frequency
SLDS and Vicinity Properties								
SLDS								
Plant 1	2-310	10/99	<0.4-5,400	94/99	<0.3-330	93/99	<0.4-<14	54/99
Plant 2	<2-33,000	77/144	0.5-600	137/144	0.4-14,000	144/144	<0.3-9	96/144
Plant 5	<3-170	15/54	<0.5-290	52/54	<0.5-1,000	47/54	<0.4-130	34/54
Plant 6	1.3-15,000	161/412	<0.3-2,800	396/412	0.4-3,000	402/412	0.4-440	260/412
Plant 7	<2-310	38/247	<0.3-490	235/247	0.4-870	224/234	<0.4-210	162/247
Plant 10	<2-370	12/52	0.5-16	45/52	0.3-38	49/49	<0.5-7	32/52
City property	0.5-20,000	68/335	<0.2-1,300	289/336	<0.6-590	319/336	<0.3-46	245/336
Vicinity properties								
McKinley Iron Company	<3-68	20/29	0.7-85	29/29	0.9-84	29/29	<1-3	10/29
Thomas & Proetz Lumber Company	<2-<82	16/38	0.7-1,800	36/38	1.1-290	38/38	0.8-160	15/38
PVO Foods, Inc.	<3-<11	0/11	0.9-5	11/11	1.3-5.8	11/11	<1-2	6/11
Norfolk & Western Railroad	<3-1,100	10/24	0.5-300	24/24	1.8-2,100	24/24	0.9-56	20/24
St. Louis Terminal Railroad Association	<4-<45	1/23	1.3-48	23/23	2-51	23/23	<1-160	10/23
Chicago, Burlington & Quincy Railroad	4-120	15/25	0.9-9	25/25	1.9-450	25/25	0.9-3	15/25
SLAPS and Vicinity Properties								
SLAPS	0-1,800	151/752	<0.3-5,600	507/751	0.6-2,800	484/464	<0.4-63	393/752
SLAPS vicinity properties								
St. Louis Airport Authority	<3-<11	0/137	0.8-3.3	136/137	<0.7-39	136/137	0.8-5	116/137
Banshee Road	<1-<46	3/292	0.7-7	283/292	<0.4-34	290/291	0.8-7	198/292
Ditches north and south of SLAPS	<1-94	102/295	0.7-130	294/295	0.9-15,000	245/245	0.7-6	265/295
Ballfield	<3-42	19/565	<0.5-190	558/565	<0.1-2,300	594/599	0.8-5	539/565
Haul roads								
Latty Avenue	<3-48	9/892	0.8-39.9	880/892	<0.2-360	936/946	<0.1-9.5	786/892
McDonnell Boulevard	<2-59	12/354	0.7-64	343/354	<0.7-2,900	354/354	0.7-9	263/354
Hazelwood Avenue	<4-72	5/122	0.8-42	119/122	0.9-4,800	122/122	0.8-9	107/122
Pershall Road	<3-73	20/901	0.4-92	891/901	0.8-4,900	898/901	0.8-9	799/901
Eva Avenue[b]	-	-	-	-	-	-	-	-
Frost Avenue[b]	-	-	-	-	-	-	-	-

TABLE 2.3 (Cont.)

Property	Uranium-238		Radium-226		Thorium-230		Thorium-232	
	Concentration Range (pCi/g)	Detection Frequency	Concentration Range (pCi/g)	Detection Frequency	Concentration Range (pCi/g)	Detection Frequency	Concentration Range (pCi/g)	Detection Frequency
SLAPS and Vicinity Properties (Cont.)								
SLAPS vicinity properties (cont.)								
Haul roads vicinity properties								
Property 1	NA[c]	NA	NA	NA	NA	NA	NA	NA
Property 2	-	-	-	-	<0.6-3.5	20/23	-	-
Property 3	-	-	-	-	<0.6-2.4	4/6	-	-
Property 4	-	-	-	-	1.4-3.9	5/5	-	-
Property 5	-	-	-	-	1.1-14	6/6	-	-
Property 6	-	-	-	-	1.1-2.8	5/5	-	-
Property 7	-	-	-	-	<0.6-32	16/20	-	-
Property 8	-	-	-	-	1.2-2.2	3/3	-	-
Property 9	-	-	-	-	<0.5-12	4/5	-	-
Property 10	-	-	-	-	1.2-7.2	9/9	-	-
Property 11	-	-	-	-	<0.8-18	11/12	-	-
Property 12	<3-<19	0/36	0.6-13	36/35	<1-570	44/45	0.7-5	29/36
Property 13	-	-	-	-	<0.7-370	51/53	-	-
Property 14	-	-	-	-	<0.9-33	42/45	-	-
Property 14A	-	-	-	-	<0.4-36	43/45	-	-
Property 15	-	-	-	-	<0.6-460	92/96	-	-
Property 16	-	-	-	-	1.5-6.6	9/9	-	-
Property 17	-	-	-	-	<0.9-1.4	3/4	-	-
Property 18	NA[c]	NA	NA	NA	NA	NA	NA	NA
Property 19	-	-	-	-	<0.7-11	11/13	-	-
Property 20	-	-	-	-	0.7-8.4	11/11	-	-
Property 20A	-	-	-	-	<0.6-2.6	5/6	-	-
Property 21	-	-	-	-	<0.5-230	19/29	-	-
Property 22	-	-	-	-	<0.6-110	15/19	-	-
Property 23	-	-	-	-	<0.8-710	23/25	-	-
Property 24	-	-	-	-	<0.4-710	55/61	-	-
Property 25	-	-	-	-	1-4.8	22/22	-	-
Property 26	-	-	-	-	1.4-6.9	11/11	-	-
Property 27	-	-	-	-	1.4-8.1	11/11	-	-
Property 28	-	-	-	-	1.5-4.6	8/8	-	-
Property 29	-	-	-	-	0.7-3.2	10/10	-	-
Property 30	-	-	-	-	1-8.8	6/8	-	-
Property 31	-	-	-	-	1.2-2.1	3/3	-	-
Property 31A	-	-	-	-	<1-41	13/15	-	-
Property 32	-	-	-	-	<0.3-540	18/19	-	-
Property 33	-	-	-	-	1.1-170	16/16	-	-

[illegible] (Cont.)

Property	Uranium-238		Radium-228		Thorium-230		Thorium-232	
	Concentration Range (pCi/g)	Detection Frequency	Concentration Range (pCi/g)	Detection Frequency	Concentration Range (pCi/g)	Detection Frequency	Concentration Range (pCi/g)	Detection Frequency
SLAPS and Vicinity Properties (Cont.)								
SLAPS vicinity properties (cont.)								
Haul roads vicinity properties (cont.)								
Property 34	-	-	-	-	1.3-140	10/10	-	-
Property 35	<0-<19	0/235	0.7-11	234/235	0.8-1,000	284/284	0.8-5	226/235
Property 37	<3-<37	0/25	0.6-7	25/25	<0.8-600	59/62	0.8-7	22/25
Property 38	<0.5-<25	0/140	0.6-6	139/140	0.5-1,200	268/274	0.7-5	120/140
Property 39	<2-<14	0/36	0.7-3.2	35/38	<0.6-200	96/99	0.6-3	22/36
Property 40	-	-	-	-	<0.5-110	24/26	-	-
Property 41	-	-	-	-	0.6-53	39/39	-	-
Property 42	-	-	-	-	1.4-63	19/19	-	-
Property 43	-	-	-	-	<0.8-22	6/8	-	-
Property 44	-	-	-	-	1.1-91	11/11	-	-
Property 45	-	-	-	-	1-21	10/10	-	-
Property 46	-	-	-	-	<0.8-7	9/10	-	-
Property 47	-	-	-	-	0.9-110	12/12	-	-
Property 48	-	-	-	-	0.7-34	35/37	-	-
Property 48A	-	-	-	-	1.4-1.9	4/4	-	-
Property 49	-	-	-	-	0.8-1.5	6/8	-	-
Property 50	-	-	-	-	1-1.4	4/4	-	-
Property 51	-	-	-	-	1-1.7	6/6	-	-
Property 52	-	-	-	-	1-4.3	16/18	-	-
Property 53	-	-	-	-	0.8-2.1	26/26	-	-
Property 54	-	-	-	-	0.7-1.7	7/7	-	-
Property 55	-	-	-	-	1.3-2.3	4/4	-	-
Property 56	-	-	-	-	<0.7-1,100	11/12	-	-
Property 57	<2-<15	0/17	0.7-2.1	14/17	1.3-19	17/17	0.7-3	6/17
Property 58	<2-<15	0/22	0.6-2.8	17/22	<0.9-8.5	25/26	0.7-3	13/22
Property 59	-	-	-	-	1.3-2.2	3/3	-	-
Property 60	-	-	-	-	<0.9-1.5	5/6	-	-
Property 61	-	-	-	-	0.8-1.7	6/6	-	-
Property 62	-	-	-	-	1-3.4	6/6	-	-
Property 63	-	-	-	-	1-10	33/33	-	-
Property 63A	-	-	-	-	0.6-200	137/141	-	-

TABLE 2.3 (Cont.)

Property	Uranium-238 Concentration Range (pCi/g)	Uranium-238 Detection Frequency	Radium-226 Concentration Range (pCi/g)	Radium-226 Detection Frequency	Thorium-230 Concentration Range (pCi/g)	Thorium-230 Detection Frequency	Thorium-232 Concentration Range (pCi/g)	Thorium-232 Detection Frequency
SLAPS and Vicinity Properties (Cont.)								
SLAPS vicinity properties (cont.)								
Norfolk & Western Railroad properties								
Adjacent to Latty Avenue	<4-390	10/470	0.6-1,100	466/470	0.7-26,000	430/430	0.6-7	422/470
Adjacent to Hanley Road	<1-<7	0/2	1.6-2.2	2/2	0.8-6	29/29	2-2.5	2/2
South of SLAPS	<3-27	3/237	0.6-8	237/237	1.5-170	154/154	0.6-5	193/237
Adjacent to Coldwater Creek	<3-<23	3/129	0.7-15	122/129	0.3-1,300	129/129	0.8-7	109/129
Adjacent to Hazelwood Avenue and south of Latty Avenue	-	-	-	-	1.2-210	43/43	-	-
Adjacent to Hazelwood Avenue and north of Latty Avenue[d]	-	-	-	-	1.9-3.6	6/8	-	-
Adjacent to Eva Avenue	-	-	-	-	<0.8-85	64/72	-	-
Coldwater Creek[e]	0.4-9	240/255	0.3-3.1	255/255	0.5-110	255/255	<0.1-3	252/255
Coldwater Creek vicinity properties[f]	<2-78	11/199	0.6-71	197/199	0.80-5,100	198/199	0.7-5	181/199
Coldwater Creek vicinity properties[g]								
Property 1	<3-<14	0/9	0.8-2.7	9/9	1.4-38	9/9	<0.7-5	5/9
Property 2	<5-<20	0/13	0.7-3	13/13	<1-7.7	12/13	0.9-4	10/13
Property 3	<2-<16	0/26	0.3-4	21/26	<0.8-79	26/26	0.8-4	18/26
Property 4	<3-<11	0/12	0.6-1.8	12/12	<0.6-5.1	11/12	0.9-3	12/12
Property 5	<2-<16	0/12	0.9-3	11/12	<0.7-61	11/12	0.9-4	10/12
Property 6	<6-<13	0/3	1.2-1.7	3/3	1.1-5.2	3/3	<0.4-3	2/3
Property 7	<4-<6	0/5	0.9-2.2	5/5	0.9-3.7	5/5	<0.3-3	3/5
Property 8	<3-<11	0/15	0.4-2.8	13/15	1.1-23	15/15	<1-4	13/15
Property 9	<5-<10	0/5	<1-2.3	4/5	1-8.5	5/5	<1-3	3/5
Property 10	<7-<11	0/3	1.6-1.8	3/3	1.5-5.7	3/3	1.7-3	3/3

(Cι----,

Property	Uranium-238		Radium-228		Thorium-230		Thorium-232	
	Concentration Range (pCi/g)	Detection Frequency	Concentration Range (pCi/g)	Detection Frequency	Concentration Range (pCi/g)	Detection Frequency	Concentration Range (pCi/g)	Detection Frequency
Latty Avenue Properties								
Futura Coatings, Inc.	<3-2,500	58/547	0.4-2,300	545/547	0.7-2,000	218/221	0.7-26	504/547
HISS	<3-800	50/333	0.5-700	332/333	0.8-790	91/91	0.7-5	294/333
Latty Avenue vicinity properties								
Property 1	<3.0-30	1/83	0.5-11	88/88	0.7-810	208/208	0.7-5	79/88
Property 2	<3-100	18/290	<0.5-89	289/290	0.4-5,700	277/277	0.7-5	269/290
Property 3	<4-<39	0/37	0.8-4	37/37	0.2-31	54/54	<1.0-5	31/37
Property 4	<4-<20	0/37	0.5-10	37/37	0.7-460	37/37	0.5-4	34/37
Property 5	<4-<30	0/27	0.7-4	27/27	0.8-12	32/32	0.8-7	25/27
Property 8	<5-<14	1/63	0.4-3	59/63	<0.7-21	62/63	0.8-4	56/63

[a] For concentration ranges where the lower and upper limit are preceded by a less than symbol (<), this denotes that none of the samples was positively identified to contain the radionuclide at a certain level, although these samples are definitely identified as not containing the radionuclide at over the absolute value reported following the less than symbol. Detection frequency indicates the total number of samples and, of these, the number of samples in which levels were measured over the minimum detectable activity (MDA) of the specific radionuclide. The method MDA for radium-228, thorium-230, and thorium-232 is 0.5 pCi/g; the method MDA for uranium-238 is 5 pCi/g; however, the MDA varies somewhat from sample to sample because of factors such as inherent radioactivity and background noise. A hyphen indicates not measured.

[b] Eva Avenue and Frost Avenue have not been characterized; however, they have been designated as haul roads because, during a previous characterization study of the vicinity properties adjacent to them, samples from these roads were radioactively contaminated.

[c] NA indicates no data available for property 1 or property 18.

[d] This property is also property no. 38.

[e] Data are from the 1986 and 1987 characterizations of Coldwater Creek sediments (BNI 1990c); 240 samples were collected in 1986 and 15 samples in 1987.

[f] Source: BNI (1990c, Table 6-3).

[g] Source: BNI (1990c, Tables 6-5, 6-7, 6-9, 6-11, 6-13, 6-15, 6-17, 6-19, 6-21, and 6-23).

Sources: BNI (1990c, 1990d); DOE (1994).

TABLE 2.4 Radionuclide Concentrations in Composite Samples from the HISS Pile[a]

	Radionuclide Concentration (pCi/g)		
Radionuclide	Composite 1	Composite 2	Composite Average
Actinium-227	205 ± 2	Not analyzed	205 ± 2
Protactinium-231	114 ± 2	117 ± 8	116 ± 4
Radium-226	64 ± 1	50 ± 1	57 ± 1
Radium-228	2.3 ± 0.6	1.5 ± 0.5	1.9 ± 0.4
Thorium-228	2.1 ± 0.5	2.0 ± 0.5	2.1 ± 0.3
Thorium-230	8,770 ± 100	8,950 ± 370	8,860 ± 190
Thorium-232[b]	2.3 ± 0.6	1.5 ± 0.5	1.9 ± 0.4
Uranium-235	3.6 ± 0.3[c]	4.4 ± 0.3	4.0 ± 0.2
Uranium-238	82 ± 8	62 ± 15	72 ± 9

[a] Samples collected from the HISS pile in 1981.

[b] Based on radium-228 and assumption of secular equilibrium of the thorium decay series nuclides.

[c] Errors are 2σ from counting statistics only.

Source: Oak Ridge Associated Universities (1981).

TABLE 2.5 Concentrations of Radionuclides in Groundwater at SLDS, SLAPS, and HISS

	Radionuclide Concentration[a] (pCi/L)		
Site	Total Uranium	Radium-226	Thorium-230
SLDS	<3-190	0.3-3.2	<0.1-3.7
SLAPS	<3-8,700	<0.1-4.0	<0.1-130
HISS	<3-120	<0.07-6.0	<0.1-320

[a] Total number of samples for each radionuclide is 32 at SLDS and 218 at HISS; total number of samples at SLAPS is 328 for total uranium and radium-226 and 327 for thorium-230.

Sources: SLDS — BNI (1990d); SLAPS — BNI (1985b, 1986b, 1987e, 1988b, 1989c, 1990e, 1991b); HISS — BNI (1985a, 1986a, 1987b, 1988a, 1989a, 1990a, 1991a).

TABLE 2.6 Radiological Measurements in Selected SLDS Buildings[a]

Building	Radon Concentration (pCi/L)	Gamma Exposure Rate[b] (μR/h)	Direct Beta-Gamma Measurement[c] (dpm/100 cm^2)
K1E	1.7-73	18-200	130-35,000
25	<0.04-0.3	6-72	29-150,000
50	<0.04-0.1	6-10	500-9,000
51	0.1-0.3	6-32	43-270,000
51A	0.8-1.1	6-18	170-49,000
52	<0.04-<0.04	8-34	170-99,000
52A	0.5-0.6	17-30	1,400-250,000
100	0.2-0.4	6-7	530-30,000
101	0.5-48	6-48	-[d]
116	<0.04-0.5	5-10	43-140,000
116B	-[d]	6-20	390-4,900
117	0.1-1.0	5-29	91-21,000
700	<0.04-<0.04	5-13	130-35,000
704	0.2-0.4	6-8	7-15,000
705	<0.04-0.25	3-10	49-220,000
706	<0.04-0.12	4-6	200-7,000
707	<0.04-0.4	4-6	25-7,000
708	<0.04-0.4	5-21	35-5,600
81	0.1-0.3	2-6	100-740
82	0.1-0.5	6-10	51-2,800

[a] Measurements rounded to two significant figures.

[b] Background exposure rate = 10 μR/h.

[c] Reported measurements obtained from walls.

[d] Not measured.

Source: DOE (1994).

TABLE 2.7 Concentrations of Radionuclides in Samples Collected from 50 Manholes at SLDS

Radionuclide	Concentration (pCi/g)	Detection Frequency
Uranium-238	<2-270	15/50
Radium-226	0.8-930	46/50
Thorium-232	0.7-640	38/50
Thorium-230	<0.5-2,600	48/50

TABLE 2.8 Characterization Results for Metals and Mobile Anions in Soil at the St. Louis Site[a]

	SLDS			City Property		
Contaminant	Range (mg/kg)	Mean (mg/kg)	Detection Frequency	Range (mg/kg)	Mean (mg/kg)	Detection Frequency
Metals						
Aluminum[b]	<37-66,000	7,400	165/166	2,600-7,300	4,900	18/18
Antimony	<9.3-3,200	15	43/166	<11-380	98	15/18
Arsenic	<16-200	30	82/166	<18-32	22	1/18
Barium	<31-7,700	200	162/166	100-1,500	220	18/18
Beryllium	0.78-10	1.2	49/163	<0.69-1.8	1.2	5/18
Boron	<16-250	35	95/163	18-230	53	17/18
Cadmium	<0.60-44	1.5	66/163	<1.0-18	1.8	13/18
Calcium	1,100-200,000	17,000	166/166	13,000-140,000	29,000	18/18
Chromium	<1.8-520	17	163/166	7.4-4,400	17	18/18
Cobalt	<7.8-230	12	24/163	<6.9-16	11	2/16
Copper	6.4-620	44	166/166	13-1,100	82	18/16
Iron[b]	1,000-140,000	28,000	166/166	6,400-420,000	40,000	18/18
Lead	<17-32,000	120	147/166	23-8,300	250	18/16
Lithium	-	-	-	-	-	-
Magnesium	<760-44,000	2,900	147/168	<690-22,000	2,600	15/18
Manganese	25-5,200	400	166/168	150-3,600	360	18/18
Mercury	<0.12-38	1.3	56/58	-	-	-
Molybdenum	<2.3-200	22	4/166	<16-<32	22	0/18
Nickel	<7.4-230	22	162/166	10-50	18	17/18
Potassium[b]	<760-18,000	1,500	66/166	<890-1,600	1,200	4/18
Selenium	<16-1,300	46	84/166	<18-200	31	3/18
Silver	<1.6-160	3.4	71/166	<1.8-3.2	2.2	1/18
Sodium[b]	<760-10,000	1,200	30/166	<690-1,800	1,200	4/18
Strontium	-	-	-	-	-	-
Thallium	<16-320	32	92/166	<20-64	29	9/16
Tin	-	-	-	-	-	-
Uranium[c]	4.0-96,000	36	103/332	1.5-59,000	35	31/210
Vanadium	10-260	29	163/156	13-43	25	18/16
Zinc	24-6,700	170	166/156	62-11,000	340	18/18
Inorganic anions						
Fluoride	-	-	-	-	-	-
Nitrate	-	-	-	-	-	-
Sulfate	-	-	-	-	-	-

TABLE [illegible] (Cont.)

	SLAPS and SLAPS Ditches[d]			Ballfield		
Contaminant	Range (mg/kg)	Mean (mg/kg)	Detection Frequency	Range (mg/kg)	Mean (mg/kg)	Detection Frequency
Metals						
Aluminum[b]	1,700-23,000	6,600	122/122	5,000-15,000	9,800	31/31
Antimony	<1.0-2,300	8.1	2/122	<11-200	15	2/31
Arsenic	1.4-240	15	38/122	<18-670	26	2/31
Barium	58-14,000	230	122/122	91-810	170	31/31
Beryllium	<0.10-190	0.94	20/122	<0.88-18	1.3	3/31
Boron	<18-100	32	81/122	<22-760	36	28/31
Cadmium	<0.40-50	1.4	47/122	<0.88-18	1.3	4/31
Calcium	1,400-180,000	10,000	122/122	1,500-18,000	4,800	31/31
Chromium	3.1-3,200	12	122/122	8.0-80	16	31/31
Cobalt	3.8-6,000	21	75/122	<8.8-180	13	3/31
Copper	7.7-4,400	26	122/122	<5.2-95	13	26/31
Iron[b]	3,600-34,000	12,000	122/122	8,400-22,000	15,000	31/31
Lead	<1.0-1,200	22	75/122	<13-190	28	19/31
Lithium	<20-<50	32	0/15	-	-	-
Magnesium	<1,000-27,000	4,000	120/122	1,200-8,700	3,200	31/31
Manganese	71-3,300	520	122/122	230-1,100	560	31/31
Mercury	0.010-0.047	0.024	2/33	-	-	-
Molybdenum	<0.50-260	11	24/122	<18-750	25	2/31
Nickel	<7.7-7,600	33	114/122	<8.9-190	17	28/31
Potassium[b]	<20-17,000	520	29/104	<880-3,100	1,200	4/31
Selenium	<0.30-180	8.6	9/122	<18-700	26	3/31
Silver	<0.20-4.0	1.3	2/122	<1.8-14	2.3	1/31
Sodium[b]	<100-2,000	960	8/104	<880-2,700	1,200	2/31
Strontium	12-380	22	33/33	-	-	-
Thallium	<1.0-40	14	4/122	<18-730	26	3/31
Tin	<0.60-4,400	3.7	2/33	-	-	-
Uranium[c]	3.0-4,700	50	55/194	8.9-120	20	14/384
Vanadium	11-860	47	122/122	16-200	31	31/31
Zinc	21-4,300	53	122/122	20-200	43	31/31
Inorganic anions						
Fluoride	1.0-63	5.4	80/81	0.47-5.7	1.8	27/29
Nitrate	0.30-1,100	7.4	73/79	0.47-8.0	0.8	15/29
Sulfate	44-860	110	68/80	27-860	110	27/29

TABLE 2.8 (Cont.)

	Futura Coatings			HISS			Average Background Concentration in Missouri Soil[a] (mg/kg)
Contaminant	Range (mg/kg)	Mean (mg/kg)	Detection Frequency	Range (mg/kg)	Mean (mg/kg)	Detection Frequency	
Metals							
Aluminum[b]	1,800-15,000	7,100	16/16	3,100-8,300	5,700	11/11	41,000
Antimony	<11-<18	13	0/16	<11-240	18	1/11	0.52
Arsenic	<18-320	26	1/16	<18-1,000	35	2/11	8.7
Barium	100-3,500	280	16/16	83-4,400	360	11/11	580
Beryllium	<0.33-22	1.3	2/16	0.95-27	1.7	3/11	0.80
Boron	<23-180	48	13/16	22-1,000	42	10/11	31
Cadmium	<0.90-16	1.4	4/16	<1.1-27	1.7	5/11	<1.0
Calcium	1,300-140,000	13,000	16/16	2,000-34,000	7,200	11/11	3,300
Chromium	4.5-92	14	16/16	4.5-110	12	11/11	54
Cobalt	9.9-14,000	45	10/16	<11-1,500	47	6/11	10
Copper	6.2-9,100	55	16/16	8.5-950	44	11/11	13
Iron[b]	4,700-23,000	14,000	16/16	7,800-17,000	12,000	11/11	21,000
Lead	<22-530	44	12/16	<21-460	46	6/11	20
Lithium	-	-	-	-	-	-	22
Magnesium	<1,200-43,000	6,400	15/16	1,400-8,200	3,800	11/11	2,600
Manganese	76-2,000	460	16/16	300-970	670	11/11	740
Mercury	-	-	-	-	-	-	0.039
Molybdenum	<18-950	30	6/16	19-1,100	36	4/11	<3.0
Nickel	<9.6-17,000	69	15/16	9.3-1,800	58	11/11	14
Potassium[b]	<900-<1,500	1,100	0/16	<900-2,200	1,300	2/11	14,000
Selenium	<18-1,000	28	1/16	<18-1,000	34	2/11	0.28
Silver	<1.8-<3.0	2.2	0/16	<1.8-18	2.8	1/11	<0.70
Sodium[b]	<900-<1,500	1,100	0/16	<900-2,700	1,400	2/11	5,300
Strontium	-	-	-	-	-	-	110
Thallium	<18-<30	22	0/16	<18-960	35	2/11	<0.10
Tin	-	-	-	-	-	-	<15
Uranium[c]	8.9-7,400	41	8/41	8.9-2,400	51	25/35	3.8
Vanadium	13-2,200	40	16/16	13-710	44	11/11	69
Zinc	17-360	54	16/16	23-310	50	11/11	49
Inorganic anions							
Fluoride	1.9-21	4.6	12/12	0.50-17	2.8	10/11	270
Nitrate	0.50-370	6.6	8/12	0.49-1,000	140	10/11	NA
Sulfate	72-440	160	12/12	50-820	140	8/11	NA

See next page for footnotes

BLE 2.8 (Cont.)

---

[a] All values are rounded to two significant figures. Except as noted, averages are geometric means to facilitate comparison with Missouri background levels. All values, including those reported as the sample detection limit, were used to calculate the site means. A hyphen indicates that the contaminant was not measured at that property; NA indicates that data were not available. Site data sources: metals — BNI (1987c, 1989b, 1990a, 1990d); uranium — BNI (1987a, 1987c, 1987d, 1990c, 1990d).

[b] Background and site levels are arithmetic means.

[c] Mean uranium values were obtained from radiological analyses of the upper 1 ft of soil; maximum values reported are sitewide for all depths.

[d] Includes data from the 1987 radiological and limited chemical characterization report (BNI 1987c).

[e] Sources: Tidball (1984), except for antimony (Shacklette and Boerngen 1984) and thallium (Bowen 1966); Tidball data based on 1,140 soil samples (10 each from 114 counties) obtained from the upper 15 cm (6 in.) in agricultural fields (a less than symbol [<] indicates that the metal was not present at the level of the method detection limit).

TABLE 2.9 Characterization Results for Organic Compounds in Soil at the St. Louis Site[a]

Property/ Contaminant	Range (μg/kg)	Detection Frequency
SLDS		
Volatile organic compounds		
Benzene	2.2-16	3/40
Carbon tetrachloride	4.9	1/40
Chlorobenzene	4.5	1/40
Chloroform	1-62	12/40
1,1-Dichloroethane	2.2-5.5	3/40
trans-1,2-Dichloroethene	6.4	1/40
Ethyl benzene	1-3.6	4/40
Methylene chloride	4.1-77	11/40
Toluene	1.2-340	31/40
1,1,1-Trichloroethane	1.4-47	4/40
Trichloroethene	1.4-430	8/40
Trichlorofluoromethane	1.8-70	12/40
Total xylenes	1.5-66	10/40
Semivolatile organic compounds		
Acenaphthene	400-7,400	19/56
Acenaphthylene	450-4,200	9/56
Anthracene	420-84,000	34/56
Benz(a)anthracene	400-34,000	48/56
Benzo(b)fluoranthene	510-78,000	40/56
Benzo(k)fluoranthene	540-94,000	31/56
Benzo(g,h,i)perylene	540-6,400	18/56
Benzo(a)pyrene	400-110,000	40/56
Benzyl alcohol	7,000	1/56
Bis(2-ethylhexyl)phthalate	310-1,600	11/56
4-Chloro-3-methylphenol	880	1/56
2-Chlorophenol	660	1/56
Chrysene	430-110,000	47/56
Dibenz(a,h)anthracene	440-3,900	6/56
Dibenzofuran	400-11,000	17/56
Di-n-butylphthalate	410-760	2/56
2,4-Dimethylphenol	2,600-5,500	2/56
Fluoranthene	410-300,000	50/56
Fluorene	500-15,000	16/56
Hexachlorobutadiene	1,900	1/56
Indeno(1,2,3-cd)pyrene	430-12,000	25/56
2-Methylnaphthalene	410-8,600	10/56
4-Methylphenol	3,200	1/56
Naphthalene	460-32,000	12/56
Phenanthrene	520-280,000	49/56
Phenol	5,700	1/56
Pyrene	500-63,000	52/56

TABLE 2.9 (Cont.)

Property/ Contaminant	Range (µg/kg)	Detection Frequency
SLAPS		
Volatile organic compounds		
trans-1,2-Dichloroethene	1.3-7.7	5/90
Toluene	1.5-1,200	26/90
Trichloroethene	1.6-15	6/90
SLAPS Vicinity Property (Ballfield)		
Volatile organic compounds		
Toluene	1.3-48	14/29
1,1,1-Trichloroethane	1.3-1.7	6/29
Pesticide		
Dieldrin	230	1/11
Futura Coatings Property		
Volatile organic compounds		
Toluene	1.5-15	4/16
Trichlorofluoromethane	1.3	1/16
Semivolatile organic compound		
2-Propanol-1,3-dichlorophosphate[b]	250,000	1/1
HISS		
Volatile organic compound		
Toluene	2.9	1/12

[a] All values are rounded to two significant figures. Only detected values are included in the ranges given.

[b] Qualitative and quantitative identification of this compound is tentative.

Sources: BNI (1989b, 1990a, 1990d).

TABLE 2.10 Chemical Characterization Results for Coldwater Creek Sediment[a]

Contaminant	Concentration		Detection Frequency	Average Background Concentration in Missouri Soil[b] (mg/kg)
	Range	Mean		
Metals[c] (mg/kg)				
Aluminum[d]	3,000-6,400	4,300	4/4	41,000
Antimony	7.8-10	9.0	0/4	0.52
Arsenic	20-25	22	0/4	8.7
Barium	64-180	110	4/4	580
Beryllium	0.98-1.3	1.1	0/4	0.80
Boron	20-25	22	0/4	31
Cadmium	0.98-1.3	1.1	1/4	<1.0
Calcium	5,500-100,000	26,000	4/4	3,300
Chromium	8.3-25	15	4/4	54
Cobalt	9.8-13	11	0/4	10
Copper	13-57	25	4/4	13
Iron[d]	6,100-12,000	9,200	4/4	21,000
Lead	20-99	46	3/4	20
Magnesium	2,800-12,000	6,100	4/4	2,600
Manganese	260-880	540	4/4	740
Molybdenum	20-26	23	0/4	<3.0
Nickel	11-18	16	4/4	14
Potassium[d]	980-1,300	1,100	0/4	14,000
Selenium	25-84	49	4/4	0.28
Silver	2.0-2.6	2.3	1/4	<0.70
Sodium[d]	980-1,300	1,100	0/4	5,300
Thallium	20-23	22	0/4	<0.10
Uranium[e]	0.59-27	2.7	240/255	3.8
Vanadium	15-23	18	4/4	69
Zinc	39-1,400	140	4/4	49
Inorganic anions[c] (mg/kg)				
Fluoride	1.5-5.3	3.1	4/4	270
Nitrate	0.55-0.67	0.58	2/4	NA[f]
Sulfate	110-150	130	3/4	NA
Volatile organic compounds[g] (µg/kg)				
Acetone	34-37	-	3/4	-
Acrylonitrile[h]	2	-	1/4	-
2-Butanone[h]	8	-	1/4	-
Chloroethane[h]	2	-	1/4	-
Methylene chloride[i]	30-45	-	4/4	-
Toluene[h]	1	-	1/4	-
Semivolatile organic compounds[g] (µg/kg)				
Acenaphthene	870-890	-	2/4	-
Anthracene	190-3,200	-	2/4	-
Benz(a)anthracene	120-6,000	-	3/4	-
Benzo(b)fluoranthene	88-5,100	-	2/4	-
Benzo(k)fluoranthene	110-4,900	-	2/4	-
Benzo(g,h,i)perylene	93-4,000	-	2/4	-
Benzo(a)pyrene	100-5,400	-	2/4	-

TABLE 2.10 (Cont.)

Contaminant	Concentration Range	Concentration Mean	Detection Frequency	Average Background Concentration in Missouri Soil[b] (mg/kg)
Semivolatile organic compounds[g] (µg/kg) (Cont.)				
Bis(2-ethylhexyl)phthalate[i]	130-1,700	-	4/4	-
Chrysene	1,700-13,000	-	2/4	-
Dibenzofuran[h]	190-760	-	2/4	-
Di-n-butylphthalate[h]	43	-	1/4	-
Fluoranthene[i]	140-24,000	-	4/4	-
Fluorene	1,300-1,600	-	2/4	-
2-Methylnaphthalene[h]	50	-	1/4	-
Naphthalene[h]	110	-	1/4	-
Phenanthrene[i]	62-14,000	-	4/4	-
Phenol[h]	970	-	1/4	-
Pyrene[i]	76-9,500	-	4/4	-

[a] All values are rounded to two significant figures.

[b] Sources: Tidball (1984), except antimony (Shacklette and Boerngen 1984) and thallium (Bowen 1966).

[c] Except as noted, averages are geometric means to facilitate comparison with Missouri background levels. For metals and inorganic anions, all values (including those reported as the sample detection limit) were used to calculate the site mean.

Background and site levels are arithmetic means.

[e] Uranium data from BNI (1990c).

[f] NA indicates that data were not available.

[g] For organic compounds, only detected values are included in the ranges given. Means are not given for organic compounds because comparison with background means is inappropriate (i.e., background level is assumed to be zero).

[h] All detected values for this compound are estimated values that are below the contract-required detection limit.

[i] This compound was also detected in associated blank samples.

Sources: BNI (1991c); DOE (1993) — except as noted.

TABLE 2.11 Summary of Chemical Data for Groundwater at the St. Louis Site: Inorganics[a]

Contaminant	SLDS Concentration Range (µg/L)	SLDS Detection Frequency	SLAPS Concentration Range (µg/L)	SLAPS Detection Frequency	HISS Concentration Range (µg/L)	HISS Detection Frequency
Metals						
Aluminum	<200-400	12/32	<30-2,300	51/64	<30-1,600	59/60
Antimony	<40-<60	0/32	<40-89	6/64	<40-150	15/60
Arsenic	<100-130	2/32	<16-<100	0/64	<16-<100	0/60
Barium	<200-540	8/32	66-720	45/64	60-2,300	51/60
Beryllium	<5.0	0/32	<5-5	2/64	<5.0-5.0	1/60
Boron	<100-1,800	31/32	33-500	56/64	22-340	46/60
Cadmium	<5.0-11	2/32	<4-23	10/64	<4.0-47	11/60
Calcium[b]	26-290	32/32	66-1,500	64/64	54-2,100	60/60
Chromium	<10-50	1/32	<10-380	2/64	<10-120	7/60
Cobalt	<50	0/32	<20-<50	0/64	<20-130	4/60
Copper	<25-37	4/32	<20-160	44/64	<20-130	49/60
Iron	<100-21,000	24/32	<30-2,400	33/64	<30-7,800	38/60
Lead	<100	0/32	<100	0/64	<100	0/60
Magnesium[b]	<5-70	31/32	27-410	64/64	16-640	60/60
Manganese	<15-4,500	31/32	<10-6,800	60/64	<10-7,000	52/60
Molybdenum	<100	0/32	<100-170	7/64	<100-140	8/60
Nickel	<40-710	5/32	<20-100	12/64	<20-100	12/60
Potassium[b]	<5-63	29/32	<0.20-33	38/64	0.26-20	29/60
Selenium	<100-110	1/32	<8.0-6,000	25/64	<8-3,600	24/60
Silver	<10	0/32	<10-34	2/64	<10-15	1/60
Sodium[b]	8.6-510	32/32	21-200	64/64	18-360	60/60
Thallium	<100	0/32	<100-110	1/64	<100-180	10/60
Vanadium	<50	0/32	<10-160	9/64	<10-140	7/60
Zinc	<20-300	29/32	<20-7,700	60/64	13-1,400	56/60
Inorganic anions						
Fluoride	150-6,200	7/7	NA[c]	NA	NA	NA
Nitrate	100-210	7/7	NA	NA	NA	NA

[a] Data from 8 wells (SLDS), 16 wells (SLAPS), or 15 wells (HISS) collected quarterly for 12 months; all values are rounded to two significant figures.

[b] The actual concentrations are 1,000 times the values given in the table for these contaminants.

[c] NA indicates not analyzed.

Sources: BNI (1990b, 1990d, 1990e).

TABLE 2.12 Summary of Chemical Data for Groundwater at the St. Louis Site: Organic Compounds

	Concentration Range[a] (µg/L)		
Contaminant	SLDS	SLAPS	HISS
Aroclor 1254	<1-1.5	ND	ND
Benzene	<5-21	ND	ND
Bis(2-ethylhexyl)phthalate	<10-1,100	22-430	ND-650
Chlorobenzene	<5-8	ND	ND
1,2-Dichlorobenzene	<10-93	ND	ND
1,2-Dichloroethene	<5-150	77-95	ND
1,2-Dichloropropane	<5-130	ND	ND
4,4'-DDT	<0.10-0.98	ND	ND
Endosulfan	ND	0.060-0.090	ND
Toluene	ND	11-170	ND
Trichloroethene	<5-5	110-130	ND
Vinyl chloride	<10-29	ND	ND

[a] ND indicates not detected.

Sources: DOE (1993).

TABLE 2.13 Chemicals in Groundwater at the St. Louis Site that Exceed Regulatory Standards

Chemical	Maximum Contaminant Level[a] (µg/L)	Maximum Site Level (µg/L)
Metals		
Arsenic	50	130
Barium	1,000	2,300
Cadmium	10	47
Chromium	50	380
Iron	3,000[b]	21,000
Lead	50	<100
Manganese	50[b]	7,000
Selenium	10	6,000
Silver	50	64
Zinc	5,000[b]	7,700
Inorganic anions		
Fluoride	4,000	6,200
Organic compounds		
Benzene	5	21
Trichloroethene	5	130
Vinyl chloride	2	29

[a] Sources: 40 CFR 141.11, 40 CFR 141.61a, 40 CFR 143.3.

[b] Secondary maximum contaminant level.

TABLE 2.14 Groupings of Radionuclides

Parent Radionuclide	Associated Decay Products
Actinium-227+D	Thorium-227, radium-223, radon-219, polonium-215, lead-211, bismuth-211, thallium-207
Lead-210+D	Bismuth-210, polonium-210
Protactinium-231	-
Radium-226+D	Radon-222, polonium-218, lead-214, bismuth-214, polonium-214
Radium-228+D	Actinium-228
Thorium-228+D	Radium-224, radon-220, polonium-216, lead-212, bismuth-212, polonium-212, thallium-208
Thorium-230	-
Thorium-232	-
Uranium-234	-
Uranium-235+D	Thorium-231
Uranium-238+D	Thorium-234, protactinium-234

LE 2.10 Derived Concentrations from the Source rm Analysis[a]

Radionuclide Group[b]	SLDS Sitewide[c]	City Property[d]	SLAPS[e]	Residential Vicinity Properties[f]	HISS/Futura[g]
	Basis of Calculated Radionuclide Concentrations				
Actinium-227+D	0.39 *Radium-226+D*	0.95 *Radium-226+D*	0.92 *Radium-226+D*	0.007 *Thorium-230*	1.1 *Radium-226+D*
Lead-210+D	1.3 *Radium-226+D*	1.8 *Radium-226+D*	1.7 *Radium-226+D*	0.014 *Thorium-230*	2.4 *Radium-226+D*
Protactinium-231	0.36 *Radium-226+D*	0.95 *Radium-226+D*	1.0 *Radium-226+D*	0.008 *Thorium-230*	1.3 *Radium-226+D*
Radium-226+D	1.0 *Radium-226+D*	1.0 *Radium-226+D*	1.0 *Radium-226+D*	0.007 *Thorium-230*	1.0 *Radium-226+D*
Radium-228+D	0.81 *Thorium-232*	0.39 *Thorium-232*	0.28 *Thorium-232*	0.00036 *Thorium-230*	0.08 *Thorium-232*
Thorium-228+D	1.0 *Thorium-232*	0.94 *Thorium-232*	0.85 *Thorium-232*	0.001 *Thorium-230*	1.0 *Thorium-232*
Thorium-230	1.0 *Thorium-230*	1.0 *Thorium-230*	1.0 *Thorium-230*	1.0 *Thorium-230*	1.0 *Thorium-230*
Thorium-232	1.0 *Thorium-232*	1.0 *Thorium-232*	1.0 *Thorium-232*	0.001 *Thorium-230*	1.0 *Thorium-232*
Uranium-234	1.0 *Uranium-238+D*	1.0 *Uranium-238+D*	1.0 *Uranium-238+D*	0.012 *Thorium-230*	1.0 *Uranium-238+D*
Uranium-235+D	0.046 *Uranium-238+D*	0.046 *Uranium-238+D*	0.046 *Uranium-238+D*	0.00052 *Thorium-230*	0.046 *Uranium-238+D*
Uranium-238+D	1.0 *Uranium-238+D*	1.0 *Uranium-238+D*	1.0 *Uranium-238+D*	0.012 *Thorium-230*	1.0 *Uranium-238+D*

[a] Concentrations are based on ratios obtained from the results of the source term analysis (Liedle 1990). The results of the source term analysis confirmed that uranium-238, -234, and -235 are present in their natural activity concentration ratio of 1:1:0.046. A ratio of the actual concentrations of uranium-238 and uranium-235 series radionuclides relative to the concentration of radium-226 in the source term analysis was determined and applied to site radium-226 data to derive concentrations of the remaining radionuclides not measured in the database. The thorium-232 series ratios are relative to the concentration of thorium-232.

[b] These groupings are used by the RESRAD code and are based on immediate decay products of the parent radionuclide (all decay products between the parent and first decay product to have a half-life greater than 1 year).

[c] Calculated by averaging the source term results obtained from Plants 1, 2, 5, 6, 7, 7E, and 10.

[d] Based on the source term ratios calculated from one composite sample obtained at Plant 7E.

[e] Calculated by averaging source term results from five composite samples. These ratios were applied for calculating exposures at SLAPS and the ballfield.

[f] Based on the source term ratios obtained for SLAPS. For the residential properties where only thorium-230 levels were characterized, uranium-238, uranium-235, and thorium-232 series are relative to the concentration of thorium-230.

[g] Based on the source term results from one composite sample. These ratios were applied for calculating exposures at HISS/Futura and Coldwater Creek.

TABLE 2.16 Concentration-Toxicity Screening Procedure for St. Louis Site Soil and Sediment: Oral Reference Doses

Contaminant	Maximum Concentration	Oral Reference Dose mg/kg-d	Oral Reference Dose Source[a]	Risk Factor	Contaminant of Concern
SLDS					
Metals (mg/kg)					
Antimony	3,200	4.0×10^{-4}	IRIS	8.0×10^{6}	Yes
Arsenic (inorganic)	200	3.0×10^{-4}	IRIS	6.7×10^{5}	Yes
Beryllium	10	5.0×10^{-3}	IRIS	2.0×10^{3}	No
Boron	250	9.0×10^{-2}	IRIS	2.8×10^{3}	No
Cadmium	44	1.0×10^{-3}	IRIS	4.4×10^{4}	No
Cobalt	230	-	-	-	-
Copper[b]	620	3.7×10^{-2}	HEAST	1.7×10^{4}	No
Lead	32,000	-	-	-	-
Mercury	38	3.0×10^{-4}	HEAST	1.3×10^{5}	No
Molybdenum	200	4.0×10^{-3}	HEAST	5.0×10^{4}	No
Nickel (soluble salts)	230	2.0×10^{-2}	IRIS	1.2×10^{4}	No
Selenium	1,300	5.0×10^{-3}	IRIS	2.6×10^{5}	No
Silver	160	5.0×10^{-3}	IRIS	3.2×10^{4}	No
Thallium (soluble salts)	320	7.0×10^{-5}	HEAST	4.6×10^{6}	Yes
Uranium (soluble salts)	98,000	3.0×10^{-3}	IRIS	3.3×10^{7}	Yes
Zinc	6,700	2.0×10^{-1}	HEAST	3.4×10^{4}	No
Volatile organic compounds (μg/kg)					
Benzene	16	-	-	-	-
Carbon tetrachloride	4.9	7.0×10^{-4}	IRIS	7.0	No
Chlorobenzene[c]	4.5	5.0×10^{-3}	HEAST	9.0×10^{-1}	No
Chloroform	62	1.0×10^{-2}	IRIS	6.2	No
1,1-Dichloroethane	5.5	1.0×10^{-1}	HEAST	5.5×10^{-2}	No
trans-1,2-Dichloroethene	6.4	2.0×10^{-2}	IRIS	3.2×10^{-1}	No
Ethyl benzene	3.6	1.0×10^{-1}	HEAST	3.6×10^{-2}	No
Methylene chloride	77	6.0×10^{-2}	IRIS	1.3	No
Toluene	340	2.0×10^{-1}	IRIS	1.7	No
1,1,1-Trichloroethane	47	9.0×10^{-2}	IRIS	5.2×10^{-1}	No
Trichloroethene	430	-	-	-	-
Trichlorofluoromethane[c]	70	2.0×10^{-1}	IRIS	3.5×10^{-1}	No
Total xylenes[c]	66	9.0×10^{-2}	HEAST	7.3×10^{-1}	No
Semivolatile organic compounds (μg/kg)					
Acenaphthene	7,400	6.0×10^{-2}	IRIS	1.2×10^{2}	No
Acenaphthylene[d]	4,200	4.0×10^{-3}	-	1.1×10^{3}	No
Anthracene	84,000	3.0×10^{-1}	HEAST	2.8×10^{2}	No
Benz(a)anthracene	34,000	-	-	-	-
Benzo(b)fluoranthene	78,000	-	-	-	-
Benzo(k)fluoranthene	94,000	-	-	-	-
Benzo(g,h,i)perylene[d]	6,400	4.0×10^{-3}	-	1.6×10^{3}	No
Benzo(a)pyrene	110,000	-	-	-	-
Benzyl alcohol	7,000	3.0×10^{-1}	HEAST	2.3×10^{1}	No
Bis(2-ethylhexyl)phthalate	1,600	2.0×10^{-2}	IRIS	8.0×10^{1}	No
4-Chloro-3-methylphenol	880	-	-	-	-
2-Chlorophenol	660	5.0×10^{-3}	IRIS	1.3×10^{2}	No
Chrysene	110,000	-	-	-	-
Dibenz(a,h)anthracene	3,900	-	-	-	-
Dibenzofuran	11,000	-	-	-	-
Di-n-butylphthalate	760	1.0×10^{-1}	IRIS	7.6	No
2,4-Dimethylphenol	5,500	2.0×10^{-2}	IRIS	2.8×10^{2}	No
Fluoranthene	300,000	4.0×10^{-2}	IRIS	7.5×10^{3}	No
Fluorene	15,000	4.0×10^{-2}	IRIS	3.8×10^{2}	No

TABLE 2.16 (Cont.)

Contaminant	Maximum Concentration	Oral Reference Dose mg/kg-d	Oral Reference Dose Source[a]	Risk Factor	Contaminant of Concern
SLDS (Cont.)					
Semivolatile organic compounds (µg/kg) (cont.)					
Hexachlorobutadiene	1,900	2.0×10^{-3}	IRIS	9.5×10^{2}	No
Indeno(1,2,3-cd)pyrene	12,000	-	-	-	-
2-Methylnaphthalene[d]	8,600	4.0×10^{-3}	-	2.2×10^{3}	No
4-Methylphenol (p-Cresol)	3,200	5.0×10^{-2}	HEAST	6.4×10^{1}	No
Naphthalene	32,000	4.0×10^{-3}	HEAST	8.0×10^{3}	No
Phenanthrene[d]	280,000	4.0×10^{-3}	-	7.0×10^{4}	No
Phenol	5,700	6.0×10^{-1}	IRIS	9.5	No
Pyrene	63,000	3.0×10^{-2}	IRIS	2.1×10^{3}	No
Total				4.7×10^{7}	
City Property[e]					
Metals (mg/kg)					
Antimony	380	4.0×10^{-4}	IRIS	9.5×10^{5}	Yes
Arsenic (inorganic)	32	3.0×10^{-4}	IRIS	1.1×10^{5}	No
Beryllium	1.8	5.0×10^{-3}	IRIS	3.6×10^{2}	No
Boron	230	9.0×10^{-2}	IRIS	2.6×10^{3}	No
Cadmium	18	1.0×10^{-3}	IRIS	1.8×10^{4}	No
Cobalt	16	-	-	-	-
Copper[b]	1,100	3.7×10^{-2}	HEAST	3.0×10^{4}	No
Lead	8,300	-	-	-	-
Molybdenum	32	4.0×10^{-3}	HEAST	8.0×10^{3}	No
Nickel (soluble salts)	50	2.0×10^{-2}	IRIS	2.5×10^{3}	No
Selenium	200	5.0×10^{-3}	IRIS	4.0×10^{4}	No
Silver	3.2	5.0×10^{-3}	IRIS	6.4×10^{2}	No
Thallium (soluble salts)	64	7.0×10^{-5}	HEAST	9.1×10^{5}	Yes
Uranium (soluble salts)	59,000	3.0×10^{-3}	IRIS	2.0×10^{7}	Yes
Zinc	11,000	2.0×10^{-1}	HEAST	5.5×10^{4}	No
Total				2.2×10^{7}	
SLAPS and SLAPS Ditches					
Metals (mg/kg)					
Antimony	2,300	4.0×10^{-4}	IRIS	5.8×10^{6}	Yes
Arsenic (inorganic)	240	3.0×10^{-4}	IRIS	8.0×10^{5}	Yes
Beryllium	190	5.0×10^{-3}	IRIS	3.8×10^{4}	No
Boron	100	9.0×10^{-2}	IRIS	1.1×10^{3}	No
Cadmium	50	1.0×10^{-3}	IRIS	5.0×10^{4}	No
Cobalt	6,000	-	-	-	-
Copper	4,400	3.7×10^{-2}	HEAST	1.2×10^{5}	Yes
Lead	1,200	-	-	-	-
Mercury	0.047	3.0×10^{-4}	HEAST	1.6×10^{2}	No
Molybdenum	260	4.0×10^{-3}	HEAST	6.5×10^{4}	No
Nickel (soluble salts)	7,600	2.0×10^{-2}	IRIS	3.8×10^{5}	Yes
Selenium	180	5.0×10^{-3}	IRIS	3.6×10^{4}	No
Silver	4.0	5.0×10^{-3}	IRIS	8.0×10^{2}	No
Thallium (soluble salts)	40	7.0×10^{-5}	HEAST	5.7×10^{5}	Yes
Tin	4,400	6.0×10^{-1}	IRIS	7.3×10^{3}	No
Uranium (soluble salts)	4,700	3.0×10^{-3}	IRIS	1.6×10^{6}	Yes
Zinc	4,300	2.0×10^{-1}	HEAST	2.2×10^{4}	No

TABLE 2.16 (Cont.)

Contaminant	Maximum Concentration	Oral Reference Dose		Risk Factor	Contaminant of Concern
		mg/kg-d	Source[a]		
SLAPS and SLAPS Ditches (Cont.)					
Inorganic anions (mg/kg)					
Nitrate	1,100	1.6	IRIS	6.9×10^{2}	No
Volatile organic compounds (μg/kg)					
trans-1,2-Dichloroethene	7.7	2.0×10^{-2}	IRIS	3.9×10^{-1}	No
Toluene	1,200	2.0×10^{-1}	IRIS	6.0	No
Trichloroethene	15	-	-	-	-
Total				9.4×10^{6}	
Ballfield					
Metals (mg/kg)					
Antimony	200	4.0×10^{-4}	IRIS	5.0×10^{5}	Yes
Arsenic (inorganic)	670	3.0×10^{-4}	IRIS	2.2×10^{6}	Yes
Beryllium	18	5.0×10^{-3}	IRIS	3.6×10^{3}	No
Boron	760	9.0×10^{-2}	IRIS	8.4×10^{3}	No
Cadmium	18	1.0×10^{-3}	IRIS	1.8×10^{4}	No
Cobalt	180	-	-	-	-
Copper	95	3.7×10^{-2}	HEAST	2.6×10^{3}	No
Lead	190	-	-	-	-
Molybdenum	750	4.0×10^{-3}	HEAST	1.9×10^{5}	Yes
Nickel (soluble salts)	190	2.0×10^{-2}	IRIS	9.5×10^{3}	No
Selenium	700	5.0×10^{-3}	IRIS	1.4×10^{5}	Yes
Silver	14	5.0×10^{-3}	IRIS	2.8×10^{3}	No
Thallium (soluble salts)	730	7.0×10^{-5}	HEAST	1.0×10^{7}	Yes
Uranium (soluble salts)	120	3.0×10^{-3}	IRIS	4.0×10^{4}	No
Inorganic anions (mg/kg)					
Nitrate	8	1.6	IRIS	5.0	No
Volatile organic compounds (μg/kg)					
Toluene	48	2.0×10^{-1}	IRIS	2.4×10^{-1}	No
1,1,1-Trichloroethane	1.7	9.0×10^{-2}	IRIS	1.9×10^{-2}	No
Pesticides (μg/kg)					
Dieldrin	230	5.0×10^{-5}	IRIS	4.6×10^{3}	No
Total				1.4×10^{7}	
Coldwater Creek					
Metals (mg/kg)					
Antimony	10	4.0×10^{-4}	IRIS	2.5×10^{4}	Yes
Arsenic (inorganic)	25	3.0×10^{-4}	IRIS	8.3×10^{4}	Yes
Beryllium	1.3	5.0×10^{-3}	IRIS	2.6×10^{2}	No
Cadmium	1.3	1.0×10^{-3}	IRIS	1.3×10^{3}	No
Cobalt	13	-	-	-	-
Copper	57	3.7×10^{-2}	HEAST	1.5×10^{3}	No
Lead	99	-	-	-	-
Molybdenum	26	4.0×10^{-3}	HEAST	6.5×10^{3}	Yes
Nickel (soluble salts)	18	2.0×10^{-2}	IRIS	9.0×10^{2}	No
Selenium	84	5.0×10^{-3}	IRIS	1.7×10^{4}	Yes
Silver	2.6	5.0×10^{-3}	IRIS	5.2×10^{2}	No

TABLE 2.16 (Cont.)

Contaminant	Maximum Concentration	Oral Reference Dose		Risk Factor	Contaminant of Concern
		mg/kg-d	Source[a]		
Coldwater Creek (Cont.)					
Metals (mg/kg) (cont.)					
Thallium (soluble salts)	23	7.0×10^{-5}	HEAST	3.3×10^{5}	Yes
Zinc	1,400	2.0×10^{-1}	HEAST	7.0×10^{3}	Yes
Inorganic anions (mg/kg)					
Nitrate	0.67	1.6	IRIS	4.2×10^{-1}	No
Volatile organic compounds (µg/kg)					
Acetone	37	1.0×10^{-1}	IRIS	3.7×10^{-1}	No
Acrylonitrile[c]	2	2.0×10^{-3}	IRIS	1.0	No
2-Butanone (Methyl ethyl ketone)	8	5.0×10^{-2}	HEAST	1.6×10^{-1}	No
Chloroethane[f]	2	2.8	IRIS	7.1×10^{-4}	No
Methylene chloride	45	6.0×10^{-2}	IRIS	7.5×10^{-1}	No
Toluene	1	2.0×10^{-1}	IRIS	5.0×10^{-3}	No
Semivolatile organic compounds (µg/kg)					
Acenaphthene	890	6.0×10^{-2}	IRIS	1.5×10^{1}	No
Anthracene	3,200	3.0×10^{-1}	HEAST	1.1×10^{1}	No
Benz(a)anthracene	6,000	-	-	-	-
Benzo(b)fluoranthene	5,100	-	-	-	-
Benzo(k)fluoranthene	4,900	-	-	-	-
Benzo(g,h,i)perylene[d]	4,000	4.0×10^{-3}	-	1.0×10^{3}	No
Benzo(a)pyrene	5,400	-	-	-	-
Bis(2-ethylhexyl)phthalate	1,700	2.0×10^{-2}	IRIS	8.5×10^{1}	No
Chrysene	13,000	-	-	-	-
Dibenzofuran	760	-	-	-	-
Di-n-butylphthalate	43	1.0×10^{-1}	IRIS	4.3×10^{-1}	No
Fluoranthene	24,000	4.0×10^{-2}	IRIS	6.0×10^{2}	No
Fluorene	1,600	4.0×10^{-2}	IRIS	4.0×10^{1}	No
2-Methylnaphthalene[d]	50	4.0×10^{-3}	-	1.3×10^{1}	No
Naphthalene	110	4.0×10^{-3}	HEAST	2.8×10^{1}	No
Phenanthrene[d]	14,000	4.0×10^{-3}	-	3.5×10^{3}	No
Phenol	970	6.0×10^{-1}	IRIS	1.6	No
Pyrene	9,500	3.0×10^{-2}	IRIS	3.2×10^{2}	No
Total				4.8×10^{5}	
Futura Coatings Property					
Metals (mg/kg)					
Antimony	18	4.0×10^{-4}	IRIS	4.5×10^{4}	No
Arsenic (inorganic)	320	3.0×10^{-4}	IRIS	1.1×10^{6}	Yes
Beryllium	22	5.0×10^{-3}	IRIS	4.4×10^{3}	No
Boron	180	9.0×10^{-2}	IRIS	2.0×10^{3}	No
Cadmium	16	1.0×10^{-3}	IRIS	1.6×10^{4}	No
Cobalt	14,000	-	-	-	-
Copper	9,100	3.7×10^{-2}	HEAST	2.5×10^{5}	Yes
Lead	530	-	-	-	-
Molybdenum	950	4.0×10^{-3}	HEAST	2.4×10^{5}	Yes
Nickel (soluble salts)	17,000	2.0×10^{-2}	IRIS	8.5×10^{5}	Yes
Selenium	1,000	5.0×10^{-3}	IRIS	2.0×10^{5}	Yes
Silver	3	5.0×10^{-3}	IRIS	6.0×10^{2}	No
Thallium (soluble salts)	30	7.0×10^{-5}	HEAST	4.3×10^{5}	Yes
Uranium (soluble salts)	7,400	3.0×10^{-3}	IRIS	2.5×10^{6}	Yes
Zinc	360	2.0×10^{-1}	HEAST	1.8×10^{3}	No

TABLE 2.16 (Cont.)

Contaminant	Maximum Concentration	Oral Reference Dose		Risk Factor	Contaminant of Concern
		mg/kg-d	Source[a]		
Futura Coatings Property (Cont.)					
Inorganic anions (mg/kg)					
Nitrate	370	1.6	IRIS	2.3×10^{2}	No
Volatile organic compounds (µg/kg)					
Toluene	15	2.0×10^{-1}	IRIS	7.5×10^{-2}	No
Trichlorofluoromethane	1.3	2.0×10^{-1}	IRIS	6.5×10^{-3}	No
Semivolatile organic compounds (µg/kg)					
2-Propanol-1,3-dichlorophosphate	250,000	-	-	-	-
Total				5.6×10^{6}	
HISS					
Metals (mg/kg)					
Antimony	240	4.0×10^{-4}	IRIS	6.0×10^{5}	Yes
Arsenic (inorganic)	1,000	3.0×10^{-4}	IRIS	3.3×10^{6}	Yes
Beryllium	27	5.0×10^{-3}	IRIS	5.4×10^{3}	No
Boron	1,000	9.0×10^{-2}	IRIS	1.1×10^{4}	No
Cadmium	27	1.0×10^{-3}	IRIS	2.7×10^{4}	No
Cobalt	1,500	-	-	-	-
Copper	950	3.7×10^{-2}	HEAST	2.6×10^{4}	No
Lead	460	-	-	-	-
Molybdenum	1,100	4.0×10^{-3}	HEAST	2.8×10^{5}	Yes
Nickel (soluble salts)	1,800	2.0×10^{-2}	IRIS	9.0×10^{4}	No
Selenium	1,000	5.0×10^{-3}	IRIS	2.0×10^{5}	Yes
Silver	18	5.0×10^{-3}	IRIS	3.6×10^{3}	No
Thallium (soluble salts)	960	7.0×10^{-5}	HEAST	1.4×10^{7}	Yes
Uranium (soluble salts)	2,400	3.0×10^{-3}	IRIS	8.0×10^{5}	Yes
Zinc	310	2.0×10^{-1}	HEAST	1.6×10^{3}	No
Inorganic anions (mg/kg)					
Nitrate	1,000	1.6	IRIS	6.3×10^{2}	No
Volatile organic compounds (µg/kg)					
Toluene	2.9	2.0×10^{-1}	IRIS	1.5×10^{-2}	No
Total				1.9×10^{7}	

[a] IRIS = *Integrated Risk Information System* (EPA 1992); HEAST = *Health Effects Assessment Summary Tables* (EPA 1991a).

[b] Oral RfD for copper was derived from data in HEAST (EPA 1990a).

[c] Inhalation reference concentration (RfC) was used because it was lower than the oral RfD.

[d] Oral RfD for naphthalene of 4.0×10^{-3} mg/kg-d was used for noncarcinogenic PAHs where no oral RfDs were available from IRIS or HEAST.

[e] City property samples were not analyzed for organic compounds; organic compounds identified as contaminants of concern for SLDS were also considered for the city property.

[f] Inhalation RfC was used; no oral RfD available.

Sources: EPA (1991a, 1992).

TABLE 2. oncen Toxicity Screening Procedure for St. Louis Site Soil
and Sedi Oral actors

ninant	Maximum Concentration	Oral Slope Factor (mg/kg-d)$^{-1}$	Oral Slope Factor Source[a]	Risk Factor	Contaminant of Concern
SLDS					
Metals (mg/k					
Antimony	3,200	-	-	-	-
Arsenic	200	1.75	HEAST	3.5×10^{2}	Yes
Beryllium	10	4.3	IRIS	4.3×10^{1}	Yes
Boron	250	-	-	-	-
Cadmium	44	-	-	-	-
Cobalt	230	-	-	-	-
Copper	620	-	-	-	-
Lead	32,000	-	-	-	-
Mercury	38	-	-	-	-
Molybden	200	-	-	-	-
Nickel (soluble salts)	230	-	-	-	-
Selenium	1,300	-	-	-	-
Silver	160	-	-	-	-
Thallium (soluble salts)	320	-	-	-	-
Uranium (soluble salts)	98,000	-	-	-	-
Zinc	6,700	-	-	-	-
Volatile organic compounds (µg/					
Benzene	16	2.9×10^{-2}	IRIS	4.6×10^{-4}	No
Carbon tetrachloride	4.9	1.3×10^{-1}	IRIS	6.4×10^{-4}	No
Chlorobenzene	4.5	-	-	-	-
Chloroform	62	6.1×10^{-3}	IRIS	3.8×10^{-4}	No
1,1-Dichloroethane	5.5	-	-	-	-
trans-1,2-Dichloroethene	6.4	-	-	-	-
Ethyl benzene	3.6	-	-	-	-
Methylene chloride	77	7.5×10^{-3}	IRIS	5.8×10^{-4}	No
Toluene	340	-	-	-	-
1,1,1-Trichloroethane	47	-	-	-	-
Trichloroethene	430	1.1×10^{-2}	HEAST	4.7×10^{-3}	No
Trichlorofluoromethane	70	-	-	-	-
Total xylenes	66	-	-	-	-
Semivolatile organic compounds (µ					
Acenaphthene	7,400	-	-	-	-
Acenaphthylene	4,200	-	-	-	-
Anthracene	84,000	-	-	-	-
Benz(a)anthracene[b]	34,000	5.8	-	2.0×10^{2}	Yes[b]
Benzo(b)fluoranthene[b]	78,000	5.8	-	4.5×10^{2}	Yes[b]
Benzo(k)fluoranthene[b]	94,000	5.8	-	5.5×10^{2}	Yes[b]
Benzo(g,h,i)perylene	6,400	-	-	-	-
Benzo(a)pyrene	110,000	5.8	IRIS	6.4×10^{2}	Yes
Benzyl alcohol	7,000	-	-	-	-
Bis(2-ethylhexyl)phthalate	1.600	1.4×10^{-2}	IRIS	2.2×10^{-7}	No
4-Chloro-3-methylphenol	880	-	-	-	-
2-Chlorophenol	660	-	-	-	-
Chrysene[b]	110,000	5.8	-	6.4×10^{2}	Yes[b]
Dibenz(a,h)anthracene[b]	3,900	5.8	-	2.3×10^{1}	No[b]
Dibenzofuran	11,000	-	-	-	-
Di-n-butylphthalate	760	-	-	-	-
2,4-Dimethylphenol	5,500	-	-	-	-
Fluoranthene	300,000	-	-	-	-
Fluorene	15,000	-	-	-	-

TABLE 2.17 (Cont.)

Contaminant	Maximum Concentration	Oral Slope Factor (mg/kg-d)$^{-1}$	Oral Slope Factor Source[a]	Risk Factor	Contaminant of Concern
SLDS (Cont.)					
Semivolatile organic compounds (µg/kg) (cont.)					
Hexachlorobutadiene	1,900	7.8×10^{-2}	IRIS	1.5×10^{-1}	No
Indeno(1,2,3-cd)pyrene[b]	12,000	5.8	-	7.0×10^{1}	Yes[b]
2-Methylnaphthalene	8,600	-	-	-	-
4-Methylphenol (p-Cresol)	3,200	-	-	-	-
Naphthalene	32,000	-	-	-	-
Phenanthrene	280,000	-	-	-	-
Phenol	5,700	-	-	-	-
Pyrene	63,000	-	-	-	-
Total				3.0×10^{3}	
City Property[c]					
Metals (mg/kg)					
Antimony	380	-	-	-	-
Arsenic	32	1.75	HEAST	5.6×10^{1}	Yes
Beryllium	1.8	4.3	IRIS	7.7	Yes
Boron	230	-	-	-	-
Cadmium	18	-	-	-	-
Cobalt	16	-	-	-	-
Copper	1,100	-	-	-	-
Lead	8,300	-	-	-	-
Molybdenum	32	-	-	-	-
Nickel (soluble salts)	50	-	-	-	-
Selenium	200	-	-	-	-
Silver	3.2	-	-	-	-
Thallium (soluble salts)	64	-	-	-	-
Uranium (soluble salts)	59,000	-	-	-	-
Zinc	11,000	-	-	-	-
Total				6.4×10^{1}	
SLAPS and SLAPS Ditches					
Metals (mg/kg)					
Antimony	2,300	-	-	-	-
Arsenic	240	1.75	HEAST	4.2×10^{2}	Yes
Beryllium	190	4.3	IRIS	8.2×10^{2}	Yes
Boron	100	-	-	-	-
Cadmium	50	-	-	-	-
Cobalt	6,000	-	-	-	-
Copper	4,400	-	-	-	-
Lead	1,200	-	-	-	-
Mercury	0.047	-	-	-	-
Molybdenum	260	-	-	-	-
Nickel (soluble salts)	7,600	-	-	-	-
Selenium	180	-	-	-	-
Silver	4.0	-	-	-	-
Thallium (soluble salts)	40	-	-	-	-
Tin	4,400	-	-	-	-
Uranium (soluble salts)	4,700	-	-	-	-
Zinc	4,300	-	-	-	-

TABLE 2.17 (Cont.)

Contaminant	Maximum Concentration	Oral Slope Factor		Risk Factor	Contaminant of Concern
		$(mg/kg\text{-}d)^{-1}$	Source[a]		
SLAPS and SLAPS Ditches (Cont.)					
Inorganic anions (mg/kg)					
Nitrate	1,100	-	-	-	-
Volatile organic compounds (µg/kg)					
trans-1,2-Dichloroethene	7.7	-	-	-	-
Toluene	1,200	-	-	-	-
Trichloroethene	15	1.1×10^{-2}	HEAST	1.7×10^{-4}	No
Total				1.2×10^{3}	
Ballfield					
Metals (mg/kg)					
Antimony	200	-	-	-	-
Arsenic	670	1.75	HEAST	1.2×10^{3}	Yes
Beryllium	18	4.3	IRIS	7.7×10^{1}	Yes
Boron	760	-	-	-	-
Cadmium	18	-	-	-	-
Cobalt	180	-	-	-	-
Copper	95	-	-	-	-
Lead	190	-	-	-	-
Molybdenum	750	-	-	-	-
Nickel (soluble salts)	190	-	-	-	-
Selenium	700	-	-	-	-
Silver	14	-	-	-	-
Thallium (soluble salts)	730	-	-	-	-
Uranium (soluble salts)	120	-	-	-	-
Inorganic anions (mg/kg)					
Nitrate	8	-	-	-	-
Volatile organic compounds (µg/kg)					
Toluene	48	-	-	-	-
1,1,1-Trichloroethane	1.7	-	-	-	-
Pesticides (µg/kg)					
Dieldrin	230	1.6×10^{1}	IRIS	3.7	No
Total				1.3×10^{3}	
Coldwater Creek					
Metals (mg/kg)					
Antimony	10	-	-	-	-
Arsenic	25	1.75	HEAST	4.4×10^{1}	Yes
Beryllium	1.3	4.3	IRIS	5.6	Yes
Cadmium	1.3	-	-	-	-
Cobalt	13	-	-	-	-
Copper	57	-	-	-	-
Lead	99	-	-	-	-
Molybdenum	26	-	-	-	-
Nickel (soluble salts)	18	-	-	-	-
Selenium	84	-	-	-	-
Silver	2.6	-	-	-	-

TABLE 2.17 (Cont.)

Contaminant	Maximum Concentration	Oral Slope Factor (mg/kg-d)$^{-1}$	Oral Slope Factor Source[a]	Risk Factor	Contaminant of Concern
Coldwater Creek (Cont.)					
Metals (mg/kg) (cont.)					
Thallium (soluble salts)	23	-	-	-	-
Zinc	1,400	-	-	-	-
Inorganic anions (mg/kg)					
Nitrate	0.67	-	-	-	-
Volatile organic compounds (µg/kg)					
Acetone	37	-	-	-	-
Acrylonitrile	2	5.4×10^{-1}	IRIS	1.1×10^{-3}	No
2-Butanone (Methyl ethyl ketone)	8	-	-	-	-
Chloroethane	2	-	-	-	-
Methylene chloride	45	7.5×10^{-3}	IRIS	3.4×10^{-4}	No
Toluene	1	-	-	-	-
Semivolatile organic compounds (µg/kg)					
Acenaphthene	890	-	-	-	-
Anthracene	3,200	-	-	-	-
Benz(a)anthracene[b]	6,000	5.8	-	3.5×10^{1}	Yes[b]
Benzo(b)fluoranthene[b]	5,100	5.8	-	3.0×10^{1}	Yes[b]
Benzo(k)fluoranthene[b]	4,900	5.8	-	2.8×10^{1}	Yes[b]
Benzo(g,h,i)perylene	4,000	-	-	-	-
Benzo(a)pyrene	5,400	5.8	IRIS	3.1×10^{1}	Yes
Bis(2-ethylhexyl)phthalate	1,700	1.4×10^{-2}	IRIS	2.4×10^{-2}	No
Chrysene[b]	13,000	5.8	-	7.5×10^{1}	Yes[b]
Dibenzofuran	760	-	-	-	-
Di-n-butylphthalate	43	-	-	-	-
Fluoranthene	24,000	-	-	-	-
Fluorene	1,600	-	-	-	-
2-Methylnaphthalene	50	-	-	-	-
Naphthalene	110	-	-	-	-
Phenanthrene	14,000	-	-	-	-
Phenol	970	-	-	-	-
Pyrene	9,500	-	-	-	-
Total				2.5×10^{2}	
Futura Coatings Property					
Metals (mg/kg)					
Antimony	18	-	-	-	-
Arsenic	320	1.75	HEAST	5.6×10^{2}	Yes
Beryllium	22	4.3	IRIS	9.5×10^{1}	Yes
Boron	180	-	-	-	-
Cadmium	16	-	-	-	-
Cobalt	14,000	-	-	-	-
Copper	9,100	-	-	-	-
Lead	530	-	-	-	-
Molybdenum	950	-	-	-	-
Nickel (soluble salts)	17,000	-	-	-	-
Selenium	1,000	-	-	-	-
Silver	3	-	-	-	-
Thallium (soluble salts)	30	-	-	-	-
Uranium (soluble salts)	7,400	-	-	-	-
Zinc	360	-	-	-	-

TABLE 2.17 (Cont.)

Contaminant	Maximum Concentration	Oral Slope Factor		Risk Factor	Contaminant of Concern
		(mg/kg-d)$^{-1}$	Source[a]		
Futura Coatings Property (Cont.)					
Inorganic anions (mg/kg)					
Nitrate	370	-	-	-	-
Volatile organic compounds (μg/kg)					
Toluene	15	-	-	-	-
Trichlorofluoromethane	1.3	-	-	-	-
Semivolatile organic compounds (μg/kg)					
2-Propanol-1,3-dichlorophosphate	250,000	-	-	-	-
Total				6.5×10^2	
HISS					
Metals (mg/kg)					
Antimony	240	-	-	-	-
Arsenic	1,000	1.75	HEAST	1.8×10^3	Yes
Beryllium	27	4.3	IRIS	1.2×10^2	Yes
Boron	1,000	-	-	-	-
Cadmium	27	-	-	-	-
Cobalt	1,500	-	-	-	-
Copper	950	-	-	-	-
Lead	460	-	-	-	-
Molybdenum	1,100	-	-	-	-
Nickel (soluble salts)	1,800	-	-	-	-
Selenium	1,000	-	-	-	-
Silver	18	-	-	-	-
Thallium (soluble salts)	960	-	-	-	-
Uranium (soluble salts)	2,400	-	-	-	-
Zinc	310	-	-	-	-
Inorganic anions (mg/kg)					
Nitrate	1,000	-	-	-	-
Volatile organic compounds (μg/kg)					
Toluene	2.9	-	-	-	-
Total				1.9×10^3	

[a] IRIS = *Integrated Risk Information System* (EPA 1992); HEAST = *Health Effects Assessment Summary Tables* (EPA 1991a).

[b] Oral slope factor for benzo(a)pyrene was used for the carcinogenic PAHs.

[c] City property samples were not analyzed for organic compounds; organic compounds identified as contaminants of concern for SLDS were also considered for the city property.

Sources: EPA (1991a, 1992).

TABLE 2.18 Concentration-Toxicity Screening Procedure for St. Louis Site Soil and Sediment: Inhalation Slope Factors

Contaminant	Maximum Concentration	Inhalation Slope Factor (mg/kg-d)$^{-1}$	Inhalation Slope Factor Source[a]	Risk Factor	Contaminant of Concern
SLDS					
Metals (mg/kg)					
Antimony	3,200	-	-	-	-
Arsenic (inorganic)	200	1.5×10^1	IRIS	3.0×10^3	Yes
Beryllium	10	8.4	IRIS	8.4×10^1	Yes
Boron	250	-	-	-	-
Cadmium	44	6.3	IRIS	2.8×10^2	Yes
Cobalt	230	-	-	-	-
Copper	620	-	-	-	-
Lead	32,000	-	-	-	-
Mercury	38	-	-	-	-
Molybdenum	200	-	-	-	-
Nickel (refinery dust)	230	8.4×10^{-1}	IRIS	1.9×10^2	Yes
Selenium	1,300	-	-	-	-
Silver	160	-	-	-	-
Thallium (soluble salts)	320	-	-	-	-
Uranium (soluble salts)	98,000	-	-	-	-
Zinc	6,700	-	-	-	-
Volatile organic compounds (µg/kg)					
Benzene	16	2.9×10^{-2}	IRIS	4.6×10^{-4}	No
Carbon tetrachloride	4.9	5.3×10^{-2}	IRIS	2.6×10^{-4}	No
Chlorobenzene	4.5	-	-	-	-
Chloroform	62	8.1×10^{-2}	IRIS	5.0×10^{-3}	No
1,1-Dichloroethane	5.5	-	-	-	-
trans-1,2-Dichloroethene	6.4	-	-	-	-
Ethyl benzene	3.6	-	-	-	-
Methylene chloride	77	1.6×10^{-3}	IRIS	1.2×10^{-4}	No
Toluene	340	-	-	-	-
1,1,1-Trichloroethane	47	-	-	-	-
Trichloroethene	430	1.7×10^{-2}	HEAST	7.3×10^{-3}	No
Trichlorofluoromethane	70	-	-	-	-
Total xylenes	66	-	-	-	-
Semivolatile organic compounds (µg/kg)					
Acenaphthene	7,400	-	-	-	-
Acenaphthylene	4,200	-	-	-	-
Anthracene	84,000	-	-	-	-
Benz(a)anthracene[b]	34,000	6.1	-	2.1×10^2	Yes[b]
Benzo(b)fluoranthene[b]	78,000	6.1	-	4.8×10^2	Yes[b]
Benzo(k)fluoranthene[b]	94,000	6.1	-	5.7×10^2	Yes[b]
Benzo(g,h,i)perylene	6,400	-	-	-	-
Benzo(a)pyrene	110,000	6.1	HEAST	6.7×10^2	Yes
Benzyl alcohol	7,000	-	-	-	-
Bis(2-ethylhexyl)phthalate	1,600	-	-	-	-
4-Chloro-3-methylphenol	880	-	-	-	-
2-Chlorophenol	660	-	-	-	-
Chrysene[b]	110,000	6.1	-	6.7×10^2	Yes[b]
Dibenz(a,h)anthracene[b]	3,900	6.1	-	2.4×10^1	No[b]
Dibenzofuran	11,000	-	-	-	-
Di-n-butylphthalate	760	-	-	-	-
2,4-Dimethylphenol	5,500	-	-	-	-
Fluoranthene	300,000	-	-	-	-
Fluorene	15,000	-	-	-	-

TABLE 2.18 (Cont.)

Contaminant	Maximum Concentration	Inhalation Slope Factor		Risk Factor	Contaminant of Concern
		(mg/kg-d)$^{-1}$	Source[a]		
SLDS (Cont.)					
Semivolatile organic compounds (μg/kg) (cont.)					
Hexachlorobutadiene	1,900	7.8×10^{-2}	IRIS	1.5×10^{-1}	No
Indeno(1,2,3-cd)pyrene[b]	12,000	6.1	-	7.3×10^{1}	Yes[b]
2-Methylnaphthalene	8,600	-	-	-	-
4-Methylphenol (p-Cresol)	3,200	-	-	-	-
Naphthalene	32,000	-	-	-	-
Phenanthrene	280,000	-	-	-	-
Phenol	5,700	-	-	-	-
Pyrene	63,000	-	-	-	-
Total				6.3×10^{3}	
City Property[c]					
Metals (mg/kg)					
Antimony	380	-	-	-	-
Arsenic (inorganic)	32	1.5×10^{1}	IRIS	4.8×10^{2}	Yes
Beryllium	1.8	8.4	IRIS	1.5×10^{1}	Yes
Boron	230	-	-	-	-
Cadmium	18	6.3	IRIS	1.1×10^{2}	Yes
Cobalt	16	-	-	-	-
Copper	1,100	-	-	-	-
Lead	8,300	-	-	-	-
Molybdenum	32	-	-	-	-
Nickel (refinery dust)	50	8.4×10^{-1}	IRIS	4.2×10^{1}	Yes
Selenium	200	-	-	-	-
Silver	3.2	-	-	-	-
Thallium (soluble salts)	64	-	-	-	-
Uranium (soluble salts)	59,000	-	-	-	-
Zinc	11,000	-	-	-	-
Total				6.5×10^{2}	
SLAPS and SLAPS Ditches					
Metals (mg/kg)					
Antimony	2,300	-	-	-	-
Arsenic (inorganic)	240	1.5×10^{1}	IRIS	3.6×10^{3}	Yes
Beryllium	190	8.4	IRIS	1.6×10^{3}	Yes
Boron	100	-	-	-	-
Cadmium	50	6.3	IRIS	3.1×10^{2}	Yes
Cobalt	6,000	-	-	-	-
Copper	4,400	-	-	-	-
Lead	1,200	-	-	-	-
Mercury	0.047	-	-	-	-
Molybdenum	260	-	-	-	-
Nickel (refinery dust)	7,600	8.4×10^{-1}	IRIS	6.4×10^{3}	Yes
Selenium	180	-	-	-	-
Silver	4.0	-	-	-	-
Thallium (soluble salts)	40	-	-	-	-
Tin	4,400	-	-	-	-
Uranium (soluble salts)	4,700	-	-	-	-
Zinc	4,300	-	-	-	-

TABLE 2.18 (Cont.)

Contaminant	Maximum Concentration	Inhalation Slope Factor (mg/kg d)$^{-1}$	Inhalation Slope Factor Source[a]	Risk Factor	Contaminant of Concern
SLAPS and SLAPS Ditches (Cont.)					
Inorganic anions (mg/kg)					
Nitrate	1,100	-	-	-	-
Volatile organic compounds (μg/kg)					
trans-1,2-Dichloroethene	7.7	-	-	-	-
Toluene	1,200	-	-	-	-
Trichloroethene	15	1.7 × 10^{-2}	HEAST	2.6 × 10^{-4}	No
Total				1.2 × 10^{4}	
Ballfield					
Metals (mg/kg)					
Antimony	200	-	-	-	-
Arsenic (inorganic)	670	1.5 × 10^{1}	IRIS	1.0 × 10^{4}	Yes
Beryllium	18	8.4	IRIS	1.6 × 10^{2}	Yes
Boron	760	-	-	-	-
Cadmium	18	6.3	IRIS	1.1 × 10^{2}	Yes
Cobalt	180	-	-	-	-
Copper	95	-	-	-	-
Lead	190	-	-	-	-
Molybdenum	750	-	-	-	-
Nickel (refinery dust)	190	8.4 × 10^{-1}	IRIS	1.6 × 10^{2}	Yes
Selenium	700	-	-	-	-
Silver	14	-	-	-	-
Thallium (soluble salts)	730	-	-	-	-
Uranium (soluble salts)	120	-	-	-	-
Inorganic anions (mg/kg)					
Nitrate	8	-	-	-	-
Volatile organic compounds (μg/kg)					
Toluene	48	-	-	-	-
1,1,1-Trichloroethane	1.7	-	-	-	-
Pesticides (μg/kg)					
Dieldrin	230	1.6 × 10^{1}	IRIS	3.7	No
Total				1.0 × 10^{4}	
Coldwater Creek					
Metals (mg/kg)					
Antimony	10	-	-	-	-
Arsenic (inorganic)	25	1.5 × 10^{1}	IRIS	3.8 × 10^{2}	Yes
Beryllium	1.3	8.4	IRIS	1.1 × 10^{1}	Yes
Cadmium	1.3	6.3	IRIS	8.2	Yes
Cobalt	13	-	-	-	-
Copper	57	-	-	-	-
Lead	99	-	-	-	-
Molybdenum	26	-	-	-	-
Nickel (refinery dust)	18	8.4 × 10^{-1}	IRIS	1.5 × 10^{1}	Yes
Selenium	84	-	-	-	-
Silver	2.6	-	-	-	-

TABLE 2.18 (Cont.)

Contaminant	Maximum Concentration	Inhalation Slope Factor (mg/kg-d)$^{-1}$	Inhalation Slope Factor Source[a]	Risk Factor	Contaminant of Concern
Coldwater Creek (Cont.)					
Metals (mg/kg) (cont.)					
Thallium	23	-	-	-	-
Zinc	1,400	-	-	-	-
Inorganic anions (mg/kg)					
Nitrate	0.67	-	-	-	-
Volatile organic compounds (μg/kg)					
Acetone	37	-	-	-	-
Acrylonitrile	2	2.4 × 10^{-1}	IRIS	4.8 × 10^{-4}	No
2-Butanone (Methyl ethyl ketone)	8	-	-	-	-
Chloroethane	2	-	-	-	-
Methylene chloride	45	1.6 × 10^{-3}	IRIS	7.2 × 10^{-5}	No
Toluene	1	-	-	-	-
Semivolatile organic compounds (μg/kg)					
Acenaphthene	890	-	-	-	-
Anthracene	3,200	-	-	-	-
Benz(a)anthracene[b]	6,000	6.1	-	3.7 × 10^{1}	Yes[b]
Benzo(b)fluoranthene[b]	5,100	6.1	-	3.1 × 10^{1}	Yes[b]
Benzo(k)fluoranthene[b]	4,900	6.1	-	3.0 × 10^{1}	Yes[b]
Benzo(g,h,i)perylene	4,000	-	-	-	-
Benzo(a)pyrene	5,400	6.1	HEAST	3.3 × 10^{1}	Yes
Bis(2-ethylhexyl)phthalate	1,700	-	-	-	-
Chrysene[b]	13,000	6.1	-	7.9 × 10^{1}	Yes[b]
Dibenzofuran	760	-	-	-	-
Di-n-butylphthalate	43	-	-	-	-
Fluoranthene	24,000	-	-	-	-
Fluorene	1,600	-	-	-	-
2-Methylnaphthalene	50	-	-	-	-
Naphthalene	110	-	-	-	-
Phenanthrene	14,000	-	-	-	-
Phenol	970	-	-	-	-
Pyrene	9,500	-	-	-	-
Total				6.2 × 10^{2}	
Futura Coatings Property					
Metals (mg/kg)					
Antimony	18	-	-	-	-
Arsenic (inorganic)	320	1.5 × 10^{1}	IRIS	4.8 × 10^{3}	Yes
Beryllium	22	8.4	IRIS	1.8 × 10^{2}	No
Boron	180	-	-	-	-
Cadmium	16	6.3	IRIS	1.0 × 10^{2}	No
Cobalt	14,000	-	-	-	-
Copper	9,100	-	-	-	-
Lead	530	-	-	-	-
Molybdenum	950	-	-	-	-
Nickel (refinery dust)	17,000	8.4 × 10^{-1}	IRIS	1.4 × 10^{4}	Yes
Selenium	1,000	-	-	-	-
Silver	3	-	-	-	-
Thallium (soluble salts)	30	-	-	-	-
Uranium (soluble salts)	7,400	-	-	-	-
Zinc	360	-	-	-	-

TABLE 2.18 (Cont.)

Contaminant	Maximum Concentration	Inhalation Slope Factor		Risk Factor	Contaminant of Concern
		(mg/kg-d)$^{-1}$	Source[a]		
Futura Coatings Property (Cont.)					
Inorganic anions (mg/kg)					
Nitrate	370	-	-	-	-
Volatile organic compounds (μg/kg)					
Toluene	15	-	-	-	-
Trichlorofluoromethane	1.3	-	-	-	-
Semivolatile organic compounds (μg/kg)					
2-Propanol-1,3-dichlorophosphate	250,000	-	-	-	-
Total				1.9×10^4	
HISS					
Metals (mg/kg)					
Antimony	240	-	-	-	-
Arsenic (inorganic)	1,000	1.5×10^1	IRIS	1.5×10^4	Yes
Beryllium	27	8.4	IRIS	2.3×10^2	Yes
Boron	1,000	-	-	-	-
Cadmium	27	6.3	IRIS	1.7×10^2	Yes
Cobalt	1,500	-	-	-	-
Copper	950	-	-	-	-
Lead	460	-	-	-	-
Molybdenum	1,100	-	-	-	-
Nickel (refinery dust)	1,800	8.4×10^{-1}	IRIS	1.5×10^3	Yes
Selenium	1,000	-	-	-	-
Silver	18	-	-	-	-
Thallium (soluble salts)	960	-	-	-	-
Uranium (soluble salts)	2,400	-	-	-	-
Zinc	310	-	-	-	-
Inorganic anions (mg/kg)					
Nitrate	1,000	-	-	-	-
Volatile organic compounds (μg/kg)					
Toluene	2.9	-	-	-	-
Total				1.7×10^4	

[a] IRIS = *Integrated Risk Information System* (EPA 1992); HEAST = *Health Effects Assessment Summary Tables* (EPA 1991a).

[b] Inhalation slope factor for benzo(a)pyrene was used for the carcinogenic PAHs.

[c] City property samples were not analyzed for organic compounds; organic compounds identified as contaminants of concern for SLDS were also considered for the city property.

Sources: EPA (1991a, 1992).

TABLE 2.19 Chemical Contaminants in Soil and Sediment Deleted from the Risk Assessment

Contaminant	Screening Rationale
All Properties	
Inorganics	
Aluminum	Levels lower than background level in Missouri soil for all properties; a normal dietary constituent of low toxicity.
Barium	Levels lower than background level in Missouri soil for all properties.
Boron	Coldwater Creek level lower than background level in Missouri soil; contribution to risks for other properties is insignificant on the basis of the concentration-toxicity screen.
Calcium	A normal dietary constituent of low toxicity.
Chromium	Levels lower than background level in Missouri soils for all properties.
Fluoride	Levels lower than background level in Missouri soils for all properties.
Iron	Levels lower than background level in Missouri soils for all properties but SLDS; a normal dietary constituent of low toxicity.
Magnesium	A normal dietary constituent of low toxicity.
Manganese	Levels lower than background level in Missouri soils for all properties.
Mercury	SLAPS level lower than background level in Missouri soils; contribution to risks at SLDS is insignificant on the basis of the concentration-toxicity screen.
Nitrate	Contribution to risks for all properties is insignificant on the basis of the concentration-toxicity screen.
Potassium	Levels lower than background level in Missouri soils for all properties; a normal dietary constituent of low toxicity.
Silver	Contribution to risks for all properties is insignificant on the basis of the concentration-toxicity screen.
Sodium	Levels lower than background level in Missouri soils for all properties; a normal dietary constituent of low toxicity.
Sulfate	A normal dietary constituent of low toxicity.
Vanadium	Levels lower than background level in Missouri soils for all properties.
Zinc	Ballfield level lower than background level in Missouri soils; contribution to risks for other properties is insignificant on the basis of the concentration-toxicity screen.

TABLE 2.19 (Cont.)

Contaminant	Screening Rationale
All Properties (Cont.)	
Organic compounds	
trans-1,2-Dichloroethene	Detected only at SLDS and SLAPS; contribution to risks at these properties is insignificant on the basis of the concentration-toxicity screen.
Dieldrin	Detected only at the ballfield; contribution to risk at this property is insignificant on the basis of the concentration-toxicity screen.
2-Propanol-1,3-dichlorophosphate	Detected only at the Futura Coatings property; compound has a low detection frequency and toxicity data are not available.
Toluene	Contribution to risks for all properties is insignificant on the basis of the concentration-toxicity screen.
1,1,1-Trichloroethane	Detected only at SLDS and the ballfield; contribution to risks at these properties is insignificant on the basis of the concentration-toxicity screen.
Trichloroethene	Detected only at SLDS and SLAPS; contribution to risks at these properties is insignificant on the basis of the concentration-toxicity screen.
Trichlorofluoromethane	Detected only at SLDS and the Futura Coatings property; contribution to risks at these properties is insignificant on the basis of the concentration-toxicity screen.
SLDS and City Property	
SLDS	
Inorganics	
Copper	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Molybdenum	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Selenium	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Volatile organic compounds	
Benzene	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Carbon tetrachloride	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.

TABLE 2.19 (Cont.)

Contaminant	Screening Rationale
SLDS and City Property (Cont.)	
SLDS (Cont.)	
Volatile organic compounds (cont.)	
Chlorobenzene	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Chloroform	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
1,1-Dichloroethane	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Ethyl benzene	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Methylene chloride	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
1,1,1-Trichloroethane	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Trichlorofluoromethane	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Total xylenes	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Semivolatile organic compounds	
Acenaphthene	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Acenaphthylene	Low concentration; contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Anthracene	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Benzo(g,h,i)perylene	Low concentration; contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Benzyl alcohol	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Bis(2-ethylhexyl)phthalate	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.

TABLE 2.19 (Cont.)

Contaminant	Screening Rationale
SLDS and City Property (Cont.)	
SLDS (Cont.)	
Semivolatile organic compounds (cont.)	
4-Chloro-3-methylphenol	Low detection frequency and concentration.
2-Chlorophenol	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Dibenzofuran	Low concentration; no toxicity data available.
Di-n-butylphthalate	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
2,4-Dimethylphenol	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Fluoranthene	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Fluorene	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Hexachlorobutadiene	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
2-Methylnaphthalene	Low concentration; contribution to risks is insignificant on the basis of the concentration-toxicity screen.
4-Methylphenol	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Naphthalene	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Phenanthrene	Low concentration; contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Phenol	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Pyrene	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.

TABLE 2.19 (Cont.)

Contaminant	Screening Rationale
SLDS and City Property (Cont.)	
City property	
Inorganics	
Copper	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Molybdenum	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Selenium	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
SLAPS and Vicinity Properties	
SLAPS	
Inorganics	
Lithium	Levels comparable to background level in Missouri soils for all properties; a normal dietary constituent of low toxicity.
Molybdenum	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Selenium	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Strontium	Levels lower than background level in Missouri soils for all properties.
Tin	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Ballfield	
Inorganics	
Copper	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Uranium	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Coldwater Creek	
Inorganics	
Copper	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Uranium	Levels lower than background level in Missouri soils.

TABLE 2.19 (Cont.)

Contaminant	Screening Rationale
SLAPS and Vicinity Properties (Cont.)	
Coldwater Creek (cont.)	
Volatile organic compounds	
Acetone	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Acrylonitrile	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
2-Butanone	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Chloroethane	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Methylene chloride	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Semivolatile organic compounds	
Acenaphthene	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Anthracene	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Benzo(g,h,i)perylene	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Bis(2-ethylhexyl)phthalate	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Dibenzofuran	Low concentration; no toxicity data available.
Di-n-butylphthalate	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Fluoranthene	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Fluorene	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
2-Methylnaphthalene	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Naphthalene	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.

TABLE 2.19 (Cont.)

Contaminant	Screening Rationale
SLAPS and Vicinity Properties (Cont.)	
Coldwater Creek (cont.)	
Semivolatile organic compounds (cont.)	
Phenanthrene	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Phenol	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Pyrene	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Latty Avenue Properties	
Futura Coatings, Inc.	
Inorganics	
Antimony	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
Cadmium	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.
HISS	
Inorganics	
Copper	Contribution to risks is insignificant on the basis of the concentration-toxicity screen.

TABLE 2.20 Chemical Contaminants in Groundwater Deleted from the Risk Assessment for All Properties

Contaminant	Screening Rationale
Aluminum	Widespread natural occurrence in groundwater; a normal dietary constituent of low toxicity; essential nutrient for humans.
Calcium	Widespread natural occurrence in groundwater; a normal dietary constituent of low toxicity; essential nutrient for humans.
Iron	Widespread natural occurrence in groundwater; a normal dietary constituent of low toxicity; essential nutrient for humans.
Magnesium	Widespread natural occurrence in groundwater; a normal dietary constituent of low toxicity; essential nutrient for humans.
Potassium	Widespread natural occurrence in groundwater; a normal dietary constituent of low toxicity; essential nutrient for humans.
Sodium	Widespread natural occurrence in groundwater; a normal dietary constituent of low toxicity; essential nutrient for humans.

TABLE 2.21 Chemical Contaminants of Concern in Soil and Sediment at the St. Louis Site

SLDS	City Property	SLAPS	Ballfield	Coldwater Creek	Futura	HISS
Antimony	Antimony	Antimony	Antimony	Antimony	Arsenic	Antimony
Arsenic	Arsenic	Arsenic	Arsenic	Arsenic	Beryllium	Arsenic
Beryllium	Beryllium	Beryllium	Beryllium	Beryllium	Cobalt	Beryllium
Cadmium	Cadmium	Cadmium	Cadmium	Cadmium	Copper	Cadmium
Cobalt	Cobalt	Cobalt	Cobalt	Cobalt	Lead	Cobalt
Lead	Lead	Copper	Lead	Lead	Molybdenum	Lead
Nickel	Nickel	Lead	Molybdenum	Molybdenum	Nickel	Molybdenum
Thallium	Thallium	Nickel	Nickel	Nickel	Selenium	Nickel
Uranium	Uranium	Thallium	Selenium	Selenium	Thallium	Selenium
cPAHs[a]	cPAHs[a]	Uranium	Thallium	Thallium	Uranium	Thallium
				Zinc		Uranium
				cPAHs[a]		

[a] cPAHs are carcinogenic polycyclic aromatic hydrocarbons; the seven classified as carcinogenic by EPA are benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

3 EXPOSURE ASSESSMENT

The exposure setting for the various properties comprising the St. Louis Site is characterized in Section 3.1. Potential human exposure pathways are described in Section 3.2, including a discussion of source areas, contaminant fate and transport, and ocations and routes of potential exposure. Exposure point concentrations are estimated for each medium that may contribute to human exposure, i.e., soil, air, groundwater, structural urfaces, and biota. These estimates are presented in Section 3.3, and associated ontaminant intakes and doses for human receptors are presented in Section 3.4.

3.1 CHARACTERIZATION OF EXPOSURE SETTING

The exposure setting for the St. Louis Site is described briefly in this BRA in terms f both the natural environment and local land use and demography. The setting is described in more detail in the RI/FS-EIS work plan (DOE 1993) and the RI for the St. Louis Site (DOE 994). The purpose of the following discussion is to provide information helpful in assessing otential impacts to various site resources associated with past uranium-processing activities and to identify exposure pathways for potential human receptors.

3.1.1 Environmental Setting

3.1.1.1 Climate

The St. Louis area has a modified continental climate. Temperatures reach 0°C (32°F) or lower for fewer than 20 to 25 days in most years. Summers are warm, with maximum temperatures of 32°C (90°F) or higher occurring an average of 35 to 40 days per year. Normal annual precipitation for the St. Louis area is about 92 cm (35 in.). Winds are predominantly from the south, with a mean speed of 15 km/h (9.5 mph).

3.1.1.2 Ecological Resources

The ecological resources of the St. Louis Site and surrounding area are limited because of the site's location within an urban area of concentrated industrial, commercial ncluding the Lambert-St. Louis International Airport), and residential developments U.S. Army Corps of Engineers 1987). Site vegetation consists of a mixture of prairie species, disturbance-related aggressive species, and remnants of landscape plantings, i.e., plants ypical to old fields and less-maintained landscape lawns (the predominant on-site habitat types). Typical species include various grasses, wild carrot, aster, clover, dandelion, oldenrod, dock, milkweed, ragweed, and thistle. Overall, no potentially important habitats r biota occur either on-site or adjacent to the three main subareas (SLDS, SLAPS, and ISS) that comprise the St. Louis Site. A riparian woodlot west of HISS is the highest uality habitat in the immediate vicinity of the site, but this area is separated from HISS by a commercial property and railroad tracks. Nevertheless, it may have been subject to some runoff from HISS in the past.

The vertebrate fauna of the area consists of species that have adapted to urban encroachment. Mammals that would be expected in the site area include small mammals (e.g., deer mouse, white-footed mouse, prairie vole, Norway rat, and house mouse), furbearers and small game mammals (e.g., opossum, eastern cottontail rabbit, gray squirrel, fox squirrel, raccoon, and striped skunk), and burrowing mammals (e.g., woodchuck and eastern mole) (Schwartz and Schwartz 1986; Parker and Szlemp 1987). Birds that would be expected in the site area include Canada goose, mallard, American kestrel, rock dove (domestic pigeon), mourning dove, common flicker, American crow, American robin, European starling, common grackle, house sparrow, northern cardinal, dark-eyed junco, and field sparrow (Robbins et al. 1983; Parker and Szlemp 1987).

A number of common reptile and amphibian species would also be expected to occur on-site along or in Coldwater Creek (located near SLAPS and HISS). Reptiles include the eastern garter snake, western ribbon snake, midland brown snake, northern water snake, northern fence lizard, western painted turtle, and snapping turtle. Amphibians include the leopard frog, green frog, bullfrog, western chorus frog, gray treefrog, northern spring peeper, Blanchard's cricket frog, Woodhouse's toad, and American toad (Johnson 1987; Parker and Szlemp 1987).

On the basis of walkover surveys of the site, coupled with the absence of both on-site hydric soils (Williams 1992; Benham 1982) and mapped wetlands (National Wetlands Inventory 1989), it can be concluded that the St. Louis Site does not contain wetlands. Several isolated patches of riparian forested wetlands bordering Coldwater Creek occur between SLAPS and HISS. One of these wetlands occurs west of HISS, separated from this site by a commercial development and railroad tracks. The riparian habitat along Coldwater Creek has been greatly impacted by commercial and industrial developments. Portions of these riparian woodlands could be impacted by flood-damage-reduction measures proposed for Coldwater Creek (U.S. Army Corps of Engineers 1987). The most extensive amount of riparian forested habitat within the Coldwater Creek basin occurs between Old Halls Ferry Road and the creek's confluence with the Missouri River; this area is located about 8 km (5 mi) downstream of HISS and would not be subject to impacts from site contaminant releases.

Other than the Mississippi River, the major aquatic habitat in the immediate area is Coldwater Creek (located west of SLAPS and HISS; see Figures 1.3 and 1.4). Generally, the water quality of Coldwater Creek is very poor due to pollutant runoff from residential, commercial, industrial, and airport development within the watershed (U.S. Army Corps of Engineers 1987). The closest pond or lake is a small excavated pond located about 230 m (750 ft) east of SLAPS. No standing water bodies within the Coldwater Creek watershed would be subject to impact from St. Louis Site contaminants.

The biotic composition of Coldwater Creek downstream of Lambert-St. Louis International Airport is restricted to species tolerant of polluted water and turbid, silty onditions. Fish species collected from Coldwater Creek include the golden shiner, red shiner, thead minnow (predominant species), carp, black bullhead, and bluegill (Parker and Szlemp 987). Other fish species that could be expected on the basis of their habitat preferences and olerance to stream degradation (e.g., siltation and turbidity) include creek chub, white sucker, green sunfish, and orangespotted sunfish (Pflieger 1975).

The invertebrate community is dominated by aquatic worms and midges. The polluted nature of Coldwater Creek is reflected by the high numbers of these two invertebrate axa (which are generally dominant in streams degraded by sediment and other types of rban pollutants), coupled with the low diversity of the benthic invertebrate community and the absence of invertebrates considered to be pollution intolerant, e.g., stoneflies and addisflies (Parker and Szlemp 1987).

All of the above-mentioned species are ubiquitous and none are dependent upon the t. Louis Site for continued survival. In addition, nonpoint sources of pollution are expected o increase due to continued commercial and industrial development expected within the Coldwater Creek basin. Thus, the aquatic ecosystem of Coldwater Creek is expected to emain degraded (U.S. Army Corps of Engineers 1987). Additionally, the terrestrial habitat eatures of the St. Louis Site would not be expected to notably change until final remediation occurs at the site.

The only federally threatened or endangered species that may occur in the vicinity of the site is the bald eagle. Although the bald eagle has been observed in St. Louis County, ost observations have been of migrating and wintering individuals along the Missouri River. rthermore, no critical habitat occurs for the bald eagle near the St. Louis Site (Tieger 989). No state-listed species occur in the vicinity of the St. Louis Site (Figg 1991); this onclusion is based on a combination of habitat requirements of state-listed species, habitat types and conditions present at the St. Louis Site, known collection locales for state-listed pecies, and/or last observed dates for these species in St. Louis County.

3.1.1.3 Geology and Stratigraphy

The St. Louis area is overlain by approximately 1,830 m (6,000 ft) of sedimentary ck consisting of sequences of sandstone, shale, and limestone, and more recent (past 00,000 years) deposits of glacial till, loess, and alluvium from the major rivers. The St. Louis Site borders the Mississippi Embayment to the south, which includes the New adrid seismic zone. Some scattered earthquake activity is known to occur throughout this rea, primarily in the southern part of the region in the New Madrid seismic zone (BNI 1990d).

The SLDS is on the western boundary of the Mississippi River, 11 km (7 mi) downstream of the confluence of the Mississippi and Missouri rivers. Much of the SLDS roperty is covered by either concrete or asphalt, which interferes with natural runoff and charge mechanisms for surficial materials. Under this cover, a layer of rubble and fill isturbed material) with an average thickness of 4 m (13 ft) is present over most of the property. Beneath the fill are unconsolidated deposits of stratified clays, silts, sands, and gravels. Beneath these deposits is limestone bedrock at a depth ranging from 5.9 m (19.5 ft) on the western side of the property to 24.4 m (80 ft) near the Mississippi River. Continuity of these materials varies both horizontally and laterally.

At SLAPS, the site stratigraphy is divided into six units; the upper four units are composed of unconsolidated materials, including fill, loess, lacustrine, and glacial deposits with varying continuity and thicknesses of 15.2 to 24.4 m (50 to 80 ft). Beneath the unconsolidated deposits are bedrock units of cyclical clastic sediments that are believed to be associated with the Cherokee Group and limestone units that are thought to be part of the St. Genevieve Formation.

The stratigraphy at the Latty Avenue Properties is similar to that observed at SLAPS. However, the subsurface characterization of the stratigraphy has been less extensive.

3.1.1.4 Surface Water and Groundwater

The major surface water bodies in the area are the Mississippi, Missouri, and Meramec rivers, which supply most of the drinking and industrial water for the St. Louis area. All of the water intakes are located upstream of SLDS, except one. This intake is located on the east bank of the Mississippi River, 3.2 km (2 mi) downstream from SLDS, and it supplies only a small percentage of the water requirements for the city of East St. Louis.

The primary surface water feature at SLAPS and the Latty Avenue Properties is Coldwater Creek. At McDonnell Boulevard, the creek has an upstream drainage area of approximately 32 km^2 (12 mi^2). The creek is not used for drinking water, although two municipal water intakes are present on the Mississippi River downstream of the discharge of Coldwater Creek.

The concrete or asphalt that covers most of SLDS has altered natural runoff and recharge mechanisms. An extensive levee system parallel to the river has been constructed near the riverbank to protect the site from flooding. The SLDS is not located in the 100-year floodplain of the Mississippi River (Federal Insurance Administration 1979).

The majority of HISS lies within the 100-year floodplain of Coldwater Creek. However, the two storage piles have been flood-protected to an elevation of 0.6 m (2 ft) above the level of the 100-year flood by means of synthetic membrane covers and riprap (i.e., crushed stone with a maximum particle size of at least 7.5 cm [3 in.] in diameter). With a membrane cover and riprap in place, the effects of a flood in terms of redistribution of contaminated materials are minimized (Picel et al. 1991).

The principal aquifers in the St. Louis area are located in the alluvial deposits associated with the major rivers. Groundwater also occurs in unconsolidated sand and gravel channel fills and in shallow and deep bedrock aquifers. The bedrock aquifers typically yield ess than 3 L/s (50 gpm), and water quality tends to deteriorate with depth as a result of rcasing salinity and increased concentrations of other dissolved minerals.

The SLDS is underlain by a portion of the Mississippi River alluvial aquifer, which is composed of unconsolidated deposits. The alluvial aquifer is thought to be hydraulically connected to the underlying upper bedrock and to the Mississippi River. The average groundwater velocity at SLDS is estimated to be 3 to 6 m/yr (10 to 20 ft/yr) in the lower aquifer units and 0.03 to 0.3 m/yr (0.1 to 1 ft/yr) in the upper unit.

At SLAPS and the Latty Avenue Properties, the bedrock groundwater is very hard and high in dissolved solids. In groundwater with lower total dissolved solids (TDS) concen-rations, calcium/magnesium/bicarbonate-type water is predominant; in groundwater with high TDS concentrations, sodium chloride is the dominant constituent. Major alluvial aquifers in the area are the basal sand and gravel channel fills and terrace deposits of the Meramec and Missouri rivers. Alluvial deposits may vary considerably in thickness and type of material, thereby making it difficult to establish well yield capabilities. Preliminary investigations indicate that the predominant material encountered in the unconsolidated verburden is clay. The approximate thickness and material distributions vary across the area. A clayey, fine-grained sand has been consistently encountered near and parallel to Coldwater Creek. Discharge in the area is thought to be westward toward Coldwater Creek or the near-surface system and northward toward the Missouri River for the regional or deep flow direction.

1.2 Land Use and Demography

3.1.2.1 St. Louis Downtown Site and Vicinity Properties

The SLDS is located in an industrial area on the eastern border of the city of St. Louis, about 90 m (300 ft) west of the Mississippi River. The 18-ha (45-acre) site is owned by Mallinckrodt, Inc., and is currently used for the production of specialty chemicals. Numerous buildings and facilities cover a large portion of the site, and much of the remainder of the site is covered with asphalt or concrete. Access to the site is currently limited to approximately 900 employees, 200 subcontracting construction workers, and uthorized visitors.

Land use within a 1.6-km (1-mi) radius of the SLDS reflects a mixture of public, gricultural, industrial, commercial, and residential activities. Three of the vicinity properties — the McKinley Iron Company, the Thomas & Proetz Lumber Company, and PVO oods — are commercial/industrial properties where site features such as topography and land use are similar to those of SLDS. The other three vicinity properties are railroad properties that bisect the SLDS from north to south. A city property is located adjacent to LDS on the west bank of the Mississippi River. The surface of the city property is not ved, and the property is accessible to the public.

3.1.2.2 SLAPS And Vicinity Properties

The SLAPS is located approximately 24 km (15 mi) from downtown St. Louis and immediately north of Lambert-St. Louis International Airport. The site is between the Norfolk & Western Railroad and Banshee Road on the south, Coldwater Creek on the west, and McDonnell Boulevard and adjacent recreational fields on the north and east. The property covers 8.8 ha (21.7 acres) and is enclosed by security fencing. Adjacent land uses are varied. Largely because of its proximity to the airport, more than two-thirds of the land within an 0.8-km (0.5-mi) radius is used for transportation-related purposes; the remaining land in the immediate vicinity is primarily commercial and recreational. No permanent buildings or facilities remain at SLAPS. The property is grassy, with a slight incline to the east. Maintenance and surveillance, including environmental monitoring, are the only activities currently taking place at SLAPS; a trailer is located on the property to support these activities. The nearest residential area is located approximately 0.8 km (0.5 mi) west of the property.

The vicinity properties associated with SLAPS are listed in Table 1.1. The St. Louis Airport Authority Property is located south of SLAPS and is currently used for transportational purposes. The ditches adjacent to SLAPS on the north and south sides contain residual contamination above background levels. These areas are immediately outside the fence line surrounding SLAPS and are therefore accessible to the public. The recreational fields adjacent to SLAPS on the north are not currently fenced to restrict access, but a "no trespassing" sign is posted.

The six haul roads that have been identified as containing radioactive contamination exceeding background levels are heavily traveled during the work week and provide major access to employment centers in the area. A vehicle count performed in 1982 totaled about 16,000 per day on McDonnell Boulevard near SLAPS, about 18,000 per day on McDonnell Boulevard north of Airport Road, and about 32,000 per day south of Airport Road. About 10,000 vehicles per day use Banshee Road between Lindbergh and McDonnell boulevards (DOE 1993). Of the approximately 70 vicinity properties along the haul roads that have been designated for evaluation of cleanup alternatives, five are occupied by homes and are zoned as residential properties. The remaining properties are zoned commercial/industrial/municipal.

Coldwater Creek, which borders the western side of SLAPS, is also considered a vicinity property. Coldwater Creek originates about 5.8 km (3.6 mi) south of the property, flows for a distance of 153 m (500 ft) along the western side of SLAPS, and discharges into the Missouri River about 24 km (15 mi) northeast of the property. The creek, including the portion that is near SLAPS, is accessible to the public. The water in Coldwater Creek is not a source of drinking water for the adjacent locality. The 10 vicinity properties near Coldwater Creek are all used for municipal purposes. The seven railroad properties are privately owned and are currently in use.

3.1.2.3 Latty Avenue Properties

The Latty Avenue Properties include the Futura Coatings property, the HISS, and six commercial/industrial properties on Latty Avenue. The Futura Coatings property is a commercial establishment for the manufacture of plastic coatings. The HISS is currently occupied by two covered temporary waste storage piles, a 3.7-m by 17-m (12-ft by 56-ft) trailer used as office space for the property caretaker, and a 7.3-m by 17-m (24-ft by 56-ft) trailer used as a public information office. The residential area nearest HISS is about 0.5 km (0.3 mi) to the east in the city of Berkeley. Several high-density residential areas that nclude single-family homes and apartment buildings are located about 1.2 to 1.6 km (0.75 to 1.0 mi) east and southeast of the property in Hazelwood and Berkeley (DOE 1993). The Latty Avenue vicinity properties are zoned for industrial use, and the immediately surrounding area is primarily industrial and commercial.

3.2 IDENTIFICATION OF EXPOSURE PATHWAYS

Potential human exposure pathways were identified on the basis of the following factors:

- Locations of contaminated source areas, types of contaminants found at the source areas, and potential mechanisms of contaminant release from those areas;
- Likely fate and transport of the contaminants within or between environmental media;
- Estimated concentrations of contaminants at points of potential human contact (i.e., exposure points) and the associated probable routes of human exposure (e.g., ingestion, inhalation, dermal contact, and external gamma irradiation); and
- Completeness of each exposure pathway — i.e., the presence of a source and a mechanism of contaminant release, an environmental transport medium, a point of human contact with the contaminated source or medium, and a route of human exposure at that point.

These factors were considered in developing the exposure assessment for the St. Louis Site nd are discussed in Sections 3.2.1 through 3.2.3. Figures 3.1 and 3.2[*] are schematic diagrams depicting these factors for the St. Louis Site. The SLDS and its vicinity properties ere considered separately from the remaining properties because of the distance of SLDS nd its vicinity properties from the remaining properties comprising the St. Louis Site, the

---

or readability, all figures and tables in this chapter are presented in sequence at the end of the text of the chapter.

mainly industrial land use of the SLDS properties, and the nature and type of contamination (e.g., contaminated structural surfaces).

3.2.1 Source Areas

The primary source of contamination at the SLDS area (including the city property and the six vicinity properties) is surface and subsurface soil. At SLDS, the highest levels of contamination have been measured in the Plant 1 and Plant 2 areas. Some building surfaces and manholes or drains within SLDS have also been identified as containing radioactive contamination exceeding background levels (Section 2.3.5). However, the majority of the manholes are not currently in operation, and intermittent maintenance is the only activity at the manholes. In addition, the SLDS building surfaces contain mostly fixed contamination and the buildings that contain the higher levels of contamination are mainly used for storage (e.g., Building K1E).

At the SLAPS and HISS areas (including all associated vicinity properties), the main source of contamination is surface and subsurface soil. Contamination at the haul roads vicinity properties is mostly located along the roads at the edges of the properties. In addition, two covered stockpiles of contaminated material currently stored at the HISS are potential sources of exposure. However, because the piles are covered and monitored, potential exposures from the piles were assessed in this BRA only with regard to the estimation of future risks. Limited data collected from the single pile existing in 1981 were used for the calculation of estimated doses and risks from the piles.

3.2.2 Contaminant Fate and Transport

The fate and transport of site contaminants was assessed to identify the environmental media that could be impacted by releases from on-site source areas. Possible release mechanisms and potentially impacted environmental media at the St. Louis Site include the following:

- Potential external gamma irradiation from various surfaces contaminated with radionuclides (i.e., areas of contaminated soil, building interiors, drains, and manholes);
- Radon gas generation from radium-contaminated soil, groundwater, and building surfaces;
- Wind dispersal of building contaminants and fugitive dust (particulates) generated from contaminated site soil;
- Surface deposition of airborne particulates, e.g., pursuant to fugitive dust generation or release of building contaminants;

- Surface runoff over contaminated soil following precipitation, with transport to other on-site soil and drainage areas (e.g., Coldwater Creek);

- Leaching from contaminated surface and subsurface soil areas to groundwater;

- Transport from contaminated groundwater to surface water and sediment (e.g., Coldwater Creek); and

- Uptake by biota (i.e., animals and plants) from contaminated soil.

Because of site-specific environmental factors, certain of these potential release mechanisms and receiving media do not play a primary role in contaminant fate and transport leading to current human exposure at the St. Louis Site. These mechanisms include wind dispersal of building contamination and eventual surface redeposition of such contaminants and uptake by biota of contaminants from soil. Building contamination at the SLDS has been found to be primarily fixed; insignificant or minimal amounts of removable contamination have been detected. Because of the industrial nature of the site, limited wildlife and vegetation are present at the site, so uptake by biota is not currently an mportant release mechanism. Finally, although contaminants have been identified in site groundwater, the groundwater in the area of the site is not currently utilized for drinking or other household purposes.

Surface waters potentially impacted by site contaminants via runoff include Coldwater Creek (adjacent to SLAPS and the Latty Avenue Properties) and the Mississippi River (adjacent to the SLDS/city property area). For Coldwater Creek, current exposure to a hypothetical recreational user was assumed, although sediment contamination is currently minimal and bank soil contamination is spotty. Levels of measured radionuclides in surface water samples from Coldwater Creek were consistent with background levels and lower than proposed guidelines (BNI 1991b).

Contamination that may have been transported via groundwater or surface water into the Mississippi River is briefly addressed in this BRA through an assessment of plausible exposure to contamination that is anticipated to be present in the sediment and surface water of the Mississippi River. Data from Mississippi River surface water are not available; however, it can be postulated that any contaminants that might be transported into the river water column would be diluted to below detectable levels because of the large dilution volume. This assumption is supported by low levels of contaminants detected in water samples from Coldwater Creek, a small stream in which less dilution occurs. Limited data are available on sediment radionuclide levels from the Mississippi River; three samples were collected from locations adjacent to SLDS (see Section 2.3.3). Because the river near SLDS is deep and relatively fast flowing, direct human contact with the sediment, such as through wading or swimming, was considered unlikely and, therefore, was not assessed in this report. However, an evaluation of the potential exposure from consumption of fish caught in the Mississippi River was included in this BRA; this pathway was evaluated for the recreational user at the city property adjacent to SLDS (the most likely receptor to incur this exposure of all the receptors analyzed in this report). The assumptions and calculations performed to evaluate this exposure are described in Sections 3.3.5 and 3.4.6. A similar scenario was not evaluated for any of the future receptors because the risk estimates for the current recreational user at the city property serve as a measure of the potential future risk from consumption of fish.

For the hypothetical future land-use scenarios assumed for the site (primarily future residents), conservative assumptions were made to include the potential use of groundwater for drinking and other household uses such as showering. The possibility of a farm with farm animals was not considered as a future scenario because all of the properties are in areas that are likely to remain urban. A scenario in which a home garden is planted to provide edible produce was assumed because this was considered plausible under the resident scenario; the discussion and calculations for this pathway are presented separately (see Appendix D) because of the considerable uncertainty in the soil-to-plant transfer factors available in the literature for the site contaminants of concern — that is, most of the values were derived from data used for the evaluation of radiological exposure from weapons testing fallout and may not be suitable for the evaluation of chemical toxicity. In addition, EPA guidance for evaluation of the home garden pathway is still evolving. Because of the uncertainties described above, a qualitative evaluation is recommended in the interim (EPA 1991b). The quantitative risks for this pathway are presented in Appendix D and were used for the qualitative evaluation.

In summary, the environmental release mechanisms and transport pathways that are considered most important for potential human exposures to site contaminants under current conditions are as follows:

- External gamma radiation from radioactively contaminated materials (including soil and structural surfaces);
- Radon gas generation from radium-contaminated soil and structural surfaces; and
- Wind dispersal of fugitive dust generated from contaminated site soil.

Additional release mechanisms and transport pathways that might become factors in future scenarios include leaching of soil contaminants to groundwater and biouptake of soil contaminants by plants.

3.2.3 Exposure Points, Exposure Routes, and Receptors

Exposure points are defined as points of potential contact with a contaminated medium located at site areas. The contaminated media associated with the St. Louis Site include soil, groundwater, structural surfaces, and drains at SLDS; soil at the vicinity properties and at the city property adjacent to SLDS; and soil and groundwater at SLAPS and HISS and associated vicinity properties. Likely human activities under current and potential future land-use conditions at the St. Louis Site were considered in identifying the potential receptors at exposure points associated with these media for the human health evaluation. Routes of human exposure identify the means by which the contaminant(s) could be taken in by a receptor at an exposure point. For this assessment, external gamma irradiation, inhalation, ingestion, and dermal absorption were considered potential exposure routes.

Although dermal exposure via direct contact with soil is considered a potential exposure route, it was not quantitatively evaluated in this assessment. All soil contaminants are radionuclides and metals, except for the carcinogenic PAHs. The EPA's *Interim Guidance for Dermal Exposure Assessment* (EPA 1991f) states that "no studies were identified in which the dermal uptake of metals from soil was reported." Furthermore, the principal goal of that report was to provide methodologies for assessing exposure to chemicals in water; therefore, guidance for absorption of metals from soil is still unavailable. Because of the uncertainties in assessing dermal absorption for the St. Louis Site soil contaminants of concern, it was believed that a quantitative assessment of dermal absorption of contaminants from soil based on currently available toxicological data would be inconclusive. However, available toxicological data on the extent of dermal absorption of the soil contaminants of concern are included in Appendix B, and the possible impact of not quantitating this exposure route is discussed in Section 5.3.

Two scenarios were considered that involve possible dermal contact with contaminated water — a recreator using Coldwater Creek and a future resident using groundwater. Dermal absorption of contaminants was not evaluated for the Coldwater Creek recreational user because contamination is found in creek sediment, not creek water. The limitations discussed above for evaluating radionuclide and metal contaminants in soil would also apply to evaluating dermal contact with Coldwater Creek sediment.

The most significant dermal contact with groundwater would be while showering. Again, EPA interim guidance on the assessment of dermal exposure acknowledges that the currently available methods of deriving dermal permeability constants "can not and do not provide a reasonable estimate" for metals and defers this methodology to work currently under way (EPA 1991f). Therefore, in this assessment, possible dermal uptake of metal contaminants was not evaluated for the future resident. In addition, for the few volatile organic contaminants present in groundwater, dermal absorption was assumed to be less significant compared with exposure via the inhalation route.

Currently, the perimeter of SLDS is fenced, limiting access to the plant areas; the presence of 24-hour security also makes routine trespassing unlikely. However, approximately 1,100 employees work routinely inside SLDS in the production of specialty chemicals as well as maintenance of the plant. Because the six SLDS vicinity properties are also of a commercial/industrial nature, i.e., with employees occupying the properties during work hours, an on-site employee has been identified as a current receptor for these areas. Direct contact with contaminated soil by the employees is limited (if it occurs at all) because the surfaces at SLDS are almost fully paved or covered by buildings, which also prevents fugitive dust generation. For this reason, incidental soil ingestion and particulate inhalation were not considered for the current SLDS or SLDS vicinity property employee in this assessment.

To account for the likely occurrence of plant improvement activities within SLDS, a construction worker scenario was also assessed to determine potential exposure if renovation or excavation work were undertaken. Because of the nature of the assumed activities, exposure via incidental soil ingestion and particulate inhalation as well as exposure via external gamma irradiation and radon inhalation were considered plausible for this SLDS receptor.

A third receptor, a SLDS maintenance employee, was identified to evaluate possible exposure to contaminated drain sediment. This maintenance employee was assumed to conduct infrequent drain maintenance, with possible exposure via external gamma irradiation and incidental ingestion of the sediment. Inhalation was not considered to be a potential pathway for drain sediment because fugitive dust would not be generated from the wet sediment.

The city property adjacent to SLDS is not fenced, so it is possible for a member of the public to wander onto this property and access the Mississippi River for recreational purposes like fishing. Therefore, the receptor identified for the city property in this assessment was a recreational user.

The SLAPS and the HISS are both fenced and monitored by DOE, and currently only authorized personnel (mainly site caretakers) have routine access to these properties. Although highly unlikely, members of the public might trespass into these areas and be exposed to contaminants identified at these properties. Therefore, to address current reasonable exposure at SLAPS and HISS, current on-site receptors were identified as a maintenance worker (caretaker) and a youth trespasser. The maintenance worker's employment hours were assumed to be divided between activities at SLAPS and HISS (see Table 3.28).

In addition, to account for the possibility of excavations for utility improvements and other similar activities, a construction worker conducting these activities was assumed for the ditches adjacent to SLAPS. Of the SLAPS and HISS vicinity properties, the ditch area near SLAPS contains one of the more elevated concentrations of radioactive contamination and it is also a plausible area for activities such as those assumed for this scenario. Therefore, if this same scenario occurred in another area within any of the other vicinity properties, the level of exposure would most likely be similar if not much lower.

An employee has been identified as the most likely current receptor at the Futura Coatings property and at all SLAPS and HISS vicinity properties zoned as commercial/industrial/municipal properties (Table 1.1). At the five vicinity properties currently categorized as residential, exposure to a long-term resident living on one of these properties was assessed. However, because the contamination on these properties is primarily at the edges of the properties along the roads (Section 2.3.1.2), an additional current receptor who would have routine contact with the more contaminated area was evaluated. This second rent receptor was identified as a child routinely waiting for a school bus and standing in e contaminated area at the edge of the property.

Although a "no trespassing" sign is posted at the ballfield, it is possible for this area to be used for recreational purposes, especially by children living in the vicinity of the allfield. Therefore, the exposure of a child recreational user to contaminants at the ballfield was evaluated as a current land-use scenario.

Coldwater Creek is accessible to members of the public, most likely for recreational purposes. Therefore, a youth spending time at the creek to fish or wade was assessed as a current receptor. For radioactive contaminants, bank soil data are available for calculating he ingestion and inhalation pathways. Available chemical data are for sediment, which is usually assumed not to contribute to inhalation intake. However, in this assessment, the hemical concentrations in sediment were assumed to represent bank soil concentrations, and ngestion and inhalation were evaluated for both radioactive and chemical contaminants.

Other current receptors could be identified, e.g., joggers along the haul roads and/or ndividuals driving by the site properties or on the haul roads. However, potential risks to these receptors were not explicitly evaluated because their exposures would be less than hose estimated for the specific receptors considered in this assessment.

Finally, worst-case hypothetical receptors were considered for the future scenarios essed in this BRA. For future scenarios, a long-term resident was assessed for all site perties except Coldwater Creek, where a future recreational user was considered. This is consistent with EPA (1989c) guidance.

3.2.4 Summary of Exposure Pathways

The property groups and corresponding receptors that were assumed for the evaluation of current and future land uses at the St. Louis Site are listed in Table 3.1.[*] otentially completed pathways for current and future land-use scenarios were assessed in his BRA on the basis of the following: a source of contamination and a release from that source, an exposure point at which contact could occur, and an exposure route by which the ntact could occur. These completed pathways are summarized in Tables 3.2 and 3.3.

3 ESTIMATION OF EXPOSURE POINT CONCENTRATIONS

The media-specific concentration of a contaminant at the location of exposure (i.e., e exposure point concentration) must be estimated in order to calculate the potential human exposure that might be associated with a contaminated source. For soil, air,

---

[*] r readability, all figures and tables in this chapter are presented in sequence at the end of the text the chapter.

groundwater, and structural surfaces, the exposure point concentrations of all contaminants of concern identified for each property or group of properties were estimated on the basis of the data described in Chapter 2.

In addition, in accordance with EPA (1989c) guidance, use of the 95% upper confidence limit (UL_{95}) values of the arithmetic means of site contaminant concentrations is preferable. In this assessment, UL_{95} values were derived from soil contaminant concentrations; however, because of the limited nature of available data for sediment, groundwater, and surface contamination, maximum values were used as exposure point concentrations in the calculations for contaminants detected in these media. Exposure point concentrations for particulates in air were based on soil UL_{95} values of the various contaminants and on assumptions regarding the transfer of these contaminants to air. Exposure point concentrations for inhalation of radon and external gamma irradiation were based on radon measurements and gamma exposure rates, respectively, when these data were available; otherwise, exposures via these pathways were calculated on the basis of projections from soil concentrations.

The UL_{95} value of the arithmetic mean of each soil contaminant was derived from the following equation (Gilbert 1987):

$$UL_{95} = \bar{x} + t_{1-\alpha/2,n-1}\left(\frac{s}{\sqrt{n}}\right) \tag{3.1}$$

where:

$\bar{x}$ = arithmetic mean of sample;

$t_{1-\alpha/2,n-1}$ = *t*-distribution factor (taken from statistical *t*-tables) for the upper 95% confidence interval of a two-tailed test (i.e., $\alpha = 0.05$) and n-1 degrees of freedom;

n = number of samples; and

s = standard deviation of the sample mean, as calculated from $s = \sqrt{\frac{\Sigma (x_i - \bar{x})^2}{n-1}}$ where x_i is the concentration of sample i.

For HISS, the results of soil sampling for chemicals yielded a highly skewed sample distribution, for which use of the UL_{95} of the geometric mean was appropriate (see Section 3.3.1.1). The geometric mean is defined as antilog $[1/n\ (\Sigma \log x_i)]$. The UL_{95} of the geometric mean is calculated from Equation 3.1, treating the log-transformed data exactly as an untransformed data set and taking the antilog of the log-transformed UL_{95}. The UL_{95} values of the geometric means were used as exposure point concentrations for HISS soil contaminants.

Statistical parameters needed to derive the appropriate UL_{95} values for the various contaminants from the various site areas are summarized in Tables 3.4 and 3.5 for radioactive and chemical contaminants of concern, respectively. Details on the derivation of exposure point concentrations for the various soil-associated exposure pathways are provided in Sections 3.3.1.1 through 3.3.1.3.

3.3.1 Soil

Available soil data from all site areas and 1981 data on the then-existing HISS pile (Table 2.4) were used for the estimation of exposure point concentrations for the following athways: external gamma irradiation, incidental ingestion, inhalation of radon, and inhalation of particulates.

3.3.1.1 Exposure Point Concentrations for External Gamma Irradiation and Incidental Ingestion

Radiological Data. Radiological data indicate that contamination with uranium-238, radium-226, and thorium-230 is widespread in soil at most site properties. vailable characterization results were used in conjunction with results from the source term analysis (Section 2.5.1 and Table 2.15) to estimate soil exposure point concentrations of all dionuclides in the three decay series. For HISS, where thorium-230 data were limited, orium-230 levels were estimated from the ratio of the thorium-230 concentration to the radium-226 concentration in the source term analysis. For the residential properties where nly thorium-230 levels were characterized, the potential levels of other radionuclides were estimated from source term ratios, with thorium-230 as the reference radionuclide.

The UL_{95} values of the arithmetic means of the measured radionuclides (i.e., uranium-238, radium-226, thorium-230, and thorium-232) were used to derive the concentrations of the other radionuclides in the decay series, so all values are analogous to nticipated arithmetic mean UL_{95} values. These values are considered to represent an upper bound of likely exposure point concentrations at each property, which accounts for localized reas of elevated concentrations of contaminants. To account for the remote possibility that he entire area of SLDS and the city property could be developed for future residential use, the data for the SLDS and city property were combined for deriving the exposure point concentrations for the future resident scenarios at these properties.

Contaminant concentrations in the upper 0.9 m (3 ft) of soil were used to calculate ingestion intakes. This soil depth accounts for possible limited intrusion by current and future receptors into areas where contamination is also found below the ground surface. Exposure to external gamma irradiation results mainly from the top 0.3 m (1 ft) of soil because of gamma ray attenuation by the overlying soil at deeper depths. Therefore, the L_{95} values of the arithmetic means of data from the 0- to 0.3-m (0- to 1-ft) and the 0.3- to 9-m (1- to 3-ft) soil layers were used individually to calculate external gamma exposure.

For the construction worker scenario at SLDS and the ditches, the UL_{95} values of data from the 0- to 2.4-m (0- to 8-ft) soil layer were used to calculate ingestion intake and external gamma exposure. This depth was used to account for mixing that might occur during excavation activities for construction or utility installation.

The radionuclide exposure point concentrations for external gamma irradiation and incidental ingestion of soil at the St. Louis Site are presented in Tables 3.6 through 3.10 for current receptors; the exposure point concentrations for external gamma irradiation and incidental ingestion of soil by future receptors are presented in Tables 3.11 through 3.13.

Chemical Data. As for radioactive contaminants, the UL_{95} values of the arithmetic means of the measured soil concentrations were calculated as exposure point concentrations for the chemical contaminants of concern for each of the properties except HISS. The UL_{95} values were calculated for surface soil and for soil overall (i.e., all available data for both surface and subsurface soil). The UL_{95} values of the arithmetic means for surface soil only were used as exposure point concentrations for the current land-use scenarios. The concentrations reported for the shallowest depth sampled at each property borehole were used as surface sample values. In general, this included data from the upper 1.5 m (5 ft) of soil; however, in some instances, data from composite samples extending to depths of 5.4 m (18 ft) were included. When data from a composite sample were used, soil contaminants were assumed to be evenly distributed throughout the sample.

For HISS, UL_{95} values of the geometric means rather than the arithmetic means were used as exposure point concentrations because, of the six surface samples available, results for most metals were extremely elevated in only one sample, indicating a highly skewed sample distribution. The derivation of UL_{95} values for arithmetic means assumes an approximately normal sample distribution. Because the HISS data set did not indicate a normal distribution, the log transformation allowed for more accurate modeling of the exposure point concentration.

Uranium data were collected separately from data for other inorganics. For each property, the UL_{95} value of the arithmetic mean of the uranium-238 concentration from the 0- to 0.9-m [0- to 3-ft] layer was converted to milligrams per kilogram and used as the exposure point concentration for uranium.

The exposure point concentrations used for the current construction worker scenario (i.e., at SLDS and the ditches) and the future receptor scenarios were the UL_{95} values of the arithmetic means (or geometric means for HISS) derived from overall soil contaminant levels (i.e., surface and subsurface combined); these exposure point concentrations were used in order to account for possible current and future conditions at properties where excavation activities and, therefore, mixing of soil might occur. However, as a conservative assumption for areas where surficial soil contaminant levels were higher than overall levels, UL_{95} values from the surficial soil were used as exposure point concentrations. Surficial soil contaminant levels were higher than overall levels at the SLDS and city property, SLAPS, and HISS.

Except for PAHs, all contaminants of concern for soil are inorganic substances. Most [illegible] these inorganics have been detected at a frequency of 10% or more in site soil (Table 2.8). Therefore, it was considered possible that these contaminants were present at some level less than the detection limit in samples where inorganics were reported as not detected. To determine UL_{95} values, half the sample detection limit was used as the concentration for any inorganic contaminant reported as not detected.

Data for PAHs at SLDS were obtained from composite samples from 56 boreholes. A more conservative method for estimating exposure point concentrations for carcinogenic PAHs was used because the data for PAHs were not as extensive as the data for inorganics. The exposure point concentration used for both SLDS and the city property was the sum of the maximum levels reported for any of the 56 composite samples of the seven PAHs classified as carcinogenic by the EPA.

Contaminants of concern for the Coldwater Creek sediment are nine metals and the carcinogenic PAHs. Because the available data consist of only four samples, the maximum reported level was used as the exposure point concentration for metals and the sum of the maximum detected levels was used as the exposure point concentration for the carcinogenic PAHs.

The chemical exposure point concentrations for incidental ingestion of soil and sediment are presented in Table 3.14 for current receptors and Table 3.15 for future receptors.

3.3.1.2 Exposure Point Concentrations for Radon

Radon measurements were available only for indoor air at the HISS trailers, inside the SLDS buildings, and inside the Futura Coatings buildings. These measurements were used to estimate indoor radon exposures to the applicable current receptors at these sites. For the properties where no direct measurements were taken, radium-226 concentrations in soil were used to derive both outdoor and indoor radon concentrations. This method takes into account radon generated from the current concentrations of radium-226 at the various properties; however, for the future scenarios, the radon levels are projected to be higher than the levels used in this assessment because of ingrowth from decay of thorium-230. This is especially significant for site properties where the current thorium-230 levels are much higher than radium-226. However, the potential impacts associated with ingrowth over an extended time period of hundreds to thousands of years is difficult to quantify accurately because of the complex interactions of dispersion mechanisms. The methodology used in this assessment is considered to adequately represent site conditions in the near future. Further discussion on health impacts from this methodology is presented in Sections 5.2.2 and 5.3.2. The indoor and outdoor radon concentrations for each property are summarized in Table 3.16 for current receptors and Table 3.17 for future receptors.

Indoor Radon-222 Concentration. The maximum measured radon concentrations inside each SLDS building (see Table 2.6), inside the HISS trailers, and inside the Futura buildings (see Section 2.3.4) were used to calculate the indoor radon exposures for the employees at these properties and for the SLDS construction worker during renovation or remodeling activities. Building and trailer indoor air concentrations in units of working level (WL) were calculated from the following equation:

$$AC_b = \frac{EF \times C_{in}}{100\ pCi/L} \tag{3.2}$$

where:

AC_b = building indoor air concentration of radon-222 decay products, WL;

EF = indoor equilibrium factor, 0.5 (assumed); and

C_{in} = maximum measured radon concentrations, pCi/L.

One working level corresponds to the potential alpha energy released by the decay of short-lived radon-222 decay products in radioactive equilibrium with a radon-222 activity concentration of 100 pCi/L (International Commission on Radiological Protection [ICRP] 1981). However, because the concentrations of short-lived decay products of radon are seldom in equilibrium with radon-222, an equilibrium factor is used to relate the actual concentration of radon decay products to those that would be present under equilibrium conditions. For this assessment, an indoor equilibrium factor of 0.5 was assumed, which is the average of the two reported equilibrium factors for the United States (National Council on Radiation Protection and Measurements [NCRP] 1988).

For the future residential scenarios, indoor radon concentrations were calculated from the UL_{95} value for the radium-226 concentration in the 0- to 2.4-m (0- to 8-ft) layer for each property. The depth of 2.4 m (8 ft) was selected to account for the possible construction of homes with basements and the potential for radon emanation into the homes through the basement foundations. However, for the residential vicinity property, only data from the 0- to 0.9-m (0- to 3-ft) layer were available, so the radium-226 UL_{95} value for that layer was used to calculate the indoor radon concentration. The indoor radon concentrations in air for each property were estimated as follows:

$$AC_i = \frac{SC \times CR \times EF}{100\ pCi/L} \tag{3.3}$$

where:

AC_i = indoor concentration of radon-222 decay products in air, WL;

SC = radium-226 concentration in soil, pCi/g;

CR = concentration ratio, 0.81 (pCi/L)/(pCi/g), the ratio of the radon-222 concentration in indoor air to the average concentration of radium-226 in soil (Gilbert et al. 1983); and

EF = indoor equilibrium factor, 0.5 (assumed).

The concentration ratio of 0.81 (pCi/L of radon-222)/(pCi/g of radium-226) was eveloped for a home with a basement and takes into consideration the time one spends on different floors in the home (Gilbert et al. 1983). This value is based on the average indoor adon concentration measured in homes in the New Jersey and New York area and is onsidered reasonable for use in this assessment. An indoor equilibrium factor of 0.5 was also used to calculate the indoor radon concentration for the future residential scenarios.

Outdoor Radon-222 Concentration. The outdoor radon concentration depends n many meteorological and soil factors that control the release of radon to the atmosphere nd its movement therein. The relations are quite complex, making it difficult to estimate radon concentrations by means of modeling. Therefore, for this analysis, estimates were otained on the basis of measured values of naturally occurring radon in the atmosphere and aturally occurring radium in the soil. A concentration ratio of 0.19 (pCi/L of radon-222)/(pCi/g of radium-226) was obtained from Gilbert et al. (1983). This ratio was derived from [illegible] national average concentration of radium-226 in soil and the average radon concentration [illegible] the atmosphere and was used to estimate the outdoor radon-222 concentrations at the various receptor locations. An outdoor equilibrium factor of 0.3 was used for this assessment, hich is based on the algorithm incorporated in the CAP-88 computer code (Beres 1990) for distances close to the point of release (i.e., less than 1 km [0.6 mi]). The CAP-88 computer ode is a collection of computer models, databases, and associated utility programs developed y the EPA for assessing compliance of radionuclide releases with limits established under the Clean Air Act.

For both current and future scenarios, the outdoor radon concentration in air was calculated from the UL_{95} value for the radium-226 concentration in the 0- to 0.9-m (0- to 3-ft) yer of soil for each property. The data from this layer were selected because this depth presents the approximate diffusion length of radon in soil (United Nations Scientific Committee on the Effects of Atomic Radiation 1988). The equation used to estimate the door radon-222 concentrations was also used to estimate the outdoor radon-222 oncentrations except that the latter calculations assumed an outdoor concentration ratio of 0 19 (pCi/L of radon-222)/(pCi/g of radium-226) from Gilbert et al. (1983) and an outdoor uilibrium factor of 0.3.

3.3.1.3 Exposure Point Concentrations for Inhalation of Particulates

Air concentrations of both radioactive and chemical contaminants of concern were derived from soil concentrations and data related specifically to the St. Louis area. For that area, it has been estimated that about 0.08 mg of total particulates is resuspended per cubic meter of air, of which approximately 50% originates from soil or similar material (Trijonis et al. 1980). For current land-use scenarios, the appropriate UL_{95} values for the radionuclide and chemical concentrations in the surface soil were used to apportion the same concentration to 0.04 mg soil/m^3 air (i.e., 0.08 mg/m^3 × 50%). However, for construction worker scenarios, the particulate concentrations in air were assumed to be 15 mg/m^3, which is the Occupational Safety and Health Administration (OSHA) standard for nuisance total particulates. Because of possible generation of high levels of fugitive dust during excavation, 100% of the particulates was assumed to be derived from contaminated soil for the construction worker scenarios.

For radionuclides, surface soil concentrations were estimated from the data for the 0- to 0.3-m (0- to 1-ft) layer; for chemicals, surface soil concentrations were estimated as described in Section 3.3.1.1. Only the surface soil layer was used because the erosion rate of the soil is low enough to preclude the deeper layers from contributing to inhalation exposure (Knight 1983). However, for the construction worker scenarios at SLDS and the ditches, radionuclide concentrations were estimated from data for the 0- to 2.4-m (0- to 8-ft) layer. For estimating chemical concentrations in air for future land-use scenarios, the UL_{95} values from the overall soil chemical data points were used in instances where these values were higher than the UL_{95} values obtained from surface levels. This is similar to the procedure used to calculate chemical exposure point concentrations in soil, as described in Section 3.3.1.1.

The respirable portion of the total particulate concentrations (i.e., 30%) was used as the exposure point concentration for all calculations involving the inhalation of particulates. Paustenbach (1989) gives a 30 to 50% range for the fraction of suspended particulates that is respirable. For this assessment, 30% was believed to be a sufficiently conservative estimate because it was assumed that 100% of the total resuspended particulates coming from soil-like material (i.e., 50% of 0.08 mg/m^3) would be derived from contaminated soil.

The radionuclide exposure point concentrations for air are presented in Table 3.18 for current receptors and Table 3.19 for future receptors. The chemical exposure point concentrations for air are presented in Table 3.20 for current receptors and Table 3.21 for future receptors.

3.3.2 Groundwater

Exposure point concentrations were estimated for two groundwater pathways applicable to the future-use scenarios: ingestion of groundwater and inhalation of volatile contaminants from groundwater.

3.3.2.1 Exposure Point Concentrations for Ingestion of Groundwater

Because groundwater data are not as extensive as soil data, UL_{95} values were not calculated as exposure point concentrations. Instead, the maximum detected level of each radioactive or chemical contaminant of concern in any well at SLDS, SLAPS, or HISS was sed as the exposure point concentration for that property. This procedure assumes that groundwater contaminant concentrations will not change over time and that every ontaminant will be present at the maximum detected level at the specific location of a hypothetical well placed by a future resident at these properties. It is reasonable to assume a slow rate of change for the inorganic contaminants because they do not degrade and are enerally not highly mobile. However, it is likely that with no additional source input, the organic contaminants would degrade and dissipate over time. It is also conservative to assume that the maximum concentration of each contaminant would be present at a single ocation. Therefore, the groundwater exposure point concentrations used for this assessment might result in considerable overestimates. The exposure point concentrations for ingestion of groundwater by future receptors are presented in Table 3.22 for radionuclides and able 3.23 for chemicals.

3.3.2.2 Exposure Point Concentrations for Inhalation of Contaminants from Groundwater

Potential exposure from inhalation of radon-222 and its decay products and of chemicals from groundwater use inside the house was considered for the future resident scenario. It was assumed that the most significant source of household inhalation exposure o chemicals would be from showering; therefore, the exposure evaluated in this BRA was that from VOCs detected in groundwater with molecular weights of less than 200; the olatilization and inhalation of other contaminants would be insignificant (EPA 1991d).

Radium-226 (not radon-222) concentrations were measured in groundwater. lthough no generally accepted correlation exists between dissolved radium-226 and adon-222 levels in groundwater, a nationwide survey comparing levels of dissolved radium-226 and radon-222 indicates that the radon concentration in groundwater at the t. Louis Site could be approximately 110 times higher than the radium-226 concentration (Longtin 1988). Thus, a ratio of 110:1 was used to estimate the concentration of radon-222 in groundwater from measured radium-226 concentrations at SLDS, SLAPS, and HISS.

The contribution to indoor radon levels associated with groundwater usage was estimated as follows. The concentration of radium-226 in groundwater was multiplied by 110 o obtain the radon-222 concentration in groundwater. The resulting radon concentration in household air was calculated with a transfer coefficient of 1×10^{-4}, relating the radon oncentration in air (pCi/L of air) to that in water (pCi/L of water) (Cross et al. 1985). The esults of these calculations indicate that the contributions from groundwater to radon in usehold air are less than 1% of the contribution from soil. This finding is consistent with he results of other studies, which have reported that water sources generally make a relatively small contribution to indoor radon levels (Cothern et al. 1986). Therefore, this source of radon was not further evaluated in this assessment.

The method used to estimate contaminant concentrations in air while showering was based on that presented by Byard (1989). Thus, the amount of contaminant volatilized was calculated for VOCs, as follows:

$$\text{Amount volatilized (pCi or mg)} = C_w \times V \times \%\text{Vol} \tag{3.4}$$

where:

C_w = maximum concentration of contaminant in water, pCi/L or mg/L;

V = total volume of water used per shower, L; and

$\%\text{Vol}$ = percent of contaminant volatilized, assumed to be 100%.

Byard (1989) and McKone and Bogen (1991) have estimated that about 50 and 80 L (13 and 21 gal), respectively, of water is used per shower; however, for conservatism in this assessment, 200 L (or about 53 gal) was assumed to be used per shower.

The maximum contaminant concentration was assumed to be the amount volatilized divided by the shower volume (estimated as 2.5 m^3). The contaminant concentration in air would start at zero and increase linearly over time; thus, the average concentration was assumed to be the maximum concentration divided by 2. This average air concentration was used as the exposure point concentration for showering, which is a sufficiently conservative approach because it is based on the maximum level of contaminant detected in groundwater. The exposure point concentrations for inhalation of chemicals in groundwater while showering are presented in Table 3.24.

3.3.3 Exposure to Contaminated Drains

External gamma irradiation and incidental ingestion of sediment were evaluated for the SLDS plant employee conducting intermittent maintenance of contaminated drains. Sludge or sidewall samples were collected and analyzed from 50 manholes. The depth of contamination was assumed to be 1 cm. The UL_{95} value of the arithmetic mean was determined from data for all samples and was used as the exposure point concentration for the external gamma irradiation and incidental ingestion exposure routes; these values are presented in Tables 3.6 and 3.10, respectively.

3.4 Exposure to Contaminated Building Surfaces

Potential radiological exposures of a general plant employee were evaluated for each of the 17 buildings at SLDS that are known to be contaminated. Maximum radon and gamma rate measurements from each building were used as the exposure point concentrations; the exposure frequency assumed for each building was based on current usage (see Table 3.7). For the SLDS construction worker, the amount of time spent indoors in any one building while conducting renovation work could vary; therefore, exposures were estimated by assuming that, overall, a construction worker would spend no more than 100 hours at a building in any one year.

External gamma irradiation from indoor building surfaces was evaluated for the SLDS general plant employee and the construction worker. The maximum measured gamma exposure rate in each building (Table 2.6) was used to estimate the indoor gamma exposure from building surfaces. Because surface contamination is mainly fixed, inhalation and ingestion of particulates were not evaluated for the general plant employee. However, fugitive dust would be generated during renovation of the buildings, so inhalation and ingestion of particulates from building surfaces were evaluated for the construction worker.

Although direct alpha measurements were taken in each building, the maximum direct beta-gamma measurements (Table 2.6) were used to calculate ingestion intakes and inhalation of particulates from building surfaces. In general, the measurements taken in the buildings show that the beta-gamma values per unit area are significantly greater than the alpha values per unit area. Because SLDS was mainly used to process uranium material, much of the residual contamination is likely to be from uranium-238 and its decay products. Thus, the alpha and beta-gamma values would be expected to be comparable on the basis of the number of alpha and beta particles emitted by uranium-238 and its associated decay products. However, much lower values were measured for alpha contamination (in terms of dpm/cm^2), which is probably due to undercounting of the actual number of alpha particles emitted by various radionuclides. Alpha particles have a very short range and can be effectively shielded by rust and dirt, which were likely to be prevalent when the surveys were performed. Because beta particles and gamma rays are more penetrating than alpha particles, these two forms of radiation are easier to detect with field instruments and are likely to be more representative of the actual levels of contamination. Thus, the direct beta-gamma measurements, in dpm/cm^2, were converted to an equivalent concentration of alpha-emitting radionuclides, in pCi/g, to calculate ingestion intakes, as follows:

$$SC = \frac{DM \times CF}{T \times D} \tag{3.5}$$

where:

SC = wall surface concentration, pCi/g;

DM = direct beta-gamma measurement, dpm/cm^2;

CF = conversion factor, 0.45 pCi/dpm;

T = thickness of contamination on wall surfaces, 0.1 cm (assumed); and

D = density of concrete, 2.3 g/cm^3 (U.S. Public Health Service 1970).

The respirable concentration in air was calculated by multiplying the wall surface concentration by the respirable particulate concentration in air (i.e., 5 mg particulates/m^3). The maximum measured gamma exposure rates and exposure point concentrations for building surfaces and air in each building are presented in Table 3.8.

3.3.5 Exposure from Ingestion of Fish

Ingestion of fish caught in the Mississippi River was evaluated for the city property recreational user with sediment data obtained from the Mississippi River (only radiological data were available). Radionuclide concentrations in water were estimated from sediment concentrations on the basis of an assumed sediment loading factor. The sediment data indicate that, of the four radionuclides measured (i.e., uranium-238, radium-226, thorium-230, and thorium-232), radium-226 and uranium-238 levels were elevated over soil background concentrations (background sediment data were unavailable, so soil background data were used for comparative purposes). The average concentrations of radium-226 and uranium-238 were 370 and 26, respectively (Section 2.3.3). These values were used as the basis for estimating the potential exposure from the ingestion of fish from the Mississippi River. The fish ingestion pathway and the equation used to calculate potential doses from this exposure are discussed further in Section 3.4.6.

3.4 ESTIMATION OF CONTAMINANT DOSE AND INTAKE

Estimates of exposure are based on the contaminant concentrations at the exposure points (as described in Section 3.3) and scenario-specific assumptions and intake parameters. The scenario-specific assumptions include factors such as the age and weight of a potential receptor and the frequency and duration of exposure to contaminated media. Intake factors are specific to the route of exposure (e.g., inhalation or ingestion rates). The assumptions and intake factors for the exposure scenarios evaluated in this BRA are presented in Section 3.4.1. Estimated contaminant doses and intakes at the potential exposure points are presented in Sections 3.4.2 through 3.4.5.

In accordance with EPA guidance (EPA 1989c), intakes were estimated for a single route of exposure (e.g., incidental ingestion of soil) at a single exposure point (e.g., the HISS property). Exposure estimates have been based on the "reasonable maximum exposure" (RME) expected to occur under current and future land-use conditions. The RME is defined as the highest exposure that can reasonably be expected to occur at an exposure point.

Scenario assumptions and intake parameters used to estimate the RME were based, to the extent possible, on values provided in the *Human Health Evaluation Manual* (EPA 1989c) and in a recent supplement to that manual (EPA 1991b). In general, the value used for each parameter is the 90th or 95th percentile value; for some variables, the 50th percentile value is recommended.

Exposure to radioactive contaminants is expressed in terms of the 50-year committed effective dose equivalent (CEDE). To calculate the CEDE, the contaminant concentration at the exposure point (as estimated in Section 3.3) is multiplied by the intake factors appropriate for each medium and the appropriate dose conversion factor (DCF). Dose conversion factors, which are specific to the radionuclide and pathway, are used to determine the CEDE per unit intake of the radionuclide. The derivation of DCFs incorporates the following considerations for each radionuclide:

- The radiosensitivity of each internal organ,
- The three types of radiation emitted by the radionuclide (alpha, beta, and gamma), and
- The retention time of the radionuclide in the body following ingestion or inhalation — some radionuclides remain in the body for many years, continually irradiating the organ(s).

The radiological doses were calculated with the dose conversion factors summarized in Table 3.25. Separate dose conversion factors are provided for the various exposure routes (i.e., external gamma radiation, inhalation, and ingestion) for the radionuclides at the St. Louis Site. If several inhalation and ingestion dose conversion factors were available for a radionuclide, the factor resulting in the highest dose estimate was applied. The dose conversion factors reported in Table 3.25 are based on the dose conversion factors reported by DOE (1988a, 1988b); however, the dose contributions from decay product nuclides with half-lives of less than 1 year have been incorporated into the dose conversion factor for the parent radionuclide. For example, the dose contributions from thorium-234 and protactinium-234 have been included in the dose conversion factor for uranium-238. The radiological doses estimated for the current and future receptors are summarized in Tables 3.26 and 3.27.

The concept of committed dose applies only to internal pathways. For external pathways, there is no long-term residence of radionuclides in the body and the appropriate measure of dose is the effective dose equivalent (EDE). The sum of the CEDE (internal pathways) and the EDE (external pathways) is termed the total committed effective dose equivalent. For purposes of simplification, both CEDE and EDE are referred to as dose (expressed as mrem) in the following discussion.

Effective dose equivalents for external gamma radiation from soil and committed effective dose equivalents for inhalation of particulates were calculated with RESRAD, a computer program used to estimate doses to on-site receptors at radioactively contaminated sites (Gilbert et al. 1989). The doses received from inhalation of radon, incidental ingestion of soil, ingestion of groundwater, and external gamma radiation from field measurements were computed according to the methods described in Section 3.4.2.

Exposure to radon-222 and its short-lived decay products is reported in units of working-level month (WLM), rather than as dose in mrem. This method incorporates recent information on the radiological hazards associated with the inhalation of radon and its decay products (ICRP 1989).

Exposure to chemical contaminants is expressed in terms of intake, which is the amount of contaminant taken into the body per unit body weight per unit time (generally expressed as mg/kg-d).

3.4.1 Scenario-Specific Assumptions and Intake Parameters

The assumptions used to estimate radiological and chemical intakes for the receptors described in Section 3.2 are discussed in Sections 3.4.1.1 through 3.4.1.3 and summarized in Table 3.28.

3.4.1.1 Exposure Time, Exposure Frequency, and Exposure Duration

Exposure time, frequency, and duration represent the total time a receptor may spend at an exposure point. Exposure time is the number of hours per day that a receptor is present at a specific exposure point, exposure frequency is the number of days per year that the exposure occurs, and exposure duration is the total number of years over which exposure occurs.

Exposure for the SLDS employee was based on measurements taken from individual buildings within SLDS that are known to be contaminated. Because measurements taken in one building are considered to be distinct from measurements taken in another building, the potential exposure of any employee receptor is related to the amount of time this receptor spends in a certain building. Therefore, it was more appropriate to set the exposure time on the basis of the actual occupancy times in these buildings. These occupancy times were then based on current usage of these buildings, as summarized in Table 3.7. For buildings known to be used currently as a work area, the assumption was an exposure time of 8 hours per day and an exposure frequency of 250 days per year; at buildings known to be used for storage or warehousing, exposure time and frequency were assumed to be less, i.e., 2 hours per day, 125 days per year. Because the conditions and usages of these buildings could change or vary, the exposure duration was evaluated for 1 year and for 25 years (the latter is the EPA-recommended 95th percentile value for employment at the same location [EPA 1991b]); this presentation facilitates any variations of exposure durations desired to evaluate the aggregate risk for a given receptor who might spend time at several of these buildings in any given year or throughout that receptor's work life within the plant (i.e., 25 years).

The SLDS maintenance worker exposed to drain sediment was assumed to conduct ain maintenance activities twice annually, with an exposure time of 1 hour for each event. he assumed exposure duration was 25 years. The exposure time and frequency were based n site information indicating that required drain maintenance is infrequent.

Calculations for the SLDS construction worker were based on exposure for 8 hours er day, 25 days per year (including indoor and outdoor work). It was assumed that 50% of the exposure frequency for this worker would be related to indoor projects (e.g., renovation) nd 50% to outdoor projects (e.g., excavations). Calculations for the construction worker at he ditches adjacent to SLAPS were based on 8 hours per day for 50 days per year. Activities for this worker would be performed outdoors only.

For construction worker scenarios, an exposure duration of 1 year was assumed for ease of presentation, although the exposure duration might plausibly vary from 1 to 25 years, epending on needed construction and excavation work. To adjust the calculated radiological oses and chemical intakes for longer exposure durations, the doses, intakes, and risks resented in the tables in Chapters 3 and 5 should be multiplied by the number of years of stimated exposure.

For Futura Coatings and the commercial vicinity properties, it was assumed that xposure would take place 8 hours per day, 250 days per year (or 50 five-day work weeks per year) for 25 years. The exposure duration of 25 years is again based on a 95th percentile alue for employment at the same location (EPA 1991b).

The exposure frequencies for the SLAPS and HISS workers were set at 50 and 00 days per year, respectively, on the basis of maintenance activities currently required at hese properties. The exposure time and duration were assumed to be 8 hours per day and 25 years, respectively, for these receptors. In addition, the HISS maintenance worker was ssumed to spend 3 hours per day and the SLAPS worker 6 hours per day engaged in outdoor ctivities. The risks to maintenance workers at these two properties were added for the risk characterization (Section 5.2.1) because the same employee currently conducts maintenance t both SLAPS and HISS.

With one exception, the trespasser and recreational user scenarios assumed an xposure frequency of 26 days per year (once per week for 6 months). For the recreational user at the ballfield, exposure was assumed to be somewhat more frequent at 78 days per ear (three times per week for 6 months). Exposure time estimates for these scenarios varied rom 2 to 3 hours per exposure event. The exposure duration was estimated as 9 years for each of these scenarios, which is the range in years of the age groups considered (i.e., either 0 to 18 or 6 to 14) and is also the median time spent at one residence (EPA 1989c).

The child commuter at the residential vicinity property was assumed to be attending chool from grades 1 through 12 and to stand in the area of contamination while waiting for school bus 0.2 hours per day (1 hour per 5-day week) for about 9 months per year (180 days tal exposure frequency). This scenario assumed a 12-year exposure duration.

The current and future resident scenarios assumed an exposure frequency of 350 days per year and an exposure duration of 30 years, as recommended in EPA guidanc[illegible] (EPA 1991b). The assumed exposure time was 20 hours per day, allowing for 4 hours per day spent away from the property. Two hours per day was assumed to be spent outdoors on the property. For the evaluation of chemical intake via inhalation from household use of groundwater, it was assumed that the future resident would take a 10-minute shower daily.

3.4.1.2 Inhalation Rates

Recent EPA guidance recommends the use of an inhalation rate of 0.83 m^3/h (20 m^3/d) for the assessment of resident adult scenarios (EPA 1991b). This inhalation rate (which is based on the average inhalation rate over an entire day — including periods of rest, and light, moderate, and heavy activity) was used in this BRA for the current and future resident scenarios. It was also used for the employee scenarios for indoor work, which were assumed to involve light office or laboratory work.

The inhalation rate for other scenarios was adjusted to account for greater activity while working outdoors (SLAPS/HISS maintenance worker scenarios and SLDS/ditch construction worker scenarios) and higher inhalation rates in youths and children (trespasser scenarios and recreational users of the ballfield, city property, and Coldwater Creek). For the employee/maintenance worker scenarios, an inhalation rate of 1.2 m^3/h was applied, which is based on a combination of light, moderate, and heavy activity (EPA 1989a). An inhalation rate of 2.5 m^3/m was used for construction worker scenarios; these workers were assumed to have a high activity rate, so the high inhalation rate recommended by EPA (1991b) was appropriate. For the trespasser scenarios and the city property and Coldwater Creek recreational user scenarios, an inhalation rate of 1.8 m^3/h was applied; this rate is based on a combination of light and moderate activity and age-adjusted inhalation rates (EPA 1989a). The inhalation rate of 2.1 m^3/h for the ballfield recreational user was calculated on the basis of a combination of light and moderate activity and an inhalation rate for a 10-year-old child. The inhalation rate for the resident commuter was 0.83 m^3/h, which is based on light-activity inhalation rates for a child (EPA 1989a).

An inhalation rate of 0.83 m^3/h for the average adult doing light activity (EPA 1989a) was applied to assess the inhalation of contaminants during household use of groundwater (i.e., during showering). This pathway was assessed only for the future resident scenarios because there are no current users of groundwater at the St. Louis Site properties.

3.4.1.3 Ingestion Rates

Incidental soil ingestion rates were also based on recent EPA guidance (EPA 1991b). For most scenarios, the recommended soil ingestion rate of 100 mg per exposure event for adults and youths more than 6 years of age was appropriate. The soil ingestion rate recommended for employees working primarily indoors is 50 mg per exposure event (EPA 1991b); this rate was used in this BRA for employees at Futura Coatings and the commercial icinity properties. Because these employees were assumed to spend the entire exposure ration (i.e., 8 hours per day) indoors, a factor of 0.4 (Alzona et al. 1979) was applied to account for percentage of outdoor dust (particulates) transported indoors.

For the construction worker scenarios, a higher ingestion rate of 300 mg/d was used to account for extended daily exposure to the contaminated material and ingestion of inhaled material that is not retained in the lungs. For estimation of chemical exposure to the SLDS construction worker while engaged in indoor activities such as renovations (i.e., 12.5 days per year), a factor of 0.4 was applied to account for the percent of outdoor dust estimated to be transported indoors. This procedure was not necessary for radiological dose estimations because radiological ingestion estimates for indoor activities were based on measured surface contamination in buildings.

The EPA guidance recommends considering both childhood (when intake is greater) and adult exposures when evaluating soil ingestion for a residential scenario. Therefore, for the soil ingestion pathway only, exposure for the current and future resident was evaluated assuming 6 years of exposure as a child, with an ingestion rate of 200 mg per exposure event, and 24 years of exposure as an adult, with an ingestion rate of 100 mg per exposure event.

3.4.1.4 Body Weight

The standard assumption for adult body weight is 70 kg (EPA 1989c). Therefore, a dy weight of 70 kg was used for all employee/maintenance worker/construction worker scenarios and for that portion of the current or future resident scenario for which an adult was assessed. A body weight of 50 kg for youths aged 10 to 18 (EPA 1989a) was considered epresentative for the trespasser scenarios and the city property and Coldwater Creek recreational user receptors, and a body weight of 25 kg for youths aged 6 to 14 was assumed or the recreational user of the ballfield and the residential vicinity property commuter. A ody weight of 15 kg was used for the child portion of the future resident scenario (EPA 1991b).

3.4.2 Equations for Exposure to Soil

3.4.2.1 External Gamma Exposure

The RESRAD code was used to estimate external doses. Calculation of external gamma dose is detailed in Gilbert et al. (1989) and summarized as follows:

$$D_i = R_{si} \times ETF \times ED \times DCF_i \tag{3.6}$$

where:

D_i – dose from radionuclide i, mrem;

R_{si} = UL_{95} soil concentration of radionuclide i, pCi/g;

ETF = environmental transport factor, g/cm^3 (takes into account density of soil material, thickness of contaminated zone and cover, occupancy factor, shielding factor, shape factor, area factor, and depth factor);

ED = exposure duration, yr; and

DCF_i = external gamma dose conversion factor for radionuclide i, (mrem/yr)/(pCi/cm^3) (Table 3.25).

Scenario-specific assumptions on exposure time, frequency, and duration are given in Table 3.28. The depth, area, and shape factors (i.e., fractional values) are provided in Gilbert et al. (1989) to account for smaller areas of contamination and proximity to the contaminated source. It was assumed that the indoor external gamma exposure rate was reduced by 30% due to shielding afforded by structural materials. In calculating the dose from the 0.3- to 0.9-m (1-to 3-ft) layer, a cover of 0.3 m (1 ft) was assumed. The estimated external gamma doses are presented in Table 3.6 through 3.9 for current receptors and in Tables 3.11 and 3.13 for future receptors.

3.4.2.2 Inhalation of Radon

The doses resulting from inhalation of radon-222 and its short-lived decay products were based on the exposure point concentrations in either indoor or outdoor air (Section 3.3.1.2). Scenario-specific assumptions on exposure time, frequency, and duration and the assumed inhalation rates are given in Table 3.28. Estimated doses were calculated as follows:

$$WLM = \frac{C_{Rn} \times IR \times ET \times EF \times ED}{CF} \qquad (3.7)$$

where:

WLM = working level month(s);

C_{Rn} = indoor or outdoor air concentration of radon-222 decay products, WL;

IR = inhalation rate, m^3/h;

ET = exposure time, h/d;

EF = exposure frequency, d/yr;

ED = exposure duration, yr; and

CF = conversion factor, 204 m^3/mo (CF is the product of the inhalation rate, 1.2 m^3/h, and the number of working hours in 1 month, 170 h/mo).

These doses are not true doses but are actually exposures expressed in WLM. The WLM unit was used because the risk of inhalation of radon decay products is typically expressed in this unit (1 WLM is equivalent to 1,000 mrem [ICRP 1981]). The estimated doses associated with the inhalation of radon-222 decay products are presented in Tables 3.7, 3.8, 3.9, and 3.16 for current receptors and in Tables 3.13 and 3.17 for future receptors.

3.4.2.3 Incidental Ingestion of Soil

Scenario-specific assumptions on exposure time, frequency, and duration, and the ssumed ingestion rates for the various receptors are given in Table 3.28. For all scenarios xcept the SLDS construction worker and Futura Coatings employee, it was assumed that 100% of the soil or particulates ingested was from the contaminated source. The intake for he Future Coatings employee and for the indoor portion of the SLDS construction worker exposure frequency was multiplied by a factor of 0.4 to account for the exposures being indoors where particulates do not all originate from contaminated soil (Section 3.4.1.3).

Radiological Dose. Doses associated with the intake of radioactive contaminants sulting from incidental ingestion of surface soil were calculated as follows:

$$D_i = R_{si} \times IR_s \times CF \times EF \times ED \times DCF_i \qquad (3.8)$$

where:

D_i = dose from radionuclide i, mrem;

R_{si} = UL_{95} soil concentration of radionuclide i, pCi/g;

IR_s = soil ingestion rate, mg/d (from EPA 1991b);

CF = conversion factor, 10^{-3} g/mg;

EF = exposure frequency, d/yr;

ED = exposure duration, yr; and

DCF_i = ingestion dose conversion factor for radionuclide i, mrem/pCi (Table 3.25).

The estimated radiological doses from incidental ingestion are given in Tables 3.8 rough 3.10 for current receptors and in Tables 3.12 and 3.13 for future receptors.

Chemical Intake. The basic equation used to calculate chemical intake via ingestion is as follows:

$$\text{Intake (mg/kg-d)} = \frac{(C_i \times IR_s \times CF \times EF \times ED)}{(BW \times AF \times AD)} \qquad (3.9)$$

where:

C_i = UL_{95} soil concentration of chemical i, mg/kg (Section 3.3.1.1);

IR_s = soil ingestion rate, mg/d, as recommended by the EPA (1991b);

CF = conversion factor, 10^{-6} kg/mg

EF = exposure frequency, d/yr;

ED = exposure duration, yr;

BW = body weight, kg;

AF = averaging frequency, 365 d/yr; and

AD = averaging duration, yr (equal to ED for noncarcinogens and 70 years for carcinogens).

A modified equation was used for the future resident scenarios to model 6 years of childhood exposure and 24 years of adult exposure. The modified equation is as follows:

$$\text{Intake (mg/kg-d)} = \frac{(C_i \times IR_{sc} \times CF \times EF \times ED_c)}{(BW_c \times AF \times AD)} + \frac{(C_i \times IR_{sa} \times CF \times EF \times ED_a)}{(BW_a \times AF \times AD)} \qquad (3.10)$$

where:

C_i = UL_{95} soil concentration of chemical i, mg/kg (Section 3.3.1.1);

IR_{sc} = child soil ingestion rate, mg/d;

IR_{sa} = adult soil ingestion rate, mg/d;

CF = conversion factor, 10^{-6} kg/mg;

EF = exposure frequency, d/yr;

ED_c = child exposure duration, 6 yr;

ED_a = adult exposure duration, 24 yr;

BW_c = child body weight, 15 kg; and

BW_a = adult body weight, 70 kg;

AF = averaging frequency, 365 d/yr; and

AD = averaging duration, yr (equal to 30 years for noncarcinogens and 70 years for carcinogens).

Because chemical intakes for carcinogenic risk calculations are averaged over a lifetime of 70 years, the intakes calculated for use in carcinogenic risk estimates differ somewhat from those calculated for noncarcinogenic endpoint estimations. The estimated intakes from incidental ingestion of soil for both noncarcinogenic and carcinogenic risks are presented in Tables 3.29 and 3.30 for current and future receptors, respectively.

3.4.2.4 Inhalation of Particulates

Dose estimates and chemical intakes for the inhalation pathway for radioactive contaminants were calculated from the exposure point concentrations in air (Section 3.3.1.3). Scenario-specific assumptions on exposure time, frequency, and duration, and the assumed inhalation rates are given in Table 3.28. Particulate concentrations for indoor exposure were assumed to be 40% of those outdoors. It was also assumed that 100% of the total suspended particulates originating from soil-like matter (i.e., 50% of 0.08 mg/m^3) would be derived from contaminated soil.

Radiological Dose. The RESRAD code was used to calculate the radiological dose from inhalation of particulates. The dose calculation is detailed in Gilbert et al. (1989) and summarized as follows:

$$D_i = R_{ai} \times FA \times ET \times EF \times ED \times IR \times DCF_i \qquad (3.11)$$

where:

D_i = dose from radionuclide i, mrem;

R_{ai} = UL_{95} air concentration of radionuclide i, pCi/m^3, which is based on the UL_{95} soil concentration (Section 3.3.1.3);

FA = area factor, dimensionless (represents the fraction of air-borne particulates that is contaminated);

ET = exposure time, h/d;

EF = exposure frequency, d/yr;

ED = exposure duration, yr;

IR = inhalation rate, m^3/h; and

DCF_i = inhalation dose conversion factor for radionuclide i, mrem/pCi (Table 3.25).

The estimated doses for the identified receptors resulting from the inhalation of airborne radioactive particulates are presented in Table 3.18 for current receptors and Tables 3.13 and 3.19 for future receptors.

Chemical Intake. The following equation was used to calculate chemical intake via inhalation when all exposure was outdoors:

$$\text{Intake (mg/kg-d)} = \frac{(C_i \times IR \times ET \times EF \times ED)}{(BW \times AF \times AD)} \qquad (3.12)$$

where:

C_i = concentration of chemical i in air, mg/m^3, based on UL_{95} soil concentration (Section 3.3.1.3);

IR = inhalation rate, m^3/h;

ET = exposure time, h/d;

EF = exposure frequency, d/yr;

ED = exposure duration, yr;

BW = body weight, kg;

AF = averaging frequency, 365 d/yr; and

AD = averaging duration, yr (70 years for carcinogens).

For receptors assumed to spend some portion of the exposure time indoors (i.e., SLAPS/HISS maintenance worker, SLDS construction worker, Futura Coatings employee, and future resident), the concentration of particulates indoors was assumed to be reduced by 60%. Equation 3.12 was modified to account for this assumption, as follows:

$$\text{Intake (mg/kg-d)} = \frac{(C_i \times IR_{out} \times ET_{out} \times EF \times ED)}{(BW \times AF \times AD)} + \frac{(C_i \times IR_{in} \times ET_{in} \times 0.4 \times EF \times ED)}{(BW \times AF \times AD)} \qquad (3.13)$$

where:

C_i = concentration of chemical i in air, mg/m^3, based on UL_{95} soil concentration Section 3.3.1.3);

IR_{out} = outdoor inhalation rate, m^3/h;

IR_{in} = indoor inhalation rate, m^3/h;

ET_{out} = exposure time outdoors;

ET_{in} = exposure time indoors;

EF = exposure frequency, d/yr;

ED = exposure duration, yr;

BW = body weight, kg;

AF = averaging frequency, 365 d/yr; and

AD = averaging duration, yr (70 years for carcinogens).

Because data on noncarcinogenic toxicity from inhalation of soil contaminants of oncern are not available (see Section 4.2.2.2), only the potential carcinogenicity of inhalation ould be evaluated. Therefore, inhalation intakes were calculated for carcinogens only, and all intakes were averaged over 70 years. The estimated chemical intakes for the inhalation of carcinogens are summarized in Tables 3.31 and 3.32 for current and future receptors, respectively.

3.4.3 Equations for Exposure to Groundwater

3.4.3.1 Ingestion of Groundwater

Radionuclide doses and chemical intakes from ingestion of groundwater were calculated on the basis of exposure point concentrations in groundwater (Section 3.3.2.1). Scenario-specific assumptions on exposure time, frequency, and duration, and the assumed ngestion rates are given in Table 3.28.

Radiological Dose. The doses associated with intake of radioactive contaminants resulting from ingestion of groundwater were calculated as follows:

$$D_i = R_{wi} \times IR_w \times EF \times ED \times DCF_i \qquad (3.14)$$

where:

D_i = dose from radionuclide i, mrem;

R_{wi} = concentration of radionuclide i in water, pCi/L (based on maximum level in groundwater for each property);

IR_w = water ingestion rate, L/d;

EF = exposure frequency, d/yr;

ED = exposure duration, yr; and

DCF_i = ingestion dose conversion factor for radionuclide i, mrem/pCi (Table 3.25).

Estimated doses from ingestion of radioactive contaminants in groundwater are presented in Table 3.22.

Chemical Intake. The following equation was used for the calculation of chemical intake via ingestion of groundwater:

$$\text{Intake (mg/kg-d)} = \frac{(C_i \times IR_w \times EF \times ED)}{(BW \times AF \times AD)} \qquad (3.15)$$

where:

C_i = concentration of chemical i in groundwater, mg/L (based on maximum level detected in groundwater for each property);

IR_w = water ingestion rate, L/d;

EF = exposure frequency, d/yr;

ED = exposure duration, yr;

BW = body weight, kg;

AF = averaging frequency, 365 d/yr; and

AD = averaging duration, yr (equal to ED for noncarcinogens and 70 years for carcinogens).

Because chemical intakes for carcinogenic risk calculations were averaged over a ifetime of 70 years, the intakes calculated for use in carcinogenic risk estimates differ somewhat from those calculated for noncarcinogenic endpoint estimations. The estimated intakes of chemical contaminants from ingestion of groundwater are presented in Table 3.33.

3.4.3.2 Inhalation of Contaminants from Groundwater

Potential inhalation of radon from groundwater is addressed in Section 3.3.2.2. Therefore, only estimated chemical intakes are discussed in this section. Chemical intakes were based on the exposure point concentrations in shower air (Section 3.3.2.2). These air concentrations were calculated from maximum groundwater concentrations for each property. Scenario-specific assumptions on exposure time, frequency, and duration and the assumed inhalation rates are given in Table 3.28.

The following equation was used to calculate chemical intake of contaminants from groundwater via inhalation:

$$\text{Intake (mg/kg-d)} = \frac{(C_i \times IR \times ET \times EF \times ED)}{(BW \times AF \times AD)} \qquad (3.16)$$

where:

C_i = concentration of chemical i in shower air, mg/m^3 (based on maximum level detected in groundwater for each property);

IR = inhalation rate, m^3/h;

ET = exposure time, h/d;

EF = exposure frequency, d/yr;

ED = exposure duration, yr;

BW = body weight, kg;

AF = averaging frequency, 365 d/yr; and

AD = averaging duration, yr (equal to ED for noncarcinogens and 70 years for carcinogens).

Data on both noncarcinogenic and carcinogenic toxicity (i.e., inhalation reference doses and slope factors) are available for several of the groundwater contaminants of concern. Because chemical intakes for carcinogenic risk calculations were averaged over a lifetime of 70 years, the intakes calculated for use in carcinogenic risk estimates differ somewhat from hose calculated for noncarcinogens. The estimated chemical intakes from showering for both noncarcinogenic and carcinogenic risks are presented in Table 3.34.

3.4.4 Equations for Exposure to External Gamma Radiation and Radioactive Contaminants from Incidental Ingestion of Sediment in Drains

The exposures to external gamma irradiation and radioactive contaminants from incidental ingestion of sediment for a worker conducting intermittent maintenance of contaminated drains were calculated with Equations 3.6 and 3.8 (Sections 3.4.2.1 and 3.4.2.3). The estimated doses from external gamma irradiation and incidental ingestion of sediment are given in Tables 3.6 and 3.10, respectively.

3.4.5 Equations for Contaminated Building Surfaces

Field measurements obtained from SLDS buildings were used to calculate the indoor external gamma irradiation dose to an employee and construction worker from contaminated building surfaces. The dose from external gamma irradiation was calculated by multiplying the length of time an individual was assumed to be exposed to the radiation field by the measured field strength and a dose conversion factor of 0.95 mrem/mR. The exposures from ingestion and inhalation of airborne particulates resulting from building renovation for the construction worker were calculated with Equations 3.8 and 3.11 (Sections 3.4.2.3 and 3.4.2.4). In this analysis, the dose conversion factor for uranium-238 was applied to all alpha-emitting radionuclides in the buildings. This approach was considered reasonable because the buildings were used primarily to process uranium materials and the inhalation and ingestion dose conversion factors for uranium-238 are representative of those for the other alpha-emitting radionuclides in the buildings.

Estimated external gamma doses from contaminated building surfaces are presented in Table 3.7 for the SLDS plant employee. The estimated doses from external gamma irradiation, inhalation, and ingestion of particulates are given in Table 3.8 for a construction worker assumed to spend 100 hours in each building. The dose to the construction worker from outdoor exposure, also for 100 hours, is given in Table 3.9.

3.4.6 Equations for Ingestion of Fish

Radiological doses from ingestion of fish were calculated on the basis of exposure point concentrations in sediment (see Section 3.3.5). Dose estimates for the ingestion of fish pathway were calculated as follows:

$$D_i = SC_i \times SLF \times CF \times BCF_i \times FT \times IR_f \times EF \times ED \times DCF_i \qquad (3.17)$$

where:

D_i = dose from radionuclide i, mrem;

SC_i = concentration of radionuclide i in sediment, pCi/g;

SLF = sediment loading factor, 1,100 mg/L (Reed et al. 1990);

CF = conversion factor, 10^{-3} g/mg;

BCF_i = bioconcentration factor, 50 L/kg for radium-226 and 2 L/kg for uranium-238 (Gilbert et al. 1989);

FT = fraction of time fish is in area of contaminated sediment, 0.1 (assumed);

IR_f = fish ingestion rate, 0.25 kg/event (EPA 1991b);

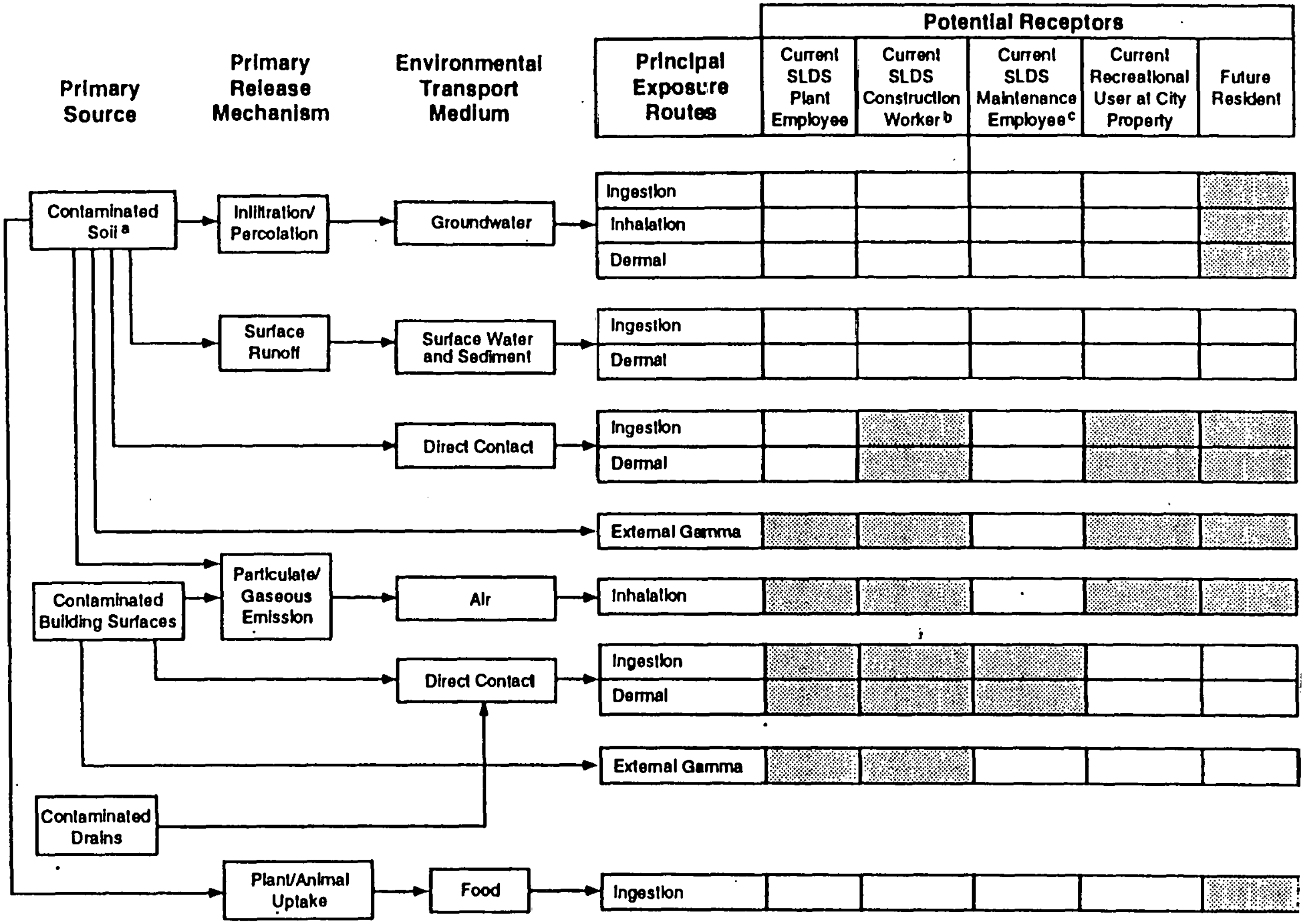
EF = exposure frequency, events/year;

ED = exposure duration, yr; and

DCF = ingestion dose conversion factor for radionuclide i, mrem/pCi (Table 3.25).

The sediment loading factor was obtained from the U.S. Geological Survey water report for Missouri (Reed et al. 1990). The sediment loading data for 1990 indicate that these alues were generally highest in the month of June. The value of 1,100 mg/L used in this analysis was obtained by averaging the daily average sediment loading measurements from [illegible]at month.

The concentrations in fish were estimated from the bioconcentration factors for freshwater fish presented in Gilbert et al. (1989). The scenario intake parameters include he fraction of time the fish is assumed to be in the area of contaminated sediment (i.e., 0.1) and an ingestion rate of 250 g per event or meal, which is based on the assumption of 8 oz er serving or per meal, as described in EPA (1991b) guidance. Other parameters are those presented in Table 3.28 for the city property recreational user scenario. The results indicate that an estimated dose of 130 mrem from radium-226 and 2.1 mrem from uranium-238 could e incurred by a recreational user at the city property from this pathway.

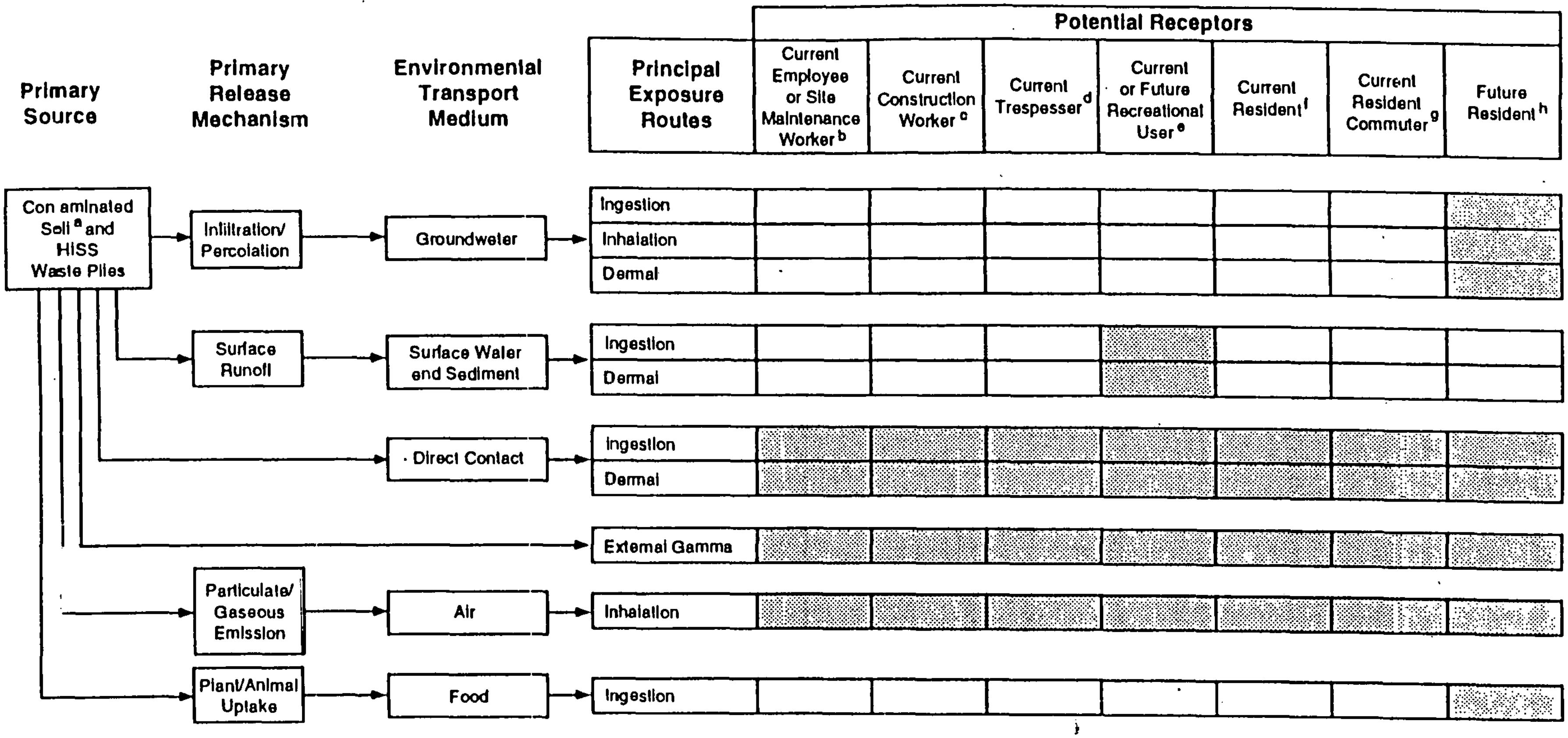


Environmental Transport Medium	Principal Exposure Routes	Current SLDS Plant Employee	Current SLDS Construction Worker[b]	Current SLDS Maintenance Employee[c]	Current Recreational User at City Property	Future Resident
Groundwater	Ingestion					▨
	Inhalation					▨
	Dermal					▨
Surface Water and Sediment	Ingestion					
	Dermal					
Direct Contact	Ingestion		▨		▨	▨
	Dermal		▨		▨	▨
	External Gamma	▨	▨		▨	▨
Air	Inhalation	▨	▨		▨	▨
Direct Contact	Ingestion	▨	▨	▨		
	Dermal	▨	▨	▨		
	External Gamma	▨	▨			
Food	Ingestion					▨

[a] Contaminated soil at the SLDS is currently covered by buildings, concrete, or asphalt, which prevents exposure via direct contact or surface runoff.
[b] Exposure of the SLDS construction worker assumes that concrete and asphalt has been removed.
[c] Represents worker conducting infrequent drain maintenance; only exposure to drain sediment is considered.

▨ Potentially complete exposure pathway

FIGURE 3.1 Conceptual Site Model for SLDS, SLDS Vicinity Properties, and City Property



Environmental Transport Medium	Principal Exposure Routes	Current Employee or Site Maintenance Worker[b]	Current Construction Worker[c]	Current Trespasser[d]	Current or Future Recreational User[e]	Current Resident[f]	Current Resident Commuter[g]	Future Resident[h]
Groundwater	Ingestion							▨
	Inhalation							▨
	Dermal							▨
Surface Water and Sediment	Ingestion				▨			
	Dermal				▨			
Direct Contact	Ingestion	▨	▨	▨	▨	▨	▨	▨
	Dermal	▨	▨	▨	▨	▨	▨	▨
	External Gamma	▨	▨	▨	▨	▨	▨	▨
Air	Inhalation	▨	▨	▨	▨	▨	▨	▨
Food	Ingestion							▨

[a] Includes soil along the banks of Coldwater Creek.
[b] Employee at Futura or commercial/industrial/municipal vicinity property; maintenance worker at SLAPS or HISS.
[c] Construction worker doing excavation activities at the ditches or other vicinity properties.
[d] Trespasser at SLAPS or HISS.
[e] Current recreational user of ballfield area and current or future recreational user of Coldwater Creek.
[f] Receptor in dwelling at residential vicinity property.
[g] Receptor near area of contamination at residential vicinity property.
[h] A resident at all properties except Coldwater Creek.

▨ Potentially complete exposure pathway

FIGURE 3.2 Conceptual Site Model for SLAPS, HISS, and Other Properties

TABLE 3.1 Property Groups and Corresponding Receptors Assumed for Current and Future Land-Use Scenarios at the St. Louis Site

Property Grouping	Current Receptor	Future Receptor
SLDS, SLDS vicinity properties, and city property	SLDS/SLDS vicinity property employee, SLDS construction worker, SLDS maintenance worker (drains), city property recreational user	Resident
SLAPS, SLAPS ditches, and HISS	Maintenance worker, trespasser, construction worker	Resident
Residential vicinity properties	Child commuter, resident	Resident
Ballfield area	Recreational user	Resident
Coldwater Creek	Recreational user	Recreational user
Futura Coatings property and other properties used for commercial/industrial/ municipal purposes	Employee	Resident

TABLE 3.2 Environmental Transport Media and Exposure Pathways Assessed for Current Receptors at the St. Louis Site[a]

	Air			Direct Contact
	External Gamma Irradiation[b]	Inhalation[c]		
Potential Receptors		Particulates	Radon	Ingestion[b]
SLDS employee	R	IC	R[d]	IC
SLDS construction worker	R	R, C	R[d]	R, C
SLDS maintenance worker (drains)	R	IC	IC	R
City property recreational user	R	R, C	R	R, C[e]
SLAPS trespasser	R	R, C	R	R, C
SLAPS maintenance worker	R	R, C	R	R, C
Ditch construction worker	R	R, C	R	R, C
Residential vicinity property child commuter	R	R	R	R
Residential vicinity property current resident	R	R	R	R
Ballfield recreational user	R	R, C	R	R, C
Coldwater Creek recreational user	R	R, C	R	R, C
Futura Coatings employee	R	R, C	R[d]	R, C
HISS trespasser	R	R, C	R	R, C
HISS maintenance worker	R	R, C	R[d]	R, C

[a] R = radiological dose and risk assessed; C = chemical intake and risk assessed; IC = incomplete pathway.

[b] Exposure from soil, sediment, surfaces, or drains.

[c] Exposure from soil, sediment, or surfaces.

[d] Indoor radon based on measurements taken inside buildings or trailers (Table 2.6).

[e] Ingestion of contaminated fish was also assessed for this receptor; only radiological data were available for the evaluation.

TABLE 3.3 Environmental Transport Media and Exposure Pathways Assessed for Future Receptors at the St. Louis Site[a]

Potential Receptors	Air: External Gamma Irradiation[b]	Air: Inhalation[b]: Particulates	Air: Inhalation[b]: Radon	Direct Contact: Ingestion[c]
SLDS/SLDS vicinity property/ city property future resident	R	R, C	R	R, C
SLAPS future resident	R	R, C	R	R, C
Residential vicinity property future resident	R	R	R	R
Ballfield future resident	R	R, C	R	R, C
Coldwater Creek future recreational user[d]	R	R, C	R	R, C
Futura Coatings future resident	R	R, C	R	R, C
HISS future resident[e]	R	R, C	R	R, C

[a] R = radiological dose and risk assessed; C = chemical intake and risk assessed.

[b] Exposure from soil.

[c] Exposure from soil; radiological and chemical exposure resulting from ingestion of groundwater was also assessed for SLDS, SLAPS, and HISS future residents.

[d] Same risk estimates as for the current site use estimates.

[e] Additional radiological exposure (via similar pathways as for soil) were also estimated on the basis of data from the HISS pile as it existed in 1981; these results are presented in Table 3.13.

TABLE 3.4 Statistical Parameters for Derivation of Soil UL_{95} Values for Radionuclides[a]

		Uranium-238				Radium-226			
Property	Depth (ft)	Mean	n	s	UL_{95}	Mean	n	s	UL_{95}
City property	0-1	110	210	1,400	300	30	210	130	47
	1-3	2.8	16	2.0	3.8	4.8	16	3.6	6.7
	0-3	100	227	1,300	280	28	227	120	44
SLDS/City property	0-1	130	542	1,100	220	46	542	270	69
	1-3	53	143	200	87	11	143	44	18
	0-3	110	772	960	180	36	772	230	52
	0-8	140	1,115	1,400	220	27	1,115	190	38
SLDS (drains)[b]	0-1	27	50	50	41	11	50	22	17
SLAPS/Ditches	0-1	32	194	56	39	26	194	160	49
	1-3	21	178	40	27	23	178	140	43
	0-3	28	398	50	33	26	398	150	41
	0-8	40	636	97	48	41	635	290	63
SLAPS (ditches only)	0-8	12	295	11	13	3.9	295	9.3	5.0
Residential VPs[c]	0-1	-[d]	-	-	-	-	-	-	-
	1-3	-	-	-	-	-	-	-	-
	0-3	-	-	-	-	-	-	-	-
Ballfield	0-1	7.1	384	3.1	7.4	2.1	384	9.9	3.1
	1-3	7.3	142	2.6	7.8	1.5	142	0.50	1.6
	0-3	7.2	526	3.0	7.4	1.9	526	8.5	2.7
	0-8	7.2	549	3.0	7.4	1.9	549	8.3	2.6
Coldwater Creek	0-1	1.2	255	1.4	1.3	1.1	255	0.38	1.2
Futura Coatings	0-1	19	41	21	26	8.7	41	19	15
	1-3	18	116	68	30	12	116	72	25
	0-3	18	157	59	27	11	157	62	21
	0-8	24	439	120	35	17	439	120	29
HISS	0-1	44	35	130	89	35	35	120	75
	1-3	30	69	78	48	23	69	60	37
	0-3	34	104	99	54	27	104	83	43
	0-8	17	280	62	25	11	280	52	17

TABLE 3.4 (Cont.)

Property	Depth (ft)	Thorium-232				Thorium-230			
		Mean	n	s	UL_{95}	Mean	n	s	UL_{95}
City property	0-1	2.6	210	4.5	3.2	28	210	85	40
	1-3	1.8	16	1.2	2.4	2.2	16	1.7	3.1
	0-3	2.5	227	4.4	3.1	26	227	82	37
SLDS/City property	0-1	6.5	542	31	9.0	84	542	780	150
	1-3	3.1	143	4.6	3.8	10	143	28	15
	0-3	5.4	772	26	7.2	71	772	690	120
	0-8	4.5	1,115	22	5.8	56	1,111	580	90
SLDS (drains)[b]	0-1	23	50	92	49	88	50	380	190
SLAPS/Ditches	0-1	2.6	194	2.5	3.0	400	115	1,500	670
	1-3	2.2	178	1.9	2.5	140	98	400	220
	0-3	2.5	398	2.2	2.7	280	213	1,100	430
	0-8	2.9	636	3.7	3.2	190	404	840	270
SLAPS (ditches only)	0-8	1.8	295	0.78	1.9	200	245	1,000	320
Residential VPs[c]	0-1	-	-	-	-	27	8	41	61
	1-3	-	-	-	-	1.4	3	0.15	1.7
	0-3	-	-	-	-	20	11	36	44
Ballfield	0-1	1.8	384	0.65	1.8	17	485	120	28
	1-3	1.8	142	0.71	2.0	2.2	75	1.7	2.6
	0-3	1.8	526	0.67	1.8	15	560	110	24
	0-8	1.8	549	0.66	1.8	14	583	110	23
Coldwater Creek	0-1	0.76	255	0.38	0.80	5.1	255	9.9	6.3
Futura Coatings	0-1	2.4	41	1.2	2.8	65	12	82	120
	1-3	2.1	116	1.1	2.3	79	54	170	120
	0-3	2.2	157	1.1	2.3	76	66	150	110
	0-8	2.1	439	1.7	2.3	52	209	180	77
HISS	0-1	2.0	35	0.93	2.4	-	-	-	-
	1-3	1.8	69	0.89	2.0	78	27	200	160
	0-3	1.9	104	0.91	2.1	78	27	200	160
	0-8	1.7	280	0.76	1.8	28	91	120	52

[a] This table is a summary of the UL_{95} values used to calculate radiological exposures from soil-associated pathways for this assessment. The means are arithmetic means of soil concentrations for a given radionuclide measured in pCi/g; n = number of samples and s = standard deviation. The UL_{95} values presented here for uranium-238, radium-226, thorium-232, and thorium-230 were used in conjunction with the ratios presented in Table 2.15 to obtain analogous values for the remaining radionuclides.

[b] SLDS drain data is based on sediment and sludge measurements; the depth of contamination was assumed to be 1 cm.

[c] VPs = vicinity properties.

[d] A hyphen indicates that no measurement was available.

TABLE 3.5 Statistical Parameters for Derivation of Soil UL_{95} Values for Chemical Contaminants[a]

	SLDS				City Property				SLDS and City Property Combined[b]			
Contaminant	Mean	n	s	UL_{95}	Mean	n	s	UL_{95}	Mean	n	s	UL_{95}
Antimony	49	102	320	110	180	7	130	310	57	109	310	120
Arsenic	28	102	26	33	11	7	1.8	12	27	109	25	32
Beryllium	0.78	102	0.51	0.88	0.73	7	0.25	0.96	0.77	109	0.50	0.87
Cadmium	2.3	102	5.0	3.3	1.2	7	0.58	1.8	2.2	109	4.8	3.1
Cobalt	9.3	102	23	14	6.1	7	1.8	7.8	9.1	109	22	13
Copper	-[c]	-	-	-	-	-	-	-	-	-	-	-
Lead	730	102	3,300	1,400	350	7	230	560	710	109	3,200	1,300
Molybdenum	-	-	-	-	-	-	-	-	-	-	-	-
Nickel	24	102	23	29	19	7	4.5	23	24	109	23	28
Selenium	-	-	-	-	-	-	-	-	-	-	-	-
Thallium	38	102	51	48	30	7	20	49	37	109	50	47
Uranium	330	545	2,200	520	310	227	3,900	820	320	772	2,800	530
Zinc	-	-	-	-	-	-	-	-	-	-	-	-

	SLAPS				Ballfield				Ballfield (Surface and Subsurface Soil)[d]			
Contaminant	Mean	n	s	UL_{95}	Mean	n	s	UL_{95}	Mean	n	s	UL_{95}
Antimony	4.8	41	2.3	5.6	6.5	13	0.45	6.7	13	31	34	26
Arsenic	16	41	36	28	11	13	0.76	11	35	31	120	78
Beryllium	0.99	41	1.7	1.5	0.53	13	0.040	0.56	1.3	31	3.2	2.4
Cadmium	1.3	41	1.3	1.7	0.60	13	0.24	0.75	1.3	31	3.1	2.4
Cobalt	350	41	1,200	720	5.8	13	1.5	6.7	13	31	33	25
Copper	230	41	770	470	-	-	-	-	-	-	-	-
Lead	81	41	150	130	21	13	12	28	28	31	33	41
Molybdenum	-	-	-	-	11	13	0.76	11	36	31	130	85
Nickel	460	41	1,500	920	14	13	7.5	19	22	31	32	34
Selenium	-	-	-	-	11	13	0.76	11	38	31	130	84
Thallium	8.9	41	5.2	11	11	13	0.76	11	39	31	130	87
Uranium	83	398	150	98	-	-	-	-	-	-	-	-
Zinc	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 3.5 (Cont.)

	Futura Coatings				Futura Coatings (Surface and Subsurface Soil)[d]				HISS[e]			
Contaminant	Mean	n	s	UL_{95}	Mean	n	s	UL_{95}	Mean	n	s	UL_{95}
Antimony	-	-	-	-	-	-	-	-	12	6	4.4	56
Arsenic	11	6	0.94	12	30	16	77	71	30	6	6.3	210
Beryllium	0.54	6	0.052	0.59	2.0	16	5.4	4.8	1.5	6	4.5	7.4
Cadmium	-	-	-	-	-	-	-	-	1.9	6	4.2	8.4
Cobalt	50	6	51	100	940	16	3,500	2,800	130	6	6.1	860
Copper	55	6	42	99	630	16	2,300	1,800	-	-	-	-
Lead	59	6	46	110	72	16	130	140	69	6	3.5	260
Molybdenum	15	6	5.6	20	75	16	230	200	38	6	5.7	240
Nickel	79	6	73	160	1,200	16	4,300	3,500	190	6	4.5	900
Selenium	11	6	0.94	12	75	16	260	210	29	6	6.2	200
Thallium	11	6	0.94	12	11	16	1.4	12	30	6	6.2	200
Uranium	53	157	175	80	53	157	180	80	79	104	250	160
Zinc	-	-	-	-	-	-	-	-	-	-	-	-

[a] This table is a summary of the UL_{95} values used to calculate chemical exposures from soil-associated pathways for this assessment. Parameters are given for the chemical contaminants of concern for surface soil at each site property (see Table 2.21). No statistical parameters are given for Coldwater Creek or for PAHs at SLDS and the city property because maximum values were used as exposure point concentrations. For samples reported at the detection limit, half the sample detection limit was used as the sample concentration. The means are arithmetic means of soil concentrations for a given chemical measured in mg/kg, except as noted; n = number of samples, and s = standard deviation. The UL_{95} values are 95% upper confidence limits of the arithmetic means (see Section 3.3).

[b] These data were used for the evaluation of potential future residential land use at SLDS and the city property combined.

[c] A hyphen indicates that the substance is not a contaminant of concern for that property.

[d] Data for surface and subsurface soil were combined for the evaluation of potential future residential land use of the ballfield and Futura Coatings property because these overall concentrations were higher than the surface soil concentrations.

[e] Except for uranium, the means and standard deviations given are geometric means and geometric standard deviations. The UL_{95} of the geometric mean was used in risk calculations for HISS, as recommended for highly skewed sample distributions (Gilbert 1987); the UL_{95} of the arithmetic mean was used for uranium.

TABLE 3.6 Radionuclide Exposure Point Concentrations and Estimated External Gamma Doses for Current Receptors at the St. Louis Site[a]

	Actinium-227+D			Lead-210+D		
	Soil Concentration (pCi/g)		External Gamma Dose (mrem)	Soil Concentration (pCi/g)		External Gamma Dose (mrem)
Property and Receptor	0-1 ft	1-3 ft		0-1 ft	1-3 ft	
SLDS employee[b]	-	-	-	-	-	-
SLDS construction worker[b]	-	-	-	-	-	-
SLDS maintenance worker (drains)[c]	6.7	-	9.2×10^{-5}	22	-	6.4×10^{-7}
City property recreational user	45	6.4	10	85	12	0.030
SLAPS trespasser	45	40	6.7	81	71	0.019
SLAPS maintenance worker	45	40	130	81	71	0.38
Ditch construction worker[d]	5.0	-	0.65	9.0	-	1.8×10^{-3}
Residential vicinity property child commuter	0.43	0.012	0.045	0.86	0.024	1.5×10^{-4}
Residential vicinity property current resident	0.43	0.012	6.4	0.86	0.024	0.021
Ballfield recreational user	2.9	1.5	2.0	5.1	2.7	5.5×10^{-3}
Coldwater Creek recreational user[e]	1.3	-	0.19	2.9	-	6.8×10^{-4}
Futura Coatings employee	16	27	180	35	59	0.62
HISS trespasser	82	40	12	180	87	0.043
HISS maintenance worker	82	40	850	180	87	2.9

	Protactinium-231			Radium-226+D		
	Soil Concentration (pCi/g)		External Gamma Dose (mrem)	Soil Concentration (pCi/g)		External Gamma Dose (mrem)
Property and Receptor	0-1 ft	1-3 ft		0-1 ft	1-3 ft	
SLDS employee[b]	-	-	-	-	-	-
SLDS construction worker[b]	-	-	-	-	-	-
SLDS maintenance worker (drains)[c]	6.1	-	6.8×10^{-6}	17	-	9.9×10^{-4}
City property recreational user	45	6.4	0.80	47	6.7	58
SLAPS trespasser	51	45	0.61	49	43	41
SLAPS maintenance worker	51	45	12	49	43	820
Ditch construction worker[d]	5.0	-	0.051	5.0	-	3.6
Residential vicinity property child commuter	0.49	0.014	4.1×10^{-3}	0.43	0.012	0.25
Residential vicinity property current resident	0.49	0.014	0.58	0.43	0.012	35
Ballfield recreational user	3.2	1.7	0.17	3.1	1.6	12
Coldwater Creek recreational user[e]	1.6	-	0.019	1.2	-	0.97
Futura Coatings employee	20	33	18	15	25	980
HISS trespasser	99	49	1.2	75	37	62
HISS maintenance worker	99	49	82	75	37	4,300

TABLE 3.6 (Cont.)

	Radium-228+D			Thorium-228+D		
	Soil Concentration (pCi/g)		External Gamma Dose (mrem)	Soil Concentration (pCi/g)		External Gamma Dose (mrem)
Property and Receptor	0-1 ft	1-3 ft		0-1 ft	1-3 ft	
SLDS employee[b]	-	-	-	-	-	-
SLDS construction worker[b]	-	-	-	-	-	-
SLDS maintenance worker (drains)[c]	40	-	1.3×10^{-3}	50	-	2.0×10^{-3}
City property recreational user	1.2	0.94	0.80	3.0	2.3	3.3
SLAPS trespasser	0.83	0.69	0.37	2.6	2.1	1.9
SLAPS maintenance worker	0.83	0.69	7.3	2.6	2.1	37
Ditch construction worker[d]	0.54	-	0.21	1.6	-	1.0
Residential vicinity property child commuter[f]	0	0	0	0.061	1.7×10^{-3}	0.029
Residential vicinity property current resident[f]	0	0	0	0.061	1.7×10^{-3}	4.2
Ballfield recreational user	0.50	0.55	1.0	1.5	1.7	17
Coldwater Creek recreational user[e]	0.064	-	0.027	0.80	-	0.53
Futura Coatings employee	0.22	0.18	7.3	2.8	2.3	150
HISS trespasser	0.19	0.16	0.084	2.4	2.0	1.7
HISS maintenance worker	0.19	0.16	5.9	2.4	2.0	120

	Thorium-230			Thorium-232		
	Soil Concentration (pCi/g)		External Gamma Dose (mrem)	Soil Concentration (pCi/g)		External Gamma Dose (mrem)
Property and Receptor	0-1 ft	1-3 ft		0-1 ft	1-3 ft	
SLDS employee[b]	-	-	-	-	-	-
SLDS construction worker[b]	-	-	-	-	-	-
SLDS maintenance worker (drains)[c]	190	-	3.4×10^{-6}	49	-	5.4×10^{-7}
City property recreational user	40	3.1	6.3×10^{-3}	3.2	2.4	3.0×10^{-4}
SLAPS trespasser	670	220	0.070	3.0	2.5	1.9×10^{-4}
SLAPS maintenance worker	670	220	1.4	3.0	2.5	3.7×10^{-3}
Ditch construction worker[d]	320	-	0.029	1.9	-	1.0×10^{-4}
Residential vicinity property child commuter	61	1.7	4.5×10^{-3}	0.061	1.7×10^{-3}	2.7×10^{-6}
Residential vicinity property current resident	61	1.7	0.64	0.061	1.7×10^{-3}	3.8×10^{-4}
Ballfield recreational user	28	2.6	0.013	1.8	2.0	5.1×10^{-4}
Coldwater Creek recreational user[e]	6.3	-	6.6×10^{-4}	0.80	-	5.0×10^{-5}
Futura Coatings employee	120	120	0.95	2.8	2.3	0.013
HISS trespasser	160	160	0.017	2.4	2.0	1.5×10^{-4}
HISS maintenance worker	160	160	1.2	2.4	2.0	0.011

TABLE 3.6 (Cont.)

Property and Receptor	Uranium-234 Soil Concentration (pCi/g) 0-1 ft	Uranium-234 Soil Concentration (pCi/g) 1-3 ft	Uranium-234 External Gamma Dose (mrem)	Uranium-235+D Soil Concentration (pCi/g) 0-1 ft	Uranium-235+D Soil Concentration (pCi/g) 1-3 ft	Uranium-235+D External Gamma Dose (mrem)
SLDS employee[b]	-	-	-	-	-	-
SLDS construction worker[b]	-	-	-	-	-	-
SLDS maintenance worker (drains)[c]	41	-	4.5×10^{-7}	1.9	-	1.3×10^{-6}
City property recreational user	300	3.8	0.033	14	0.17	1.0
SLAPS trespasser	39	27	2.8×10^{-3}	1.8	1.2	0.087
SLAPS maintenance worker	39	27	0.056	1.8	1.2	1.7
Ditch construction worker[d]	13	-	8.1×10^{-4}	0.60	-	0.025
Residential vicinity property child commuter[f]	0.73	0.020	3.7×10^{-5}	0	0	0
Residential vicinity property current resident[f]	0.73	0.020	5.3×10^{-3}	0	0	0
Ballfield recreational user	7.4	7.8	2.4×10^{-3}	0.34	0.36	0.074
Coldwater Creek recreational user[e]	1.3	-	9.4×10^{-5}	0.060	-	2.9×10^{-3}
Futura Coatings employee	26	30	0.14	1.2	1.4	4.4
HISS trespasser	89	48	6.5×10^{-3}	4.1	2.2	0.20
HISS maintenance worker	89	48	0.45	4.1	2.2	13

Property and Receptor	Uranium-238+D Soil Concentration (pCi/g) 0-1 ft	Uranium-238+D Soil Concentration (pCi/g) 1-3 ft	Uranium-238+D External Gamma Dose (mrem)	Total Dose (mrem)
SLDS employee[b]	-	-	-	-
SLDS construction worker[b]	-	-	-	-
SLDS maintenance worker (drains)[c]	41	-	2.4×10^{-5}	0.0044
City property recreational user	300	3.8	3.0	77
SLAPS trespasser	39	27	0.27	51
SLAPS maintenance worker	39	27	5.3	1,000
Ditch construction worker[d]	13	-	0.077	5.6
Residential vicinity property child commuter	0.73	0.020	3.5×10^{-3}	0.34
Residential vicinity property current resident	0.73	0.020	0.50	47
Ballfield recreational user	7.4	7.8	0.23	32
Coldwater Creek recreational user[e]	1.3	-	8.8×10^{-3}	1.7
Futura Coatings employee	26	30	14	1,400
HISS trespasser	89	48	0.61	78
HISS maintenance worker	89	48	43	5,400

[a] Based on soil data for depths of 0-1 and 1-3 ft; however, for HISS, the thorium-230 data for 1-3 ft were used for both layers because no thorium-230 data were available for 0-1 ft. The doses presented in this table are the sum of the doses from the two incremental layers.

[b] Indoor external gamma doses are based on gamma exposure rate measurements taken inside the SLDS buildings; the results of the indoor external gamma dose calculations for the SLDS employee and SLDS construction worker are presented in Tables 3.7 and 3.8, respectively. Outdoor external gamma doses for the SLDS construction worker are presented in Table 3.9; these doses are based on soil concentrations.

[c] Calculated for drain sediment/sludge; the depth of contamination was assumed to be 1 cm.

[d] Based on soil data for a depth of 0-8 ft.

[e] Based on sediment data for a depth of 0-1 ft.

[f] A zero indicates that the soil concentration of this radionuclide was less than background and would result in an insignificant dose.

TABLE 3.7 Exposure Point Concentrations and Estimated Doses for Employees in SLDS Buildings[a]

Building	Occupancy Time[b] (h/yr)	External Gamma[c] Exposure Rate (μR/h)	External Gamma[c] Annual Dose[e] (mrem/yr)	External Gamma[c] Total Dose[f] (mrem)	Inhalation of Radon[d] Air Concentration (pCi/L)	Inhalation of Radon[d] Air Concentration (WL)	Inhalation of Radon[d] Annual Dose[e] (WLM/yr)	Inhalation of Radon[d] Total Dose[f] (WLM)	Total Dose[g] (mrem) 1 year	Total Dose[g] (mrem) 25 years
K1E	250	190	45	1,100	73	0.37	0.38	9.4	430	11,000
25	250	62	15	370	0.27	0.0014	0.0014	0.035	16	410
50	2,000	NA	NA	NA	0.050	0.00030	0.0024	0.060	2.4	60
51	2,000	22	42	1,000	0.28	0.0014	0.011	0.28	53	1,300
51A	250	8.0	1.9	48	1.1	0.0056	0.0056	0.14	7.5	190
52	250	24	5.7	140	-	-	-	-	5.7	140
52A	250	7.0	1.7	42	0.55	0.0028	0.0028	0.071	4.5	110
100	250	NA	NA	NA	0.41	0.0021	0.0021	0.053	2.1	53
101	250	38	9.0	230	4.8	0.024	0.024	0.61	33	840
116	NA	NA	NA	NA	0.51	0.0026	0.0026	0.066	2.6	66
116B	250	10	2.4	59	-	-	-	-	2.4	59
117	250	19	4.5	110	1.0	0.0051	0.0051	0.13	9.6	240
700	250	3.0	0.71	18	-	-	-	-	0.71	18
704	2,000	NA	NA	NA	0.41	0.0021	0.017	0.43	17	430
705	250	NA	NA	NA	0.25	0.0013	0.0013	0.033	1.3	33
706	250	NA	NA	NA	0.12	0.00061	0.00061	0.015	0.61	15
707	250	NA	NA	NA	0.41	0.0021	0.0021	0.053	2.1	53
708	250	11	2.6	65	0.040	0.00020	0.00020	0.0051	2.8	70
81	250	NA	NA	NA	0.27	0.0014	0.0014	0.036	1.4	36
82	250	NA	NA	NA	0.48	0.0024	0.0024	0.061	2.4	61

[a] All values are rounded to two significant figures.

[b] Occupancy time for each building was based on current usage of the building.

[c] Based on maximum measurement minus background exposure of 10 μR/h; NA indicates that the external gamma exposure rate is less than the background level and would result in an insignificant dose.

[d] Based on maximum radon measurement; a hyphen indicates that no measurement was available.

[e] Represents the dose per year of exposure.

[f] Represents the dose for an exposure duration of 25 years.

[g] To obtain the total annual dose (in mrem), the radon dose (in WLM) was converted to mrem with a factor of 1,000 mrem/WLM, as given in Publication 32 of the ICRP (1981).

TABLE 3.3 Indoor Radionuclide Exposure Point Concentrations and Estimated Doses for Construction Workers at SLDS[a]

	External Gamma[b]		Particulate Inhalation[c]		Particulate Ingestion[c]		Radon Inhalation[d]		
Building	Gamma Exposure Rate (μR/h)	Dose (mrem)	Air Concentration (pCi/m³)	Dose (mrem)	Surface Concentration (pCi/g)	Dose (mrem)	Radon Air Concentration (WL)	Dose (WLM)	Total Dose from Nonradon Exposure (mrem)
K1E	190	18	12	110	690	0.65	0.37	0.45	130
25	62	6.0	5.0	45	3,000	2.8	0.0015	0.0018	54
50	NA	NA	3.0	27	180	0.17	0.00050	0.00061	27
51	22	2.1	90	810	5,300	5.0	0.0015	0.0018	820
51A	8.0	0.76	16	150	980	0.92	0.0055	0.0067	150
52	24	2.3	33	290	2,000	1.9	0.00020	0.00025	290
52A	20	1.9	83	750	5,000	4.7	0.0030	0.0037	760
100	NA	NA	10	90	600	0.56	0.0020	0.0025	91
101	38	3.6	-	-	-	-	0.024	0.029	3.6
116	NA	NA	47	420	2,700	2.5	0.0025	0.0031	420
116B	10	0.95	1.6	15	98	0.092	-	-	16
117	19	1.8	6.6	60	410	0.38	0.0050	0.0061	62
700	3.0	0.29	11	100	690	0.65	0.00020	0.00024	100
704	NA	NA	5.0	45	300	0.28	0.0020	0.0024	45
705	NA	NA	73	660	4,300	4.0	0.0013	0.0016	660
706	NA	NA	2.3	21	140	0.13	0.00060	0.00074	21
707	NA	NA	2.3	21	140	0.13	0.0020	0.00025	21
708	11	1.0	1.8	17	110	0.10	0.0020	0.0025	18
81	NA	NA	0.24	2.2	15	0.014	0.0015	0.0018	2.2
82	NA	NA	0.93	8.4	56	0.053	0.0025	0.0031	8.5

[a] Estimated doses are for a construction worker doing renovation activities for 100 hours in each building for 1 year. The data used for the calculations are presented in Table 2.6.

[b] Based on maximum measurement minus background exposure of 10 μR/h; NA indicates that the measured external gamma exposure rate was less than the background level and would result in an insignificant dose.

[c] Derived from maximum direct beta-gamma measurements on walls; a hyphen indicates that no measurement was available.

[d] Based on maximum radon measurement; a hyphen indicates that no measurement was available.

TABLE 3.9 Outdoor Radionuclide Exposure Point Concentrations and Estimated Doses for Construction Workers at SLDS[a]

		Estimated Dose			
Radionuclide	Soil Concentration[b] (pCi/g)	External Gamma (mrem)	Soil Ingestion (mrem)	Particulate Inhalation[c] (mrem)	Radon Inhalation[d] (WLM)
Actinium-227+D	15	0.48	0.84	120	-
Lead-210+D	50	0.0025	1.3	1.3	-
Protactinium-231	14	0.036	0.58	23	-
Radium-226+D	38	6.9	0.16	0.37	0.0056
Radium-228+D	4.7	0.45	0.021	0.026	-
Thorium-228+D	5.8	0.90	0.016	2.2	-
Thorium-230	90	0.0020	0.18	37	-
Thorium-232	5.8	0.000078	0.061	12	-
Uranium-234	220	0.0034	0.21	37	-
Uranium-235+D	10	0.10	0.0094	1.5	-
Uranium-238+D	220	0.33	0.21	33	-
Total dose		9.2	3.6	270	0.0056

[a] Estimated doses are for a construction worker doing outdoor activities (e.g., excavation) for 100 hours for 1 year.

[b] Based on soil data for a depth of 0-8 ft.

[c] Based on air concentrations derived as follows: soil UL_{95} pCi/g × assumed particulate concentration in air (i.e., 15 mg/m^3) × 10^{-3} g/mg × 30% respirable.

[d] Estimated dose is based on an air concentration of 0.022 WL, which was derived from the radium-226 soil concentration of 38 pCi/g. A hyphen indicates that the entry is not applicable.

TABLE 3.10 Radionuclide Exposure Point Concentrations and Estimated Doses for Incidental Ingestion of Soil by Current Receptors at the St. Louis Site[a]

	Actinium-227+D		Lead-210+D	
Property and Receptor	Soil Concentration (pCi/g)	Dose (mrem)	Soil Concentration (pCi/g)	Dose (mrem)
SLDS employee[b]	NA	NA	NA	NA
SLDS construction worker[c]	-	-	-	-
SLDS maintenance worker (drains)[d]	6.7	0.54	22	0.74
City property recreational user	42	15	80	12
SLAPS trespasser	38	13	68	11
SLAPS maintenance worker	38	71	68	57
Ditch construction worker[e]	5.0	1.1	9.0	0.91
Residential vicinity property child commuter	0.31	1.0	0.62	0.90
Residential vicinity property current resident	0.31	5.9	0.62	5.1
Ballfield recreational user	2.4	2.6	4.3	2.1
Coldwater Creek recreational user[f]	1.3	0.46	2.9	0.46
Futura Coatings employee	23	43	50	42
HISS trespasser	47	16	100	16
HISS maintenance worker	47	350	100	340

	Protactinium-231		Radium-226+D	
Property and Receptor	Soil Concentration (pCi/g)	Dose (mrem)	Soil Concentration (pCi/g)	Dose (mrem)
SLDS employee[b]	NA	NA	NA	NA
SLDS construction worker[c]	-	-	-	-
SLDS maintenance worker (drains)[d]	6.1	0.34	17	0.094
City property recreational user	42	11	44	1.1
SLAPS trespasser	42	11	41	1.1
SLAPS maintenance worker	42	58	41	5.6
Ditch construction worker[e]	5.0	0.83	5.0	0.083
Residential vicinity property child commuter	0.36	0.86	0.31	0.074
Residential vicinity property current resident	0.36	5.0	0.31	0.42
Ballfield recreational user	2.7	2.2	2.6	0.21
Coldwater Creek recreational user[f]	1.6	0.41	1.2	0.031
Futura Coatings employee	28	38	21	2.9
HISS trespasser	57	15	43	1.1
HISS maintenance worker	57	310	43	24

TABLE 3.10 (Cont.)

Property and Receptor	Radium-228+D Soil Concentration (pCi/g)	Radium-228+D Dose (mrem)	Thorium-228+D Soil Concentration (pCi/g)	Thorium-228+D Dose (mrem)
SLDS employee[b]	NA	NA	NA	NA
SLDS construction worker[c]	-	-	-	-
SLDS maintenance worker (drains)[d]	40	0.24	50	0.19
City property recreational user	1.2	0.034	2.9	0.051
SLAPS trespasser	0.75	0.021	2.3	0.040
SLAPS maintenance worker	0.75	0.11	2.3	0.22
Ditch construction worker[e]	0.54	0.010	1.6	0.018
Residential vicinity property child commuter[g]	0	0	0.044	0.0071
Residential vicinity property current resident[g]	0	0	0.044	0.041
Ballfield recreational user	0.50	0.042	1.5	0.079
Coldwater Creek recreational user[f]	0.064	0.0018	0.80	0.014
Futura Coatings employee	0.18	0.027	2.3	0.22
HISS trespasser	0.17	0.0048	2.1	0.037
HISS maintenance worker	0.17	0.10	2.1	0.79

Property and Receptor	Thorium-230 Soil Concentration (pCi/g)	Thorium-230 Dose (mrem)	Thorium-232 Soil Concentration (pCi/g)	Thorium-232 Dose (mrem)
SLDS employee[b]	NA	NA	NA	NA
SLDS construction worker[c]	-	-	-	-
SLDS maintenance worker (drains)[d]	190	0.50	49	0.69
City property recreational user	37	0.46	3.1	0.20
SLAPS trespasser	430	5.3	2.7	0.18
SLAPS maintenance worker	430	28	2.7	0.95
Ditch construction worker[e]	320	2.6	1.9	0.080
Residential vicinity property child commuter	44	5.0	0.044	0.027
Residential vicinity property current resident	44	29	0.044	0.14
Ballfield recreational user	24	0.89	1.8	0.35
Coldwater Creek recreational user[f]	6.3	0.078	0.80	0.052
Futura Coatings employee	110	7.3	2.3	0.80
HISS trespasser	160	2.0	2.1	0.14
HISS maintenance worker	160	42	2.1	2.9

TABLE 3.10 (Cont.)

	Uranium-234		Uranium-235+D	
Property and Receptor	Soil Concentration (pCi/g)	Dose (mrem)	Soil Concentration (pCi/g)	Dose (mrem)
SLDS employee[b]	NA	NA	NA	NA
SLDS construction worker[c]	-	-	-	-
SLDS maintenance worker (drains)[d]	41	0.053	1.9	0.0024
City property recreational user	280	1.7	13	0.076
SLAPS trespasser	33	0.20	1.5	0.0088
SLAPS maintenance worker	33	1.1	1.5	0.047
Ditch construction worker[e]	13	0.051	0.60	0.0022
Residential vicinity property child commuter[g]	0.53	0.030	0	0
Residential vicinity property current resident[g]	0.53	0.16	0	0
Ballfield recreational user	7.4	0.14	0.34	0.0060
Coldwater Creek recreational user[f]	1.3	0.0076	0.060	0.00035
Futura Coatings employee	27	0.88	1.2	0.038
HISS trespasser	54	0.33	2.5	0.015
HISS maintenance worker	54	7.0	2.5	0.31

	Uranium-238+D		
Property and Receptor	Soil Concentration (pCi/g)	Dose (mrem)	Total Dose (mrem)
SLDS employee[b]	NA	NA	NA
SLDS construction worker[c]	-	-	-
SLDS maintenance worker (drains)[d]	41	0.051	3.4
City property recreational user	280	1.6	43
SLAPS trespasser	33	0.19	42
SLAPS maintenance worker	33	1.0	220
Ditch construction worker[e]	13	0.049	5.7
Residential vicinity property child commuter	0.53	0.029	8.0
Residential vicinity property current resident	0.53	0.16	46
Ballfield recreational user	7.4	0.13	8.7
Coldwater Creek recreational user[f]	1.3	0.0076	1.5
Futura Coatings employee	27	0.84	140
HISS trespasser	54	0.32	51
HISS maintenance worker	54	6.8	1,100

[a] Based on soil data for a depth of 0-3 ft; however, for HISS, thorium-230 data for 1-3 ft were used because no thorium-230 data were available for 0-1 ft.

[b] NA indicates not applicable because not a pathway of concern for that receptor.

[c] Results for this receptor are presented in Tables 3.8 and 3.9.

[d] Calculated for drain sediment/sludge; the depth of contamination was assumed to be 1 cm.

[e] Based on soil data for a depth of 0-8 ft.

[f] Based on sediment data for a depth of 0-1 ft.

[g] A zero indicates that the soil concentration of this radionuclide was less than background and would result in an insignificant dose.

TABLE 3.11 Radionuclide Exposure Point Concentrations and Estimated External Gamma Doses for Future Receptors at the St. Louis Site[a]

	Actinium-227+D			Lead-210+D		
	Soil Concentration (pCi/g)		External Gamma Dose (mrem)	Soil Concentration (pCi/g)		External Gamma Dose (mrem)
Property and Receptor	0-1 ft	1-3 ft		0-1 ft	1-3 ft	
SLDS future resident[b]	27	7.1	1.3×10^3	89	23	6.9
SLAPS future resident	45	40	2.2×10^3	81	71	6.3
Residential vicinity property future resident	0.43	0.012	21	0.86	0.024	0.067
Ballfield future resident	2.9	1.5	140	5.1	2.7	0.40
Coldwater Creek future recreational user[c]	1.3	-	0.19	2.9	-	6.8×10^{-4}
Futura Coatings future resident	16	27	800	35	59	2.7
HISS future resident	82	40	4.0×10^3	180	87	14

	Protactinium-231			Radium-226+D		
	Soil Concentration (pCi/g)		External Gamma Dose (mrem)	Soil Concentration (pCi/g)		External Gamma Dose (mrem)
Property and Receptor	0-1 ft	1-3 ft		0-1 ft	1-3 ft	
SLDS future resident[b]	25	6.5	98	69	18	1.9×10^4
SLAPS future resident	51	45	200	49	43	1.4×10^4
Residential vicinity property future resident	0.49	0.014	1.9	0.43	0.012	110
Ballfield future resident	3.2	1.7	13	3.1	1.6	840
Coldwater Creek future recreational user[c]	1.6	-	0.019	1.2	-	0.97
Futura Coatings future resident	20	33	79	15	25	4.3×10^3
HISS future resident	99	49	390	75	37	2.0×10^4

	Radium-228+D			Thorium-228+D		
	Soil Concentration (pCi/g)		External Gamma Dose (mrem)	Soil Concentration (pCi/g)		External Gamma Dose (mrem)
Property and Receptor	0-1 ft	1-3 ft		0-1 ft	1-3 ft	
SLDS future resident[b]	7.3	3.1	1.0×10^3	9.3	3.9	2.1×10^3
SLAPS future resident	0.83	0.69	120	2.6	2.1	610
Residential vicinity property future resident[d]	0	0	0	0.061	1.7×10^{-3}	13
Ballfield future resident	0.50	0.55	74	1.5	1.7	360
Coldwater Creek future recreational user[c]	0.064	-	0.027	0.80	-	0.53
Futura Coatings future resident	0.22	0.18	32	2.8	2.3	660
HISS future resident	0.19	0.16	28	2.4	2.0	570

TABLE 3.11 (Cont.)

	Thorium-230			Thorium-232		
	Soil Concentration (pCi/g)		External Gamma Dose (mrem)	Soil Concentration (pCi/g)		External Gamma Dose (mrem)
Property and Receptor	0-1 ft	1-3 ft		0-1 ft	1-3 ft	
SLDS future resident[b]	150	15	5.2	9.0	3.8	0.19
SLAPS future resident	670	220	23	3.0	2.5	0.062
Residential vicinity property future resident	61	1.7	2.1	0.061	1.7×10^{-3}	1.3×10^{-3}
Ballfield future resident	28	2.6	0.97	1.8	2.0	0.037
Coldwater Creek future recreational user[c]	6.3	-	6.6×10^{-4}	0.80	-	5.0×10^{-5}
Futura Coatings future resident	120	120	4.1	2.8	2.3	0.058
HISS future resident	160	160	5.4	2.4	2.0	0.050

	Uranium-234			Uranium-235+D		
	Soil Concentration (pCi/g)		External Gamma Dose (mrem)	Soil Concentration (pCi/g)		External Gamma Dose (mrem)
Property and Receptor	0-1 ft	1-3 ft		0-1 ft	1-3 ft	
SLDS future resident[b]	220	87	5.3	10	4.0	160
SLAPS future resident	39	27	0.93	1.8	1.2	29
Residential vicinity property future resident[d]	0.73	0.020	0.018	0	0	0
Ballfield future resident	7.4	7.8	0.18	0.34	0.36	5.4
Coldwater Creek future recreational user[c]	1.3	-	9.4×10^{-5}	0.060	-	2.9×10^{-3}
Futura Coatings future resident	26	30	0.62	1.2	1.4	19
HISS future resident	89	48	2.1	4.1	2.2	65

	Uranium-238+D			
	Soil Concentration (pCi/g)		External Gamma Dose (mrem)	Total Dose (mrem)
Property and Receptor	0-1 ft	1-3 ft		
SLDS future resident[b]	220	87	490	24,000
SLAPS future resident	39	27	88	17,000
Residential vicinity property future resident	0.73	0.020	1.6	150
Ballfield future resident	7.4	7.8	17	1,500
Coldwater Creek future recreational user[c]	1.3	-	8.8×10^{-3}	1.7
Futura Coatings future resident	26	30	59	6,000
HISS future resident	89	48	200	25,000

[a] Based on soil data for depths of 0-1 and 1-3 ft; however for HISS, the thorium-230 data for 1-3 ft were used for both layers because no thorium-230 data were available for 0-1 ft. The doses presented in this table are the sum of the doses from the two incremental layers.

[b] Data for the city property were incorporated into the SLDS data to estimate the soil concentrations.

[c] Based on sediment data for a depth of 0-1 ft.

[d] A zero indicates that the soil concentration of this radionuclide was less than background and would result in an insignificant dose.

TABLE 3.12 Radionuclide Exposure Point Concentrations and Estimated Doses for Incidental Ingestion of Soil by Future Receptors at the St. Louis Site[a]

	Actinium-227+D		Lead-210+D	
Property and Receptor	Soil Concentration (pCi/g)	Dose (mrem)	Soil Concentration (pCi/g)	Dose (mrem)
SLDS future resident[b]	20	380	67	570
SLAPS future resident	38	720	68	570
Residential vicinity property future resident	0.31	5.9	0.62	5.1
Ballfield future resident	2.5	47	4.5	38
Coldwater Creek future recreational user[c]	1.3	0.46	2.9	0.46
Futura Coatings future resident	23	430	50	420
HISS future resident	47	890	100	840

	Protactinium-231		Radium-226+D	
Property and Receptor	Soil Concentration (pCi/g)	Dose (mrem)	Soil Concentration (pCi/g)	Dose (mrem)
SLDS future resident[b]	19	260	52	72
SLAPS future resident	42	580	41	57
Residential vicinity property future resident	0.36	5.0	0.31	0.42
Ballfield future resident	2.8	39	2.7	3.7
Coldwater Creek future recreational user[c]	1.6	0.41	1.2	0.031
Futura Coatings future resident	28	390	21	29
HISS future resident	57	790	43	60

	Radium-228+D		Thorium-228+D	
Property and Receptor	Soil Concentration (pCi/g)	Dose (mrem)	Soil Concentration (pCi/g)	Dose (mrem)
SLDS future resident[b]	5.8	8.8	7.4	7.0
SLAPS future resident	0.75	1.1	2.3	2.2
Residential vicinity property future resident[d]	0	0	0.044	0.038
Ballfield future resident	0.50	0.76	1.5	1.4
Coldwater Creek future recreational user[c]	0.064	0.0018	0.80	0.014
Futura Coatings future resident	0.18	0.27	2.3	2.2
HISS future resident	0.17	0.26	2.1	2.0

TABLE 3.12 (Cont.)

	Thorium-230		Thorium-232	
Property and Receptor	Soil Concentration (pCi/g)	Dose (mrem)	Soil Concentration (pCi/g)	Dose (mrem)
SLDS future resident[b]	120	80	7.2	25
SLAPS future resident	430	290	2.7	9.5
Residential vicinity property future resident	44	29	0.044	0.14
Ballfield future resident	24	16	1.8	6.4
Coldwater Creek future recreational user[c]	6.3	0.078	0.80	0.052
Futura Coatings future resident	110	73	2.3	8.1
HISS future resident	160	110	2.1	7.4

	Uranium-234		Uranium-235+D	
Property and Receptor	Soil Concentration (pCi/g)	Dose (mrem)	Soil Concentration (pCi/g)	Dose (mrem)
SLDS future resident[b]	180	59	8.3	2.6
SLAPS future resident	33	11	1.5	0.47
Residential vicinity property future resident[d]	0.53	0.16	0	0
Ballfield future resident	7.4	2.4	0.34	0.11
Coldwater Creek future recreational user[c]	1.3	0.0076	0.060	0.00035
Futura Coatings future resident	27	8.8	1.2	0.38
HISS future resident	54	18	2.5	0.79

	Uranium-238+D		
Property and Receptor	Soil Concentration (pCi/g)	Dose (mrem)	Total Dose (mrem)
SLDS future resident[b]	180	57	1,500
SLAPS future resident	33	10	2,300
Residential vicinity property future resident	0.53	0.16	46
Ballfield future resident	7.4	2.3	160
Coldwater Creek future recreational user[c]	1.3	0.0076	1.5
Futura Coatings future resident	27	8.5	1,400
HISS future resident	54	17	2,700

[a] Based on soil data for a depth of 0-3 ft; however, for HISS, thorium-230 data for 1-3 ft were used because no thorium-230 data were available for 0-1 ft.

[b] Data for the city property were incorporated into the SLDS data to estimate soil concentrations.

[c] Based on sediment data for a depth of 0-1 ft.

[d] A zero indicates that the soil concentration of this radionuclide was less than background and would result in an insignificant dose.

TABLE 3.13 Radionuclide Exposure Point Concentrations and Estimated Doses for Future Receptors from Contaminants in the HISS Storage Pile[a]

		Estimated Dose			
Radionuclide[b]	Soil Concentration (pCi/g)	External Gamma (mrem)	Soil Ingestion (mrem)	Particulate Inhalation[c] (mrem)	Radon Inhalation[d] (WLM)
Actinium-227+D	200	9,900	3,900	1,300	-
Protactinium-231	120	470	1,600	150	-
Radium-226+D	57	16,000	79	0.43	180
Radium-228+D	1.9	280	2.9	0.0080	-
Thorium-228+D	2.1	500	2.0	0.60	-
Thorium-230	8,900	310	5,900	2,700	-
Thorium-232	1.9	0.039	6.7	2.9	-
Uranium-235+D	4	64	1.3	0.46	-
Uranium-238+D	72	160	23	8.0	-
Total dose		28,000	12,000	4,200	180

[a] Based on radiological data taken from the existing pile in 1981 (Oak Ridge Associated Universities 1981).

[b] Radionuclide groups presented in this table are based on the results presented in Table 2.4.

[c] Estimated dose is based on the air concentration, which was derived as follows: soil UL_{95} pCi/g × assumed particulate concentration in air (i.e., 0.04 mg/m^3) × 10^{-3} g/mg × 30% respirable.

[d] Estimated dose is based on an air concentration of 0.23 WL, which was derived from the radium-226 soil concentration of 57 pCi/g. A hyphen indicates that the entry is not applicable.

TABLE 3.14 Chemical Exposure Point Concentrations for Incidental Ingestion of Soil by Current Receptors at the St. Louis Site[a]

	Exposure Point Concentration[b] (mg/kg)						
Contaminant	SLDS	City Property	SLAPS[c]	Ballfield	Coldwater Creek	Futura	HISS
Metals							
Antimony	110	310	5.6	6.7	10	-	56
Arsenic	33	12	28	11	25	12	210
Beryllium	0.88	0.96	1.5	0.56	1.3	0.59	7.4
Cadmium	3.3	1.8	1.7	0.75	1.3	-	8.4
Cobalt	14	7.8	720	6.7	13	100	860
Copper	-	-	470	-	-	99	-
Lead	1,400	560	130	28	99	110	260
Molybdenum	-	-	-	11	26	20	240
Nickel	29	23	920	19	18	160	900
Selenium	-	-	-	11	84	12	200
Thallium	48	49	11	11	23	12	200
Uranium[d]	520	820	98	-	-	80	160
Zinc	-	-	-	-	1,400	-	-
PAHs	440	440	-	-	34	-	-

[a] Exposure point concentrations are the 95% upper confidence limits (UL_{95}) of the arithmetic mean of the surface sample values for all properties except HISS and Coldwater Creek. For HISS, the UL_{95} of the geometric mean was used because of the highly skewed sample distribution; for Coldwater Creek, the maximum reported value was used as the exposure point concentration. Basis of data: SLDS metals data, 102 samples; city property metals data, 7 samples; SLDS and city property PAH data, 56 composite samples; SLAPS, 41 samples; ballfield, 13 samples; Coldwater Creek, 4 samples; Futura, 6 samples; HISS, 6 samples. All values are rounded to two significant figures.

[b] A hyphen indicates that the substance is not a contaminant of concern for that property.

[c] Data from SLAPS were used to assess potential exposure to chemicals at the ditches and other vicinity property areas where excavation and similar activities might occur. This approach is conservative because contaminant concentrations at SLAPS are higher than levels at a vicinity property (e.g., the ballfield).

[d] Uranium concentrations are UL_{95} values of the arithmetic mean for the 0- to 3-ft layer for 227 samples (city property); 545 samples (SLDS plant); 398 samples (SLAPS); 157 samples (Futura); and 104 samples (HISS).

TABLE 3.15 Chemical Exposure Point Concentrations for Incidental Ingestion of Soil by Future Receptors at the St. Louis Site[a]

	Exposure Point Concentration[b] (mg/kg)					
Contaminant	SLDS	SLAPS	Ballfield	Coldwater Creek	Futura	HISS
Metals						
Antimony	120	5.6	26	10	-	56
Arsenic	32	28	78	25	71	210
Beryllium	0.87	1.5	2.4	1.3	4.8	7.4
Cadmium	3.1	1.7	2.4	1.3	-	8.4
Cobalt	13	720	25	13	2,800	860
Copper	-	470	-	-	1,800	-
Lead	1,300	130	41	99	140	260
Molybdenum	-	-	85	26	200	240
Nickel	28	920	34	18	3,500	900
Selenium	-	-	84	84	210	200
Thallium	47	11	87	23	12	200
Uranium[c]	530	98	-	-	80	160
Zinc	-	-	-	1,400	-	-
PAHs	440	-	-	34	-	-

[a] Exposure point concentrations are the 95% upper confidence limit (UL_{95}) of the arithmetic mean of all samples or surface samples, whichever were greater at each property. The exception is HISS, where the UL_{95} of the geometric mean was used because of the highly skewed sample distribution. Basis of data: SLDS, 109 surface samples (plant and city property combined); SLAPS, 41 surface samples; ballfield, 31 samples; Futura, 16 samples; and HISS, 6 surface samples.

[b] A hyphen indicates that the substance is not a contaminant of concern for that property.

[c] Uranium concentrations are UL_{95} values of the arithmetic mean for the 0- to 3-ft layer based on 772 samples (SLDS and city property combined); 398 samples (SLAPS); 157 samples (Futura); and 104 samples (HISS).

TABLE 3.10 Exposure Point Concentrations and Estimated Doses for Inhalation of Radon-222 and Its Decay Products by Current Receptors at the St. Louis Site[a]

Property and Receptor	Indoors Air Concentration (WL)	Indoors Dose (WLM)	Outdoors[b] Air Concentration (WL)	Outdoors[b] Dose WLM)	Total Dose (WLM)
SLDS employee[c]	-	-	-	-	-
SLDS construction worker[c]	-	-	-	-	-
SLDS maintenance worker (drains)	NA	NA	NA	NA	NA
City property recreational user	NA	NA	0.025	0.16	0.16
SLAPS trespasser	NA	NA	0.023	0.097	0.097
SLAPS maintenance worker	NA	NA	0.023	1.0	1.0
Ditch construction worker	NA	NA	0.0029	0.014	0.014
Residential vicinity property child commuter	NA	NA	0.00018	0.00032	0.00032
Residential vicinity property current resident[d]	-	-	0.00017	0.014	0.014
Ballfield recreational user	NA	NA	0.0015	0.033	0.033
Coldwater Creek recreational user	NA	NA	0.00068	0.0028	0.0028
Futura Coatings employee[e]	0.0035	0.71	NA	NA	0.71
HISS trespasser	NA	NA	0.024	0.099	0.099
HISS maintenance worker[f]	0.0065	0.66	0.024	2.1	2.8

[a] NA indicates not applicable because it is not a pathway of concern for that receptor.

[b] Outdoor air concentrations are based on the UL_{95} values of radium-226 in the 0- to 3-ft layer for all properties except ditches and Coldwater Creek where the concentrations are based on the 0- to 8-ft layer and 0- to 1-ft layer, respectively.

[c] Estimated doses for the SLDS employee are presented in Table 3.7. Estimated doses for the SLDS construction worker are presented in Tables 3.8 and 3.9.

[d] Indoor dose was not estimated because the air concentrations were determined to be equal to background concentrations on the basis of the diffusion length of 3 ft for radon through soil and the distance of the residential vicinity property from the edge of the contaminated soil (30 ft); outdoor dose was calculated with the assumption that the current resident would be exposed to contaminated soil at the edge of the property.

[e] Indoor air concentration is based on the maximum radon measurement of 0.7 pCi/L taken inside the buildings during 1986 (DOE 1993).

[f] Indoor air concentration is based on the maximum radon measurement of 1.25 pCi/L taken inside the trailers (Section 2.3.4).

TABLE 3.17 Exposure Point Concentrations and Estimated Doses for Inhalation of Radon-222 and Its Decay Products by Future Receptors at the St. Louis Site

Property and Receptor	Indoors Air Concentration[a] (WL)	Indoors Dose (WLM)	Outdoors Air Concentration[b] (WL)	Outdoors Dose (WLM)	Total Dose (WLM)
SLDS future resident	0.15	120	0.030	2.6	120
SLAPS future resident	0.26	200	0.023	2.0	200
Residential vicinity property future resident	0.0012	0.92	0.00017	0.014	0.93
Ballfield future resident	0.011	8.4	0.0015	0.13	8.5
Coldwater Creek future recreational user	NA[c]	NA	0.00068	0.0028	0.0028
Futura Coatings future resident	0.11	85	0.012	1.0	86
HISS future resident	0.069	53	0.024	2.1	55

[a] Indoor air concentration for each property is based on the UL_{95} value for radium-226 in soil at a depth of 0-8 ft.

[b] Outdoor air concentration for each property is based on the UL_{95} value for radium-226 in soil at a depth of 0-3 ft.

[c] NA indicates not applicable because it is not a pathway of concern for that receptor.

TABLE 3.18 Radionuclide Exposure Point Concentrations and Estimated Doses for Inhalation of Particulates by Current Receptors at the St. Louis Site

Property and Receptor	Actinium-227+D Air Concentration[a] (pCi/m^3)	Actinium-227+D Dose (mrem)	Lead-210+D Air Concentration[a] (pCi/m^3)	Lead-210+D Dose (mrem)
SLDS employee[b]	NA	NA	NA	NA
SLDS construction worker[c]	-	-	-	-
SLDS maintenance worker (drains)[b]	NA	NA	NA	NA
City property recreational user	5.5×10^{-4}	4.5	1.0×10^{-3}	0.027
SLAPS trespasser	5.5×10^{-4}	3.0	9.5×10^{-4}	0.017
SLAPS maintenance worker	5.5×10^{-4}	35	9.5×10^{-4}	0.20
Ditch construction worker	2.3×10^{-2}	167	4.1×10^{-2}	0.77
Residential vicinity property child commuter	5.0×10^{-6}	0.011	1.1×10^{-5}	6.5×10^{-5}
Residential vicinity property current resident	5.0×10^{-6}	2.5	1.1×10^{-5}	0.017
Ballfield recreational user	3.5×10^{-5}	1.0	6.0×10^{-5}	5.5×10^{-3}
Coldwater Creek recreational user	1.6×10^{-5}	0.085	3.5×10^{-5}	6.0×10^{-4}
Futura Coatings employee	1.9×10^{-4}	21	4.2×10^{-4}	0.15
HISS trespasser	1.0×10^{-3}	5.5	2.2×10^{-3}	0.037
HISS maintenance worker	1.0×10^{-3}	170	2.2×10^{-3}	1.2

Property and Receptor	Protactinium-231 Air Concentration[a] (pCi/m^3)	Protactinium-231 Dose (mrem)	Radium-226+D Air Concentration[a] (pCi/m^3)	Radium-226+D Dose (mrem)
SLDS employee[b]	NA	NA	NA	NA
SLDS construction worker[c]	-	-	-	-
SLDS maintenance worker (drains)[b]	NA	NA	NA	NA
City property recreational user	5.5×10^{-4}	0.85	5.5×10^{-4}	5.5×10^{-3}
SLAPS trespasser	6.0×10^{-4}	0.65	6.0×10^{-4}	3.9×10^{-3}
SLAPS maintenance worker	6.0×10^{-4}	7.5	6.0×10^{-4}	0.045
Ditch construction worker	2.3×10^{-2}	32	2.3×10^{-2}	0.19
Residential vicinity property child commuter	6.0×10^{-6}	2.4×10^{-3}	5.0×10^{-6}	1.3×10^{-5}
Residential vicinity property current resident	6.0×10^{-6}	0.60	5.0×10^{-6}	3.2×10^{-3}
Ballfield recreational user	3.9×10^{-5}	0.22	3.7×10^{-5}	1.3×10^{-3}
Coldwater Creek recreational user	1.9×10^{-5}	0.021	1.4×10^{-5}	9.5×10^{-5}
Futura Coatings employee	2.4×10^{-4}	5.0	1.8×10^{-4}	0.023
HISS trespasser	1.2×10^{-3}	1.3	9.0×10^{-4}	5.8×10^{-3}
HISS maintenance worker	1.2×10^{-3}	40	9.0×10^{-4}	0.18

TABLE 3.18 (Cont.)

Property and Receptor	Radium-228+D Air Concentration[a] (pCi/m^3)	Radium-228+D Dose (mrem)	Thorium-228+D Air Concentration[a] (pCi/m^3)	Thorium-228+D Dose (mrem)
SLDS employee[b]	NA	NA	NA	NA
SLDS construction worker[c]	-	-	-	-
SLDS maintenance worker (drains)[b]	NA	NA	NA	NA
City property recreational user	1.5×10^{-5}	8.0×10^{-5}	3.6×10^{-5}	0.014
SLAPS trespasser	1.0×10^{-5}	3.7×10^{-5}	3.1×10^{-5}	8.0×10^{-3}
SLAPS maintenance worker	1.0×10^{-5}	4.4×10^{-4}	3.1×10^{-5}	0.095
Ditch construction worker	2.4×10^{-3}	0.020	7.2×10^{-3}	2.4
Residential vicinity property child commuter[d]	0	0	7.5×10^{-7}	7.1×10^{-5}
Residential vicinity property current resident[d]	0	0	7.5×10^{-7}	0.018
Ballfield recreational user	6.0×10^{-6}	1.2×10^{-4}	1.8×10^{-5}	0.081
Coldwater Creek recreational user	7.7×10^{-7}	2.9×10^{-6}	9.6×10^{-6}	2.5×10^{-3}
Futura Coatings employee	2.7×10^{-6}	2.0×10^{-4}	3.4×10^{-5}	0.17
HISS trespasser	2.3×10^{-6}	8.5×10^{-6}	2.9×10^{-5}	7.5×10^{-3}
HISS maintenance worker	2.3×10^{-6}	2.7×10^{-4}	2.9×10^{-5}	0.24

Property and Receptor	Thorium-230 Air Concentration[a] (pCi/m^3)	Thorium-230 Dose (mrem)	Thorium-232 Air Concentration[a] (pCi/m^3)	Thorium-232 Dose (mrem)
SLDS employee[b]	NA	NA	NA	NA
SLDS construction worker[c]	-	-	-	-
SLDS maintenance worker (drains)[b]	NA	NA	NA	NA
City property recreational user	4.8×10^{-4}	0.19	3.9×10^{-5}	0.075
SLAPS trespasser	8.0×10^{-3}	2.2	3.6×10^{-5}	0.048
SLAPS maintenance worker	8.0×10^{-3}	25	3.6×10^{-5}	0.55
Ditch construction worker	1.5	500	8.9×10^{-3}	15
Residential vicinity property child commuter	7.5×10^{-4}	0.072	7.5×10^{-7}	3.7×10^{-4}
Residential vicinity property current resident	7.5×10^{-4}	19	7.5×10^{-7}	0.092
Ballfield recreational user	3.4×10^{-4}	0.47	2.2×10^{-5}	0.15
Coldwater Creek recreational user	7.6×10^{-5}	0.020	9.6×10^{-6}	0.013
Futura Coatings employee	1.5×10^{-3}	7.5	3.4×10^{-5}	0.85
HISS trespasser	1.9×10^{-3}	0.50	2.9×10^{-5}	0.038
HISS maintenance worker	1.9×10^{-3}	16	2.9×10^{-5}	1.2

TABLE 3.18 (Cont.)

	Uranium-234		Uranium-235+D	
Property and Receptor	Air Concentration[a] (pCi/m^3)	Dose (mrem)	Air Concentration[a] (pCi/m^3)	Dose (mrem)
SLDS employee[b]	NA	NA	NA	NA
SLDS construction worker[c]	-	-	-	-
SLDS maintenance worker (drains)[b]	NA	NA	NA	NA
City property recreational user	3.6×10^{-3}	0.58	1.7×10^{-4}	0.025
SLAPS trespasser	4.7×10^{-4}	0.050	2.2×10^{-5}	2.2×10^{-3}
SLAPS maintenance worker	4.7×10^{-4}	0.60	2.2×10^{-5}	0.025
Ditch construction worker	5.9×10^{-2}	8.3	2.7×10^{-3}	0.37
Residential vicinity property child commuter[d]	9.0×10^{-6}	3.6×10^{-4}	0	0
Residential vicinity property current resident[d]	9.0×10^{-6}	0.089	0	0
Ballfield recreational user	9.0×10^{-5}	0.051	4.1×10^{-6}	2.2×10^{-3}
Coldwater Creek recreational user	1.6×10^{-5}	1.7×10^{-3}	7.2×10^{-7}	7.0×10^{-5}
Futura Coatings employee	3.1×10^{-4}	0.65	1.5×10^{-5}	0.028
HISS trespasser	1.1×10^{-3}	0.12	4.9×10^{-5}	4.9×10^{-3}
HISS maintenance worker	1.1×10^{-3}	3.6	4.9×10^{-5}	0.16

	Uranium-238+D		
Property and Receptor	Air Concentration[a] (pCi/m^3)	Dose (mrem)	Total Dose (mrem)
SLDS employee[b]	NA	NA	NA
SLDS construction worker[c]	-	-	-
SLDS maintenance worker (drains)[b]	NA	NA	NA
City property recreational user	3.6×10^{-3}	0.55	6.8
SLAPS trespasser	4.7×10^{-4}	0.047	6.0
SLAPS maintenance worker	4.7×10^{-4}	0.55	70
Ditch construction worker	5.9×10^{-2}	7.7	730
Residential vicinity property child commuter	9.0×10^{-6}	3.3×10^{-4}	0.088
Residential vicinity property current resident	9.0×10^{-6}	0.083	22
Ballfield recreational user	9.0×10^{-5}	0.047	2.0
Coldwater Creek recreational user	1.6×10^{-5}	1.6×10^{-3}	0.15
Futura Coatings employee	3.1×10^{-4}	0.60	36
HISS trespasser	1.1×10^{-3}	0.11	7.6
HISS maintenance worker	1.1×10^{-3}	3.4	240

[a] Air concentrations were calculated from soil UL_{95} values at a depth of 0-1 ft, as follows: soil UL_{95} pCi/g × assumed particulate concentration in air (i.e., 0.04 mg/m^3) × 10^{-3} g/mg × 30% respirable. However, for HISS, the thorium-230 data for 1-3 ft were used because no thorium-230 data were available for 0-1 ft. Air concentrations for the ditch construction worker were derived by assuming 15 mg/m^3 total particulates in air, of which 30% is respirable, and using the soil UL_{95} concentrations for a depth of 0-8 ft.

[b] NA indicates not applicable because it is not a pathway of concern for that receptor.

[c] Results for the SLDS construction worker are presented in Tables 3.8 and 3.9.

[d] A zero indicates that air concentrations based on soil data were not estimated because soil concentrations were below background.

TABLE 3.19 Radionuclide Exposure Point Concentrations and Estimated Doses for Inhalation of Particulates by Future Receptors at the St. Louis Site

	Actinium-227+D		Lead-210+D	
Property and Receptor	Air Concentration[a] (pCi/m^3)	Dose (mrem)	Air Concentration[a] (pCi/m^3)	Dose (mrem)
SLDS future resident[b]	3.3×10^{-4}	180	1.1×10^{-3}	1.8
SLAPS future resident	5.5×10^{-4}	290	9.5×10^{-4}	1.6
Residential vicinity property future resident	5.0×10^{-6}	2.7	1.1×10^{-5}	0.017
Ballfield future resident	3.5×10^{-5}	19	6.0×10^{-5}	0.10
Coldwater Creek future recreational user	1.6×10^{-5}	0.085	3.5×10^{-5}	6.0×10^{-4}
Futura Coatings future resident	1.9×10^{-4}	100	4.2×10^{-4}	0.70
HISS future resident	1.0×10^{-3}	520	2.2×10^{-3}	3.6

	Protactinium-231		Radium-226+D	
Property and Receptor	Air Concentration[a] (pCi/m^3)	Dose (mrem)	Air Concentration[a] (pCi/m^3)	Dose (mrem)
SLDS future resident[b]	3.0×10^{-4}	31	8.5×10^{-4}	0.50
SLAPS future resident	6.0×10^{-4}	65	6.0×10^{-4}	0.37
Residential vicinity property future resident	6.0×10^{-6}	0.60	5.0×10^{-6}	3.2×10^{-3}
Ballfield future resident	3.9×10^{-5}	4.0	3.7×10^{-5}	0.024
Coldwater Creek future recreational user	1.9×10^{-5}	0.021	1.4×10^{-5}	9.5×10^{-5}
Futura Coatings future resident	2.4×10^{-4}	25	1.8×10^{-4}	0.11
HISS future resident	1.2×10^{-3}	120	9.0×10^{-4}	0.55

	Radium-228+D		Thorium-228+D	
Property and Receptor	Air Concentration[a] (pCi/m^3)	Dose (mrem)	Air Concentration[a] (pCi/m^3)	Dose (mrem)
SLDS future resident[b]	9.0×10^{-5}	0.032	1.1×10^{-4}	2.8
SLAPS future resident	1.0×10^{-5}	3.6×10^{-3}	3.1×10^{-5}	0.75
Residential vicinity property future resident[c]	-	-	7.5×10^{-7}	0.018
Ballfield future resident	6.0×10^{-6}	2.2×10^{-3}	1.8×10^{-5}	0.45
Coldwater Creek future recreational user	7.7×10^{-7}	2.9×10^{-6}	9.6×10^{-6}	2.5×10^{-3}
Futura Coatings future resident	2.7×10^{-6}	9.5×10^{-4}	3.4×10^{-5}	0.80
HISS future resident	2.3×10^{-6}	8.0×10^{-4}	2.9×10^{-5}	0.70

TABLE 3.19 (Cont.)

Property and Receptor	Thorium-230		Thorium-232	
	Air Concentration[a] (pCi/m^3)	Dose (mrem)	Air Concentration[a] (pCi/m^3)	Dose (mrem)
SLDS future resident[b]	1.8×10^{-3}	46	1.1×10^{-4}	14
SLAPS future resident	8.0×10^{-3}	210	3.6×10^{-5}	4.6
Residential vicinity property future resident	7.5×10^{-4}	19	7.5×10^{-7}	0.090
Ballfield future resident	3.4×10^{-4}	8.5	2.2×10^{-5}	2.8
Coldwater Creek future recreational user	7.6×10^{-5}	0.020	9.6×10^{-6}	0.013
Futura Coatings future resident	1.5×10^{-3}	36	3.4×10^{-5}	4.2
HISS future resident	1.9×10^{-3}	48	2.9×10^{-5}	3.6

Property and Receptor	Uranium-234		Uranium-235+D	
	Air Concentration[a] (pCi/m^3)	Dose (mrem)	Air Concentration[a] (pCi/m^3)	Dose (mrem)
SLDS future resident[b]	2.7×10^{-3}	28	1.2×10^{-4}	1.2
SLAPS future resident	4.7×10^{-4}	4.9	2.2×10^{-5}	0.21
Residential vicinity property future resident[c]	9.0×10^{-6}	0.090	-	-
Ballfield future resident	9.0×10^{-5}	0.92	4.1×10^{-6}	0.039
Coldwater Creek future recreational user	1.6×10^{-5}	1.7×10^{-3}	7.2×10^{-7}	7.0×10^{-5}
Futura Coatings future resident	3.1×10^{-4}	3.2	1.5×10^{-5}	0.14
HISS future resident	1.1×10^{-3}	11	4.9×10^{-6}	0.47

Property and Receptor	Uranium-238+D		Total Dose (mrem)
	Air Concentration[a] (pCi/m^3)	Dose (mrem)	
SLDS future resident[b]	2.7×10^{-3}	26	330
SLAPS future resident	4.7×10^{-4}	4.5	580
Residential vicinity property future resident	9.0×10^{-6}	0.085	23
Ballfield future resident	9.0×10^{-5}	0.85	37
Coldwater Creek future recreational user	1.6×10^{-5}	1.6×10^{-3}	0.15
Futura Coatings future resident	3.1×10^{-4}	3.0	170
HISS future resident	1.1×10^{-3}	10	720

[a] Air concentrations were calculated from soil UL_{95} values at depths of 0-1 ft, as follows: soil UL_{95} pCi/g × assumed particulate concentration in air (i.e., 0.04 mg/m^3) × 10^{-3} g/mg × 30% respirable. However, for HISS, the thorium-230 concentrations for 1-3 ft were used because no data were available for 0-1 ft.

[b] Data for the city property are incorporated into the SLDS data to estimate soil concentrations.

[c] A hyphen indicates that air concentrations based on soil data were not projected because soil concentrations were below background.

TABLE 3.20 Chemical Exposure Point Concentrations for Inhalation of Particulates by Current Receptors at the St. Louis Site[a]

	Exposure Point Concentration[b] (mg/m^3)							
Contaminant	SLDS	City Property	SLAPS	Ditches	Ballfield	Coldwater Creek	Futura	HISS
Metals								
Arsenic	1.7×10^{-4}	1.4×10^{-7}	3.4×10^{-7}	1.4×10^{-4}	1.3×10^{-7}	3.0×10^{-7}	1.4×10^{-7}	2.5×10^{-6}
Beryllium	4.4×10^{-6}	1.2×10^{-8}	1.8×10^{-8}	7.5×10^{-6}	6.7×10^{-9}	1.6×10^{-8}	7.2×10^{-9}	8.9×10^{-8}
Cadmium	1.7×10^{-5}	2.2×10^{-8}	2.0×10^{-8}	8.5×10^{-6}	9.0×10^{-9}	1.6×10^{-8}	-[c]	1.0×10^{-7}
Lead	7.0×10^{-3}	6.7×10^{-6}	1.6×10^{-6}	6.5×10^{-4}	3.4×10^{-7}	1.2×10^{-6}	1.3×10^{-6}	3.1×10^{-6}
Nickel	1.5×10^{-4}	2.8×10^{-7}	1.1×10^{-5}	4.6×10^{-3}	2.3×10^{-7}	2.2×10^{-7}	1.9×10^{-6}	1.1×10^{-5}
PAHs	2.2×10^{-3}	5.3×10^{-6}	-	-	-	4.1×10^{-7}	-	-

[a] Air concentrations were estimated for carcinogens only.

[b] Air concentrations for the city property, SLAPS, ballfield, Coldwater Creek, Futura Coatings property, and HISS were calculated from soil exposure point concentrations (EPCs) given in Table 3.14, as follows: soil EPC mg/kg × particulate concentration in air (i.e., 0.08 mg particulate/m^3) × 10^{-6} kg/mg × 30% respirable × 50% (fraction of particulates from contaminated source). Air concentrations for SLDS and the ditches were based on the soil EPCs for SLDS and SLAPS given in Table 3.14 and an assumed respirable particulate concentration of 5 mg/m^3.

[c] A hyphen indicates that the substance is not a contaminant of concern for that property.

TABLE 3.21 Chemical Exposure Point Concentrations for Inhalation of Particulates by Future Receptors at the St. Louis Site[a]

	Exposure Point Concentration[b] (mg/m^3)					
Contaminant	SLDS	SLAPS	Ballfield	Coldwater Creek	Futura	HISS
Arsenic	3.8×10^{-7}	3.4×10^{-7}	9.4×10^{-7}	3.0×10^{-7}	8.5×10^{-7}	2.5×10^{-6}
Beryllium	1.0×10^{-8}	1.8×10^{-8}	2.9×10^{-8}	1.6×10^{-8}	5.8×10^{-8}	8.9×10^{-8}
Cadmium	3.7×10^{-8}	2.0×10^{-8}	2.9×10^{-8}	1.6×10^{-8}	-	1.0×10^{-7}
Lead	1.6×10^{-5}	1.6×10^{-6}	4.9×10^{-7}	1.2×10^{-6}	1.7×10^{-6}	3.1×10^{-6}
Nickel	3.4×10^{-7}	1.1×10^{-5}	4.1×10^{-7}	2.2×10^{-7}	4.2×10^{-5}	1.1×10^{-5}
PAHs	5.3×10^{-6}	-	-	4.1×10^{-7}	-	-

[a] Contaminant concentrations in air were calculated from soil exposure point concentrations (EPCs) given in Table 3.15, as follows: soil EPC mg/kg × particulate concentration in air (i.e., 0.08 mg particulate/m^3) × 10^{-6} kg/mg × 30% respirable × 50% (fraction of particulates from contaminated source). Air concentrations were estimated for carcinogens only.

[b] A hyphen indicates that the substance is not a contaminant of concern for that property.

TABLE 3.22 Radionuclide Exposure Point Concentrations and Estimated Doses for Ingestion of Groundwater by Future Receptors at the St. Louis Site

	Radium-226+D		Thorium-230	
Property and Receptor	Groundwater Concentration (pCi/L)	Dose (mrem)	Groundwater Concentration (pCi/L)	Dose (mrem)
SLDS future resident	3.2	74	3.7	41
SLAPS future resident	4.0	92	130	1,400
HISS future resident	6.0	140	320	3,600

	Total Uranium[a]		
Property and Receptor	Groundwater Concentration (pCi/L)	Dose (mrem)	Total Dose (mrem)
SLDS future resident	190	1,000	1,100
SLAPS future resident	8,700	46,000	47,000
HISS future resident	120	660	4,400

[a] The dose conversion factors for uranium-238 and uranium-234 were averaged and used in the dose calculation for total uranium.

TABLE 3.23 Exposure Point Concentrations of Chemicals for Ingestion of Groundwater by Future Receptors at the St. Louis Site[a]

	Exposure Point Concentration[b] (µg/L)		
Contaminant	SLDS	SLAPS	HISS
Metals			
Antimony	40	89	150
Arsenic	130	16	16
Barium	540	720	2,300
Beryllium	5.0	5.0	5.0
Boron	1,800	500	340
Cadmium	11	23	47
Chromium	50	380	120
Cobalt	50	20	130
Copper	37	160	130
Lead	100	100	100
Manganese	4,500	6,800	7,000
Molybdenum	100	170	140
Nickel	710	100	100
Selenium	110	6,000	3,600
Silver	10	64	15
Thallium	100	110	180
Uranium[c]	570	26,000	360
Vanadium	50	160	140
Zinc	300	7,700	1,400
Inorganic anions			
Fluoride	6,200	NA	NA
Nitrate	210	NA	NA
Volatile organic compounds			
Benzene	21	ND	ND
Chlorobenzene	8.0	ND	ND
1,2-Dichloroethene	150	95	ND
1,2-Dichloropropane	130	ND	ND
Toluene	ND	170	ND
Trichloroethene	5.0	130	ND
Vinyl chloride	29	ND	ND
Semivolatile organic compounds			
Bis(2-ethylhexyl)phthalate	1,100	430	650
1,2-Dichlorobenzene	93	ND	ND
PCBs/Pesticides			
Aroclor 1254 (PCB)	1.5	ND	ND
4,4'-DDT	0.98	ND	ND
Endosulfan	ND	0.090	ND

[a] Basis of data: SLDS, maximum in 8 wells during 4 quarters; SLAPS, maximum in 16 wells during 4 quarters; HISS, maximum in 15 wells during 4 quarters. All values are rounded to two significant figures.

[b] NA indicates not analyzed; ND indicates not detected.

[c] Uranium concentrations are maximum values reported in BNI (1987e, 1990b) and DOE (1993).

TABLE 3.24 Exposure Point Concentrations of Chemicals for Inhalation of Groundwater by Future Receptors at the St. Louis Site[a]

	Exposure Point Concentration[b] (mg/m^3)		
Contaminant	SLDS	SLAPS	HISS
Volatile organic compounds			
Benzene	0.84	ND	ND
Chlorobenzene	0.32	ND	ND
1,2-Dichloropropane	5.2	ND	ND
Toluene	ND	6.8	ND
Trichloroethene	0.20	5.2	ND
Vinyl chloride	1.2	ND	ND
Semivolatile organic compound			
1,2-Dichlorobenzene	3.7	ND	ND

[a] Organic compounds with molecular weights greater than 200 were not evaluated for this pathway because volatilization of these contaminants is insignificant (EPA 1991d). Equation 3.4 was used to derive air concentrations from groundwater concentrations (Section 3.3.2.2).

[b] ND indicates not detected.

TABLE 3.25 Dose Conversion Factors Used for Calculating Doses from External Exposure, Ingestion, and Inhalation

Radionuclide	External Gamma[a] [(mrem/yr)/(pCi/cm^3)]	Ingestion[b] (mrem/pCi)	Inhalation[b] (mrem/pCi)
Actinium-227+D	2.9	1.5×10^{-2}	6.7
Lead-210+D	4.8×10^{-3}	6.7×10^{-3}	2.1×10^{-2}
Protactinium-231	2.4×10^{-1}	1.1×10^{-2}	1.3
Radium-226+D	1.6×10^{1}	1.1×10^{-3}	7.9×10^{-3}
Radium-228+D	8.6	1.2×10^{-3}	4.5×10^{-3}
Thorium-228+D	1.4×10^{1}	7.5×10^{-4}	3.1×10^{-1}
Thorium-230	2.1×10^{-3}	5.3×10^{-4}	3.2×10^{-1}
Thorium-232	1.3×10^{-3}	2.8×10^{-3}	1.6
Uranium-234	1.5×10^{-3}	2.6×10^{-4}	1.3×10^{-1}
Uranium-235+D	9.4×10^{-1}	2.5×10^{-4}	1.2×10^{-1}
Uranium-238+D	1.3×10^{-1}	2.5×10^{-4}	1.2×10^{-1}

[a] Based on soil density of 1.6 g/cm^3; derived from values given in Gilbert et al. (1989).

[b] Source: Gilbert et al. (1989).

TABLE 3.26 Summary of Estimated Doses to Current Receptors from Radionuclide Exposure at the St. Louis Site[a]

Property and Receptor	Dose from Nonradon Exposures (mrem) External Exposure	Soil Ingestion	Particulate Inhalation	Total Dose from Nonradon Exposures (mrem)	Dose from Inhalation of Radon Decay Products (WLM)
SLDS employee[b]	-	NA	NA	-	-
SLDS construction worker[c]	-	-	-	-	-
SLDS maintenance worker (drains)[d]	0.0044	3.4	NA	3.4	NA
City property recreational user	77	43	6.8	130	0.16
SLAPS trespasser	51	42	6.0	100	0.097
SLAPS maintenance worker	1,000	220	70	1,300	1.0
Ditch construction worker	5.6	5.7	730	740	0.014
Residential vicinity property child commuter	0.34	8.0	0.088	8.4	0.00032
Residential vicinity property current resident	47	46	22	120	0.014
Ballfield recreational user	32	8.7	2.0	43	0.033
Coldwater Creek recreational user	1.7	1.5	0.15	3.4	0.0028
Futura Coatings employee	1,400	140	36	1,600	0.71
HISS trespasser	78	51	7.6	140	0.099
HISS maintenance worker	5,400	1,100	240	6,700	2.8

[a] Dose results are rounded to two significant figures.

[b] Results for the SLDS employee are presented in Table 3.7; NA indicates not applicable because it is not a pathway of concern for that receptor.

[c] Results for the SLDS construction worker are presented in Tables 3.8 and 3.9.

[d] NA indicates not applicable because it is not a pathway of concern for that receptor.

TABLE 3.21 Summary of Estimated Doses to Future Receptors from Radionuclide Exposure at the St. Louis Site[a]

Property and Receptor	Dose from Nonradon Exposures (mrem)				Total Dose from Nonradon Exposures (mrem)	Dose from Inhalation of Radon Decay Products (WLM)
	Groundwater Ingestion[b]	External Exposure	Soil Ingestion	Particulate Inhalation		
SLDS future resident	1,100	24,000	1,500	330	27,000	120
SLAPS future resident	47,000	17,000	2,300	580	67,000	200
Residential vicinity property future resident	-	150	46	23	220	0.93
Ballfield future resident	-	1,500	160	37	1,700	8.5
Coldwater Creek future recreational user	-	1.7	1.5	0.15	3.4	0.0028
Futura Coatings future resident	-	6,000	1,400	170	7,600	86
HISS future resident[c]	4,400	25,000	2,700	720	33,000	55

[a] Dose results are rounded to two significant figures.

[b] A hyphen indicates that a dose from groundwater ingestion was not calculated because no groundwater data are available for this property.

[c] Additional estimated doses from the contribution of contaminants in the HISS storage piles are given in Table 3.13.

TABLE 3.28 Values Assumed for Scenario Parameters

Parameter	Unit	SLDS/ Futura/VPs Employee[a]	SLDS Maintenance Worker[b]	City Property Recreational User[c]	SLAPS/HISS Maintenance Worker[d]	SLAPS/HISS Trespasser[e]	SLDS/Ditch Construction Worker[f]
Exposure time (ET)	h/d	8	1	3	8	2	8
Exposure time for showering (ET)	min/d	NA[g]	NA	NA	NA	NA	NA
Time spent outdoors	h/d	0	1	3	6 (SLAPS) 3 (HISS)	2	8 (Ditch) 0 or 8 (SLDS)[h]
Exposure frequency (EF)	d/yr	250	2	26	50 (SLAPS) 200 (HISS)	26	50 (Ditch) 25 (SLDS)[h]
Exposure duration[i] (ED)	yr	25	25	9	25	9	1
Body weight[j] (BW)	kg	70	70	50	70	50	70
Inhalation rate[k] (IR)	m^3/h	0.83	NA	1.8	0.83 Indoors 1.2 Outdoors	1.8	2.5 Indoors 2.5 Outdoors
Particulate concentration in air[l]	mg/m^3	0.08	NA	0.08	0.08	0.08	15
Amount of particulates from contaminated soil[m]	%	50	NA	50	50	50	100
Amount of particulates that is respirable[m]	%	30	NA	30	30	30	30
Amount of outdoor particulates assumed to be present indoors[n]	%	40	NA	NA	40	NA	40
Soil ingestion rate[o] (IR_s)	mg/d	50	100	100	100	100	300
Water ingestion rate[p] (IR_w)	L/d	NA	NA	NA	NA	NA	NA

TABLE 3.28 (Cont.)

Parameter	Unit	Ballfield Recreational User[q]	Coldwater Creek Recreational User[r]	Residential VP Commuter[s]	Residential VP Current Resident[t]	Future Resident[u]
Exposure time (ET)	h/d	3	2	0.2	20	20
Exposure time for showering (ET)	h/d	NA	NA	NA	NA	0.17
Time spent outdoors	h/d	3	2	0.2	2	2
Exposure frequency (EF)	d/yr	78	26	180	350	350
Exposure duration[i] (ED)	yr	9	9	12	30	30
Body weight[j] (BW)	kg	25	50	25	70	70
Inhalation rate[k] (IR)	m^3/h	2.1	1.8	0.83	0.83	0.83
Particulate concentration in air[l]	mg/m^3	0.08	0.08	0.08	0.08	0.08
Amount of particulates from contaminated soil[m]	%	50	50	50	50	50
Amount of particulates that is respirable[m]	%	30	30	30	30	30
Amount of outdoor particulates assumed to be present indoors[n]	%	NA	NA	NA	40	40
Soil ingestion rate[o] (IR_s)	mg/d	100	100	100	100 (adult) 200 (child)	100 (adult) 200 (child)
Water ingestion rate[p] (IR_w)	L/d	NA	NA	NA	NA	2

See next page for footnotes.

TABLE 3.28 (Cont.)

---

[a] Current employees at SLDS, Futura Coatings property, and commercial/industrial/municipal VPs (vicinity properties). Employees doing light work indoors (e.g., office workers) are evaluated.

[b] Current worker conducting intermittent maintenance of drains.

[c] A 10- to 18-year-old youth using the city property for recreation under current conditions.

[d] Current maintenance and monitoring personnel. These exposures have been summed (see Section 5.2.1.2) because the receptor is a single individual.

[e] A 10- to 18-year-old youth trespassing at SLAPS or HISS under current conditions.

[f] Current construction worker at SLDS or at the ditches adjacent to SLAPS. The construction worker at the ditches is representative for all SLAPS and HISS vicinity properties.

[g] NA indicates not applicable.

[h] For ease of presentation, the exposure frequency assumed for the SLDS construction worker was 12.5 days per year spent at indoor projects (e.g., renovation) and another 12.5 days per year spent at outdoor projects (e.g., excavations).

[i] Exposure duration values for occupational and residential scenarios (i.e., 25 and 30 years) as recommended by the EPA (1991b). For other scenarios involving child and youth receptors, 9 years is the age-range duration and is also the median time at one residence (EPA 1989a). A 12-year exposure duration for the residential vicinity property commuter corresponds to the number of years a child might commute to school by bus. Exposure to the SLDS employee was calculated for exposure durations of 1 and 25 years. Construction work at SLDS and vicinity properties was assumed to be intermittent small projects; therefore, a duration of 1 year was assumed.

[j] Body weights: 70 kg for adult scenarios (EPA 1991b); 50 kg for youth scenarios (12 to <15 years old [EPA 1989a]); 25 kg for child scenarios (6 to <9 years old [EPA 1989a]); and 15 kg for young child (EPA 1991b).

[k] Based on EPA levels for residential and occupational scenarios (EPA 1991b) and EPA child and adult inhalation rates (EPA 1992), accounting for resting, light, moderate, and heavy activity patterns, as follows:

SLDS/Futura/vicinity properties employee and SLAPS/HISS maintenance worker: approximate value for adult engaged in light activity.

SLAPS/HISS maintenance worker: outdoor average adult inhalation rate of 1.2 m^3/h, with 0.75 exposure time at light activity + 0.125 exposure time at moderate activity + 0.125 exposure time at heavy activity (EPA 1989a).

SLDS/vicinity properties construction worker: value from EPA (1991b).

Youth scenarios (ages 10 to 18): average inhalation rate for a 10-year-old child and adult of 1.8 m^3/h, with 0.5 exposure time at light activity + 0.5 exposure time at moderate activity (EPA 1989a).

Child scenarios (ages 6 to 14): inhalation rate for a 10-year-old child of 2.1 m^3/h, with 0.5 exposure time at light activity + 0.5 exposure time at moderate activity (EPA 1989c).

TABLE 3.28 (Cont.)

---

[l] Based on measured particulate concentrations in the St. Louis area (Trijonis et al. 1980) for all scenarios except the SLDS/ditch construction worker; for that scenario, the average concentration was assumed to be the OSHA standard for nuisance particulates (29 CFR 1910.1000, Subpart Z).

[m] Based on estimates from Trijonis et al. (1980) and Paustenbach (1989).

[n] Based on value given in Alzona et al. (1979).

[o] Rates recommended by the EPA (1991b). For the future resident scenario, the soil ingestion pathway assumed an ingestion rate of 200 mg/d and body weight of 15 kg for 6 years of exposure as a child, and an ingestion rate of 100 mg/d and body weight of 70 kg for 24 years of exposure as an adult. A higher rate was used for the construction worker because of longer exposure to contaminated material and ingestion of inhaled material that is not retained in the lungs. In instances where all daily exposure was indoors (i.e., SLDS/Futura/VPs employee and half of the SLDS construction worker exposure), the soil ingestion rate was multiplied by 0.4 to account for the percent of outdoor soil present in indoor dust.

[p] Values recommended by the EPA (1991b).

[q] A 6- to 14-year-old child using the ballfield for recreation under current conditions.

[r] A 10- to 18-year-old youth using Coldwater Creek for recreation under current or future conditions.

[s] A 6- to 14-year-old child at a residential VP (vicinity property) who commutes to school by bus.

[t] A current receptor in a dwelling at a residential VP (vicinity property) distant from the area of contamination.

[u] Assumed future worst-case scenario for all properties except Coldwater Creek. In accordance with EPA (1991b) guidance, the future resident is assumed to be an adult for all exposure pathways except the soil ingestion pathway, where 6 years of the exposure duration are modeled as childhood exposure.

TABLE 3.29 Estimated Daily Intake of Chemicals from Incidental Ingestion of Soil by Current Receptors at the St. Louis Site[a]

	Estimated Daily Intake for Current Receptor Averaged over Exposure Period[b] (mg/kg-d)				
Contaminant	SLDS Construction Worker[c]	City Property Recreational User	SLAPS Trespasser	SLAPS Maintenance Worker	Ditch Construction Worker
Metals					
Antimony	2.3×10^{-5}	4.4×10^{-5}	8.0×10^{-7}	1.1×10^{-6}	3.3×10^{-6}
Arsenic	6.8×10^{-6}	1.7×10^{-6}	4.0×10^{-6}	5.5×10^{-6}	1.6×10^{-5}
Beryllium	1.8×10^{-7}	1.4×10^{-7}	2.1×10^{-7}	2.9×10^{-7}	8.8×10^{-7}
Cadmium	6.8×10^{-7}	2.6×10^{-7}	2.4×10^{-7}	3.3×10^{-7}	1.0×10^{-6}
Cobalt	2.9×10^{-6}	1.1×10^{-6}	1.0×10^{-4}	1.4×10^{-4}	4.2×10^{-4}
Copper	-	-	6.7×10^{-5}	9.2×10^{-5}	2.8×10^{-4}
Lead	2.9×10^{-4}	8.0×10^{-5}	1.9×10^{-5}	2.5×10^{-5}	7.6×10^{-5}
Molybdenum	-	-	-	-	-
Nickel	6.0×10^{-6}	3.3×10^{-6}	1.3×10^{-4}	1.8×10^{-4}	5.4×10^{-4}
Selenium	-	-	-	-	-
Thallium	9.9×10^{-6}	7.0×10^{-6}	1.6×10^{-6}	2.2×10^{-6}	6.5×10^{-6}
Uranium	1.1×10^{-4}	1.2×10^{-4}	1.4×10^{-5}	1.9×10^{-5}	5.8×10^{-5}
Zinc	-	-	-	-	-

	Estimated Daily Intake for Current Receptor Averaged over Exposure Period[b] (mg/kg-d)				
Contaminant	Ballfield Recreational User	Coldwater Creek Recreational User	Futura Coatings Employee[c]	HISS Trespasser	HISS Maintenance Worker
Metals					
Antimony	5.7×10^{-6}	1.4×10^{-6}	-	8.0×10^{-6}	4.4×10^{-5}
Arsenic	9.4×10^{-6}	3.6×10^{-6}	2.3×10^{-6}	3.0×10^{-5}	1.6×10^{-4}
Beryllium	4.8×10^{-7}	1.9×10^{-7}	1.2×10^{-7}	1.1×10^{-6}	5.8×10^{-6}
Cadmium	6.4×10^{-7}	1.9×10^{-7}	-	1.2×10^{-6}	6.6×10^{-6}
Cobalt	5.7×10^{-6}	1.9×10^{-6}	2.0×10^{-5}	1.2×10^{-4}	6.7×10^{-4}
Copper	-	-	1.9×10^{-5}	-	-
Lead	2.4×10^{-5}	1.4×10^{-5}	2.2×10^{-5}	3.7×10^{-5}	2.0×10^{-4}
Molybdenum	9.4×10^{-6}	3.7×10^{-6}	3.9×10^{-6}	3.4×10^{-5}	1.9×10^{-4}
Nickel	1.6×10^{-5}	2.6×10^{-6}	3.1×10^{-5}	1.3×10^{-4}	7.0×10^{-4}
Selenium	9.4×10^{-6}	1.2×10^{-5}	2.3×10^{-6}	2.8×10^{-5}	1.6×10^{-4}
Thallium	9.4×10^{-6}	3.3×10^{-6}	2.3×10^{-6}	2.8×10^{-5}	1.6×10^{-4}
Uranium	-	-	1.6×10^{-5}	2.3×10^{-5}	1.3×10^{-4}
Zinc	-	2.0×10^{-4}	-	-	-

TABLE 3.29 (Cont.)

	Estimated Daily Intake for Current Receptor Averaged over Lifetime[b,d] (mg/kg-d)				
Contaminant	SLDS Construction Worker[c]	City Property Recreational User	SLAPS Trespasser	SLAPS Maintenance Worker	Ditch Construction Worker
Metals					
Arsenic	9.7×10^{-8}	2.2×10^{-7}	5.1×10^{-7}	2.0×10^{-6}	2.4×10^{-7}
Beryllium	2.6×10^{-9}	1.8×10^{-8}	2.8×10^{-8}	1.1×10^{-7}	1.3×10^{-8}
Lead	4.1×10^{-6}	1.0×10^{-5}	2.4×10^{-6}	9.1×10^{-6}	1.1×10^{-6}
PAHs	1.3×10^{-6}	8.1×10^{-6}	-	-	-

	Estimated Daily Intake for Current Receptor Averaged over Lifetime[b,d] (mg/kg-d)				
Contaminant	Ballfield Recreational User	Coldwater Creek Recreational User	Futura Coatings Employee[c]	HISS Trespasser	HISS Maintenance Worker
Metals					
Arsenic	1.2×10^{-6}	4.6×10^{-7}	8.4×10^{-7}	3.9×10^{-6}	5.9×10^{-5}
Beryllium	6.2×10^{-8}	2.4×10^{-8}	4.2×10^{-8}	1.4×10^{-7}	2.1×10^{-6}
Lead	3.1×10^{-6}	1.8×10^{-6}	7.7×10^{-6}	4.8×10^{-6}	7.3×10^{-5}
PAHs	-	6.3×10^{-7}	-	-	-

---

[a] Exposure point concentrations are given in Table 3.14. Equation 3.9 was used to calculate intake (Section 3.4.2.3).

[b] A hyphen indicates that the substance is not a contaminant of concern for that property.

[c] For the SLDS construction worker, half the exposure occurs indoors where contaminant concentrations in dust are reduced by 60%, so half the intake is multiplied by a factor of 0.4. For the Futura employee, the entire exposure occurs indoors, so the entire intake is multiplied by 0.4.

[d] Estimated for carcinogenic contaminants only.

TABLE 3.30 Estimated Daily Intake of Chemicals from Incidental Ingestion of Soil by Future Receptors at the St. Louis Site[a]

	Estimated Daily Intake for Future Receptor Averaged over Exposure Period[b] (mg/kg-d)					
Contaminant	SLDS	SLAPS	Ballfield	Coldwater Creek	Futura	HISS
Metals						
Antimony	4.4×10^{-4}	2.0×10^{-5}	9.5×10^{-5}	1.4×10^{-6}	-	2.0×10^{-4}
Arsenic	1.2×10^{-4}	1.0×10^{-4}	2.8×10^{-4}	3.6×10^{-6}	2.6×10^{-4}	7.7×10^{-4}
Beryllium	3.2×10^{-6}	5.5×10^{-6}	8.8×10^{-6}	1.9×10^{-7}	1.8×10^{-5}	2.7×10^{-5}
Cadmium	1.1×10^{-5}	6.2×10^{-6}	8.8×10^{-6}	1.9×10^{-7}	-	3.1×10^{-5}
Cobalt	4.7×10^{-5}	2.6×10^{-3}	9.1×10^{-5}	1.9×10^{-6}	1.0×10^{-2}	3.1×10^{-3}
Copper	-	1.7×10^{-3}	-	-	6.6×10^{-3}	-
Lead	4.7×10^{-3}	4.7×10^{-4}	1.5×10^{-4}	1.4×10^{-5}	5.1×10^{-4}	9.4×10^{-4}
Molybdenum	-	-	3.1×10^{-4}	3.7×10^{-6}	7.3×10^{-4}	8.8×10^{-4}
Nickel	1.0×10^{-4}	3.4×10^{-3}	1.2×10^{-4}	2.6×10^{-6}	1.3×10^{-2}	3.3×10^{-3}
Selenium	-	-	3.1×10^{-4}	1.2×10^{-5}	7.7×10^{-4}	7.3×10^{-4}
Thallium	1.7×10^{-4}	4.0×10^{-5}	3.2×10^{-4}	3.3×10^{-6}	4.4×10^{-5}	7.3×10^{-4}
Uranium	1.9×10^{-3}	3.6×10^{-4}	-	-	2.9×10^{-4}	5.8×10^{-4}
Zinc	-	-	-	2.0×10^{-4}	-	-

	Estimated Daily Intake for Future Receptor Averaged over Lifetime[b,c] (mg/kg-d)					
Contaminant	SLDS	SLAPS	Ballfield	Coldwater Creek	Futura	HISS
Metals						
Arsenic	5.0×10^{-5}	4.4×10^{-5}	1.2×10^{-4}	4.6×10^{-7}	1.1×10^{-4}	3.3×10^{-4}
Beryllium	1.4×10^{-6}	2.4×10^{-6}	3.8×10^{-6}	2.4×10^{-8}	7.5×10^{-6}	1.2×10^{-5}
Lead	2.0×10^{-3}	2.0×10^{-4}	6.4×10^{-5}	1.8×10^{-6}	2.2×10^{-4}	4.1×10^{-4}
PAHs	6.9×10^{-4}	-	-	6.3×10^{-7}	-	-

[a] Exposure point concentrations are given in Table 3.15. Equations 3.9 and 3.10 were used to calculate intake (Section 3.4.2.3). All future receptors are residents except for the Coldwater Creek recreational user.

[b] A hyphen indicates that the substance is not a contaminant of concern for that property.

[c] Estimated for carcinogenic contaminants only.

TABLE 3.31 Estimated Daily Intake of Chemicals from Inhalation of Particulates by Current Receptors at the St. Louis Site[a]

Contaminant	SLDS Construction Worker	City Property Recreational User	SLAPS Trespasser	SLAPS Maintenance Worker	Ditch Construction Worker
	Estimated Daily Intake for Current Receptor Averaged over Lifetime[b,c] (mg/kg-d)				
Metals					
Arsenic	3.2×10^{-8}	1.4×10^{-10}	2.2×10^{-10}	1.9×10^{-9}	7.8×10^{-8}
Beryllium	8.6×10^{-10}	1.1×10^{-11}	1.2×10^{-11}	9.9×10^{-11}	4.2×10^{-9}
Cadmium	3.2×10^{-9}	2.1×10^{-11}	1.4×10^{-11}	1.1×10^{-10}	4.8×10^{-9}
Lead	1.4×10^{-6}	6.7×10^{-9}	1.0×10^{-9}	8.6×10^{-9}	3.6×10^{-7}
Nickel	2.8×10^{-8}	2.7×10^{-10}	7.3×10^{-9}	6.1×10^{-8}	2.6×10^{-6}
PAHs	4.3×10^{-7}	5.2×10^{-9}	-	-	-

Contaminant	Ballfield Recreational User	Coldwater Creek Recreational User	Futura Coatings Employee	HISS Trespasser	HISS Maintenance Worker
	Estimated Daily Intake for Current Receptor Averaged over Lifetime[b,c] (mg/kg-d)				
Metals					
Arsenic	9.1×10^{-10}	2.0×10^{-10}	1.3×10^{-9}	1.7×10^{-9}	3.7×10^{-8}
Beryllium	4.7×10^{-11}	1.0×10^{-11}	6.7×10^{-11}	5.9×10^{-11}	1.3×10^{-9}
Cadmium	6.2×10^{-11}	1.0×10^{-11}	-	6.7×10^{-11}	1.5×10^{-9}
Lead	2.3×10^{-9}	7.8×10^{-10}	1.2×10^{-8}	2.1×10^{-9}	4.6×10^{-8}
Nickel	1.6×10^{-9}	1.4×10^{-10}	1.8×10^{-8}	7.1×10^{-9}	1.6×10^{-7}
PAHs	-	2.7×10^{-10}	-	-	-

[a] Exposure point concentrations are given in Table 3.20. Equations 3.12 and 3.13 were used to calculate intake (Section 3.4.2.4).

[b] A hyphen indicates that the substance is not a contaminant of concern for that property.

[c] Estimated for carcinogenic contaminants only.

TABLE 3.32 **Estimated Daily Intake of Chemicals from Inhalation of Particulates by Future Receptors at the St. Louis Site**[a]

	Estimated Daily Intake for Future Receptor Averaged over Lifetime[b,c] (mg/kg-d)					
Contaminant	SLDS	SLAPS	Ballfield	Coldwater Creek	Futura	HISS
Metals						
Arsenic	1.7×10^{-8}	1.5×10^{-8}	4.2×10^{-8}	2.0×10^{-10}	3.8×10^{-8}	1.1×10^{-7}
Beryllium	4.7×10^{-10}	8.1×10^{-10}	1.3×10^{-9}	1.0×10^{-11}	2.6×10^{-9}	4.0×10^{-9}
Cadmium	1.7×10^{-9}	9.2×10^{-10}	1.3×10^{-9}	1.0×10^{-11}	-	4.5×10^{-9}
Lead	7.0×10^{-7}	7.0×10^{-8}	2.2×10^{-8}	7.8×10^{-10}	7.5×10^{-8}	1.4×10^{-7}
Nickel	1.5×10^{-8}	5.0×10^{-7}	1.8×10^{-8}	1.4×10^{-10}	1.9×10^{-6}	4.8×10^{-7}
PAHs	2.4×10^{-7}	-	-	2.7×10^{-10}	-	-

[a] Exposure point concentrations are given in Table 3.21. Equations 3.12 and 3.13 were used to calculate intake (Section 3.4.2.4). All future receptors are residents except for the Coldwater Creek recreational user.

[b] A hyphen indicates that the substance is not a contaminant of concern for that property.

[c] Estimated for carcinogenic contaminants only.

TABLE 3.33 Estimated Daily Intake of Chemicals from Ingestion of Groundwater by Future Receptors at the St. Louis Site[a]

	Estimated Daily Intake for Future Resident Averaged over Exposure Period[b] (mg/kg-d)		
Contaminant	SLDS	SLAPS	HISS
Metals			
Antimony	1.1×10^{-3}	2.4×10^{-3}	4.1×10^{-3}
Arsenic	3.5×10^{-3}	4.4×10^{-4}	4.4×10^{-4}
Barium	1.5×10^{-2}	2.0×10^{-2}	6.2×10^{-2}
Beryllium	1.4×10^{-4}	1.4×10^{-4}	1.4×10^{-4}
Boron	5.1×10^{-2}	1.4×10^{-2}	9.2×10^{-3}
Cadmium	3.0×10^{-4}	6.3×10^{-4}	1.3×10^{-3}
Chromium	1.4×10^{-3}	1.0×10^{-2}	3.4×10^{-3}
Cobalt	1.4×10^{-3}	5.5×10^{-4}	3.6×10^{-3}
Copper	1.0×10^{-3}	4.4×10^{-3}	3.6×10^{-3}
Lead	2.7×10^{-3}	2.7×10^{-3}	2.7×10^{-3}
Manganese	1.2×10^{-1}	1.9×10^{-1}	1.9×10^{-1}
Molybdenum	2.7×10^{-3}	4.8×10^{-3}	3.8×10^{-3}
Nickel	2.0×10^{-2}	2.8×10^{-3}	2.7×10^{-3}
Selenium	3.0×10^{-3}	1.6×10^{-1}	1.0×10^{-1}
Silver	2.7×10^{-4}	1.8×10^{-3}	4.1×10^{-4}
Thallium	2.7×10^{-3}	3.1×10^{-3}	5.0×10^{-3}
Uranium	1.6×10^{-2}	7.0×10^{-1}	9.9×10^{-3}
Vanadium	1.4×10^{-3}	4.4×10^{-3}	3.8×10^{-3}
Zinc	8.2×10^{-3}	2.1×10^{-1}	3.8×10^{-2}
Inorganic anions			
Fluoride	1.7×10^{-1}	NA	NA
Nitrate	5.8×10^{-3}	NA	NA
Volatile organic compounds			
Benzene	5.8×10^{-4}	ND	ND
Chlorobenzene	2.2×10^{-4}	ND	ND
1,2-Dichloroethene	4.1×10^{-3}	2.6×10^{-3}	ND
1,2-Dichloropropane	3.6×10^{-3}	ND	ND
Toluene	ND	4.7×10^{-3}	ND
Trichloroethene	1.4×10^{-4}	3.6×10^{-3}	ND
Vinyl chloride	7.9×10^{-4}	ND	ND
Semivolatile organic compounds			
Bis(2-ethylhexyl)phthalate	3.0×10^{-2}	1.2×10^{-2}	1.8×10^{-2}
1,2-Dichlorobenzene	2.5×10^{-3}	ND	ND
PCBs/Pesticides			
Aroclor 1254 (PCB)	4.1×10^{-5}	ND	ND
4,4′-DDT	2.7×10^{-5}	ND	ND
Endosulfan	ND	2.5×10^{-6}	ND

TABLE 3.33 (Cont.)

Contaminant	Estimated Daily Intake for Future Resident Averaged over Lifetime[b,c] (mg/kg-d) SLDS	SLAPS	HISS
Metals			
Arsenic	1.5×10^{-3}	1.9×10^{-4}	1.9×10^{-4}
Beryllium	5.9×10^{-5}	5.9×10^{-5}	5.9×10^{-5}
Lead	1.2×10^{-3}	1.2×10^{-3}	1.2×10^{-3}
Volatile organic compounds			
Benzene	2.5×10^{-4}	ND	ND
1,2-Dichloropropane	1.5×10^{-3}	ND	ND
Trichloroethene	5.9×10^{-5}	1.5×10^{-3}	ND
Vinyl chloride	3.4×10^{-4}	ND	ND
Semivolatile organic compound			
Bis(2-ethylhexyl)phthalate	1.3×10^{-2}	5.0×10^{-3}	7.6×10^{-3}
PCBs/Pesticides			
Aroclor 1254 (PCB)	1.8×10^{-5}	ND	ND
4,4′-DDT	1.2×10^{-5}	ND	ND

[a] Exposure point concentrations are given in Table 3.23. Equation 3.15 was used to calculate intake (Section 3.4.3.1).

[b] NA indicates not analyzed; ND indicates not detected.

[c] Estimated for carcinogenic contaminants only.

TABLE 3.34 Estimated Daily Intake of Chemicals from Inhalation of Groundwater by Future Receptors at the St. Louis Site[a]

	Estimated Daily Intake for Future Resident Averaged over Exposure Period[b] (mg/kg-d)		
Contaminant	SLDS	SLAPS	HISS
Volatile organic compounds			
Chlorobenzene	6.2×10^{-4}	ND	ND
1,2-Dichloropropane	1.0×10^{-2}	ND	ND
Toluene	ND	1.3×10^{-2}	ND
Semivolatile organic compound			
1,2-Dichlorobenzene	7.2×10^{-3}	ND	ND

	Estimated Daily Intake for Future Resident Averaged over Lifetime[b,c] (mg/kg-d)		
Contaminant	SLDS	SLAPS	HISS
Volatile organic compounds			
Benzene	7.0×10^{-4}	ND	ND
1,2-Dichloropropane	4.3×10^{-3}	ND	ND
Trichloroethene	1.7×10^{-4}	4.3×10^{-3}	ND
Vinyl chloride	9.9×10^{-4}	ND	ND

[a] Exposure point concentrations are given in Table 3.24. Equation 3.16 was used to calculate intake (Section 3.4.3.2).

[b] ND indicates not detected.

[c] Estimated for carcinogenic contaminants only.

4 TOXICITY ASSESSMENT

A brief summary of the toxicity of radioactive and chemical contaminants of concern is presented in this chapter. A more detailed assessment of the individual contaminants of concern at the St. Louis Site is presented in Appendix B.

4.1 RADIATION TOXICITY

Radiation health effects for humans have been confirmed only at relatively high doses or at high dose rates with large populations. At low doses, health effects are presumed to occur but can only be estimated statistically. Thus, risk estimates are strictly applicable only to large populations because the appearance of health effects after an exposure is a chance event. Predicting health effects with certainty for small populations (e.g., a few individuals) is not possible.

For purposes of radiological impact assessment, potential health risks are expressed as the increased incidence of cancer in the exposed population. However, risk estimates in the low dose range are uncertain because they are extrapolated from high doses on the basis of unconfirmed assumptions regarding dose-response relationships and the underlying mechanisms of carcinogenesis. In fact, studies of populations chronically exposed to low-level radiation, such as those residing in regions of elevated natural background, have not shown consistent conclusive evidence of an associated increase in the risk of cancer.

Radiation exposure pathways can be separated into either external or internal exposure. External exposure occurs when the radioactive material is outside the body. Internal exposure occurs when the radioactive material enters the body by inhalation or ingestion. Inhaled material can be exhaled, expelled from the lungs to be spit or swallowed and excreted, deposited in the lungs, or absorbed by the blood and relocated to other organs where it is excreted over time. Some ingested material enters the blood and is either excreted in the urine or feces or relocated to other organs and excreted over time; most insoluble ingested material is not absorbed into the blood but is excreted directly in the feces.

Alpha, beta, and gamma radiations are released during the radioactive decay processes of radionuclides in the thorium, uranium, and actinium decay series. Each type of radiation differs in its physical properties and in its ability to induce damage to biological tissue. Alpha particles are a hazard principally when taken into the body because, for external exposure, alpha particles lose their energy in the outer layer of dead skin cells of the body before reaching living tissue. Within the body, they are the most effective of the three types of radiation in damaging cells because their energy is completely absorbed by tissue. Beta particles are primarily an internal hazard; however, in cases of external skin exposure, very energetic beta particles can penetrate to living skin cells, thus representing an external hazard as well. However, beta particles deposit less energy to small volumes of tissue and therefore induce much less damage than alpha particles. Gamma radiation is primarily an external hazard because it can penetrate tissue and reach internal organs. Alpha and beta particles are the dominant concern for internal exposures because their energy is absorbed in cells before the particles leave the body; gamma rays are most likely to leave the body without depositing a large fraction of their energy.

4.1.1 Radiation Toxicity Related to the St. Louis Site

The radioactive contamination at the St. Louis Site has been characterized as low-level ionizing radiation. Potential health effects associated with exposure to this type of radiation include an increase in the occurrence of cancer, depending on the organ irradiated, and possible genetic effects in future generations. The major potential impact resulting from exposure to site contaminants is cancer induction; the risk of serious genetic effects is much lower. Thus, the assessment of radiological health risks in this BRA is limited to cancer induction. This approach is consistent with EPA guidance, which notes that cancer risk is generally the limiting effect for radionuclides and suggests that radiation carcinogenesis be used as the sole basis for assessing radiation-related human health risks (EPA 1989c).

Elements in the uranium-238, thorium-232, and actinium (uranium-235) decay series (Figures 2.1, 2.2, and 2.3) are the radioactive contaminants of concern at the St. Louis Site. Both soluble and insoluble forms may cause health effects via inhalation and ingestion. Actinium, lead, and thallium are primarily beta and gamma emitters. Inhalation or ingestion of soluble actinium and lead may result in health effects in bone. Soluble thallium entering the blood is quickly and uniformly distributed throughout all organs and tissues of the body (ICRP 1978-1982). Bismuth and protactinium are alpha, beta, and gamma emitters. Following inhalation or ingestion of soluble bismuth and protactinium, the primary organs for deposition are the liver and kidneys, respectively.

Potential health effects resulting from exposure to insoluble radionuclides of the three decay series are associated primarily with the inhalation pathway. Most ingested insoluble radionuclides pass through the body and are excreted. Thorium, radium, uranium, radon, and polonium emit primarily alpha radiation. Most alpha-emitting radionuclides that are inhaled are hazardous to the lungs, and, once they enter the bloodstream, these nuclides tend to concentrate in bone. Potential health effects from thorium are related to its incorporation in the liver, bone marrow, and lymph nodes. Health effects of radium include the induction of skeletal tumors and of carcinomas in the paranasal sinuses and mastoid air cells. Uranium deposits uniformly in the bone and can cause kidney damage. Evidence of carcinogenicity for uranium is inconclusive for both humans and animals. Lung cancer is the primary health effect resulting from exposure to radon and radon decay products, including polonium-214 and polonium-218. Polonium concentrates in kidneys, blood cells, and the reticuloendothelial system (i.e., the precursors to red blood cells and the cells lining the capillaries). The effects of high doses of polonium are similar to those of whole-body radiation and involve all major organ systems.

4.1.2 Methods of Evaluating Radiation Toxicity

The EPA has developed guidance for radiological risk assessment that is generally consistent with the guidance for assessing chemical carcinogenic risks, except that it consists of a two-phase (i.e., dual-endpoint) evaluation (EPA 1989c). For the first phase, radiation doses are calculated for all relevant radionuclides and pathways for the purpose of comparing committed effective dose equivalents with established radiation protection standards and criteria. For the second phase, carcinogenic risks are calculated for the radionuclides of concern in a manner similar to existing methods for chemical carcinogens by using an age-averaged lifetime excess cancer incidence per unit intake (and per unit external exposure). To support this second evaluation, the EPA has recently developed cancer incidence factors per unit intake that are synonymous with the slope factors developed for chemical carcinogens. However, these factors have not been independently verified by the scientific community, nor have they been widely used. Because of resultant uncertainty, these factors have not been used to estimate radiological health risks in this BRA; rather, these risks have been estimated from the risk estimators discussed below.

For this assessment, a risk factor of 6 × 10^{-7}/mrem was used to estimate the likelihood of cancer induction from radiation exposure for the ingestion, inhalation (excluding radon), and external gamma irradiation pathways. This risk factor was used by the EPA in developing revisions to the National Emission Standards for Hazardous Air Pollutants (NESHAPs) for radionuclides under Section 112 of the Clean Air Act (EPA 1989b). This risk actor is a lifetime average value and is believed to be representative of conditions defined for the exposure scenarios at the St. Louis Site.

The recently issued BEIR V study of the Committee on Biological Effects of Ionizing Radiations (BEIR) presents a detailed description of current data on the health risks associated with radiation exposure (National Research Council 1990). A mortality risk factor of about 8 × 10^{-7}/mrem can be obtained from the information provided in the BEIR V report. However, not all radiation-induced cancers are fatal, i.e., the cancer mortality rate is about 60% of the cancer induction rate given in EPA (1989b). A cancer induction rate of about 1.3 × 10^{-6}/mrem can thus be inferred from the results presented in the BEIR V study. This value is about a factor of two greater than that used by the EPA in their evaluation of NESHAPs for radionuclides, which was adopted for use in this assessment. However, the results of the BEIR V study are recent and have not as yet been uniformly accepted by the scientific community. In addition, the BEIR V estimates were derived primarily from data on acute exposures (a single instantaneous exposure), and it is suggested in the BEIR V report that it may be appropriate to reduce this risk by applying a dose-rate-effectiveness factor of two in cases of continuous low-level exposure. Thus, the radiation risk factor used in this BRA is similar to the value reported in BEIR V and is believed to be appropriate for this assessment. Also, because portions of the St. Louis Site are on the NPL and final leanup decisions would have to be made in conjunction with the EPA, use of this value is onsistent with that recommended by the EPA for evaluating the health risks associated with adiation exposure.

In this BRA, the risk of fatal cancer from inhalation of radon-222 decay products has been estimated with the risk factor of 3.5 × 10^{-4}/WLM recommended in the BEIR IV study (National Research Council 1988). Because most lung cancers are fatal, this estimator can also be used to estimate the rate of cancer induction. In the BEIR IV study, the results were largely based on information for adult exposures (i.e., miners exposed to elevated levels of radon gas and associated decay products) but were adjusted to account for exposures that could occur in the general population over a lifetime. Hence, the BEIR IV risk factor is believed to be an accurate representation of the health risks associated with exposure to radon-222 decay products at the St. Louis Site.

4.2 CHEMICAL TOXICITY

4.2.1 General Data Related to the St. Louis Site

The chemical contaminants of concern in soil and groundwater at the various areas of the St. Louis Site include several inorganic and organic substances. The specific inorganics of concern are the metals antimony, arsenic, beryllium, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, thallium, and uranium; and the inorganic anions fluoride and nitrate.

Inorganics are naturally found at varying levels in rocks and soils and in most plant and animal food products. Some metals of concern — such as arsenic, cobalt, copper, molybdenum, and selenium — are essential in the daily human diet. The extent of absorption of metals and ions from the respiratory tract, digestive tract, or across the skin is highly dependent on the chemical form of the substance (e.g., inorganic or methylated compounds, oxidation state, and soluble or insoluble compounds).

Most of the metals of concern are not well absorbed through the respiratory system, but inhalation of high levels of the metals can cause irritation of the respiratory tract. Inhalation exposure to high levels over several years may progress from lung irritation to irreversible lung disease. Some of the metals (e.g., arsenic, beryllium, cadmium, lead, and selenium) are also easily absorbed from the lungs into the bloodstream, causing toxic effects to organs outside the respiratory tract. Prolonged inhalation exposure to arsenic, beryllium, cadmium, or nickel has been linked to the induction of lung cancer.

When ingested, less than 10% of the elemental form of most metals is absorbed from the digestive tract; however, up to 50% of inorganic compounds of arsenic, cobalt, copper, and lead may be absorbed. Ingestion of high levels of the metals of concern is likely to cause irritation of the digestive tract. Ingestion or inhalation of arsenic, cadmium, lead, and uranium can result in toxicity to the kidneys and liver; and ingestion of selenium or thallium at elevated levels can cause hair loss and peripheral nervous system toxicity. Ingestion of water containing nitrate at levels greater than 10 mg/L has led to serious hemoglobin damage in infants, resulting in potentially fatal cyanosis, although this effect has not been observed in children over 1 year of age. Ingestion of very high levels of fluoride can result in discoloration of the teeth or injury to the bone. Ingestion of arsenic, beryllium, and lead over a long period of time has been associated with the induction of cancer.

Dermal uptake of the elemental forms of metals is low, but some compounds of thallium and uranium can be absorbed through the skin. Dermal contact with many of the metals (e.g., antimony, arsenic, beryllium, cobalt, nickel, and selenium) can also cause skin irritation or allergic dermatitis reactions in sensitive individuals.

Lead can be toxic by exposure through either the inhalation or ingestion pathway. Exposure to high levels of lead can cause anemia and other toxic effects. Exposure to even low levels of lead during pregnancy may cause low birth weights, preterm births, and delayed development; low-level exposures may also be linked with high blood pressure in adult males and decreased IQ scores in children. In addition, lead has been shown to induce cancer in laboratory animals when given at high doses.

Some PAHs have been shown to induce cancer in laboratory animals through ingestion, inhalation, or dermal exposure. Studies have reported increased mortality due to lung cancer in humans exposed to coke-oven emissions, roofing-tar emissions, and cigarette smoke; these substances contain many PAHs classified by the EPA as probably carcinogenic to humans.

Twelve organic compounds have been detected in groundwater samples from SLDS, SLAPS, or HISS: benzene, bis(2-ethylhexyl)phthalate, chlorobenzene, 4,4′-DDT, 1,2-dichloroenzene, cis-1,2,-dichloroethene, 1,2-dichloropropane, endosulfan, PCBs, toluene, trichloroethene, and vinyl chloride. Exposure to many of these compounds has been associated with iver and kidney damage. In addition, seven of the compounds are classified as probable or known human carcinogens.

.2.2 Methods of Evaluating Chemical Toxicity

Methods for evaluating the toxicity of chemical contaminants of concern are described in detail in Appendix B. Two toxicity values were used: the chronic RfD for the evaluation of noncarcinogenic toxicity and the slope factor for the evaluation of carcinogenicity.

The chronic RfD is defined as "an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk f deleterious effects during a lifetime" (EPA 1989c). If the sum of the ratios of intake to RfD value (i.e., hazard indexes) for all contaminants is less than 1, this indicates that noncarcinogenic toxicity is unlikely. The slope factor is defined as a "plausible upper-bound estimate f the probability of a response (i.e., cancer) per unit intake of a chemical over a lifetime" (EPA 1989c). The slope factors multiplied by the intake levels yield lifetime cancer risk stimates. Both RfD and slope factor values are specific to either ingestion or inhalation posure.

4.2.2.1 Chemicals for Which EPA Toxicity Values Are Available

The EPA reviews the available literature and derives toxicity values on the basis of the most applicable study or studies. Current EPA-derived oral RfD values are available for all inorganic contaminants of concern at the St. Louis Site except cobalt and lead. Inhalation slope factors are not available for bis(2-ethylhexyl)phthalate, 1,2-dichloropropane, or PCBs. Neither an oral nor an inhalation slope factor is available for lead.

Available toxicity values and data pertinent to their use are summarized in Tables 4.1 and 4.2. Further information on the derivation of these values is presented in Appendix B. The RfD values and slope factors given in Tables 4.1 and 4.2 were used to calculate potential health risks for the St. Louis Site; the risk assessment is presented in Chapter 5.

4.2.2.2 Chemicals for Which No EPA Toxicity Values Are Available

No EPA-derived inhalation RfD values are available for the inorganic chemical contaminants of concern for soils at the St. Louis Site. The EPA is developing inhalation RfD values for various elements and compounds and recommends that, until these inhalation RfD values have been verified, the noncarcinogenic effects of inhalation of these substances should be evaluated qualitatively. Therefore, in Chapter 5 of this assessment, noncarcinogenic toxicity is quantitatively evaluated for the ingestion pathway only, except for the inhalation of organic contaminants while showering. The possible impacts of the absence of a quantitative noncarcinogenic risk estimation for the inhalation pathway is discussed in Section 5.3.

No RfD values specific to dermal absorption are currently available. The extent of dermal uptake of a chemical can be influenced by many factors, including the form of the chemical, the condition of the skin (e.g., the presence of abrasions), and the medium in which the chemical is present (e.g., water, oil-like substance, or soil). In general, uptake from solids (e.g., soil) is much less efficient than uptake from liquids, partially because hydrated skin is more permeable than dry skin (Klaasen et al. 1986). Therefore, when soil is the contaminant source, ingestion and inhalation exposure are likely to be far more significant pathways of uptake than dermal exposure. In addition, because EPA policies are still evolving on how exposure via the dermal pathway should be estimated, dermal exposure via soil was not included in the quantitative exposure estimates derived in Chapter 5. Also, dermal exposure to VOCs while showering was considered negligible compared with inhalation exposure.

Evaluating the toxicity of lead produces uncertainties because no "safe" level of exposure (i.e., a dose below which no toxicity is observed) has been determined. The absence of both RfD values and slope factors for lead does not allow for a quantitative evaluation of the potential risk associated with lead exposure similar to that performed for the other site chemical contaminants of concern; however, an uptake/biokinetic model proposed by the EPA was used to evaluate lead levels at the St. Louis Site. The application of this model is discussed in Section 5.3.5.

TABLE 4.1 Toxicity Values for Chemical Contaminants of Concern for Oral and Inhalation Exposure: Potential Noncarcinogenic Effects[a]

Route/Contaminant	Chronic RfD[b] (mg/kg-d)	Confidence[c] Level	Critical Effect	RfD Basis	RfD Source	Uncertainty and Modifying Factors[d]
Oral Route						
Metals						
Antimony	0.0004	Low	Reduced lifespan; altered blood chemistry	Water	IRIS	UF=1,000 for H,A,L
Arsenic	0.0003	Medium	Hyperpigmentation, keritosis, and possible vascular complications	Oral	IRIS	UF=3
Barium	0.07	Medium	Increased blood pressure	Water	IRIS	UF=3
Beryllium	0.005	Low	No adverse effects	Water	IRIS	UF=100 for H,A
Boron	0.09	Medium	Testicular lesions	Diet	IRIS	UF=100 for H,A
Cadmium	0.001	High	Significant proteinuria	Diet	IRIS	UF=10 for H
Copper	0.037^{e}	NA	Gastrointestinal irritation	Single dose	HEAST	NA
Chromium VI	0.005	Low	No adverse effects	Water	IRIS	UF=500 for H,A,S
Manganese	0.1	Medium	Effects on central nervous system	Diet	IRIS	UF=1
Molybdenum	0.004	NA	Changes in biochemical indexes	Oral	HEAST	UF=1
Nickel (soluble salts)	0.02	Medium	Decreased body and organ weights	Diet	IRIS	UF=100 for H,A; MF=3
Selenium	0.005	Medium	Nail and hair loss	Diet	IRIS	UF=3 for H
Silver	0.005	Low	Argyria (skin discoloration)	I.V.	IRIS	UF=3
Thallium (soluble salts)	7×10^{-5}	Low	Increased SGOT and serum LDH levels, alcopecia	Oral	HEAST	UF=1,000 for H,A,S; MF=3
Uranium (soluble salts)	0.003	Medium	Weight loss, moderate kidney toxicity	Oral	IRIS	UF=1,000 for H,A,L
Vanadium	0.007	NA	No adverse effects	Water	HEAST	UF=100 for H,A
Zinc	0.2	NA	Anemia	Oral	HEAST	UF=10 for H
Inorganic anions						
Fluoride	0.06	High	Dental fluorosis	Water	IRIS	UF=1
Nitrate	1.6	High	Methemoglobinemia	Water	IRIS	UF=1
Organic compounds						
Bis(2-ethylhexyl)phthalate	0.02	Medium	Increased relative liver weight	Diet	IRIS	UF=1,000 for H,A,S
Chlorobenzene	0.02	Medium	Liver toxicity	Oral	IRIS	UF=1,000 for H,A,S
4,4'-DDT	0.0005	Medium	Liver lesions	Diet	IRIS	UF=100 for H,A
1,2-Dichlorobenzene	0.09	Low	No adverse effects	Oral	IRIS	UF=1,000 for H,A,S

TABLE 4.1 (Cont.)

Route/Contaminant	Chronic RfD[b] (mg/kg-d)	Confidence[c] Level	Critical Effect	RfD Basis	RfD Source	Uncertainty and Modifying Factors[d]
Oral Route (Cont.)						
Organic compounds (cont.)						
cis-1,2-Dichloroethene	0.01	NA	Decreased hematocrit and hemoglobin	Oral	HEAST	UF=1,000 for H,A,S; MF=3
Endosulfan	0.00005	Medium	Kidney toxicity	Diet	IRIS	UF=1,000 for H,A,L; MF=3
Toluene	0.2	Medium	Changes in liver and kidney weights	Oral	IRIS	UF=1,000 for H,A,S
Inhalation Route						
Metals						
Barium	0.0001	NA	Fetotoxicity	Rats	HEAST	UF=1,000 for H,A,S
Chromium VI	6×10^{-7}	NA	Nasal mucosa atrophy	Rats	HEAST	UF=100 for H,A; MF=3
Manganese	0.0001	Medium	Respiratory symptoms and psychomotor disturbances	Human	IRIS	UF=300 for H,S,L; MF=3
Organic compounds						
Chlorobenzene	0.005	NA	Liver and kidney effects	Rats	HEAST	UF=10,000 for H,A,S,L
1,2-Dichlorobenzene	0.04	NA	Decreased body weight gain	Rats	HEAST	UF=1,000 for H,A,L
1,2-Dichloropropane	0.001	Medium	Hyperplasia of the nasal mucosa	Rats	IRIS	UF=300 for H,A,S,L
Toluene	0.6	NA	Central nervous system effects; eye and nose irritation	Human	HEAST	UF=100 for H,S

[a] Notation: RfD = Reference Dose; IRIS = *Integrated Risk Information System* (EPA 1992); HEAST = *Health Effects Assessment Summary Tables* (EPA 1991a); NA = not available; I.V. = intravenous; SGOT = serum glutamic-oxaloacetic transaminase and LDH = lactic dehydrogenase, enzymes whose presence in the blood serum are diagnostic of heart and liver damage. RfD values are not available for cobalt, lead, benzene, carcinogenic PAHs, PCBs, trichloroethene, and vinyl chloride.

[b] Chronic RfDs are used for exposure durations of 7 years or more.

[c] Confidence level for the oral RfD from IRIS: high, medium, or low.

[d] UF = uncertainty factor; MF = modifying factor. Uncertainty adjustments: H = variation in human sensitivity; A = animal to human extrapolation; S = extrapolation from subchronic to chronic NOAEL; L = extrapolation from LOAEL to NOAEL.

[e] Adapted from drinking water standard cited in an earlier HEAST (EPA 1990a).

TABLE 4.2 Toxicity Values for Chemical Contaminants of Concern for Oral and Inhalation Exposure: Potential Carcinogenic Effects[a]

Chemical	Slope Factor [(mg/kg-d)$^{-1}$]	Weight-of-Evidence Classification[b]	Type of Cancer	Slope Factor		Maximum Concentration for Use of Slope Factor
				Basis	Source	
Oral Route						
Metals						
Arsenic	1.75[c]	A	Skin	Water	HEAST	ND
Beryllium	4.3	B2	Total tumors	Water	IRIS	83 µg/L
Organic compounds						
Benzene	0.029	A	Leukemia	Occupational	IRIS	10,000 µg/L
Benzo(a)pyrene	5.8	B2	Stomach	Diet	IRIS	ND
Bis(2-ethylhexyl)phthalate	0.014	B2	Liver	Diet	IRIS	40,000 µg/L
4,4′-DDT	0.34	B2	Liver	Diet	IRIS	1,000 µg/L
1,2-Dichloropropane	0.068	B2	Liver	Oral	HEAST	ND
PCBs	7.7	B2	Liver	Diet	IRIS	50 µg/L
Trichloroethene	0.011	B2	Liver	Oral	HEAST	ND
Vinyl chloride	1.9	A	Lung	Diet	HEAST	ND
Inhalation Route						
Metals						
Arsenic	15	A	Respiratory tract	Human	IRIS	2 µg/m^3
Beryllium	8.4	B2	Lung	Occupational	IRIS	4 µg/m^3
Cadmium	6.3	B1	Respiratory tract	Occupational	IRIS	6 µg/m^3
Chromium VI	42	A	Lung	Occupational	IRIS	0.8 µg/m^3
Nickel dust	0.84	A	Respiratory tract	Occupational	IRIS	40 µg/m^3

TABLE 4.2 (Cont.)

Chemical	Slope Factor $[(\text{mg/kg-d})^{-1}]$	Weight-of-Evidence Classification[b]	Type of Cancer	Slope Factor Basis	Slope Factor Source	Maximum Concentration for Use of Slope Factor
Inhalation Route (Cont.)						
Organic compounds						
Benzene	0.029	A	Leukemia	Occupational	IRIS	100 μg/m^3
Benzo(a)pyrene	6.1	B2	Respiratory tract	Hamster	HEAST	NA
4,4′-DDT	0.34	B2	Liver	Route-to-route extrapolation	IRIS	ND
Trichloroethene	0.017	B2	Lung	Mouse	HEAST	ND
Vinyl chloride	0.294	A	Liver	Rat	HEAST	ND

[a] Notation: IRIS = *Integrated Risk Information System* (EPA 1992); HEAST = *Health Effects Assessment Summary Tables* (EPA 1991a); ND = not determined; NA = not available.

[b] Weight-of-Evidence Classification: A = human carcinogen (sufficient evidence of carcinogenicity in humans); B = probable human carcinogen (B1, limited evidence of carcinogenicity in humans; B2, sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans). The following chemicals have been classified as B2, but no oral or inhalation slope factors have been determined: lead, benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene. Inhalation slope factors have not been determined for the following carcinogens: bis(2-ethylhexyl)phthalate, 1,2-dichloropropane, and PCBs.

[c] Proposed by EPA's Risk Assessment Forum, under review by the Science Advisory Board.

No EPA-derived oral RfD value is currently available for cobalt, and the toxicity of this substance was not quantitatively evaluated. However, this should have little or no effect on this risk assessment because cobalt toxicity is low; a level of 1 mg/kg per day can be safely tolerated by humans (National Academy of Sciences 1977).

Oral RfD values are also unavailable for several organic compounds (i.e., benzene, 1,2-dichloropropane, carcinogenic PAHs, PCBs, trichloroethene, and vinyl chloride). However, the assessment of potential carcinogenic risk from ingestion of these compounds provides at least a partial estimate of site risks associated with their presence in soil or groundwater.

The estimated carcinogenic risk from inhalation of organic compounds while showering is uncertain because an inhalation slope factor is not available for 1,2-dichloropropane. This is the only organic carcinogen evaluated for this pathway that does not have a slope factor.

Of the seven carcinogenic PAH compounds evaluated in this assessment, oral and inhalation slope factors are available only for benzo(a)pyrene. These slope factors for benzo(a)pyrene were used for the evaluation of all carcinogenic PAH compounds.

The EPA-derived RfD values incorporate uncertainty factors to account for data that were used but would not be applicable to chronic exposures in the most sensitive human subpopulations (Table 4.1). The uncertainty factors applied in this analysis are further described in Appendix B. In general, the use of these uncertainty factors provides confidence that exposure levels less than the RfD values are unlikely to cause toxic effects. However, the RfD values may actually be much lower than levels that will cause toxic effects in sensitive human subpopulations.

5 RISK CHARACTERIZATION

The radiological and chemical health risks resulting from exposure to contamination at the St. Louis Site are characterized in this BRA; the methodology and results of this characterization are presented in Sections 5.1 through 5.4. Potential carcinogenic risks for both radiological and chemical exposures were assessed in terms of the increased probability that an individual would develop cancer over a lifetime. The EPA has indicated that, for known or suspected carcinogens, acceptable exposure levels for the general public at NPL sites are generally concentration levels that represent an excess upper-bound lifetime cancer risk to an individual of between 1×10^{-6} and 1×10^{-4} (EPA 1990b). This range is referred to as the "target risk range" in this BRA and is used as a point of reference for discussing the results of the carcinogenic risk assessment for the site.

Potential health effects other than cancer from exposure to chemical contaminants were also assessed. The quantitative measures of noncarcinogenic health effects are the hazard quotient and hazard index (see Section 5.1.2.2).

5.1 RISK CHARACTERIZATION METHODOLOGY

5.1.1 Radiological Risks

Exposures to low levels of ionizing radiation can result in cancer induction, serious genetic effects, and other detrimental health effects. The predominant health concern associated with the radioactive contaminants at the St. Louis Site is the induction of cancer. The radiological health risks presented in this BRA are limited to this concern. This approach is consistent with EPA guidance, which notes that, in general, the risk of cancer is limiting and may be used as the sole basis for assessing the radiation-related human health risks for a site contaminated with radionuclides (EPA 1989c).

The potential radiological doses associated with the various scenarios considered in this assessment are presented in Chapter 3. These doses are given in units of millirem (mrem) for all exposure routes except inhalation of radon-222 and its short-lived decay products, which are given in units of working-level month (WLM).. The radiological risks were calculated by multiplying these doses by risk factors that estimate the probability of cancer induction per unit dose.

A risk factor of 6×10^{-7}/mrem was used to estimate the likelihood of cancer induction for all exposure routes except inhalation of radon-222 and its short-lived decay products. This factor was developed by the EPA as the overall risk factor for cancer induction in the general population (EPA 1989e). A risk factor of 3.5×10^{-4}/WLM was used for inhalation of radon-222 and its short-lived decay products. This value is recommended in the BEIR IV study for estimating the likelihood of inducing a fatal cancer as a result of such exposure

(National Research Council 1988). Because most lung cancers are fatal, this value can also be used as an estimator for cancer induction.

The radiological risks associated with exposures to contaminants at the St. Louis Site are considered in the context of risks resulting from natural sources of radiation. In most cases, the radiological health risks given in this document are reported as incremental risks above that from background sources of radiation. Radiation exposure from natural sources of radioactivity results in an annual dose of about 300 mrem/yr — 200 mrem/yr from exposure to radon-222 and its short-lived decay products and 100 mrem/yr from exposure to other natural sources of radiation (NCRP 1987). The annual risk of cancer induction from this background dose, calculated from the corresponding risk factors given above and the conversion factor of 1 WLM/rem for radon-222 exposures (ICRP 1981), is 1.3×10^{-4}/yr. The EPA has estimated that the individual lifetime risk of fatal cancer associated with background radiation, including radon, is 1×10^{-2} (EPA 1989b).

5.1.2 Chemical Risks and Hazard Quotients

5.1.2.1 Carcinogenic Risks

The risk to an individual resulting from exposure to chemical carcinogens is expressed as the increased probability of a cancer occurring over a lifetime. To calculate the excess cancer risk, the daily intake averaged over a lifetime is multiplied by a chemical-specific slope factor. Slope factors have been derived by the EPA for a number of carcinogens, and they represent the incremental lifetime cancer risk per milligram of carcinogen per kilogram of body weight, assuming that the exposure occurs over a lifetime of 70 years. The estimated daily intakes (averaged over a lifetime) resulting from exposure to the chemical carcinogens of concern at the St. Louis Site are presented in Section 3.4, and available slope factors are identified in Section 4.3. Slope factors are unavailable for lead, a contaminant of concern for all site properties. However, the levels of lead exposure that have caused cancer in laboratory animals are higher than the levels that have caused noncarcinogenic adverse effects in humans and animals (ATSDR 1990a). Therefore, it appears that carcinogenicity is not the most sensitive end point to use in evaluating health effects of lead exposure.

5.1.2.2 Hazard Quotients and Hazard Indexes

A hazard quotient provides a measure of the potential for adverse health effects other than cancer. For an individual contaminant, the daily intake averaged over the exposure period is divided by the RfD to derive the hazard quotient. The RfD is the average daily dose that can be incurred without an appreciable risk of deleterious health effects during a lifetime. The EPA has derived RfDs for exposure periods of more than 7 years (chronic) and less than 7 years (subchronic). Because the potential exposures considered in this BRA are for periods of more than 7 years, only chronic RfDs are considered. Although he construction worker scenario assumes an exposure duration of only 1 year, this assumption is for ease of presentation; the actual exposure duration could be longer (Section 3.4.1.1).

The estimated average daily intakes resulting from exposure to the contaminants of concern at the St. Louis Site are presented in Section 3.4, and the RfDs for these contaminants are identified in Section 4.2. For an individual contaminant, a hazard quotient of 1 or greater is considered to indicate a potential for adverse health effects. The individual hazard quotients for each contaminant are summed to determine a hazard index. In instances where each contaminant-specific hazard quotient may be less than 1, but their sum greater than 1, the major toxicological effects of the individual contaminants must be examined to determine the potential hazard associated with exposure to multiple contaminants.

As in the case of carcinogenic slope factors, RfDs are specific to the contaminant and route of exposure. For the oral route, RfDs are available for most of the contaminants of concern; oral RfDs are not available for cobalt, lead, and five of the organic groundwater contaminants. In contrast, inhalation RfDs are available for only four of the organic groundwater contaminants of concern for the St. Louis Site and are not available for the soil contaminants. Because of the lack of inhalation RfDs for soil contaminants, the hazard index was not estimated for inhalation of soil-derived particulates.

Although RfDs are not available for lead, an uptake/biokinetic model has been roposed for use in evaluating lead levels at waste sites (EPA 1991e). This model indicates that adverse symptoms of lead exposure (e.g., delayed mental and physical development in children) have been associated with blood lead concentrations as low as 10 µg/dL (EPA 1991e). The model evaluates lead exposures from soil, water, food, and air, and it correlates the total average daily lead uptake with blood lead concentrations. The model evaluates children aged 0 to 7 years, who are considered to be the most sensitive receptors for adverse effects of lead. The results of applying this model to evaluate the potential hazard posed by lead at the various St. Louis Site properties is presented in Section 5.3.5.

5.2 RISK ESTIMATES FOR THE ST. LOUIS SITE

Potential risks resulting from exposure to contaminants at the St. Louis Site were estimated for reasonable current site uses and hypothetical future uses of the site properties. Risk estimates are discussed in Section 5.2.1 for current site use and in Section 5.2.2 for uture site use.

The exposure points at site properties include contaminated soil, sediment, groundwater, air, and fish. Contaminated soil, sediment, and groundwater have been identified in various areas at the St. Louis Site, as indicated by the characterization and environmental monitoring results. Air is being considered because of the potential for ransport of airborne particulates from contaminated soil, radon gas emanation from radium-contaminated soil and groundwater, and external gamma irradiation from contaminated soil.

Fish ingestion is being considered because of the potential for uptake of contaminants from sediment by fish and subsequent intake by humans.

The potential receptors and routes of exposure to contamination at the respective properties comprising the St. Louis Site are summarized in Section 3.2. Exposure point concentrations and intakes and doses are presented in Sections 3.3 and 3.4. For clarity of presentation, the risk estimates resulting from potential radiological and chemical exposures are presented separately in Sections 5.2.1 and 5.2.2. However, chemical and radiological carcinogenic risks were also summed, and these results are discussed in Section 5.5.

5.2.1 Current Site Use

Risk estimates for potential exposure from current site use are presented in Tables 5.1* through 5.13. The estimated radiological risks for the SLDS current employee and SLDS construction worker are presented separately (see Tables 5.2 through 5.4); a detailed discussion of these results is presented in Section 5.2.1.1. The overall radiological risks (including the radon pathway) estimated for the city property recreational user, the SLAPS maintenance worker, the ditch construction worker, the Futura Coatings and commercial vicinity property employee, and the HISS trespasser and maintenance worker (Table 5.8) exceed the target risk range recommended by the EPA. Estimated risks are within the target risk range for the SLDS maintenance worker, SLAPS trespasser, residential vicinity property receptors, ballfield recreational user, and Coldwater Creek recreational user. The radon pathway contributes from 20 to 43% of the risk for each receptor for whom longer exposure frequencies were evaluated; this pathway contributes only 1 to 2% of the total risk for the receptors exposed infrequently (the ditch construction worker and residential child receptor) or 7% of the total risk for those farther away from the area of contamination (residential adult receptor). In general, the external gamma irradiation pathway contributes the highest percentage of risk from the nonradon pathway, and radium-226 contributes the highest percentage of risk from external gamma irradiation.

The hazard index estimated for every current receptor except the HISS maintenance worker is less than the reference index of 1 (Table 5.13). Similarly, the total chemical carcinogenic risk across pathways for each current receptor except the HISS maintenance worker is within the target risk range of 1×10^{-6} to 1×10^{-4} recommended by the EPA (Table 5.12). The estimated hazard index for the HISS maintenance worker is 3.1, which is mainly due to the ingestion of thallium from soil, i.e., a hazard quotient of 2.2 from ingestion of thallium in soil (Table 5.10). The chemical carcinogenic risk to the maintenance worker at HISS is slightly over the target risk range, i.e., 1.1×10^{-4} (Tables 5.9 and 5.12). The majority of this risk (over 90%) is attributable to ingestion of arsenic from soil. The estimated risk for the remaining receptors ranges from 1.0×10^{-6} to 4.7×10^{-5}. In general,

---

*For readability, all tables in this chapter are presented in sequence at the end of the text of the chapter.

he chemical risk from inhalation is more than one order of magnitude less than that from ingestion for each property's receptors.

5.2.1.1 SLDS, SLDS Vicinity Properties, and City Property

For ease of presentation and interpretation, the results of the radiological assessment for two of the three receptors evaluated for SLDS (i.e., the employee and construction worker) are presented separately from the remaining receptors for the St. Louis Site. The results for the SLDS employee and construction worker are presented in Tables 3.7 through 3.9 and Tables 5.2 through 5.4.

On the basis of the exposure scenario assumptions used to evaluate the radiological risks for the SLDS employee, the annual dose and risks are estimated to be less than 100 mrem/yr (Table 3.7) and 2.1×10^{-7} to 2.9×10^{-5} (Table 5.2), respectively, for a current SLDS employee at any one of the buildings except Building K1E. At Building K1E, the estimated dose is 430 mrem/yr and the estimated annual risk is 1.6×10^{-4}. For buildings where 2,000 hours per year occupancy time was assumed (i.e., the full-time work schedule for an employee), the annual dose and risk estimates are within the levels considered protective. The annual dose estimates for Buildings 50, 51, and 704 are 2.4, 53, and 17 mrem, respectively (Table 3.7) — which result in estimated annual risks of 8.4×10^{-7}, 2.9×10^{-5}, and 6.0×10^{-6}, respectively (Table 5.2). Also, in most cases, the annual dose stimates at buildings considered to be used for storage or warehousing were all less than 25 mrem. The percentage of risk contributions from the external gamma irradiation and radon pathways varies from building to building. The risks that might be incurred if employees work inside any of these buildings for 25 years at the same yearly exposure time (see Tables 3.7 and 3.28) are estimated to range from 5.3×10^{-6} to 4.0×10^{-3} (Table 5.2). No exposure pathways are complete for chemical contaminants for current employees at the SLDS and vicinity properties because chemical contamination is found primarily under paved or covered surfaces.

The dose and risk estimates for the SLDS construction worker involved in excavation or similar outdoor activities at the site or renovation and remodeling activities inside a site building are presented in Tables 3.8 and 3.9 and Tables 5.3 and 5.4. For various reasons — ncluding the fact that these activities occur sporadically in any given year, that the mix of activities may vary (e.g., more excavation than renovation or vice versa), and that the workers involved may not always be the same ones (e.g., when contractors are assigned to perform the activities) — the exposure time evaluated in this BRA was 100 hours each for indoor and outdoor activities (i.e., the risks are estimated for a total of 200 hours in any one year). This method allows risk results to be multiplied by the necessary factors to obtain an estimate of what might be incurred for higher or lower exposure durations at the various site locations. Likewise, if any given receptor were to perform renovation activities inside several buildings in any given year, the risk incurred by this receptor would be the aggregate risks etermined for those buildings. For example, if a construction worker performed renovations requiring 100 hours of work each in Buildings K1E, 51, 51A, 52, 52A, 100, 116, 117, 700, and 705 (the buildings that yielded the highest risk estimates), the potential risk to this construction worker would be about 2.3 × 10^{-3}; and if this same worker were to perform excavations for the remaining 1,000 working hours available during the year (the tot[illegible] exposure time involved in renovation activities at the 10 buildings was assumed to be 1,000 hours), the additional potential risk from all pathways would be 1.7 × 10^{-3}. This example receptor, who can be considered to be a reasonably maximally exposed construction worker at SLDS, would incur a total risk of 4.0 × 10^{-3} from radiological exposures. The inhalation of particulates pathway is the primary contributor to the indoor and outdoor radiological exposures for this worker. The particulate pathway contributes a large portion of the risk because of the extremely conservative assumptions used to estimate particulate concentrations (e.g., 5 mg/m^3; 100% from contaminated source), which do not consider engineering and personal devices that would limit exposures.

The chemical risks incurred by the construction worker would be mainly from excavation activities, although the assessment included a calculation for indoor risk by assuming that a portion of the outdoor contaminant levels (i.e., 40%) would be present indoors. The assumed intake parameters were similar to those used to evaluate radiological exposures (i.e., exposure time of 100 hours each for outdoor and indoor activities in any one year) so that the risks from all types of sources could be summed. On the basis of these assumptions, the chemical carcinogenic risk for this construction worker is estimated to be 1.1 × 10^{-5} (Table 5.12). The additional risk due to chemical contaminants for the example scenario, i.e., the reasonably maximally exposed worker described above for radiological risk, is about 1.1 × 10^{-4}; the total risk would be about 4.1 × 10^{-3} (including the radiological risk given above). Ingestion of soil contributes more than half of the chemical risk for this worker. The hazard index for the reasonably maximally exposed construction worker is greater than 1 (i.e., 2.6); this is mainly due to the ingestion pathway.

To assess the potential risks from exposure to contaminated drains and manholes at SLDS, risks were estimated for a worker performing intermittent maintenance of these drains or manholes. The results indicate that the potential risk incurred, i.e., 2.0 × 10^{-6} (Table 5.8), is within the target risk range.

The radiological risk for a recreational user of the city property is estimated to be 1.3 × 10^{-4}, with approximately equal contributions from radon and nonradon exposures — 5.6 × 10^{-5} and 7.8 × 10^{-5}, respectively (Table 5.8). An additional pathway considered plausible for this receptor is the risk from ingesting fish caught in the Mississippi River. The analysis indicates that the radiological risk incurred by this receptor might be higher by 7.9 × 10^{-5} due to the radium-226 and uranium-238 levels potentially present in Mississippi River sediment (Sections 3.3.5 and 3.4.6). The estimated hazard index from chemical contaminants present at the city property is 0.26 (Table 5.13). The chemical carcinogenic risk is estimated to be 4.7 × 10^{-5}, which is within the target risk range (Table 5.12). The main pathway contributing to this risk would be the ingestion of soil, primarily ingestion of PAHs in the soil (Table 5.9).

5.2.1.2 SLAPS and Vicinity Properties

The receptors assessed for the main site at SLAPS and the ditches to the north and south of SLAPS are a trespasser, a maintenance worker, and a construction worker at the ditches. The radiological risk to a trespasser is estimated to be 9.4×10^{-5}, with the radon pathway contributing about 36% of this risk (Table 5.8). The chemical risk to this trespasser, 1.0×10^{-6}, is much lower than the radiological risk (Table 5.12). The hazard index from ingestion is 0.051 (Table 5.13).

The other receptor assessed at SLAPS is a DOE worker who maintains the site and performs monitoring activities. Because it was assumed that the same person(s) also takes care of the HISS site (Section 3.2.3), the exposure duration of this receptor was divided between the two sites (Table 3.28); as a result, the total risk potentially incurred by this receptor would be the sum of the exposure at SLAPS and HISS. The combined radiological risks potentially incurred by this maintenance worker are estimated to be 4.8×10^{-3} from nonradon exposure and 1.3×10^{-3} from the radon pathway for a total radiological risk of 6.1×10^{-3} (Table 5.8). The combined chemical risk for the SLAPS/HISS maintenance worker is estimated to be 1.1×10^{-4}, with a hazard index of 3.2 (Tables 5.12 and 5.13).

Thallium is the major contributor to the hazard index of 3.1 for the HISS maintenance worker (Table 5.10); all other hazard quotients for individual contaminants are less than 1. However, the hazard quotient for arsenic is 0.55, indicating that arsenic toxicity should also be considered if other contaminants affecting similar body functions are present. Thallium and arsenic can both cause gastrointestinal irritation and toxicity to the nervous system, so it is appropriate to consider their toxic effects to be additive, as in the calculated hazard index.

The radiological risk for a ditch construction worker is 4.4×10^{-4} (Table 5.8). All of this risk is contributed by the particulate inhalation pathway. The chemical risk for the ditch construction worker is much lower, at 3.9×10^{-6}, and the hazard index is 0.21 (Tables 5.12 and 5.13). Although the radiological risk exceeds the target risk range, very conservative assumptions were used to estimate particulate concentrations and engineering and personal protective devices were not considered.

The child recreational user at the ballfield, considered a reasonable potential receptor for current use of this property, is estimated to incur a carcinogenic risk of 3.8×10^{-5} from exposure to radioactive contamination at the property (Table 5.8). The external gamma irradiation pathway contributes approximately 50% of this risk (i.e., 1.9×10^{-5}). A carcinogenic risk of 2.4×10^{-6} from exposure to chemicals detected at the property is estimated for this receptor (Table 5.12), primarily from ingestion of soil containing arsenic (Table 5.9). The hazard index is estimated to be 0.19 (Table 5.13).

The total estimated carcinogenic risks from radiological exposure for receptors at the residential vicinity property are within the target risk range, i.e., 5.1×10^{-6} for the child commuter and 7.4×10^{-5} for the long-term resident (Table 5.8). Because of the lack of data, the chemical carcinogenic risks and hazard indexes were not quantified for this group of vicinity properties. However, these risks are likely to be lower than the associated radiological risks and, hence, would be within or below the carcinogenic target risk range an a hazard index of 1.

At Coldwater Creek, the current recreational user is estimated to incur a carcinogenic risk from exposure to radioactive contaminants of 3.0×10^{-6} (Table 5.8), with about equal contributions from three of the pathways assessed: inhalation of radon, ingestion of soil, and external gamma irradiation; the contribution from inhalation of particulates is not significant. The recreational user at Coldwater Creek is also estimated to incur a carcinogenic risk of 4.6×10^{-6} from exposure to chemical contaminants present in the sediment (Table 5.12). The noncarcinogenic hazard index is estimated to be 0.067 (Table 5.13). The estimated risk levels for the current recreational user at Coldwater Creek were considered to serve as an estimation of future risk at this property; exposure point concentrations were assumed to remain similar to current levels.

5.2.1.3 Latty Avenue Properties

The employee at the Futura Coatings property is estimated to incur a carcinogenic risk of 1.2×10^{-3} from radionuclide exposure, with external gamma irradiation being the major contributor, i.e., 8.4×10^{-4} (Table 5.8). The estimated chemical risk for this receptor is again much lower, 1.6×10^{-6}, and the hazard index is 0.051 (Tables 5.12 and 5.13). The scenarios used to assess the radiological and chemical risks at Futura Coatings are considered to be applicable at other vicinity properties categorized as commercial/municipal/industrial because an employee is the most likely long-term receptor at these vicinity properties. However, the potential risks incurred at the vicinity properties would probably be significantly lower because of lower contaminant levels and, in some cases, lower exposure frequency (i.e., number of hours working at the properties).

The trespasser at HISS is estimated to incur a radiological risk of 1.2×10^{-4} (Table 5.8); risk contributions are approximately equally divided between external gamma irradiation (39%), inhalation of radon (29%), and soil ingestion (26%). The chemical carcinogenic risk to this receptor is estimated to be 7.3×10^{-6}, and the hazard index is estimated to be 0.56 (Tables 5.12 and 5.13). The risk to a maintenance worker at HISS is discussed in Section 5.2.1.2.

5.2.2 Hypothetical Future Site Use

The future scenarios assessed in this BRA were those considered to be conservative depictions of potential means of exposure, as required by guidance for the performance of baseline risk estimates; the results presented in this report are considered to provide (within the scope of the assessment) a reasonably plausible worst-case estimate of potential risk at the site if no remedial action were taken. The future scenario considered for the St. Louis Site properties was that of a hypothetical on-site resident, except for Coldwater Creek where a hypothetical recreational user was assumed. The assumptions made to estimate potential isk to these hypothetical receptors are presented in Table 3.28. The results, given separately for chemical and radiological risks, are presented in Tables 5.14 through 5.29.

A future resident scenario was assessed for SLDS, SLAPS, Futura Coatings property (includes commercial vicinity properties), HISS, and other vicinity properties (i.e., residential vicinity properties and the ballfield). Because the scenario exposure assumptions were the same in all cases, the only differing factor contributing to the relative levels of risk incurred at these properties would be the exposure point concentrations considered in the assessment. Exposure point concentrations for future scenario risk estimates were based on current levels. The potential resident at the HISS property is anticipated to incur the highest risk from exposure to radionuclides, primarily because of exposure to the extrapolated radionuclide levels in the two waste piles. The estimated potential risk from radioactive sources, including the projected risk from the piles, could be as high as 1.3×10^{-1} (Tables 5.19 and 5.20). Inhalation of radon-222 and its decay products contributes over half the risk, with external gamma irradiation being the highest contributor of the nonradon sources. For the SLAPS future resident, the main contributors to the total potential radiological risk of 1.1×10^{-1} are (in order of contribution) the radon, groundwater ingestion, and external gamma irradiation pathways. The estimated radiological risks for the future resident at the SLDS, residential vicinity property, ballfield, and Futura Coatings property are 5.8×10^{-2}, 4.6×10^{-4}, 4.0×10^{-3}, and 3.5×10^{-2}, respectively (Table 5.20).

Overall, exposure via inhalation of radon and its decay products from soil is the ighest contributor of all the radiological pathways assessed for the future resident at all properties; the contribution from this pathway ranges from 49 to 86% of the total risk. Because the exposure point concentrations used to calculate the radon risk did not include ngrowth from the decay of thorium-230, the risk from the radon pathway might be even higher in the future (Section 3.3.1.2); levels of thorium-230 are most significant at SLAPS and the adjacent ditches. At SLAPS, the estimated concentration ratio of thorium-230 to radium-226 is currently 10. The radium-226 concentration will increase threefold in 500 years and fourfold in 1,000 years; the maximum radium-226 concentration would occur 3,000 years in the future. The amount of radon generated will increase in proportion to the radium-226 levels.

Potential radiological risks for a future recreational user at Coldwater Creek were also assessed. The exposure point concentrations and estimated risks are the same as those for the current recreational user scenario (Tables 3.11, 3.12, 3.17, 3.19, 3.27, 5.14 through 5.17, and 5.20.

Potential chemical carcinogenic risks for future receptors at each property exceed the arget risk range. The estimated risks range from 2.3×10^{-4} for future residents at the ballfield and Futura Coatings property to 8.3×10^{-3} at SLDS. The estimated risks to future residents at SLAPS and HISS are 8.3×10^{-4} and 1.3×10^{-3}, respectively (Table 5.28). The uture resident at the SLDS area might incur the highest carcinogenic risk, primarily from he ingestion of PAHs present in soil and arsenic present in groundwater. The highest ontributor to carcinogenic risk for the future resident at SLAPS is ingestion of groundwater containing arsenic and beryllium; the carcinogenic risks at the ballfield and Futura Coatings property are mainly due to incidental ingestion of soil containing arsenic. At HISS, the chemical carcinogenic risk is equally attributable to ingestion of arsenic in soil and ingestion of arsenic and beryllium in groundwater.

All the hazard indexes for future receptors also exceed the reference value of 1. The future resident at SLAPS is estimated to incur the highest hazard index of 330; the hazard indexes for future residents at SLDS, the ballfield, Futura Coatings, and HISS are 84, 5.9, 2.7, and 130, respectively (Table 5.29). Ingestion of contaminants in groundwater is the primary contributor to the hazard index at SLDS, SLAPS, and HISS; because groundwater data were not available for the ballfield and Futura Coatings property, the calculated hazard index is due only to soil contaminants. At SLDS, 7 of the 24 contaminants quantitatively evaluated have estimated hazard quotients for groundwater ingestion that are greater than 1; thallium and arsenic contribute approximately 59% of the total hazard index and approximately 73% of the hazard index from groundwater ingestion alone. Inhalation of 1,2-dichloropropane while showering contributes 12% of the hazard index for SLDS. At SLAPS, ingestion of uranium from groundwater contributes approximately 70% of the total hazard index (i.e., a hazard quotient of 230 out of the total hazard index of 330), and thallium contributes the second highest percentage at 13% (i.e., a hazard quotient of 44 out of the hazard index of 330). At HISS, the hazard quotient from the groundwater ingestion pathway is 120 out of a total hazard index (across pathways) of 130; thallium, with a hazard quotient of 72, is the main contributor to the hazard quotient of 120.

5.3 UNCERTAINTIES RELATED TO RISK ESTIMATES

Because of the numerous assumptions necessary to perform risk assessment, uncertainty is inherent in each step of the risk assessment process. The uncertainties related to the identification of contaminants of concern, the exposure assessment, the toxicity assessment, and the risk characterization presented in this BRA for the St. Louis Site are discussed in Sections 5.3.1 through 5.3.4.

5.3.1 Identification of the Contaminants of Concern

The contaminants of concern for the various properties at the St. Louis Site were identified from available characterization data and a selection process recommended by the EPA for human health evaluation (EPA 1989c). For the radionuclides of concern, the source term analysis (Section 2.2.3.3) was used as a basis for determining whether the levels of radionuclides — other than those included in the site database — could be elevated at the site. Because the results of the source term analysis indicated possible elevated levels (over background) of other radionuclides in the uranium-238, thorium-232, and actinium decay series, the radiological assessment in this BRA included all radionuclides from the three decay series in the estimation of potential risks attributable to radioactive contamination at the site. This more comprehensive approach is expected to reduce the overall bias, even hough the radionuclide estimates obtained from the source term analysis have greater uncertainty than the direct measurements of the nuclides included in the database.

During mass spectral characterization of soil samples from the St. Louis Site, several nonstandardized organic compounds were tentatively identified. However, in accordance with EPA (1989c) guidance, these compounds were not evaluated in this assessment because the identification and quantitation of these compounds is uncertain in the absence of a calibration standard. Also, these compounds are not included by the EPA in its list of compounds typically analyzed at Superfund sites, which includes the majority of industrial compounds that are considered hazardous by the EPA. Soil samples from the St. Louis Site were analyzed for compounds on the EPA list, which is presented in Appendix C, Tables C.2 and C.3.

Data used to assess the groundwater pathway are mainly from the environmental monitoring program at SLAPS and HISS. Limited groundwater data are also available from monitoring wells located at SLDS. Because background levels of groundwater in these areas are currently unavailable, most radiological and chemical analytes that have been detected were considered as contaminants of concern; a few chemical analytes (metals) were screened out because they were considered to be essential human nutrients. This approach may result in overestimating the number of contaminants of concern attributable to MED/AEC activities at these properties and, consequently, could result in overestimating potential risks.

5.3.2 Exposure Assessment

The identification of potential receptors was based on reasonable land uses for the current scenarios. Future site use is hypothetical and was intended to indicate a reasonable worst-case use of the site properties. This is anticipated to result in overestimating future risks for the majority of properties comprising the St. Louis Site because it is likely that use of these properties will remain industrial. Continued industrial use is especially true for SLDS, which is located in the heart of the city of St. Louis and has been an operating chemical plant for more than 100 years.

Scenario assumptions (e.g., body weight and exposure duration), which were factored into calculations for intakes and doses, were based primarily on EPA recommendations (EPA 1989a). These assumptions might result in underestimating or overestimating the intakes or doses calculated for specific receptors, depending on the accuracy of the assumptions relative to actual site conditions and uses. For example, these factors are considered to have overestimated the risk to various current receptors, including the SLDS employee and SLDS construction worker. The majority of the contaminated buildings at SLDS are currently used for storage or warehousing, so the amount of time any one employee spends inside these buildings is probably less than that assumed for this assessment. The amount of respirable particulates assumed for the construction worker scenario is conservatively high; in actuality, these individuals work under conditions that are protective of their health. Measures such as wearing respirators and protective clothing and spraying water on dusty surfaces are common practices in the conduct of activities such as those assumed for this scenario.

Furthermore, in calculating the exposure point concentrations for radionuclides in soil, data that were reported as "less than" values were incorporated into the exposure poi[illegible] estimations by using the reported value without the "less than" symbol; this technique results in an elevated average and, therefore, an overestimation of the associated risk. Overestimation is also expected with regard to deriving the exposure point concentration for uranium-238 because the majority of samples were reported at the detection limit for uranium and the uranium-238 concentrations in site soil samples were ancillary data obtained from gamma spectroscopic analysis for radium-226 in soil. As a result, the MDAs reported were not optimum — i.e., lower MDAs would have been possible if the preferred method of alpha spectroscopy could have been used to determine uranium-238 concentrations.

Even though thorium-232 data were also ancillary data obtained from radium-226 gamma spectroscopic analyses, the overall overestimation from using "less than" values reported for thorium-232 is not as significant because the thorium-232 isotope has a higher gamma yield and is therefore easier to detect. As a result, the calculated "less than" values are lower — i.e., the "less than" values reported from gamma spectroscopic analyses of thorium-232 would not be much higher than the optimum MDAs from alpha spectroscopic analysis of the isotope. Also, thorium-232 levels at the site are only slightly elevated above background.

Exposure point concentrations for uranium-234 and uranium-235+D were estimated by applying the ratios of these radionuclides to uranium-238 in the source term analysis to actual measurements of uranium-238 exposure point concentrations. Because of the overestimation of uranium-238 (as discussed above), this results in an overestimation of the potential concentrations of uranium-234 and uranium-235+D. However, these radionuclides do not contribute significantly to risks at the site through the nonradon pathways, i.e., external gamma irradiation, soil ingestion, and inhalation of particulates.

At HISS, thorium-230 data were not available for the 0- to 1-ft layer, so data for the 1- to 3-ft layer were used to represent the 0- to 1-ft layer in the dose calculations. Because the concentrations of other radionuclides measured at HISS were higher in the surface layer (0 to 1 ft) than in the lower layers, it is reasonable to expect that the actual surficial concentration of thorium-230 is higher than the concentration used in this assessment. However, for all pathways, the dose from thorium-230 is only a small percentage of the total dose, so using the data for the 1- to 3-ft layer is expected to have only a minor effect on the results presented herein.

For the residential vicinity properties, where only thorium-230 levels were characterized, the levels of other radionuclides were estimated from the results of the SLAPS source term analysis, with thorium-230 as the reference radionuclide. This approach contains uncertainty but serves as a realistic approach for addressing the doses from radionuclides not measured. In addition, the SLAPS source term analysis was considered appropriate because of the origin of contamination (i.e., the vicinity properties were contaminated largely due to windblown contamination occurring during truck transport of contaminated material from SLAPS to HISS) and because of the proximity of SLAPS to these vicinity properties.

At site properties such as SLAPS and the adjacent ditches where thorium-230 levels are quite elevated, radium ingrowth from the decay of thorium-230 was not accounted for in estimating the risk from radon inhalation. The exposure point concentrations for the radon pathway are expected to be higher with time (Section 5.2.2). Although the potential health impacts associated with this ingrowth over hundreds to thousands of years is difficult to quantify accurately because of the complex interactions of dispersion mechanisms, the methodology used in this assessment should adequately represent site conditions in the near future (i.e., less than the next 500 years). Similarly, the radionuclide exposure point concentrations used to calculate the other pathways for the future resident scenarios might also change (e.g., due to decay, erosion, and leaching). However, the impact to risk estimates from this shift is not considered to be significant; in fact, future risks from these pathways are expected to be lower than those presented in this report. This conclusion is supported by the level of conservatism already incorporated in this assessment.

Another factor affecting the potential overestimation of risk estimates presented in this BRA may be the use of maximum measured values as exposure point concentrations for contaminants found in groundwater because the available data for groundwater are not as extensive as the available data for site soil. For similar reasons, maximum gamma exposure rates and maximum concentrations of radon and fixed structural contamination were used as exposure point concentrations for estimating current indoor risks to the SLDS employee and SLDS construction worker; this technique is expected to greatly overestimate the risk estimates for these receptors.

For samples in which analytes were reported as not detected, chemical exposure point concentrations were estimated by using half the detection limit as the concentration value. For contaminants with reported detection limits higher than background levels — such as antimony, arsenic, and thallium — this technique is likely to result in overestimation of the risk. For example, the detection limit for thallium is about 18 mg/kg; therefore, 9 mg/kg was used as the value for samples reported as not detected. The exposure point concentrations for thallium resulting from this method are probably overestimated for site soil because the background value of thallium in soil is less than 0.1 mg/kg and the detection frequency for thallium in site soil ranged from 0 to 55% for the various site properties (Table 2.8). Similarly, the detection limit was somewhat elevated for arsenic, and the detection frequency for arsenic in site soil ranged from 6 to 49%. Again, the exposure point concentrations for arsenic were therefore likely overestimates, impacting the projected future chemical carcinogenic risks because arsenic was the primary contributor to risk for all properties except the SLDS/city property.

5.3.3 Toxicity Assessment

A key area of uncertainty in assessing the chemical risks at the St. Louis Site results from the lack of data on the noncarcinogenic toxicity of inhaling low levels of the contaminants of concern. Although the EPA is in the process of developing reference concentrations for many common environmental contaminants, this has been accomplished for only a few of the groundwater contaminants of concern for the St. Louis Site and none of the soil contaminants. Therefore, quantitative noncarcinogenic risk estimates (i.e., hazard indexe[illegible] could not be derived for the inhalation pathway. The implications of this factor are discuss[illegible] further in Section 5.3.4.

Exposure to lead can cause significant toxic effects, and lead may also be carcinogenic. Reference values (i.e., RfDs and slope factors) to quantitatively assess the likelihood of toxic effects at given exposure levels are not available (Section 4.2.2.2), although recent draft guidance from the EPA (1991e) suggests a quantitative method for estimating detrimental concentrations of lead in the environment. This method is not analogous to other quantitative risk estimation methods used in this BRA. In addition, although lead is classified as a possible human carcinogen, the doses that have induced cancer are higher than the doses that have induced noncarcinogenic effects (ATSDR 1990a). Therefore, carcinogenesis is not evaluated for lead because it is not the most sensitive end point.

Two other pathways were considered plausible for the scenarios evaluated in this assessment: dermal absorption and ingestion of homegrown produce. However, they were not included in the estimation of potential exposures for the St. Louis Site because the EPA's policies on quantifying these pathways for the contaminants of concern included in this BRA are still evolving (EPA 1991b, 1991f) and the values necessary to calculate or estimate these pathways (e.g., dermal absorption coefficients and soil-to-plant uptake factors) are uncertain. Additional discussion of the rationale for not assessing the dermal pathway is presented in Section 3.2.3. The ingestion of homegrown produce was evaluated because preliminary calculations indicated the potential for additional risk contributions from this pathway; th[illegible] results are presented in Appendix D of this report. The soil-to-plant uptake factors used in the calculations are considered to be conservative; in general, lower values have been cited in various other literature sources not included in this assessment.

The uncertainties associated with the risk factors used for the radiological assessment in this BRA are low. Extensive data are available on which to base estimates of human radiation toxicity. The BEIR V study (National Research Council 1990) presents a detailed description of current data on the health risks of exposure to low levels of ionizing radiation. This report, along with the BEIR IV study (National Research Council 1988) that addresses the health risks associated with radon and other alpha-emitting radionuclides, provide ample scientific information for this assessment.

5.3.4 Risk Characterization

Some procedures and uncertainties in the human health assessment process may tend to underestimate potential risks, including the use of standard dose conversion factors to estimate radiation doses that are based on adult exposures and the lack of appropriate methodology and toxicity values to quantify chemical health effects for all contaminants of concern and routes of exposure. However, most of the assumptions built into this BRA tend to overestimate rather than underestimate potential risks — including conservative assumptions for the exposure scenarios (e.g., the number of times a trespasser would enter the site in light of the presence of security). Thus, actual risks are likely to be lower than those presented in this assessment.

The radiological dose conversion factors used in this assessment are based on the ICRP reference man, an adult male weighing 70 kg (ICRP 1975). The ICRP selected such a standardized individual for their dosimetry models because their main concern is associated with worker protection, and the majority of radiation workers are adult males. Similar dose factors for other age or gender groups are being developed by ICRP but are not yet available. Although children are more susceptible to radiation exposure, i.e., the radiation doses for the same intake of radioactive substances are larger for children than adults, such effects are generally significant only for young children (Cristy et al. 1986; ICRP 1989). The only scenarios for which this might be significant are the child commuter and ballfield recreational user scenarios. However, the radiological risks to these hypothetical individuals are low. Even if the estimated radiological risk for the child commuter were increased by a factor of 10, it would still be within the target risk range. The radiological risk for the ballfield recreational user could be increased by a factor of 2.5 before exceeding the upper end of the target risk range.

The estimation of health effects associated with radiation doses was based on lifetime average risk estimators for all routes of exposure. Two different risk estimators were used in this assessment: a risk factor of 6×10^{-7}/mrem for all exposures except inhalation of radon decay products and a risk factor of 3.5×10^{-4}/WLM for inhalation of radon decay products. These lifetime average risk estimators are appropriate because they reflect the likely conditions of exposure at the site, i.e., any given age group could be exposed to the radioactive contaminants, and they are based on extensive data for the human health effects associated with radiation exposure.

Few inhalation RfDs are available for the chemical contaminants of concern. Hence, the potential for noncarcinogenic effects, as indicated by the inhalation hazard index, is expected to be significantly underestimated. However, inhalation slope factors are available for most of the carcinogens, and the carcinogenic end point is generally more sensitive than the noncarcinogenic effect. Thus, the primary health effect associated with these chemicals has been quantified for most of the carcinogenic contaminants of concern. On the basis of the oral RfDs for the noncarcinogenic contaminants, the most toxic of the contaminants of concern are antimony and thallium. Both of these elements are readily absorbed via inhalation, which suggests that toxicity via this route is possible. Therefore, soil levels of these substances that are substantially greater than background should be considered potential inhalation hazards, although quantitative hazard estimates cannot be derived at this time.

Carcinogenic slope factors are available for the known or suspected oral carcinogens, except lead. The lack of an oral slope factor for lead is expected to result in underestimating the carcinogenic risk associated with oral exposure. However, carcinogenesis is not the most sensitive end point for lead exposure.

Inhalation slope factors are available for the carcinogenic metals of concern, except lead. The lack of an inhalation slope factor for lead may result in some underestimation [illegible] carcinogenic risk from inhalation of particulates for both current and future receptors. An inhalation slope factor is not available for 1,2-dichloropropane, which is a groundwater contaminant of concern for SLDS with respect to inhalation. The lack of this inhalation slope factor is expected to result in underestimating risks for future SLDS receptors from showering.

The slope factor derived for a single PAH, benzo(a)pyrene, was used to evaluate the carcinogenicity of all the PAHs classified as potential human carcinogens. Thus, the quantitative carcinogenic risk estimates for the PAHs have a higher degree of uncertainty associated with them than the estimates for the other carcinogens.

Finally, for this assessment, it was assumed that the toxic and carcinogenic effects of the chemical contaminants of concern are additive. This assumption could result in the underestimation of risks because concurrent exposure to several contaminants might have synergistic toxic effects, i.e., exposure to two of the metals concurrently might induce a greater toxic effect than that expected if the separate effects were simply added. Conversely, concurrent exposure to some of the metals might also mitigate the toxic effects of exposure to individual metals, e.g., selenium and thallium (Venugopal and Luckey 1978).

5.3.5 Assessment of Lead Toxicity

The EPA uptake/biokinetic model for evaluating environmental lead concentrations (EPA 1991e) was used to assess the significance of lead concentrations at the St. Louis Site properties. This model, currently in draft form, estimates the blood lead concentrations of children aged 0 to 7 years; such children were assumed to be residents at the site properties evaluated, and the blood lead concentrations were derived from concentrations of lead in the various site media. Although lead concentrations in homegrown produce can also be included in the model, this assessment assumed the default dietary lead uptake concentration of 3 to 4 µg/L because of the uncertainty associated with estimating lead concentrations in produce (see Appendix D). Air particulate concentrations included in the model were estimated from soil lead concentrations. Groundwater concentrations were included at half the detection limit (i.e., 50 µg/L) because lead has not been detected in any site groundwater samples. The results from the uptake/biokinetic modeling are presented in Table 5.30. The occurrence of adverse health effects are considered unlikely below 10 µg/dL of blood lead. The estimated blood lead concentrations for all properties except SLDS are less than 10 µg/dL; the estimated blood lead concentration for SLDS is 29 µg/dL.

4 SUMMARY OF THE RISK CHARACTERIZATION

5.4.1 Radiological Risks

The estimated risks for current receptors from exposure to radioactive contaminants at the St. Louis Site are presented in Tables 5.2, 5.3, 5.4, and 5.8. These risks exceed the target risk range for two of three receptors at SLDS (SLDS/SLDS vicinity property employee and SLDS construction worker), the city property recreational user, the SLAPS maintenance worker, the ditch construction worker, the Futura Coatings and other commercial vicinity property employees, and the HISS trespasser and maintenance worker. The risks are within the target risk range for the SLAPS trespasser, ballfield recreational user, residential vicinity property child commuter, long-term resident at the residential vicinity properties, and Coldwater Creek recreational user.

The estimated risks for future receptors from exposure to radioactive contaminants are all above the target risk range (Table 5.20). The highest risks would be incurred by a future resident at HISS, followed (in order) by a future resident at SLAPS, SLDS, Futura Coatings, the ballfield, and the residential vicinity property. Radon inhalation contributes about 64% of the future risk at HISS, with 77% of this due to the storage piles. Although the radon pathway dominates the risk at SLAPS (64%), the ingestion of groundwater at this property also contributes approximately 25% of the total potential risk from radioactive contaminants. At all other properties, external gamma irradiation contributes the second highest levels. Total uranium is the major contributor to the ingestion of groundwater pathway; radium-226, followed by actinium-227, contributes over 64% of the risk from the external gamma pathway.

5.4.2 Chemical Risks

The potential risks to current receptors of carcinogenic effects from exposure to chemical contamination at the St. Louis Site are within EPA's target risk range, except for the HISS maintenance worker (Tables 5.12 and 5.13). The carcinogenic risk for this worker slightly exceeds the range at 1.1×10^{-4}. All noncarcinogenic hazard indexes are also less than the reference value of 1, except for the HISS maintenance worker; the hazard index for this receptor is 3.1.

The highest estimated chemical carcinogenic risk for the future resident is at SLDS, primarily from ingestion of PAHs in soil and ingestion of arsenic in groundwater (Table 5.28). The chemical carcinogenic risk for SLAPS is primarily attributable to the ingestion of groundwater, with the main contributors being arsenic followed by beryllium. The total chemical carcinogenic risks at the Futura Coatings property and the ballfield area are both estimated to be 2.3×10^{-4}. Although this risk only slightly exceeds the upper limit of the target risk range, it may be underestimated because groundwater was not included in the estimation. The chemical carcinogenic risk for the HISS future resident is due about equally to the ingestion of arsenic in soil and the ingestion of arsenic and beryllium in groundwater.

The hazard index is estimated to be as high as 330 for the future resident at SLAPS, wi[illegible] ingestion of uranium in groundwater contributing 70% of this index. The hazard indexes for the future resident at all other site properties are also greater than 1, ranging from 2.7 to 130 (Table 5.29). The chemical risks for the future receptors at other vicinity properties where chemical characterization has not been performed should be about the same as or lower than those derived for SLAPS or HISS because of the nature of the area and the origin of contamination.

It is likely that chemical carcinogenic and noncarcinogenic risk estimates for the St. Louis Site could be substantially lowered if a larger database becomes available and if more sensitive analytical methods for arsenic and thallium are utilized.

5.4.3 Overall Risks

To lend perspective for overall site risk, radiological and chemical carcinogenic risks were combined (summed) for both current and hypothetical future receptor scenarios; these data are presented in Tables 5.31 and 5.32. For current scenarios, potential radiological risks are generally higher than chemical risks by at lease one order of magnitude. For the hypothetical future scenarios, estimated risks from potential radiological and chemical exposures both exceed the target risk range. The total risk at HISS is the highest, primarily because of the radionuclide levels assumed to be associated with the storage piles. As for current receptors, radiological risk estimates for future receptors are higher than chemical risk estimates by approximately one order of magnitude or more.

TABLE 5.1 Radiological Carcinogenic Risk from External Gamma Irradiation for Current Receptors at the St. Louis Site[a]

Property and Receptor	Carcinogenic Risk Actinium-227+D	Lead-210+D	Protactinium-231	Radium-226+D
SLDS employee[b]	-	-	-	-
SLDS construction worker[b]	-	-	-	-
SLDS maintenance worker (drains)	5.5×10^{-11}	3.8×10^{-13}	4.1×10^{-12}	6.0×10^{-10}
City property recreational user	6.0×10^{-6}	1.8×10^{-8}	4.8×10^{-7}	3.5×10^{-5}
SLAPS trespasser	4.0×10^{-6}	1.1×10^{-8}	3.7×10^{-7}	2.5×10^{-5}
SLAPS maintenance worker	7.8×10^{-5}	2.3×10^{-7}	7.2×10^{-6}	4.9×10^{-4}
Ditch construction worker	3.9×10^{-7}	1.1×10^{-9}	3.1×10^{-8}	2.2×10^{-6}
Residential vicinity property child commuter	2.7×10^{-8}	9.0×10^{-11}	2.5×10^{-9}	1.5×10^{-7}
Residential vicinity property current resident	3.8×10^{-6}	1.3×10^{-8}	3.5×10^{-7}	2.1×10^{-5}
Ballfield recreational user	1.2×10^{-6}	3.3×10^{-9}	1.0×10^{-7}	7.2×10^{-6}
Coldwater Creek recreational user	1.1×10^{-7}	4.1×10^{-10}	1.1×10^{-8}	5.8×10^{-7}
Futura Coatings employee	1.1×10^{-4}	3.7×10^{-7}	1.1×10^{-5}	5.9×10^{-4}
HISS trespasser	7.2×10^{-6}	2.6×10^{-8}	7.2×10^{-7}	3.7×10^{-5}
HISS maintenance worker	5.1×10^{-4}	1.7×10^{-6}	4.9×10^{-5}	2.6×10^{-3}

Property and Receptor	Carcinogenic Risk Radium-228+D	Thorium-228+D	Thorium-230	Thorium-232
SLDS employee[b]	-	-	-	-
SLDS construction worker[b]	-	-	-	-
SLDS maintenance worker (drains)	7.8×10^{-10}	1.2×10^{-9}	2.0×10^{-12}	3.2×10^{-13}
City property recreational user	4.8×10^{-7}	2.0×10^{-6}	3.8×10^{-9}	1.8×10^{-10}
SLAPS trespasser	2.2×10^{-7}	1.1×10^{-6}	4.2×10^{-8}	1.1×10^{-10}
SLAPS maintenance worker	4.4×10^{-6}	2.2×10^{-5}	8.4×10^{-7}	2.2×10^{-9}
Ditch construction worker	1.3×10^{-7}	6.0×10^{-7}	1.7×10^{-8}	6.0×10^{-11}
Residential vicinity property child commuter[c]	0	1.7×10^{-8}	2.7×10^{-9}	1.6×10^{-12}
Residential vicinity property current resident[c]	0	2.5×10^{-6}	3.8×10^{-7}	2.3×10^{-10}
Ballfield recreational user	6.0×10^{-7}	1.0×10^{-5}	7.8×10^{-9}	3.1×10^{-10}
Coldwater Creek recreational user	1.6×10^{-8}	3.2×10^{-7}	4.0×10^{-10}	3.0×10^{-11}
Futura Coatings employee	4.4×10^{-6}	9.0×10^{-5}	5.7×10^{-7}	7.8×10^{-9}
HISS trespasser	5.0×10^{-8}	1.0×10^{-6}	1.0×10^{-8}	9.0×10^{-11}
HISS maintenance worker	3.5×10^{-6}	7.2×10^{-5}	7.2×10^{-7}	6.6×10^{-9}

TABLE 5.1 (Cont.)

Property and Receptor	Carcinogenic Ri			Total Carcinogenic Risk
	Uranium-234	Uranium-235+D	Uranium-238+D	
SLDS employee[b]	-	-	-	-
SLDS construction worker[b]	-	-	-	-
SLDS maintenance worker (drains)	2.7×10^{-13}	7.8×10^{-12}	1.4×10^{-11}	2.6×10^{-9}
City property recreational user	2.0×10^{-8}	6.0×10^{-7}	1.8×10^{-6}	4.6×10^{-5}
SLAPS trespasser	1.7×10^{-9}	5.2×10^{-8}	1.6×10^{-7}	3.1×10^{-5}
SLAPS maintenance worker	3.4×10^{-8}	1.0×10^{-6}	3.2×10^{-6}	6.0×10^{-4}
Ditch construction worker	4.9×10^{-10}	1.5×10^{-8}	4.6×10^{-8}	3.4×10^{-6}
Residential vicinity property child commuter[c]	2.2×10^{-11}	0	2.1×10^{-9}	2.0×10^{-7}
Residential vicinity property current resident[c]	3.2×10^{-9}	0	3.0×10^{-7}	2.8×10^{-5}
Ballfield recreational user	1.4×10^{-9}	4.4×10^{-8}	1.4×10^{-7}	1.9×10^{-5}
Coldwater Creek recreational user	5.6×10^{-11}	1.7×10^{-9}	5.3×10^{-9}	1.0×10^{-6}
Futura Coatings employee	8.4×10^{-8}	2.6×10^{-6}	8.4×10^{-6}	8.4×10^{-4}
HISS trespasser	3.9×10^{-9}	1.2×10^{-7}	3.7×10^{-7}	4.7×10^{-5}
HISS maintenance worker	2.7×10^{-7}	7.8×10^{-6}	2.6×10^{-5}	3.2×10^{-3}

[a] The risk estimates presented in this table are derived from exposure point concentrations and estimated doses given in Table 3.6.

[b] The risk estimates for the SLDS employee are presented in Table 5.2, and those for the SLDS construction worker are presented in Tables 5.3 and 5.4.

[c] A zero indicates that the soil concentration of this radionuclide was less than background and would result in an insignificant risk.

TABLE [illegible] Radiologic Carcinogenic Risk for Employees in [illegible]DS Buildings

Building	External Gamma[b]		Inhalation of Radon[c]		Total Risk[d]	
	1 year	25 years	1 year	25 years	1 year	25 years
K1E	2.7×10^{-5}	6.6×10^{-4}	1.3×10^{-4}	3.3×10^{-3}	1.6×10^{-4}	4.0×10^{-3}
25	9.0×10^{-6}	2.2×10^{-4}	4.9×10^{-7}	1.2×10^{-5}	9.5×10^{-6}	2.3×10^{-4}
50	NA	NA	8.4×10^{-7}	2.1×10^{-5}	8.4×10^{-7}	2.1×10^{-5}
51	2.5×10^{-5}	6.0×10^{-4}	4.0×10^{-6}	9.8×10^{-5}	2.9×10^{-5}	7.0×10^{-4}
51A	1.1×10^{-6}	2.9×10^{-5}	2.0×10^{-6}	4.9×10^{-5}	3.1×10^{-6}	7.8×10^{-5}
52	3.4×10^{-6}	8.6×10^{-5}	-	-	3.4×10^{-6}	8.6×10^{-5}
52A	1.0×10^{-6}	2.5×10^{-5}	9.8×10^{-7}	2.5×10^{-5}	2.0×10^{-6}	5.0×10^{-5}
100	NA	NA	7.4×10^{-7}	1.9×10^{-5}	7.4×10^{-7}	1.9×10^{-5}
101	5.4×10^{-6}	1.4×10^{-4}	8.5×10^{-6}	2.1×10^{-4}	1.4×10^{-5}	3.5×10^{-4}
116	NA	NA	9.1×10^{-7}	2.3×10^{-5}	9.1×10^{-7}	2.3×10^{-5}
116B	1.4×10^{-6}	3.5×10^{-5}	-	-	1.4×10^{-6}	3.5×10^{-5}
117	2.7×10^{-6}	6.6×10^{-5}	1.8×10^{-6}	4.4×10^{-5}	4.5×10^{-6}	1.1×10^{-4}
700	4.3×10^{-7}	1.1×10^{-5}	-	-	4.3×10^{-7}	1.1×10^{-5}
704	NA	NA	6.0×10^{-6}	1.5×10^{-4}	6.0×10^{-6}	1.5×10^{-4}
705	NA	NA	4.6×10^{-7}	1.2×10^{-5}	4.6×10^{-7}	1.2×10^{-5}
706	NA	NA	2.1×10^{-7}	5.3×10^{-6}	2.1×10^{-7}	5.3×10^{-6}
707	NA	NA	7.4×10^{-7}	1.9×10^{-5}	7.4×10^{-7}	1.9×10^{-5}
708	1.6×10^{-6}	3.9×10^{-5}	7.0×10^{-8}	1.8×10^{-6}	1.6×10^{-6}	4.1×10^{-5}
81	NA	NA	4.9×10^{-7}	1.3×10^{-5}	4.9×10^{-7}	1.3×10^{-5}
82	NA	NA	8.4×10^{-7}	2.1×10^{-5}	8.4×10^{-7}	2.1×10^{-5}

[a] The risk estimates presented in this table are derived from exposure point concentrations and dose estimates given in Table 3.7. Risks are for 1 and 25 years of exposure.

[b] NA indicates that the measured external exposure rate is less than background and would result in an insignificant risk.

[c] A hyphen indicates that no measurement was available, so no risk was calculated.

[d] Total risk across pathways, based on risk factors of 6×10^{-7}/mrem and 3.5×10^{-4}/WLM.

TABLE 5.3 Radiological Carcinogenic Risk for Indoor Construction Workers at SLDS[a]

Building	External Exposure[b]	Particulate Inhalation[c]	Particulate Ingestion[c]	Radon Inhalation[c]	Total Risk[d]
K1E	1.1×10^{-5}	6.6×10^{-5}	3.9×10^{-7}	1.6×10^{-4}	2.3×10^{-4}
25	3.6×10^{-6}	2.7×10^{-5}	1.7×10^{-6}	6.3×10^{-7}	3.3×10^{-5}
50	NA	1.6×10^{-5}	1.0×10^{-7}	2.1×10^{-7}	1.7×10^{-5}
51	1.3×10^{-6}	4.9×10^{-4}	3.0×10^{-6}	6.3×10^{-7}	4.9×10^{-4}
51A	4.6×10^{-7}	9.0×10^{-5}	5.5×10^{-7}	2.3×10^{-6}	9.3×10^{-5}
52	1.4×10^{-6}	1.7×10^{-4}	1.1×10^{-6}	8.8×10^{-8}	1.8×10^{-4}
52A	1.1×10^{-6}	4.5×10^{-4}	2.8×10^{-6}	1.3×10^{-6}	4.6×10^{-4}
100	NA	5.4×10^{-5}	3.4×10^{-7}	8.8×10^{-7}	5.5×10^{-5}
101	2.2×10^{-6}	-	-	1.0×10^{-5}	1.2×10^{-5}
116	NA	2.5×10^{-4}	1.5×10^{-6}	1.1×10^{-6}	2.5×10^{-4}
116B	5.7×10^{-7}	9.0×10^{-6}	5.5×10^{-8}	-	9.6×10^{-6}
117	1.1×10^{-6}	3.6×10^{-5}	2.3×10^{-7}	2.1×10^{-6}	3.9×10^{-5}
700	1.7×10^{-7}	6.0×10^{-5}	3.9×10^{-7}	8.4×10^{-8}	6.1×10^{-5}
704	NA	2.7×10^{-5}	1.7×10^{-7}	8.4×10^{-7}	2.8×10^{-5}
705	NA	4.0×10^{-4}	2.4×10^{-6}	5.6×10^{-7}	4.0×10^{-4}
706	NA	1.3×10^{-5}	7.8×10^{-8}	2.6×10^{-7}	1.3×10^{-5}
707	NA	1.3×10^{-5}	7.8×10^{-8}	8.8×10^{-8}	1.3×10^{-5}
708	6.0×10^{-7}	1.0×10^{-5}	6.0×10^{-8}	8.8×10^{-7}	1.2×10^{-5}
81	NA	1.3×10^{-6}	8.4×10^{-9}	6.3×10^{-7}	2.0×10^{-6}
82	NA	5.0×10^{-6}	3.2×10^{-8}	1.1×10^{-6}	6.2×10^{-6}

[a] Estimated risks are for a construction worker doing renovation activities for 100 hours in each building for 1 year. The risk estimates presented in this table were derived from exposure point concentrations and estimated doses given in Table 3.8.

[b] NA indicates that the measured external gamma exposure rate was less than background and would result in an insignificant risk.

[c] A hyphen indicates that no measurement was available, so no risk was calculated.

[d] Total risk across pathways for each building.

TABLE 5.4 Radiological Carcinogenic Risk for Outdoor Construction Workers at SLDS[a]

	Estimated Risk				
Radionuclide	External Exposure	Soil Ingestion	Particulate Inhalation	Radon Inhalation[b]	Total[c]
Actinium-227+D	2.9×10^{-7}	5.0×10^{-7}	7.2×10^{-5}	-	7.3×10^{-5}
Lead-210+D	1.5×10^{-9}	7.8×10^{-7}	7.8×10^{-7}	-	2.0×10^{-6}
Protactinium-231	2.2×10^{-8}	3.5×10^{-7}	1.4×10^{-5}	-	1.4×10^{-5}
Radium-226+D	4.1×10^{-6}	9.6×10^{-8}	2.2×10^{-7}	2.0×10^{-6}	6.3×10^{-6}
Radium-228+D	2.7×10^{-7}	1.3×10^{-8}	1.6×10^{-8}	-	3.0×10^{-7}
Thorium-228+D	5.4×10^{-7}	9.6×10^{-9}	1.3×10^{-6}	-	1.9×10^{-6}
Thorium-230	1.2×10^{-9}	1.1×10^{-7}	2.2×10^{-5}	-	2.2×10^{-5}
Thorium-232	4.7×10^{-11}	3.7×10^{-8}	7.2×10^{-6}	-	7.2×10^{-6}
Uranium-234	2.0×10^{-9}	1.3×10^{-7}	2.2×10^{-5}	-	2.2×10^{-5}
Uranium-235+D	6.0×10^{-8}	5.6×10^{-9}	9.0×10^{-7}	-	9.6×10^{-7}
Uranium-238+D	2.0×10^{-7}	1.3×10^{-7}	2.0×10^{-5}	-	2.0×10^{-5}
Total risk	5.5×10^{-6}	2.2×10^{-6}	1.6×10^{-4}	2.0×10^{-6}	1.7×10^{-4}

[a] Estimated risks are for a construction worker working outdoors (e.g., excavation activities) for 100 hours for 1 year. The risk estimates presented in this table were derived from exposure point concentrations and estimated doses given in Table 3.9.

[b] A hyphen indicates that the entry is not applicable.

[c] Total risk across pathways for each radionuclide.

TABLE 5.5 Radiological Carcinogenic Risk from Incidental Ingestion of Soil for Current Receptors at the St. Louis Site[a]

	Carcinogenic Risk			
Property and Receptor	Actinium-227+D	Lead-210+D	Protactinium-231	Radium-226+D
SLDS employee[b]	NA	NA	NA	NA
SLDS construction worker[c]	-	-	-	-
SLDS maintenance worker (drains)	3.2×10^{-7}	4.4×10^{-7}	2.0×10^{-7}	5.6×10^{-8}
City property recreational user	9.0×10^{-6}	7.2×10^{-6}	6.6×10^{-6}	6.6×10^{-7}
SLAPS trespasser	7.8×10^{-6}	6.6×10^{-6}	6.6×10^{-6}	6.6×10^{-7}
SLAPS maintenance worker	4.3×10^{-5}	3.4×10^{-5}	3.5×10^{-5}	3.4×10^{-6}
Ditch construction worker	6.6×10^{-7}	5.5×10^{-7}	5.0×10^{-7}	5.0×10^{-8}
Residential vicinity property child commuter	6.0×10^{-7}	5.4×10^{-7}	5.2×10^{-7}	4.4×10^{-8}
Residential vicinity property current resident	3.5×10^{-6}	3.1×10^{-6}	3.0×10^{-6}	2.5×10^{-7}
Ballfield recreational user	1.6×10^{-6}	1.3×10^{-6}	1.3×10^{-6}	1.3×10^{-7}
Coldwater Creek recreational user	2.8×10^{-7}	2.8×10^{-7}	2.5×10^{-7}	1.9×10^{-8}
Futura Coatings employee	2.6×10^{-5}	2.5×10^{-5}	2.3×10^{-5}	1.7×10^{-6}
HISS trespasser	9.6×10^{-6}	9.6×10^{-6}	9.0×10^{-6}	6.6×10^{-7}
HISS maintenance worker	2.1×10^{-4}	2.0×10^{-4}	1.9×10^{-4}	1.4×10^{-5}

	Carcinogenic Risk			
Property and Receptor	Radium-228+D	Thorium-228+D	Thorium-230	Thorium-232
SLDS employee[b]	NA	NA	NA	NA
SLDS construction worker[c]	-	-	-	-
SLDS maintenance worker (drains)	1.4×10^{-7}	1.1×10^{-7}	3.0×10^{-7}	4.1×10^{-7}
City property recreational user	2.0×10^{-8}	3.1×10^{-8}	2.8×10^{-7}	1.2×10^{-7}
SLAPS trespasser	1.3×10^{-8}	2.4×10^{-8}	3.2×10^{-6}	1.1×10^{-7}
SLAPS maintenance worker	6.6×10^{-8}	1.3×10^{-7}	1.7×10^{-5}	5.7×10^{-7}
Ditch construction worker	6.0×10^{-9}	1.1×10^{-8}	1.6×10^{-6}	4.8×10^{-8}
Residential vicinity property child commuter[d]	0	4.3×10^{-9}	3.0×10^{-6}	1.6×10^{-8}
Residential vicinity property current resident[d]	0	2.5×10^{-8}	1.7×10^{-5}	8.4×10^{-8}
Ballfield recreational user	2.5×10^{-8}	4.7×10^{-8}	5.3×10^{-7}	2.1×10^{-7}
Coldwater Creek recreational user	1.1×10^{-9}	8.4×10^{-9}	4.7×10^{-8}	3.1×10^{-8}
Futura Coatings employee	1.6×10^{-8}	1.3×10^{-7}	4.4×10^{-6}	4.8×10^{-7}
HISS trespasser	2.9×10^{-9}	2.2×10^{-8}	1.2×10^{-6}	8.4×10^{-8}
HISS maintenance worker	6.0×10^{-8}	4.7×10^{-7}	2.5×10^{-5}	1.7×10^{-6}

TABLE 5.5 (Cont.)

Property and Receptor	Carcinogenic Risk			Total Carcinogenic Risk
	Uranium-234	Uranium-235+D	Uranium-238+D	
SLDS employee[b]	NA	NA	NA	NA
SLDS construction worker[c]	-	-	-	-
SLDS maintenance worker (drains)	3.2×10^{-8}	1.4×10^{-9}	3.1×10^{-8}	2.0×10^{-6}
City property recreational user	1.0×10^{-6}	4.6×10^{-8}	9.6×10^{-7}	2.6×10^{-5}
SLAPS trespasser	1.2×10^{-7}	5.3×10^{-9}	1.1×10^{-7}	2.5×10^{-5}
SLAPS maintenance worker	6.6×10^{-7}	2.8×10^{-8}	6.0×10^{-7}	1.3×10^{-4}
Ditch construction worker	3.1×10^{-8}	1.3×10^{-9}	2.9×10^{-8}	3.4×10^{-6}
Residential vicinity property child commuter[d]	1.8×10^{-8}	0	1.7×10^{-8}	4.8×10^{-6}
Residential vicinity property current resident[d]	9.6×10^{-8}	0	9.6×10^{-8}	2.8×10^{-5}
Ballfield recreational user	8.4×10^{-8}	3.6×10^{-9}	7.8×10^{-8}	5.2×10^{-6}
Coldwater Creek recreational user	4.6×10^{-9}	2.1×10^{-10}	4.6×10^{-9}	9.0×10^{-7}
Futura Coatings employee	5.3×10^{-7}	2.3×10^{-8}	5.0×10^{-7}	8.2×10^{-5}
HISS trespasser	2.0×10^{-7}	9.0×10^{-9}	1.9×10^{-7}	3.1×10^{-5}
HISS maintenance worker	4.2×10^{-6}	1.9×10^{-7}	4.1×10^{-6}	6.6×10^{-4}

[a] The risk estimates presented in this table are derived from exposure point concentrations and estimated doses given in Table 3.10.

[b] NA indicates not applicable because soil ingestion is not a pathway of concern for that receptor.

The risk estimates for the SLDS construction worker are presented in Tables 5.3 and 5.4.

A zero indicates that the soil concentration of this radionuclide was less than background and would result in an insignificant risk.

TABLE 5.6 Radiological Carcinogenic Risk from Inhalation of Radon-222 and Its Decay Products for Current Receptors at the St. Louis Site[a]

Property and Receptor	Carcinogenic Risk: Indoors	Carcinogenic Risk: Outdoors	Total Carcinogenic Risk
SLDS employee[b]	-	NA	-
SLDS construction worker[c]	-	-	-
SLDS maintenance worker (drains)	NA	NA	NA
City property recreational user	NA	5.6×10^{-5}	5.6×10^{-5}
SLAPS trespasser	NA	3.4×10^{-5}	3.4×10^{-5}
SLAPS maintenance worker	NA	3.5×10^{-4}	3.5×10^{-4}
Ditch construction worker	NA	4.9×10^{-6}	4.9×10^{-6}
Residential vicinity property child commuter	NA	1.1×10^{-7}	1.1×10^{-7}
Residential vicinity property current resident[d]	-	4.9×10^{-6}	4.9×10^{-6}
Ballfield recreational user	NA	1.2×10^{-5}	1.2×10^{-5}
Coldwater Creek recreational user	NA	9.8×10^{-7}	9.8×10^{-7}
Futura Coatings employee	2.5×10^{-4}	NA	2.5×10^{-4}
HISS trespasser	NA	3.5×10^{-5}	3.5×10^{-5}
HISS maintenance worker	2.3×10^{-4}	7.4×10^{-4}	9.8×10^{-4}

[a] The risk estimates presented in this table are based on exposure point concentrations and estimated doses given in Table 3.16. NA indicates not applicable because radon inhalation is not a pathway of concern.

[b] The indoor risk estimates for the SLDS employee are presented in Table 5.2.

[c] The risk estimates for the SLDS construction worker are presented in Tables 5.3 and 5.4.

[d] Because of the distance from the contamination to the house, indoor radon levels are expected to be equal to background levels. Outdoor risks were calculated on the assumption that the current resident would be exposed to contaminated soil at the edge of the property.

TABLE 5.7 Radiological Carcinogenic Risk from Inhalation of Particulates for Current Receptors at the St. Louis Site[a]

	Carcinogenic Risk			
Property and Receptor	Actinium-227+D	Lead-210+D	Protactinium-231	Radium-226+D
SLDS employee[b]	NA	NA	NA	NA
SLDS construction worker[c]	-	-	-	-
SLDS maintenance worker (drains)[b]	NA	NA	NA	NA
City property recreational user	2.7×10^{-6}	1.6×10^{-8}	5.1×10^{-7}	3.3×10^{-9}
SLAPS trespasser	1.8×10^{-6}	1.0×10^{-8}	3.9×10^{-7}	2.3×10^{-9}
SLAPS maintenance worker	2.1×10^{-5}	1.2×10^{-7}	4.5×10^{-6}	2.7×10^{-8}
Ditch construction worker	1.0×10^{-4}	4.6×10^{-7}	1.9×10^{-5}	1.1×10^{-7}
Residential vicinity property child commuter	6.6×10^{-9}	3.9×10^{-11}	1.4×10^{-9}	7.8×10^{-12}
Residential vicinity property current resident	1.5×10^{-6}	1.0×10^{-8}	3.6×10^{-7}	1.9×10^{-9}
Ballfield recreational user	6.0×10^{-7}	3.3×10^{-9}	1.3×10^{-7}	7.8×10^{-10}
Coldwater Creek recreational user	5.1×10^{-8}	3.6×10^{-10}	1.3×10^{-8}	5.7×10^{-11}
Futura Coatings employee	1.3×10^{-5}	9.0×10^{-8}	3.0×10^{-6}	1.4×10^{-8}
HISS trespasser	3.3×10^{-6}	2.2×10^{-8}	7.8×10^{-7}	3.5×10^{-9}
HISS maintenance worker	9.9×10^{-6}	7.2×10^{-7}	2.4×10^{-5}	1.1×10^{-7}

	Carcinogenic Risk			
Property and Receptor	Radium-228+D	Thorium-228+D	Thorium-230	Thorium-232
SLDS employee[b]	NA	NA	NA	NA
SLDS construction worker[c]	-	-	-	-
SLDS maintenance worker (drains)[b]	NA	NA	NA	NA
City property recreational user	4.8×10^{-11}	8.4×10^{-9}	1.1×10^{-7}	4.5×10^{-8}
SLAPS trespasser	2.2×10^{-11}	4.8×10^{-9}	1.3×10^{-6}	2.9×10^{-8}
SLAPS maintenance worker	2.6×10^{-10}	5.7×10^{-8}	1.5×10^{-5}	3.3×10^{-7}
Ditch construction worker	1.2×10^{-8}	1.4×10^{-6}	3.0×10^{-4}	9.0×10^{-6}
Residential vicinity property child commuter[d]	0	4.3×10^{-11}	4.3×10^{-8}	2.2×10^{-10}
Residential vicinity property current resident[d]	0	1.1×10^{-8}	1.1×10^{-5}	5.5×10^{-8}
Ballfield recreational user	7.2×10^{-11}	4.9×10^{-8}	2.8×10^{-7}	9.0×10^{-8}
Coldwater Creek recreational user	1.7×10^{-12}	1.5×10^{-9}	1.2×10^{-8}	7.8×10^{-9}
Futura Coatings employee	1.2×10^{-10}	1.0×10^{-7}	4.5×10^{-6}	5.1×10^{-7}
HISS trespasser	5.1×10^{-12}	4.5×10^{-9}	3.0×10^{-7}	2.3×10^{-8}
HISS maintenance worker	1.6×10^{-10}	1.4×10^{-7}	9.6×10^{-6}	7.2×10^{-7}

TABLE 5.7 (Cont.)

Property and Receptor	Carcinogenic Risk			Total Carcinogenic Risk
	Uranium-234	Uranium-235+D	Uranium-238+D	
SLDS employee[b]	NA	NA	NA	NA
SLDS construction worker[c]	-	-	-	-
SLDS maintenance worker (drains)[b]	NA	NA	NA	NA
City property recreational user	3.5×10^{-7}	1.5×10^{-8}	3.3×10^{-7}	4.1×10^{-6}
SLAPS trespasser	3.0×10^{-8}	1.3×10^{-9}	2.8×10^{-8}	3.6×10^{-6}
SLAPS maintenance worker	3.6×10^{-7}	1.5×10^{-8}	3.3×10^{-7}	4.2×10^{-5}
Ditch construction worker	5.0×10^{-6}	2.2×10^{-7}	4.6×10^{-6}	4.4×10^{-4}
Residential vicinity property child commuter[d]	2.2×10^{-10}	0	2.0×10^{-10}	5.3×10^{-8}
Residential vicinity property current resident[d]	5.3×10^{-8}	0	5.0×10^{-8}	1.3×10^{-5}
Ballfield recreational user	3.1×10^{-8}	1.3×10^{-9}	2.8×10^{-8}	1.2×10^{-6}
Coldwater Creek recreational user	1.0×10^{-9}	4.2×10^{-11}	9.6×10^{-10}	9.0×10^{-8}
Futura Coatings employee	3.9×10^{-7}	1.7×10^{-8}	3.6×10^{-7}	2.2×10^{-5}
HISS trespasser	7.2×10^{-8}	2.9×10^{-9}	6.6×10^{-8}	4.6×10^{-6}
HISS maintenance worker	2.2×10^{-6}	9.6×10^{-8}	2.0×10^{-6}	1.4×10^{-4}

[a] The risk estimates presented in this table are derived from exposure point concentrations and estimated doses given in Table 3.18.

[b] NA indicates not applicable because inhalation of particulates is not a pathway of concern for that receptor.

[c] The risk estimates for the SLDS construction worker are presented in Tables 5.3 and 5.4.

[d] A zero indicates that the soil concentration of this radionuclide was less than background and would result in an insignificant risk.

TABLE 5.8 Summary of Estimated Radiological Carcinogenic Risk for Current Receptors at the St. Louis Site

	Lifetime Carcinogenic Risk from Nonradon Exposures		
Property and Receptor	External Exposure	Soil Ingestion	Particulate Inhalation
SLDS employee[a]	-	NA	NA
SLDS construction worker[b]	-	-	-
SLDS maintenance worker (drains)[c]	2.6×10^{-9}	2.0×10^{-6}	NA
City property recreational user	4.6×10^{-5}	2.6×10^{-5}	4.1×10^{-6}
SLAPS trespasser	3.1×10^{-5}	2.5×10^{-5}	3.6×10^{-6}
SLAPS maintenance worker	6.0×10^{-4}	1.3×10^{-4}	4.2×10^{-5}
Ditch construction worker	3.4×10^{-6}	3.4×10^{-6}	4.4×10^{-4}
Residential vicinity property child commuter	2.0×10^{-7}	4.8×10^{-6}	5.3×10^{-8}
Residential vicinity property current resident	2.8×10^{-5}	2.8×10^{-5}	1.3×10^{-5}
Ballfield recreational user	1.9×10^{-5}	5.2×10^{-6}	1.2×10^{-6}
Coldwater Creek recreational user	1.0×10^{-6}	9.0×10^{-7}	9.0×10^{-8}
Futura Coatings employee	8.4×10^{-4}	8.2×10^{-5}	2.2×10^{-5}
HISS trespasser	4.7×10^{-5}	3.1×10^{-5}	4.6×10^{-6}
HISS maintenance worker	3.2×10^{-3}	6.6×10^{-4}	1.4×10^{-4}

Property and Receptor	Total Carcinogenic Risk from Nonradon Exposures	Carcinogenic Risk for Lung Cancer from Inhalation of Radon Decay Products	Total Carcinogenic Risk from All Exposure Routes
SLDS employee[a]	-	-	-
SLDS construction worker[b]	-	-	-
SLDS maintenance worker (drains)[c]	2.0×10^{-6}	NA	2.0×10^{-6}
City property recreational user	7.8×10^{-5}	5.6×10^{-5}	1.3×10^{-4}
SLAPS trespasser	6.0×10^{-5}	3.4×10^{-5}	9.4×10^{-5}
SLAPS maintenance worker	7.8×10^{-4}	3.5×10^{-4}	1.1×10^{-3}
Ditch construction worker	4.4×10^{-4}	4.9×10^{-6}	4.4×10^{-4}
Residential vicinity property child commuter	5.0×10^{-6}	1.1×10^{-7}	5.1×10^{-6}
Residential vicinity property current resident	6.9×10^{-5}	4.9×10^{-6}	7.4×10^{-5}
Ballfield recreational user	2.6×10^{-5}	1.2×10^{-5}	3.8×10^{-5}
Coldwater Creek recreational user	2.0×10^{-6}	9.8×10^{-7}	3.0×10^{-6}
Futura Coatings employee	9.4×10^{-4}	2.5×10^{-4}	1.2×10^{-3}
HISS trespasser	8.4×10^{-5}	3.5×10^{-5}	1.2×10^{-4}
HISS maintenance worker	4.0×10^{-3}	9.8×10^{-4}	5.0×10^{-3}

[a] Results for external gamma exposure and inhalation of radon for the SLDS employee are presented in Table 5.2; NA indicates not applicable because it is not a pathway of concern.

[b] Results for the SLDS construction worker are presented in Tables 5.3 and 5.4..

[c] NA indicates not applicable because it is not a pathway of concern.

TABLE 5.9 Chemical Carcinogenic Risk from Ingestion of Soil for Current Receptors at the St. Louis Site[a]

	Carcinogenic Risk[b]				
Contaminant	SLDS Construction Worker	City Property Recreational User	SLAPS Trespasser	SLAPS Maintenance Worker	Ditch Construction Worker
Metals					
Arsenic	1.7×10^{-7}	3.8×10^{-7}	9.0×10^{-7}	3.4×10^{-6}	4.1×10^{-7}
Beryllium	1.1×10^{-8}	7.6×10^{-8}	1.2×10^{-7}	4.5×10^{-7}	5.4×10^{-8}
PAHs	7.5×10^{-6}	4.7×10^{-5}	-	-	-
Total carcinogenic risk	7.7×10^{-6}	4.7×10^{-5}	1.0×10^{-6}	3.9×10^{-6}	4.7×10^{-7}

	Carcinogenic Risk[b]				
Contaminant	Ballfield Recreational User	Coldwater Creek Recreational User	Futura Coatings Employee[c]	HISS Trespasser	HISS Maintenance Worker
Metals					
Arsenic	2.1×10^{-6}	8.0×10^{-7}	1.5×10^{-6}	6.7×10^{-6}	1.0×10^{-4}
Beryllium	2.6×10^{-7}	1.0×10^{-7}	1.8×10^{-7}	5.8×10^{-7}	8.9×10^{-6}
PAHs	-	3.7×10^{-6}	-	-	-
Total carcinogenic risk	2.4×10^{-6}	4.6×10^{-6}	1.6×10^{-6}	7.3×10^{-6}	1.1×10^{-4}

[a] The risk estimates presented in this table were derived from exposure point concentrations given in Table 3.14 and estimated daily intakes given in Table 3.29.

[b] A hyphen indicates that the substance is not a contaminant of concern for that property.

[c] Represents all commercial/municipal/industrial vicinity properties.

TABLE 5.10 Chemical Hazard Quotients for Ingestion of Soil by Current Receptors at the St. Louis Site[a]

	Hazard Quotient[b]				
Contaminant	SLDS Construction Worker	City Property Recreational User	SLAPS Trespasser	SLAPS Maintenance Worker	Ditch Construction Worker
Metals					
Antimony	5.7×10^{-2}	1.1×10^{-1}	2.0×10^{-3}	2.7×10^{-3}	8.2×10^{-3}
Arsenic	2.3×10^{-2}	5.7×10^{-3}	1.3×10^{-2}	1.8×10^{-2}	5.5×10^{-2}
Beryllium	3.6×10^{-5}	2.7×10^{-5}	4.3×10^{-5}	5.8×10^{-5}	1.8×10^{-4}
Cadmium	6.8×10^{-4}	2.6×10^{-4}	2.4×10^{-4}	3.3×10^{-4}	1.0×10^{-3}
Cobalt	NQ	NQ	NQ	NQ	NQ
Copper	-	-	1.8×10^{-3}	2.5×10^{-3}	7.5×10^{-3}
Molybdenum	-	-	-	-	-
Nickel	3.0×10^{-4}	1.6×10^{-4}	6.6×10^{-3}	9.0×10^{-3}	2.7×10^{-2}
Selenium	-	-	-	-	-
Thallium	1.4×10^{-1}	1.1×10^{-1}	2.2×10^{-2}	3.1×10^{-2}	9.2×10^{-2}
Uranium	3.6×10^{-2}	3.9×10^{-2}	4.7×10^{-3}	6.4×10^{-3}	1.9×10^{-2}
Zinc	-	-	-	-	-
Hazard index	0.26	0.26	0.051	0.070	0.21

	Hazard Quotient[b]				
Contaminant	Ballfield Recreational User	Coldwater Creek Recreational User	Futura Coatings Employee[c]	HISS Trespasser	HISS Maintenance Worker
Metals					
Antimony	1.4×10^{-2}	3.6×10^{-3}	-	2.0×10^{-2}	1.1×10^{-1}
Arsenic	3.1×10^{-2}	1.2×10^{-2}	7.8×10^{-3}	1.0×10^{-1}	5.5×10^{-1}
Beryllium	9.6×10^{-5}	3.7×10^{-5}	2.3×10^{-5}	2.1×10^{-4}	1.2×10^{-3}
Cadmium	6.4×10^{-4}	1.9×10^{-4}	-	1.2×10^{-3}	6.6×10^{-3}
Cobalt	NQ	NQ	NQ	NQ	NQ
Copper	-	-	5.2×10^{-4}	-	-
Molybdenum	2.4×10^{-3}	9.3×10^{-4}	9.8×10^{-4}	8.5×10^{-3}	4.7×10^{-2}
Nickel	8.1×10^{-4}	1.3×10^{-4}	1.6×10^{-3}	6.4×10^{-3}	3.5×10^{-2}
Selenium	1.9×10^{-3}	2.4×10^{-3}	4.7×10^{-4}	5.7×10^{-3}	3.1×10^{-2}
Thallium	1.3×10^{-1}	4.7×10^{-2}	3.4×10^{-2}	4.1×10^{-1}	2.2
Uranium	-	-	5.2×10^{-3}	7.6×10^{-3}	4.2×10^{-2}
Zinc	-	1.0×10^{-3}	-	-	-
Hazard index	0.19	0.067	0.051	0.56	3.1

[a] The hazard quotients presented in this table were derived from exposure point concentrations given in Table 3.14 and estimated daily intakes given in Table 3.29.

[b] A hyphen indicates that the substance is not a contaminant of concern for that property; NQ means not quantified because no oral RfD is available.

[c] Represents all commercial/municipal/industrial vicinity properties.

TABLE 5.11 Chemical Carcinogenic Risk from Inhalation of Particulates for Current Receptors at the St. Louis Site[a]

	Carcinogenic Risk[b]				
Contaminant	SLDS Construction Worker	City Property Recreational User	SLAPS Trespasser	SLAPS Maintenance Worker	Ditch Construction Worker
Metals					
Arsenic	4.8×10^{-7}	2.1×10^{-9}	3.3×10^{-9}	2.8×10^{-8}	1.2×10^{-6}
Beryllium	7.2×10^{-9}	9.6×10^{-11}	1.0×10^{-10}	8.3×10^{-10}	3.5×10^{-8}
Cadmium	2.0×10^{-8}	1.3×10^{-10}	8.5×10^{-11}	7.1×10^{-10}	3.0×10^{-8}
Nickel	2.4×10^{-8}	2.3×10^{-10}	6.1×10^{-9}	5.1×10^{-8}	2.2×10^{-6}
PAHs	2.6×10^{-6}	3.2×10^{-8}	-	-	-
Total carcinogenic risk	3.2×10^{-6}	3.4×10^{-8}	9.6×10^{-9}	8.0×10^{-8}	3.4×10^{-6}

	Carcinogenic Risk[b]				
Contaminant	Ballfield Recreational User	Coldwater Creek Recreational User	Futura Coatings Employee[c]	HISS Trespasser	HISS Maintenance Worker
Metals					
Arsenic	1.4×10^{-8}	3.0×10^{-9}	2.0×10^{-8}	2.5×10^{-8}	5.6×10^{-7}
Beryllium	3.9×10^{-10}	8.6×10^{-11}	5.6×10^{-10}	4.9×10^{-10}	1.1×10^{-8}
Cadmium	3.9×10^{-10}	6.5×10^{-11}	-	4.2×10^{-10}	9.3×10^{-9}
Nickel	1.3×10^{-9}	1.2×10^{-10}	1.5×10^{-8}	6.0×10^{-9}	1.3×10^{-7}
PAHs	-	1.7×10^{-9}	-	-	-
Total carcinogenic risk	1.6×10^{-8}	4.9×10^{-9}	3.6×10^{-8}	3.2×10^{-8}	7.1×10^{-7}

[a] The risk estimates presented in this table are derived from exposure point concentrations given in Table 3.20 and estimated daily intakes given in Table 3.31.

[b] A hyphen indicates that the substance is not a contaminant of concern for that property.

[c] Represents all commercial/municipal/industrial vicinity properties.

TABLE 5.12 Chemical Carcinogenic Risk across Pathways for Current Receptors at the St. Louis Site

Property and Receptor	Carcinogenic Risk: Ingestion	Carcinogenic Risk: Inhalation	Total Carcinogenic Risk
SLDS construction worker	7.7×10^{-6}	3.2×10^{-6}	1.1×10^{-5}
City property recreational user	4.7×10^{-5}	3.4×10^{-8}	4.7×10^{-5}
SLAPS trespasser	1.0×10^{-6}	9.6×10^{-9}	1.0×10^{-6}
SLAPS maintenance worker	3.9×10^{-6}	8.0×10^{-8}	4.0×10^{-6}
Ditch construction worker	4.7×10^{-7}	3.4×10^{-6}	3.9×10^{-6}
Ballfield recreational user	2.4×10^{-6}	1.6×10^{-8}	2.4×10^{-6}
Coldwater Creek recreational user	4.6×10^{-6}	4.9×10^{-9}	4.6×10^{-6}
Futura Coatings employee[a]	1.6×10^{-6}	3.6×10^{-8}	1.6×10^{-6}
HISS trespasser	7.3×10^{-6}	3.2×10^{-8}	7.3×10^{-6}
HISS maintenance worker	1.1×10^{-4}	7.1×10^{-7}	1.1×10^{-4}

[a] Represents all commercial/municipal/industrial vicinity properties.

TABLE 5.13 Chemical Hazard Index across Pathways for Current Receptors at the St. Louis Site

Property and Receptor	Hazard Quotient[a]: Ingestion	Hazard Quotient[a]: Inhalation	Hazard Index[b]
SLDS construction worker	0.26	NQ	0.26
City property recreational user	0.26	NQ	0.26
SLAPS trespasser	0.051	NQ	0.051
SLAPS maintenance worker	0.070	NQ	0.070
Ditch construction worker	0.21	NQ	0.21
Ballfield recreational user	0.19	NQ	0.19
Coldwater Creek recreational user	0.067	NQ	0.067
Futura Coatings employee[c]	0.051	NQ	0.051
HISS trespasser	0.56	NQ	0.56
HISS maintenance worker	3.1	NQ	3.1

[a] NQ indicates not quantified because no RfD values were available.

[b] Hazard index does not include contribution from cobalt and lead because no RfDs were available for these contaminants.

[c] Represents all commercial/municipal/industrial vicinity properties.

TABLE 5.14 Radiological Carcinogenic Risk from External Gamma Irradiation for Future Receptors at the St. Louis Site[a]

Property and Receptor	Carcinogenic Risk			
	Actinium-227+D	Lead-210+D	Protactinium-231	Radium-226+D
SLDS future resident	7.8×10^{-4}	4.1×10^{-6}	5.9×10^{-5}	1.1×10^{-2}
SLAPS future resident	1.3×10^{-3}	3.8×10^{-6}	1.2×10^{-4}	8.4×10^{-3}
Residential vicinity property future resident	1.3×10^{-5}	4.0×10^{-8}	1.1×10^{-6}	6.6×10^{-5}
Ballfield future resident	8.4×10^{-5}	2.4×10^{-7}	7.8×10^{-6}	5.0×10^{-4}
Coldwater Creek future recreational user	1.1×10^{-7}	4.1×10^{-10}	1.1×10^{-8}	5.8×10^{-7}
Futura Coatings future resident	4.8×10^{-4}	1.6×10^{-6}	4.7×10^{-5}	2.6×10^{-3}
HISS future resident[b]	2.4×10^{-3}	8.4×10^{-6}	2.3×10^{-4}	1.2×10^{-2}

Property and Receptor	Carcinogenic Risk			
	Radium-228+D	Thorium-228+D	Thorium-230	Thorium-232
SLDS future resident	6.0×10^{-4}	1.3×10^{-3}	3.1×10^{-6}	1.1×10^{-7}
SLAPS future resident	7.2×10^{-5}	3.7×10^{-4}	1.4×10^{-5}	3.7×10^{-8}
Residential vicinity property future resident[c]	0	7.8×10^{-6}	1.3×10^{-6}	7.8×10^{-10}
Ballfield future resident	4.4×10^{-5}	2.2×10^{-4}	5.8×10^{-7}	2.2×10^{-8}
Coldwater Creek future recreational user	1.6×10^{-8}	3.2×10^{-7}	4.0×10^{-10}	3.0×10^{-11}
Futura Coatings future resident	1.9×10^{-5}	4.0×10^{-4}	2.5×10^{-6}	3.5×10^{-8}
HISS future resident[b]	1.7×10^{-5}	3.4×10^{-4}	3.2×10^{-6}	3.0×10^{-8}

Property and Receptor	Carcinogenic Risk			Total Carcinogenic Risk
	Uranium-234	Uranium-235+D	Uranium-238+D	
SLDS future resident	3.2×10^{-6}	9.6×10^{-5}	2.9×10^{-4}	1.4×10^{-2}
SLAPS future resident	5.6×10^{-7}	1.7×10^{-5}	5.3×10^{-5}	1.0×10^{-2}
Residential vicinity property future resident[c]	1.1×10^{-8}	0	9.6×10^{-7}	9.0×10^{-5}
Ballfield future resident	1.1×10^{-7}	3.2×10^{-6}	1.0×10^{-5}	9.0×10^{-4}
Coldwater Creek future recreational user	5.6×10^{-11}	1.7×10^{-9}	5.3×10^{-9}	1.0×10^{-6}
Futura Coatings future resident	3.7×10^{-7}	1.1×10^{-5}	3.5×10^{-5}	3.6×10^{-3}
HISS future resident[b]	1.3×10^{-6}	3.9×10^{-5}	1.2×10^{-4}	1.5×10^{-2}

[a] The risk estimates presented in this table are derived from exposure point concentrations and estimated doses given in Table 3.11.

[b] Additional estimated risks from contaminants in the HISS storage pile are given in Table 5.19.

[c] A zero indicates that the soil concentration of this radionuclide was less than background and would result in an insignificant risk.

TABLE 5.15 Radiological Carcinogenic Risk from Incidental Ingestion of Soil for Future Receptors at the St. Louis Site[a]

Property and Receptor	Carcinogenic Risk											Total Carcinogenic Risk
	Actinium-227+D	Lead-210+D	Protactinium-231	Radium-226+D	Radium-228+D	Thorium-228+D	Thorium-230	Thorium-232	Uranium-234	Uranium-235+D	Uranium-238+D	
SLDS future resident	2.3×10^{-4}	3.4×10^{-4}	1.6×10^{-4}	4.3×10^{-5}	5.3×10^{-6}	4.2×10^{-6}	4.8×10^{-5}	1.5×10^{-6}	3.5×10^{-5}	1.6×10^{-6}	3.4×10^{-6}	9.1×10^{-4}
SLAPS future resident	4.3×10^{-4}	3.4×10^{-4}	3.5×10^{-4}	3.4×10^{-5}	6.6×10^{-7}	1.3×10^{-6}	1.7×10^{-4}	5.7×10^{-6}	6.6×10^{-6}	2.8×10^{-7}	6.0×10^{-6}	1.4×10^{-3}
Residential vicinity property future resident[c]	3.5×10^{-6}	3.1×10^{-6}	3.0×10^{-6}	2.5×10^{-7}	0	2.3×10^{-8}	1.7×10^{-5}	8.4×10^{-8}	9.6×10^{-8}	0	9.6×10^{-8}	2.8×10^{-5}
Ballfield future resident	2.8×10^{-5}	2.3×10^{-5}	2.3×10^{-5}	2.2×10^{-6}	4.6×10^{-7}	8.4×10^{-7}	9.6×10^{-6}	3.8×10^{-6}	1.4×10^{-6}	6.6×10^{-8}	1.4×10^{-6}	9.6×10^{-5}
Coldwater Creek future recreational user	2.8×10^{-7}	2.8×10^{-7}	2.5×10^{-7}	1.9×10^{-8}	1.1×10^{-9}	8.4×10^{-9}	4.7×10^{-8}	3.1×10^{-8}	4.6×10^{-9}	2.1×10^{-10}	4.6×10^{-9}	9.0×10^{-7}
Futura Coatings future resident	2.6×10^{-4}	2.5×10^{-4}	2.3×10^{-4}	1.7×10^{-5}	1.6×10^{-7}	1.3×10^{-6}	4.4×10^{-5}	4.9×10^{-6}	5.3×10^{-6}	2.3×10^{-7}	5.1×10^{-6}	8.4×10^{-4}
HISS future resident[b]	5.3×10^{-4}	5.0×10^{-4}	4.7×10^{-4}	3.6×10^{-5}	1.6×10^{-7}	1.2×10^{-6}	6.6×10^{-5}	4.4×10^{-6}	1.1×10^{-5}	4.7×10^{-7}	1.0×10^{-5}	1.6×10^{-3}

[a] The risk estimates presented in this table are derived from exposure point concentrations and estimated doses given in Table 3.12.

[b] Additional estimated risks from contaminants in the HISS storage pile are given in Table 5.19.

[c] A zero indicates that the soil concentration of this radionuclide was less than background and would result in an insignificant risk.

TABLE 5.16 Radiological Carcinogenic Risk from Inhalation of Radon-222 and Its Decay Products for Future Receptors at the St. Louis Site[a]

Property and Receptor	Carcinogenic Risk: Indoors	Carcinogenic Risk: Outdoors	Total Carcinogenic Risk
SLDS future resident	4.2×10^{-2}	9.1×10^{-4}	4.2×10^{-2}
SLAPS future resident	7.0×10^{-2}	7.0×10^{-4}	7.0×10^{-2}
Residential vicinity property future resident	3.2×10^{-4}	4.9×10^{-6}	3.3×10^{-4}
Ballfield future resident	2.9×10^{-3}	4.6×10^{-5}	3.0×10^{-3}
Coldwater Creek future recreational user	NA[b]	9.8×10^{-7}	9.8×10^{-7}
Futura Coatings future resident	3.0×10^{-2}	3.5×10^{-4}	3.0×10^{-2}
HISS future resident[c]	1.9×10^{-2}	7.4×10^{-4}	1.9×10^{-2}

[a] The risk estimates presented in this table are derived from exposure point concentrations and estimated doses given in Table 3.17.

[b] NA indicates not applicable.

[c] Additional estimated risks from contaminants in the HISS storage pile are given in Table 5.19.

TABLE 5.17 Radiological Carcinogenic Risk from Inhalation of Particulates for Future Receptors at the St. Louis Site[a]

	Carcinogenic Risk			
Property and Receptor	Actinium-227+D	Lead-210+D	Protactinium-231	Radium-226+D
SLDS future resident	1.1×10^{-4}	1.1×10^{-6}	1.9×10^{-5}	3.0×10^{-7}
SLAPS future resident	1.7×10^{-4}	9.6×10^{-7}	3.9×10^{-5}	2.2×10^{-7}
Residential vicinity property future resident	1.6×10^{-6}	1.0×10^{-8}	3.6×10^{-7}	1.9×10^{-9}
Ballfield future resident	1.1×10^{-5}	6.0×10^{-8}	2.4×10^{-6}	1.4×10^{-8}
Coldwater Creek future recreational user	5.1×10^{-8}	3.6×10^{-10}	1.3×10^{-8}	5.7×10^{-11}
Futura Coatings future resident	6.0×10^{-5}	4.2×10^{-7}	1.5×10^{-5}	6.6×10^{-8}
HISS future resident[b]	3.1×10^{-4}	2.2×10^{-6}	7.2×10^{-5}	3.3×10^{-7}

	Carcinogenic Risk			
Property and Receptor	Radium-228+D	Thorium-228+D	Thorium-230	Thorium-232
SLDS future resident	1.9×10^{-8}	1.7×10^{-6}	2.8×10^{-5}	8.4×10^{-6}
SLAPS future resident	2.2×10^{-9}	4.5×10^{-7}	1.3×10^{-4}	2.8×10^{-6}
Residential vicinity property future resident[c]	0	1.1×10^{-8}	1.1×10^{-5}	5.4×10^{-8}
Ballfield future resident	1.3×10^{-9}	2.7×10^{-7}	5.1×10^{-6}	1.7×10^{-6}
Coldwater Creek future recreational user	1.7×10^{-12}	1.5×10^{-9}	1.2×10^{-8}	7.8×10^{-9}
Futura Coatings future resident	5.7×10^{-10}	4.8×10^{-7}	2.2×10^{-5}	2.5×10^{-6}
HISS future resident[b]	4.8×10^{-10}	4.2×10^{-7}	2.9×10^{-5}	2.2×10^{-6}

	Carcinogenic Risk			Total Carcinogenic Risk
Property and Receptor	Uranium-234	Uranium-235+D	Uranium-238+D	
SLDS future resident	1.7×10^{-5}	7.2×10^{-7}	1.6×10^{-6}	2.0×10^{-4}
SLAPS future resident	2.9×10^{-6}	1.3×10^{-7}	2.7×10^{-6}	3.5×10^{-4}
Residential vicinity property future resident[c]	5.4×10^{-8}	0	5.1×10^{-8}	1.4×10^{-5}
Ballfield future resident	5.5×10^{-7}	2.3×10^{-8}	5.1×10^{-7}	2.2×10^{-5}
Coldwater Creek future recreational user	1.0×10^{-9}	4.2×10^{-11}	9.6×10^{-10}	9.0×10^{-8}
Futura Coatings future resident	1.9×10^{-6}	8.4×10^{-8}	1.8×10^{-6}	1.0×10^{-4}
HISS future resident[b]	6.6×10^{-6}	2.8×10^{-7}	6.0×10^{-6}	4.3×10^{-4}

[a] The risk estimates presented in this table are derived from exposure point concentrations and estimated doses given in Table 3.19.

[b] Additional estimated risks from contaminants in the HISS storage pile are given in Table 5.19.

[c] A zero indicates that the soil concentration of this radionuclide was less than background and would result in an insignificant risk.

TABLE 5.18 Radiological Carcinogenic Risk from Ingestion of Groundwater for Future Receptors at the St. Louis Site[a]

Property and Receptor	Carcinogenic Risk: Radium-226+D	Carcinogenic Risk: Thorium-230	Carcinogenic Risk: Total Uranium	Total Carcinogenic Risk
SLDS future resident	4.4×10^{-5}	2.5×10^{-5}	6.0×10^{-4}	6.6×10^{-4}
SLAPS future resident	5.5×10^{-5}	8.4×10^{-4}	2.8×10^{-2}	2.8×10^{-2}
HISS future resident	8.4×10^{-5}	2.2×10^{-3}	4.0×10^{-4}	2.6×10^{-3}

[a] The risk estimates presented in this table are derived from exposure point concentrations and estimated doses given in Table 3.22.

TABLE 5.19 Radiological Carcinogenic Risk for a Future Resident from Contaminants in the HISS Storage Pile[a]

Radionuclide	Carcinogenic Risk: External Exposure	Soil Ingestion	Particulate Inhalation	Radon Inhalation[b]
Actinium-227+D	5.9×10^{-3}	2.3×10^{-3}	7.8×10^{-4}	-
Protactinium-231	2.8×10^{-4}	9.6×10^{-4}	9.0×10^{-5}	-
Radium-226+D	9.5×10^{-3}	4.7×10^{-5}	2.6×10^{-7}	6.3×10^{-2}
Radium-228+D	1.7×10^{-4}	1.8×10^{-6}	4.8×10^{-9}	-
Thorium-228+D	3.0×10^{-4}	1.2×10^{-6}	3.6×10^{-7}	-
Thorium-230	1.9×10^{-4}	3.5×10^{-3}	1.6×10^{-3}	-
Thorium-232	2.3×10^{-8}	4.0×10^{-6}	1.7×10^{-6}	-
Uranium-235+D	3.8×10^{-5}	7.8×10^{-7}	2.8×10^{-7}	-
Uranium-238+D	9.6×10^{-5}	1.4×10^{-5}	4.8×10^{-6}	-
Total risk[c]	1.7×10^{-2}	6.8×10^{-3}	2.5×10^{-3}	6.3×10^{-2}

[a] The risk estimates presented in this table are derived from exposure point concentrations and estimated doses given in Table 3.13.

[b] A hyphen indicates that the entry is not applicable.

[c] Total risk across pathways from the HISS storage pile is 8.9×10^{-2}.

TABLE 5.20 Summary of Estimated Radiological Carcinogenic Risk for Future Receptors at the St. Louis Site

	Lifetime Carcinogenic Risk from Nonradon Exposures			
Property and Receptor	Groundwater Ingestion[a]	External Exposure	Soil Ingestion	Particulate Inhalation
SLDS future resident	6.6×10^{-4}	1.4×10^{-2}	9.1×10^{-4}	2.0×10^{-4}
SLAPS future resident	2.8×10^{-2}	1.0×10^{-2}	1.4×10^{-3}	3.5×10^{-4}
Residential vicinity property future resident	-	9.0×10^{-5}	2.8×10^{-5}	1.4×10^{-5}
Ballfield future resident	-	9.0×10^{-4}	9.6×10^{-5}	2.2×10^{-5}
Coldwater Creek future recreational user	-	1.0×10^{-6}	9.0×10^{-7}	9.0×10^{-8}
Futura Coatings future resident	-	3.6×10^{-3}	8.4×10^{-4}	1.0×10^{-4}
HISS future resident[b]	2.6×10^{-3}	1.5×10^{-2}	1.6×10^{-3}	4.3×10^{-4}

Property and Receptor	Total Carcinogenic Risk from Nonradon Exposures	Carcinogenic Risk for Lung Cancer from Inhalation of Radon Decay Products	Total Carcinogenic Risk from All Exposure Routes
SLDS future resident	1.6×10^{-2}	4.2×10^{-2}	5.8×10^{-2}
SLAPS future resident	4.0×10^{-2}	7.0×10^{-2}	1.1×10^{-1}
Residential vicinity property future resident	1.3×10^{-4}	3.3×10^{-4}	4.6×10^{-4}
Ballfield future resident	1.0×10^{-3}	3.0×10^{-3}	4.0×10^{-3}
Coldwater Creek future recreational user	2.0×10^{-6}	9.8×10^{-7}	3.0×10^{-6}
Futura Coatings future resident	4.6×10^{-3}	3.0×10^{-2}	3.5×10^{-2}
HISS future resident[b]	2.0×10^{-2}	1.9×10^{-2}	3.9×10^{-2}

[a] A hyphen indicates that a risk from groundwater ingestion was not calculated because no groundwater data were available for that property.

[b] Additional estimated risks from contaminants in the HISS storage pile are given in Table 5.19.

TABLE 5.21 Chemical Carcinogenic Risk from Incidental Ingestion of Soil for Future Receptors at the St. Louis Site[a]

	Carcinogenic Risk[b]					
Contaminant	SLDS[c]	SLAPS	Ballfield	Coldwater Creek	Futura[d]	HISS
Metals						
Arsenic	8.8×10^{-5}	7.7×10^{-5}	2.1×10^{-4}	8.0×10^{-7}	1.9×10^{-4}	5.8×10^{-4}
Beryllium	5.9×10^{-6}	1.0×10^{-5}	1.6×10^{-5}	1.0×10^{-7}	3.2×10^{-5}	5.0×10^{-5}
PAHs	4.0×10^{-3}	-	-	3.7×10^{-6}	-	-
Total carcinogenic risk	4.1×10^{-3}	8.7×10^{-5}	2.3×10^{-4}	4.6×10^{-6}	2.3×10^{-4}	6.3×10^{-4}

[a] The risk estimates presented in this table are derived from exposure point concentrations given in Table 3.15 and estimated daily intakes given in Table 3.30. All future receptors are residents except for the Coldwater Creek recreational user.

[b] A hyphen indicates that the substance is not a contaminant of concern for that property.

[c] Includes the SLDS main site, SLDS vicinity properties, and city property.

[d] Represents all commercial/municipal/industrial vicinity properties.

TABLE 5.22 Chemical Hazard Quotients for Incidental Ingestion of Soil by Future Receptors at the St. Louis Site[a]

	Hazard Quotient[b]					
Contaminant	SLDS[c]	SLAPS	Ballfield	Coldwater Creek	Futura[d]	HISS
Metals						
Antimony	1.1	0.051	0.24	0.0036	-	0.51
Arsenic	0.39	0.34	0.95	0.012	0.86	2.6
Beryllium	0.00064	0.0011	0.0018	0.000037	0.0035	0.0054
Cadmium	0.011	0.0062	0.0088	0.00019	-	0.031
Cobalt	NQ	NQ	NQ	NQ	NQ	NQ
Copper	-	0.046	-	-	0.18	-
Molybdenum	-	-	0.078	0.00093	0.18	0.22
Nickel	0.0051	0.17	0.0062	0.00013	0.64	0.16
Selenium	-	-	0.061	0.0024	0.15	0.15
Thallium	2.5	0.57	4.5	0.047	0.63	10
Uranium	0.65	0.12	-	-	0.097	0.19
Zinc	-	-	-	0.0010	-	-
Hazard index	4.6	1.3	5.9	0.067	2.7	14

[a] The hazard quotients presented in this table are derived from exposure point concentrations given in Table 3.15 and estimated daily intakes given in Table 3.30. All future receptors are residents except for the Coldwater Creek recreational user.

[b] NQ indicates not quantified because no oral RfDs were available; a hyphen indicates that the substance is not a contaminant of concern for that property.

[c] Includes the SLDS main site, SLDS vicinity properties, and city property.

[d] Represents all commercial/municipal/industrial vicinity properties.

TABLE 5.23 Chemical Carcinogenic Risk from Inhalation of Particulates for Future Receptors at the St. Louis Site[a]

	Carcinogenic Risk[b]					
Contaminant	SLDS[c]	SLAPS	Ballfield	Coldwater Creek	Futura[d]	HISS
Metals						
Arsenic	2.6×10^{-7}	2.3×10^{-7}	6.3×10^{-7}	3.0×10^{-9}	5.7×10^{-7}	1.7×10^{-6}
Beryllium	3.9×10^{-9}	6.8×10^{-9}	1.1×10^{-8}	8.6×10^{-11}	2.2×10^{-8}	3.3×10^{-8}
Cadmium	1.1×10^{-8}	5.8×10^{-9}	8.1×10^{-9}	6.5×10^{-11}	-	2.8×10^{-8}
Nickel	1.3×10^{-8}	4.2×10^{-7}	1.5×10^{-8}	1.2×10^{-10}	1.6×10^{-6}	4.1×10^{-7}
PAHs	1.5×10^{-6}	-	-	1.7×10^{-9}	-	-
Total carcinogenic risk	1.8×10^{-6}	6.5×10^{-7}	6.6×10^{-7}	4.9×10^{-9}	2.2×10^{-6}	2.2×10^{-6}

[a] The risk estimates presented in this table are derived from exposure point concentrations given in Table 3.21 and estimated daily intakes given in Table 3.32. All future receptors are residents except for the Coldwater Creek recreational user.

[b] A hyphen indicates that the substance is not a contaminant of concern for that property.

[c] Includes the SLDS main site, SLDS vicinity properties, and city property.

[d] Represents all commercial/municipal/industrial vicinity properties.

TABLE 5.24 Chemical Carcinogenic Risk from Ingestion of Groundwater for Future Residents at the St. Louis Site[a]

	Carcinogenic Risk[b]		
Contaminant	SLDS[c]	SLAPS	HISS
Metals			
Arsenic	2.6×10^{-3}	3.3×10^{-4}	3.3×10^{-4}
Beryllium	2.5×10^{-4}	2.5×10^{-4}	2.5×10^{-4}
Volatile organic compounds			
Benzene	7.2×10^{-6}	-	-
1,2-Dichloropropane	1.0×10^{-4}	-	-
Trichloroethene	6.5×10^{-7}	1.7×10^{-5}	-
Vinyl chloride	6.5×10^{-4}	-	-
Semivolatile organic compound			
Bis(2-ethylhexyl)phthalate	1.8×10^{-4}	7.1×10^{-5}	1.1×10^{-4}
PCBs/Pesticides			
Aroclor 1254 (PCB)	1.4×10^{-4}	-	-
4,4′-DDT	3.9×10^{-6}	-	-
Total carcinogenic risk	3.9×10^{-3}	6.7×10^{-4}	6.9×10^{-4}

[a] The risk estimates presented in this table are derived from exposure point concentrations given in Table 3.23 and estimated daily intakes given in Table 3.33.

[b] A hyphen indicates that the substance is not a contaminant of concern for that property.

[c] Includes the SLDS main site, SLDS vicinity properties, and city property.

TABLE 5.25 Chemical Hazard Quotients for Ingestion of Groundwater by Future Residents at the St. Louis Site[a]

Contaminant	Hazard Quotient[b]		
	SLDS	SLAPS	HISS
Metals			
Antimony	2.7	6.1	10
Arsenic	12	1.5	1.5
Barium	0.21	0.28	0.88
Beryllium	0.027	0.027	0.027
Boron	0.56	0.15	0.10
Cadmium	0.30	0.63	1.3
Chromium	0.27	2.1	0.68
Cobalt	NQ	NQ	NQ
Copper	0.028	0.12	0.097
Manganese	1.2	1.9	1.9
Molybdenum	0.68	1.2	0.96
Nickel	0.98	0.14	0.14
Selenium	0.59	33	20
Silver	0.055	0.35	0.084
Thallium	39	44	72
Uranium	5.2	230	3.3
Vanadium	0.20	0.63	0.54
Zinc	0.041	1.1	0.19
Inorganic anions			
Fluoride[c]	2.8	NA	NA
Nitrate[c]	0.0036	NA	NA
Volatile organic compounds			
Benzene	NQ	-	-
Chlorobenzene	0.011	-	-
1,2-Dichloroethene	0.41	0.26	-
1,2-Dichloropropane	NQ	-	-
Toluene	-	0.023	-
Trichloroethene	NQ	NQ	-
Vinyl chloride	NQ	-	-
Semivolatile organic compounds			
Bis(2-ethylhexyl)phthalate	1.5	0.59	0.89
1,2-Dichlorobenzene	0.028	-	-
PCBs/Pesticides			
Aroclor 1254 (PCB)	NQ	-	-
4,4'-DDT	0.054	-	-
Endosulfan	-	0.049	-
Hazard index	69	330	120

[a] Based on exposure point concentrations given in Table 3.23 and estimated daily intakes from Table 3.33.

[b] NQ indicates not quantified because no RfD was available; a hyphen indicates that the substance is not a contaminant of concern for that property. All values are rounded to two significant figures.

[c] NA indicates that fluoride and nitrate were not analyzed at SLAPS and HISS.

TABLE 5.26 Chemical Carcinogenic Risk for Inhalation of Groundwater by Future Residents at the St. Louis Site[a]

	Carcinogenic Risk[b]		
Contaminant	SLDS[c]	SLAPS	HISS
Volatile organic compounds			
Benzene	2.0×10^{-5}	-	-
1,2-Dichloropropane	NQ	-	-
Trichloroethene	2.9×10^{-6}	7.3×10^{-5}	-
Vinyl chloride	2.9×10^{-4}	-	-
Total carcinogenic risk	3.1×10^{-4}	7.3×10^{-5}	-

[a] The risk estimates presented in this table are derived from exposure point concentrations given in Table 3.24 and estimated daily intakes given in Table 3.34. The pathway evaluated was inhalation of organic contaminants from groundwater during showering. Inorganic contaminants were not evaluated because they would not volatilize from water.

[b] NQ indicates not quantified because no slope factor was available; a hyphen indicates that the substance is not a contaminant of concern for that property.

[c] Includes the SLDS main site, SLDS vicinity properties, and city property.

TABLE 5.27 Chemical Hazard Quotients for Inhalation of Groundwater by Future Residents at the St. Louis Site[a]

	Hazard Quotient[b]		
Contaminant	SLDS[c]	SLAPS	HISS
Volatile organic compounds			
Chlorobenzene	0.12	-	-
1,2-Dichloropropane	10	-	-
Toluene	-	0.022	-
Trichloroethene	NQ	NQ	-
Vinyl chloride	NQ	-	-
Semivolatile organic compounds			
1,2-Dichlorobenzene	0.18	-	-
Hazard index	10	0.022	NQ

[a] The hazard quotients presented in this table are derived from exposure point concentrations given in Table 3.24 and estimated daily intakes given in Table 3.34. The pathway analyzed was inhalation of organic contaminants from groundwater during showering. Inorganic contaminants of concern were not evaluated because they would not volatilize from water.

[b] A hyphen indicates that the substance is not a contaminant of concern at that property; NQ indicates not quantified because no inhalation RfD was available.

[c] Includes the SLDS main site, SLDS vicinity properties, and city property.

ABLE 5.28 Chemical Carcinogenic Risk across Pathways for Future Receptors at the St. Louis Site

	Carcinogenic Risk for Individual Pathways				
	Soil		Groundwater[b]		
Property and Receptor	Ingestion	Inhalation	Ingestion	Inhalation	Total Carcinogenic Risk
SLDS future resident[a]	4.1×10^{-3}	1.8×10^{-6}	3.9×10^{-3}	3.1×10^{-4}	8.3×10^{-3}
SLAPS future resident	8.7×10^{-5}	6.5×10^{-7}	6.7×10^{-4}	7.3×10^{-5}	8.3×10^{-4}
Ballfield future resident	2.3×10^{-4}	6.6×10^{-7}	-	-	2.3×10^{-4}
Coldwater Creek future recreational user	4.6×10^{-6}	4.9×10^{-9}	NA	NA	4.6×10^{-6}
Futura Coatings future resident[c]	2.3×10^{-4}	2.2×10^{-6}	-	-	2.3×10^{-4}
HISS future resident	6.3×10^{-4}	2.2×10^{-6}	6.9×10^{-4}	NQ	1.3×10^{-3}

[a] Includes the SLDS main site, SLDS vicinity properties, and city property.

[b] A hyphen indicates not assessed because no data are available specific to the site areas; NA indicates not applicable; NQ indicates not quantified because no slope factors were available for the contaminants of concern.

[c] Represents all commercial/municipal/industrial vicinity properties.

TABLE 5.29 Chemical Hazard Indexes across Pathways for Future Receptors at the St. Louis Site[a]

	Hazard Quotient			
		Groundwater[b]		
Property and Receptor	Soil Ingestion	Ingestion	Inhalation	Hazard Index
SLDS future resident[c]	4.6	69	10	84
SLAPS future resident	1.3	330	0.022	330
Ballfield future resident	5.9	-	-	5.9
Coldwater Creek future recreational user	0.067	NA	NA	0.067
Futura Coatings future resident[d]	2.7	-	-	2.7
HISS future resident	14	120	NQ	130

[a] Soil inhalation pathway was not quantified because no RfD values were available.

[b] A hyphen indicates not assessed because no data were available specific to the site area; NA indicates not applicable; NQ indicates not quantified because no inhalation RfDs were available for the contaminants of concern.

[c] Includes the SLDS main site, SLDS vicinity properties, and city property.

[d] Represents all commercial/municipal/industrial vicinity properties.

TABLE 5.30 Correlation of Lead Concentrations in Soil, Air, and Groundwater at the St. Louis Site with Blood Lead Concentrations[a]

	Lead Concentration			Maximum Blood Lead Concentration[e] (µg/dL)
Property	Soil and Dust[b] (mg/kg)	Air[c] (mg/m^3)	Groundwater[d] (µg/L)	
SLDS	1,300	5.2×10^{-5}	50	29
SLAPS	130	5.2×10^{-6}	50	7.5
Ballfield	41	1.6×10^{-6}	50	5.9
Futura Coatings	140	5.6×10^{-6}	50	7.7
HISS	260	1.0×10^{-5}	50	9.8

[a] Based on the linear absorption model of the uptake/biokinetic model (EPA 1991e). Model default uptake values of 3 to 4 µg/d were assumed for dietary lead exposure. All values are rounded to two significant figures.

[b] Soil concentrations are UL_{95} values for lead, as shown in Table 3.15. An ingestion rate of 200 mg soil per day was assumed for children aged 0 to 6 years, and a rate of 100 mg soil per day was assumed for children aged 6 to 7 years. Lead concentrations in dust were assumed to be equal to those in soil.

[c] Outdoor air concentrations were calculated as follows: soil concentration (mg/kg) × 0.08 mg particulates/m^3 air × 10^{-6} kg/mg × 50% (fraction of particulates from contaminated source); a factor of 30% respirable was accounted for in the model. Indoor air concentration = outdoor air concentration × 0.4.

[d] Lead was not detected in groundwater at any of the St. Louis Site properties. The assumed concentration of 50 µg/L is equal to half the detection limit. The default ingestion rate of approximately 0.5 L/d for children aged 0 to 7 years was assumed.

[e] The maximum blood lead concentrations presented are for children aged 0 to 7 years.

TABLE 5.31 **Total Estimated Carcinogenic Risk from All Exposures for Current Receptors at the St. Louis Site**

Property and Receptor	Carcinogenic Risk from Radionuclide Exposure	Carcinogenic Risk from Chemical Exposure	Total Carcinogenic Risk
SLDS employee[a]	-	NQ	-
SLDS construction worker[b]	-	-	-
SLDS maintenance worker (drains)	2.0×10^{-6}	NQ	2.0×10^{-6}
City property recreational user	1.3×10^{-4}	4.7×10^{-5}	1.8×10^{-4}
SLAPS trespasser	9.4×10^{-5}	1.0×10^{-6}	9.5×10^{-5}
SLAPS maintenance worker	1.1×10^{-3}	4.0×10^{-6}	1.1×10^{-3}
Ditch construction worker	4.4×10^{-4}	3.9×10^{-6}	4.4×10^{-4}
Residential vicinity property child commuter[c]	5.1×10^{-6}	NA	5.1×10^{-6}
Residential vicinity property current resident[c]	7.4×10^{-5}	NA	7.4×10^{-5}
Ballfield recreational user	3.8×10^{-5}	2.4×10^{-6}	4.0×10^{-5}
Coldwater Creek recreational user	3.0×10^{-6}	4.6×10^{-6}	7.6×10^{-6}
Futura Coatings employee	1.2×10^{-3}	1.6×10^{-6}	1.2×10^{-3}
HISS trespasser	1.2×10^{-4}	7.3×10^{-6}	1.3×10^{-4}
HISS maintenance worker	5.0×10^{-3}	1.1×10^{-4}	5.1×10^{-3}

[a] The risk from radionuclide exposure for the SLDS employee is presented in Table 5.2; NQ indicates not quantified because chemical exposure is not a pathway of concern for that receptor.

[b] The risks from radionuclide exposure for the SLDS construction worker are presented in Tables 5.3 and 5.4. The total risk for the reasonably maximally exposed receptor (as described in Section 5.2.1.1) is 4.1×10^{-3}.

[c] NA indicates that the risk was not assessed because no data were available specific to the site area.

TABLE 5.32 Total Estimated Carcinogenic Risk from All Exposures for Future Receptors at the St. Louis Site

Property and Receptor	Carcinogenic Risk from Radionuclide Exposure	Carcinogenic Risk from Chemical Exposure	Total Carcinogenic Risk
SLDS future resident	5.8×10^{-2}	8.3×10^{-3}	6.6×10^{-2}
SLAPS future resident	1.1×10^{-1}	8.3×10^{-4}	1.1×10^{-1}
Residential vicinity property future resident	4.6×10^{-4}	-[a]	4.6×10^{-4}
Ballfield future resident	4.0×10^{-3}	2.3×10^{-4}	4.2×10^{-3}
Coldwater Creek future recreational user	3.0×10^{-6}	4.6×10^{-6}	7.6×10^{-6}
Futura Coatings future resident	3.5×10^{-2}	2.3×10^{-4}	3.5×10^{-2}
HISS future resident[b]	3.9×10^{-2}	1.3×10^{-3}	4.0×10^{-2}

[a] A hyphen indicates that the risk was not assessed because insufficient data were available.

[b] Estimated additional radiological risk from the storage pile is 8.9×10^{-2} (see Table 5.19); therefore, the total radiological risk estimated for the HISS future resident is 1.3×10^{-1}, and the total carcinogenic risk (including chemical) is 1.3×10^{-1}.

6 ENVIRONMENTAL ASSESSMENT FOR BIOTA

An ecological assessment is a qualitative and/or quantitative appraisal of actual or potential effects of a hazardous waste site on biota. Although ecological assessments can identify exposure pathways to human populations, their primary function is to identify environmental threats to ecological resources for which remedial action may be required. This environmental assessment incorporates site-specific information from characterization studies and environmental monitoring programs at the St. Louis Site. Information on the biota of the area was used to evaluate potential adverse environmental impacts that could result from the presence of contaminated materials at the site. The assessment of potential impacts also incorporates information from the available literature and information that was used for the human health evaluation in this BRA.

Potential impacts to local vegetation, wildlife, and aquatic biota from exposure to the St. Louis Site contaminants are difficult to quantify because of the lack of a comprehensive site-specific database and the limited availability of relevant environmental data. Therefore, the following ecological assessment is qualitative in nature and is based largely on information regarding the kinetics, effects, and mechanisms of biouptake and transport that have been reported in the literature for the contaminants of ecological concern. This information is detailed in Appendix B.

The biotic uptake and ultimate effect of a contaminant are influenced by a variety of abiotic and biotic factors. Abiotic factors include the physicochemical characteristics of the contaminant (liquid, solid, or gas), the type and nature of the medium in which the contaminant is present (soil, water, and air), climatic conditions (temperature and rainfall), contaminant mobility within and between media, and contaminant similarity to biologically active ions and compounds. Important biotic factors include the species, age, and size of the biotic receptor; the length of exposure to a contaminant; the growth stage (juvenile, larvae, or adult) and growth rate of the receptor; the mode of contaminant intake (via roots, ingestion, or inhalation); the diet and mode of nutrient and water intake of the receptor; for vegetation, the depth of the rooting zone; the respiration/transpiration rates of the receptor; species-specific physiological mechanisms of contaminant intake, internal transport, assimilation, elimination, and detoxification; the trophic status of the receptor (primary producer, primary consumer, or top predator); and the position of the receptor in the ecosystem's food web.

In the absence of any remedial action, exposure of biota at the St. Louis Site to site-associated contamination would continue. If, in the future, the contamination were to pread to a larger area through leaching, biouptake, and/or ingestion, the exposure of local biota could increase. The greatest potential impacts would be to those species that are restricted to, or heavily use, the site. In addition, the transport of contaminants to local [illegible]rface waters (particularly Coldwater Creek) would continue, and their subsequent biouptake could impact biota that use them.

In the past, many risk assessments have focused on human health effects and ha[illegible] not considered potential impacts to plant or animal receptors. However, numerous studies have been conducted in which plants and animals were analyzed for possible effects of exposure to specific contaminants. Reported effects on biota (in addition to acute toxicity) include reduced reproductive output or survival of young, decreased growth rates, behavioral aberrations, and numerous biochemical and physiological abnormalities. Prolonged exposure of local biota to contaminants from the St. Louis Site could potentially result in the manifestation of such adverse effects.

No investigations have been conducted at the St. Louis Site to assess the extent to which local biota have been contaminated or affected as a result of exposure to site wastes. Also, no analyses have been performed to determine the radionuclide or chemical contaminant concentrations in biota at the site. Therefore, the following evaluation for biota is based primarily on a comparison of threshold values given in the literature for adverse effects from several of the major contaminants of concern with the values of these contaminants that have been determined in soil samples from the site and in water and sediment samples from Coldwater Creek (see Appendix B).

6.1 RADIOLOGICAL TOXICITY

Some biological effects from radiation (e.g., chromosomal aberrations and organ failure) are similar in different species. However, except for warm-blooded species, most biota are more resistant than humans to radiotoxicity. Also, the loss of individual members of plant or animal communities is not normally a source of concern unless the loss involves threatened or endangered species, critical members of the food chain, and/or commercially important species or the loss places populations or the integrity of the ecosystem at risk. The more important issue may be the potential for plants and animals to serve as vectors for the transport of radioactive contaminants from the St. Louis Site to humans or other biota.

The interaction of plants with radionuclides can occur by foliar absorption of radionuclides deposited on leaf and stem surfaces or by uptake from the plant root zone in the soil. Information describing uptake and accumulation of radionuclides by plants is based mostly on short-term, relatively high-exposure laboratory experiments (Knight 1983) that may not be applicable to long-term, low-level exposure conditions such as those at the St. Louis Site. Of the radionuclides present in site wastes, radium-226 appears to have the highest potential for uptake and accumulation by plants because it serves as an analog for calcium, an essential plant nutrient (Knight 1983). Lead-210 that is taken up by the plant roots will remain in the roots, with little translocation to aboveground plant parts (Knight 1983).

Uptake of radionuclides by plants could lead to subsequent animal exposure via ingestion of contaminated vegetation. Small mammals or other animals that use areas of contaminated soil can be considered vectors for the transport and redistribution of radioactive contamination. Excavation of contaminated soil by biota can bring the contaminants to the surface, and animal burrows can allow for increased water infiltration. Additional modes of

Waste transport could include dispersal of animals with elevated levels of radionuclides, wind or water transport of contaminated soil brought to the surface by animals, and movement of radionuclides by predators that feed on contaminated prey (Arthur et al. 1986).

A toxicity assessment of radioactive contaminants of concern to St. Louis Site biota was not conducted for reasons explained in Appendix B.

6.2 CHEMICAL TOXICITY

Inorganic and organic chemical contamination, primarily metals and PAHs, have been identified at the St. Louis Site (Table 2.21). The toxicity of metals varies with biotic species and depends on physical and chemical factors such as pH and the presence of complexing agents or other metals. At low concentrations, metals may have biological implications by interfering with essential nutrients rather than by direct toxic effects (Sandstead 1977). Compounds of a number of metals (e.g., beryllium, cadmium, lead, and nickel) have been demonstrated to induce cancer in laboratory animals (Sunderman 1977). However, such experiments have generally involved greatly elevated levels of exposure and/or methods of exposure (e.g., injection) that would not be expected under field conditions. In general, plant uptake response to substrate concentrations of metals is not linear; some elements are accumulators whereas others are excluders. Therefore, the use of a plant/soil concentration ratio to predict plant concentrations could be misleading (Simon and Ibrahim [illegible]87). Additionally, it is difficult to propose a limit for toxic concentrations of metals to plants because there are no completely unambiguous methods for determining the biologically available fraction of metals in soil (Pahlsson 1989). Also, the toxicity of metals to biota under natural conditions cannot be accurately predicted from laboratory tests because many environmental variables affect both the metal and the organism with regard to metal availability, degree of biouptake, and resulting toxicological effects.

Polycyclic aromatic hydrocarbons constitute a diverse class of compounds that are formed during the incomplete burning of organic substances such as coal, oil, and gas. The PAHs tend to be elevated in nonbiological materials within urban industrial areas (Eisler 1987). The compounds are found in the air attached to dust particles and are emitted from vehicle exhausts, asphalt roads, and furnaces burning wood or coal. Most of the PAHs released to the atmosphere eventually reach the soil by direct deposition or deposition on vegetation. Terrestrial vegetation and aquatic invertebrates can accumulate significant concentrations of PAHs, whereas fish do not appear to contain highly elevated levels. Wildlife can also assimilate PAHs, but the occurrence of significant concentrations in wildlife is unlikely. The PAHs do not tend to biomagnify through the food chain. In water, PAHs may either evaporate, disperse into the water column, become incorporated into sediment, concentrate in biota, or undergo chemical oxidation and biodegradation (Suess 1976). In view of the carcinogenic characteristics of many PAH compounds, the increasing concentrations of PAHs in the environment should be considered cautiously. Thus, efforts should be taken to reduce or eliminate PAHs whenever possible (Suess 1976).

6.3 SUMMARY

Environmental concentrations of a number of the contaminants of concern at the St. Louis Site (particularly arsenic, lead, nickel, and PAHs) are usually elevated in urban areas. Thus, the specific effect that the St. Louis Site has on ecological resources can probably not be isolated. Rather, contaminants from the site could add to the cumulative impacts to biota that are associated with the St. Louis metropolitan area, although the industrial and commercial urban habitats found in the area have little value to most wildlife species (U.S. Army Corps of Engineers 1987). The levels of several of the contaminants in site soil are near or higher than threshold concentrations for which chronic toxicities or other adverse impacts to biota have been reported to occur; therefore, the toxicity of these contaminants to biota is discussed in Appendix B.

Coldwater Creek has an extremely low biotic diversity. It is dominated by pollution-tolerant invertebrates such as aquatic worms and midge larvae, and it has limited populations of pollution-tolerant fish such as fathead minnows, golden shiners, and black bullheads (Section 3.1.1.2). Few samples from Coldwater Creek have been analyzed for contaminant concentrations. However, initial indications are that metal concentrations are generally an order of magnitude or more below toxic levels (Appendix B). Also, water concentrations (Rains 1981) upstream of the St. Louis Site properties were similar to or higher than concentrations downstream of the site for most contaminants.

Certain elements — such as beryllium, thallium, and uranium — warrant special attention because rare or localized contaminants that are introduced to the general environment (even at low levels) may cause adverse or toxic responses to biota that are not adapted to those contaminants (Peterson and Girling 1981). Potentially adverse impacts could occur to biota in the area if the contaminated site soil is not remediated. Generally, most of the chemical contaminant concentrations are highest at SLDS (Table 2.8). The SLDS contains both the least amount and lowest quality of biotic habitat. On the basis of the contaminant-by-contaminant assessment in Appendix B, the chemical contaminants that pose the most probable risk to biota are arsenic, thallium, and PAHs. However, biota are exposed to the totality of contaminants with a given medium (e.g., soil). Therefore, although the concentrations of most contaminants at the St. Louis Site are not at levels that are individually toxic, they may still contribute to a chronic toxicity to biota because of the cumulative contribution of all the contaminants. The cumulative action of contaminants can be subtractive (i.e., less than additive), but more often are additive or synergistic (e.g., greater than additive). For example, Eaton (1973) found that the chronic effects to fathead minnows from a mixture of copper, cadmium, and zinc were greater than the effects expected from the individual sums of the same concentrations of the three metals. Nevertheless, this is somewhat offset by the fact that organisms have a number of mechanisms to overcome the adverse effects of otherwise toxic metal concentrations: avoidance, exclusion, immobilization, excretion, and biochemical mechanisms (Tyler et al. 1989).

No federal- or state-listed threatened or endangered species occur at the St. Louis Site (Tieger 1989; Figg 1991). Therefore, no adverse impacts to listed species from contaminants at the St. Louis Site are expected. Also, the site area does not contain any ecologically vital groundwaters (Vinikour and Yin 1989). (Ecologically vital groundwaters are those supplying a sensitive ecological system that supports a unique habitat, i.e., those that either are used by federal-listed or proposed endangered or threatened species or are federal land management areas congressionally designated and managed for the purpose of ecological protection.)

Habitats and biota occurring at the St. Louis Site are not (1) unique or unusual; (2) necessary for continued propagation of key species; or (3) valued economically, recreationally, or aesthetically. Thus, 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 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 (Section 5.4.3).

7 SUMMARY

7.1 BACKGROUND

The U.S. Department of Energy, under its Formerly Utilized Sites Remedial Action Program (FUSRAP), is implementing a cleanup program for three groups of properties in and near St. Louis, Missouri (Figure 1.1). These properties, collectively referred to as the St. Louis Site, include (1) the St. Louis Downtown Site (SLDS); (2) the St. Louis Airport Site (SLAPS); and (3) the Latty Avenue Properties at 9200 Latty Avenue, which include the Hazelwood Interim Storage Site (HISS) and the adjacent Futura Coatings property. Contamination at the SLDS, SLAPS, and Latty Avenue Properties is the result of uranium processing and waste management activities that took place from the 1940s through the 1970s. A number of industrial, commercial, municipal, and residential properties (referred to as vicinity properties) in the vicinity of these three sites have also been designated as part of the St. Louis Site and are being evaluated for potential cleanup of related contamination under FUSRAP. The SLAPS, Futura Coatings property, and HISS are on the National Priorities List of the U.S. Environmental Protection Agency (EPA).

The responsibilities of the U.S. Department of Energy (DOE) at the St. Louis Site are explicitly defined in the Federal Facility Agreement. These responsibilities are limited to all radioactive and nonradioactive contamination at the SLDS, SLAPS, and Latty Avenue properties and their related vicinity properties that is associated with the original processes conducted at SLDS under the Manhattan Engineer District/Atomic Energy Commission (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 contamination. This baseline risk assessment (BRA) has been prepared to assess the potential impacts to human health and the environment that could result from exposure to hese site contaminants under current and hypothetical future conditions if no cleanup action were taken. This assessment provides a framework for supporting cleanup decisions in the remedial investigation/feasibility study process. Potential impacts to human health and the nvironment under alternative cleanup actions will be developed as part of the feasibility study. For the St. Louis Site, values of the National Environmental Policy Act (NEPA) have been integrated with those of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Under this approach, the BRA provides information for NEPA evaluation of the no-action alternative. The activities and environmental compliance ocuments for the St. Louis Site are developed in coordination with EPA Region VII and the state of Missouri. Public involvement is an important component of the decision-making process for site remediation, and this BRA and other primary documents are issued for public omment.

CHARACTERIZATION OF SITE CONTAMINATION

Contamination at the St. Louis Site originated from the processing of over 45,000 t 50,000 tons) of uranium-containing materials at SLDS between 1942 and 1957. Several operations were performed, including process development, production of various forms uranium compounds and metals, and recovery of uranium metal from residues and scrap. Some domestic ores were processed, but the primary ore processed was African Congo pitchblende. A pitchblende residue fraction containing high levels of radium-226 (commonly referred to as K-65 residue) was separated out and transported to DOE storage facilities in Ohio and New York. The remaining residues from SLDS activities were transported to SLAPS for aboveground storage or, in some cases, burial. These materials included pitchblende raffinate residues, barium sulfate cake, Colorado raffinate residues, and contaminated scrap material.

From 1948 through 1950, and again in 1962, buildings, equipment, and soil were decontaminated at a number of the SLDS facilities to meet cleanup criteria in effect at that time. The wastes generated from these decontamination efforts were also transported to SLAPS for storage. The SLDS property currently includes a number of the original buildings plus other newly constructed buildings. The current owner, Mallinckrodt, Inc., uses part of the facility for the processing or storage of various materials related to the production of commercial chemical products.

In 1966, the wastes at SLAPS were purchased by the Continental Mining and Milling Company and were removed and placed in storage at 9200 Latty Avenue. After most of the wastes had been removed, the buildings at SLAPS were demolished and buried on-site, and the whole area was covered with clean fill material. At 9200 Latty Avenue, all of the wastes transferred from SLAPS were placed in a storage pile on the ground surface. During 1967 to 1970, the wastes stored at Latty Avenue were dried and shipped to Colorado by the Commercial Discount Corporation and Cotter Corporation. The materials currently in the storage piles at HISS originated from a 1979 demolition and excavation activity on the adjoining Futura Coatings property. Additional material at HISS came from remedial action and construction activities on and around the Latty Avenue vicinity properties that took place from 1984 through 1986.

Most of the contamination at properties in the vicinity of SLDS, SLAPS, and 9200 Latty Avenue is probably related to the inadvertent dispersion of contaminated materials from these sites. Such dispersion could have resulted from the movement of materials during area construction activities; from windblown dust; from runoff into drains and surface water, including Coldwater Creek; and from spillage or fugitive dust emissions during transport of the wastes on haul roads between the sites.

Radionuclides considered for evaluation at the St. Louis Site included those in the uranium-238, thorium-232, and uranium-235 (actinium) radioactive decay series. Uranium-238 is a significant component of natural uranium-containing materials, thorium-232 is often a coincidental component of uranium ores, and uranium-235 decay series nuclides could also represent important sources of contamination.

Inorganic anions and metals were evaluated as potential sources of contamination because inorganic acids (nitric, hydrofluoric, and sulfuric) were among the chemicals used in the processing activities and metals typically occur in natural uranium ores. In addition to ranium, pitchblende ores generally contain arsenic, lead, manganese, and thorium; and domestic ores may be enriched in arsenic, cobalt, copper, molybdenum, nickel, selenium, vanadium, and zinc.

7.2.1 Radioactive Contamination

The characterization of radioactive soil contamination at the St. Louis Site initially involved walkover surveys and near-surface gamma scans at all locations to identify the horizontal extent of elevated radionuclide concentrations. These surveys were followed by extensive collection of surface and borehole soil samples, and these samples were analyzed primarily for uranium-238, radium-226, thorium-230, and thorium-232. The results of this characterization (summarized in Table 2.3) indicated widespread radioactive contamination of soil at SLDS. Considerable radioactive contamination was also detected at SLAPS, Futura Coatings, and HISS. Of the vicinity properties, soil samples from the haul roads and from the ditches adjacent to SLAPS had the highest concentrations, but these levels were typically less than those at SLAPS, Futura Coatings, and HISS. Other residential, commercial, and industrial properties in the vicinity of the haul roads and storage sites had concentrations approximately one order of magnitude lower than the levels detected at SLAPS, Futura Coatings, and HISS. To supplement the characterization data for uranium-238, radium-226, thorium-230, and thorium-232 concentrations in soil samples, a source term analysis was nducted for the various radionuclides in the uranium-238, uranium-235, and thorium-235 ecay series.

Groundwater was sampled and analyzed for possible radioactive contamination at SLDS, SLAPS, and HISS. Elevated levels of uranium were detected at each of these sites.

Building air inside several buildings at SLDS was also monitored for radon and exposure gamma rates; radon levels measured in 2 of 17 buildings exceeded the DOE guideline of 3 pCi/L, and gamma exposure rates obtained from 11 of 20 buildings were elevated over the background level of 10 µR/h. Radon levels were also measured in two trailers at the HISS property and in a building at the Futura Coatings property.

The radioactive contamination in 20 buildings at SLDS was characterized with spot-surveys for direct radiation and collection of removable (swipe) samples for analysis of uranium-238, radium-226, thorium-230, and thorium-232 activity levels. Although some of the buildings had beta-gamma levels exceeding DOE guidelines, the average levels were below the guidelines; little removable contamination was found. Contamination was detected on the roofs of four SLDS buildings. Also at SLDS, 35 of 50 manhole sludge or sidewall samples collected had residual radioactivity concentrations exceeding DOE uranium guidelines for surface soil.

Surface water samples collected from Coldwater Creek have not had elevated levels of radionuclides. However, slightly elevated levels of radionuclides have been detected in sediment samples from some isolated areas of Coldwater Creek and in sediment samples from the Mississippi River adjacent to SLDS.

The concentrations of radionuclides detected in the various media at the St. Lo[illegible] Site are summarized in Tables 2.3 through 2.7. The sampling and analytical methods us[illegible] throughout the characterization efforts at the site have followed quality assurance procedures established by DOE and others (Section 2.2.3.4).

7.2.2 Chemical Contamination

In addition to radioactive contamination related to uranium processing at SLDS, DOE is also responsible for any chemical (nonradioactive) contamination that is commingled with the radioactive contamination. In view of this cleanup responsibility and other related objectives (e.g., identification of potential health hazards to the members of the public or workers performing cleanup actions), surveys for possible chemical contamination were performed at HISS, SLAPS, and various other properties considered to be representative of those comprising the St. Louis Site.

Soil samples were collected from SLDS, SLAPS, the ballfield area near SLAPS, Futura Coatings, and HISS; these samples were analyzed for metals, anions, and organic compounds. Chemical analyses were also performed on groundwater samples from SLDS, SLAPS, and HISS. A limited number of sediment samples from Coldwater Creek were analyzed for chemical constituents. The methods utilized for laboratory analyses of soil, sediment, and water samples are based on procedures approved by the EPA for use in the Superfund and Resource Conservation and Recovery Act programs. From records of know[illegible] activities related to uranium processing at the various St. Louis Site properties, surveys at the primary processing, handling, and storage sites are expected to provide indications of maximum chemical contamination related to the processing. The general locations of the chemical surveys are also consistent with the confirmed locations of maximum radioactive contamination. The concentrations of chemical contaminants detected in samples from the various media at St. Louis Site are summarized in Tables 2.8 through 2.12.

7.2.3 Contaminants of Concern

The contaminants of concern for the St. Louis Site were determined on the basis of historical records of site operations and available characterization and environmental monitoring data. An evaluation procedure recommended in EPA guidance was applied to the St. Louis Site data to determine the final list of radionuclides and chemicals of concern. This procedure (described in Section 2.5) screened all detected contaminants on the basis of parameters such as analytical methods used, comparison with background concentrations, relative toxicity, and role as essential nutrients.

The contaminants of concern that were identified from the various media evaluated for the human health assessment are listed in Table 7.1. Included are radionuclides in the uranium-238, thorium-232, and uranium-235 decay series; inorganic chemicals (19 metals and 2 inorganic anions); and a number of organic compounds. The organic compounds detected

TABLE 7.1 Contaminants of Concern for the Human Health Assessment[a]

Radionuclides	Metals	Inorganic Anions	Organic Compounds
Actinium-227+D	Antimony	Fluoride	Benzene
Lead-210+D	Arsenic	Nitrate	Bis(2-ethylhexyl)phthalate
Protactinium-231	Barium		Chlorobenzene
Radium-226+D	Beryllium		4,4′-DDT
Radium-228+D	Boron		1,2-Dichlorobenzene
Radon-222	Cadmium		1,2-Dichloroethene
Thorium-228+D	Chromium		1,2-Dichloropropane
Thorium-230	Cobalt		Endosulfan
Thorium-232	Copper		PAHs[b]
Uranium-234	Lead		PCBs
Uranium-235+D	Manganese		Toluene
Uranium-238+D	Molybdenum		Trichloroethene
	Nickel		Vinyl chloride
	Selenium		
	Silver		
	Thallium		
	Uranium		
	Vanadium		
	Zinc		

[a] Contaminants listed include those identified in the following media: soil, sediment, and groundwater.

[b] Only the carcinogenic PAHs at the site were determined to be contaminants of concern. These are benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

re commonly found in many industrial areas, and it is not likely that these organics are elated to the processing activities conducted at SLDS. The radioactive contaminants of concern have been identified in soil, groundwater, sediment or sludge, and structural urfaces. The chemical contaminants have been identified in soil, sediment, and roundwater.

.3 EXPOSURE ASSESSMENT

.3.1 Contaminant Fate and Transport

Potential human exposure pathways were identified on the basis of the presence of omplete pathway, i.e., a source and mechanism of contaminant release, an environmental ansport medium, a point of human contact with the contaminated source or medium, and route of human exposure at that point. The primary sources of contamination at the SLDS area are surface and subsurface soil and contaminated structural surfaces. At SLAPS an HISS (including all associated vicinity properties), the main sources of contamination are surface and subsurface soil and, at HISS, two covered stockpiles of contaminated material currently stored there.

The environmental release mechanisms and transport pathways considered for current conditions were external gamma radiation from radioactively contaminated materials (including soil and structural surfaces), radon gas emanation from radium-contaminated soil, contaminated structural surfaces and groundwater, wind dispersal of fugitive dust generated from contaminated site soil, and uptake of contaminants from sediment by fish. For future scenarios, leaching of soil contaminants to groundwater was also considered.

7.3.2 Potential Receptors and Routes of Exposure

Receptors identified for current and hypothetical future conditions at the St. Louis Site are presented in Table 3.1, and the pathways assessed (i.e., quantified) for each of these receptors are presented in Tables 3.2 and 3.3. The receptors identified for current site use include an employee, a construction worker, and a maintenance worker at SLDS and the SLDS vicinity properties, a recreational user at the city property adjacent to SLDS, a trespasser and a maintenance worker at SLAPS, a construction worker at the ditches adjacent to SLAPS, a recreational user at the ballfield, a child commuter and a resident at the residential vicinity properties, a recreational user at Coldwater Creek, an employee at the Futura Coatings property and all commercial/municipal/transportational vicinity properties, and a trespasser and a maintenance worker at HISS.

The pathways assessed for current scenarios were external gamma irradiation, incidental soil ingestion, inhalation of particulates, and inhalation of radon-222 and its decay products. For current employees at SLDS only, potential exposures from external gamma irradiation and radon inhalation were assessed because SLDS is almost completely covered with buildings and paving. However, ingestion and inhalation of particulates were assessed for the SLDS construction worker because of potential exposures during excavation or renovation activities. No current scenarios included contaminated groundwater as a source because the aquifer is considered to be of naturally low quality and it is not known to be used for any domestic purpose in the vicinity of the St. Louis Site.

The hypothetical future receptors were identified as a future resident at all properties except at Coldwater Creek, where a recreational user was assessed. In addition to the pathways assessed for current receptors, potential risks from the ingestion and inhalation of contaminants in groundwater were also assessed for future residents. A future resident scenario at SLDS, with buildings and paved surfaces removed, was also included even though such a scenario is considered unlikely because of the site's industrial use for over 100 years and its location in downtown St. Louis.

3.3 Exposure Point Concentrations, Doses, and Intakes

In general, exposure point concentrations were derived from site data, i.e., the 95% upper confidence limit of the arithmetic average (UL_{95}) of each contaminant of concern, as recommended by the EPA (Section 3.3). Radiological doses were estimated in terms of the 50-year committed effective dose equivalent and external dose equivalents from gamma exposure. The RESRAD code was used to calculate doses where appropriate. Estimation of chemical intakes for each pathway was based on procedures documented in EPA guidance for human health risk evaluation, with adaptations relevant to St. Louis Site conditions and exposure scenarios. Estimated chemical intakes and radiological doses for the current and future receptor scenarios are presented in Tables 3.6 through 3.27 and 3.29 through 3.34.

7.4 TOXICITY ASSESSMENT

Cancer induction and chemical toxicity are the end points generally used to assess health effects from exposure to site contaminants. Cancer induction is the primary health effect associated with radionuclides at the site, and 12 of the chemical contaminants of concern are classified by the EPA as potential carcinogens. Four of the 12 are classified as Group A carcinogens, for which strong evidence exists for human carcinogenicity. The main chemical contributors to carcinogenic risk are arsenic and — at SLDS, the city property, and Coldwater Creek only — PAHs. A number of toxic effects are also linked with exposure to ncarcinogenic contaminants. Antimony, arsenic, and thallium are among the more significant contaminants of concern relative to noncarcinogenic health effects associated with site soil.

Potential carcinogenic risks from exposure to radiation were estimated by using scientifically accepted dose conversion factors to convert estimated doses (in mrem, or in WLM for radon exposures) to the probability of cancer induction. Potential carcinogenic and noncarcinogenic effects from human exposure to chemicals were quantified according to EPA-recommended slope factors and reference doses, respectively. Noncarcinogenic toxicity is expressed by hazard indexes. A hazard index of greater than 1 may indicate a potential for adverse health effects, whereas a hazard index of less than 1 is considered to indicate otherwise.

7.5 RISK CHARACTERIZATION

Radiological and chemical health effects were evaluated for potential exposures to ontaminants at the St. Louis Site. These effects were presented separately for clarity. Potential carcinogenic risks from both radiological and chemical exposures were assessed in terms of the increased probability that an individual would develop cancer over the course f a lifetime. The EPA has identified a target range of 1×10^{-6} to 1×10^{-4} for the cremental cancer risk to an individual from exposures at NPL sites. For purposes of comparison, about one in three Americans will develop cancer, and it is estimated that 60% of all cancers are fatal. For radiological exposures, the individual lifetime risk of fatal cancer associated with background radiation, including naturally occurring radon, is estimated be approximately 1 × 10^{-2}.

7.5.1 Risk Estimates for Current Site Use

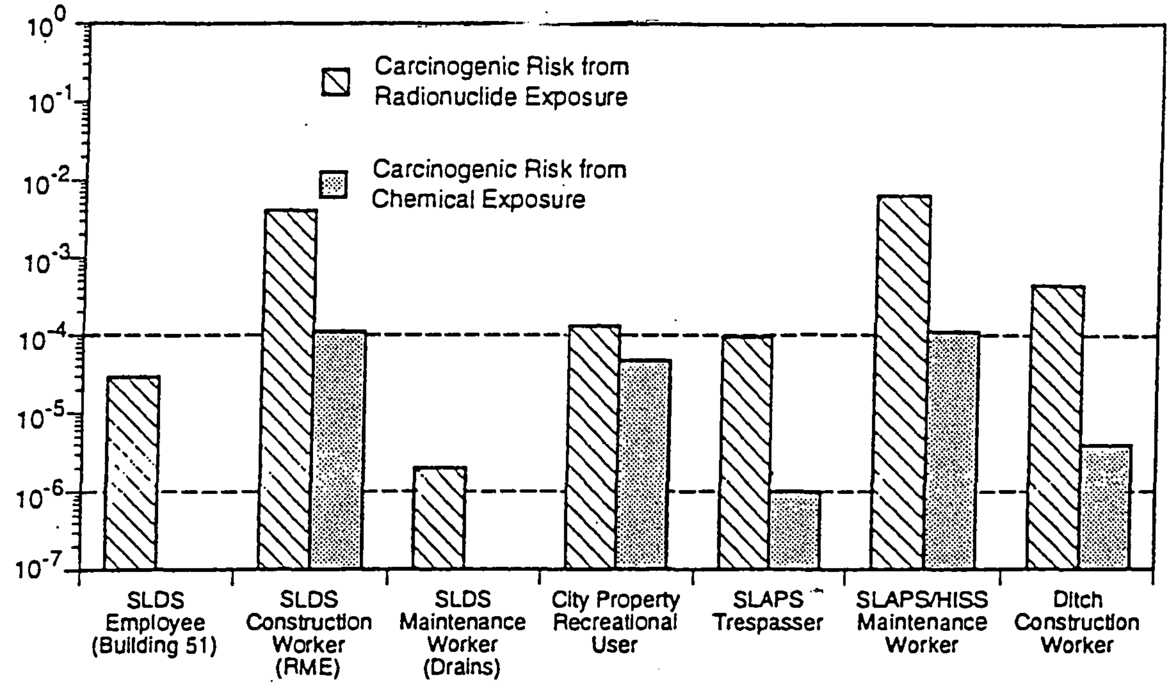
Risk estimates for potential exposures from current site uses are presented in detail in Tables 5.1 through 5.13 and are summarized in Figures 7.1 through 7.3. The overall carcinogenic risk from radiological and chemical exposure in the current scenarios is shown in Figure 7.1. The risk values depicted in Figures 7.1 and 7.2 for the SLDS employee are the risk estimates of the Building 51 receptor for this scenario; these values were selected because full-time occupancy (i.e., about 2,000 hours per year) was evaluated for the receptor at this building, which is considered to conservatively represent the potential risk to this receptor for illustrative purposes (see Tables 3.7 and 5.2 for complete results). The risk values and hazard index depicted for the SLDS construction worker are for the reasonably maximally exposed construction worker described in Section 5.2.1.1; this particular receptor is labeled as the "RME" in Figures 7.1 through 7.3. The estimated radiological risks (including the radon pathway) for current site use by the SLDS maintenance workers, SLAPS trespasser, residential vicinity property child commuter and resident, and ballfield and Coldwater Creek recreational users are within the EPA target risk range of 1 × 10^{-6} to 1 × 10^{-4}. The estimated risk for a recreational user at the city property is slightly above the 1 × 10^{-4} level. The risk estimates for the SLDS employee, SLDS construction worker, SLAPS/HISS maintenance worker, ditch construction worker, Futura Coatings employee commercial vicinity property employee, and HISS trespasser also exceed this level. Where evaluated, the carcinogenic risk from radon and its decay products was a major contributor to the overall risk from radionuclides (Figure 7.2).

The total estimated chemical carcinogenic risk for the combined pathways for each current receptor except the HISS maintenance worker (Figure 7.1) is within the EPA target risk range. The hazard index for current receptors (Figure 7.3) are all less than the reference index of 1 — except for that of the SLAPS/HISS maintenance worker, which is 3.2 (see discussion in previous paragraph regarding hazard index for the SLDS construction worker). The hazard indexes for current receptors are based on the ingestion pathway only because no RfD values were available for the inhalation pathway.

7.5.2 Risk Estimates for Hypothetical Future Site Use

The future scenarios assessed in this BRA were those considered to be conservative depictions of potential means of exposure. The future scenarios are for hypothetical on-site residents, except for Coldwater Creek where a hypothetical recreational user was assumed. The results are presented in detail in Tables 5.14 through 5.29, and are summarized in Figures 7.4 through 7.6.

The overall carcinogenic risk to future receptors from radiological and chemical exposure is illustrated in Figure 7.4. With the conservative assumptions of an on-site



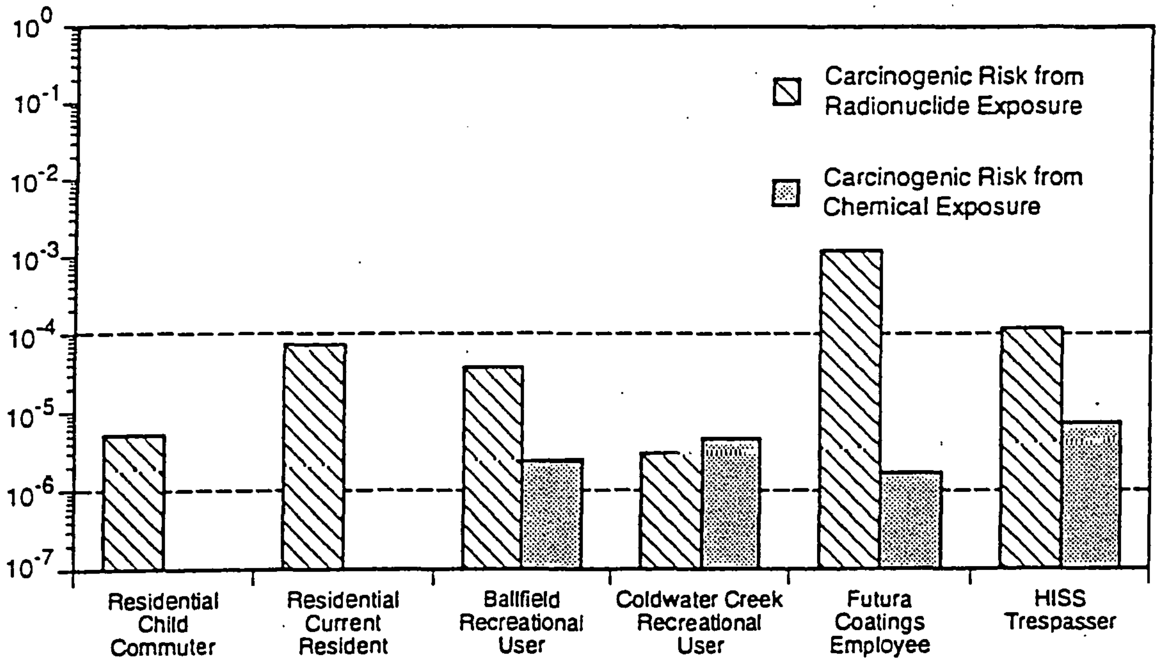


FIGURE 7.1 Total Carcinogenic Risks for Current Receptors from Radiological and Chemical Exposures

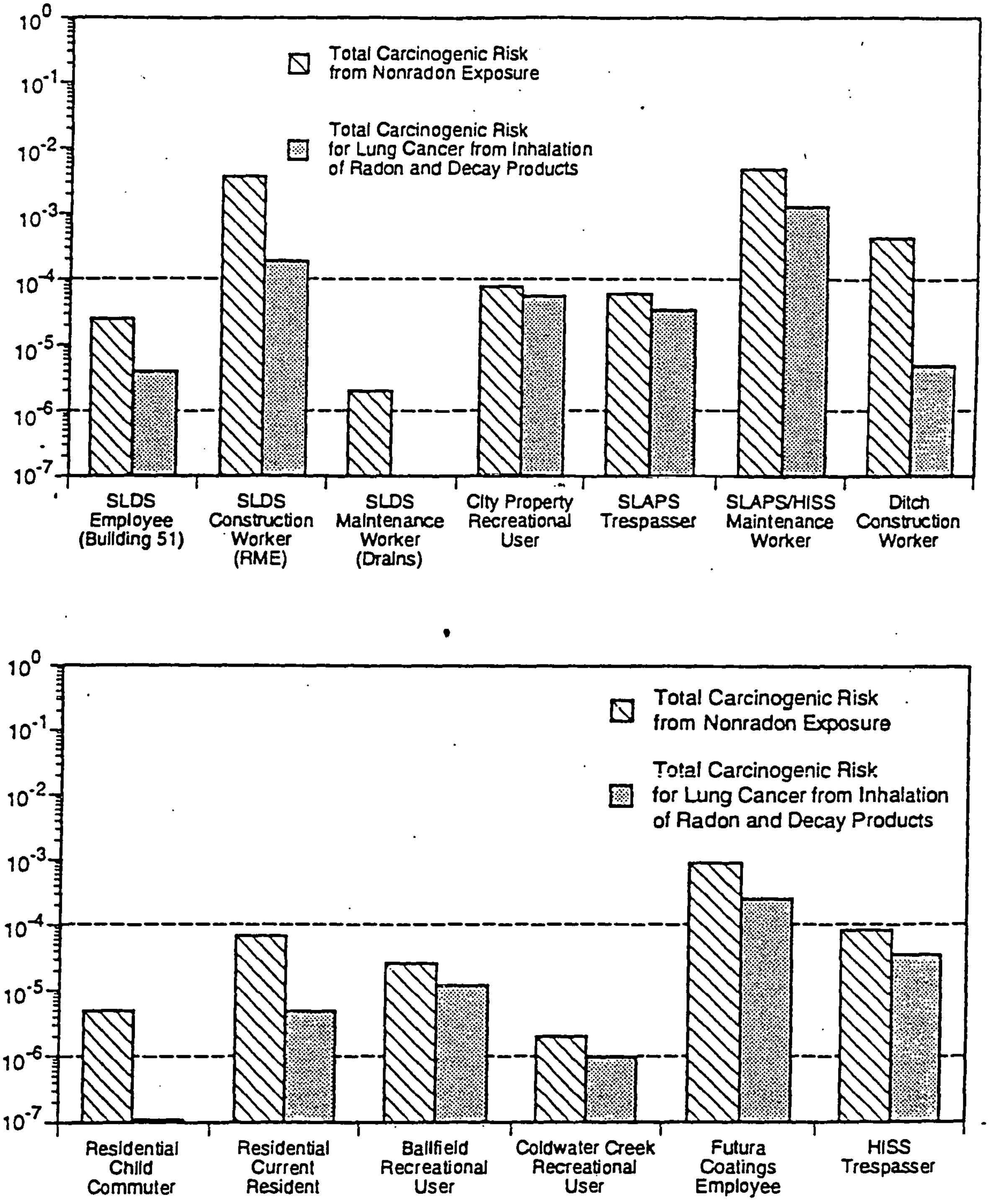


FIGURE 7.2 Total Radiological Carcinogenic Risks for Current Receptors from Radon and Nonradon Exposures

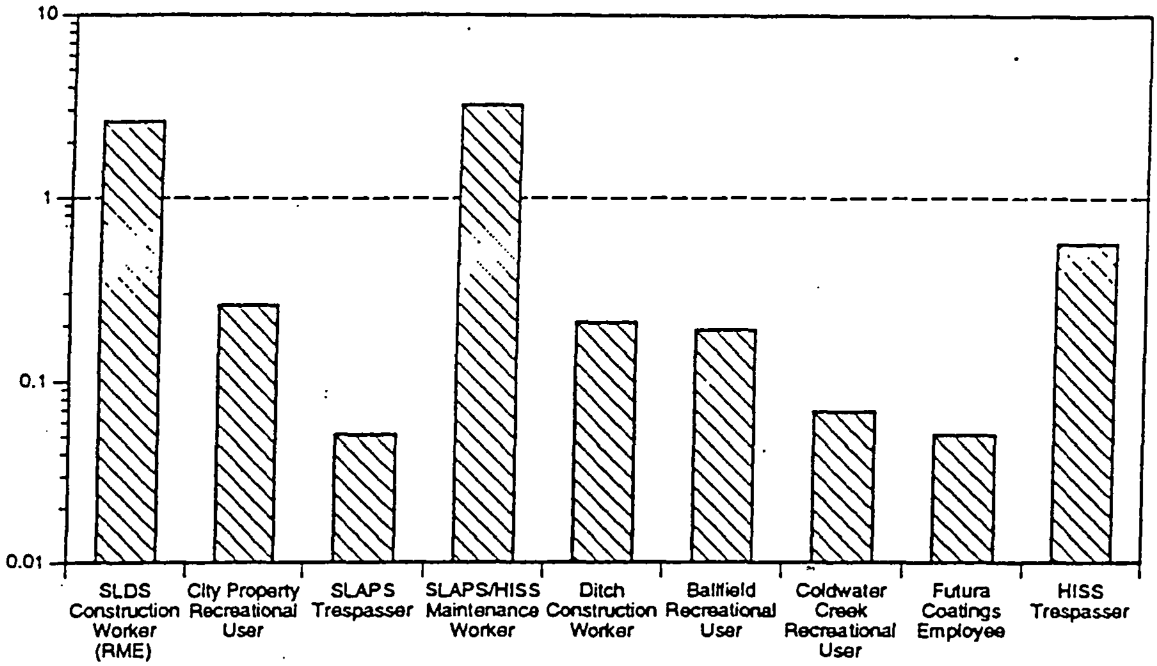


FIGURE 7.3 Hazard Indexes for Current Receptors from the Ingestion of Chemical Contaminants

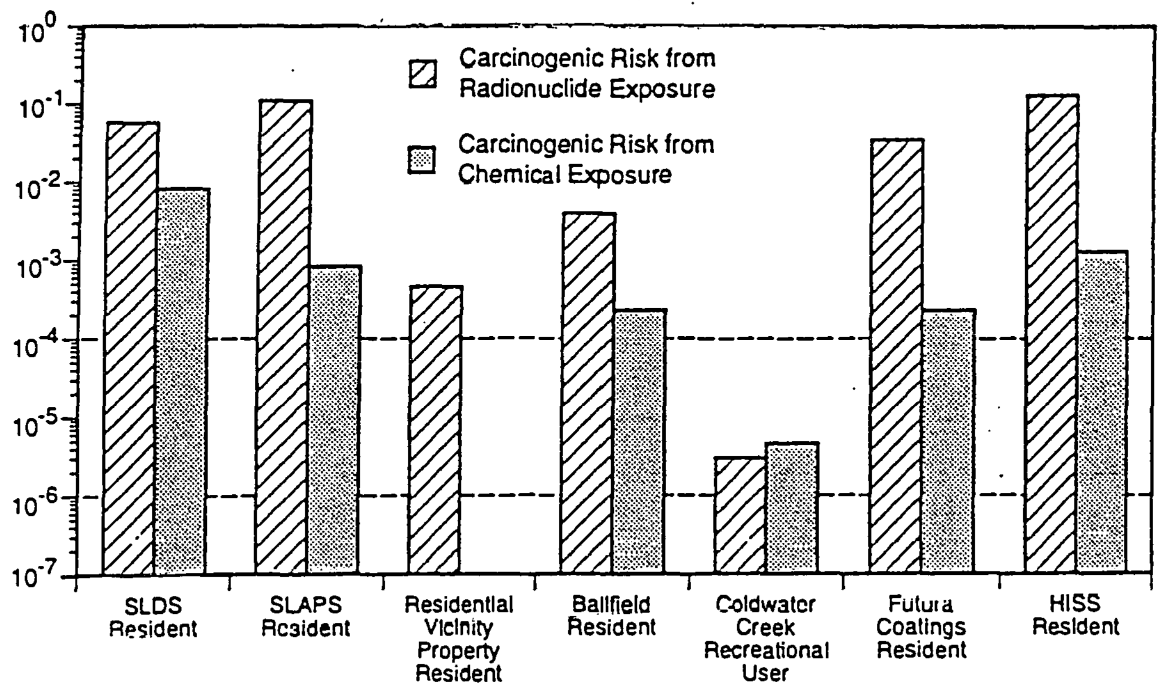


FIGURE 7.4 Total Carcinogenic Risks for Future Receptors from Radiological and Chemical Exposures

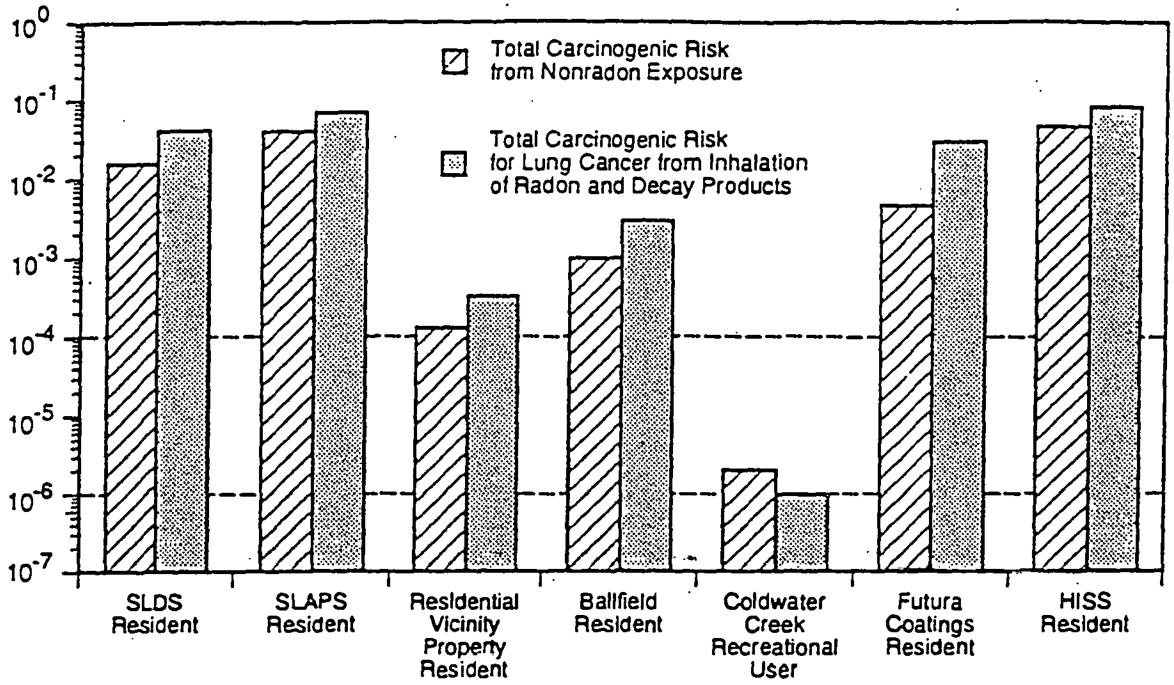


FIGURE 7.5 Total Radiological Carcinogenic Risks for Future Receptors from Radon and Nonradon Exposures

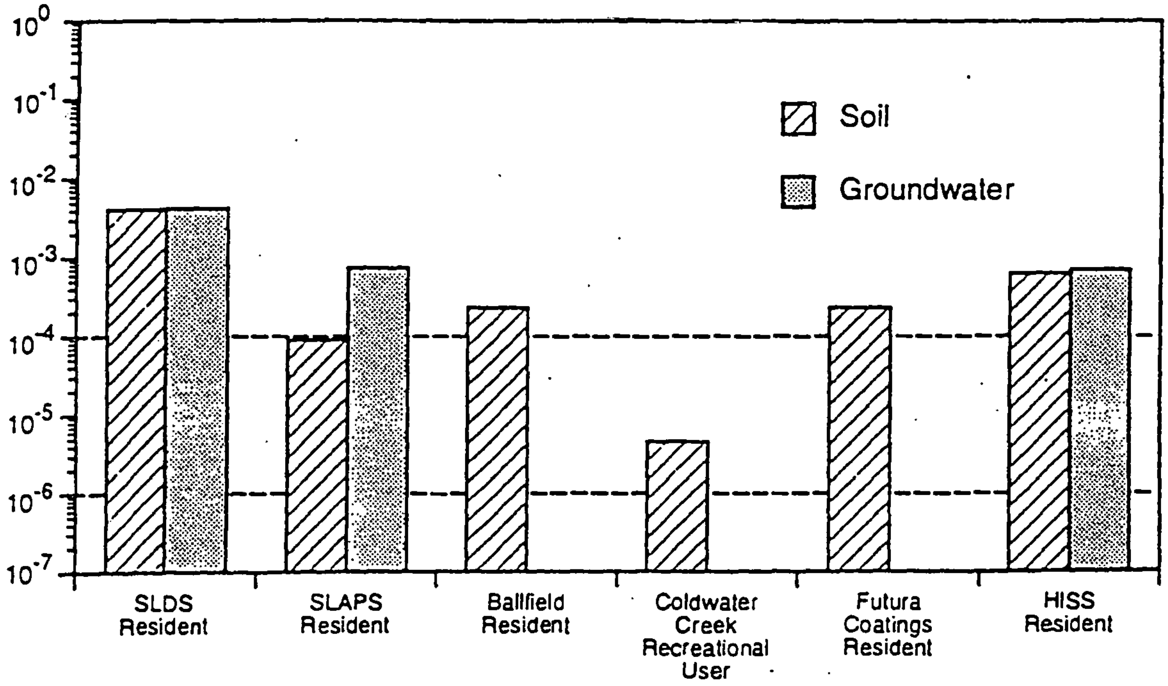


FIGURE 7.6 Total Chemical Carcinogenic Risks for Future Receptors from Alternative Pathways

esident without site cleanup, the estimated risk levels for all sites exceed 1 × 10^{-4}. The uture resident at the HISS property is estimated to incur the highest risk from exposure to radionuclides, primarily due to radionuclide levels in the two storage piles. Inhalation of radon and its decay products is the highest contributor of all radiological pathways assessed for the future resident at all properties, causing approximately half the risk from radionuclide exposure; external gamma irradiation is the highest contributor of the nonradon sources (Figure 7.5).

The future resident at the SLDS area would incur the highest chemical carcinogenic risk, primarily from the ingestion of PAHs present in soil and arsenic present in groundwater (Figure 7.6). The chemical carcinogenic risk for future residents at SLAPS would result primarily from ingestion of groundwater containing arsenic and beryllium, and the risks for future residents at the ballfield area and the Futura Coatings property would result primarily from incidental ingestion of soil containing arsenic. At HISS, the chemical carcinogenic risk is equally attributable to ingestion of arsenic in soil and ingestion of carcinogens — i.e., arsenic, beryllium, and bis(2-ethylhexyl)phthalate — in groundwater.

The estimated hazard indexes for the hypothetical future on-site residents are above the target value of 1 for all sites (Figure 7.7). The future resident at SLAPS is estimated to incur the highest noncarcinogenic chemical risk on the basis of a hazard index of 330; the highest contributor is ingestion of groundwater containing uranium. The future residents at SLDS, the ballfield, Futura Coatings, and HISS are also estimated to incur noncarcinogenic emical risks. The hazard index of 85 at SLDS is related primarily to the ingestion of groundwater containing thallium and arsenic. At the ballfield and Futura Coatings property, the hazard indexes of 5.9 and 2.7 are primarily due to ingestion of soil containing thallium nd arsenic; at HISS, the hazard index of 130 is due to ingestion of groundwater containing thallium and selenium. In addition, risk results for the Coldwater Creek future recreational user would be similar to those of the current recreational user, as discussed in Sections 5.2.1 nd 7.5.1.

.5.3 Uncertainties Related to Risk Estimates

Inherent in each step of the risk assessment process are uncertainties attributable o the numerous assumptions incorporated in the risk estimations. These uncertainties are discussed in detail in Sections 5.3.1 through 5.3.5. A key factor affecting the exact lentification of contaminants of concern for the St. Louis Site is associated with the mitations imposed by the available database, especially the limited data available for groundwater and sediment. In addition, background data are not available to identify the aturally occurring levels of radionuclides and metals and the nature and levels of anthropogenic organic compounds. In this assessment, the maximum values of radionuclides or chemicals detected in groundwater and sediment at the site were used as the exposure point centrations, which could result in overestimation of potential doses and risks. In addition, e contaminants listed in Table 7.1 might include chemicals that contribute to overall site sk but are not necessarily attributable to past uranium-processing activities at the site.

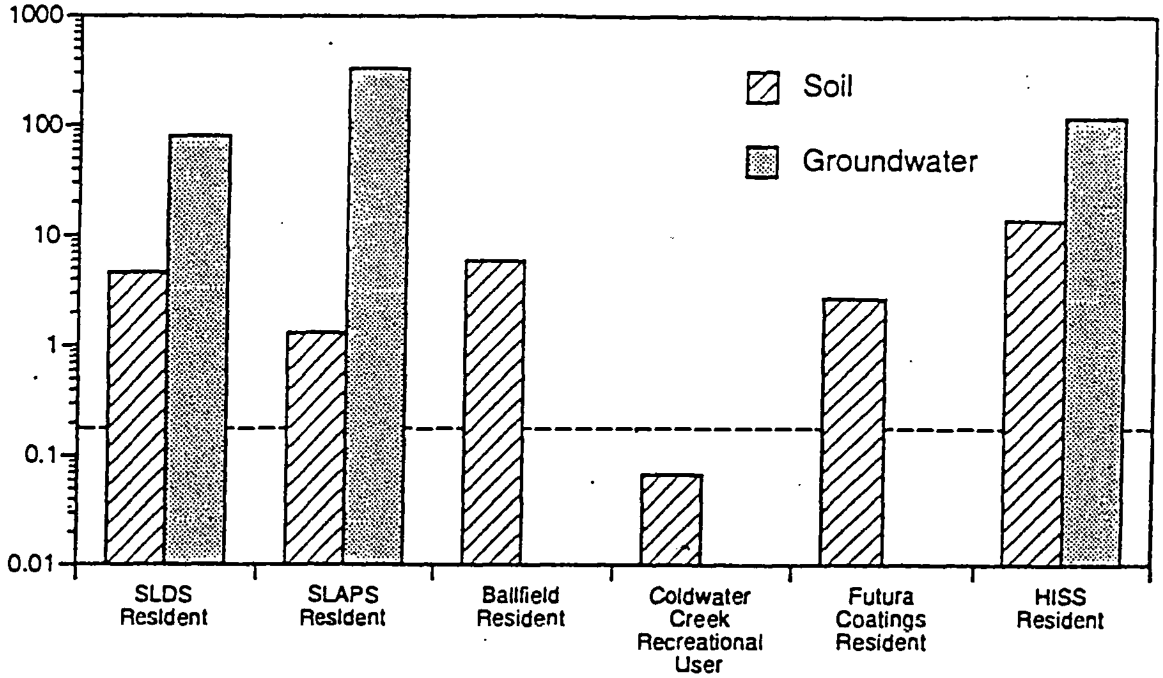


FIGURE 7.7 Hazard Indexes for Future Receptors from Alternative Pathways of Chemical Contaminants

Although realistic exposure scenarios were selected to estimate potential current site risks, hypothetical future site uses were assumed (i.e., future resident scenario) to indicate a reasonably maximally exposed individual. Because the majority of the properties comprising the St. Louis Site will likely remain industrial, risk estimates for residents may be overestimates of potential future risks at these site properties (e.g., SLDS). The conservative approach of deriving exposure point concentrations (e.g., including "less than" values in averaging) would also tend to overestimate risk.

In assessing toxicity, the main contributor to potential underestimation might be the lack of data on the noncarcinogenic toxicity of inhaling low levels of the contaminants of concern. Consequently, complete quantitative noncarcinogenic risk estimates (i.e., hazard indexes) could not be derived for this pathway, although a hazard index was derived for inhalation of contaminants while showering where data were available. Another source of underestimation is related to the lack of an EPA-prescribed approach for estimating noncarcinogenic and carcinogenic risks from lead. In this assessment, the EPA-recommended uptake/biokinetic model was applied to site lead concentrations (Section 5.3.5).

The use of standard dose conversion factors to estimate radiation doses on the basis of adult exposures might tend to underestimate potential risks, particularly if the receptor were a young child. Although two of the postulated current receptors in this assessment are children (residential vicinity property child commuter and ballfield child recreational user), the estimated risks for these receptors indicate that exposure could be increased by at least a factor of two before the resulting risk would exceed the target risk range.

Most of the assumptions used in this BRA tend to overestimate rather than underestimate potential risks. Therefore, actual risks are likely to be lower than those presented in this assessment.

7.6 SUMMARY AND RECOMMENDATIONS

The results of the human health risk assessment indicate that the highest potential health impacts associated with the St. Louis Site result from postulated future exposures at HISS. Under current site conditions and uses and on the basis of the assumptions used for this BRA, the potential health impacts are highest for the HISS maintenance worker. The estimated risks to this worker from exposure to radionuclides at the site exceed the upper end of EPA's target carcinogenic risk range; also, the estimated risk from exposure to chemical contaminants is the highest for any of the receptors (i.e., 1.1×10^{-4}), although it exceeds the target risk range only slightly. However, the actual risk to this receptor would probably be much lower because of health and safety and other precautionary measures already observed by the maintenance workers at this site. The potential exposure of nearby off-site receptors (i.e., outside of HISS) should be minimal, if existent at all, because the site is fenced and monitored by DOE. In addition, results from a conservative trespasser scenario assessed for this site indicated that potential risks would be within the target risk range for chemical exposure and just slightly above the target risk range for radiological exposure. Under hypothetical future site conditions and uses, the potential carcinogenic and noncarcinogenic health impacts to future residents at all site areas assessed exceed the upper end of the target values, i.e., a hazard index of 1 and a carcinogenic risk of 1×10^{-6} to 1×10^{-4}.

Because of the inherent uncertainties in the risk assessment process (as discussed in Section 5.3 and summarized in Section 7.5), the results of the human health assessment presented in this BRA should not be taken to represent absolute risk. Rather, they should be considered to represent the most important sources of potential risk at the site, which — once identified — might be evaluated in more detail and remedied, as appropriate, during the remedial action process.

An ecological assessment was conducted to identify any actual or potential effects on biota from the contamination at the St. Louis Site. The site has both limited habitat and biotic diversity due to urban enchroachment. Therefore, the ecological assessment was based on a comparison of contaminant concentrations detected in soil, sediment, and water in the site area with literature information on the toxicities of the contaminants to biota. Only a few contaminants (i.e., arsenic, thallium, and PAHs) are at concentrations of potential concern to biota. In addition, the potential ecological impacts are not a major concern requiring extensive further field analysis because the habitats and biota occurring at the site are not unique or unusual; not necessary for continued propagation of key species; and not highly valued economically, recreationally, or aesthetically.

8 REFERENCES

Agency for Toxic Substances and Disease Registry, 1990a, *Toxicological Profile for Lead*, prepared by Syracuse Research Corporation for U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency, ATSDR/TP-88/17, June.

Agency for Toxic Substances and Disease Registry, 1990b, *Toxicological Profile for Polycyclic Aromatic Hydrocarbons*, ATSDR/TP-90/20, prepared by Clement International Corporation for U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency, Oct.

Alzona, J., et al., 1979, *Indoor-Outdoor Relationships for Airborne Particulate Matter of Outdoor Origin*, Atmospheric Environment, *13*:55-60.

American National Standards Institute, 1986, *Quality Assurance Program Requirements for Nuclear Facilities*, ANSI/ASME NQA-1-1986 Edition, American Society of Mechanical Engineers, New York.

ANSI: see American National Standards Institute.

Arthur, W.J., et al., 1986, Radiation Dose to Small Mammals Inhabiting a Solid Radioactive Waste Disposal Area, Journal of Applied Ecology, 23:13-26.

ATSDR: see Agency for Toxic Substances and Disease Registry.

echtel National, Inc., 1983, *Radiological Survey of the Ditches at the St. Louis Airport Storage Site*, prepared for U.S. Department of Energy under Contract No. DETAC05-810R20722, Aug.

Bechtel National, Inc., 1985a, *Hazelwood Interim Storage Site Environmental Monitoring Summary, Hazelwood, Missouri, Calendar Year 1984*, DOE/OR/20722-57, prepared for .S. Department of Energy, Oak Ridge Operations, Oak Ridge, Tenn., July.

Bechtel National, Inc., 1985b, *St. Louis Airport Storage Site (SLAPSS) Environmental onitoring Summary, St. Louis, Missouri, Calendar Year 1984*, DOE/OR/20722-59, prepared for U.S. Department of Energy, Oak Ridge Operations, Oak Ridge, Tenn., July.

echtel National, Inc., 1986a, *Hazelwood Interim Storage Site, Annual Site Environmental Report, Hazelwood, Missouri, Calendar Year 1985*, DOE/OR/20722-99, prepared for .S. Department of Energy, Oak Ridge Operations, Oak Ridge, Tenn., April.

Bechtel National, Inc., 1986b, *St. Louis Airport Storage Site (SLAPSS), Annual Site nvironmental Report, St. Louis, Missouri, Calendar Year 1985*, DOE/OR/20722-100, Rev. 1, pared for U.S. Department of Energy, Oak Ridge Operations, Oak Ridge, Tenn., April ev. Sept.).

Bechtel National, Inc., 1987a, *Characterization Report for the Hazelwood Interim Storage S[illegible] Hazelwood, Missouri*, DOE/OR/20722-141, prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn., June.

Bechtel National, Inc., 1987b, *Hazelwood Interim Storage Site, Annual Site Environmental Report, Hazelwood, Missouri, Calendar Year 1986*, DOE/OR/20722-143, prepared for U.S. Department of Energy, Oak Ridge Operations, Oak Ridge, Tenn., June.

Bechtel National, Inc., 1987c, *Radiological and Limited Chemical Characterization Report for the St. Louis Airport Site, St. Louis, Missouri*, DOE/OR/20722-163, prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn., Aug.

Bechtel National, Inc., 1987d, *Radiological Characterization Report for the Futura Coatings Site, Hazelwood, Missouri*, DOE/OR/20722-158, prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn., July.

Bechtel National, Inc., 1987e, *St. Louis Airport Storage Site (SLAPSS), Annual Site Environmental Report, St. Louis, Missouri, Calendar Year 1986*, DOE/OR/20722-145, prepared for U.S. Department of Energy, Oak Ridge Operations, Oak Ridge, Tenn., May.

Bechtel National, Inc., 1988a, *Hazelwood Interim Storage Site, Annual Site Environmental Report, Hazelwood, Missouri, Calendar Year 1987*, DOE/OR/20722-200, prepared for U.S. Department of Energy, Oak Ridge Operations, Oak Ridge, Tenn., April.

Bechtel National, Inc., 1988b, *St. Louis Airport Storage Site (SLAPSS), Annual Site Environmental Report, St. Louis, Missouri, Calendar Year 1987*, DOE/OR/20722-199, prepared for U.S. Department of Energy, Oak Ridge Operations, Oak Ridge, Tenn., April.

Bechtel National, Inc., 1989a, *Hazelwood Interim Storage Site, Annual Site Environmental Report, Hazelwood, Missouri, Calendar Year 1988*, DOE/OR/20722-218, prepared for U.S. Department of Energy, Oak Ridge Operations, Oak Ridge, Tenn., April.

Bechtel National, Inc., 1989b, *Preliminary Geological, Hydrogeological, and Chemical Characterization Report for the Ball Field Area, Hazelwood and Berkeley, Missouri*, DOE/OR/20722-211, prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn., Feb.

Bechtel National, Inc., 1989c, *St. Louis Airport Site, Annual Site Environmental Report, St. Louis, Missouri, Calendar Year 1988*, DOE/OR/20722-220, prepared for U.S. Department of Energy, Oak Ridge Operations, Oak Ridge, Tenn., April.

Bechtel National, Inc., 1990a, *Chemical Characterization Report for the St. Louis Airport Site and Latty Avenue Properties, St. Louis, Missouri*, DOE/OR/20722-206, Revision 1, prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn., July.

echtel National, Inc., 1990b, *Hazelwood Interim Storage Site Environmental Report for lendar Year 1989, Hazelwood, Missouri*, DOE/OR/20722-263, prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn., May.

Bechtel National, Inc., 1990c, *Radiological Characterization Report for FUSRAP Properties in the St. Louis, Missouri, Area*, DOE/OR/20722-203, Rev. 1, prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn., 3 vol., Aug.

Bechtel National, Inc., 1990d, *Radiological, Chemical, and Hydrogeological Characterization Report for the St. Louis Downtown Site in St. Louis, Missouri, Data Tables*, DOE/OR/20722-258, Revision 1, prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn., 3 vol., Sept.

Bechtel National, Inc., 1990e, *St. Louis Airport Site, Environmental Report for Calendar Year 1989, St. Louis, Missouri*, DOE/OR/20722-262, prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn., May.

Bechtel National, Inc., 1991a, *Hazelwood Interim Storage Site, Annual Environmental Report for Calendar Year 1990, Hazelwood, Missouri*, DOE/OR/21949-283, prepared for U.S. Department of Energy, DOE Field Office, Oak Ridge, Tenn., Aug.

Bechtel National, Inc., 1991b, *St. Louis Airport Site, Annual Site Environmental Report, St. Louis, Missouri, Calendar Year 1990*, DOE/OR/21949-288, prepared for U.S. Department Energy, DOE Field Office, Oak Ridge, Tenn.

Bechtel National, Inc., 1991c, personal communication from V. Gilbert (Bechtel National, Inc., Oak Ridge, Tenn.) to H. Hartmann (Argonne National Laboratory, Environmental Assessment and Information Sciences Division, Argonne, Ill.), Dec. 11.

Benham, K.E., 1982, *Soil Survey of St. Louis County and St. Louis City, Missouri*, U.S. Soil Conservation Service in cooperation with Missouri Agriculture Experiment Station.

Beres, D.A., 1990, *The Clean Air Act Assessment Package-1988 (CAP-88) — A Dose and Risk Assessment Methodology for Radionuclide Emissions to Air; Volume 1, User's Manual*, SC&A, Inc., McLean, Va.

BNI: see Bechtel National, Inc.

Bowen, H.J.M., 1966, *Trace Elements in Biochemistry*, Academic Press Inc., New York.

Byard, J.L., 1989, *Hazard Assessment of 1,1,1-Trichloroethene*, in The Risk Assessment of Environmental and Human Health Hazards: A Textbook of Case Studies, D.J. Paustenbach (ed.), John Wiley & Sons, New York.

ien, L., et al., 1968, *Infantile Gastroenteritis due to Water with High Sulfate Content*, Canadian Medical Association Journal, *99*:102-104.

Cothern, C.R., and W.L. Lappenbusch (editors), 1985, *Radioactivity in Drinking Wat*[illegible] Health Physics, *48*(5).

Cothern, C.R., W.L. Lappenbusch, and J. Michel, 1986, *Drinking-Water Contribution to Natural Background Radiation*, Health Physics, 50:33-47. [As cited in Cothern and Rebers (1990).]

Cothern, C.R., and P.A. Rebers (editors), 1990, *Radon, Radium and Uranium in Drinking Water*, Lewis Publishers, Inc., Chelsea, Mich.

Cristy, M., et al., 1986, *Relative Age-Specific Radiation Dose Commitment Factors for Major Radionuclides Released from Nuclear Fuel Facilities*, NUREG/CR-4628 (ORNL/TM-9890), prepared by Oak Ridge National Laboratory, Health and Safety Research Division, Oak Ridge, Tenn., for U.S. Nuclear Regulatory Commission, Division of Fuel Cycle and Material Safety, Aug.

Cross, F.T., N.H. Harley, and W. Hofmann, 1985, *Health Effects and Risks from* ^{222}Rn *in Drinking Water*, Health Physics, *48*(5):649-670. [As cited in Cothern and Lappenbusch (1985).]

DOE: see U.S. Department of Energy.

Dreesen, D.R., et al., 1982, *Mobility and Bioavailability of Uranium Mill Tailings Contaminants*, Environmental Science and Technology, *16*(10):702-706.

Eaton, J.G., 1973, *Chronic Toxicity of a Copper, Cadmium and Zinc Mixture to the Fathead Minnow (Pimephales promelas* Rafinesque), Water Research, 7:1723-1736.

Eisler, R., 1987, *Polycyclic Aromatic Hydrocarbon Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*, U.S. Fish and Wildlife Service Contaminant Hazard Reviews Report No. 11, Biological Report 85(1.11), May.

EPA: see U.S. Environmental Protection Agency.

Federal Insurance Administration, 1979, *Flood Insurance Rate Map, City of St. Louis*, Independent City Panel 10 of 40, Community Panel No. 290385 0010A, U.S. Department of Housing and Urban Development, July 16.

Figg, D.E., 1991, letter with attached species list from D.E. Figg (Missouri Department of Conservation, Jefferson City, Mo.) to J.R. Powers (MK-Ferguson Company, St. Charles, Mo.), November 26.

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

Gilbert, T.L., et al., 1983, *Pathways Analysis and Radiation Dose Estimates for Radioactive esidues at Formerly Utilized MED/AEC Sites*, ORO-832 (Rev.), prepared by Argonne National Laboratory, Division of Environmental Impact Studies, Argonne, Ill., for U.S. Department of Energy, Oak Ridge Operations, Oak Ridge, Tenn., March (reprinted with corrections: Jan. 1984).

Gilbert, T.L., et al., 1989, *A Manual for Implementing Residual Radioactive Material Guidelines*, ANL/ES-160 (DOE/CH/8901), prepared by Argonne National Laboratory, Energy and Environmental Systems Division, Argonne, Ill., for U.S. Department of Energy, Assistant Secretary for Nuclear Energy, June.

ICRP: see International Commission on Radiological Protection.

International Commission on Radiological Protection, 1975, *Report of the Task Group on Reference Man*, ICRP Publication 23, prepared by a Task Group of Committee 2.

International Commission on Radiological Protection, 1978-1982, *Limits for Intakes of Radionuclides by Workers, A Report of Committee 2 of the International Commission on Radiological Protection*, ICRP Publication 30, Part 1 (and Supplement), Part 2 (and Supplement), Part 3 (and Supplements A and B), and Index, Annals of the ICRP.

International Commission on Radiological Protection, 1981, *Limits for Inhalation of Radon Daughters by Workers* (Adopted March 1981), ICRP Publication 32, Annals of the ICRP, *6*(1).

International Commission on Radiological Protection, 1989, *Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 1* (Adopted April 1989), ICRP Publication 56, Annals of the ICRP, *20*(2).

Johnson, T.R., 1987, *The Amphibians and Reptiles of Missouri*, Missouri Department of Conservation, Jefferson City.

Klaasen, C.D., et al. (editors), 1986, *Casarett and Doull's Toxicology: The Basic Science of Poisons*, 3rd ed., Macmillan Publishing Company, New York.

Knight, M.J., 1983, *Uptake by Plants of Radionuclides from FUSRAP Waste Materials*, NL/EIS-19, prepared by Argonne National Laboratory, Argonne, Ill., for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn., April.

iedle, S.D., 1990, *Input for St. Louis Baseline Risk Assessment Study*, letter from S.D. Liedle (Bechtel National, Inc., Oak Ridge, Tenn.) to M. Picel (Argonne National Laboratory, rgonne, Ill.), May 29.

Longtin, J.P., 1988, *Occurrence of Radon, Radium, and Uranium in Groundwater*, Journal the American Water Works Association, *80*(7):84. [As cited in Cothern and Rebers (1990).]

Kone, T.E., and K.T. Bogen, 1991, *Predicting the Uncertainties in Risk Assessment*, nvironmental Science and Technology, *25*(10):1674.

National Academy of Sciences, 1977, *Drinking Water and Health, Volume 1*, Natio Academy Press, Washington, D.C.

National Council on Radiation Protection and Measurements, 1987, *Exposure of the Population in the United States and Canada from Natural Background Radiation*, NCRP Report No. 94, Bethesda, Md., Dec. 30.

National Council on Radiation Protection and Measurements, 1988, *Measurement of Radon and Radon Daughters in Air*, NCRP Report No. 97, Bethesda, Md., Nov. 15.

National Research Council, 1988, *Health Risks of Radon and Other Internally Deposited Alpha-Emitters, BEIR IV*, National Academy Press, Washington, D.C.

National Research Council, 1990, *Health Effects of Exposure to Low Levels of Ionizing Radiation, BEIR V Report*, Committee on the Biological Effects of Ionizing Radiations, National Academy Press, Washington, D.C.

National Wetlands Inventory, 1989, *Florissant, Missouri, Wetlands Inventory Map*, U.S. Fish and Wildlife Service.

NCRP: see National Council on Radiation Protection and Measurements.

Oak Ridge Associated Universities, 1981, *Radiological Evaluation of Decontamination Debris Located at the Futura Chemical Company Facility, 9200 Latty Avenue, Hazelwood, Missouri*, Oak Ridge, Tenn., Sept. 9.

Oak Ridge National Laboratory, 1979, *Radiological Survey of the St. Louis Airport Storage Site, St. Louis, Missouri*, DOE/EV-0005/16, prepared for U.S. Department of Energy, Oak Ridge, Tenn., Sept.

Oak Ridge National Laboratory, 1981, *Radiological Survey of the Mallinckrodt Chemical Works, St. Louis, Missouri*, DOE/EV-0005/27 (ORNL-5715), Oak Ridge, Tenn., Dec.

Oak Ridge National Laboratory, 1986, *Draft Radiological Survey of Latty Avenue in the Vicinity of the Former Cotter Site, Hazelwood/Berkeley, Missouri (LM001)*, ORNL/TM-10006, prepared for U.S. Department of Energy, Oak Ridge Operations, Oak Ridge, Tenn., Sept.

ORNL: see Oak Ridge National Laboratory.

Pahlsson, A.-M.B., 1989, *Toxicity of Heavy Metals (Zn, Cu, Cd, Pb) to Vascular Plants: A Literature Review*, Water, Air, and Soil Pollution, *47*:287-319.

Pais, G.C., 1989, *Hazelwood & St. Louis Airport Sites, St. Louis, Missouri, Job No. 14501-116*, interoffice memorandum from G.C. Pais to J. Blanke (Bechtel Civil, Inc.), March 30.

rker, M.A., and R. Szlemp, 1987, *Final Fish and Wildlife Coordination Act Report, oldwater Creek Flood Control Project, St. Louis County, Missouri*, Appendix D in U.S. Army Corps of Engineers, Coldwater Creek, Missouri, Feasibility Report and Environmental Impact Statement, St. Louis District, Lower Mississippi Valley Division, St. Louis, May.

Paustenbach, D.J., 1989, *A Comprehensive Methodology for Assessing the Risks to Humans and Wildlife Posed by Contaminated Soils: A Case Study Involving Dioxin*, in D.J. Paustenbach (editor), *The Risk Assessment of Environmental and Human Health Hazards: A Textbook of Case Studies*, John Wiley & Sons, New York, pp. 296-328.

Peterson, P.M., and C.A. Girling, 1981, *Other Trace Metals*, in N.W. Lepp (editor), Effect of Heavy Metal Pollution on Plants: Volume 1, Effects of Trace Metals on Plant Function, Applied Science Publishers, London, pp. 213-278.

Pflieger, W.L., 1975, *The Fishes of Missouri*, Missouri Department of Conservation, Jefferson City.

Picel, M.H., et al. 1991, *Engineering Evaluation/Cost Analysis for the Proposed Decontamination of Properties in the Vicinity of the Hazelwood Interim Storage Site, Hazelwood, Missouri — Environmental Assessment*, DOE/EA-0489, prepared by Argonne National Laboratory, Argonne, Ill., and Bechtel National, Inc., Oak Ridge, Tenn., for U.S. Department of Energy, Oak Ridge Operations, Oak Ridge, Tenn.

ins, B.A., 1981, letter from B.A. Rains (St. Louis Metropolitan Sewer District, St. Louis, Mo.) to A. Gudata (Argonne National Laboratory, Argonne, Ill.), Nov. 12.

Reed, H.L., et al., 1990, *Water Resources Data, Missouri, Water Year 1990*, U.S. Geological Survey Water-Data Report MO-90-1.

Robbins, C.W., B. Bruun, and H.S. Zim, 1983, *A Guide to Field Identification Birds of North America*, Golden Press, New York.

Sandstead, H.H., 1977, *Nutrient Interactions with Toxic Elements*, in Advances in Modern Toxicology: Volume 2, Toxicology of Trace Elements, R.A. Goyer and M.A. Mehlman (editors), Hemisphere Publishing Corporation, Washington, D.C., pp. 241-256.

Schwartz, C.W., and E.R. Schwartz, 1986, *The Wild Mammals of Missouri*, University of Missouri Press, Columbia.

Shacklette, H.T., and J.G. Boerngen, 1984, *Element Concentrations in Soils and Other Surficial Materials of the Coterminous United States*, U.S. Geological Survey Professional Paper 1270.

mon, S.L., and S.A. Ibrahim, 1987, *The Plant/Soil Concentration Ratio for Calcium, dium, Lead, and Polonium: Evidence for Nonlinearity with Reference to Substrate Concentration*, Journal of Environmental Radioactivity, 5:123-142.

Stokinger, H.E., 1981, *The Metals*, in Patty's Industrial Hygiene and Toxicology, 3rd e[illegible] G.D. Clayton and F.E. Clayton (editors), John Wiley and Sons, New York.

Suess, M.J., 1976, *The Environmental Load and Cycle of Polycyclic Aromatic Hydrocarbons*, Science of the Total Environment, *6*:239-250.

Sunderman, F.W., Jr., 1977, *Metal Carcinogenesis*, in Advances in Modern Toxicology: Volume 2, Toxicology of Trace Elements, R.A. Goyer and M.A. Mehlman (editors), Hemisphere Publishing Corporation, Washington, D.C., pp. 257-295.

Tidball, R.R., 1984, *Geochemical Survey of Missouri*, U.S. Geological Survey Professional Paper 954-H.

Tieger, J., 1989, letter from J. Tieger (U.S. Fish and Wildlife Service, Columbia Field Office [ES], Columbia, Mo.) to W. Vinikour (Argonne National Laboratory, Energy and Environmental Systems Division, Argonne, Ill.), April 28.

Trijonis, J., et al., 1980, *Analysis of the St. Louis RAMS Ambient Particulate Data, Final Report*, EPA-450/4-80-006a, Volume I, U.S. Environmental Protection Agency, Office of Air Quality.

Tyler, G., et al., 1989, *Heavy-Metal Ecology of Terrestrial Plants, Microorganisms and Invertebrates, A Review*, Water, Air, and Soil Pollution, *47*:189-215.

United Nations Scientific Committee on the Effects of Atomic Radiation, 1988, *Sources, Effects and Risks of Ionizing Radiation*, United Nations Publication Sales No. E.88.IX.7, Report to the General Assembly, with annexes, United Nations, New York.

U.S. Army Corps of Engineers, 1987, *Coldwater Creek, Missouri, Feasibility Report and Environmental Impact Statement*, St. Louis District, Lower Mississippi Valley Division, St. Louis, May.

U.S. Department of Energy, 1988a, *Internal Dose Conversion Factors for Calculation of Dose to the Public*, DOE/EH-0071, Assistant Secretary for Environment, Safety and Health, Washington, D.C., July.

U.S. Department of Energy, 1988b, *External Dose-Rate Conversion Factors for Calculation of Dose to the Public*, DOE/EH-0070, Assistant Secretary for Environment, Safety and Health, Washington, D.C., July.

U.S. Department of Energy, 1993, *Work Plan-Implementation Plan for the Remedial Investigation/Feasibility Study-Environmental Impact Statement for the St. Louis Site, St. Louis, Missouri*, DOE/OR/21949-271.1, prepared by Bechtel National, Inc., Oak Ridge, Tenn., for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn., Aug.

S. Department of Energy, 1994, *Remedial Investigation Report for the St. Louis Site, t. Louis, Missouri*, DOE/OR/21949-280, prepared by Bechtel National, Inc., Oak Ridge, Tenn., for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn., Feb. (in press).

U.S. Environmental Protection Agency, 1986, *Quality Criteria for Water 1986*, EPA/440/5-86-001; PB87-226759, Office of Water Regulations and Standards, Washington, D.C., May.

U.S. Environmental Protection Agency, 1989a, *Exposure Factors Handbook*, EPA/600/8-89/043, Office of Health and Environmental Assessment, Washington, D.C., July.

U.S. Environmental Protection Agency, 1989b, *National Emission Standards for Hazardous Air Pollutants; Radionuclides (40 CFR Part 61); Final Rule and Notice of Reconsideration*, Federal Register, *54*(240):51654-51715, Dec. 15.

U.S. Department of Energy, 1994, *Remedial Investigation Report for the St. Louis Site, St. Louis, Missouri*, DOE/OR/21949-280, prepared by Bechtel National, Inc., Oak Ridge, Tenn., for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn., Feb. (in press).

U.S. Environmental Protection Agency, 1989c, *Risk Assessment Guidance for Superfund, Volumes I: Human Health Evaluation Manual (Part A, Interim Final)*, EPA/540/1-89/001, epared by Office of Emergency and Remedial Response, Washington, D.C., Dec.

U.S. Environmental Protection Agency, 1989d, *Environmental Evaluation Manual (Part B, Interim Final)*, EPA/540/1-89/002, prepared by Office of Emergency and Remedial Response, Washington, D.C., March.

U.S. Environmental Protection Agency, 1989e, *Risk Assessment Methodology, Environmental mpact Statement, NESHAPS for Radionuclides, Background Information Document*, EPA/520/1-89-005, Volume 1, Washington, D.C., Sept.

U.S. Environmental Protection Agency, 1990a, *Health Effects Assessment Summary Tables, Fourth Quarter, FY - 1990*, OERR 9200 6-303 (90-4); PB90-921104, Office of Emergency and Remedial Response, Washington, D.C., Sept.

U.S. Environmental Protection Agency, 1990b, *National Oil and Hazardous Substances Pollution Contingency Plan; Final Rule (400 CFR Part 300)*, Federal Register, 55(35):6154-6176, Feb. 21.

U.S. Environmental Protection Agency, 1990c, *Guidance for Data Useability in Risk Assessment*, EPA/540/G-90/008, Interim Final, Office of Emergency and Remedial Response, Washington, D.C., Oct.

U.S. Environmental Protection Agency, 1991a, *Health Effects Assessment Summary Tables, Annual, FY - 1991*, OERR 9200.6-303 (91-1); PB91-921199, Office of Emergency and Remedial Response, Washington, D.C., Jan.

U.S. Environmental Protection Agency, 1991b, *Risk Assessment Guidance for Superfun Volume I, Human Health Evaluation Manual, Supplemental Guidance, "Standard Defau Exposure Factors," Interim Final*, OSWER Directive 9285.6-03, Office of Emergency and Remedial Response, Washington, D.C., March 25.

U.S. Environmental Protection Agency, 1991c, *National Primary Drinking Water Regulations; Radionuclides; Proposed Rule (40 CFR Parts 141 and 142)*, Federal Register, *56*(138):33050-33127, July 18.

U.S. Environmental Protection Agency, 1991d, *Risk Assessment Guidance for Superfund, Volume I — Human Health Evaluation Manual (Part B, Development of Risk-Based Remediation Goals*, Publication 9285.7-01B, Office of Emergency and Remedial Response, Washington, D.C., Dec.

U.S. Environmental Protection Agency, 1991e, *Technical Support Document on Lead*, ECAO-CIN-757, Environmental Criteria and Assessment Office, Cincinnati, Ohio, Jan. (First Draft).

U.S. Environmental Protection Agency, 1991f, *Interim Guidance for Dermal Exposure Assessment*, OHEA-E-367, prepared by Office of Health and Environmental Assessment for Office of Emergency and Remedial Response, Washington, D.C., March.

U.S. Environmental Protection Agency, 1992, *Integrated Risk Information System*, Office o Research and Development (database accessed April 1992).

U.S. Public Health Service, 1970, *Radiological Health Handbook*, rev. ed., Bureau of Radiological Health, Rockville, Md., Jan.

Venugopal, B., and T.D. Luckey, 1978, *Metal Toxicity in Mammals*, Vol. 2, Plenum Press, New York.

Vinikour, W.S., and S.C.L. Yin, 1989, *Determination of Ecologically Vital Groundwaters at Selected Sites in the Formerly Utilized Sites Remedial Action Program*, ANL/EES-TM-377, Argonne National Laboratory, Argonne, Ill., Aug.

Williams, J., 1992, facsimile transmittal from J. Williams (Bechtel National, Inc., Oak Ridge, Tenn.) to M. Picel (Argonne National Laboratory, Environmental Assessment and Information Sciences Division, Argonne, Ill.), April 8.

9 LIST OF CONTRIBUTORS

This baseline risk assessment has been prepared by the U.S. Department of Energy with contractual assistance from Argonne National Laboratory. The following Argonne staff members contributed to the preparation of this report.

Name	Education/Expertise	Contribution
I. Hartmann	M.S., Public Health 5 years experience in environmental assessment	Assessment of chemical health risks
M. Nimmagadda	M.S., Health Physics 3 years experience in environmental assessment	Assessment of radiological health risks
J.M. Peterson	M.S., Nuclear Engineering; P.E., C.H.P. 17 years experience in nuclear programs, including 12 years in environmental assessment	Assessment of radiological health risks
M.H. Picel	M.S., Environmental Health Sciences 13 years experience in environmental research, analysis, and assessment	Project leader; assessment of health risks
W.S. Vinikour	M.S., Biology 17 years experience in environmental assessment and research	Assessment of ecological impacts
K.L. Woytowich	B.S., Mathematics and Computer Science 5 years experience in computer modeling and data analysis	Compilation of data
I J. Wyman	M.S., Botany; M.A., Library Science 18 years experience in technical editing	Overall editorial responsibility

APPENDIX A:

FIGURES SHOWING AREAS AND DEPTHS OF CONTAMINATION AT THE ST. LOUIS SITE*

---

* The figures presented in this appendix were provided by Bechtel National, Inc., Oak Ridge, Tennessee, and were reproduced from the best available copies.

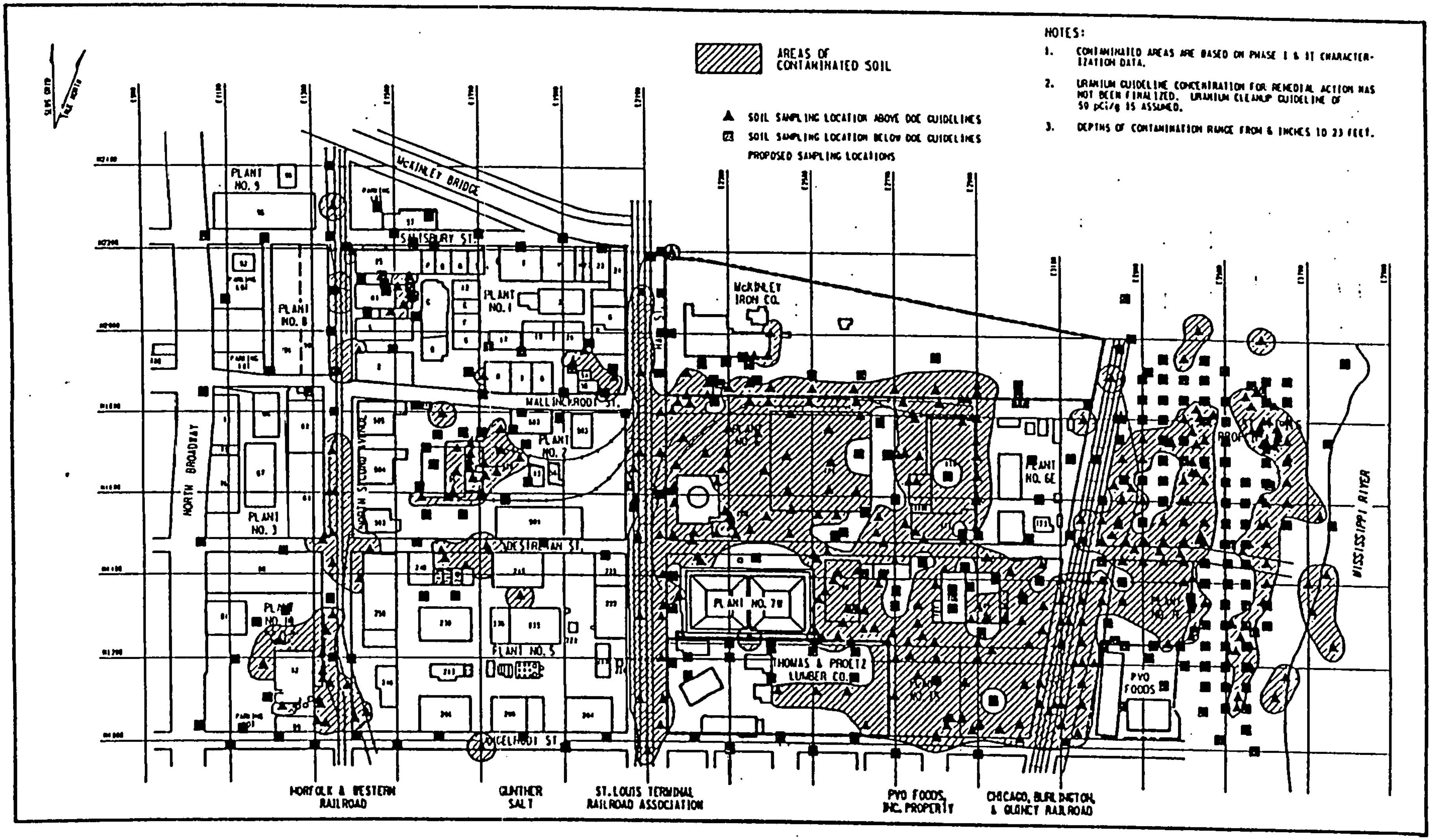


FIGURE A.1 Areas of Radioactive Contamination at SLDS

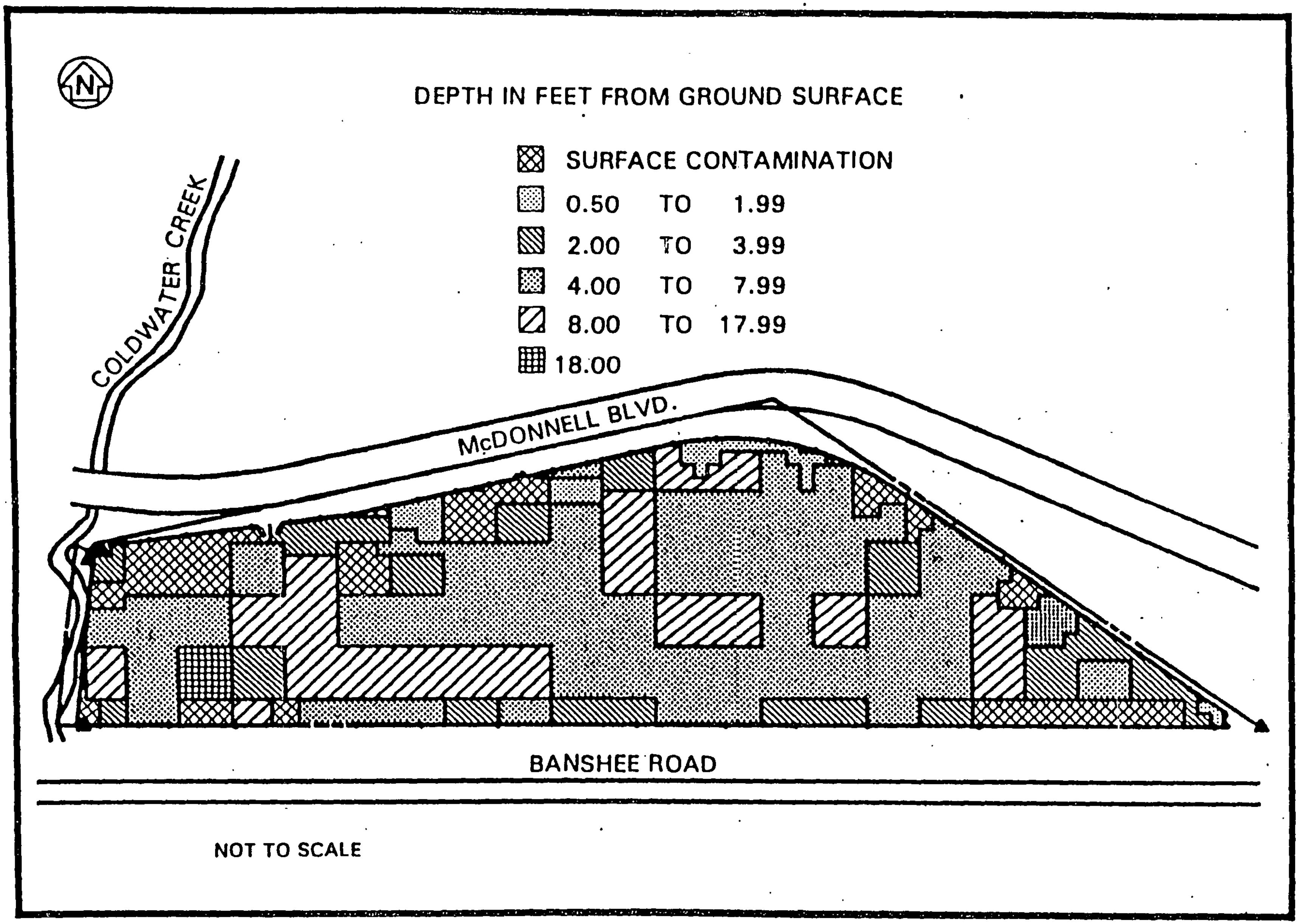


FIGURE A.2 Areas and Depths of Radioactive Contamination at SLAPS

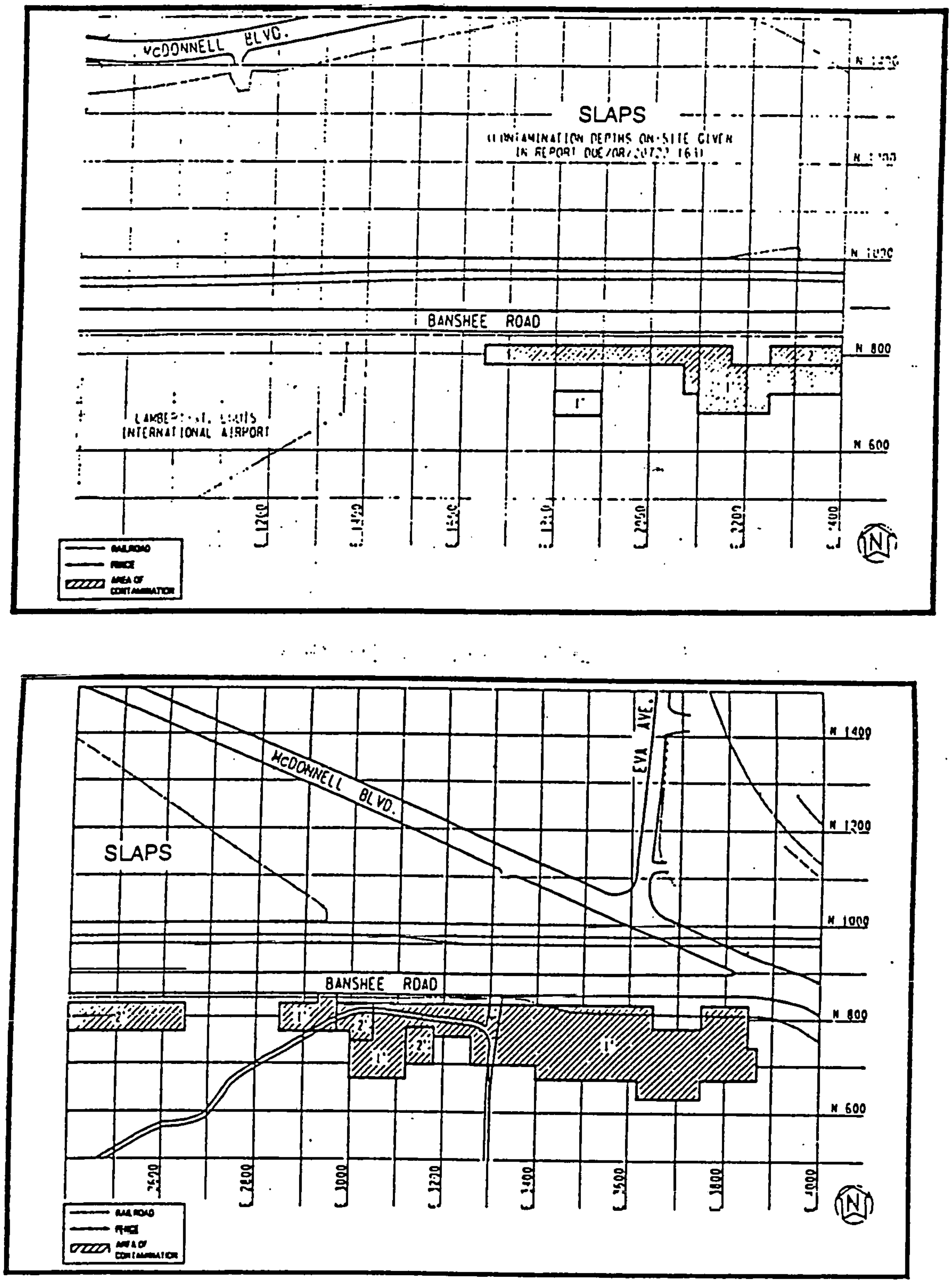


FIGURE A.3 Areas and Depths of Radioactive Contamination at the St. Louis Airport Authority Property

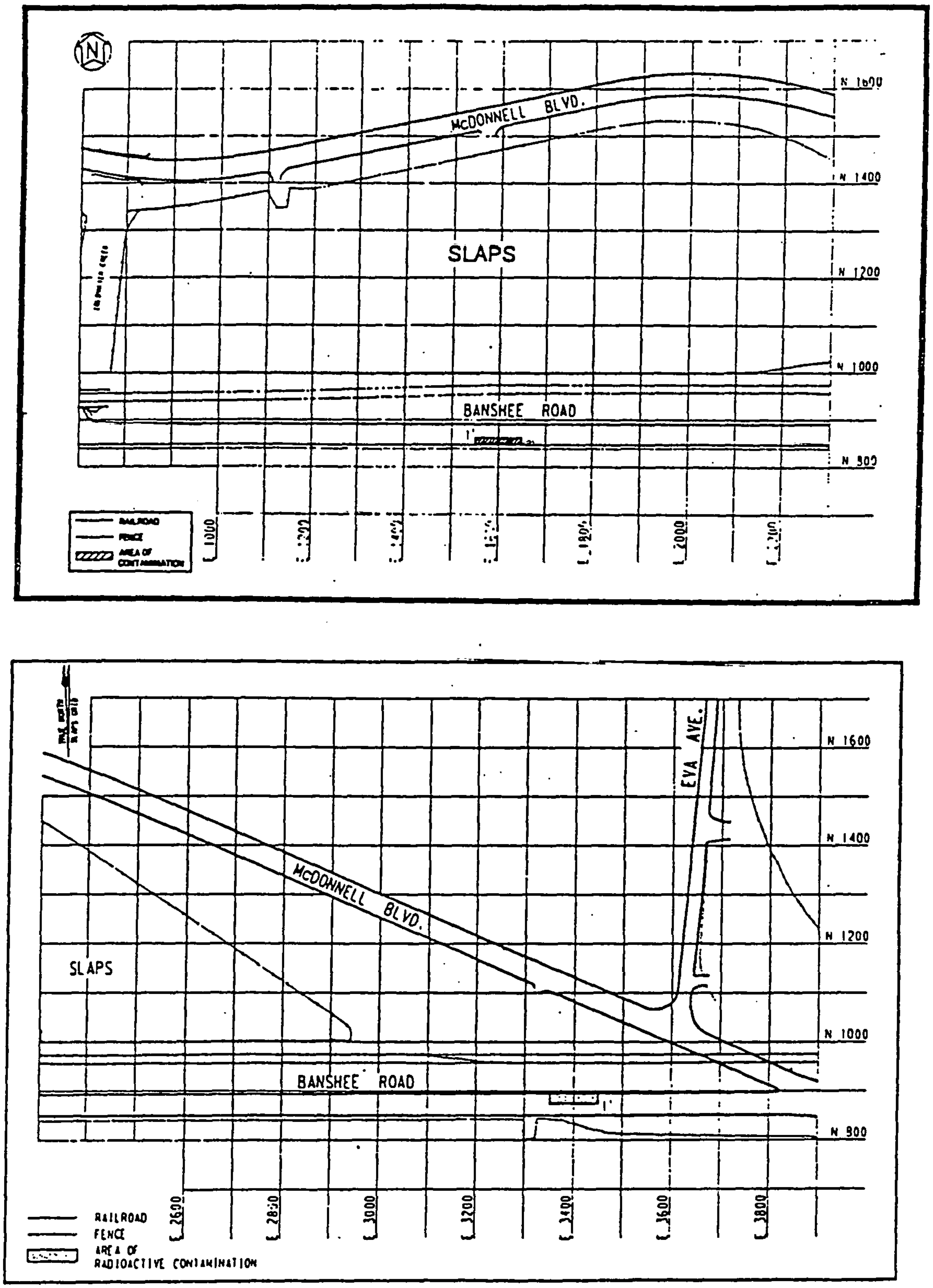


FIGURE A.4 Areas and Depths of Radioactive Contamination at Banshee Road

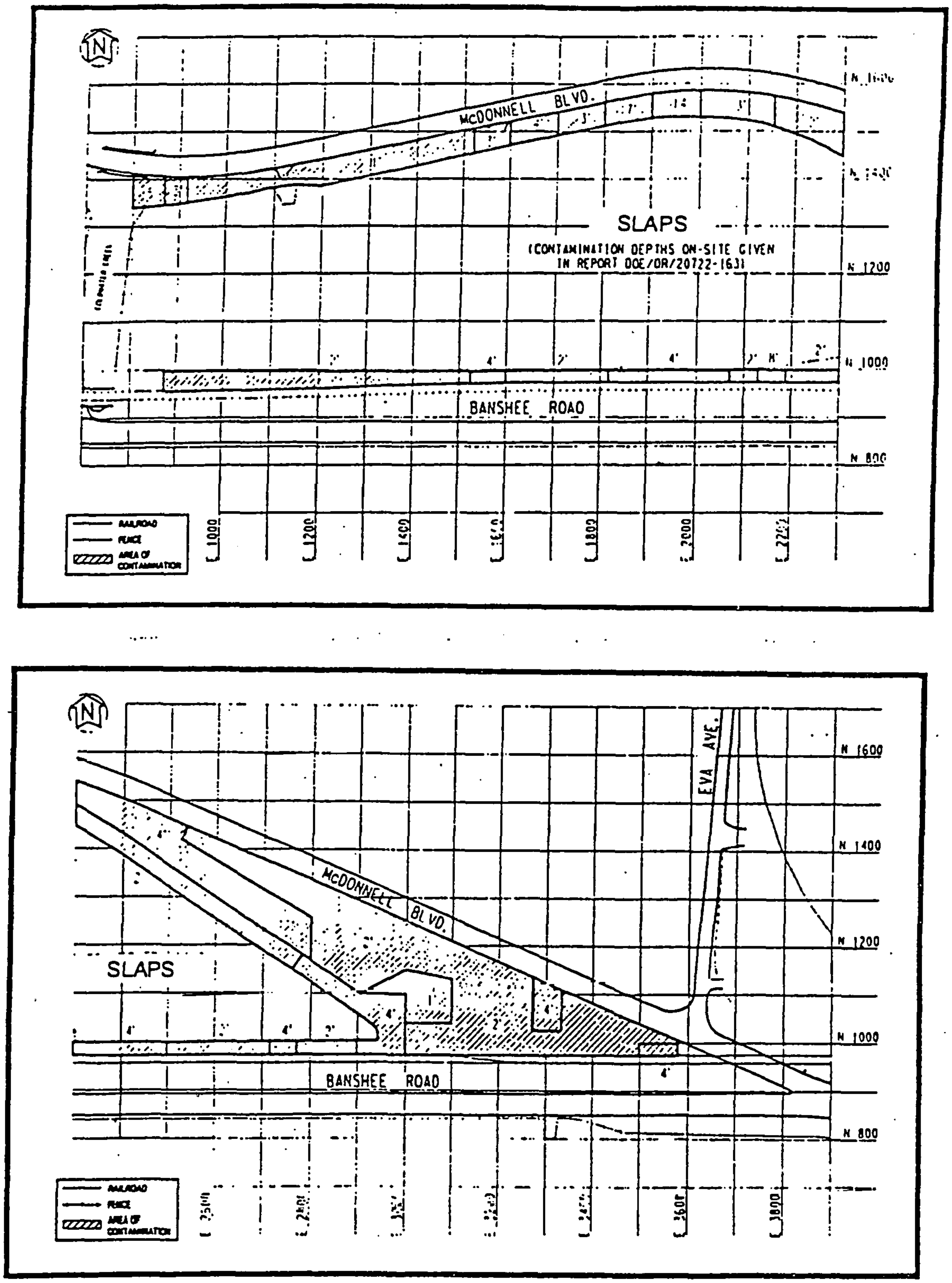


FIGURE A.5 Areas and Depths of Radioactive Contamination at the Ditches to the North and South of SLAPS

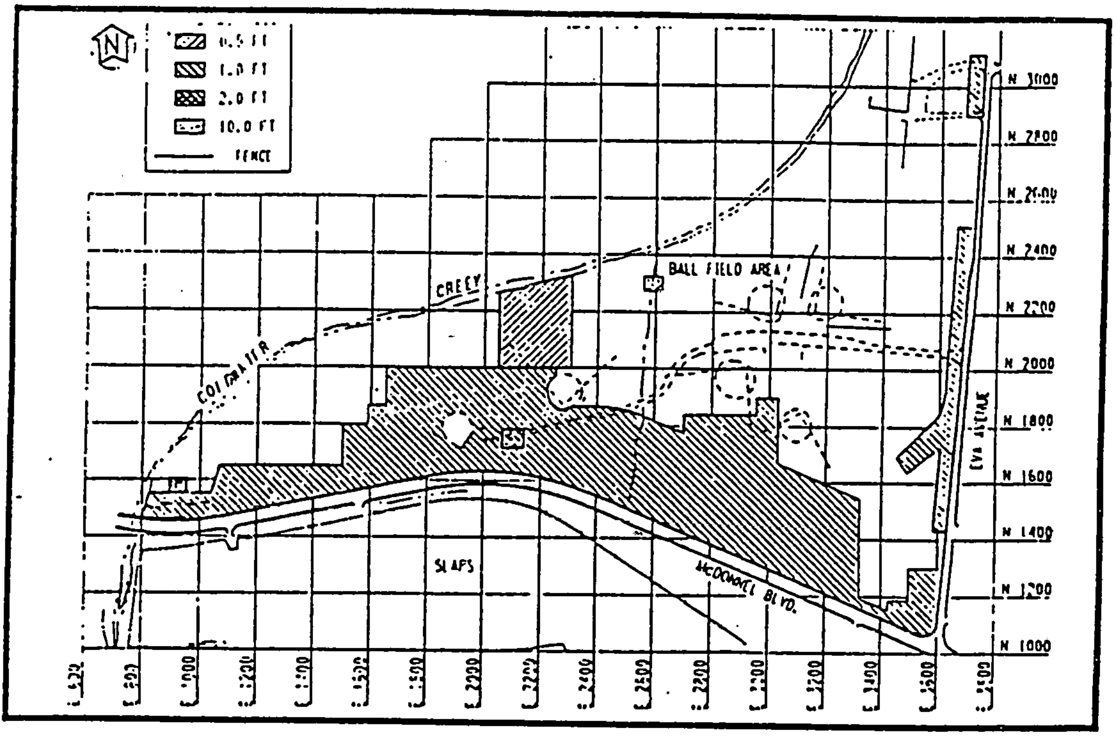


FIGURE A.6 Areas and Depths of Radioactive Contamination at the Ballfield Area

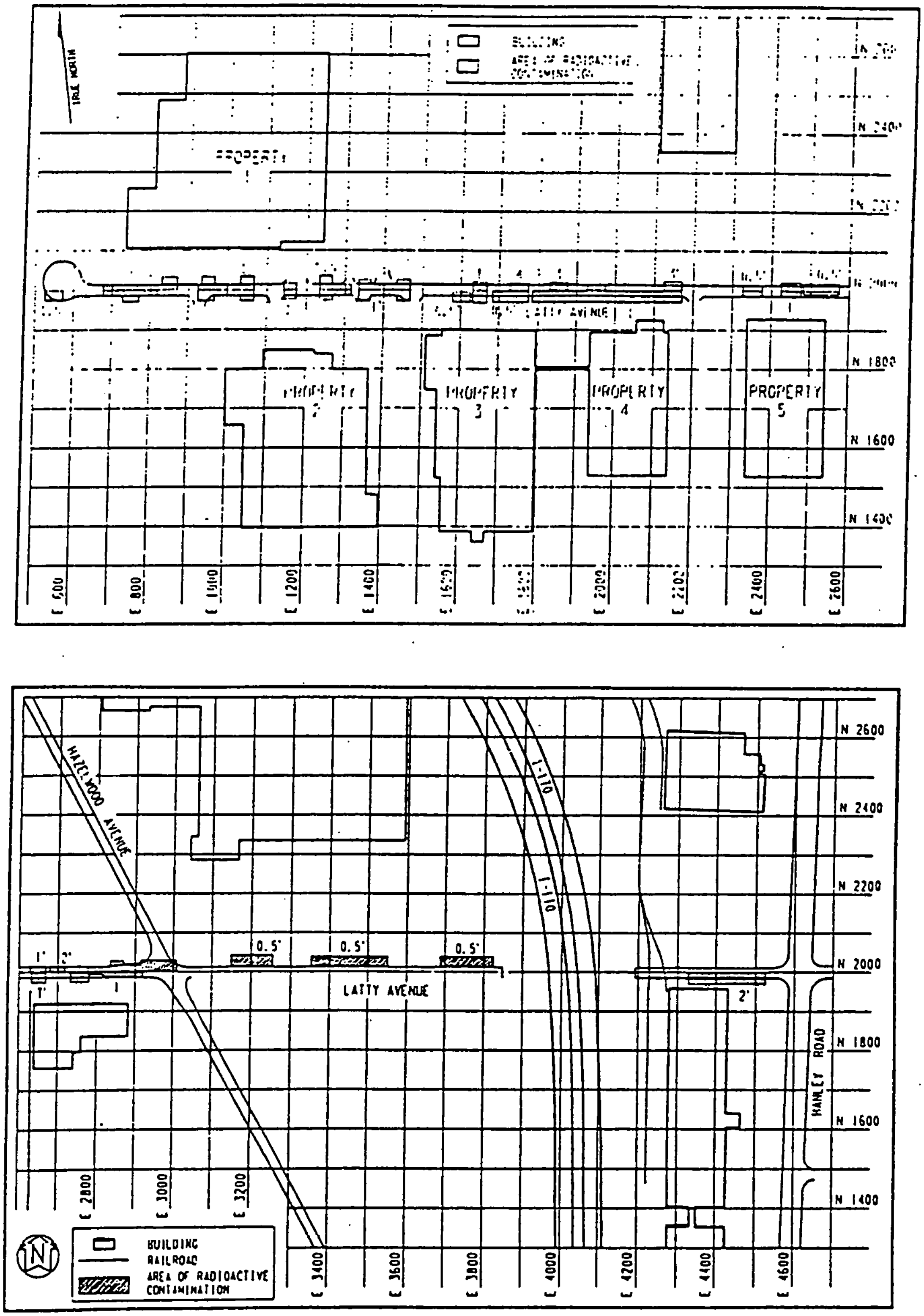


FIGURE A.7 Areas and Depths of Radioactive Contamination at Latty Avenue

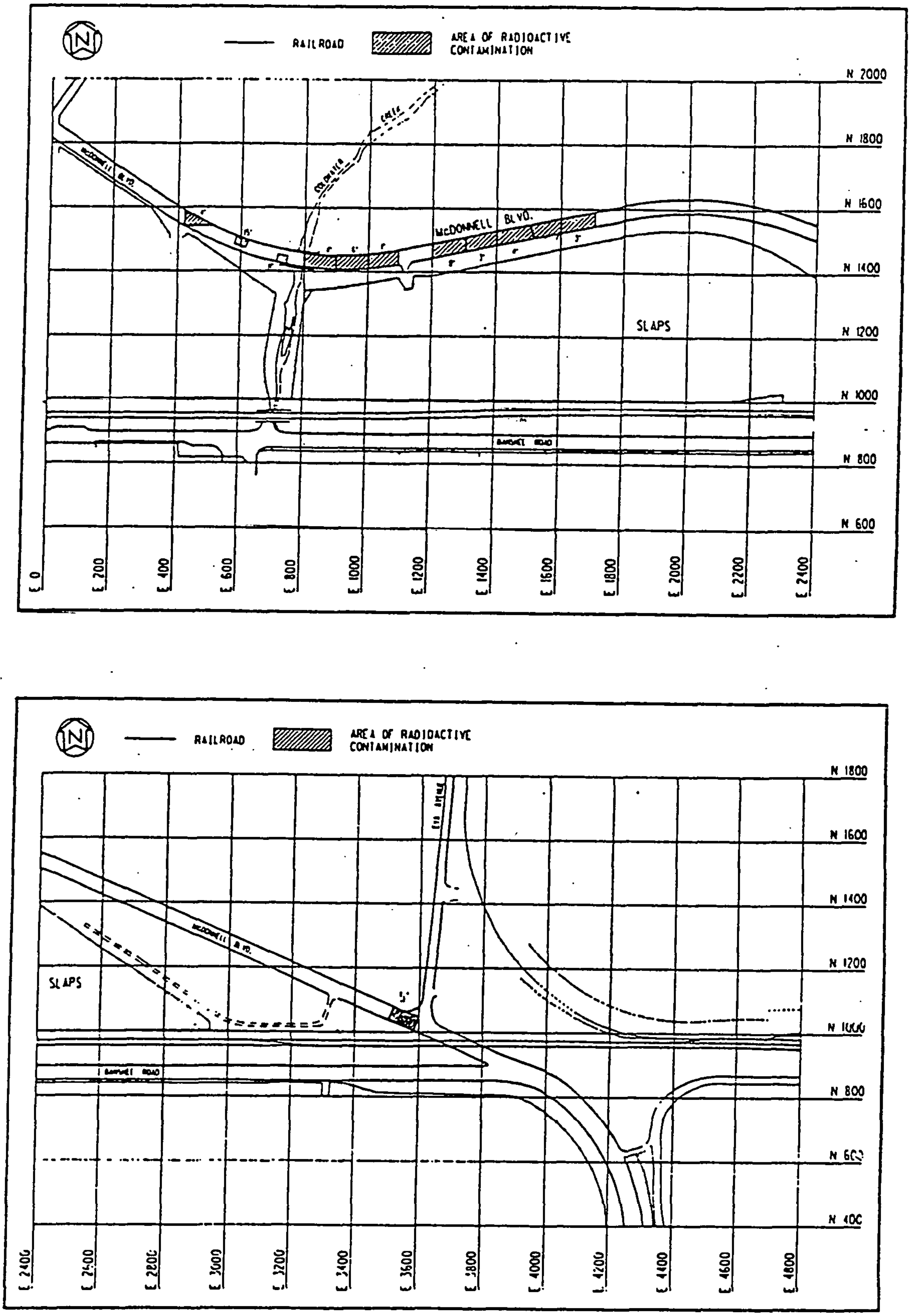


FIGURE A.8 Areas and Depths of Radioactive Contamination at McDonnell Boulevard

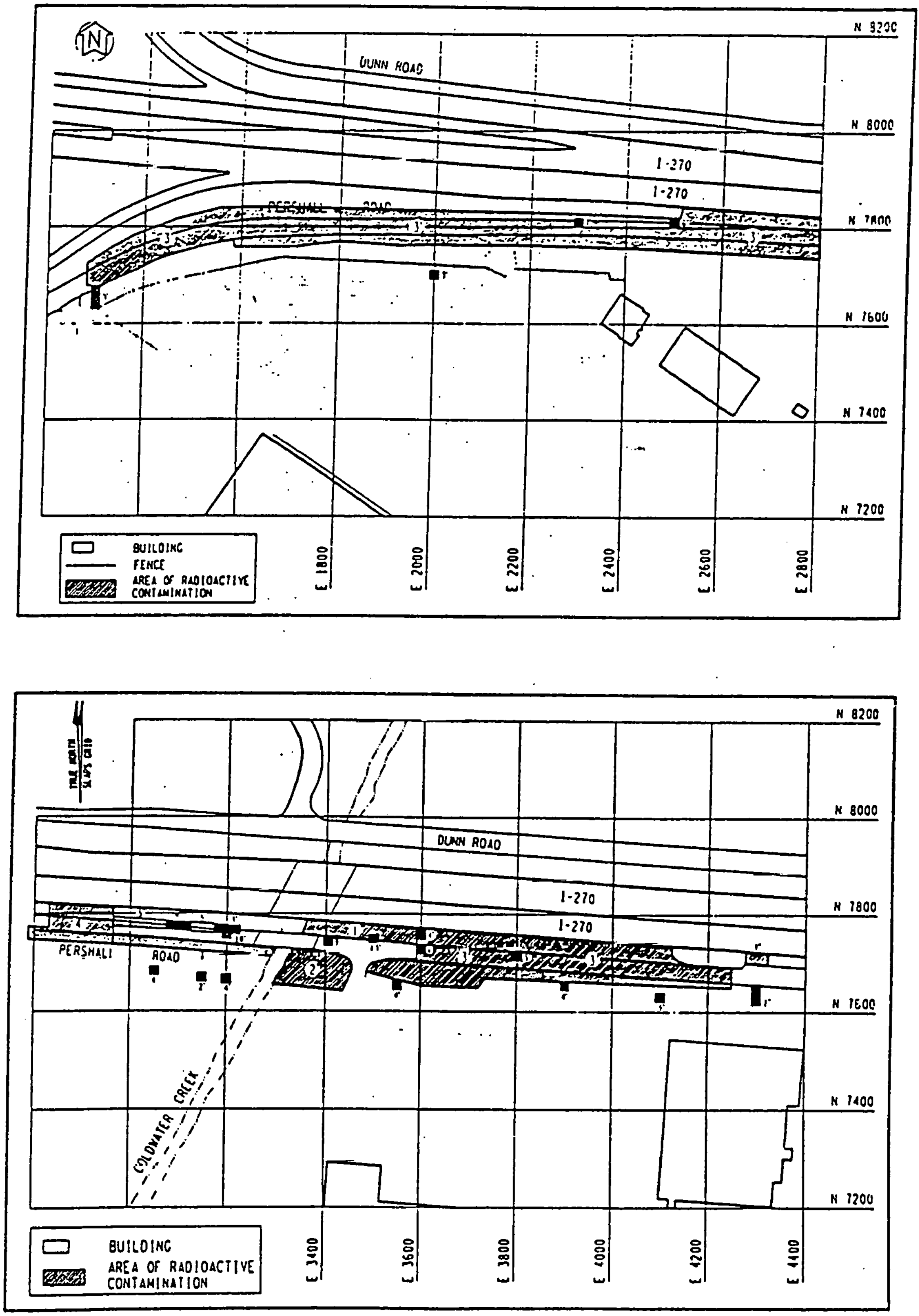


FIGURE A.9 Areas and Depths of Radioactive Contamination along Pershall Road

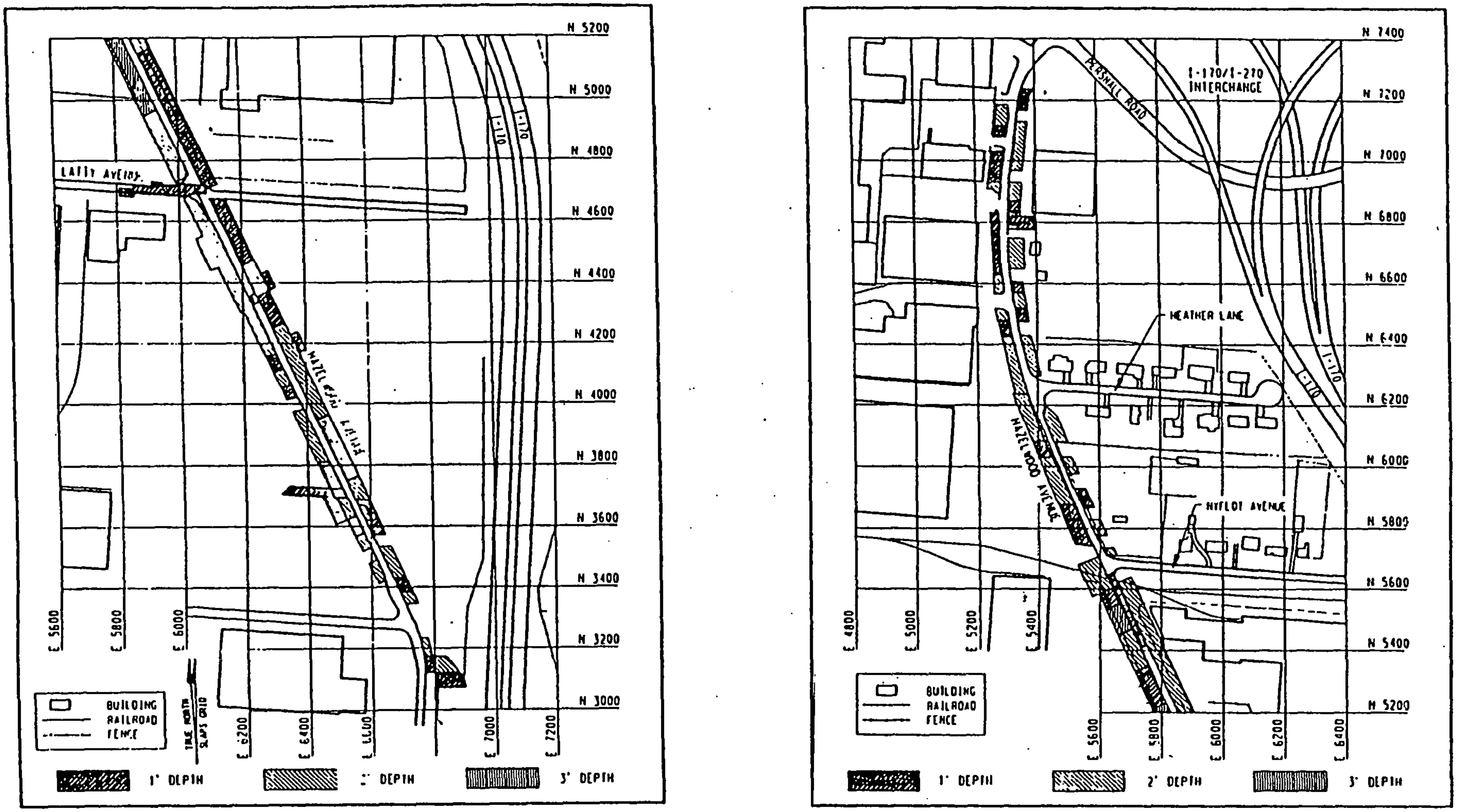


FIGURE A.10 Areas and Depths of Radioactive Contamination along Hazelwood Avenue

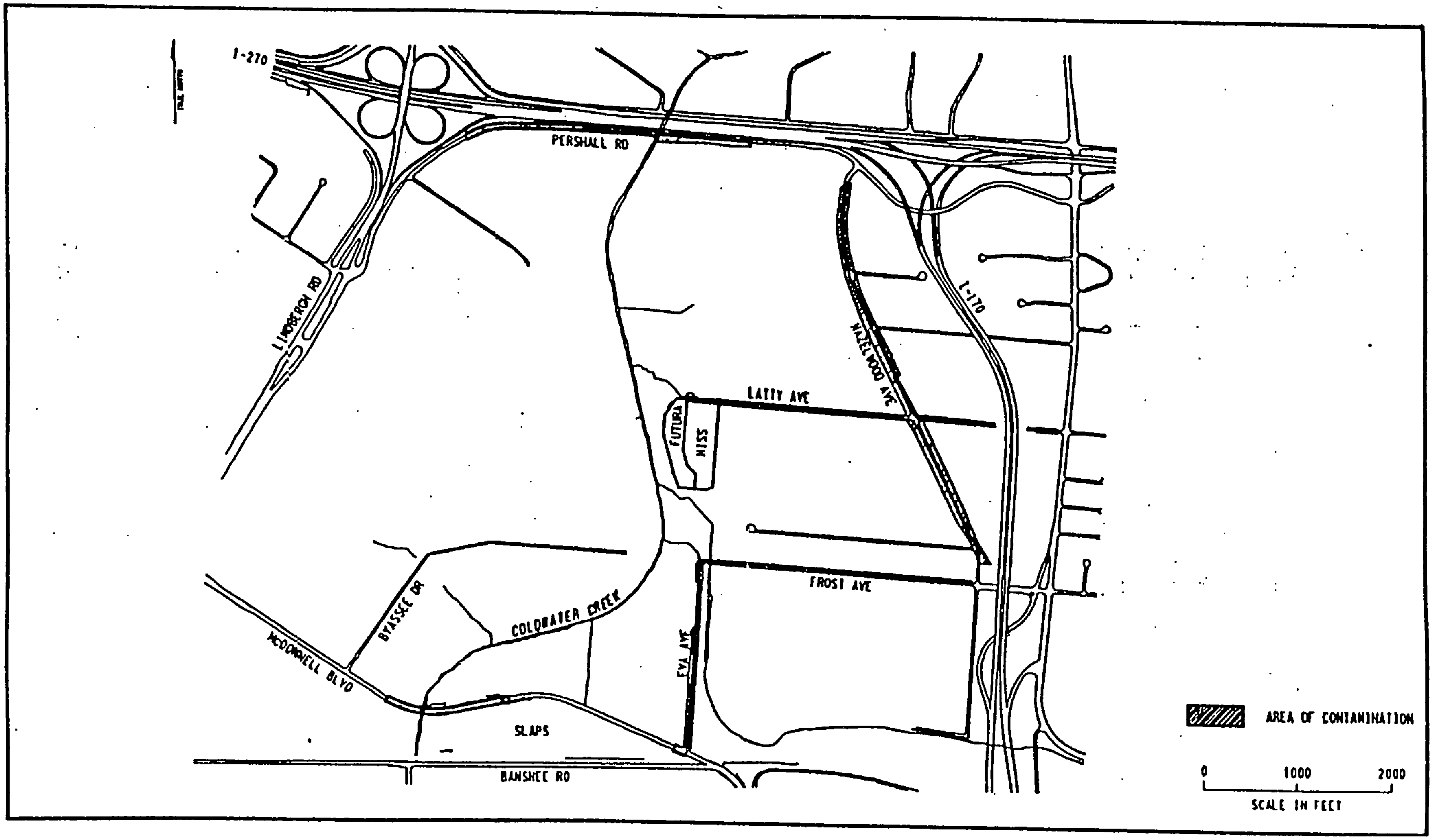


FIGURE A.11 General Areas of Contamination along the Haul Roads

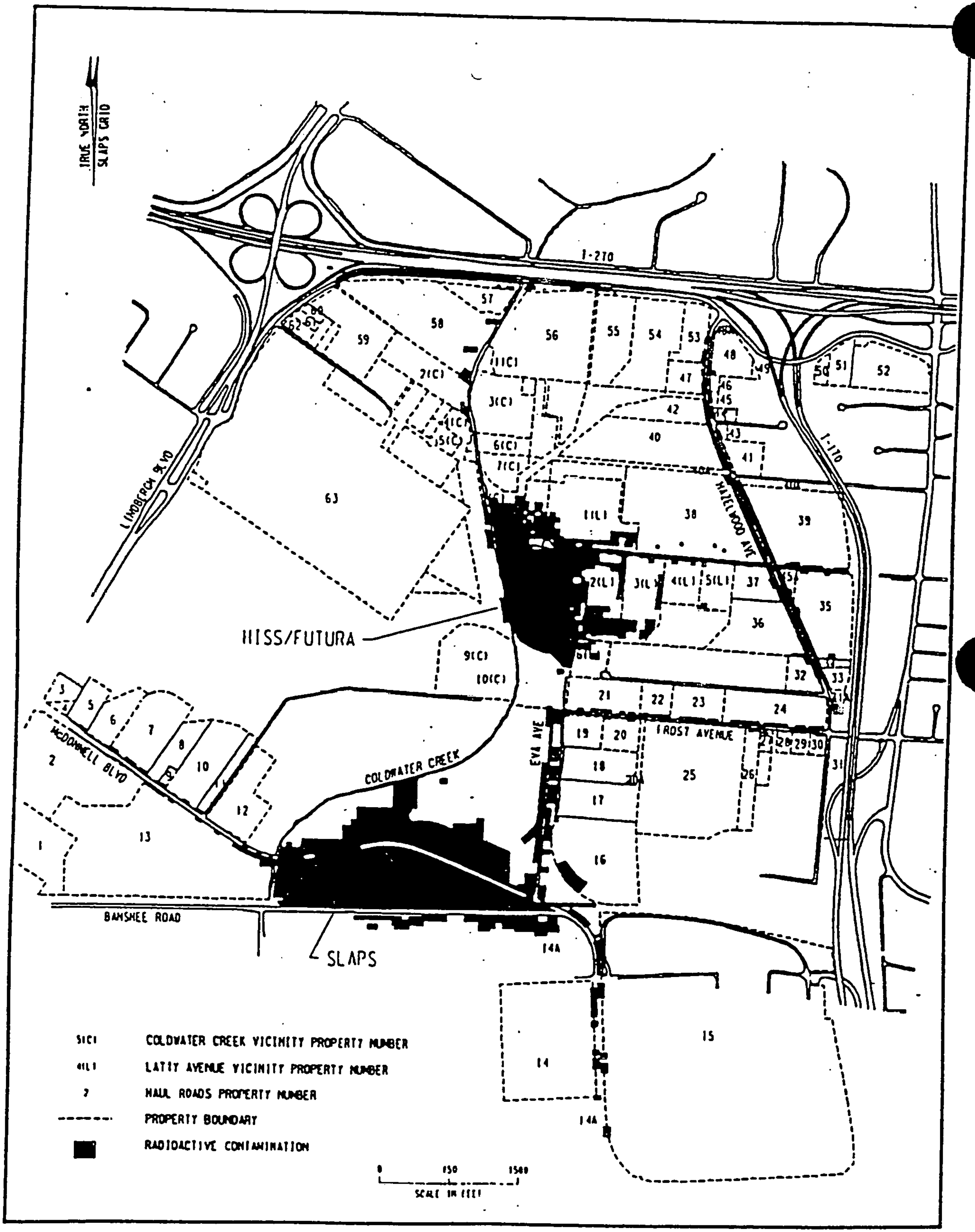


FIGURE A.12 Radioactive Contamination at the Vicinity Properties

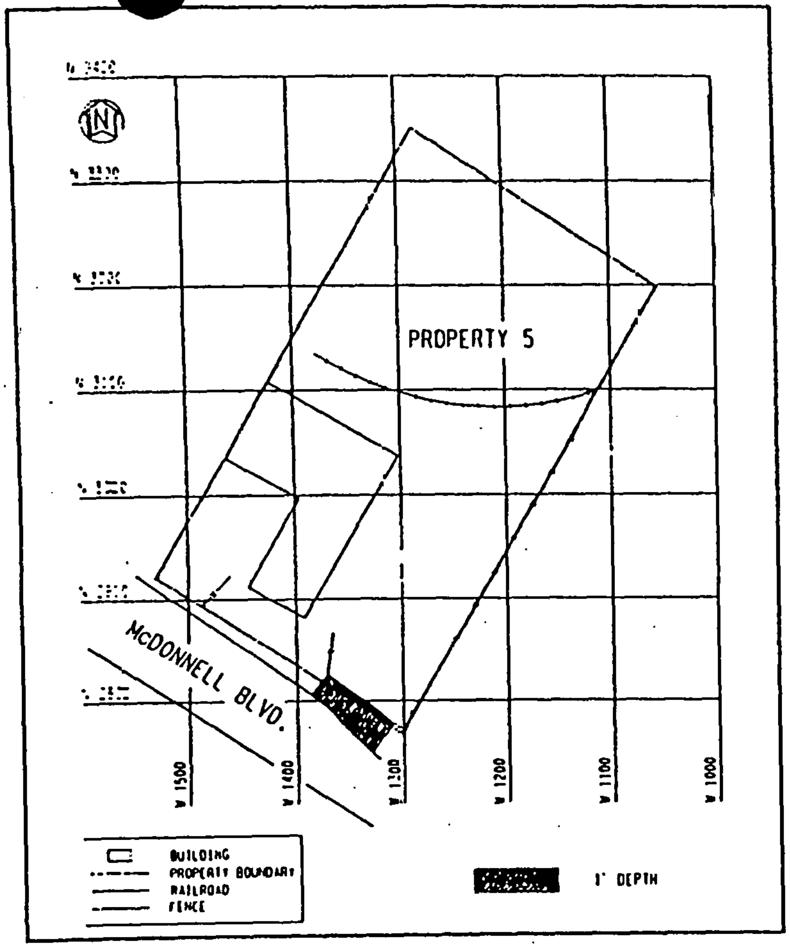


FIGURE A.13 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 5

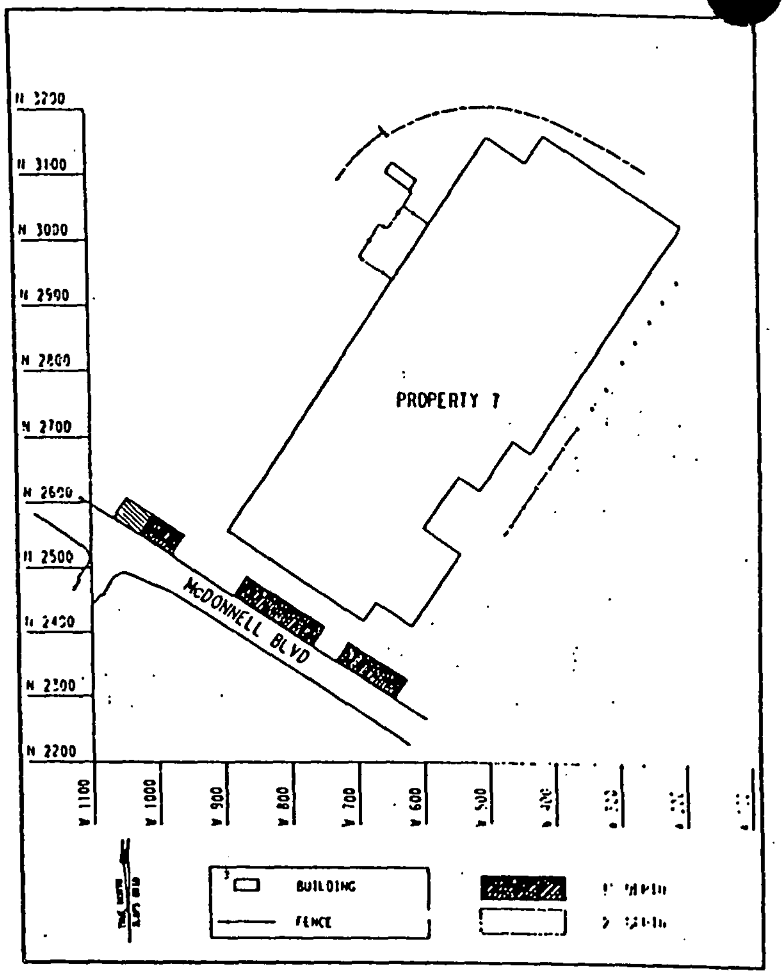


FIGURE A.14 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 7

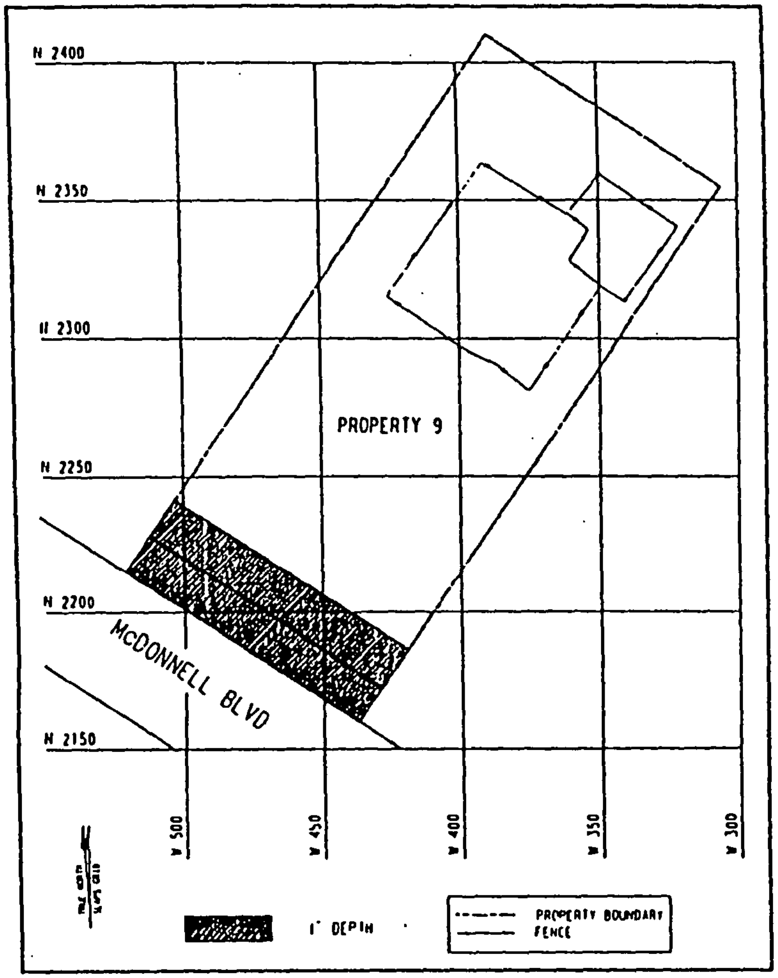


FIGURE A.15 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 9

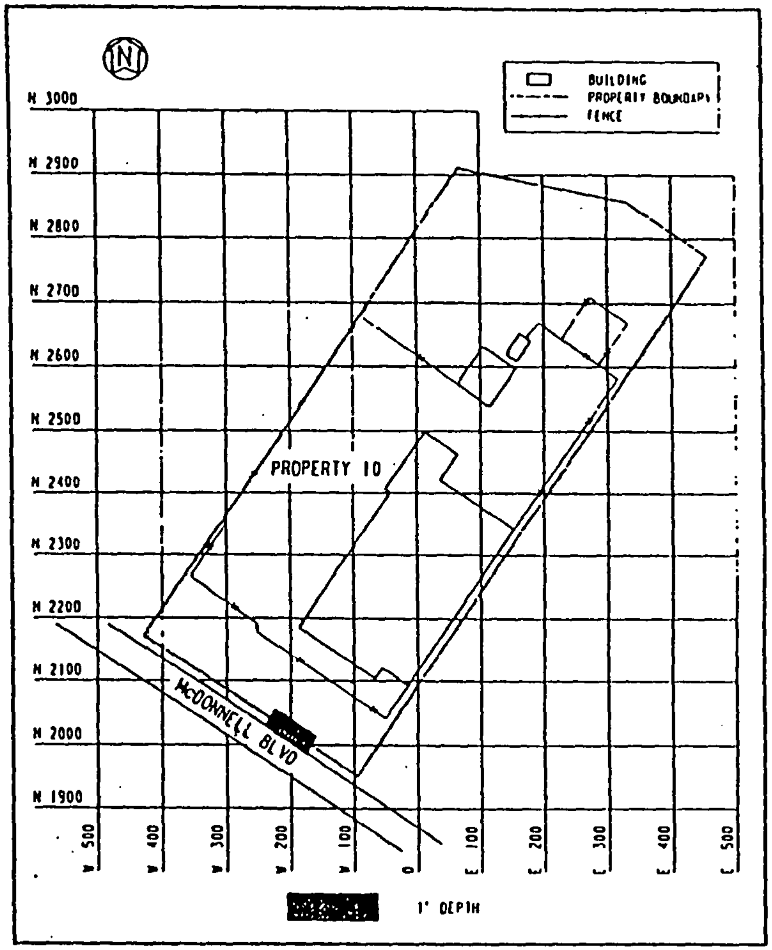


FIGURE A.16 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 10

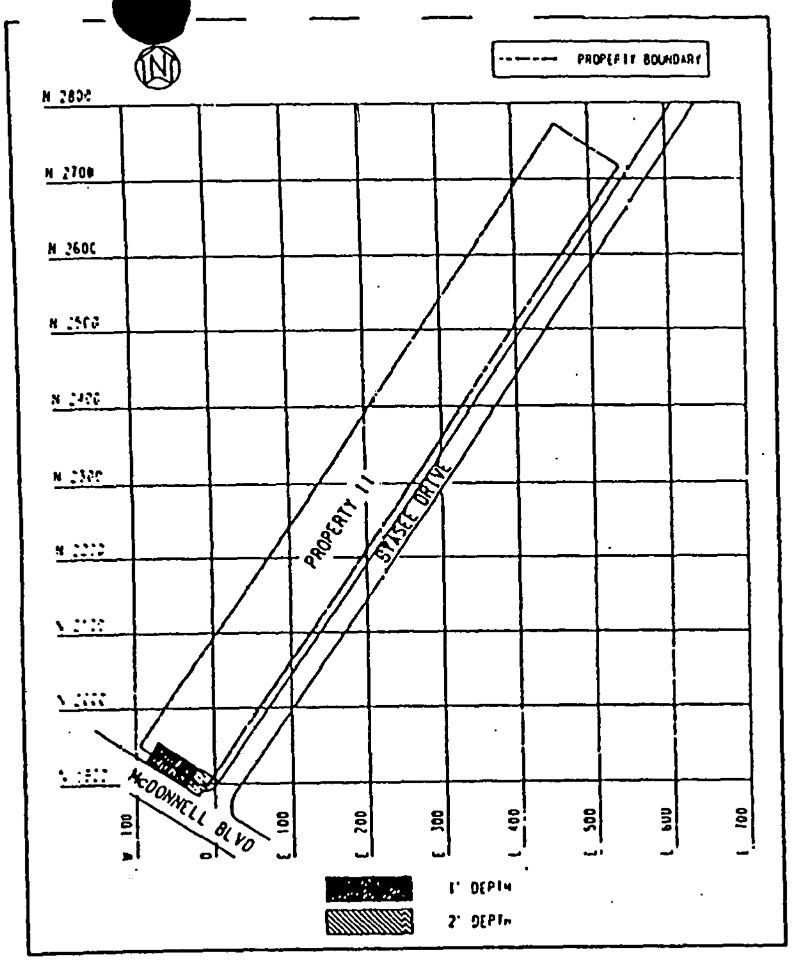


FIGURE A.17 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 11

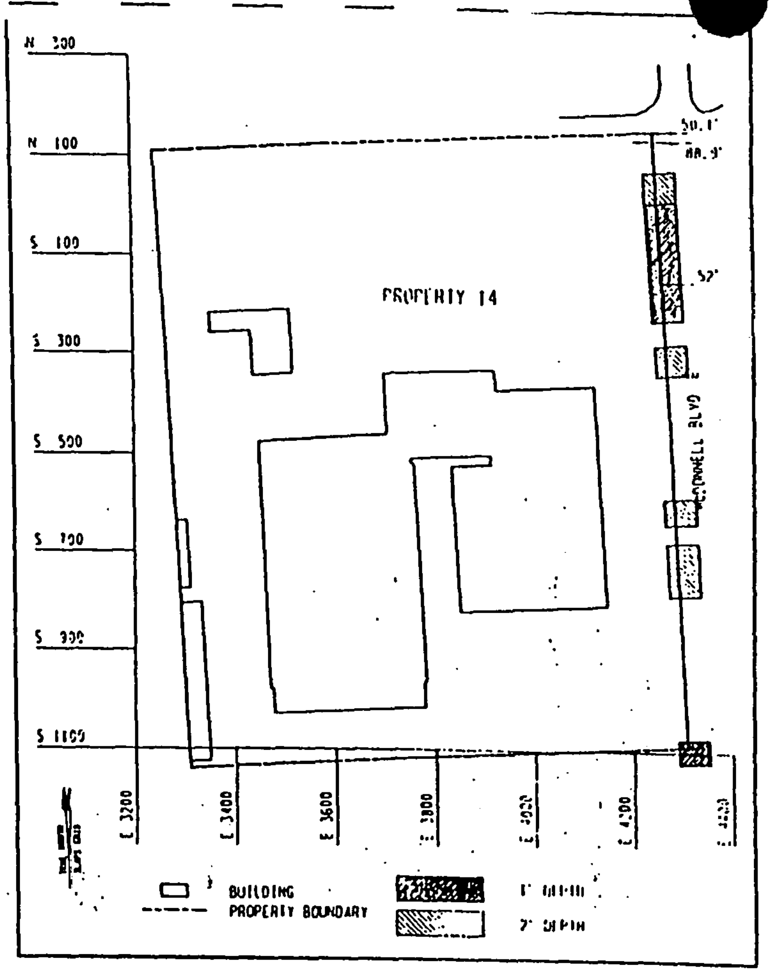


FIGURE A.18 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 14

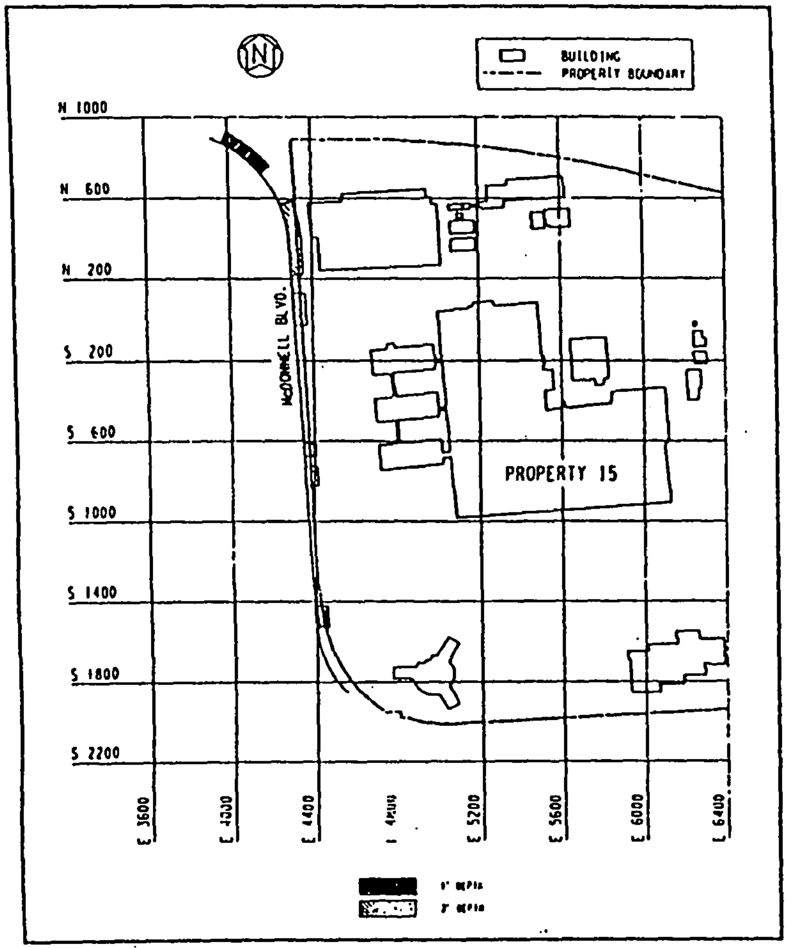


FIGURE A.19 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 15

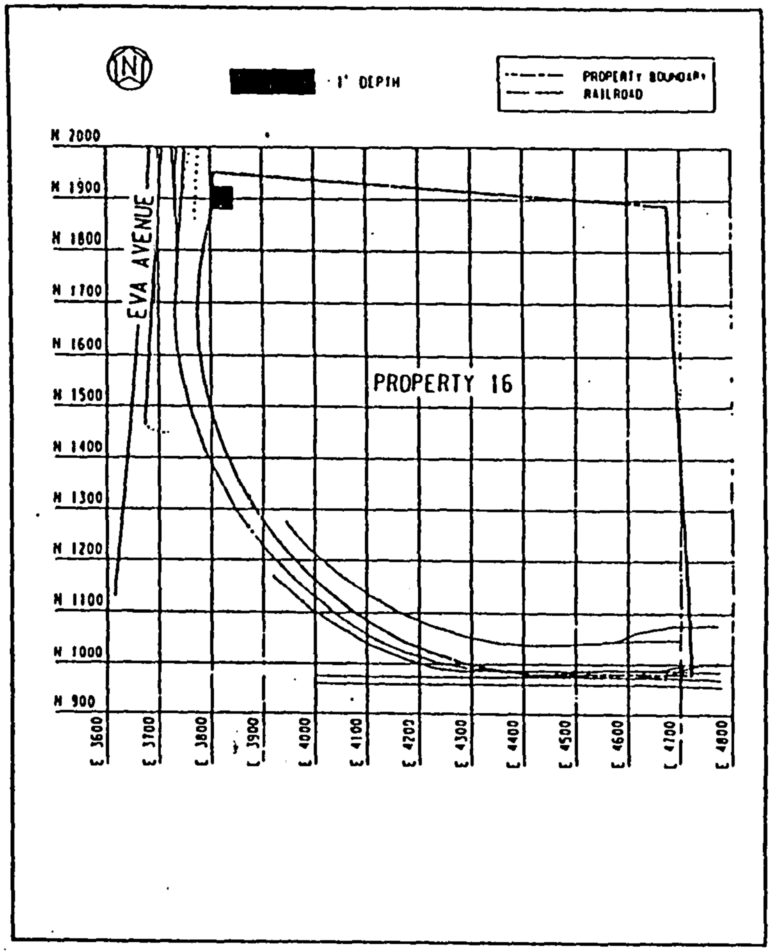


FIGURE A.20 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 16

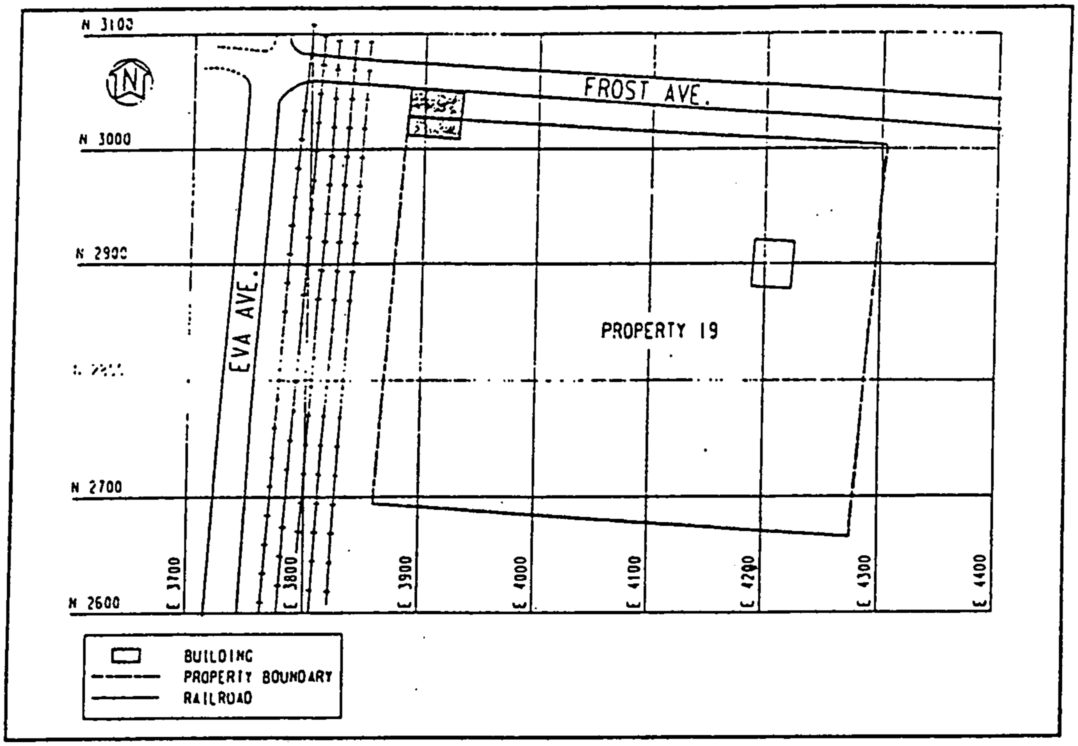


FIGURE A.21 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 19

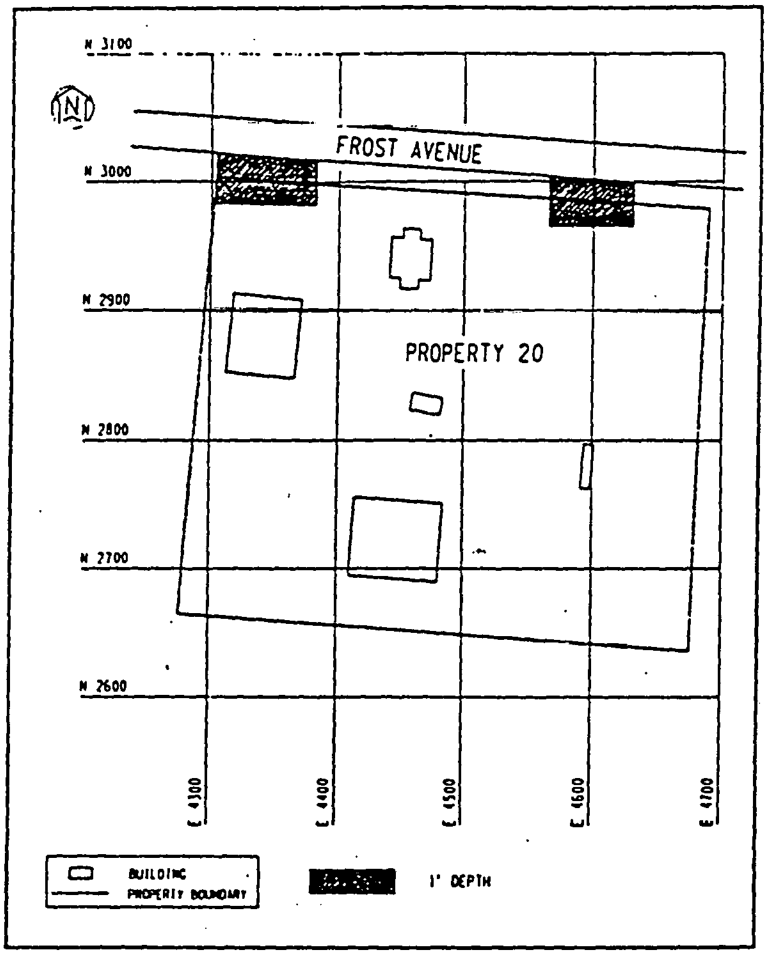


FIGURE A.22 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 20

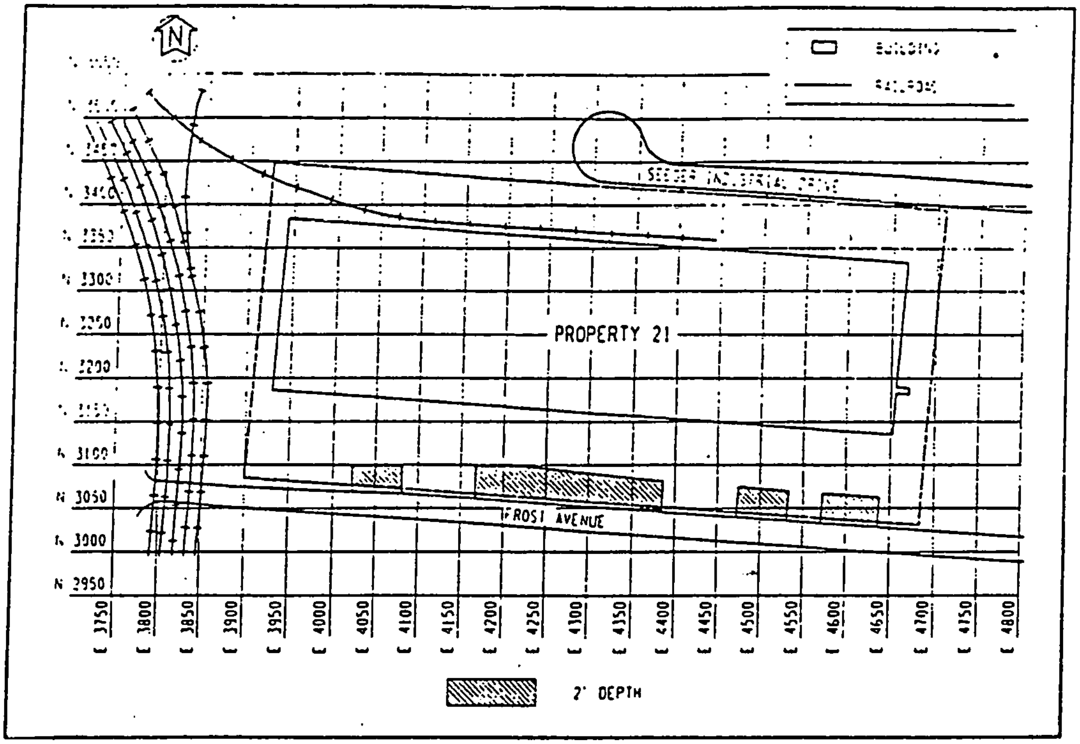


FIGURE A.23 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 21

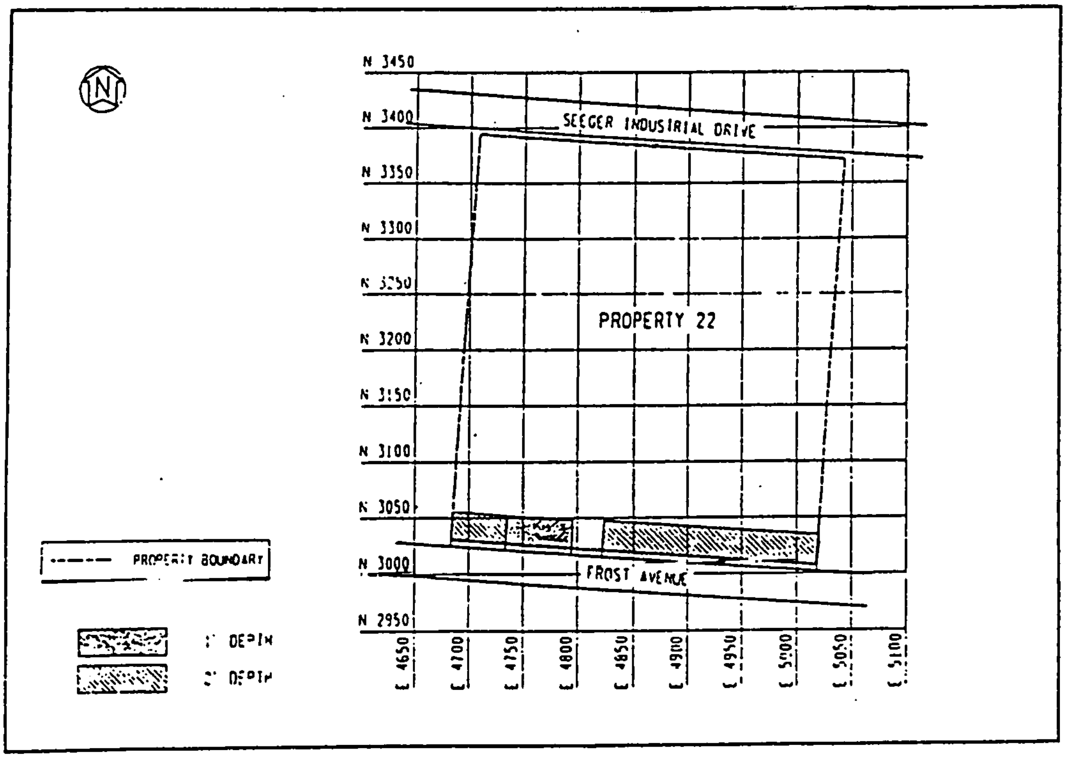


FIGURE A.24 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 22

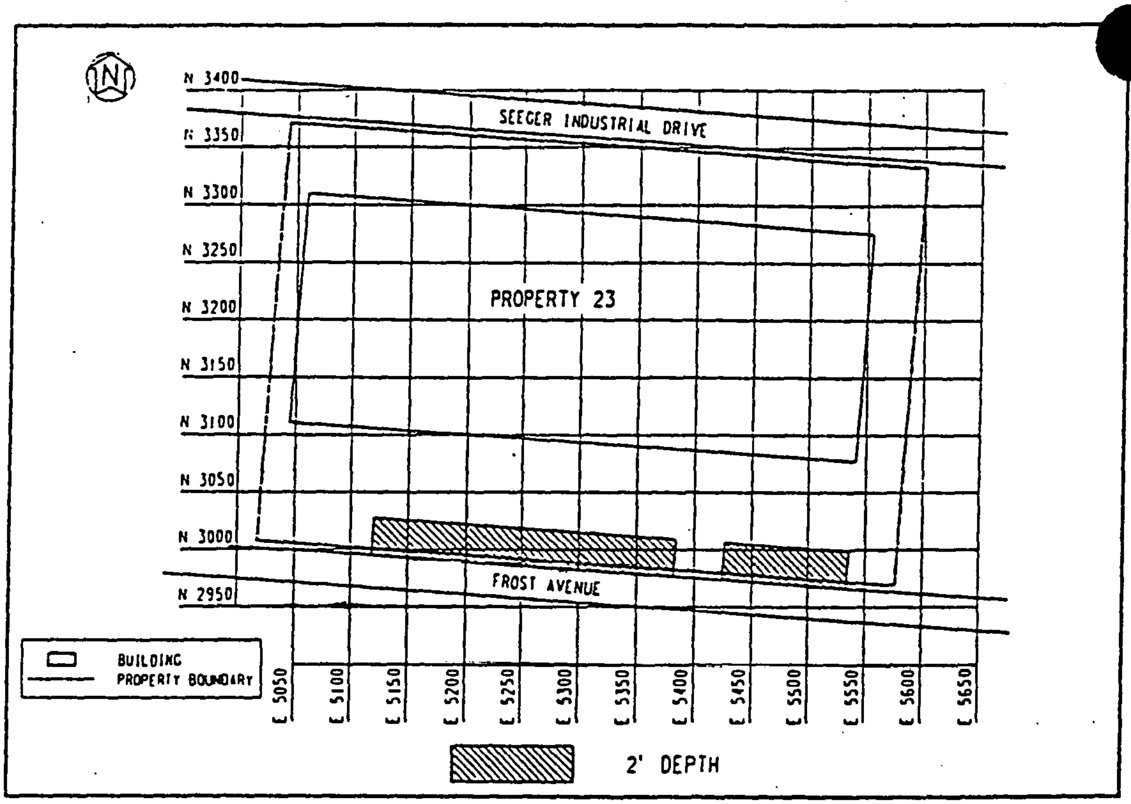


FIGURE A.25 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 23

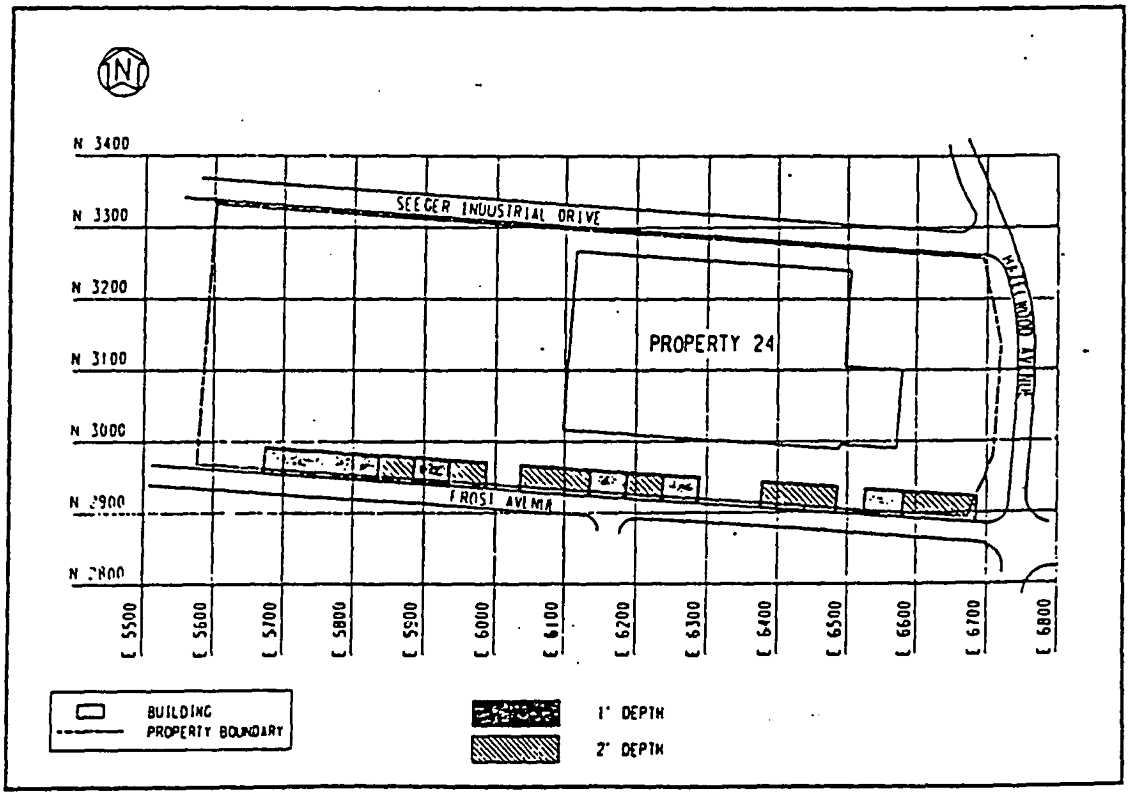


FIGURE A.26 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 24

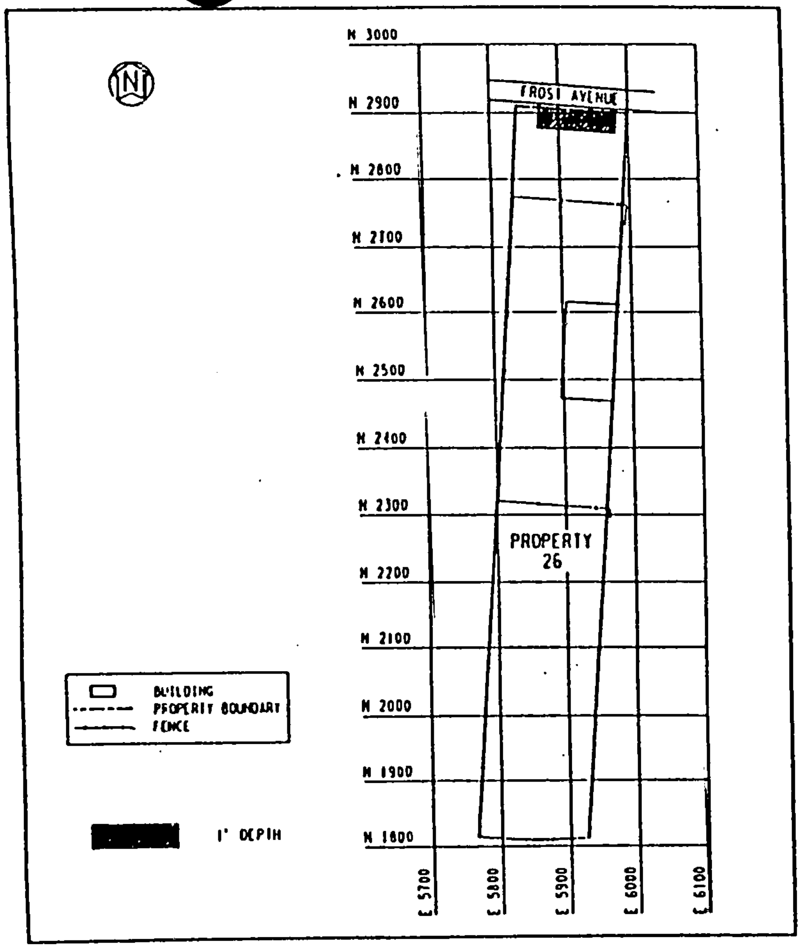


FIGURE A.27 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 26

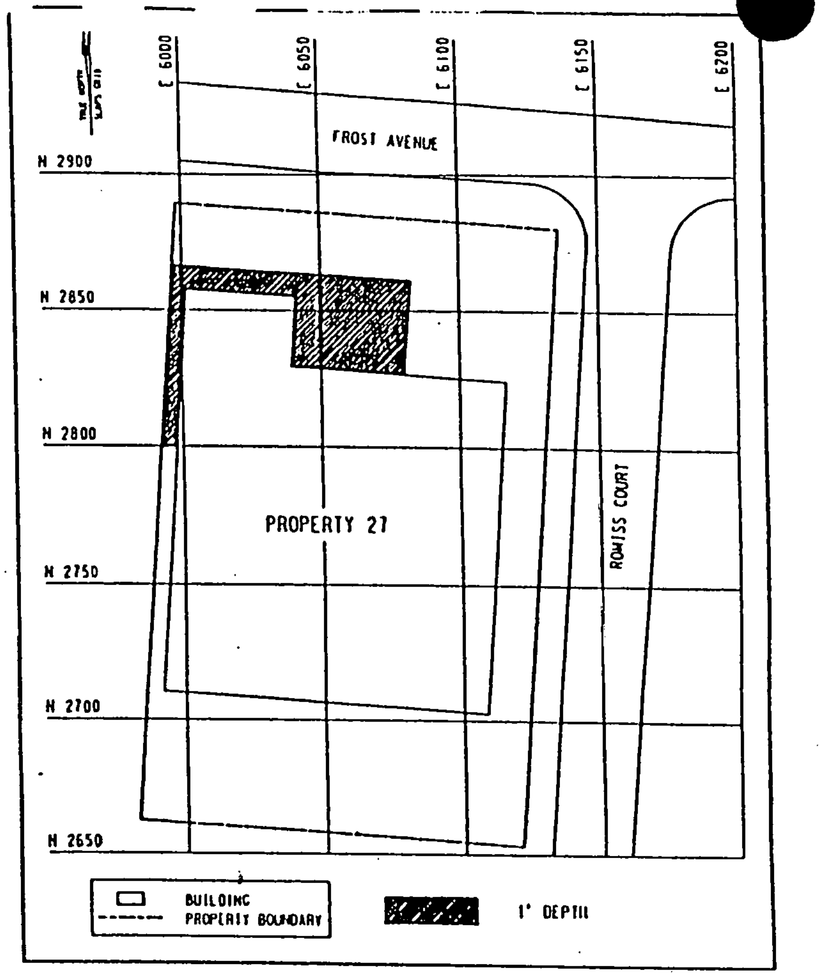


FIGURE A.28 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 27

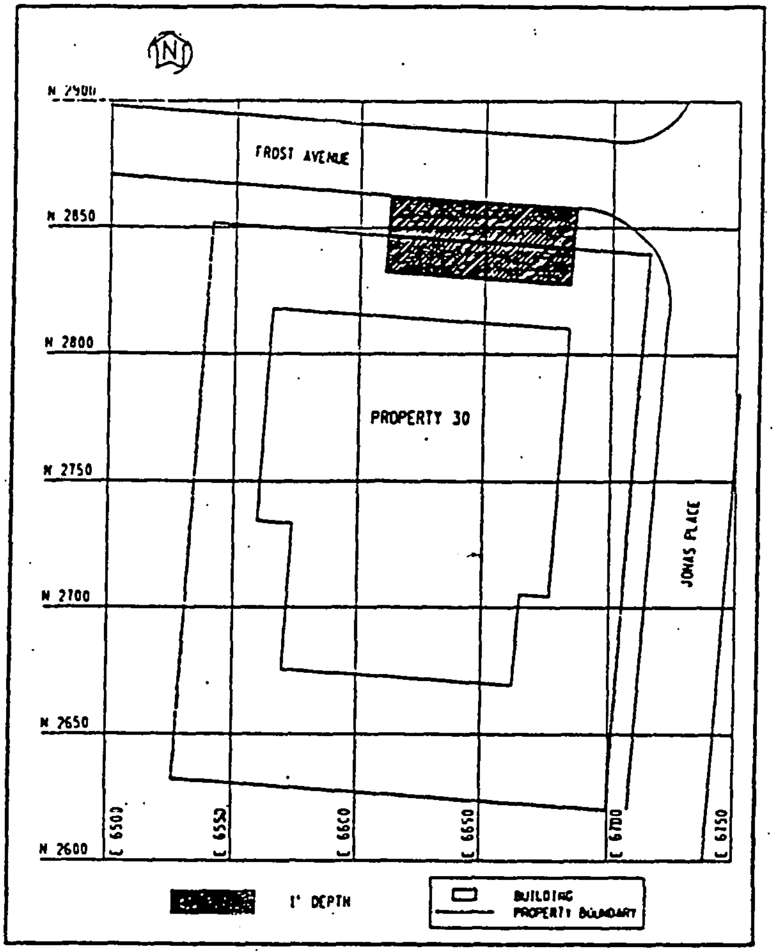


FIGURE A.29 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 30

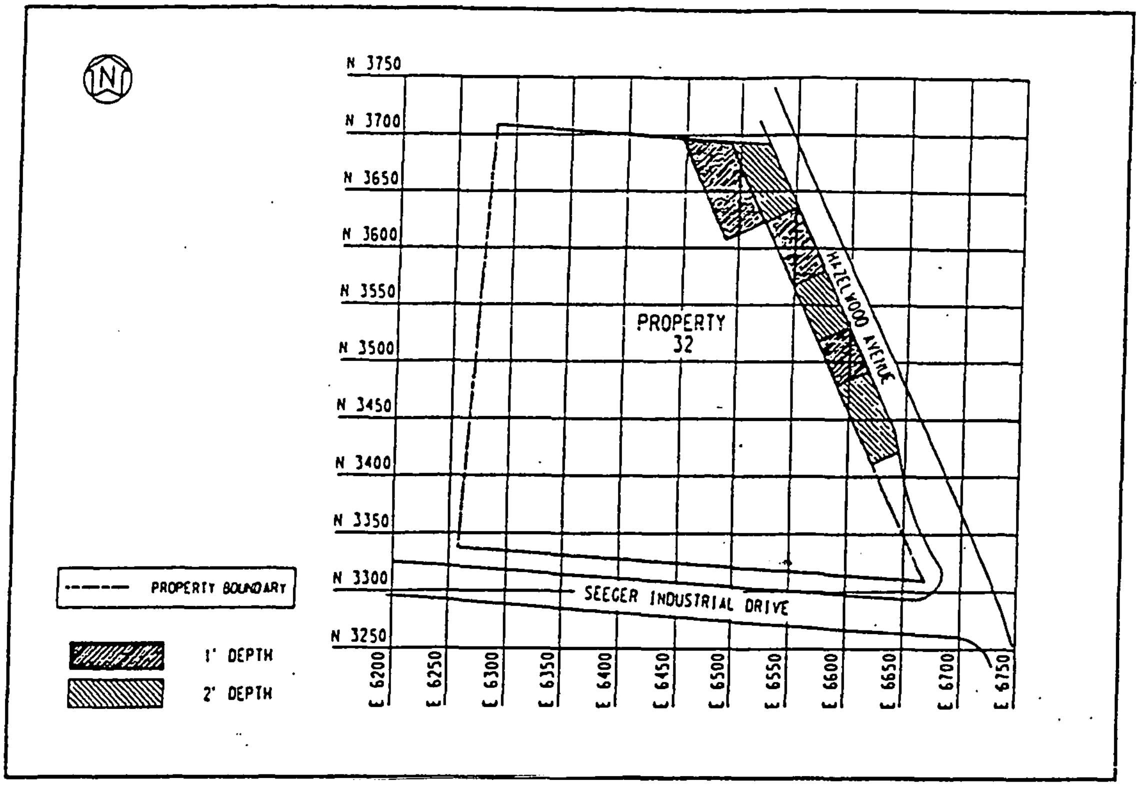


FIGURE A.30 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 32

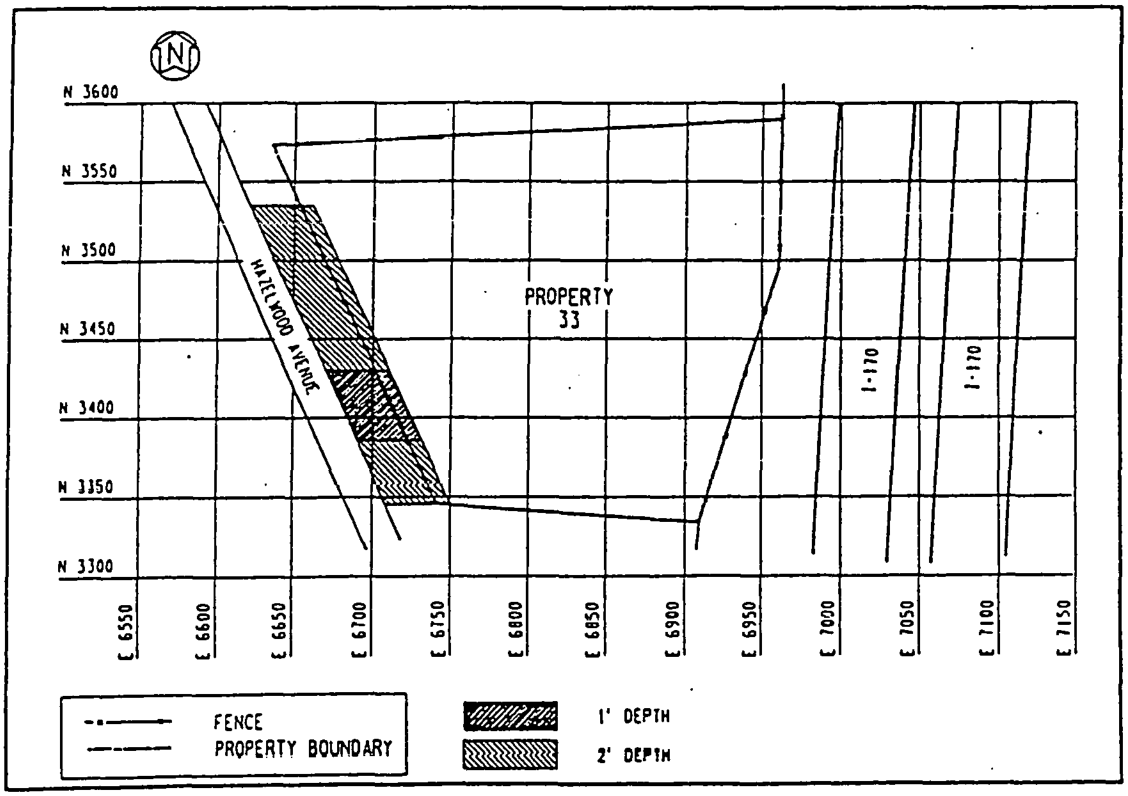


FIGURE A.31 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 33

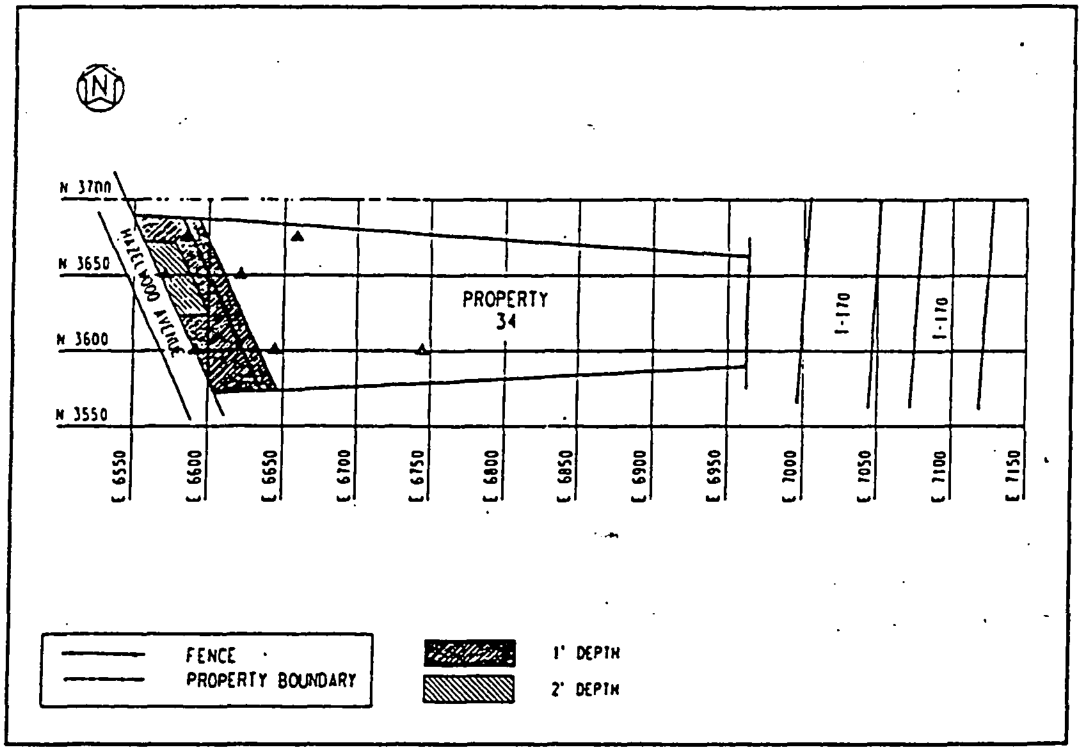


FIGURE A.32 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 34

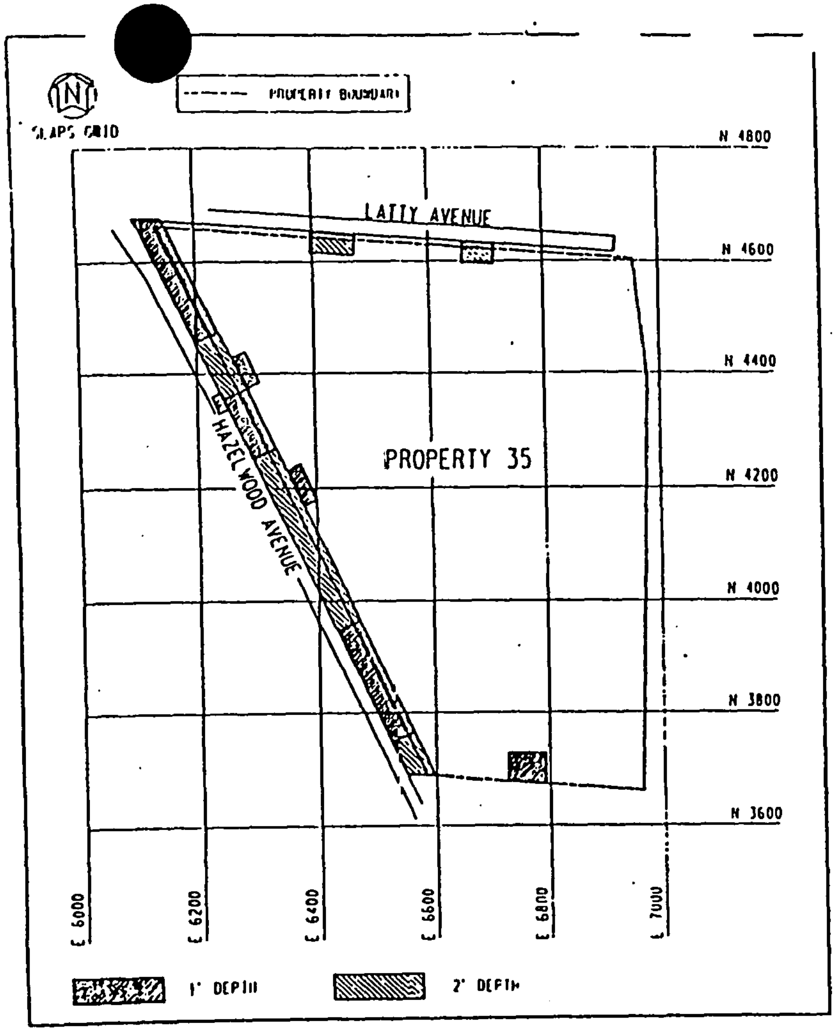


FIGURE A.33 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 35

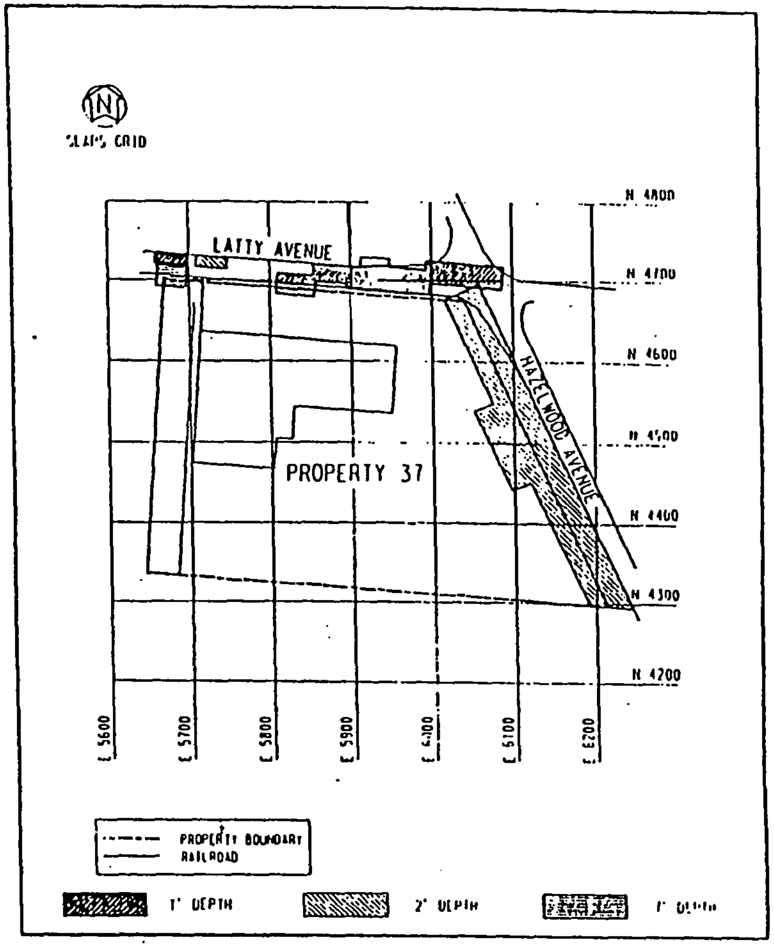


FIGURE A.34 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 37

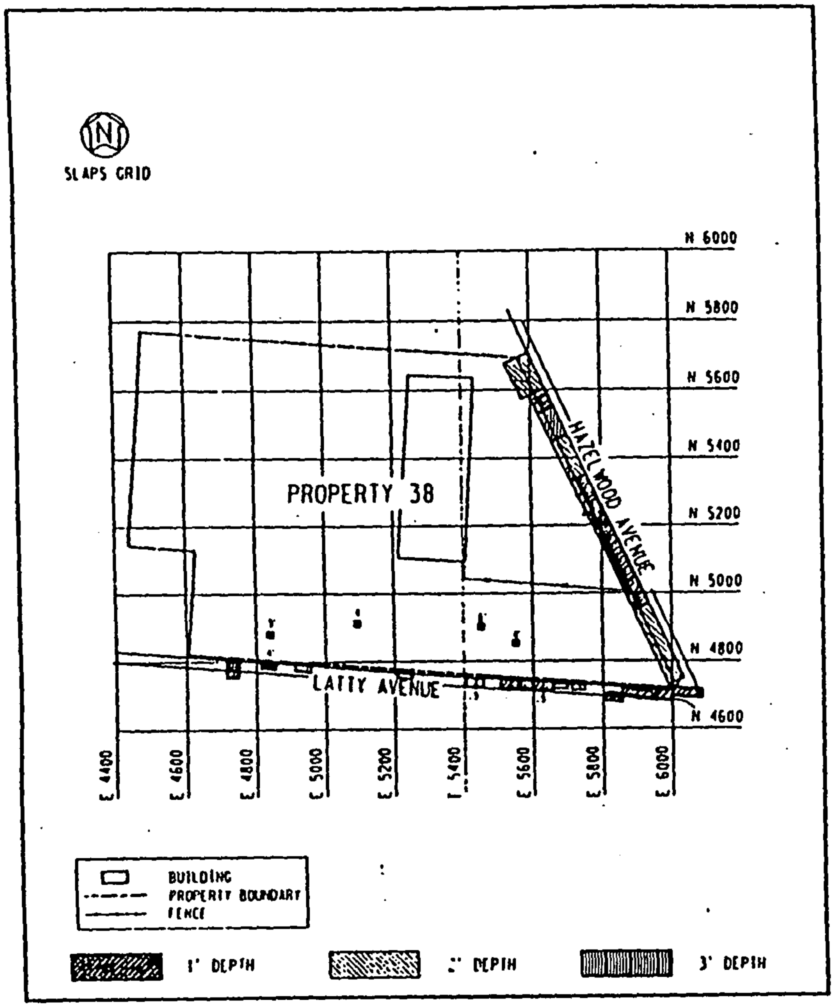


FIGURE A.35 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 38

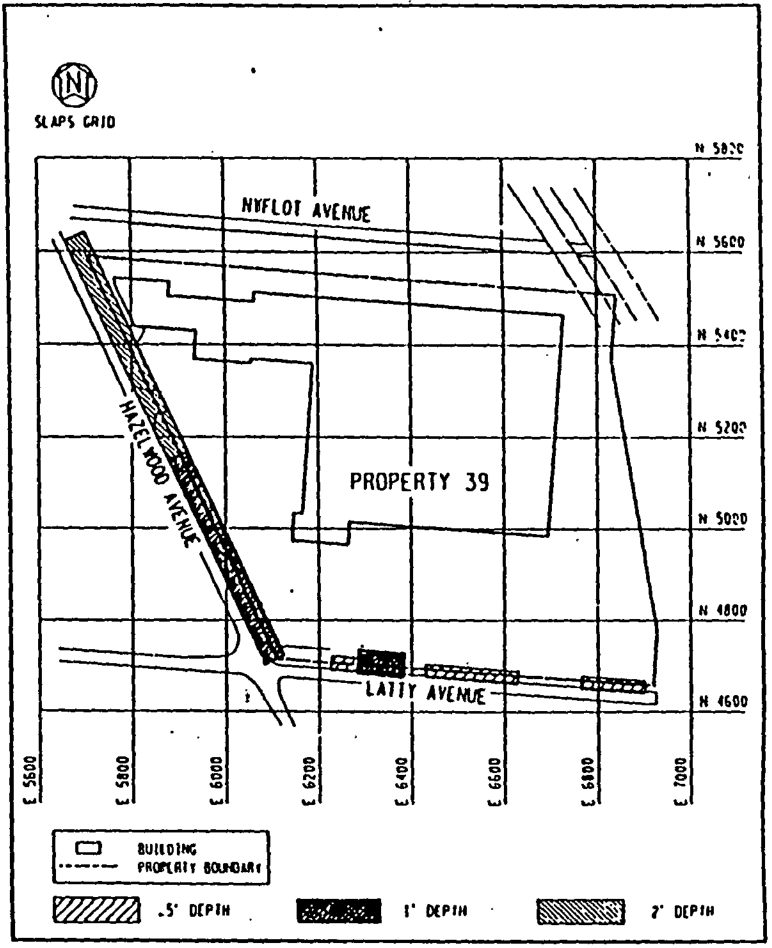


FIGURE A.36 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 39

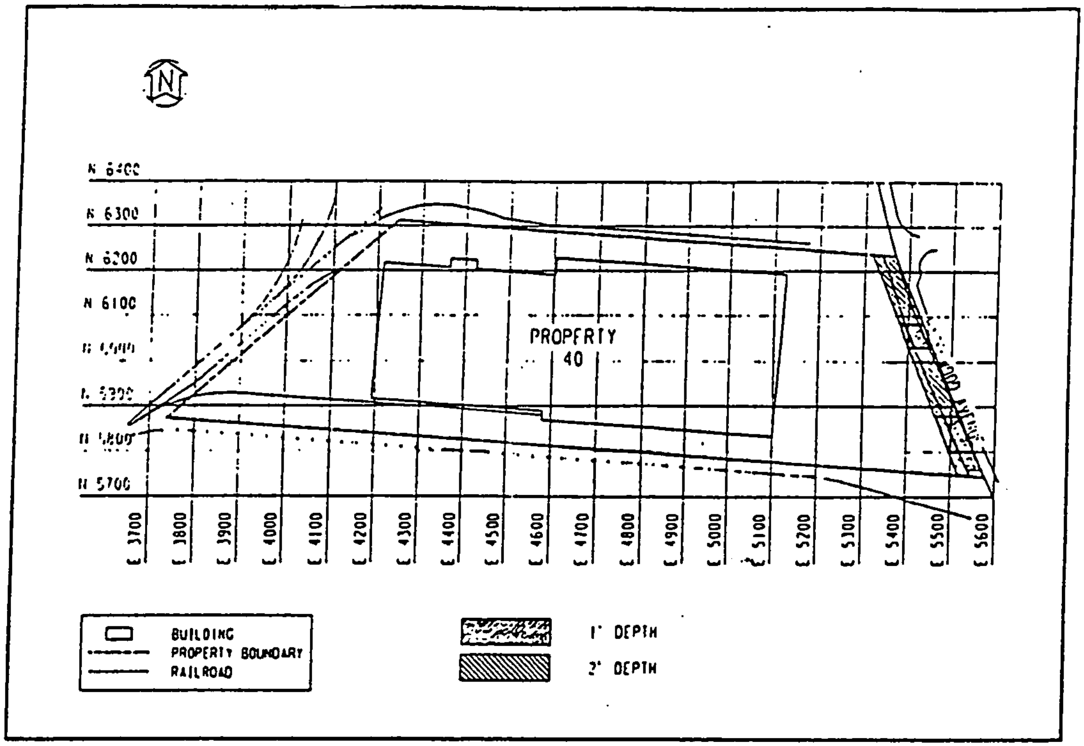


FIGURE A.37 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 40

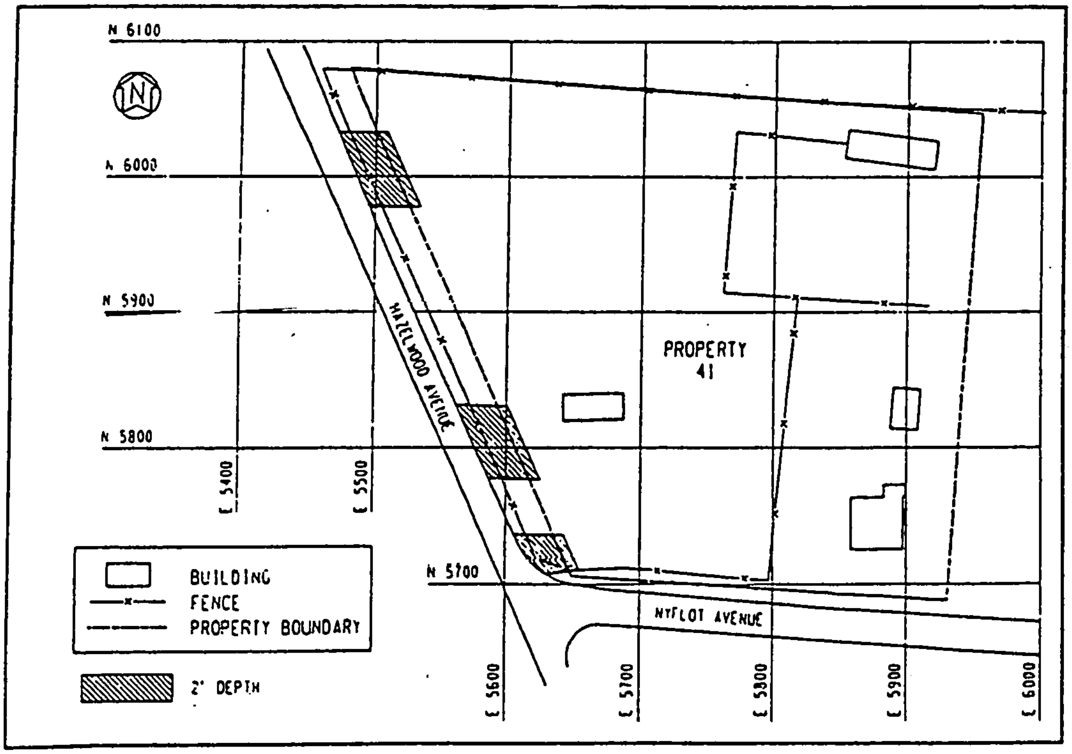


FIGURE A.38 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 41

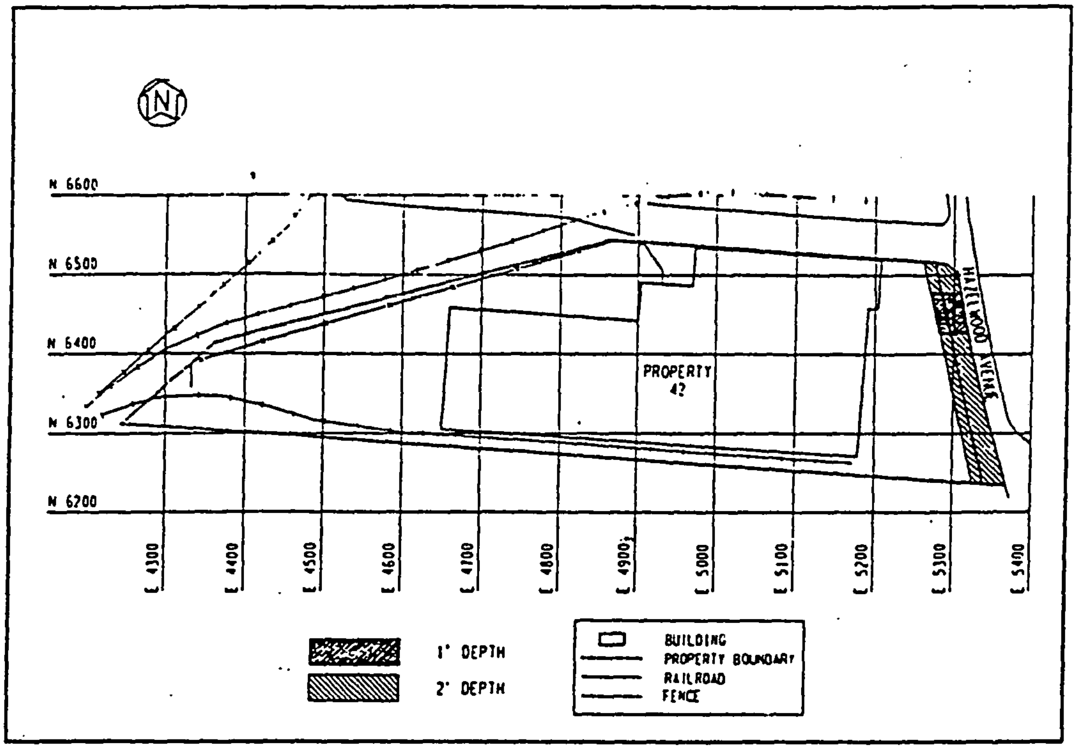


FIGURE A.39 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 42

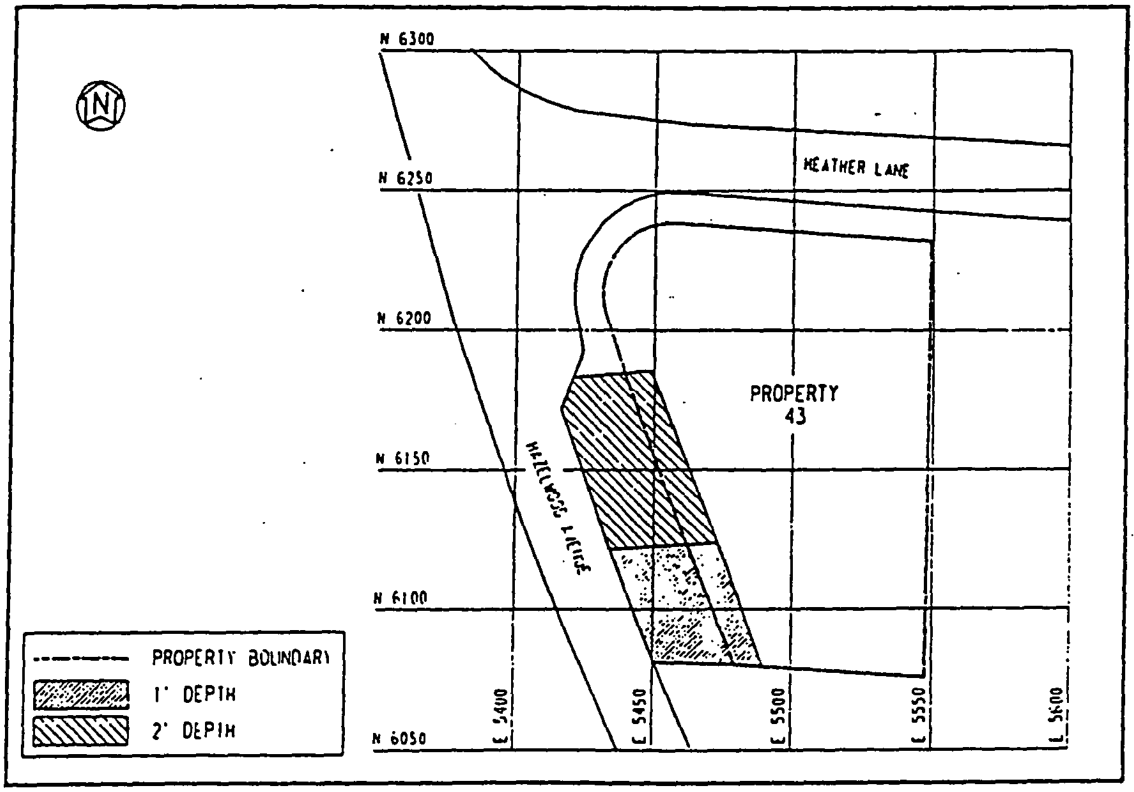


FIGURE A.40 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 43

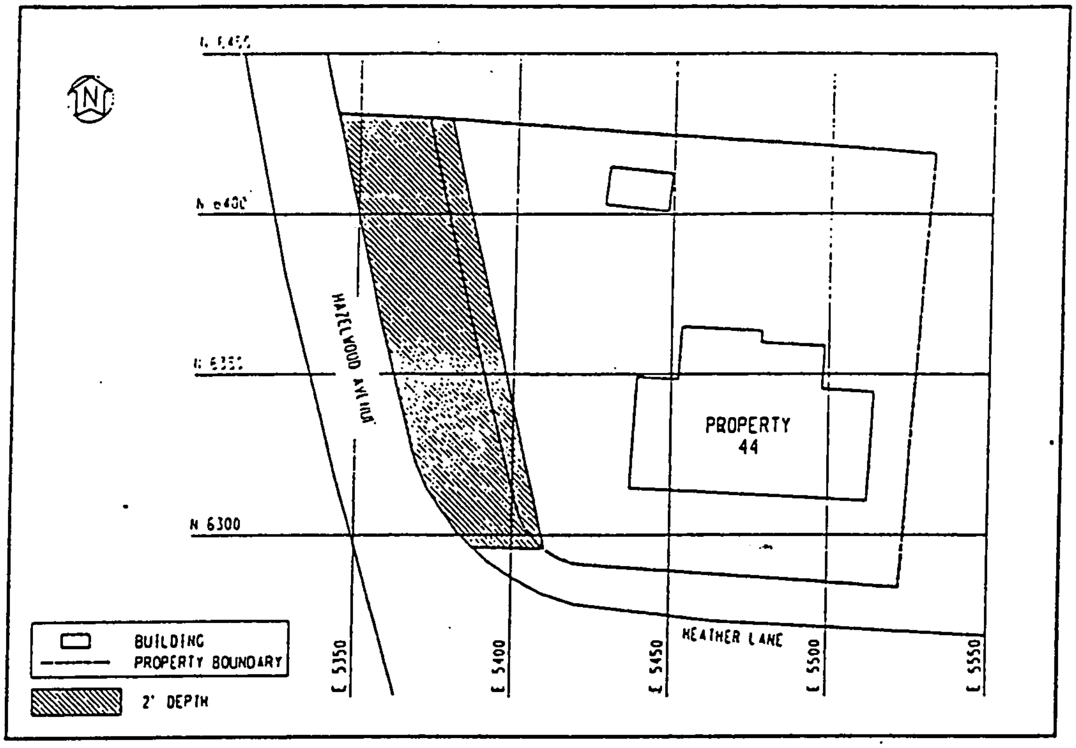


FIGURE A.41 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 44

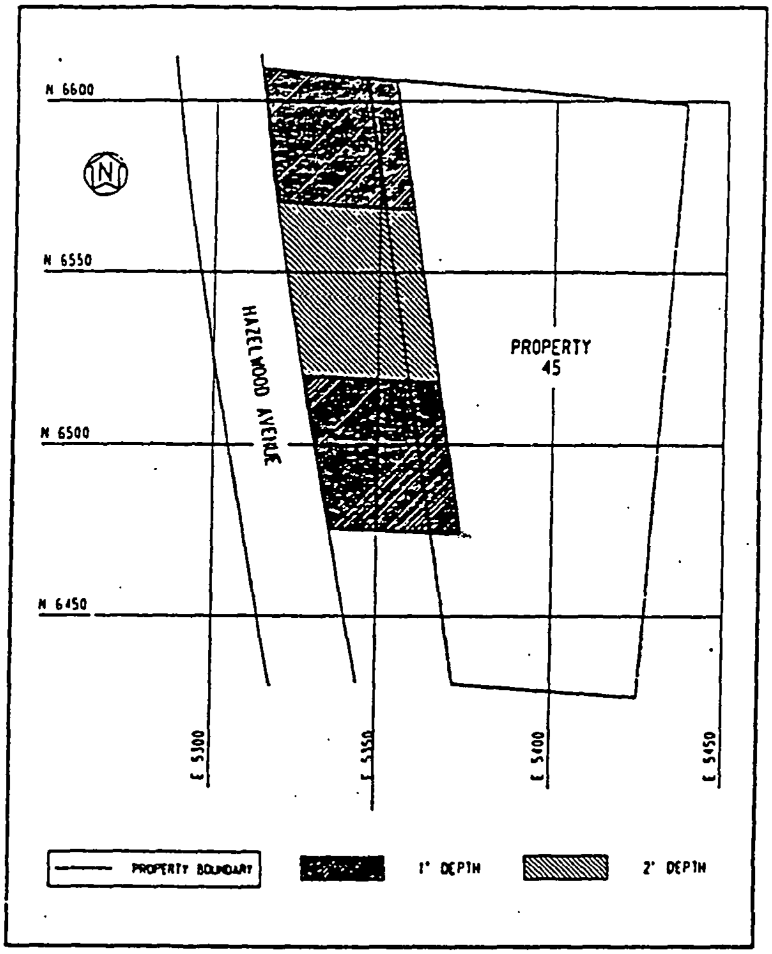


FIGURE A.42 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 45

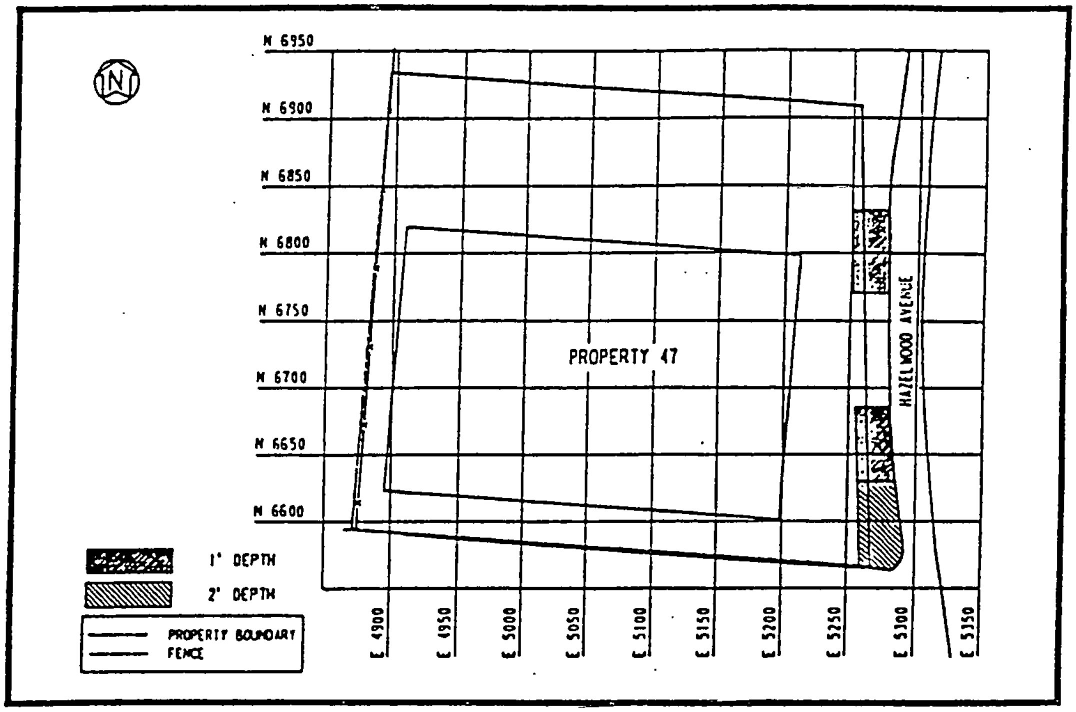


FIGURE A.43 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 47

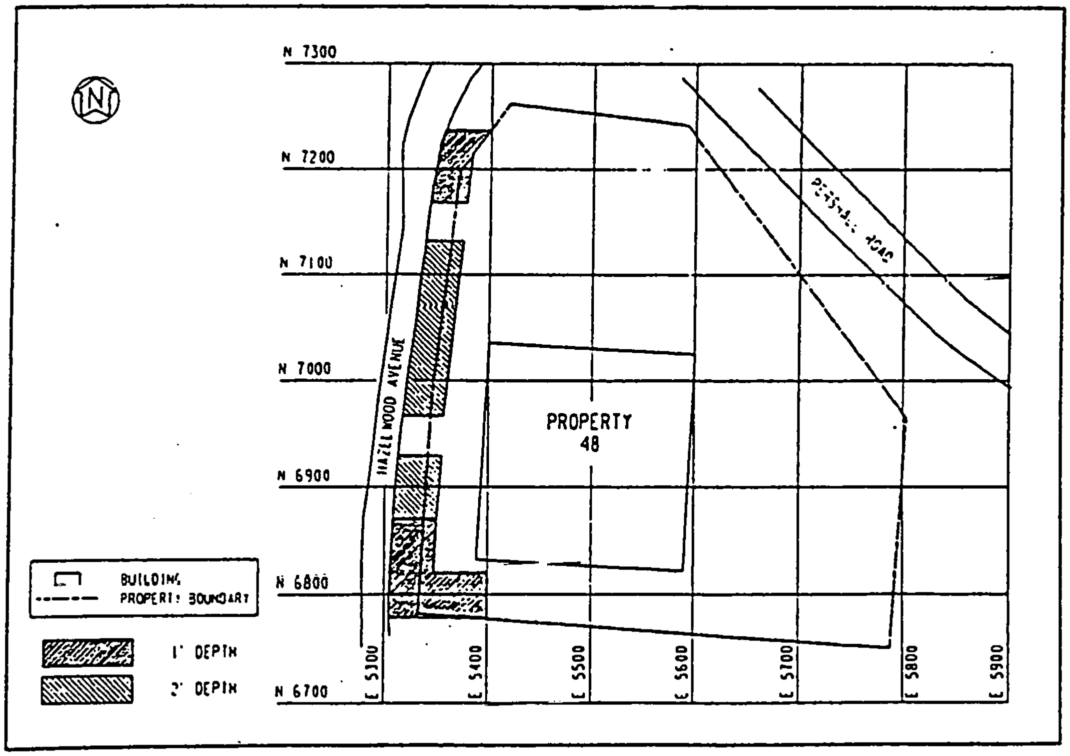


FIGURE A.44 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 48

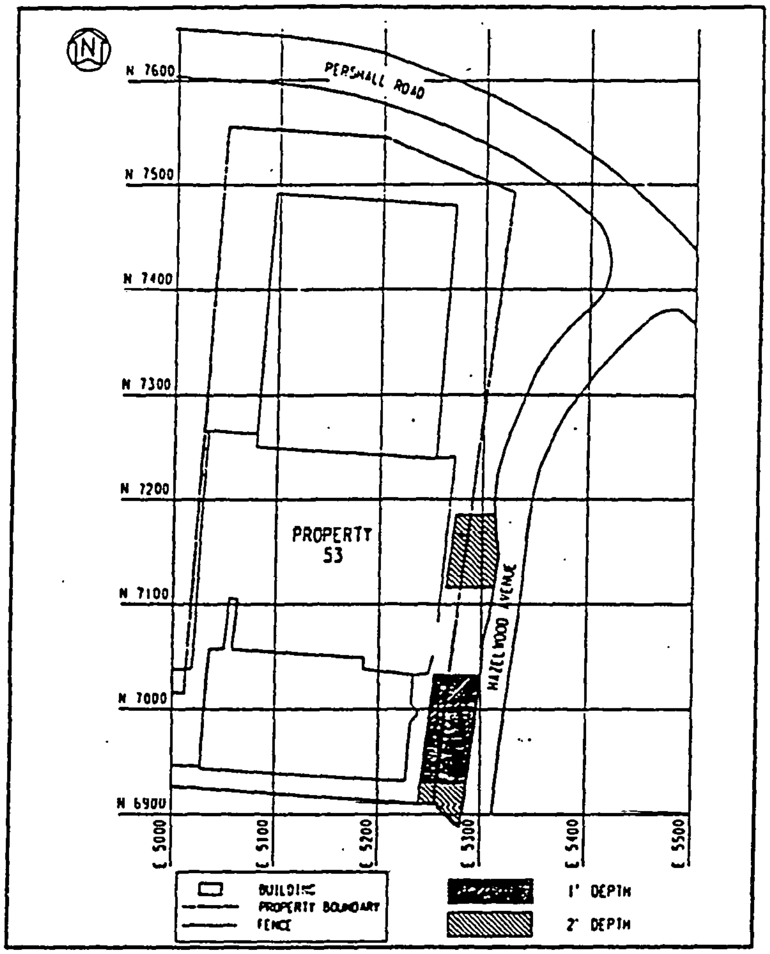


FIGURE A.45 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 53

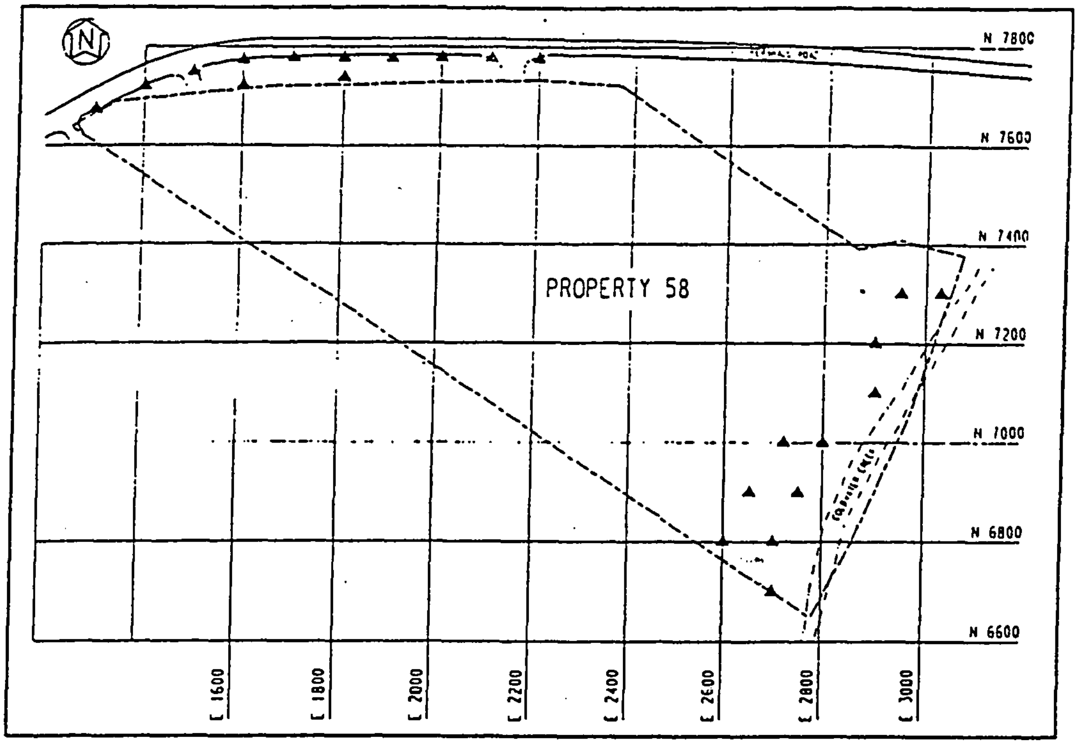


FIGURE A.46 Areas and Depths of Radioactive Contamination at Haul Roads Vicinity Property 58

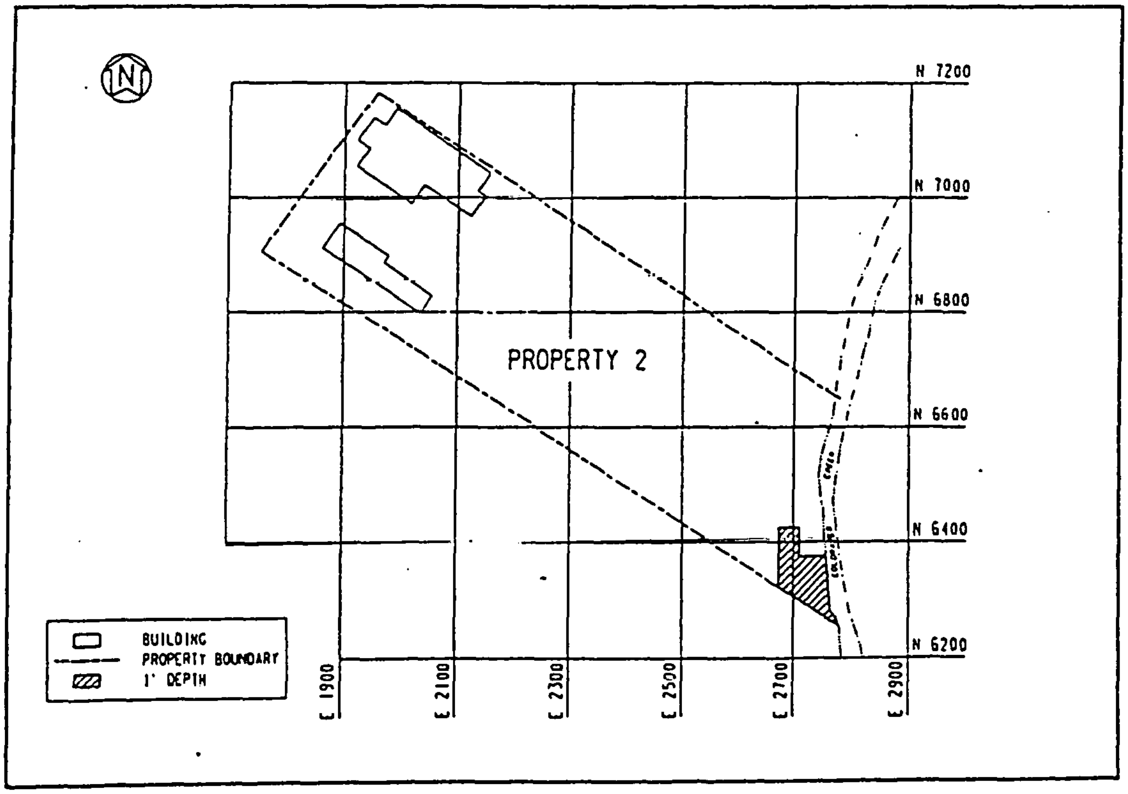


FIGURE A.47 Areas and Depths of Radioactive Contamination at Property 2 on Coldwater Creek

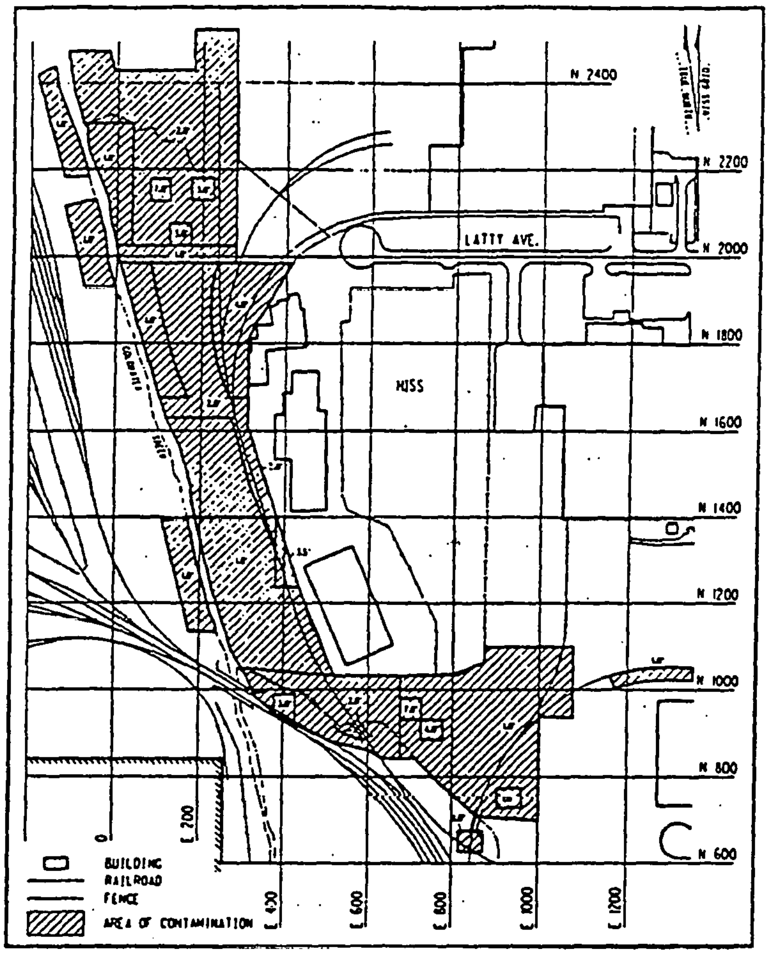


FIGURE A.48 Areas and Depths of Radioactive Contamination at the Norfolk & Western Railroad Property Adjacent to 9200 Latty Avenue

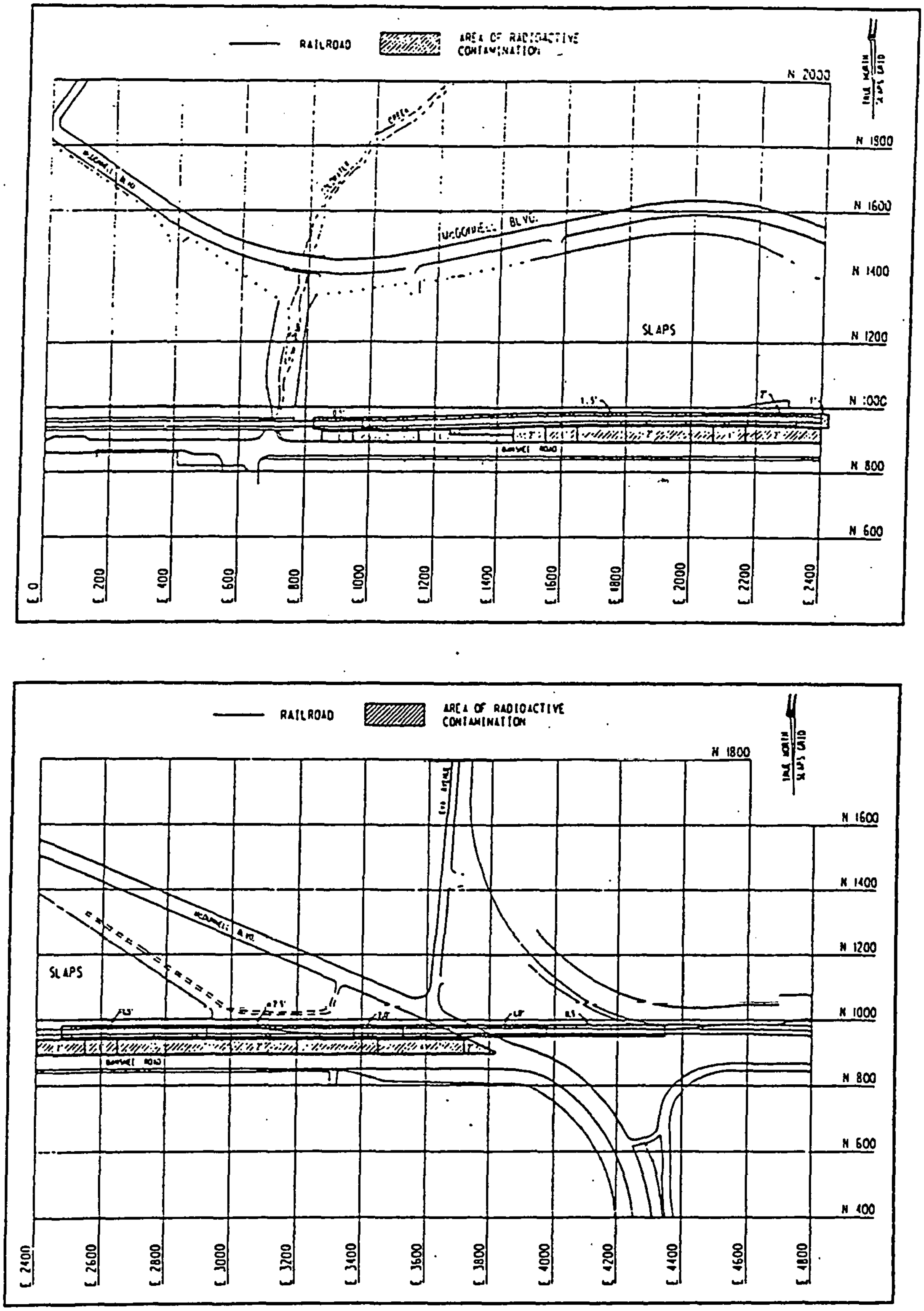


FIGURE A.49 Areas and Depths of Radioactive Contamination at the Norfolk & Western Railroad Property South of SLAPS

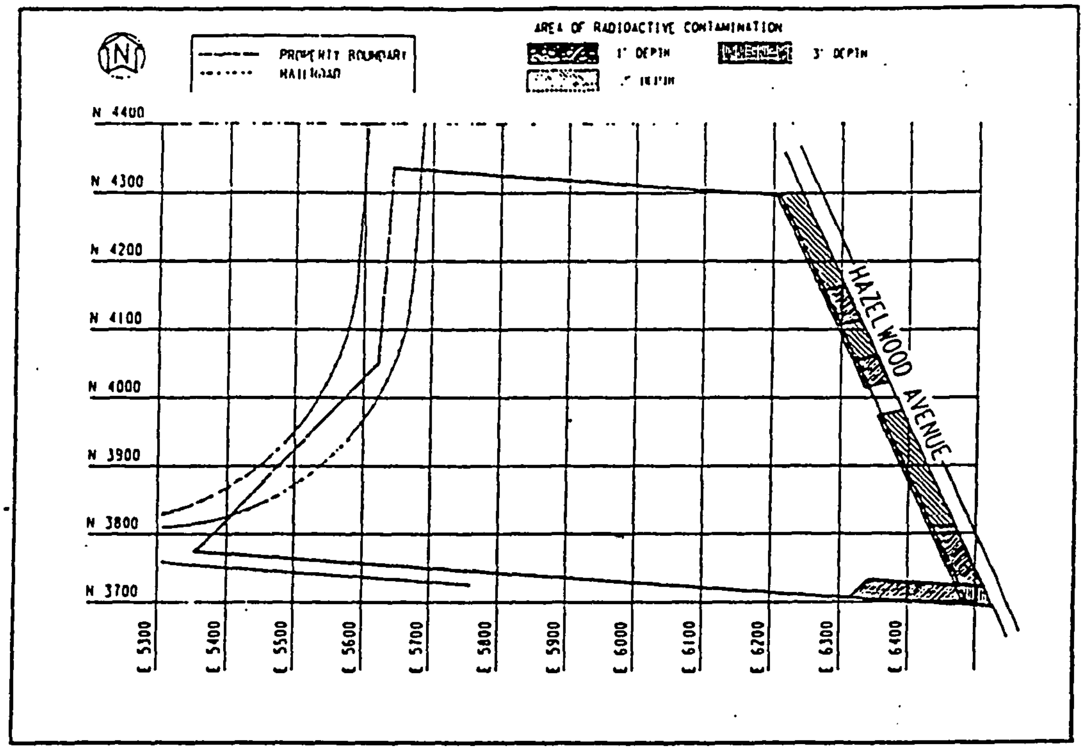


FIGURE A.50 Areas and Depths of Radioactive Contamination at the Norfolk & Western Railroad Property Adjacent to Hazelwood Avenue and South of Latty Avenue

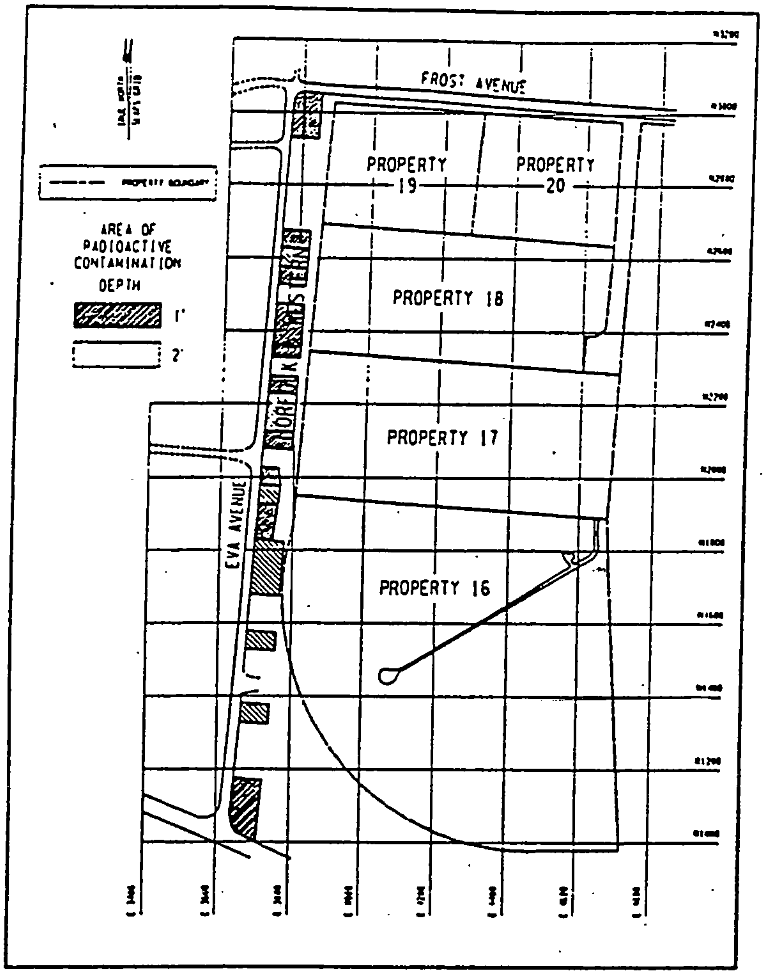


FIGURE A.51 Areas and Depths of Radioactive Contamination at the Norfolk & Western Railroad Property Adjacent to Eva Avenue

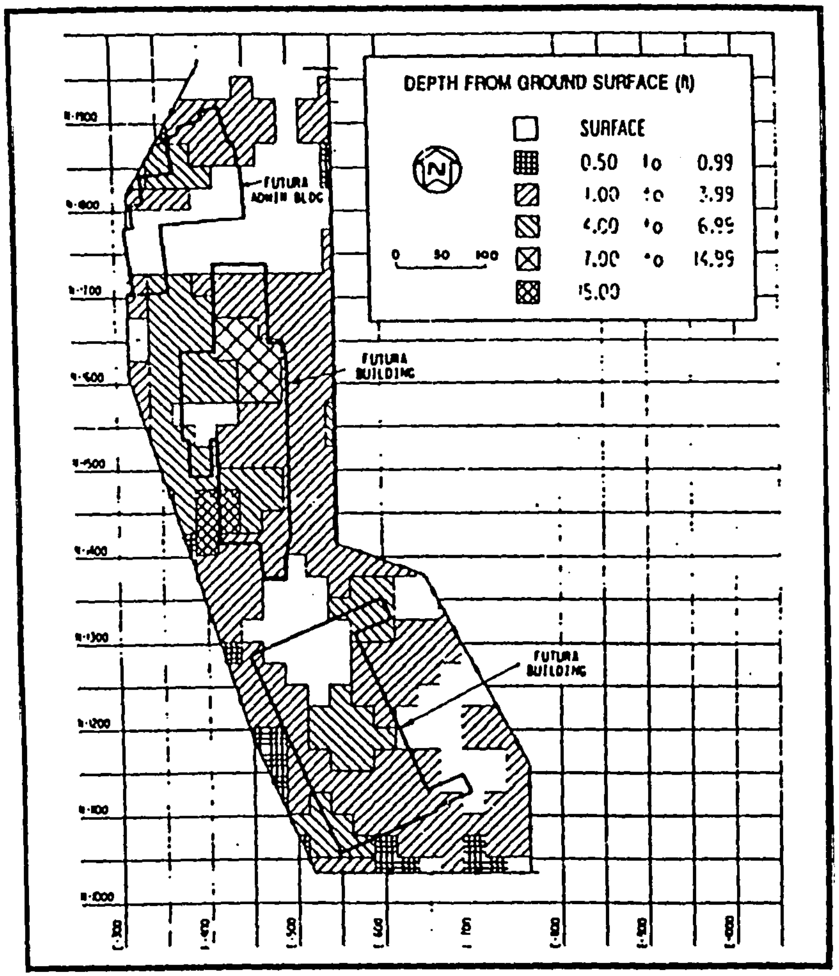


FIGURE A.52 Areas and Depths of Radioactive Contamination at the Futura Coatings Site

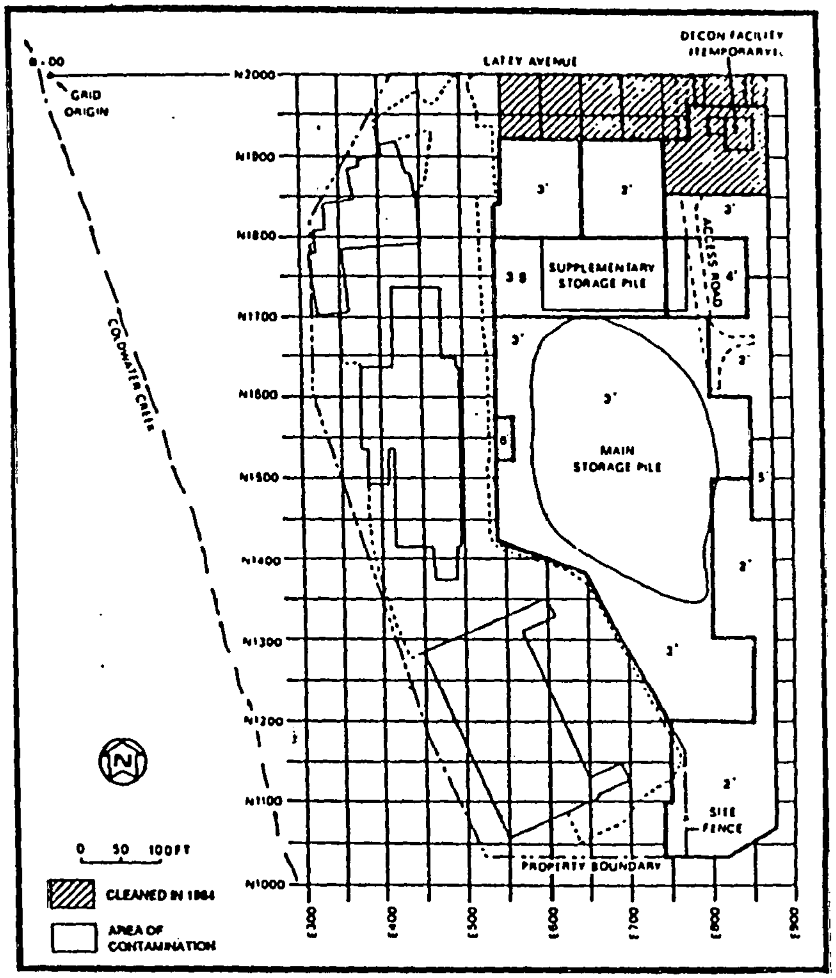


FIGURE A.53 Areas and Depths of Radioactive Contamination at HISS

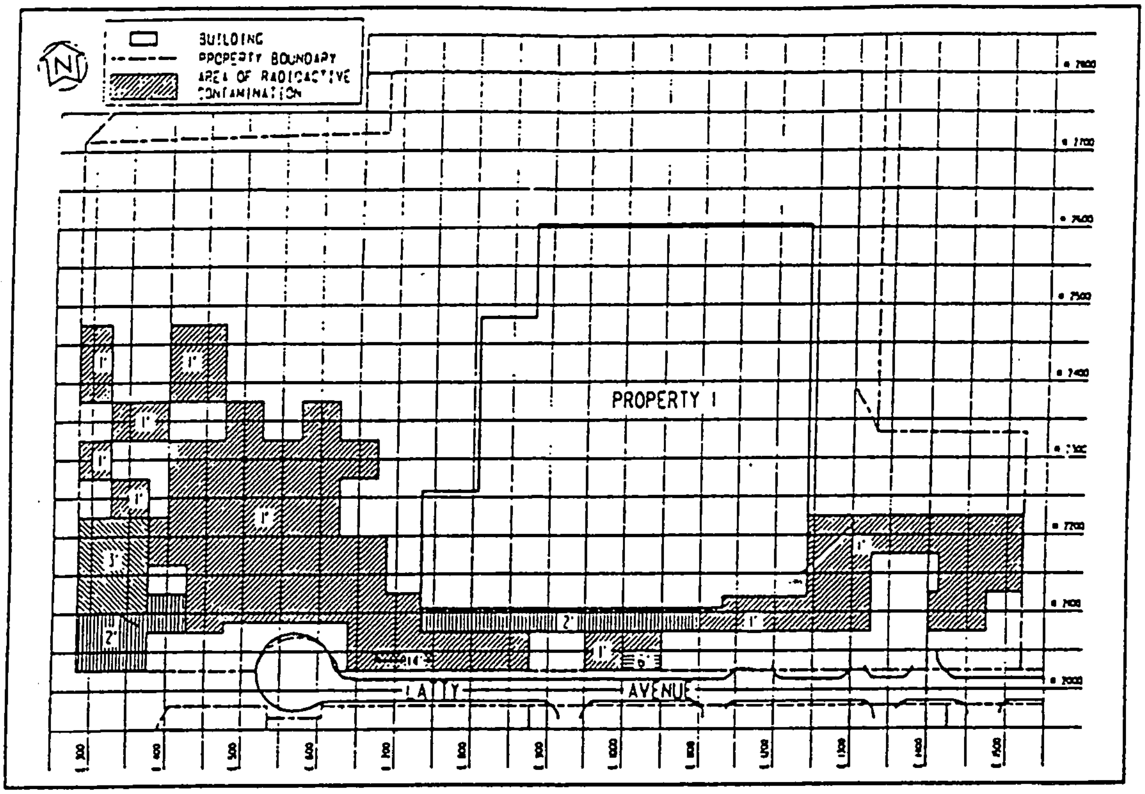


FIGURE A.54 Areas and Depths of Radioactive Contamination at Property 1 on Latty Avenue

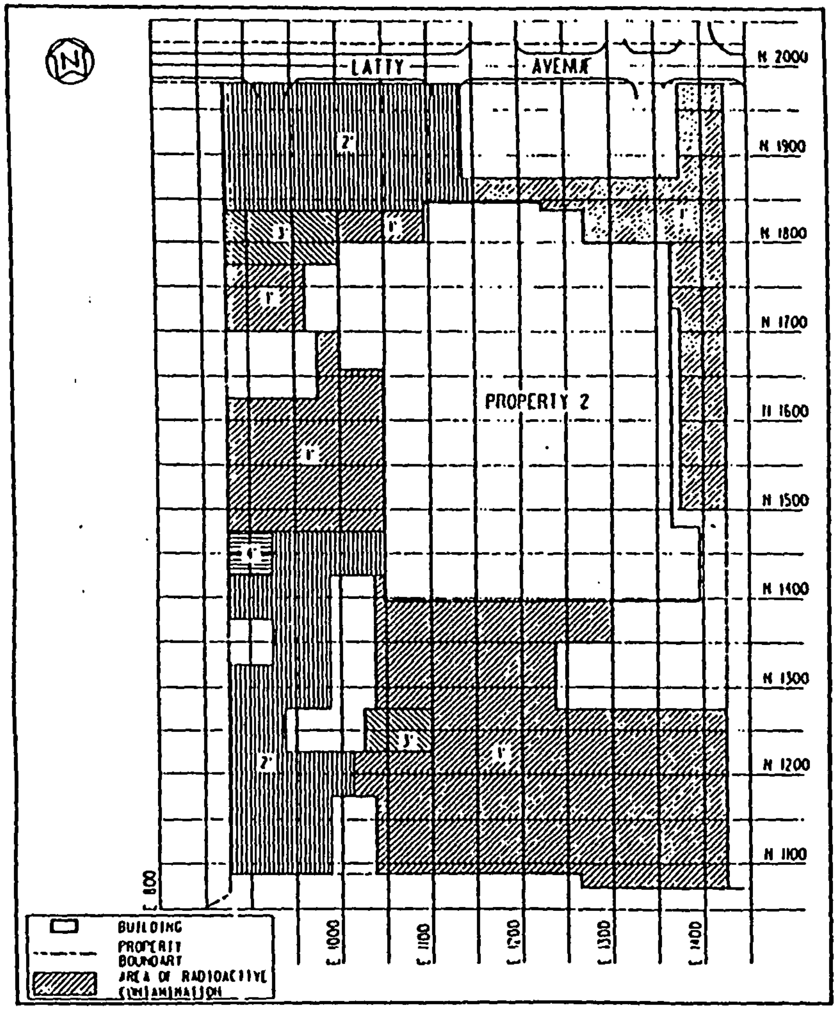


FIGURE A.55 Areas and Depths of Radioactive Contamination at Property 2 on Latty Avenue

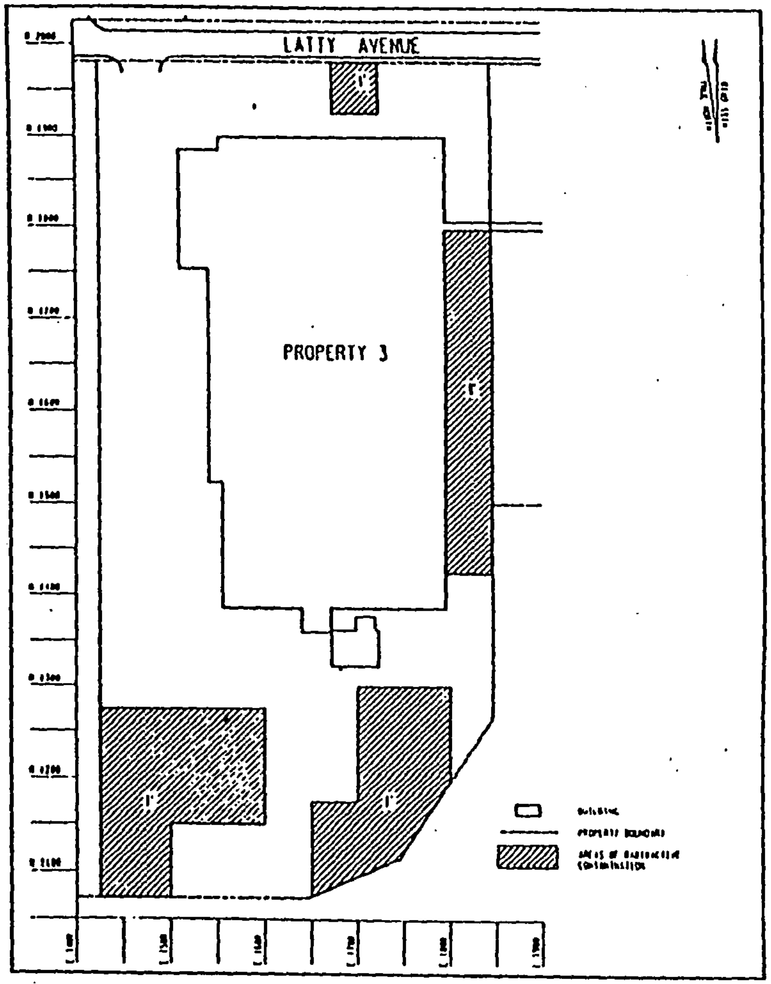


FIGURE A.56 Areas and Depths of Radioactive Contamination at Property 3 on Latty Avenue

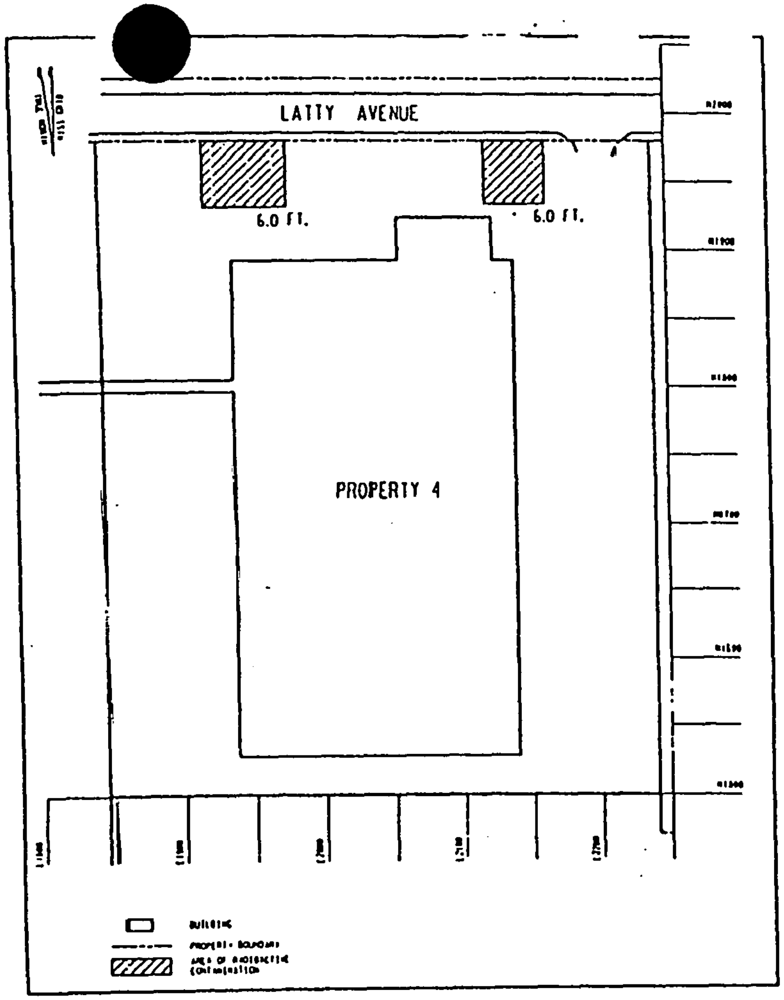


FIGURE A.57 Areas and Depths of Radioactive Contamination at Property 4 on Latty Avenue

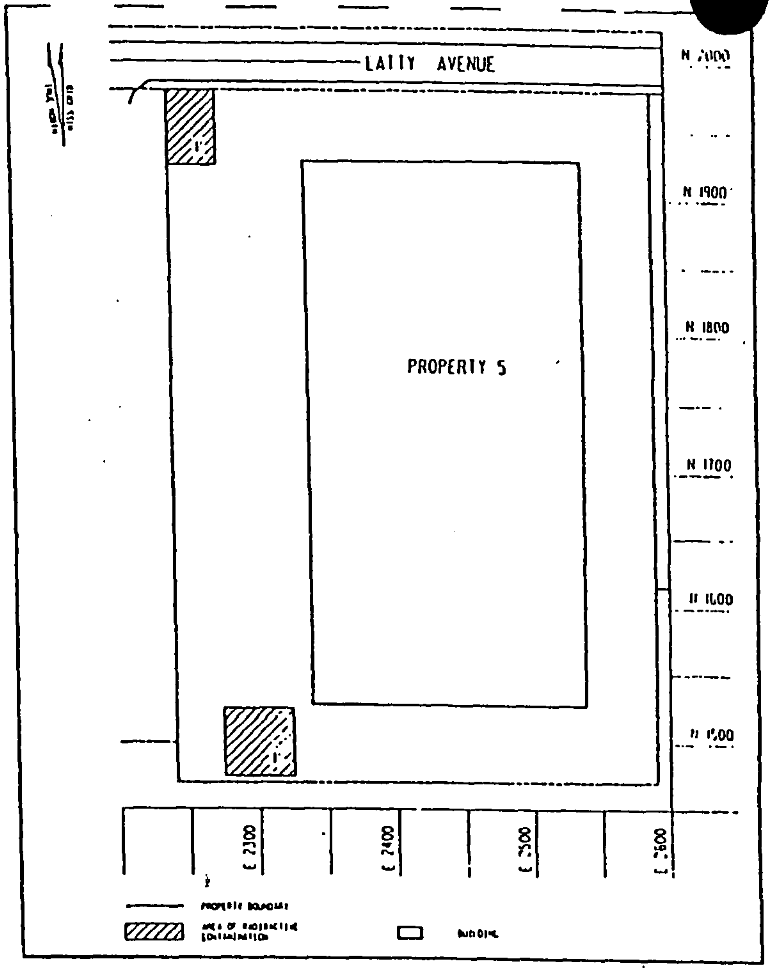


FIGURE A.58 Areas and Depths of Radioactive Contamination at Property 5 on Latty Avenue

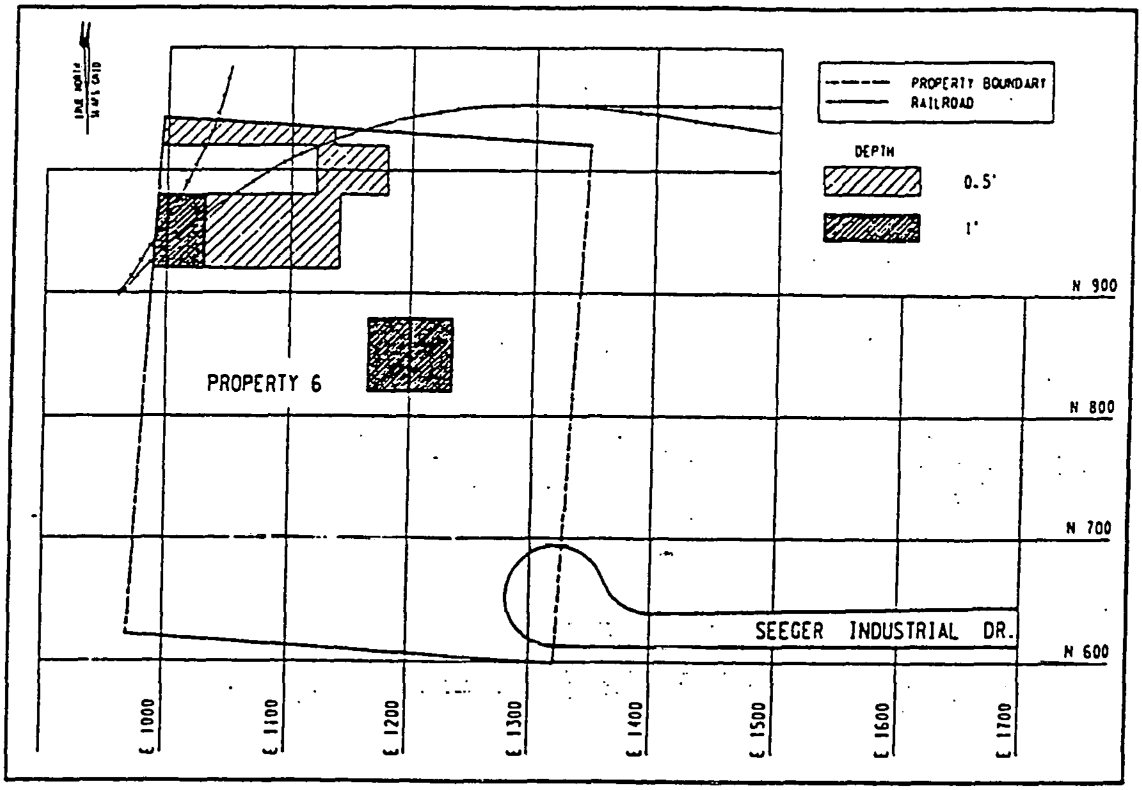


FIGURE A.59 Areas and Depths of Radioactive Contamination at Property 6 on Seeger Industrial Drive

APPENDIX B:

TOXICITY ASSESSMENT FOR INDIVIDUAL CONTAMINANTS OF CONCERN AT THE ST. LOUIS SITE

APPENDIX B:

TOXICITY ASSESSMENT FOR INDIVIDUAL CONTAMINANTS OF CONCERN AT THE ST. LOUIS SITE

Available toxicity data for the contaminants of concern at the St. Louis Site with respect to human health are summarized in this appendix. Data are also summarized for chemical contaminants with significant potential for adversely affecting biota. Toxicity to biota is considered for substances that are chemical contaminants of concern for soil or surface water but is not considered for contaminants of concern in groundwater because biota are not exposed to groundwater. The toxicity to biota of radioactive contaminants is not specifically addressed. The National Council on Radiation Protection and Measurements (1991) supports the statement of the International Commission on Radiological Protection (ICRP) that "if man is adequately protected then other living things are also likely to be sufficiently protected" (ICRP 1977).

B.1 RADIOACTIVE CONTAMINANTS OF CONCERN

Elements in the uranium-238, thorium-232, and uranium-235 (actinium) radioactive decay series are the radioactive contaminants of concern at the St. Louis Site. Human toxicity characteristics of soluble actinium, bismuth, lead, polonium, protactinium, and thallium are briefly described in this section because available data are limited. Toxicity characteristics of soluble radium, radon, thorium, and uranium are described in detail because more extensive data are available. For the insoluble radionuclides, inhalation is the primary pathway of concern for human health; insoluble nuclides that are ingested usually pass through the body and are excreted.

B.1.1 Actinium

Actinium-227 is an alpha, beta, and gamma emitter, and actinium-228 is a beta and gamma emitter. When ingested, a small fraction of actinium is absorbed from the gastrointestinal tract and the remainder is excreted. For inhalation and ingestion, the primary organ of health concern is the bone surface (ICRP 1979-1982).

B.1.2 Bismuth

Bismuth-210, -211, and -214 are alpha, beta, and gamma emitters. For inhalation and ingestion of soluble materials, bismuth is primarily deposited in the kidneys, with secondary deposition in the spleen, bone, liver, and lungs. In the blood stream, bismuth is rapidly cleared and excreted or transferred to other organs of the body (ICRP 1979-1982).

B.1.3 Lead

Lead-210, -211, -212, and -214 are primarily beta and gamma emitters. For inhalation and ingestion of soluble materials, the primary organ of health concern is bone. Secondary sites of deposition include the liver and kidneys (ICRP 1979-1982).

B.1.4 Polonium

Polonium isotopes are primarily alpha emitters. Polonium-210 is the only isotope that has a long enough half-life to appreciably accumulate in the body. Polonium-214 and polonium-218 are short-lived decay products of radon-222 and contribute a substantial fraction of the radiation dose from inhaled radon decay products. Unlike other alpha emitters, animal studies have shown that polonium concentrates in the reticuloendothelial system, kidneys, and blood cells (ICRP 1979-1982; National Research Council 1988).

B.1.5 Protactinium

Protactinium-231 is an alpha and gamma emitter, and protactinium-234 is a beta and gamma emitter. Like actinium, only a small fraction of ingested protactinium is absorbed from the gastrointestinal tract. For inhalation and ingestion, protactinium entering the blood is primarily deposited in bone; secondary sites of deposition are the liver and kidneys (ICRP 1979-1982).

B.1.6 Radium

Radium is a radioactive decay product of uranium and thorium, and it also produces decay products that are radioactive. Radium is an alpha, beta, and gamma emitter. After ingestion or inhalation of radium, the effects on human health may be attributed not only to radium itself but to the presence of any or all of its decay products and their radioactive emissions in vivo (National Research Council 1988). Most of the available information on the toxicity of radium was obtained from studies of radium dial painters exposed to radium-226 and radium-228 and from German studies of repeated injection of radium-224 into patients for treatment of tuberculosis or ankylosing spondylitis in adults (National Research Council 1988).

When radium is taken into the body, its metabolic behavior is similar to that of calcium. Upon inhalation, the deposition of radium dust particles in the lungs depends on particle size. The larger particles deposit on the mucous lining of the nasopharynx and upper respiratory tract, whereas the smaller particles tend to be inhaled deeper into the lungs. Particles deposited on the mucous lining are generally swallowed and pass through the gastrointestinal tract. Most of the radium will remain in the lungs for months, but it will gradually enter the bloodstream and be continually deposited in the bones and excretory system. When radium is ingested, about 80% leaves the body in the feces; the other 20%

ters the bloodstream and is carried primarily to bone (Agency for Toxic Substances and sease Registry [ATSDR] 1990c).

Studies of the radium dial painters have shown that chronic exposure to radium can result in the induction of bone sarcomas. After the first exposure, the minimum latency eriod is 5 years for radium-224 and 7 years for radium-226 and radium-228, but tumors can ontinue to appear throughout a lifetime (National Research Council 1988). Compared with radium-226, radium-228 has been estimated to be about 2.5 times more effective per icrocurie in inducing bone sarcomas (ATSDR 1990c). Carcinomas in the paranasal sinuses and mastoid air cells (often called head cancers) have also been observed after exposure to radium-226 or to radium-226 in combination with radium-228. In this case, cause is ttributed to the generation of radon-222 by radioactive decay of radium-226 and subsequent irradiation of the sinuses and mastoid epithelial tissues by radon-222 and its decay products.

B.1.7 Radon

Radon has several isotopes, but radon-222 has the most significant impact on human health. Radon-222 is a naturally occurring radioactive gas formed from the radioactive decay of radium-226. It is a short-lived alpha emitter that decays into four short-lived radioactive ecay products, all of which are heavy metals. Two decay products, polonium-218 and polonium-214, are alpha emitters; two others, lead-214 and bismuth-214, are beta and gamma tters. The health hazard from radon-222 is primarily related to its alpha-emitting dioactive decay products (National Research Council 1988). Most of the toxicity information on radon-222 comes from studies of workers exposed to radon and radon decay roducts in mines, primarily uranium mines, and from tests on laboratory animals (National esearch Council 1988; ATSDR 1990d).

The primary route of exposure to radon and its decay products is inhalation. Radon decay products attach to aerosol particles and are inhaled with the particles. Most of the radon gas is breathed out again; however, some radon and most of its decay products remain the lungs for a period of time and undergo radioactive decay. The decay products that are attached to dust particles deposit on the mucous lining of the respiratory tract and are eventually expelled. Unattached decay products tend to be inhaled deeper into the lungs here clearance is slower. The alpha radiation released during this process can damage the cells lining the airways, potentially leading to lung cancer. Epidemiological studies of anium miners have shown a clear connection between elevated radon exposure and lung ncer incidence (National Research Council 1988). An increased frequency of chronic, nonmalignant lung diseases, such as emphysema and pulmonary fibrosis, was also observed nong miners in the United States. However, these miners were exposed to many other hazardous substances, along with high levels of radon, so it is difficult to isolate which effects were due to radon alone (ATSDR 1990d).

B.1.8 Thallium

Thallium-207 and -210 are beta and gamma emitters. For inhalation or ingestion, thallium entering the blood is quickly and uniformly distributed throughout all organs and tissues of the body (ICRP 1979-1982).

B.1.9 Thorium

Contaminants at the St. Louis Site include thorium-232 and thorium-230. Most thorium compounds are insoluble, bind to soil particles, and do not evaporate from soil or water into the air (ATSDR 1990e). Thorium-232 and thorium-230 are primarily alpha-emitting radionuclides. Thorium-232 undergoes radioactive decay to produce radium-224, and the alpha emitters from decay of radium-224 are biologically the most important radionuclides in the thorium decay series. Most available literature on thorium toxicity is from studies of patients injected with thorotrast (colloidal thorium-232 dioxide), a radiographic contrast medium used between the years of 1928 and 1955 (ICRP 1979-1982; National Research Council 1988; ATSDR 1990e).

Inhalation is the major pathway by which thorium enters the body. Although some chemical forms of thorium can stay in the lungs for long periods of time, most thorium left in the lungs will be absorbed and leave the body in feces and urine within a few days. Most ingested thorium leaves the body through the feces; thorium remaining in the body migrates to bone surfaces (National Research Council 1988).

Epidemiological studies of patients injected with thorotrast are ongoing in Germany, Denmark, Portugal, Japan, and the United States. Currently, studies of about 4,000 patients show the induction of primarily liver cancers, bone sarcomas, and leukemia, with liver cancer the most prevalent effect (National Research Council 1988; ATSDR 1990e).

B.1.10 Uranium

Natural uranium consists of three isotopes: uranium-238, uranium-235, and uranium-234. In natural uranium, uranium-238 accounts for about half the total activity and uranium-234 and uranium-235 account for the other half. Uranium is an alpha and gamma emitter. The primary health risk from soluble uranium is related to its chemical, not its radiological, properties (ATSDR 1990b). (See Section B.2.1.17 for further discussion of the chemical toxicity of uranium.)

When uranium is inhaled, deposition of uranium dust particles in the lungs depends on particle size, and absorption into the bloodstream depends on the solubility of the compound. Once in the bloodstream, uranium is stored uniformly in the bone (ATSDR 1990b). When uranium is ingested, a little enters the blood but most is eliminated in the feces within a few days (ICRP 1979-1982). The majority entering the bloodstream is eliminated in the urine within a few days, and most of the remainder that goes to the idneys or bones is also eliminated within a few days. However, a small amount of ingested ranium may remain in the body for years (National Research Council 1988).

No human or animal studies have definitely linked inhalation or ingestion exposure to natural uranium with the induction of cancer. Although uranium miners have developed lung cancers that are mainly attributable to exposure to radon and its decay products and to synergistic effects with cigarette smoking, it is possible that one could develop cancer from swallowing or breathing large amounts of uranium (National Research Council 1988).

B.2 CHEMICAL CONTAMINANTS OF CONCERN

Several metals, the inorganic anions fluoride and nitrate, and several organic compounds are the chemical contaminants of concern for the St. Louis Site. Toxicity values have been derived by EPA for most of the chemical contaminants of human health concern. A toxicity value known as the reference dose (RfD) is used to evaluate the noncarcinogenic effects of chemicals. The chronic RfD is defined as "an estimate of a daily exposure level for he human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime" (EPA 1989a). Subchronic RfDs are used to evaluate shorter exposures, i.e., those that occur over periods of 2 weeks to 7 years. To derive an RfD value (expressed in mg/kg-d), EPA reviews all toxicity studies available for a given substance and a given route of exposure, determines a no-observed-adverse-effect l (NOAEL) or a lowest-observed-adverse-effect level (LOAEL) from the study most evant to humans (the critical study), and applies uncertainty factors to these values. The RfD values can be compared with estimated exposure levels to evaluate the potential for eleterious effects.

Currently available RfD values are specific to either the inhalation or ingestion route f exposure because the toxic mechanism and dose required for toxicity to occur can differ for hese routes of exposure. Oral RfDs currently approved by the EPA are available for the inorganic contaminants of concern, except cobalt and lead; and for the organic contaminants concern, except benzene, carcinogenic polycyclic aromatic hydrocarbons (PAHs), 1,2-dichloropropane, polychlorinated biphenyls (PCBs), trichloroethene, and vinyl chloride. Inhalation RfDs are available for only three of the organic contaminants and three of the organic contaminants of concern.

Carcinogenic risks from exposure to known and potential carcinogens were evaluated parately from noncarcinogenic risks because, hypothetically, any exposure to a carcinogen increases the risk of cancer by some finite amount. Therefore, the risk from exposure to a rcinogen at a given level can be derived, but an exposure level at which no carcinogenic fect is likely to occur (as for noncarcinogenic end points) cannot be defined. The EPA has defined two toxicity values for evaluating the potential carcinogenic effects of a given tance: the weight-of-evidence classification and the slope factor. For substances that e weight-of-evidence classifications of A (human carcinogen), B1 or B2 (probable human rcinogens), and sometimes C (possible human carcinogens), the EPA has calculated slope ctors on the basis of data from dose-response studies. The slope factor is defined as a "plausible upper-bound estimate of the probability of a response (i.e., cancer) per unit int[illegible] of a chemical over a lifetime" (EPA 1989a). Generally, slope factors are derived by extrapolation from experimental high dose ranges to low doses, and they are not valid for the evaluation of high dose levels. Also, carcinogenic risks that have been calculated from slope factors are applicable to exposures that occur over a lifetime. When exposure durations are less than a lifetime, they must be converted to equivalent lifetime values.

Several of the metals and organic contaminants of concern for the St. Louis Site have EPA weight-of-evidence classifications of A, B1, or B2. The metals cadmium, chromium, and nickel are classified as inhalation carcinogens only (evidence for carcinogenicity by the oral route is inadequate). Except for benzo(a)pyrene, slope factors have not been derived for the carcinogenic PAH compounds. No oral or inhalation slope factor is available for lead, and inhalation slope factors have not been determined for bis(2-ethylhexyl)phthalate, 1,2-dichloropropane, or the PCBs.

Metals are usually found in the environment as compounds (e.g., oxides, sulfates, and chlorides). A key factor in the toxicity of metal compounds in soil is their solubility; insoluble compounds may be quite poorly absorbed from the respiratory and digestive tracts. However, methods for analyzing the metal content of soil samples yield only the total metal concentration and give no information on specific metal compounds present. Separate RfD values and slope factors are sometimes derived for metal dusts and soluble metal salts. Where toxicity values for dusts were available (i.e., nickel), these values were cited in this assessmen[illegible] because they are most comparable to the possible exposure scenarios at the St. Louis Site. Otherwise, values for compounds of the metal were used in evaluating metal toxicity.

Only a few EPA-verified inhalation RfD values are available for the chemical contaminants of concern at the St. Louis Site. The EPA is currently developing inhalation RfD values for various elements and compounds and recommends that, until these inhalation RfD values have been verified, the noncarcinogenic effects from inhalation of substances without verified inhalation RfD values be evaluated qualitatively.

The uncertainty associated with the use of chronic RfD values varies by chemical. Once the critical study and NOAEL have been identified for a chemical, the NOAEL may be divided by various uncertainty factors, depending on the applicability of the critical study to human populations. If the NOAEL was based on human data, it will generally be divided by a factor of 10 to account for sensitive human subpopulations. If the NOAEL was based on animal data, it will be divided by an additional factor of 10, so as to be protective in the event that humans are more sensitive to the substance than the animal species tested. Additional 10-fold uncertainty factors may be added when a LOAEL is used instead of a NOAEL or to account for the extrapolation from subchronic to possible chronic exposure when the critical study is for less than a lifetime. Finally, an additional modifying factor of between 1 and 10 may be used to reflect scientific judgment when there are uncertainties in the study or database that are not reflected by the uncertainty factors detailed above (i.e., for sensitive human subpopulations or for use of animal data, LOAELs, or subchronic toxicity data).

The degree of uncertainty associated with the RfD values for each of the contaminants of concern is dependent on the above factors specific to the critical study; on the consistency of the toxic responses observed in different species, sexes, and study designs; and on the dose-response relationships observed in different studies (EPA 1989a). Substances listed in the EPA *Integrated Risk Information System* (IRIS) database have confidence levels associated with the reported RfD values; confidence levels of medium or high generally indicate that the toxicity value is not likely to change; however, RfDs with low confidence levels could change as more toxicity data become available. Of the inorganic substances evaluated in this assessment, the chronic RfDs for antimony, thallium, and uranium have incorporated uncertainty factors of 1,000 or more; and RfD values for antimony, beryllium, chromium, and thallium are associated with low confidence levels. All of the RfDs for organic ontaminants except DDT (4,4′-dichlorodiphenyltrichloroethane) and toluene have incorporated uncertainty factors of 1,000 or more. These large uncertainty factors provide onfidence that exposure levels less than the RfD values are unlikely to cause toxic effects. However, the RfD value may actually be much lower than the level that causes any toxic effect in sensitive human subpopulations.

The cancer slope factors are estimated through the use of statistical models that extrapolate from cancer risk at high-level occupational exposures (or high doses used with xperimental animals) to estimate risk at low exposure levels likely for human contact in the environment. The 95% upper confidence limit (UL_{95}) of the slope calculated with these models is used as the slope factor. The use of high-dose data to infer carcinogenic potency low dose levels may not be valid in all cases because the mechanism of biological action may differ at high and low doses.

The available toxicity data for the chemical contaminants of concern at the St. Louis Site are summarized in Sections B.2.1 through B.2.3. For each contaminant, information is provided on studies used to derive chronic RfD values or slope factors, on toxic effects that might occur at exposure levels higher than those of the RfDs, and on the efficiency with which humans can absorb these substances from the intestinal tract and lungs or through the skin. The primary references used for human health data for these toxicity summaries re given in Table B.1. For chemical contaminants with significant potential for adversely affecting biota, information on ecological toxicity is also summarized.

B.2.1 Metals

B.2.1.1 Antimony

Human Health. Antimony is generally found in U.S. soil as sulfide and oxide compounds at concentrations of less than 1 mg/kg. Antimony is used industrially in many ways and also has been administered orally to humans and animals as an emetic and an antiparasitic agent.

TABLE B.1 Primary Human Health Toxicology References for Contaminants of Potential Concern at the St. Louis Site

Contaminant	Reference(s)
Radionuclides and metals	
Actinium	ICRP (1979-1982)
Antimony	Shacklette and Boerngen (1984); Klaasen et al. (1986); Seiler et al. (1988); EPA (1992)
Arsenic	Shacklette and Boerngen (1984); ATSDR (1989a); EPA (1991a, 1992)
Barium	Shacklette and Boerngen (1984); EPA (1991a, 1992); ATSDR (1992a)
Beryllium	Shacklette and Boerngen (1984); ATSDR (1988a); Seiler et al. (1988); EPA (1992)
Bismuth	ICRP (1979-1982)
Boron	Shacklette and Boerngen (1984); Seiler et al. (1988); ATSDR (1992b); EPA (1992)
Cadmium	Seiler et al. (1988); ATSDR (1989b); EPA (1992)
Chromium	Shacklette and Boerngen (1984); ATSDR (1989e); EPA (1992)
Cobalt	National Academy of Sciences (1977); Shacklette and Boerngen (1984); Klaasen et al. (1986)
Copper	National Academy of Sciences (1977); Shacklette and Boerngen (1984); EPA (1984a, 1991a, 1992); Klaasen et al. (1986); Seiler et al. (1988)
Lead	ICRP (1979-1982); Shacklette and Boerngen (1984); Seiler et al. (1988); ATSDR (1990a); EPA (1991b, 1992)
Manganese	Shacklette and Boerngen (1984); ATSDR (1992c); EPA (1992)
Molybdenum	National Academy of Sciences (1977); Venugopal and Luckey (1978); Shacklette and Boerngen (1984); Klaasen et al. (1986); Seiler et al. (1988)
Nickel	Shacklette and Boerngen (1984); Klaasen et al. (1986); Seiler et al. (1988); ATSDR (1988b); EPA (1992)
Polonium	ICRP (1979-1982); National Research Council (1988)
Protactinium	ICRP (1979-1982)
Radium	ICRP (1979-1982); National Research Council (1988); ATSDR (1990c)
Radon	ICRP (1979-1982); National Research Council (1988); ATSDR (1990d)
Selenium	Shacklette and Boerngen (1984); EPA (1984c, 1991a); Klaasen et al. (1986); Seiler et al. (1988); ATSDR (1989d)

TABLE B.1 (Cont.)

Contaminant	Reference(s)
Radionuclides and metals (cont.)	
Silver	Shacklette and Boerngen (1984); ATSDR (1990g); EPA (1991a)
Thallium	Venugopal and Luckey (1978); ICRP (1979-1982); Klaasen et al. (1986); Seiler et al. (1988); EPA (1991a, 1992)
Thorium	ICRP (1979-1982); National Research Council (1988); ATSDR (1990e)
Uranium	ICRP (1979-1982); Shacklette and Boerngen (1984); National Research Council (1988); Seiler et al. (1988); ATSDR (1990b); EPA (1992)
Vanadium	Schroeder et al. (1970); National Academy of Sciences (1977); Venugopal and Luckey (1978); Shacklette and Boerngen (1984); Klaasen et al. (1986); Seiler et al. (1988); EPA (1991a)
Zinc	Shacklette and Boerngen (1984); ATSDR (1989f); EPA (1991a)
Inorganic anions	
Fluoride	Seiler et al. (1988); EPA (1992)
Nitrate	National Academy of Sciences (1977); EPA (1992)
Organic compounds	
Benzene	ATSDR (1989g); EPA (1992)
Bis(2-ethylhexyl) phthalate	Klaasen et al. (1986); EPA (1992)
Chlorobenzene	ATSDR (1990h); EPA (1992)
DDT	ATSDR (1989h); EPA (1992)
1,2-Dichlorobenzene	EPA (1992)
1,2-Dichloroethene	ATSDR (1990i); EPA (1991a, 1992)
1,2-Dichloropropane	ATSDR (1989i); EPA (1991a)
Endosulfan	ATSDR (1993); EPA (1992)
PAHs	ATSDR (1990f); EPA (1991a)
PCBs	ATSDR (1989j); EPA (1992)
Toluene	ATSDR (1989k); EPA (1992)
Trichloroethene	ATSDR (1989c); EPA (1991a)
Vinyl chloride	ATSDR (1989*l*); EPA (1991a)

The oral RfD for antimony, 0.0004 mg/kg-d, was determined on the basis of a st in which rats were administered 5 ppm potassium antimony tartrate in water (Schroede et al. 1970; EPA 1992). Toxic effects noted during the study were decreased longevity and alterations in blood glucose and cholesterol levels. The confidence level for the RfD is low because only one species and one dose level were used in the study, a NOAEL was not determined, and gross pathology and histology were not described adequately.

Toxic effects associated with occupational exposure to antimony have been observed in humans at exposure levels higher than the RfD. In one study, women employed at an antimony plant experienced an increased incidence of spontaneous abortion compared with a control group. Acute inhalation exposure can cause severe cardiac effects, and chronic inhalation causes obstructive lung disease. Antimony accumulates in lung tissue, and dermal exposure can cause irritation, resulting in transient skin eruptions. Absorption of ingested antimony is slow, and antimony compounds can induce vomiting.

Biota. Background soil concentration of antimony in Missouri soils is 0.5 ppm, whereas the mean values at the St. Louis Site areas range from 8.1 to 98.0 ppm (Table 2.8). Antimony concentrations in soil within 2 km of an antimony smelter range from 50 ppm to nearly 1,500 ppm (Ainsworth et al. 1990a). Ainsworth et al. (1990a) suggest that antimony concentrations in plants are largely due to aerial deposition and are not the result of uptake from the soil. In areas of marked contamination, bioaccumulation of antimony in the fo chain or accumulation of this metal by herbivorous mammals is limited (Ainsworth et 1990b).

Inhalation of antimony is generally more toxicologically potent than ingestion. Acute toxicity has been reported at oral doses of more than 100 mg/kg body weight (Browning 1969). This information indicates that antimony contamination at the St. Louis Site should be of minimal ecological concern to terrestrial biota, despite the elevated soil concentrations (i.e., over 310 ppm at the city property).

Chronic and acute toxicity of antimony to freshwater aquatic biota can occur at concentrations as low or lower than 9.0 and 16 ppm, respectively. Toxicity to algae occurs at concentrations as low as 0.6 ppm (EPA 1986).

B.2.1.2 Arsenic

Human Health. Arsenic is found in U.S. soil at an average concentration of about 7 mg/kg. Arsenic compounds are widely used as pesticides. Although inorganic arsenic compounds have been used as poisons for centuries, 1 to 10 µg/kg-d arsenic is thought to be essential in the human diet.

Arsenic is classified by the EPA as a known human carcinogen. A significant increase in lung cancer mortality has been observed in several studies of smelter workers p[illegible] to arsenic. The EPA has derived an inhalation unit risk of 4.3×10^{-3} µg/m^{3} on the [illegible] these studies; this value can be converted to a slope factor of 15 (mg/kg-d)$^{-1}$. n ction of elevated levels of arsenic in drinking water has been associated with increased in cancer incidence in several foreign populations. This effect has not been observed in .S. populations, but the U.S. studies lacked statistical power because of the small sample ze. An oral slope factor of 1.75 (mg/kg-d)$^{-1}$, based on a Taiwanese population (Tseng 1977), s been derived but not yet adopted by the EPA.

An oral RfD of 0.001 mg/kg-d has been estimated for arsenic in drinking water on basis of levels that are essential in the human diet. The National Academy of Sciences 1983) maintains that, because the human dietary requirement for arsenic is not currently t in the United States, it would be inappropriate to limit arsenic in drinking water to els dictated by the oral slope factor.

Arsenic is well absorbed via both ingestion and inhalation, but minimal dermal sorption occurs. Noncarcinogenic toxic effects from ingestion of arsenic at levels greater han about 20 µg/kg-d include severe irritation of the gastrointestinal tract, anemia, generation of the nerves, skin disorders, and toxicity to the liver, kidney, and heart. ermal contact with concentrated arsenic compounds could produce severe skin irritation.

Biota. Most soil has arsenic concentrations of less than 15 ppm (Eisler 1988a). The ve[illegible]background concentration of arsenic in Missouri soil is 8.7 ppm, whereas the mean [illegible]t the St. Louis Site range from 15 to 35 ppm (Table 2.8). Soil with an arsenic oncentration of 100 to 200 ppm can reduce growth and cause toxic symptoms in plants, and nts might be affected at soil concentrations as low as 25 ppm. However, arsenic toxicity ighly dependent on the chemical form and oxidation state of the element; water-soluble rms are more toxic than forms that bind to soil (Peterson et al. 1981). Therefore, it cannot generalized that plants will exhibit an increased arsenic content if the soil concentrations rsenic increase. However, all forms of arsenic can cause inhibition of cellular respiration owler 1977). Sensitive soil microbes experience reduced growth and metabolism at soil centrations of 375 ppm, whereas tolerant species can withstand concentrations as high s 1,600 ppm. At concentrations of 150 to 165 ppm, soil was found to be devoid of thworms, and bacteria and protozoan densities were reduced.

Because of the widespread existence of arsenic, it is readily taken into animals via ter or food; animals can accumulate abnormal levels of arsenic if the environment is taminated (Dickerson 1980). Wildlife are exposed to arsenic primarily by ingestion of ontaminated food and water, but inhalation and absorption through skin and mucous mbranes also occur (Eisler 1988a). Chronic arsenic poisoning from continuous ingestion small doses of arsenic is rare because detoxification and excretion are rapid. Rats and dogs rvived when fed sodium arsenate or sodium arsenite in their diet for 2 years at concen- [illegible] up to 400 ppm (Byron et al. 1967). Therefore, arsenic poisoning in animals is er[illegible]y caused by acute or subacute exposures. Several studies have demonstrated that arsenic is teratogenic in small animals. Although arsenic has been found to be carcinoge[illegible] in humans, evidence of carcinogenicity in other animals is limited (Eisler 1988a).

Arsenic is bioconcentrated but is not biomagnified. Susceptible species of mammals can be adversely effected at dietary levels of 50 ppm. However, it is doubtful that humans (or other animals) can experience arsenic toxicity as a result of eating contaminated plants because plants grown in high arsenic-containing soils show little growth (Dickerson 1980).

In summary, the following arsenic concentrations are toxic to terrestrial biota: plants, 25 ppm or higher; birds, more than 17 mg/kg body weight (mostly several hundred milligrams per kilogram [mg/kg] body weight); and mammals, 50 mg/kg body weight range. Toxic concentration levels can vary greatly, depending on wildlife species and formulation of arsenic. Thus, soil concentrations at the St. Louis Site are within the range that could be deleterious to biota.

Background concentrations for arsenic in water are less than 10 ppb (Eisler 1988a), and sediment concentrations are about four orders of magnitude greater than concentrations in overlying water (Dickerson 1980). Arsenic has been detected in Coldwater Creek at concentrations of ≤20 ppb in water samples (Rains 1981) and at a mean concentration of 22 ppm in sediment samples (Table 2.10). Adverse effects to aquatic organisms have been reported at water concentrations of 19 to 48 ppb (Eisler 1988a). Inorganic arsenic (V) is acutely toxic to freshwater animals at a concentration of 850 ppb (EPA 1986). Concentrations greater than or equal to 30 ppm in aquatic vegetation could alter the growth, development, and physiology of ducklings (Camardese et al. 1990). At a concentration of 85 ppb, 10 to 32% mortality of amphipods occurred over a 28-day period (Eisler 1988a). Fish exposed to 1.0 to 2.0 ppm total arsenic for 2 to 3 days showed hemorrhaging of the gills, fatty infiltration of the liver, and/or necrosis of the heart, liver, and ovarian tissues (Eisler 1988a). Arsenic concentrations in water generally decrease to background levels within a short distance downstream of an effluent, mostly complexing in the sediment (Dickerson 1980). The low bioconcentration factor and short half-life of arsenic in fish tissue indicate that residues should not be a problem to predators of aquatic life (EPA 1986). In summary, arsenic is generally toxic to algae at concentrations over 45 ppb, invertebrates at concentrations over 85 ppb, and fish and amphibians at concentrations over 40 ppb. Concentrations reported for Coldwater Creek are below the levels considered toxic.

B.2.1.3 Barium

Barium is a contaminant of concern at the St. Louis Site for groundwater only. Barium is found in U.S. soil at an average concentration of 580 mg/kg. Barium compounds are used by the oil and gas industries to make drilling muds; other uses include the manufacture of paint, glass, and ceramics. Certain barium compounds can be absorbed dermally, although inhalation of dusts and ingestion of barium compounds are the main exposure pathways.

A chronic oral RfD of 0.07 mg/kg-d was established for barium on the basis of a study [illegible] male volunteers were administered varying levels of barium in drinking water over 10-week period (Wones et al. 1990). During the study, no changes occurred in systolic or astolic blood pressure or in cardiac cycle at any dosage up to 10 mg/L. A chronic inhalation RfD of 0.0001 mg/kg-d is based on observed fetotoxicity in offspring of rats inhaling barium rbonate over a 4-month period.

An increased incidence of hypertension from exposure to high levels of barium, med baritosis, is a known health effect in humans. Workers exposed to barium dust perience this condition, although animals have not exhibited similar effects. Ingestion of rge amounts of barium also can cause damage to the liver, kidney, heart, and spleen. At y high exposure levels (i.e., 1,000 mg/L in drinking water), rats exhibited changes in the dney glomeruli.

B.2.1.4 Beryllium

Human Health. The average concentration of beryllium in uncontaminated .S. soil is about 1 mg/kg. Beryllium and its alloys are used in the electronics and nuclear ustries, among others. A major source of environmental beryllium is the combustion of oal and fuel oil; bituminous coal contains up to 3 ppm beryllium. In soil, beryllium is [illegible] found in insoluble, immobile forms.

Beryllium is rated by the EPA as a probable human carcinogen on the basis of epimiological studies of beryllium inhalation and animal studies of oral intake. Wagoner et 1980) investigated increased lung cancer rates (adjusted for smoking) in an occupationally xposed population, and an inhalation slope factor of 8.4 (mg/kg-d)$^{-1}$ was calculated from this ly (EPA 1992). An oral slope factor of 4.3 (mg/kg-d)$^{-1}$ was calculated from a study by roeder and Mitchner (1975), in which tumors increased at all sites in rats that drank ter containing 5 ppm beryllium over a lifetime. This study was also used to derive an oral of 0.005 mg/kg-d because no other adverse effects were observed. Confidence in the oral pe factor and RfD is considered low because only one nonzero dose group was included in study and because the increase in tumor incidence was not statistically significant. eral confounding variables also limit confidence in the epidemiologic study on which the halation slope factor is based. No carcinogenic response has been observed in any species wing dermal exposure to beryllium compounds.

Inhalation of beryllium oxide in industrial settings at levels greater than 2 µg/m^3 can to scarring of the lungs, shortness of breath, and reduction in lung volume. Beryllium pounds are poorly absorbed through the skin or from the digestive tract. Data on velopmental and reproductive toxicity are limited; however, in one study in which pregnant [illegible] administered 50 mg/kg beryllium oxide or beryllium chloride, an increase in fetal [illegible] and internal abnormalities in the offspring were noted.

Biota. Concentrations of beryllium in U.S. soil range from <1.0 to 15 ppm, with an average of 0.63 ppm (Kaplan et al. 1990). The average concentration in Missouri soil is 0.8 ppm, whereas the mean values at the St. Louis Site range from 0.94 to 1.7 ppm (Table 2.8). Beryllium readily complexes with organic compounds; it may accumulate in surface soil but remain relatively unavailable for uptake by plants. Furthermore, only 3% of beryllium uptake has been found to be translocated to aboveground portions of plants (Kaplan et al. 1990). Beryllium can adversely affect growth or be phytotoxic at nutrient concentrations of less than 2.0 ppm, particularly in acidic conditions. Under calcareous conditions, concentrations of beryllium up to 40 ppm have been shown to have no, or even beneficial, effects on plant growth (Peterson and Girling 1981). Kaplan et al. (1990) found that beryllium at concentrations of 4.0 ppm or less had no effect on germination of the collard *Brassica oleracea*, whereas concentrations of more than 4.0 ppm completely inhibited germination.

Less than 0.01% of ingested beryllium is absorbed from the gastrointestinal tract (Browning 1969), and there is no evidence in veterinary medicine of illness arising from the absorption of beryllium from conventional diets (Tepper 1980). Acute and chronic toxicity of beryllium to freshwater aquatic life occur at concentrations as low as 130 and 5.3 ppb, respectively (EPA 1986).

B.2.1.5 Boron

Boron is a contaminant of concern at the St. Louis Site for groundwater only. Boron is widely distributed in the environment; the average concentration in U.S. soil is 33 mg/kg. Boron and its compounds are used in many industrial applications, including the manufacture of glass, wood and leather preservatives, and cleaning and cosmetic products. Boron is found in coal and oil shale, and combustion of these products might contribute to environmental contamination with boron.

The chronic oral RfD for boron is 0.09 mg/kg-d, based on the NOAEL in a study in which dogs were administered 8.75 mg/kg-d boron in the diet for 2 years (Weir and Fisher 1972). At higher levels of boron exposure (e.g., 29 mg/kg-d), testicular lesions developed in the dogs.

At levels of 4 mg/m^3 boron dust in air, respiratory irritation occurs in humans, affecting the nose, throat, and eyes. Ingestion of very high levels of boron (e.g., 4,000 mg/kg in food) results in damage to the major organ systems or death. Dermal contact with boron dust can cause irritation of the skin but results in only minimal absorption into the bloodstream.

B.2.1.6 Cadmium

Human Health. Cadmium in the environment is usually found as stable mpounds of oxygen, chlorine, or sulfur; its concentration in uncontaminated U.S. soil is less han 1 mg/kg. Cadmium is used in metal plating, pigments, batteries, and plastics. The gest sources of cadmium release to the environment are the burning of fossil fuels, cineration of municipal wastes, and emissions from zinc, lead, and copper smelters.

Cadmium is classified as a probable human carcinogen by inhalation on the basis of ited epidemiological evidence and sufficient evidence from animal studies. The inhalation ope factor of 6.1 $(mg/kg\text{-}d)^{-1}$ is based on a two-fold excess of lung cancer observed in lmium smelter workers (Thun et al. 1985) and is supported by increased tumor incidence rats and mice exposed via inhalation or injection. The critical noncarcinogenic effect for lmium toxicity is kidney damage, as measured by proteinuria. A pharmacokinetic model s used to develop an oral RfD of 0.001 mg/kg-d for cadmium on the basis of the highest ncentration of cadmium in the human renal cortex not associated with significant teinuria (EPA 1992). The confidence in this RfD is high because of the vast quantity of nan and animal data on cadmium toxicity.

An oral dose of about 0.1 mg/kg-d cadmium or an inhalation dose of about 1 mg/m^3 uses severe digestive tract or lung irritation, respectively, but occurrences of these high [illegible]s are very uncommon. Effects in humans of long-term exposure to lower cadmium [illegible]g., 0.01 mg/kg-d) include kidney and liver damage and mineral loss in bone. Data om animal studies have shown an association between excess cadmium exposure and vated blood pressure, effects on fertility, and neurobehavioral development of newborns. se effects have not been adequately studied in humans. Cadmium is well absorbed from e lungs (30 to 50%), but it is poorly absorbed from the digestive tract (1 to 5%) and through skin.

Biota. The average background concentration of cadmium in Missouri soil is) ppm, whereas the mean values at the St. Louis Site range from 1.3 to 1.8 ppm able 2.8). On the basis of a literature review on metal effects to forest soil invertebrates, nium concentrations between 10 and 50 ppm in soil or litter are suggested as maximum owable metal concentrations that will cause no adverse effects (Bengtsson and Tranvik 89). Results of several studies indicate that soil cadmium concentrations of 26 to 885 ppm ably affect different groups of invertebrates by decreasing biomass, species numbers, or nsity (Tyler et al. 1989). Soil concentrations of 5.5 ppm in the litter layer and 2.9 ppm in nderlying soil were considered to be hazardous for insectivorous small mammals on the s of renal metal loads (Ma et al. 1991). However, mammals and birds are comparatively sistant to biocidal properties of cadmium. The lowest oral dose of cadmium resulting in [illegible] rats and guinea pigs ranged from 150 to 250 mg/kg body weight. Mallards and [illegible] tolerated dietary levels of 200 ppm for protracted periods (Eisler 1985).

Generally, concentrations of cadmium in water are <1.0 ppb (Wier and Walter 1976). The mean sediment cadmium concentration for Coldwater Creek is 1.1 ppm (Table 2.10), whereas water concentrations have been measured at <10 ppb (Rains 1981). Median cadmium bioconcentration factors for freshwater organisms are less than 100 times (fish bioconcentration factors are less than 20 times). No evidence exists in the literature for biomagnification of cadmium, and bioconcentration is only likely to be of significance for some gastropods and crustaceans (Taylor 1983).

Cadmium was found to be an algicide to *Selanastrum capricornutum* at 650 ppb. Growth inhibition was initiated at 50 ppb, and complete growth inhibition occurred at 80 ppb (Bartlett et al. 1974). On the basis of a literature review, cadmium toxicities to freshwater vascular plants range from effective concentrations of 10 ppb to LD_{50}* concentrations of 150 ppm (Outridge and Noller 1991). The acute toxicity of cadmium to the crayfish *Orconectes virilis* was found to vary from 6.1 ppm (96-hour LC_{50}*) to 0.70 ppm (14-day LC_{50}) to 0.06 ppm (incipient LC_{50}) (Mirenda 1986). For snails, the 96-hour TL_{50}* was 0.43 ppm for immature snails and 1.37 ppm for adults. The higher the cadmium concentration to which snails were exposed, the fewer the survivors, the lower the reproductive potential, and the shorter the period the young survived (Wier and Walter 1976). The cadmium 7-day LC_{50} for *Physa integra* was 114 ppb, and the 28-day LC_{50} was 10.4 ppb. The 28-day LC_{50} for *Ephemerella* sp. was <3.0 ppb (Spehar et al. 1978).

The acute cadmium toxicity concentrations for short-term (4 days or less) and long-term (20 to 100 days) toxicity tests with freshwater species from different trophic levels ranged from 0.02 to 11.1 ppm. The lowest no-toxic-effect concentrations were 0.37 ppb for crustaceans, 6.0 ppb for fishes, and 9.0 ppb for amphibians. On the basis of these test results, a water-quality criterion of 0.1 ppb was derived (Canton and Slooff 1982). Reported 48-hour LC_{50} values for cadmium nitrate were as follows: Tubificidae, 6.5 ppm; *Chironomus* gr. *thummi*, >56 ppm; *Erpobdella octoculata* (leech), 4.2 ppm; *Asellus aquaticus*, 0.5 ppm; *Lymnaea stagnalis*, 1.6 ppm; *Dugesia* cf. *lugubris*, >56 ppm; *Hydra oligactis*, 1.6 ppm; *Corixa punctata*, >56 ppm; *Gammaris pulex*, 0.08 ppm; *Ischnura elegans*, >56 ppm; *Nemoura cinerea*, 49 ppm; and *Cloeon dipterum*, 56 ppm; three species of *Daphnia*, 0.046 to 0.2 ppm; two mosquito species, 2.1 to 11.0 ppm; one *Hyrda* species, 1.6 ppm; one snail species, 1.6 ppm; four fish species, 0.15 to 115 ppm; and two amphibian species, 1.3 to 32.0 ppm (Slooff 1983; Slooff et al. 1983).

Significant reduction in the growth of Atlantic salmon alevins occurred at a cadmium concentration of 0.47 ppb. The LC_{50} for the interval from fertilization to viable hatch was estimated to be between 300 and 800 ppb. Newly hatched alevins had a 24-day LC_{50} between 1.5 and 2.7 ppm. Sensitivity increased sharply in late alevins, and significant mortality was recorded at a concentration as low as 8.2 ppb (Rombough and Garside 1982). Retarded early growth in brook trout occurred at 0.7 ppb (Christensen 1975), 3.4 ppb (Benoit et al. 1976), and 3.8 ppb (Eaton et al. 1978). The 200-hour LC_{50} for steelhead trout and chinook salmon

---

*LC_{50} is the concentration lethal to 50% of the exposed population; LD_{50} is the dose lethal to 50% of the exposed population; TL_{50} is the level toxic to 50% of the exposed population.

de[illegible]sed from >27 ppm for newly hatched alevins to 1.3 and 1.6 ppb at the swim-up stage [illegible]an 1978). Embryos and larvae of trout (brook, brown, and lake), northern pike, white ker, smallmouth bass, and coho salmon were killed or had retarded growth at cadmium oncentrations ranging from 4.0 to 12.0 ppb (Eaton et al. 1978).

The LC$_{50}$ for cadmium chloride for brook trout (*Salvelinus fontinalis*) varied from .2 ppm for 48 hours to 5.1 ppm for 96 hours (Holcombe et al. 1983). Cadmium LC$_{50}$ values r largemouth bass were 0.85 ppm for 56 days and 0.08 ppm for 82 days. For bluegills, .85 ppm cadmium killed half of the test organisms by 138 days, and no toxicity occurred ithin 6 months for cadmium concentrations of either 0.08 or 0.008 ppm (Cearley and oleman 1974). The calculated 70-day LC$_{50}$ for cadmium to the minnow *Phoxinus phoxinus* was 420 ppm, whereas the 4-day LC$_{50}$ was 39 ppm. After 14 days of exposure to 4,960 ppb dmium, the minnow exhibited humpback conditions. Vertebral damage also occurred at oncentrations between 7.5 and 960 ppb, but exposure periods were greater. Overall, 31 of 01 exposed minnows that survived 70 days of exposure had vertebral damage (Bengtsson al. 1975). Exposure of carp to cadmium concentrations of 10, 50, and 100 ppb caused ertebral column damage by days 47, 85, and 73, respectively (Muramoto 1981).

In the literature, cadmium concentrations between 0.8 and 9.9 ppb in water have een reported as lethal to several species of insects, crustaceans, and fish; concentrations of 7 to 5.0 ppb have been associated with sublethal effects such as decreased growth, inhibited production, and population alterations (Eisler 1985). It is conservatively estimated that d[illegible] effects to fish are pronounced or probable when cadmium concentrations exceed [illegible] in fresh water (Eisler 1985).

B.2.1.7 Cobalt

Cobalt is a relatively rare metal that is usually present in copper ores; its centration in U.S. soil averages about 9 mg/kg. Cobalt is used in alloys because of its agnetic properties, resistance to corrosion, and ability to withstand high temperatures.

Information on cobalt toxicity in humans is available from past administration of the etal to children with sickle cell anemia (to stimulate red blood cell production) and from its ef use as an antifoam agent in beer. The use of cobalt to treat sickle cell anemia was continued when the children developed goiters (enlargement of the thyroid gland). Its use beer was discontinued after several heavy beer drinkers died from congestive heart failure l it was determined that cobalt and alcohol exert synergistic toxic effects. On the basis hese experiences and data from animal studies, the National Academy of Sciences (1977) ncluded that doses of cobalt greater than 1 mg/kg might pose a health hazard to humans. EPA has not approved an oral RfD value for cobalt; however, the NOAEL value of mg/kg can be used with appropriate uncertainty factors to determine limits for cobalt in [illegible]ater, and soil.

Cobalt is well absorbed through both inhalation and ingestion, but it does not umulate in the human body and is easily excreted via the urine and feces. In humans, cobalt is an essential component of vitamin B12, which is required for the production of red blood cells; however, ingestion of cobalt at elevated levels causes an overproduction of red blood cells. Ingestion of elevated levels of cobalt also causes vomiting, diarrhea, and a sensation of warmth. Occupational inhalation of dust containing 0.1 mg/m^3 or more of cobalt can cause irritation of the pulmonary tract, eventually leading to more serious lung disease. Prolonged dermal contact with cobalt or its salts can cause an allergic skin reaction.

B.2.1.8 Copper

Human Health. Copper is an essential element for humans; deficiencies cause defective hemoglobin synthesis, leading to anemia. This metal is used extensively in the manufacture of electrical equipment, alloys, coins, and chemical apparatus. Copper occurs in U.S. soil at an average concentration of about 25 mg/kg.

Copper acts as a gastrointestinal irritant, and copper sulfate induces vomiting in children and adults (at concentrations of about 50 mg for children). A traditional oral RfD value for copper has not been approved by EPA because the toxicity of copper is low and 2 to 5 mg/d copper is essential for humans. However, an RfD-analogous value of 0.037 mg/kg-d can be derived from observation of the LOAEL for acute gastrointestinal symptoms in humans (EPA 1984a). In a study conducted to determine the carcinogenic effect of copper exposure in mice, no increased tumor incidence occurred in mice fed a copper compound, but an increased incidence of one type of tumor occurred in male mice injected with the copper compound. Copper is not classified by the EPA with respect to carcinogenicity because the EPA considers these animal data inadequate and because no human data are available (EPA 1992).

Less than half of dietary copper is absorbed, and the metal is poorly absorbed dermally. Ingestion of copper compounds can be extremely toxic, leading to liver damage and death at high levels (i.e., greater than 1 g). Inhalation of copper sulfate from mildew-control sprays has caused symptoms in the applicators, including weakness, anorexia, weight loss, and shortness of breath. Exposure to copper dust can cause discoloration of the skin. Individuals diagnosed with a rare genetic syndrome known as Wilson's disease cannot metabolize copper correctly, and the element builds up in soft tissues. People afflicted with this disease cannot tolerate even normal dietary levels of copper.

Biota. Copper concentrations in U.S. soil average about 25 ppm (Shacklette et al. 1971). The average background concentration in Missouri soil is 13 ppm, whereas the mean soil concentrations for the St. Louis Site range from 13 to 82 ppm (Table 2.8). On the basis of a literature review of metal effects on forest soil invertebrates, <100 ppm copper in soil or litter is suggested as the maximum allowable concentration that will cause no adverse effects (Bengtsson and Tranvik 1989). Results of several studies indicate that soil copper concentrations of 78 to 2,500 ppm (mostly between 100 and 500 ppm) variably affect different groups of invertebrates by decreasing biomass, species numbers, or density (Tyler et al. 1989).

Copper concentrations in sediment can range from less than 50 ppm in pristine [illegible]ments to several thousand parts per million in polluted ecosystems; copper [illegible]trations in the water column can range from below detection limits to 3.8 ppm. nterstitial copper concentrations are generally 2 to 5 times that of the water column (Harrison 1986). The mean sediment concentration measured for Coldwater Creek was 25 ppm (Table 2.10), whereas the concentration measured in the water column was 0.05 ppm (Rains 1981).

Copper has been shown to be algicidal to *Selanastrum capricornutum* at 300 ppb; owth inhibition was initiated at 50 ppb, and complete growth inhibition occurred at 90 ppb artlett et al. 1974). On the basis of a literature review, copper toxicities to freshwater ascular plants range from an effective concentration of 50 ppb to an LD_{50} as high as [illegible] ppm (Outridge and Noller 1991).

Copper concentrations of 17 ppb or more prevented completion of the life cycle of the ddisfly *Clistoronia magnifica*; significant reduction in adult emergence occurred at 13.0 ppb. he no-effect level for copper was 8.3 ppb (Nebeker et al. 1984). A 50% reproductive pairment of the midge *Paratanytarsus parthenogeneticus* was apparent at a copper concen- tion of 37 ppb (Hatakeyama and Yasuno 1981). Concentrations of copper that caused gnificant effects on larval standing crop for brook trout, rainbow trout, brown trout, lake ut, and white sucker ranged from 32 to 44 ppb and was 104 ppb for northern pike (McKim al. 1978).

n a review of reported copper toxicity in fresh waters (Harrison 1986), the following ges of impacts were summarized: primary producers, various toxic or inhibitory effects om 1 to 8,000 ppb (most impacts in the tens to hundreds of parts per billion); freshwater lluscs, from 10 to >9,000 ppb (varies with species and life stage); freshwater arthropods nd other invertebrates, from >1.0 to >57,000 ppb (depending on species and time of expo- re, but most in the tens to hundreds of parts per billion); and fish, from 10 to 13,000 ppb. st measurements of toxicity were observed in the range of tens to hundreds of parts per llion. Additionally, toxicity varied among species, life history stage, and length of exposure.

B.2.1.9 Chromium

Human Health. Chromium is a contaminant of concern at the St. Louis Site for ndwater only. Chromium is found in the environment in three oxidation states: mium III, chromium VI, and metallic chromium. Chromium III is the form that occurs turally in the environment; the other two forms usually result from industrial processing romium. Total chromium levels in U.S. soil average 54 mg/kg. Among its applications, romium is widely used for making steel and cement and for chrome plating.

hromium is an essential element in the human diet; 0.0007 to 0.003 mg/kg-d is a fe [illegible] adequate daily dose. Chromium III is generally nontoxic; a chronic oral RfD of [illegible]-d for insoluble salts of chromium III has been derived from a NOAEL determined in a chronic feeding study of rats. Chromium VI, however, is a human carcinogen by the inhalation route. Numerous epidemiological studies of chromate production workers in several countries have shown an association between chromium exposure and lung cancer. An epidemiological study by Mancuso (1975) was used to develop an inhalation slope factor of 41 $mg/kg\text{-}d)^{-1}$ for chromium VI. A chronic oral RfD for chromium VI of 0.005 mg/kg-d has also been developed on the basis of a NOAEL from a 1-year drinking study of rats.

Chromium VI is also a skin irritant and can cause ulcers on the skin and irritation of the nasal mucosa. Long-term feeding studies with both chromium III and chromium VI in several species have not shown adverse effects of chromium ingestion (EPA 1992). Exposure to metallic chromium is uncommon, and toxicity data for exposure to this form of chromium are lacking.

Biota. Chromium concentrations in U.S. soil average about 53 ppm, ranging from 1 to 1,500 ppm (Shacklette et al. 1971). This is comparable to the average background concentration of 54 ppm in Missouri soil and is higher than the mean values at the St. Louis Site, which range from 12 to 17 ppm (Table 2.8). No biomagnification of chromium has been observed in food chains, and concentrations are usually highest at the lowest trophic levels. Wildlife impacts occur at concentrations of 5.1 and 10 mg/kg in the diet for hexavalent chromium (VI) and trivalent chromium (III), respectively. Most chromium in soil and sediment is unavailable to living organisms. Acute and chronic adverse effects of chromium to warm-blooded organisms are primarily caused by chromium VI compounds; little conclusive evidence exists for toxic effects from chromium III compounds. Most investigators agree that chromium in biological materials is probably always in the trivalent state. Most exposure to chromium III is through the diet (for humans), but no adverse effects have been reported from such exposures. Additionally, no organic trivalent chromium complexes of toxicological importance have been described (Eisler 1986).

The mean sediment concentration measured for Coldwater Creek was 15 ppm (Table 2.10), whereas water sample concentrations were <10 ppb (Rains 1981). Growth of freshwater algae has been inhibited by chromium VI concentrations of 10 ppb or more, and growth of *Lemna* was reduced at 10 ppb chromium VI (Eisler 1986). In a review of the literature (Outridge and Noller 1991), chromium toxicities to freshwater vascular plants were reported to range from effective concentrations of 1.0 to 5.0 ppm chromium VI. The maximum acceptable toxicant concentrations of chromium VI are as low as 51 to 105 ppb for rainbow trout and as high as 1,000 to 3,950 ppb for the fathead minnow. For chromium III, the maximum acceptable toxicant concentration for freshwater organisms ranges from 47 to 1,400 ppb. Adverse effects of chromium to sensitive freshwater species have been documented at 10 ppb of chromium VI and 30 ppb chromium III, although most studies have shown toxicities to be in the hundreds to thousands of parts per billion (Eisler 1986).

B.2.1.10 Lead

Human Health. Lead has been used by humans for thousands of years because of s malleability, resistance to corrosion, and abundance. This metal can be a component of solder, paint, and gasoline, but these uses have declined dramatically in recent years as vareness of the toxicity associated with lead exposure has increased. Currently in the nited States, the predominant use of lead is in batteries. Lead is found at an average concentration of 20 mg/kg in U.S. soil, but soil levels are substantially elevated in many areas cause of lead-containing paint chips that have fallen onto the soil and gaseous emissions om smelters and automobiles.

Inhaled lead is well absorbed (up to 100%). The amount absorbed from the digestive act is greater for children than for adults (about 50% compared with 15%), and absorption s dependent on whether the lead is in food or water. In an individual, both inhaled and gested lead contribute to the blood lead concentration, which reflects recent exposure to ead. Lead is poorly absorbed dermally.

Lead can result in varied toxicologic effects, depending on the level of exposure. ead is classified by the EPA as a probable human carcinogen on the basis of studies with ts and mice. The doses of lead that induce cancer are higher than those associated with ier health effects of lead, such as reproductive toxicity, developmental toxicity, and icr[illegible]d blood pressure (ATSDR 1990a). The EPA has not derived inhalation and ingestion [illegible]es for lead because it has not been possible to establish a NOAEL or LOAEL for this tal. A range of 10 to 15 µg/dL has tentatively been selected as a level that does not cause nown adverse effects (EPA 1992), although a few studies have correlated subjective 'elopmental effects with blood lead concentrations lower than 10 µg/dL.

An uptake/biokinetic model recently developed by the EPA (1991b) designates an ake level corresponding to a blood lead concentration of 10 µg/dL in the most sensitive uman subpopulation (i.e., 36 µg/dL in 2- to 3-year-old children). The uptake level of µg/dL can be compared with uptakes estimated from soil, air, water, and food to evaluate ential health effects associated with lead in the environment.

Additionally, an interim soil cleanup concentration of 500 to 1,000 mg/kg for lead in has been established by the EPA (1989b). This concentration can be used as a guideline r evaluating soil lead concentrations with the caveat that, under circumstances of substan- exposure to children at a site (e.g., a daycare center), even lower soil concentrations ght be of concern. The EPA has set a maximum contaminant level goal of 0 mg/L lead in inking water (EPA 1992).

At blood lead concentrations greater than 40 µg/dL, lead causes miscarriages, rility in males, anemia, and damage to the central nervous system and kidneys. Lead [illegible] resulting in these high blood levels is rare today. Blood lead concentrations of [illegible] and higher have been associated with defects in vitamin D metabolism and with ered IQ scores in children; at concentrations of 20 µg/dL and lower, it becomes more difficult to define the effects of lead. Some studies report a dose-related increase in blood pressure in adult males, starting at about 10 µg/dL blood lead. Additionally, fetuses and young children are particularly sensitive to lead toxicity; even low-level lead exposure during pregnancy and early childhood can cause reduced birth weight, preterm birth, and delayed development.

Biota. The average background concentration of lead in Missouri soil is 20 ppm, whereas the mean values at the St. Louis Site range from 22 to 250 ppm. Lead does not generally biomagnify through the food chain. Plants can absorb lead through roots or absorb the lead that adheres to the surface of aboveground foliage. Generally, lead in soil has a low bioavailability to plants; movement or translocation from the absorbing roots is impeded by a variety of biochemical and physical processes (Koeppe 1981). Little of the lead taken up by plants from the soil is translocated, except during periods of active growth. Additionally, lead deposited on leaves does not appear to be transported to other parts of the plant (Waldron 1980). In most instances, damage to plants from lead is minimal. Nevertheless, current lead concentrations in urban areas can be deleterious to plant growth. Excessive levels of lead can cause growth inhibition, reduce photosynthesis, and affect mitosis and water absorption (Demayo et al. 1982). Adverse effects usually occur only at total soil lead concentrations of several hundred parts per million. For example, soybean yields have been reduced at a soil concentration of 200 ppm. Even though most lead is not absorbed into the plant, lead toxicity is a concern from a trophic standpoint because lead adsorbs to foliage surfaces (Koeppe 1981).

Lead can modify the function and structure of the kidneys, bone, central nervous system, and hematopoietic system; it can also produce adverse biochemical, histopathological, neuropsychological, fetotoxic, teratogenic, and reproductive effects (Eisler 1988b). From a literature review, Bengtsson and Tranvik (1989) suggest that a maximum allowable concentration of 100 to 200 ppm lead would not cause any adverse effects to soil invertebrates. In general, routes of lead exposure other than ingestion are unlikely to cause clinical signs of lead poisoning in birds; birds are usually adversely affected at doses over 100 mg/kg body weight.

Prior to industrialization, fresh waters probably contained about 0.5 ppb lead; the current concentration is generally between 1.0 and 10 ppb (Waldron 1980). Measured concentrations in Coldwater Creek water samples range from 30 to 250 ppb (Rains 1981), and the mean concentration measured in Coldwater Creek sediment was 46 ppm (Table 2.10). Most lead that enters a water body precipitates to the sediment bed. Lead-contaminated sediment is a continuing source of lead to biota, even after input sources have subsided (Knowlton et al. 1983). Lead in solution is more toxic than lead bound to sediment, and organic lead compounds are more toxic than inorganic forms. Reduced survival, impaired reproduction, and reduced growth of aquatic organisms have been reported at lead concentrations of 1.0 to 5.1 ppb (Eisler 1988b). Adverse effects to algae occur at lead concentrations of <1.0 ppm; impacts to invertebrates and fish occur in the mid parts-per-billion range. Amphibians are adversely affected at concentrations higher than 0.5 ppm.

ea[illegible]ncentrations higher than 10 ppb are expected to cause increasingly severe long-term [illegible]o aquatic biota (Demayo et al. 1982).

B.2.1.11 Manganese

Manganese is a contaminant of concern at the St. Louis Site for groundwater only. anganese is an abundant mineral usually found in the environment in the form of oxides, ulfides, and chlorides. The background level in U.S. soil averages 550 mg/kg, and dietary ake for humans is approximately 2.5 to 5 mg/d. Manganese is a component of some types steel and is also used in ceramics, pesticides, fertilizers, and nutritional supplements.

A chronic oral RfD for manganese of 0.1 mg/kg-d has been developed on the basis of NOAEL in humans with a dietary intake of 0.03 to 0.16 mg/kg-d. The chronic inhalation fD of 0.0001 mg/kg-d is based on a LOAEL for a group of workers exposed to manganese. e effects of concern for inhalation exposure are respiratory inflammation and psychomotor isturbances.

Manganese has been shown to be essential in the diet of some animals and might lso be essential in the human diet. However, inhalation of high levels of manganese dust r several months or years causes a condition known as manganism, which results in ntal and emotional disturbances and irreversible brain damage. Inhalation of manganese ust [illegible]o causes impotence and can lead to sterility in males. It is uncertain whether [illegible] of high-levels of manganese could cause similar neurological and reproductive ects in humans, but animals have been affected with these symptoms in several ingestion udies. Dermal absorption of manganese across intact skin is very limited.

B.2.1.12 Molybdenum

Molybdenum is present in U.S. soil at an average concentration of 1 mg/kg. It occurs nature as various compounds with differing solubilities. Molybdenite (MoS_2) is associated h copper ores, and salts of molybdenum are by-products of uranium mining and milling. he primary worldwide source of molybdenum is in ores from the U.S. Rocky Mountains. issions from coal-fired power plants also contain significant quantities of the metal. ybdenum is used in semiconductors, steel alloys, catalysts, lubricants, and dyes. It is also sed as a seed treatment or fertilizer to prevent deficiencies in plants.

Molybdenum is a component of at least two mammalian enzymes, one of which talyzes the breakdown of purines to uric acid. This metal is considered essential for ans, and its toxicity in man is low. An oral RfD of 0.004 mg/kg-d has been derived on basis of no adverse affects in humans drinking water containing a corresponding amount molybdenum. High intake levels of molybdenum in a Soviet population have been [illegible]d in the causation of a gout-like condition in which uric acid levels in blood were ev[illegible] (National Academy of Sciences 1977).

Exposure to air concentrations of molybdenum from 1 to 19 mg/m^3 for 3 to 7 years produced fibrotic lung disease in workers. Humans can efficiently absorb soluble compounds of molybdenum from the digestive tract. In animals, acute molybdenum intoxication via ingestion causes severe gastrointestinal irritation leading to diarrhea, coma, and death from heart failure. The sensitivity varies by species, with horses having the most tolerance and cattle the least. Toxicity is significant for cattle grazing on pastures containing 20 to 100 mg/kg molybdenum in soil because plants absorb significant quantities of molybdenum from the soil. Data are not available on the efficiency of absorption via inhalation or dermal exposure.

B.2.1.13 Nickel

Human Health. Nickel is found in U.S. soil at an average concentration of 19 mg/kg, and its compounds can be found in all parts of the environment. Industrial applications for nickel are found in electroplating, various steels and alloys, ceramics, and nickel-cadmium batteries.

A chronic oral RfD of 0.02 mg/kg-d for soluble nickel salts is based on a study in which decreased body and organ weights were observed in rats fed nickel sulfate hexahydrate at varying levels for 2 years (Ambrose et al. 1976; EPA 1992). The RfD includes an additional modifying factor because data from reproductive studies are inconclusive. Confidence in the overall database for the evaluation of toxicity from ingested nickel is rated as medium by the EPA. Nickel refinery dust is also classified by the EPA as a known human carcinogen. Exposure to nickel refinery dust has been associated with lung and nasal cancer in studies from several different countries, and tumors have also been produced in rats exposed via inhalation. The cancer risks calculated from the individual epidemiological studies are consistent. The EPA has selected the midpoint of the range of risks from four studies, i.e., 0.84 (mg/kg-d)$^{-1}$, for use as the slope factor for exposure to nickel refinery dust. Nickel refinery dust is composed of many nickel species, and the specific carcinogenic agent has not been determined. Exposure to nickel dust in this country is minimal because the United States has no nickel refineries.

Small amounts of nickel are essential for normal growth and reproduction in some species and might also be essential for humans. In persons inadvertently exposed to high concentrations of nickel in the blood via hemodialysis, symptoms include nausea, vomiting, weakness, headache, and palpitations; all symptoms cease a few hours after the exposure. About 1 to 5% of ingested nickel is absorbed from the digestive tract, and nickel does not appear to be significantly absorbed from the respiratory tract. Metallic nickel does not readily penetrate the skin, but dermal exposure in sensitive individuals (possibly 2.5 to 5% of the general population) might result in contact dermatitis.

Biota. Nickel concentrations in U.S. soil average about 20 ppm (Shacklette et al. 1971). The average background concentration in Missouri soil is 14 ppm, whereas the mean il concentrations for the St. Louis Site range from 17 to 69 ppm. Generally, plant [illegible]ations of nickel increase with increasing soil concentrations; as with most metals, b [illegible]ver, this trend varies among plant species. Phytotoxic effects to plants include poor owth accompanied by chlorosis and necrosis (Hutchinson 1981).

Nickel toxicity to wildlife through ingestion is low, on the order of that for zinc and anganese. Low toxicity apparently results from low intestinal absorption because only about 1 to 2% of dietary nickel is absorbed (Mushak 1980). Also, nickel does not tend to ioaccumulate during lifetime exposure (Nielsen 1977). The chemical form of nickel can fect toxicity; for example, nickel acetate and nickel chloride are more toxic than nickel arbonate. Indications of chronic effects generally occur at dietary levels of more than 0 ppm over a period of weeks to months, with levels of about 1,000 ppm required to disrupt meostatic control mechanisms. The most serious type of nickel toxicity is caused by nhalation of nickel carbonyl, which usually occurs only as a result of an industrial accident ielsen 1977).

Nickel concentrations in Coldwater Creek water samples have been measured at 20 30 ppb during dry weather conditions and at or below 6.0 ppb during storm-water nditions (Rains 1981). Decreased growth of algae occurs at nickel concentrations from 0 ppm to as low as 0.1 ppm (Hutchinson 1981). In a study of the caddisfly *Clistoronia gnifica*, a nickel concentration of 66 ppb had no effect, whereas 250 ppb significantly educed adult emergence and 690 ppb prevented completion of life cycle; the 96-hour median [illegible]ncentration (LC_{50}) was 37 ppm (Nebeker et al. 1984). The 96-hour LC_{50} for nickel [illegible]o fish in hard water generally falls in the range of 14 to 44 ppm; values range from .5 to 1.9 ppm for *Daphnia*, 3.6 to 15 ppm for copepods and amphipods, and 4.0 to 33.5 ppm aquatic insects (Birge and Black 1980).

B.2.1.14 Selenium

The average concentration of selenium in U.S. soil is about 0.5 mg/kg; however, centrations might be much higher, depending on the parent rock from which the soil was ived. Mining of uranium, lead, zinc, and phosphate; copper smelting; and seleniferous coal mbustion are significant contributors to atmospheric selenium levels. Selenium and its pounds are used in the electronics, glass, and rubber industries, and in insecticides, some tidandruff shampoos, photography, and xerographic processes.

An RfD for selenium has been calculated on the basis of Chinese populations that nsumed varying amounts of selenium-containing foods over several years (Yang et al. 1989). ptoms of selenium poisoning were observed in 5 of 439 adults, and it was possible to mate the range of selenium intake inducing selenosis and to obtain a NOAEL. The RfD sed on these data is 0.005 mg/kg-d. Selenium and most of its compounds are not idered to be carcinogenic, and several studies suggest that normal amounts of dietary l[illegible] might protect against cancer. However, selenium sulfide has been shown to be rc[illegible]enic in animals via ingestion. This compound is used in some antidandruff shampoos, but it is not usually found in the environment and its current uses do not pose a significant risk of cancer.

About 50 to 150 µg/d selenium is required in the human diet. However, higher concentrations in the diet can cause symptoms that include brittleness, loss of nails and hair, dermatitis, swelling, numbness or tingling in the extremities, and pain in the limbs; in severe cases of poisoning, paralysis could develop. Selenium compounds have not been shown to cause reproductive effects in humans and other mammals. The primary effect of short-term, high-level inhalation of selenium dust or selenium compounds in industrial settings is respiratory tract irritation, but nausea, elevated pulse rate, and irritation of the skin and eyes have also been reported. Dermal contact with selenium dust and selenium dioxide can cause dermatitis. Absorption is dependent on the chemical form of selenium, but limited data indicate that both elemental selenium and selenious acid are absorbed via inhalation. About 80% of sodium selenite ($NaSeO_3$) and organic selenium are absorbed from the digestive tract, but insoluble elemental selenium is probably poorly absorbed. Data regarding dermal absorption are limited.

B.2.1.15 Silver

The background level of silver in soil is low, i.e., less than 1 mg/kg. A valuable metal, silver is used in jewelry, tableware, photographic materials, and dental fillings. Most environmental contamination with silver stems from photographic wastes, silver mines, and natural weathering of silver-bearing rock. Silver also has some medical uses, e.g., as a salve for burn treatment.

A chronic RfD of 0.003 for silver has been estimated. This RfD is based on the development of argyria (i.e., permanent skin discoloration) in humans and is the mean level from three studies. Silver has not been classified by the EPA with respect to carcinogenicity. No evidence of cancer in humans has been reported, despite frequent therapeutic use.

Argyria is the most serious known health effect from silver exposure. Inhalation of dust containing silver can cause lung and throat irritation, and skin contact with silver compounds causes a mild allergic reaction in some people. In humans, silver is absorbed into the bloodstream to some extent when exposure occurs via either the inhalation, ingestion, or dermal route.

B.2.1.16 Thallium

Human Health. Compounds of thallium have many industrial uses (e.g., as catalysts, in alloys, and in optical lenses), and thallium compounds were used as rodenticides in the United States until 1972. Coal combustion releases significant quantities of thallium into the environment. Thallium is found only at low concentrations in most U.S. soil (less [illegible] mg/kg) but can be accumulated in edible plants from soil containing high levels of the [illegible]

The IRIS database (EPA 1992) contains oral RfDs for six thallium compounds, but the RfDs are all based on a single study in which rats were administered varying levels of thallium sulfate by gavage for 90 days. A NOAEL of 0.2 mg/kg-d for soluble thallium salts as observed, with end points of increased levels of two enzymes (serum glutamic-oxaloacetic transaminase and lactic dehydrogenase) and alopecia (hair loss). The molecular weight of ach compound has been used to convert these data to NOAELs for thallium compounds of terest. The confidence in the RfDs for thallium compounds is low because supporting studies show adverse health effects at doses only slightly higher than the NOAEL and ecause reproductive and chronic toxicity data are lacking. Therefore, a large uncertainty factor (i.e., 3,000) is used in the calculation of the oral RfDs, resulting in an RfD of 0.00007 mg/kg-d for soluble thallium salts (EPA 1991a).

Thallium is not a normal constituent of animal tissues, but the free cation (Tl+) can ubstitute for potassium and alter many cellular processes. The free ion is readily absorbed rough the skin or gastrointestinal epithelium. Thallium is one of the most toxic metals; the estimated lethal dose to humans is 8 to 12 mg/kg. The use of thallus acetate for hair moval in the 1920s and 1930s caused many severe human poisonings; symptoms included strointestinal irritation, paralysis, psychic disturbances, and loss of vision. The offspring of rats treated with thallium salts during pregnancy experienced dwarfism. Chronic thallium [illegible]tion in humans during pregnancy has also been reported to cause malformations and [illegible] nervous system defects in offspring. The average background concentration of thallium in Missouri soil is <0.10 ppm, whereas the mean values at the St. Louis Site range m 14 to 29 ppm (Table 2.8).

Biota. All forms of thallium are soluble (Peterson and Girling 1981). In part, this accounts for thallium being an extremely toxic cumulative poison. Biomethylation of thallium hances its toxicity further. Thallium concentrations in plants are generally less than 1 ppm in unpolluted areas, and plant concentrations in polluted or mineralized areas can e several hundred to several thousand parts per million. Thallium toxicity to grazers can ur at these elevated plant concentrations (Peterson and Girling 1981).

Thallium does not normally occur in animal tissues, but it will bioaccumulate when en into the body. Absorption from ingestion is rapid, and thallium is also absorbed ough the skin (Browning 1969). Rats given water containing 10 ppm thallium had a mortality rate of 15% after 40 days and 21% after 24 to 280 days. Hair loss and peripheral vous system damage also occurred in some of the test animals. Most tissues demonstrated 60- to 100-fold increase in thallium concentration compared with control subjects (Manzo t al. 1983). The toxic action of the thallium is caused by inhibiting various enzymes or [illegible]g potassium ions in activating other enzymes. Thallium can also affect mitosis and [illegible]genic (Peterson and Girling 1981).

The acute and chronic toxicity of thallium to freshwater aquatic life occurs at concentrations as low as 1,400 and 40 ppb, respectively. Toxicity to one species of fish occurred at 20 ppb after 2,600 hours of exposure (EPA 1986).

B.2.1.17 Uranium

Human Health. Uranium is used in the nuclear energy and weapons industries. The fission of one atom of uranium-235 produces approximately 200 MeV of thermal energy and, since the discovery of fission in 1938, the annual production of uranium oxide for use as fuel and in weapons has ranged from 20 to 40,000 metric tons. The richest uranium deposits are found in Africa, Europe, Australia, Brazil, Canada, and in the Colorado mountain range of the United States. The average uranium concentration in U.S. soil is about 3 mg/kg.

Although natural uranium is radioactive, the primary health effect associated with exposure is kidney toxicity. An oral RfD of 0.003 mg/kg-d for soluble uranium salts has been developed on the basis of decreased body weight and moderate renal damage induced in rabbits fed uranyl nitrate hexahydrate for 30 days (Maynard and Hodge 1949). The confidence level for this RfD is medium.

About 5% of the soluble salts of uranium are absorbed via ingestion. Only a small fraction of inhaled uranium dust penetrates to the alveolar region of the lungs, as indicated by low lung uranium levels in workers exposed to uranium dust. Animal studies show efficient dermal absorption of some uranium compounds. Kidney toxicity, the main health concern for soluble uranium exposure, might be reversible, depending on the level of exposure. The radioactivity of natural uranium has not been associated with increased cancer rates in uranium workers, although exposure to some uranium decay products, particularly radon-222 decay products, does increase the risk of cancer. A few instances of minor effects on the liver caused by oral and inhalation exposure to uranium also have been reported.

Biota. The average background concentration of uranium in Missouri soil is 3.8 ppm, whereas the mean values at the St. Louis Site range from 20 to 51 ppm (Table 2.8). Generally, elevated concentrations of uranium are toxic to plants, although some plants might adapt to such conditions (Peterson and Girling 1981). Symptoms of toxicity (e.g., loss of turgor and leaf curling) were observed in corn plant seedlings exposed to a uranium solution concentration greater than 50 ppm (Prister and Prister 1970). Four-week-old soybean plants exposed to 42 ppm uranium had significantly depressed growth and exhibited chlorosis, reduction in root growth, and tissue necrosis (Murthy et al. 1984). Haseltine and Sileo (1983) observed limited adverse impacts to black ducks fed 1,600 ppm of depleted uranium over a 6-week period.

The toxicity of uranium relative to other trace metals is low. However, the potential fo[illegible]ase of toxic levels into waterways is a concern that requires site-specific hazard ssment; in a study of *Daphnia magna*, the 48-hour LC_{50} was 6 ppm, whereas reproluction was suppressed at uranium concentrations between 0.5 and 3.5 ppm (Poston et al. 1984). In another study, the 96-hour TL_M (median tolerance level) for fathead fish was between 2.8 and 3.7 ppm, depending upon water hardness (Tarzwell and Henderson 1960).

B.2.1.18 Vanadium

Vanadium is a widespread element; its average concentration in U.S. soil is 0 mg/kg. Vanadium is associated with some uranium-bearing ores and is a by-product of etroleum refining. Vanadium and its compounds are used in the hardening of steel; in pigments, photography, and insecticides; and as a chemical catalyst.

An oral RfD for vanadium has been derived from a study in which rats were given vanadyl sulfate in drinking water over their natural lifetime (Schroeder et al. 1970). anadium has not been shown to cause cancer in animals or humans.

The oral toxicity of vanadium increases with increasing valency; pentavalent anadium is the most toxic. Excess ingestion of vanadium has caused gastrointestinal disturbances, nervous system effects, and abnormalities in renal enzyme systems. Inhalation of [illegible]adium compounds at levels above occupational air standards (e.g., 0.05 mg/m^3 [illegible]m oxide [V_2O_5] in the United States) is strongly irritating to the eyes and the air passages, and chronic inhalation could result in decreased cholesterol synthesis and the teration of various enzyme systems. Inhalation of vanadium can also result in bronchitis nd bronchopneumonia. Solutions of vanadium compounds can be absorbed through the skin, but dermal absorption of elemental vanadium is a minor route of uptake. Vanadium is more ficiently absorbed through inhalation than ingestion. About 10% of water-soluble anions of vanadium in the diet are absorbed; cations are more poorly absorbed.

B.2.1.19 Zinc

Zinc is found in U.S. soil at an average background concentration of 60 mg/kg. The metal is used extensively in alloys and electrical equipment, and as a coating on other metals.

Zinc is essential in the human diet; deficiencies can result in symptoms such as skin esions and slow wound healing. A daily intake of about 0.2 mg/kg-d is recommended, most of which is obtained from foods such as meat and poultry. The 0.2 mg/kg-d level is also the D value derived from data on therapeutic doses in humans and incorporating an uncertainty factor of 10. Zinc exposure has not been associated with carcinogenic effects.

Ingestion of large amounts of zinc (e.g., 10 times the recommended daily allowance) ca[illegible]e digestive problems and immune system effects. Inhalation of dust and fumes from zinc can result in temporary respiratory distress. Dermal contact with zinc promotes wound healing; zinc ions may also be absorbed across the skin.

B.2.2 Inorganic Anions

B.2.2.1 Fluoride

Fluoride is a common element found in the earth's crust and is present in most soil. Fluoride is also present in some foods, particularly fish and tea. An important use of fluoride in the United States is its addition to public water supplies for the reduction of dental caries. Industries that use fluoride include the chemical industry and producers of bricks, ceramics, glass, and fertilizers.

An oral RfD for fluoride of 0.06 mg/kg-d has been derived on the basis of objectionable dental fluorosis caused by ingestion of water containing 2 mg/L or more of fluoride. The EPA categorizes fluorosis as a cosmetic effect, not a toxic or adverse health effect. Mild dental fluorosis is manifested as white opaque areas partially covering tooth surfaces; severe dental fluorosis causes brown or black tooth stains and pitting of the teeth. Confidence in the RfD is rated high because extensive human exposure data were used in its derivation.

Fluoride is easily absorbed from the digestive tract and is stored in the bones and kidneys. Exposure to fluoride at levels of 0.28 mg/kg-d or greater over a 20-year period can lead to crippling skeletal fluorosis, a condition in which calcium in bone tissue is replaced by fluoride.

B.2.2.2 Nitrate (NO_3^-)

Nitrogen in the environment tends to be converted to the nitrate ion (NO_3^-), because nitrate compounds are thermodynamically stable. Therefore, sources of nitrogen are also considered to be sources of nitrate. Some common sources of nitrogen to the environment are wastewater treatment plants, animal feed lots, fertilized lands, and septic tanks. A source of human intake of nitrates is the diet; vegetables such as potatoes and cabbage may contain several thousand parts per million of nitrate.

The most important toxic effect of exposure has occurred in infants ingesting water containing elevated amounts of nitrate. Nitrate is reduced to nitrite in the stomach and in the saliva. Nitrite oxidizes hemoglobin to methemoglobin, which cannot transport oxygen efficiently. This process results in insufficient tissue oxygen levels, which is fatal in some cases. Infants are much more susceptible to nitrate toxicity than are adults because they have large amounts of nitrate-reducing bacteria in their digestive tracts and because fetal hemoglobin is more readily oxidized than adult hemoglobin. An oral RfD value for nitrate of 1.6 mg/kg-d has been established on the basis of methemoglobinemia in infants. The confidence level associated with this RfD value is high.

The possibility that dietary nitrate could be metabolized to nitrite and further react ni[illegible]condary amines or amides within the body to form carcinogenic N-nitroso compounds [illegible]s been suggested (National Academy of Sciences 1977). Although many N-nitroso ompounds have been found to be carcinogenic in animals, it is not known whether these ompounds cause cancer in humans. Conversion of amines and amides to N-nitroso compounds in the digestive tract has not been demonstrated.

B.2.3 Organic Compounds

B.2.3.1 Benzene

Benzene is a widely used organic compound made from coal and oil, although it also ccurs naturally. Benzene (C_6H_5) is used in industry as a gasoline detergent, as a pesticide, nd to synthesize other chemicals. Most significant exposure to benzene is from inhalation because it is highly volatile.

Oral and inhalation RfD values for benzene have not been established. However, benzene is classified as a known human carcinogen because of the development of leukemia n persons inhaling benzene occupationally. The inhalation unit risk of 8.3×10^{-6} $(\mu g/m^3)^{-1}$ the geometric mean of the risks derived from several studies of occupational cohorts. This unit risk can be used to derive the slope factor of 0.029 mg/kg-d, which is applied for both h[illegible]on and oral exposure. The confidence in this risk estimate is fairly high because the [illegible]ata encompass a large study population followed for an adequate time period.

Other adverse health effects from benzene exposure include reproductive effects, such low birth weight and delayed bone formation, that have been observed in animal studies. enzene exposure also can damage the immune system and cause anemia.

B.2.3.2 Bis(2-ethylhexyl)phthalate

Bis(2-ethylhexyl)phthalate is one of the two most widely produced phthalate ester lasticizers. Approximately 1 billion pounds of plastics are produced annually, and (2-ethylhexyl)phthalate is now ubiquitous in every environmental medium. Although it only slightly soluble, acid present in humic substances complexes and solubilizes this thalate, making it somewhat mobile in soil. Bis(2-ethylhexyl)phthalate is so widespread t almost any soil or water sample analyzed will contain some of this compound.

The oral RfD of 0.02 mg/kg-d for bis(2-ethylhexyl)phthalate is based on increased tive liver weight in guinea pigs fed the compound in their diet. The associated confidence vel is medium. Bis(2-ethylhexyl)phthalate is also classified as a B2 probable human inogen. The oral slope factor of 0.014 was obtained from a study in which mice fed [illegible]ylhexyl)phthalate developed hepatocellular carcinomas and adenomas (National ox[illegible]gy Program 1982). A quantitative estimate of carcinogenic risk from inhalation osure is not available.

Limited data are available on toxic effects other than cancer. The compound has inhibited reproduction in some aquatic organisms as much as 80%, even at low concentrations, and as little as 4 µg/L bis(2-ethylhexyl)phthalate was lethal to cultured chick embryo heart cells.

B.2.3.3 Chlorobenzene

Chlorobenzene is a colorless, volatile liquid that is most widely used as a solvent in industry. A study in which liver toxicity occurred in dogs fed chlorobenzene for 13 weeks was used to derive the oral RfD of 0.02 mg/kg-d. The RfD incorporates an uncertainty factor of 1,000 to account for extrapolation from animals to humans, sensitive human subpopulations, and extrapolation from subchronic to chronic exposure. Data are not adequate to classify chlorobenzene with respect to carcinogenicity, but genetic toxicity data generally do not indicate mutagenicity.

Exposure to higher levels of chlorobenzene (i.e., 10 times the NOAEL) in the diet has resulted in body weight loss, more pronounced liver toxicity, toxicity to the kidney and other tissues, and death. In occupational settings, workers have reported headaches, numbness, sleepiness, and nausea in connection with inhalation of chlorobenzene and other solvents. Animal studies have also shown that chlorobenzene exposure can result in kidney damage.

B.2.3.4 DDT (4,4'-Dichlorodiphenyltrichloroethane)

Prior to 1972, DDT was widely used in the United States as a pesticide. Although DDT is now banned in this country, except in cases of public health emergency, the chemical is still used in other parts of the world. The compound DDT and its decomposition products, DDE (dichlorodiphenyldichloroethylene) and DDD [1,1-bis(4-chlorophenyl)-2,2-dichloroethane], are relatively stable in the environment. After ingestion and absorption by humans or animals, these compounds are stored in the fatty tissues.

The oral RfD for DDT of 0.0005 mg/kg-d was derived from data from a rat feeding study (Lang et al. 1950). The rats developed liver lesions at concentrations of 5 ppm and greater in the diet; males were more affected than females. The compound DDT is classified as a B2 probable human carcinogen; the affected organ is the liver. The oral slope factor of 0.34 $(mg/kg\text{-}d)^{-1}$ is the geometric mean of the slope factors derived from six studies of mice and rats receiving DDT in the diet. The inhalation slope factor is taken from the oral carcinogenicity data.

One multigeneration rat study also showed increased mortality in offspring of rats at all dose levels, the lowest being 0.2 mg/kg-d. However, other reproduction studies showed no effects at much higher dose levels. Ingestion of high doses of DDT results in reversible effects on the nervous system, such as tremors and seizures. Dermal exposure can cause skin irritation, but DDT is not well absorbed dermally.

B.2.3.5 1,2-Dichlorobenzene

The semivolatile organic compound 1,2-dichlorobenzene is a synthetic solvent used fo industrial applications. No adverse effects were observed in rats given 86 mg/kg-d of ,2-dichlorobenzene by gavage for 2 years (National Toxicology Program 1985). An uncertainty factor of 1,000 is used to account for extrapolation from animal data to humans, lack of chronic toxicity data, and sensitive human subpopulations; the resulting oral RfD s 0.09 mg/kg-d. The EPA considers 1,2-dichlorobenzene as nonclassifiable with respect to human carcinogenicity because there are no human data. Both negative and positive data or carcinogenicity have been observed in studies of rats and mice. Mice and rats given 250 mg/kg-d of 1,2-dichlorobenzene developed liver necrosis. At 500 mg/kg-d, further liver damage, kidney damage, and decreases in red blood cell and lymphocyte counts occurred in ats, as well as death.

B.2.3.6 1,2-Dichloroethene (cis and trans)

The synthetic chemical 1,2-dichloroethene is used mainly as a solvent in industry. is volatile and flammable, and it has a harsh odor. The two isomers (forms) of this substance, cis and trans, often occur together as a mixture.

The RfD for cis-1,2-dichloroethene (0.01 mg/kg-d) is lower than that for trans-1,2-dichloroethene (0.02 mg/kg-d) and was used in this assessment to be protective, although [illegible] cific isomer detected was not identified in the groundwater data. The RfD for the cis i [illegible] s based on a subchronic study of rats administered 32 mg/kg-d by gavage. This dose esulted in decreased hematocrit and hemoglobin levels. Neither isomer is classified with spect to human carcinogenicity.

Like other solvents, inhalation of 1,2-dichloroethene causes nausea and drowsiness, d very high levels can cause death. Liver, lung, and heart damage have been observed in animals exposed to high levels via inhalation for short and long periods.

B.2.3.7 1,2-Dichloropropane

The compound 1,2-dichloropropane is a synthetic volatile compound currently used nly in research and as a solvent in industry. This chemical was also used in paint strippers, rnishes, and cleaning products and as a soil fumigant in agriculture prior to the banning these uses in the United States in the early 1980s.

No oral or inhalation RfD values have been determined for 1,2-dichloropropane. An l slope factor of 0.068 $(mg/kg\text{-}d)^{-1}$ has been determined on the basis of liver cancers nduced in mice given 1,2-dichloropropane by gavage.

Dermal contact with 1,2-dichloropropane can cause skin irritation. Ingestion or ih [illegible] on of large amounts of the chemical results in dizziness, nausea, injury to the liver and kidneys, and death if a sufficient amount is taken in. Similar effects have been observed in animal studies.

B.2.3.8 Endosulfan

Endosulfan is an insecticide used on crops such as grains, fruits, tobacco, and cotton; it is also used as a wood preservative and is nonvolatile and insoluble in water. Exposure to endosulfan is usually by ingestion of food and, to a lesser degree, through dermal contact.

An oral RfD of 5×10^{-5} was developed from a LOAEL for kidney toxicity observed in rats fed endosulfan over two generations. A large uncertainty factor of 3,000 was incorporated into the RfD to account for interspecies and intraspecies differences, the lack of an established NOAEL, and the lack of a complete database on chronic exposure. Endosulfan has not been evaluated by the EPA for evidence of carcinogenicity.

Ingestion of large amounts of endosulfan causes damage to the nervous system, liver, kidneys, blood, and immune system, and can result in death. The kidneys and reproductive systems were affected in animals fed lower levels of endosulfan over several months.

B.2.3.9 Polycyclic Aromatic Hydrocarbons

Human Health. Polycyclic aromatic hydrocarbons (PAHs) constitute a diverse class of compounds that are formed during the incomplete burning of organic substances such as coal, oil, and gas. These compounds are found in the air attached to dust particles and are emitted from vehicle exhausts, asphalt roads, and furnaces burning wood or coal. Research purposes are the only known uses for PAHs. The range of concentrations in rural soil of the best-studied PAH, benzo(a)pyrene, is reported as 0.002 to 1.3 mg/kg; the range in urban soil is 165 to 220 mg/kg.

Several PAHs have been classified by the EPA as probable human carcinogens on the basis of cancer induction in laboratory animals through ingestion, inhalation, or dermal exposure and suggestive but inconclusive evidence of carcinogenicity in humans exposed to PAH mixtures. An inhalation slope factor for benzo(a)pyrene of 6.1 $(\text{mg/kg-d})^{-1}$ has been derived from the induction of respiratory tract tumors in hamsters exposed to this PAH for 109 weeks (Thyssen et al. 1981; EPA 1984b, 1991a). Additionally, an oral slope factor of 11.5 $(\text{mg/kg-d})^{-1}$ can be derived from the increased incidence of forestomach tumors in mice fed various doses of benzo(a)pyrene for periods of 30 to 197 days (Neal and Rigdon 1967; EPA 1984b, 1991a). Slope factors are not available for the other carcinogenic PAHs, and no reference doses are available.

The specific PAHs that increase cancer risk in humans have been difficult to identify because PAHs occur together in the environment, and exposure is almost exclusively to groups of PAHs. However, epidemiological studies have shown increased mortality due to ng cancer in humans exposed to coke-oven emissions, roofing-tar emissions, and cigarette r [illegible] These substances contain many PAHs classified by the EPA as probably carcinogenic [illegible]ns — benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, rysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene (EPA 1991a).

Biota. The PAHs tend to be elevated in nonbiological materials within urban dustrial areas (Eisler 1987). Therefore, concentrations determined at the St. Louis Site ight not be exceptional for the area, and they might not have originated from past erations at the site. Most PAHs released to the atmosphere eventually reach the soil by rect deposition or deposition on vegetation. The PAHs that deposit on plants can bsequently be assimilated by the plants. Total PAH concentrations at SLDS are greater n 1,250 ppm, with carcinogenic PAHs totaling about 440 ppm at SLDS and 35 ppm in ldwater Creek sediment. Terrestrial vegetation and invertebrates can accumulate signifi- t concentrations of PAHs. For example, fruits and vegetables grown in a polluted osphere can contain PAH levels up to 100 times greater than those grown in unpolluted vironments. Also, PAH concentrations are usually higher on the plant surface compared internal tissues and higher in aboveground portions of the plant compared with the ts. However, phytotoxic effects are rare. Wildlife can assimilate PAHs by inhalation, nal contact, or ingestion, although PAHs are poorly absorbed from the gastrointestinal t.

[illegible]ncentrations of PAHs in fish do not appear to be elevated. Nevertheless, aquatic tes, fish, and amphibians in areas of high sediment levels of PAHs show increased uencies of hyperplasia and neoplasia. The PAHs do not tend to biomagnify through the chain. The higher molecular weight PAHs (containing four to seven rings) are nogenic, mutagenic, or teratogenic.

In water, PAHs could evaporate, disperse into the water column, become porated into sediment, concentrate in biota, or undergo chemical oxidation and egradation (Suess 1976). The PAHs dissolved in water will probably degrade rapidly gh photooxidation. Benthic organisms are believed to biotransform and biodegrade s that accumulate in the sediment. The PAH concentrations that are acutely toxic to ic organisms are generally several orders of magnitude higher than concentrations in most polluted waters (Neff 1979). All but the most contaminated waters contain PAH concentrations in the range of parts per billion or low parts per million, whereas y to aquatic biota generally occurs between 50 and 1,000 ppb. However, sublethal ses are sometimes observed at PAH concentrations ranging from 0.1 to 50 ppb.

Overall, terrestrial vegetation and aquatic invertebrates can accumulate significant ntrations of PAHs whereas fish do not appear to contain grossly elevated residues. gh few data are available, it is unlikely that significant PAH concentrations occur in [illegible]iew of the carcinogenic characteristics of many PAH compounds, the increasing [illegible]ns of PAHs in the environment should be considered cautiously. Thus, efforts taken to reduce or eliminate PAHs whenever possible (Suess 1976).

B.2.3.10 Polychlorinated Biphenyls

Polychlorinated biphenyls (PCBs) are a class of synthetic chemicals consisting of 209 compounds. Mixtures of PCBs sold in the United States are known by the trade name Aroclor. In the United States, manufacture of PCBs was halted in 1977 because these chemicals are toxic and accumulate in the environment.

No oral or inhalation RfD is currently available from the EPA for PCBs. However, PCBs are classified as B2 probable human carcinogens. The oral slope factor of 7.7 $(mg/kg\text{-}d)^{-1}$ was derived from a study in which rats given a PCB mixture (Aroclor 1260) in the diet for 16 months developed liver cancers (Norback and Weltman 1985). Currently, Aroclor 1260 is taken as representative of all PCB mixtures, although there is some evidence that carcinogenic potency increases with increasing degree of chlorination. Several epidemiological studies also suggest a higher incidence of cancer in humans exposed to PCBs, but the evidence is not conclusive.

Dermal contact with PCB mixtures can result in a permanent skin irritation called chloracne. Reproductive and developmental effects in offspring of humans have been associated with consumption of PCB-contaminated fish.

B.2.3.11 Toluene

Toluene is a volatile substance found naturally in crude oil and used widely in industry. Uses for toluene include the manufacture of paint, gasoline refining, and chemical manufacture. Toluene can be inhaled, ingested, or absorbed dermally.

The oral RfD for toluene of 0.2 mg/kg-d was calculated from data on changes in liver and kidney weights in rats given toluene by gavage for 13 weeks (National Toxicology Program 1989). A NOAEL was established and modified by an uncertainty factor of 1,000 to account for interspecies and intraspecies extrapolations, subchronic-to-chronic extrapolation, and limited reproductive and developmental toxicity data. Toluene is not classified by the EPA with respect to human carcinogenicity; most genotoxic assays have not indicated mutagenicity.

Ingestion or inhalation of high levels of toluene has caused reversible damage to the nervous system. Like most solvents, very high exposures lead to dizziness, unconsciousness, and death. In animals, exposure to toluene has caused slight damage to the liver, kidneys, and lungs, and inhalation has resulted in reproductive effects.

B.2.3.12 Trichloroethene

Trichloroethene is a synthetic, highly volatile compound used most often as a solvent to degrease metal parts. Trichloroethene is a common groundwater contaminant in industrial areas. Most exposure occurs via inhalation or ingestion; dermal absorption does not appear to be a significant route of exposure.

No oral or inhalation RfD for trichloroethene is currently available from the EPA. Trichloroethene is classified as a B2 probable human carcinogen. An oral slope factor of 0.011 was derived from two studies in which mice given trichloroethene by gavage developed liver cancer. Two studies in which mice inhaled trichloroethene and developed lung cancer were used to derive the inhalation slope factor of 0.017.

Inhalation of high levels of trichloroethene affects the central nervous system, resulting in dizziness, headache, and facial numbness; it also causes irritation of the eyes, nose, and throat. Animals exposed to high levels of trichloroethene experience damage to the liver, kidneys, and immune system.

B.2.3.13 Vinyl Chloride

Vinyl chloride is a synthetic, volatile chemical mainly used in the production of polyvinyl chloride, a type of plastic. Most exposure to vinyl chloride is through inhalation or ingestion. Dermal absorption is not likely to be a significant pathway of exposure.

Vinyl chloride is classified by the EPA as a known human carcinogen. The oral slope factor of 1.9 $(mg/kg\text{-}d)^{-1}$ was derived from a study in which rats given 10 to 50 ppm vinyl chloride in food developed lung cancer. The inhalation slope factor of 0.294 $(mg/kg\text{-}d)^{-1}$ was derived from a 1-year study in which rats inhaling vinyl chloride had an increased incidence of liver cancers. Oral and inhalation RfD values for vinyl chloride are not currently available.

As for other solvents, short-term, high-level inhalation of vinyl chloride results in dizziness, headache, unconsciousness, and sometimes death. Occupational exposures to lower levels have caused damage to the liver, lungs, circulation, and blood. Exposure to vinyl chloride has also been associated with an increased risk of miscarriage.

B.3 REFERENCES

Agency for Toxic Substances and Disease Registry, 1988a, *Toxicological Profile for Beryllium*, ATSDR/TP-88/07, prepared by Syracuse Research Corporation for U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency, Dec.

Agency for Toxic Substances and Disease Registry, 1988b, *Toxicological Profile for Nickel*, ATSDR/TP-88/19, prepared by Syracuse Research Corporation for U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency, Dec.

Agency for Toxic Substances and Disease Registry, 1989a, *Toxicological Profile for Arsenic*, ATSDR/TP-88/02, prepared by Life Systems, Inc., for U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency, March.

Agency for Toxic Substances and Disease Registry, 1989b, *Toxicological Profile for Cadmium*, ATSDR/TP-88/08, prepared by Life Systems, Inc., for U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency, March.

Agency for Toxic Substances and Disease Registry, 1989c, *Toxicological Profile for Trichloroethylene*, ATSDR/TP-88/24, prepared by Syracuse Research Corporation for U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency, Oct.

Agency for Toxic Substances and Disease Registry, 1989d, *Toxicological Profile for Selenium*, ATSDR/TP-89/21, prepared by Clement Associates for U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency, Dec.

Agency for Toxic Substances and Disease Registry, 1989e, *Toxicological Profile for Chromium*, ATSDR/TP-88/10, prepared by Syracuse Research Corporation for U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency, July.

Agency for Toxic Substances and Disease Registry, 1989f, *Toxicological Profile for Zinc*, ATSDR/TP-89/25, prepared by Clement Associates for U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency, Dec.

Agency for Toxic Substances and Disease Registry, 1989g, *Toxicological Profile for Benzene*, ATSDR/TP-88/03, prepared by Oak Ridge National Laboratory for U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency, May.

Agency for Toxic Substances and Disease Registry, 1989h, *Toxicological Profile for DDT, DDE, and DDD*, ATSDR/TP-89/08, prepared by Clement Associates for U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency, Dec.

Agency for Toxic Substances and Disease Registry, 1989i, *Toxicological Profile for 1,2-Dichloropropane*, ATSDR/TP-89/12, prepared by Syracuse Research Corporation for U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency, Dec.

Agency for Toxic Substances and Disease Registry, 1989j, *Toxicological Profile for Selected PCBs (Aroclor-1260, -1254, -1248, -1242, -1232, -1221, and -1016)*, ATSDR/TP-88/21, prepared by Syracuse Research Corporation for U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency, June.

Agency for Toxic Substances and Disease Registry, 1989k, *Toxicological Profile for Toluene*, ATSDR/TP-89/23, prepared by Life Systems, Inc., for U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency, Dec.

Agency for Toxic Substances and Disease Registry, 1989*l*, *Toxicological Profile for Vinyl Chloride*, ATSDR/TP-88/25, prepared by Syracuse Research Corporation for U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency, Aug.

Agency for Toxic Substances and Disease Registry, 1990a, *Toxicological Profile for Lead*, ATSDR/TP-88/17, prepared by Syracuse Research Corporation for U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency, June.

Ag[illegible]y for Toxic Substances and Disease Registry, 1990b, *Toxicological Profile for Uranium*, A[illegible]/TP-90/29, prepared by Syracuse Research Corporation for U.S. Public Health Service i[illegible]llaboration with U.S. Environmental Protection Agency, Dec.

Agency for Toxic Substances and Disease Registry, 1990c, *Toxicological Profile for Radium*, ATSDR/TP-90/22, prepared by Life Systems, Inc., for U.S. Public Health Service in ollaboration with U.S. Environmental Protection Agency, Dec.

Agency for Toxic Substances and Disease Registry, 1990d, *Toxicological Profile for Radon*, ATSDR/TP-90/23, prepared by Clement International Corporation for U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency, Dec.

Agency for Toxic Substances and Disease Registry, 1990e, *Toxicological Profile for Thorium*, ATSDR/TP-90/25, prepared by Syracuse Research Corporation for U.S. Public Health Service n collaboration with U.S. Environmental Protection Agency, Oct.

Agency for Toxic Substances and Disease Registry, 1990f, *Toxicological Profile for Polycyclic romatic Hydrocarbons*, ATSDR/TP-90/20, prepared by Clement International Corporation for U.S. Public Health Service, Dec.

gency for Toxic Substances and Disease Registry, 1990g, *Toxicological Profile for Silver*, ATSDR/TP-90/24, prepared by Clement International Corporation for U.S. Public Health Ser[illegible], Dec.

Ag[illegible]y for Toxic Substances and Disease Registry, 1990h *Toxicological Profile for Chlorobenzene*, ATSDR/TP-90/06, prepared by Life Systems, Inc., for U.S. Public Health ervice, Dec.

Agency for Toxic Substances and Disease Registry, 1990i, *Toxicological Profile for 2-Dichloroethenes*, ATSDR/TP-90/13, prepared by Syracuse Research Corporation for U.S. Public Health Service, Dec.

gency for Toxic Substances and Disease Registry, 1992a, *Toxicological Profile for Barium and Compounds*, ATSDR/TP-91/03, prepared by Clement International Corporation for U.S. Public Health Service, July.

Agency for Toxic Substances and Disease Registry, 1992b, *Toxicological Profile for Boron and ompounds*, ATSDR/TP-91/05, prepared by Life Systems, Inc., for U.S. Public Health Service, July.

gency for Toxic Substances and Disease Registry, 1992c, *Toxicological Profile for Manganese and Compounds*, ATSDR/TP-91/19, prepared by Life Systems, Inc., for U.S. Public Health Service, July.

Ag[illegible]or Toxic Substances and Disease Registry, 1993, *Toxicological Profile for Endosulfan*, A[illegible]R/TP-91/16, prepared by Clement International Corporation for U.S. Public Health rvice, April.

Ainsworth, N., J.A. Cooke, and M.S. Johnson, 1990a, *Distribution of Antimony in Contaminated Grassland: 1, Vegetation and Soils*, Environmental Pollution, *65*:65-77.

Ainsworth, N., J.A. Cooke, and M.S. Johnson, 1990b, *Distribution of Antimony in Contaminated Grassland: 2, Small Mammals and Invertebrates*, Environmental Pollution, *65*:79-87.

Ambrose, A.M., et al., 1976, *Long-Term Toxicologic Assessment of Nickel in Rats and Dogs*, Journal of Food Science Technology, *13*:181-187. [As cited in EPA (1992)].

ATSDR: See Agency for Toxic Substances and Disease Registry.

Bartlett, L., F.W. Rabe, and W.H. Funk, 1974, *Effects of Copper, Zinc and Cadmium on Selanastrum Capricornutum*, Water Research, *8*:179-185.

Bengtsson, B.-E., et al., 1975, *Vertebral Damage in Minnows, Phoxinus Phoxinus L., Exposed to Cadmium*, Ambio, *4*(4):166-168.

Bengtsson, G., and L. Tranvik, 1989, *Critical Metal Concentrations for Forest Soil Invertebrates: A Review of the Limitations*, Water, Air, Soil Pollution, *47*:381-417.

Benoit, D.A., et al., 1976, *Toxic Effects of Cadmium on Three Generations of Brook Trout (Salvelinus Fontinalis)*, Transactions of the American Fisheries Society, *105*:550-560.

Birge, W.J., and J.A. Black, 1980, *Aquatic Toxicology of Nickel*, in Nickel in the Environment, J.O. Nriagu (editor), John Wiley & Sons, New York, pp. 349-366.

Browning, E., 1969, *Toxicology of Industrial Metals*, Butterworth & Co., Ltd., London.

Byron, W.R., et al., 1967, *Pathologic Changes in Rats and Dogs from a Two-Year Feeding of Sodium Arsenite or Sodium Arsenate*, Toxicology and Applied Pharmacology, *10*:132-147.

Camardese, M.B., et al., 1990, *Effects of Arsenate on Growth and Physiology in Mallard Ducklings*, Environmental Toxicology and Chemistry, *9*:785-795.

Canton, J.H., and W. Slooff, 1982, *Toxicity and Accumulation Studies of Cadmium (Cd^{2+}) with Freshwater Organisms of Different Trophic Levels*, Ecotoxicology and Environmental Safety, *6*:113-128.

Cearley, J.E., and R.L. Coleman, 1974, *Cadmium Toxicity and Bioconcentration in Largemouth Bass and Bluegill*, Bulletin of Environmental Contamination and Toxicology, *11*(2):146-151.

Chapman, G.A., 1978, *Toxicities of Cadmium, Copper and Zinc to Four Juvenile Stages of Chinook Salmon and Steelhead*, Transactions of the American Fisheries Society, *107*:841-847.

Christensen, G.M., 1975, *Biochemical Effects of Methylmercuric Chloride, Cadmium Chloride, and Lead Nitrate on Embryos and Alevins of the Brook Trout, Salvelinus Fontinalis*, Toxicology and Applied Pharmacology, *32*:191-197.

Demayo, A., et al., 1982, *Toxic Effects of Lead and Lead Compounds on Human Health, [illegible] Life, Wildlife, Plants, and Livestock*, Critical Reviews in Environmental ([illegible]ol, *12*:257-305.

Dickerson, O.B., 1980, *Arsenic*, in Metals in the Environment, H.A. Waldron (editor), Academic Press, London, pp. 1-24.

Eaton, J.G., J.M. McKim, and G.W. Holcombe, 1978, *Metal Toxicity to Embryos and Larvae of Seven Freshwater Fish Species — I. Cadmium*, Bulletin of Environmental Contamination nd Toxicology, *19*:95-103.

Eisler, R., 1985, *Cadmium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*, U.S. Fish and Wildlife Service, Contaminant Hazard Reviews Report No. 2, Biological Report 85(1.2).

isler, R., 1986, *Chromium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*, U.S. Fish and Wildlife Service, Contaminant Hazard Reviews Report No. 6, Biological Report 85(1.6), 60 pp.

Eisler, R., 1987, *Polycyclic Aromatic Hydrocarbon Hazards to Fish, Wildlife, and vertebrates: A Synoptic Review*, U.S. Fish and Wildlife Service Contaminant Hazard eviews Report No. 11, Biological Report 85(1.11), May.

[illegible]R., 1988a, *Arsenic Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*, [illegible]sh and Wildlife Service Contaminant Hazard Reviews Report No. 12, Biological Report 85(1.12), Jan.

Eisler, R., 1988b, *Lead Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*, U.S. Fish and Wildlife Service Contaminant Hazard Reviews Report No. 14, Biological port 85(1.14), April.

EPA: See U.S. Environmental Protection Agency.

Fowler, B.A., 1977, *Toxicology of Environmental Arsenic*, in Advances in Modern Toxicology: Volume 2, Toxicology of Trace Elements, R.A. Goyer and M.A. Mehlman (editors), misphere Publishing Corporation, Washington, D.C., pp. 79-122.

arrison, F.L., 1986, *The Impact of Increased Copper Concentrations on Freshwater osystems*, in Reviews in Environmental Toxicology 2, E. Hodgson (editor), Elsevier, Amsterdam, pp. 117-250.

seltine, S.D., and L. Sileo, 1983, *Response of American Black Ducks to Dietary Uranium: A Proposed Substitute for Lead Shot*, Journal of Wildlife Management, *47*(4):1124-1129.

[illegible]yama, S., and M. Yasuno, 1981, *A Method for Assessing Chronic Effects of Toxic S[illegible]nces on the Midge, Paratanytarsus parthenogeneticus — Effects of Copper*, Archives of ronmental Contamination and Toxicology, *10*:705-713.

Holcombe, G.W., G.L. Phipps, and J.T. Fiandt, 1983, *Toxicity of Selected Priority Pollutants to Various Aquatic Organisms*, Ecotoxicology and Environmental Safety, 7:400-409.

Hutchinson, T.C., 1981, Nickel, in *Effect of Heavy Metal Pollution on Plants: Volume 1, Effects of Trace Metals on Plant Function*, N.W. Lepp (editor), Applied Science Publishers, London, pp. 171-211.

ICRP: See International Commission on Radiological Protection.

International Commission on Radiological Protection, 1977, *Recommendations of the International Commission on Radiological Protection (Adopted January 17, 1977)*, ICRP Publication 26, Annals of the ICRP, *1*(3).

International Commission on Radiological Protection, 1979-1982, *Limits for Intakes of Radionuclides by Workers, A Report of Committee 2 of the International Commission on Radiological Protection*, ICRP Publication 30, Part 1 (and Supplement), Part 2 (and Supplement), Part 3 (and Supplements A and B), and Index, Annals of the ICRP.

Kaplan, D.I., et al., 1990, *Phytoavailability and Toxicity of Beryllium and Vanadium*, Water, Air, Soil Pollution, *53*:203-212.

Klaasen, C.D., M.O. Amdur, and J. Doull (editors), 1986, *Casarett and Doull's Toxicology: The Basic Science of Poisons*, 3rd edition, Macmillan Publishing Company, New York.

Knowlton, M.F., T.P. Boyle, and J.R. Jones, 1983, *Uptake of Lead from Aquatic Sediment by Submersed Macrophytes and Crayfish*, Archives of Environmental Contamination and Toxicology, *12*:535-541.

Koeppe, D.E., 1981, *Lead: Understanding the Minimal Toxicity of Lead in Plants*, in Effect of Heavy Metal Pollution on Plants: Volume 1, Effects of Trace Metals on Plant Function, N.W. Lepp (editor), Applied Science Publishers, London, pp. 55-76.

Lang, E.P., et al., 1950, *Liver Cell Alteration and DDT Storage in the Fat of the Rat Induced by Dietary Levels of 1-50 ppm DDT*, Journal of Pharmacology and Experimental Therapeutics, *98*:268-273. [As cited in EPA (1992).]

Ma, W., W. Denneman, and J. Faber, 1991, *Hazardous Exposure of Ground-Living Small Mammals to Cadmium and Lead in Contaminated Terrestrial Ecosystems*, Archives of Environmental Contamination and Toxicology, *20*:266-270.

Mancuso, T.F., 1975, *International Conference on Heavy Metals in the Environment*, Toronto, Ontario, Canada. [As cited in EPA (1992).]

Manzo, L., et al., 1983, *Long-Term Toxicity of Thallium in the Rat*, in Chemical Toxicology and Clinical Chemistry of Metals, S.S. Brown and J. Savory (editors), Academic Press, London, pp. 401-405.

Maynard, E.A., and H.C. Hodge, 1949, *Studies of the Toxicity of Various Uranium Compounds V[illegible] Fed to Experimental Animals*, in The Pharmacology and Toxicology of Uranium [illegible]unds, C. Voegtlin and H.C. Hodge (editors), McGraw-Hill Book Company, New York, ol. I, pp. 309-376.

McKim, J.M., J.G. Eaton, and G.W. Holcombe, 1978, *Metal Toxicity to Embryos and Larvae f Eight Species of Freshwater Fish — II: Copper*, Bulletin of Environmental Contamination nd Toxicology, *19*:608-616.

lirenda, R.J., 1986, *Toxicity and Accumulation of Cadmium in the Crayfish, Orconectes irilis (Hagen)*, Archives of Environmental Contamination and Toxicology, *15*:401-407.

luramoto, S., 1981, *Vertebral Column Damage and Decrease of Calcium Concentration in ish Exposed Experimentally to Cadmium*, Environmental Pollution (Series A), *24*:125-133.

lurthy, T.C.S., P. Weinberger, and M.P. Measures, 1984, *Uranium Effects on the Growth of oybean (Glycine max (L.) Merr.)*, Bulletin of Environmental Contamination and oxicology, *32*:580-586.

ushak, P., 1980, *Metabolism and Systemic Toxicity of Nickel*, in Nickel in the Environment, O. Nriagu (editor), John Wiley & Sons, New York, pp. 499-523.

National Academy of Sciences, 1977, *Drinking Water and Health, Volume 1*, National ca[illegible]y Press, Washington, D.C.

Na[illegible]al Academy of Sciences, 1983, *Drinking Water and Health, Volume 5*, National cademy Press, Washington, D.C.

National Council on Radiation Protection and Measurements, 1991, *Effects of Ionizing diation on Aquatic Organisms*, NCRP Report No. 109, Bethesda, Md.

National Research Council, 1988, *Health Risks of Radon and Other Internally Deposited pha-Emitters, BEIR IV*, National Academy Press, Washington, D.C.

ational Toxicology Program, 1982, *Carcinogenesis Bioassay of Di-(2-ethylhexyl)phthalate AS No. 117-81-7) in F344 Rats and B6C3F Mice (Feed Study)*, NTP Technical Report Series No. 217, Research Triangle Park, N.C. [As cited in EPA (1992).]

tional Toxicology Program, 1985, *Toxicology and Carcinogenesis Studies of 1,2-Dichloro- zene (o-Dichlorobenzene) (CAS No. 95-50-1) in F344/N Rats and B6C3F1 Mice (Gavage tudies)*, NTP TR No. 255, NIH Publication No. 86-2511. [As cited in EPA (1992).]

ational Toxicology Program, 1989, *Toxicology and Carcinogenesis Studies of Toluene in 344/N Rats and B6C3F1 Mice*, Technical Report Series No. 371, Research Triangle Park, [illegible]As cited in EPA (1992).]

Neal, J., and R.H. Rigdon, 1967, *Gastric Tumors in Mice Fed Benzo(a)pyrene: A Quantitative Study*, Texas Reports on Biology and Medicine, *25*:553-557. [As cited in ATSDR (1990f).]

Nebeker, A.V., et al., 1984, *Effects of Copper, Nickel, and Zinc on the Life Cycle of the Caddisfly Clistoronia magnifica (Limnephilidae)*, Environmental Toxicology and Chemistry, *3*:645-649.

Neff, J.M., 1979, *Polycyclic Aromatic Hydrocarbons in the Aquatic Environment*, Applied Science Publishers Ltd., London.

Nielsen, F.H., 1977, *Nickel Toxicity*, in Advances in Modern Toxicology: Volume 2, Toxicology of Trace Elements, R.A. Goyer and M.A. Mehlman (editors), Hemisphere Publishing Corporation, Washington, D.C., pp. 129-146.

Norback, D.H., and R.H. Weltman, 1985, *Polychlorinated Biphenyl Induction of Hepatocellular Carcinoma in the Sprague Dawley Rat*, Environmental Health Perspectives, *60*:97-105.

Outridge, P.M., and B.N. Noller, 1991, *Accumulation of Toxic Trace Elements by Freshwater Vascular Plants*, Reviews of Environmental Contamination and Toxicology, *121*:1-63.

Peterson, P.M., and C.A. Girling, 1981, *Other Trace Metals*, in Effect of Heavy Metal Pollution on Plants: Volume 1, Effects of Trace Metals on Plant Function, N.W. Lepp (editor), Applied Science Publishers, London, pp. 213-278.

Peterson, P.M., L.M. Benson, and R. Zieve, 1981, *Metalloids*, in Effect of Heavy Metal Pollution on Plants: Volume 1, Effects of Trace Metals on Plant Function, N.W. Lepp (editor), Applied Science Publishers, London, pp. 279-342.

Poston, T.M., R.W. Hanf, Jr., and M.A. Simmons, 1984, *Toxicity of Uranium to Daphnia magna*, Water, Air, Soil Pollution, *22*:289-298.

Prister, B.W., and S.S. Prister, 1970, *Effects of Uranium on the Growth and Development of Plants and Its Accumulation as a Function of the Content in the Germination Medium*, Radiology, *10*:221-224.

Rains, B.A., 1981, letter from B.A. Rains (St. Louis Metropolitan Sewer District, St. Louis, Mo.) to A. Gudata (Argonne National Laboratory, Argonne, Ill.), Nov. 12.

Rombough, P.J., and E.T. Garside, 1982, *Cadmium Toxicity and Accumulation in Eggs and Alevins of Atlantic Salmon Salmo salar*, Canadian Journal of Zoology, *60*(8):2006-2014.

Schroeder, H.A., and M. Mitchner, 1975, *Life-Term Studies in Rats: Effects of Aluminum, Barium, Beryllium, and Tungsten*, Journal of Nutrition, *105*:421-427. [As cited in EPA (1992).]

Schroeder, H.A., M. Mitchner, and A.P. Nasor, 1970, *Zirconium, Niobium, Antimony, V[illegible]lium and Lead in Rats; Lifeterm Studies*, Journal of Nutrition, *100*:54-66.

ier, H.G., H. Sigel, and A. Sigel, 1988, *Handbook on Toxicity of Inorganic Compounds*, Marcel Dekker, Inc., New York.

Shacklette, H.T., and J.G. Boerngen, 1984, *Element Concentrations in Soils and Other urficial Materials of the Coterminous United States*, U.S. Geological Survey Professional Paper 1270.

hacklette, H.T., et al., 1971, *Elemental Composition of Surficial Materials in the Coterminous United States*, U.S. Geological Survey Professional Paper 574-D.

looff, W., 1983, *Benthic Macroinvertebrates and Water Quality Assessment: Some Toxicological Considerations*, Aquatic Toxicology, *4*:73-82.

looff, W., J.H. Canton, and J.L.M. Hermens, 1983, *Comparison of the Susceptibility of 22 Freshwater Species to 15 Chemical Compounds, I. (Sub)acute Toxicity Tests*, Aquatic oxicology, *4*:113-128.

Spehar, R.L., R.L. Anderson, and J.T. Fiandt, 1978, *Toxicity and Bioaccumulation of idmium and Lead in Aquatic Invertebrates*, Environmental Pollution, *15*:195-208.

Suess, M.J., 1976, *The Environmental Load and Cycle of Polycyclic Aromatic Hydrocarbons*, [illegible] of the Total Environment, *6*:239-250.

arzwell, C.M., and C. Henderson, 1960, *Toxicity of Less Common Metals to Fishes*, Industrial astes, *5*:12.

aylor, D., 1983, *The Significance of the Accumulation of Cadmium by Aquatic Organisms*, otoxicology and Environmental Safety, *7*:33-42.

epper, L.B., 1980, *Beryllium*, in Metals in the Environment, H.A. Waldron (editor), ademic Press, London, pp. 25-60.

hun, M.J., et al., 1985, *Mortality among a Cohort of U.S. Cadmium Production Workers: Update*, Journal of the National Cancer Institute, *74*(2):325-333. [As cited in EPA (1992).]

yssen, J., J.K.G. Althoff, and U. Mohr, 1981, *Inhalation Studies with Benzo(a)pyrene in ian Golden Hamsters*, Journal of the National Cancer Institute, *66*:575-577. [As cited in TSDR (1990f).]

ng, W.P., 1977, *Effects and Dose Response Relationships of Skin Cancer and Blackfoot isease with Arsenic*, Environmental Health Perspectives, *19*:109-119. [As cited in EPA 92).]

Tyler, G., et al., 1989, *Heavy-Metal Ecology of Terrestrial Plants, Microorganisms and Invertebrates, A Review*, Water, Air, Soil Pollution, *47*:189-215.

U.S. Environmental Protection Agency, 1984a, *Health Effects Assessment for Copper*, EPA/540/1-86/025 (PB86-134368), Office of Health and Environmental Assessment, Cincinnati, Ohio.

U.S. Environmental Protection Agency, 1984b, *Health Effects Assessment for Polycyclic Aromatic Hydrocarbons (PAHs)*, EPA/540/1-86/013 (PB86-134244), Office of Health and Environmental Assessment, Cincinnati, Ohio.

U.S. Environmental Protection Agency, 1984c, *Health Effects Assessment for Selenium and Compounds*, EPA/540/1-86/058 (PB86-134699), Office of Health and Environmental Assessment, Cincinnati, Ohio.

U.S. Environmental Protection Agency, 1986, *Quality Criteria for Water, 1986*, EPA 440/5-86-001, Office of Water Regulations and Standards, Washington, D.C.

U.S. Environmental Protection Agency, 1989a, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A)*, Interim Final, EPA/540/1-89/002, Office of Emergency and Remedial Response, Washington, D.C..

U.S. Environmental Protection Agency, 1989b, *Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites*, OSWER 9355.4-02, Office of Solid Waste and Emergency Response, Washington, D.C., Sept. 7.

U.S. Environmental Protection Agency, 1991a, *Health Effects Assessment Summary Tables*, OERR 9200.6-303 (91-4), Annual, FY-1991, Office of Emergency and Remedial Response, Jan.

U.S. Environmental Protection Agency, 1991b, *Technical Support Document on Lead*, ECAO-CIN-757, prepared by Office of Health and Environmental Assessment, Cincinnati, Ohio, for Office of Solid Waste and Emergency Response, Washington, D.C., Jan. (Draft).

U.S. Environmental Protection Agency, 1992, *Integrated Risk Information System*, Office of Research and Development, database, accessed March.

Venugopal, B., and T.D. Luckey, 1978, *Metal Toxicity in Mammals, Vol. 2, Chemical Toxicity of Metals and Metalloids,* Plenum Press, New York.

Wagoner, J.K., P.F. Infante, and D.L. Bayliss, 1980, *Beryllium: An Etiologic Agent in the Induction of Lung Cancer, Nonneoplastic Respiratory Disease, and Heart Disease among Industrially Exposed Workers*, Environmental Research, *21*:15-34. [As cited in EPA (1992).]

Waldron, H.A., 1980, *Lead*, in Metals in the Environment, H.A. Waldron (editor), Academic Press, London, pp. 155-197.

Weir, R.J., and R.S. Fisher, 1972, *Toxicologic Studies on Borax and Boric Acid*, Toxicology a[illegible]pplied Pharmacology, *23*:351-364. [As cited in ATSDR (1992b).]

Wier, C.F., and W.M. Walter, 1976, *Toxicity of Cadmium in the Freshwater Snail, <u>Physa gyrina</u> Say*, Journal of Environmental Quality, *5*(4):359-362.

Wones, R.G., B.C. Stadler, and L.A. Feohman, 1990, *Lack of Effect of Drinking Water Barium on Cardiovascular Risk Factor*, Environmental Health Perspectives, *85*:1-13. [As cited in EPA (1992).]

Yang, G., et al., 1989, *Studies of Safe Maximal Daily Dietary Se-Intake in a Seleniferous Area in China, II, Relation between Se-Intake and the Manifestation of Clinical Signs and Certain Biochemical Alterations in Blood and Urine*, Journal of Trace Elements and Electrolytes in Health and Disease, *3*(2):123-130. [As cited in EPA (1992).]

APPENDIX C:

PARAMETERS DETERMINED IN SAMPLES COLLECTED AT THE ST. LOUIS SITE

TABLE C.1 Metals Analyzed in Samples from the St. Louis Site[a]

Metal	Method Detection Limit (μg/L)
Aluminum	200.0
Antimony	40.0
Arsenic	100.0
Barium	200.0
Beryllium	5.0
Boron	100.0
Cadmium	5.0
Calcium	5,000.0
Chromium	10.0
Cobalt	50.0
Copper	20.0
Iron	100.0
Lead	100.0
Magnesium	5,000.0
Manganese	15.0
Molybdenum	100.0
Nickel	20.0
Potassium	5,000.0
Selenium	100.0
Silver	10.0
Sodium	5,000.0
Thallium	100.0
Vanadium	10.0
Zinc	20.0

[a] Method of analysis = ICPAES (inductively coupled plasma atomic emission spectroscopy); to derive the detection limit for soil in mg/kg, multiply the detection limit by 0.2.

TABLE C.2 Volatile Organic Compounds Analyzed in St. Louis Site Soils

Analyte	CAS Number	Estimated Method Detection Limits in Soil[a,b] (μg/kg)
Chloromethane	74-87-3	10
Bromoethane	74-83-9	10
Vinyl chloride	75-01-4	10
Chloroethane	75-00-3	10
Methylene chloride	75-09-2	5
Acetone	67-64-1	10
Carbon disulfide	75-15-0	5
1,1-Dichloroethene	75-35-4	5
1,1-Dichloroethane	75-35-3	5
trans-1,2-Dichloroethene	156-60-5	5
Chloroform	67-66-3	5
1,2-Dichloroethane	107-06-2	5
2-Butanone	78-93-3	10
1,1,1-Trichloroethane	71-55-6	5
Carbon tetrachloride	56-23-5	5
Vinyl acetate	108-05-4	10
Bromodichloromethane	75-27-4	5
1,1,2,2-Tetrachloroethane	79-34-5	5
1,2-Dichloropropane	78-87-5	5
trans-1,2-Dichloropropene	10061-02-6	5
Trichloroethene	79-01-6	5
Dibromochloromethane	124-48-1	5
1,1,2-Trichloroethane	79-00-5	5
Benzene	71-43-2	5
cis-1,3-Dichloropropene	10061-01-5	5
2-Chloroethyl vinyl ether	110-75-8	10
Bromoform	75-25-2	5
2-Hexanone	581-78-6	10
4-Methyl-2-pentanone	108-10-1	5
Tetrachloroethene	127-18-4	5
Toluene	108-88-3	5
Chlorobenzene	108-90-7	5
Ethyl benzene	100-42-4	5
Styrene	100-42-5	5
Total xylenes	100-42-5	5

[a] Detection limits listed for soil are based on net weight. The detection limits calculated by the laboratory for soil/sediment calculated on dry weight basis will be higher.

[b] Detection limit for specific samples are highly matrix dependent. (The detection limits listed herein are provided for guidance and may not always be achievable.)

TABLE C.3 Semivolatile Organic Compounds Analyzed in St. Louis Site Soils

Analyte	CAS Number	Estimated Method Detection Limits in Soil[a,b] (µg/kg)
N-Nitrosodimethylamine	62-75-9	330
Phenol	108-95-2	330
Aniline	62-53-3	330
Bis(2-chloroethyl)ether	111-44-4	330
2-Chlorophenol	95-57-8	330
1,3-Dichlorobenzene	541-73-1	330
1,4-Dichlorobenzene	106-46-7	330
Benzyl alcohol	100-51-6	330
1,2-Dichlorobenzene	95-50-1	330
2-Methylphenol	95-48-7	330
Bis(2-chloroisopropyl) ether	39638-32-9	330
4-Methylphenol	106-44-5	330
N-Nitroso-dipropylamine	621-64-7	330
Hexachloroethane	67-72-1	330
Nitrobenzene	98-95-3	330
Isophorone	78-59-1	330
2-Nitrophenol	88-75-5	330
2,4-Dimethylphenol	105-67-9	330
Benzoic acid	65-85-0	1600
Bis(2-chloroethoxy) methane	111-91-1	330
2,4-Dichlorophenol	120-83-2	330
1,2,4-Trichlorobenzene	120-82-1	330
Naphthalene	91-20-3	330
4-Chloroaniline	106-47-8	330
Hexachlorobutadiene	87-68-3	330
4-Chloro-3-methylphenol (para-chloro-meta-cresol)	59-50-7	330
2-Methylnaphthalene	91-57-6	330
Hexachlorocyclopentadiene	77-47-4	330
2,4,6-Trichlorophenol	88-06-2	330
2,4,5-Trichlorophenol	95-95-4	1600
2-Chloronaphthalene	91-58-7	330
2-Nitroaniline	88-74-4	1600
Dimethyl phthalate	131-11-3	330
Acenaphthylene	208-96-8	330
3-Nitroaniline	99-09-2	1600
Acenaphthene	83-32-9	330
2,4-Dinitrophenol	51-28-5	1600
4-Nitrophenol	100-02-7	1600
Dibenzofuran	132-64-9	330
2,4-Dinitrotoluene	121-14-2	330

TABLE C.3 (Cont.)

Analyte	CAS Number	Estimated Method Detection Limits in Soil[a,b] (µg/kg)
2,6-Dinitrotoluene	606-20-2	330
Diethylphthalate	84-66-2	330
4-Chlorophenyl phenyl ether	7005-2-3	330
Fluorene	86-73-7	330
4-Nitroaniline	100-01-6	1600
4,6-Dinitro-2-methylphenol	534-52-1	1600
N-Nitrosodiphenylamine	86-30-6	330
4-Bromophenyl phenyl ether	101-55-3	330
Hexachlorobenzene	118-74-1	330
Pentachlorophenol	87-86-5	1600
Phenanthrene	85-01-8	330
Anthracene	120-12-7	330
Di-n-butylphthalate	84-74-2	330
Fluoranthene	206-44-0	330
Benzidine	92-87-5	1600
Pyrene	129-00-0	330
Butyl benzyl phthalate	85-68-7	330
3,3-Dichlorobenzidine	91-94-1	660
Benz(a)anthracene	56-55-3	330
Bis(2-ethylhexyl)phthalate	117-81-7	330
Chrysene	219-01-0	330
Di-n-octyl phthalate	117-84-0	330
Benzo(b)fluoranthene	205-99-2	330
Benzo(k)fluoranthene	207-08-9	330
Benzo(a)pyrene	50-32-8	330

[a] Detection limits listed for soil are based on wet weight. The detection limits calculated by the laboratory for soil/sediment calculated on dry weight basis will be higher.

[b] Detection limits for specific samples are highly matrix dependent. (The detection limits listed herein are provided for guidance and may not always be achievable.)

TABLE C.4 Methods of Analysis for Soil

Parameter	Analytical Technique	Method Detection Limit
Metals[a,b]	ICPAES[c] = EPA 6010	2 to 10,000 µg/g
Sulfate	Colorimetric = EPA 9035	25 mg/kg
Nitrate	Kjeldahl, distillation, titration = EPA 351	1 mg/kg
Fluoride	Distillation, ISE = EPA 340.1	5 mg/kg
Volatile organic compounds	8240	5 to 10 µg/kg
Semivolatile organic compounds	8270	330 to 1,600 µg/kg
Isotopic uranium	Radiochemical = EML-U-04[d]	0.5 pCi/g
Isotopic thorium	Radiochemical = EML-Th-03[e]	0.5 pCi/g
Uranium-238	Gamma spectrometry = EML-C-02[d]	5.0 pCi/g
Radium-226	Gamma spectrometry = EML-C-02[d]	0.5 pCi/g
Thorium-230	Alpha spectrometry = EML-Th-03[e]	0.5 pCi/g
Thorium-232	Gamma spectrometry = EML-C-02[d]	0.5 pCi/g

[a] Includes aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, vanadium, and zinc.

[b] Soil samples will be prepared for analyses in accordance with procedures outlined in Exhibit D of the CLP-SOW for inorganic analysis.

[c] ICPAES = inductively coupled plasma atomic emission spectroscopy.

[d] TMA/E utilizes laboratory procedure developed by Environmental Measurements Laboratory-300 (EML-300).

[e] Modified by Environmental Measurements Laboratory procedure to accommodate the matrix.

TABLE C.5 Methods of Analysis for Water

Parameter	Analytical Technique	Method Detection Limit[a]
Metals[b,c,d]	ICPAES[e]: EPA 200.7-CLP-M	5 to 5,000 µg/L[f]
Volatile organics	EPA method 8240 (SW 846)	5 to 10 µg/L[f]
Semivolatile organics	EPA method 8270 (SW 846)	10 to 50 µg/L[f]
PCBs/Pesticides	EPA method 8080 (SW 846)	0.05 to 5.0 µg/L[f]
pH	Electrometric: EPA 150.1	–
Total organic carbon	EPA 415.1	1 mg/L
Specific conductance	Electrometric: EPA 120.1	0.1 mg/L
Fluoride	Ion-selective electrode: EPA 340.2	0.1 mg/L
Nitrate	Ion chromatography: EPA 353.1	0.14 mg/L
Sulfate	Colorimetric: EPA 375.1	10 mg/L
Total organic halides	EPA method 9020 (SW 846)	–
Uranium	Fluorimetry EML-U-03	5 µg/L
Thorium	Alpha spectrometry EML-Th-03 (modified)	0.5 pCi/L
Radium	Alpha spectrometry of radon emanation: EPA 903.1	0.1 pCi/L

[a] Published method detection limits. The laboratory attempts to maintain the published method detection limits; however, matrix interference will raise the detection limits.

[b] Include aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, vanadium, and zinc.

[c] Samples will be prepared for analyses in accordance with procedures outlined in Exhibit D of the CLP-SOW for inorganics analyses.

[d] For boron, lithium, molybdenum, and lanthanides, which are not standard CLP analyses, the following was done: interference standards were prepared and a calibration curve determined, initial calibration verification (ICV) and calibration curve verification (CCV) standards were prepared at a midrange concentration, and a laboratory control sample was prepared by digesting the ICV standard.

[e] ICPAES = inductively coupled plasma atomic emission spectroscopy.

[f] Range of detection limits.

APPENDIX D:

RISK ESTIMATES FOR THE INGESTION OF HOMEGROWN PRODUCE PATHWAY

APPENDIX D:

RISK ESTIMATES FOR THE INGESTION OF HOMEGROWN PRODUCE PATHWAY

The ingestion of produce grown in contaminated site soil is a potential exposure route to contaminants at the St. Louis Site. For current receptors, this exposure route is plausible only at the five St. Louis Airport Site (SLAPS) residential vicinity properties because the other properties comprising the St. Louis Site are not used residentially. Exposure through ingestion of homegrown produce is analyzed in this appendix for current and future residents at the residential vicinity properties and for future residents at the St. Louis Downtown Site (SLDS) and adjacent city property, SLAPS, ballfield, Futura Coatings property, and Hazelwood Interim Storage Site (HISS). However, exposure via this route for a current resident at the residential vicinity properties is unlikely because the areas of contaminated soil are narrow areas along the roadsides, and a garden is unlikely to be placed there.

The ingestion of homegrown produce pathway is evaluated separately from other exposure pathways because of considerable uncertainty in the prediction of contaminant concentrations in edible produce (see Sections D.1 and D.4). Contaminant-specific data relating concentrations in edible produce to soil concentrations are generally unavailable. Soil-to-plant transfer factors available in the literature are derived from data used for the evaluation of radiological exposure from weapons testing fallout and may not be appropriate for the evaluation of chemical toxicity. Because of the difficulty in accurately predicting contaminant concentrations (i.e., exposure point concentrations) in produce, the U.S. Environmental Protection Agency (EPA) currently recommends a qualitative evaluation of risks from this pathway (EPA 1991). Nevertheless, a quantitative evaluation is provided here to guide the assessment of potential radioactive and chemical contaminants of concern. High risk estimates for specific substances should be interpreted only as indicators of areas requiring further investigation, not as actual risks. Because of inherent uncertainties, the magnitude of actual risks may be overestimated.

D.1 EXPOSURE POINT CONCENTRATIONS

Soil data from the St. Louis Site properties were used to derive potential concentrations of site contaminants of concern in produce. The transfer of radionuclides and inorganic contaminants of concern from soil to edible produce would depend on many factors, uch as plant species, pH of the soil, and chemical form of the contaminant (Gough et al. 979). Also, for many inorganic substances, a certain level is toxic to a plant and, beyond hat level, growth will not occur. For example, nickel is toxic to tomato plants at 40 mg/kg in the plant tissue; therefore, linear accumulation of nickel in the plant fruit at a level higher han 40 mg/kg is impossible, no matter what the soil level is (Gough et al. 1979).

Although not entirely applicable for every species of produce, soil-to-plant transfer coefficients have been assigned to many radioactive and nonradioactive elements (Ng et al. 1968, 1982). Transfer factors for PAHs and thallium were obtained from literature sources; the geometric mean of five literature-derived values was used for thallium because of considerable variability in the cited transfer coefficients. The soil-to-plant transfer coefficients used in this assessment are listed in Table D.1*; these coefficients were used to estimate the concentrations of radioactive and chemical contaminants of concern that might accumulate in edible plant tissues if a garden were grown in the contaminated areas. For radionuclides, the 95% upper confidence limit (UL_{95}) values of the arithmetic means of data for the 0- to 0.9-m (0- to 3-ft) layer were used because the depths of most root systems do not extend past 0.9 m (3 ft). For chemicals, the appropriate UL_{95} values for surficial soil were used as input data to calculate concentrations in plants, except for cases in which overall soil concentrations were higher (analogous to the chemical data evaluation methodology presented in Section 3.3.1.1). Soil contaminant concentrations at the residential vicinity properties were assumed to be the same for both current and future resident scenarios; thus, risk estimates are identical. The appropriate UL_{95} value of the soil concentration was multiplied by the soil-to-plant transfer coefficient for each contaminant (Table D.1) to derive the exposure point concentrations for homegrown produce. The exposure point concentrations for the ingestion of homegrown produce at the St. Louis Site are given in Table D.2 for radionuclides and Table D.3 for chemicals.

D.2 INTAKE ASSUMPTIONS

The produce ingestion rate for calculating contaminant intake from homegrown produce was 200 g/d, which is the "typical" consumption rate for vegetables (EPA 1991). Only vegetable intake was assessed because fruits take up low amounts of radionuclides and heavy metals (EPA 1991). Other assumptions necessary for calculating dose and intake from this pathway are the fraction ingested from the contaminated source, 0.4 (EPA 1991); exposure frequency, 350 days per year; exposure duration, 30 years; and body weight, 70 kg.

D.3 EQUATIONS FOR DOSE AND INTAKE ESTIMATIONS

D.3.1 Radiological Dose

The RESRAD computer code was used to calculate the radiological dose from ingestion of homegrown produce. The dose calculation is detailed in Gilbert et al. (1989) and summarized in Equation D.1:

$$D_i = R_{pi} \times IR_p \times CF \times FI \times EF \times ED \times DCF_i \qquad (D.1)$$

---

*For readability, the tables in this appendix are presented in sequence following Section D.5.

where:

D_i = dose from radionuclide i, mrem;

R_{pi} = concentration of radionuclide i in homegrown produce, pCi/g (Table D.2);

IR_p = plant ingestion rate, kg/d (from EPA 1991);

CF = conversion factor, 1,000 g/kg;

FI = fraction ingested from contaminated source, 0.4 (from EPA 1991);

EF = exposure frequency, d/yr;

ED = exposure duration, yr; and

DCF_i = ingestion dose conversion factor for radionuclide i, mrem/pCi (Table 3.25).

The estimated doses from ingestion of homegrown produce are given in Table D.2.

D.3.2 Chemical Intake

Equation D.2 was used to calculate chemical intake via ingestion of homegrown produce:

$$\text{Intake (mg/kg-d)} = \frac{(C_i \times IR_p \times FI \times EF \times ED)}{(BW \times AF \times AD)} \qquad (D.2)$$

where:

C_i = concentration of chemical i in homegrown produce, mg/kg, based on UL_{95} soil concentration (Table D.3);

IR_p = plant ingestion rate, kg/d (from EPA 1991);

FI = fraction ingested from contaminated source, 0.4 (from EPA 1991);

EF = exposure frequency, d/yr;

ED = exposure duration, yr;

BW = body weight, kg;

AF = averaging frequency, 365 d/yr; and

AD = averaging duration, yr (equal to ED for noncarcinogens and 70 years for carcinogens).

Because chemical intakes for carcinogenic risk calculations were averaged over a lifetime of 70 years, the intakes calculated for use in estimating carcinogenic risks differ somewhat from those calculated for estimating noncarcinogenic end points. The estimated intakes for both noncarcinogenic and carcinogenic risk estimates are presented in Table D.4.

D.4 TOXICITY ASSESSMENT AND RISK ESTIMATES

The risk factor used to evaluate radiological dose is 6×10^{-7}/mrem; the derivation of this value is discussed in Section 4.1.2. The reference doses and slope factors used to evaluate noncarcinogenic and carcinogenic toxicity of the chemical contaminants are presented in Section 4.2.2. More detailed information on the toxicity of the radioactive and chemical contaminants of concern is presented in Appendix B.

D.4.1 Radiological Risks

The estimated risks associated with the produce ingestion pathway from exposure to radioactive contaminants range from 2.2×10^{-4} for the residential vicinity property (current or future resident) to 2.6×10^{-2} for the HISS future resident (Tables D.5 and D.6). An additional risk of 1.7×10^{-2} would be incurred by the HISS future resident from exposure to contaminants in the waste pile (Table D.6). These risks all exceed the target risk range of 1×10^{-6} to 1×10^{-4}. For each property, approximately 90% of the risk is contributed by lead-210, with most of the remaining risk attributable to actinium-227 and protactinium-231 (Table D.5).

D.4.2 Chemical Risks

The estimated risks associated with the produce ingestion pathway from exposure to chemical contaminants range from 2.3×10^{-4} for SLAPS to 4.0×10^{-1} for SLDS (Table D.7). These risks all exceed the target risk range. At all properties except SLDS, most of the carcinogenic risk is attributable to arsenic. For SLDS, the risk is primarily attributable to the PAHs.

The estimated hazard indexes range from 86 for SLAPS to 1,500 for HISS (Table D.8). All contaminants except beryllium and uranium have individual hazard quotients exceeding 1 for at least one of the properties evaluated. Thallium generally contributes more than 90% of the hazard index for each property; however, selenium is also a significant contributor (i.e., 33%) for the Futura Coatings property.

D.4.3 Overall Risks

The estimated carcinogenic risks associated with produce ingestion exceed the target risk range for future residents at each property (Table D.9). For current scenarios, the produce ingestion pathway applies only to the residential vicinity property. Although the risk or a current resident at the residential vicinity property (2.2×10^{-4}) slightly exceeds the target risk range, it is unlikely that a garden would be placed in the contaminated area because the area is narrow and located immediately adjacent to the road.

The radioactive and chemical carcinogenic contaminants of greatest concern are lead-210, arsenic, and PAHs. For noncarcinogenic toxicity, contaminants that may be of oncern (i.e., have hazard quotients greater than 1) are antimony, arsenic, cadmium, copper, molybdenum, nickel, selenium, and thallium. To adequately assess the produce ingestion athway, more data are needed on the actual extent of bioaccumulation of these substances om soil into edible plant tissues.

.5 SUMMARY

Considerable uncertainty exists in the methods used to estimate exposure point oncentrations for contaminants in homegrown produce on the basis of soil concentrations. Uptake of contaminants differs for each plant species and for varying soil characteristics (e.g., H). The form of the contaminant in soil must also be bioavailable to the plant, and the ontaminant must concentrate in the edible part of the plant for exposure to occur. Finally, he contaminant taken up by the plant must not be too toxic to the plant for the edible ortion to develop and subsequently be consumed by human receptors. These varied factors re not adequately represented by a simple soil-to-plant transfer factor that predicts oncentrations of contaminants in homegrown produce. For example, although 0.33 was used s the soil-to-plant transfer factor for carcinogenic PAHs in this assessment, the reported ange of transfer factors for benzo(a)pyrene is 0.002 to 0.33 (Agency for Toxic Substances and isease Registry 1990). Therefore, if the actual transfer factor for carcinogenic PAHs is at e low end of the range, the exposure point concentrations given in this assessment for arcinogenic PAHs in homegrown produce may be overestimated by a factor of more than 150. milarly, exposure point concentrations estimated in this assessment may be greater than ncentrations toxic to plants; the toxic concentration of nickel in plants is 40 mg/kg (Gough al. 1979), but a nickel concentration of 120 mg/kg was estimated for homegrown produce Futura Coatings on the basis of the soil-to-plant transfer factor of 0.033 (Table D.1) and igh soil nickel concentration (Table D.3). Therefore, this assessment offers a worst-case ediction of intakes and risks from the product ingestion pathway; further refinement might bstantially decrease the predicted risks.

TABLE D.1 Soil-to-Plant Transfer Factors for Contaminants of Concern at the St. Louis Site

Contaminant	Soil-to-Plant Transfer Factor	Reference
Metals		
Antimony	0.011	Ng et al. (1968)
Arsenic	0.01	Ng et al. (1968)
Beryllium	0.00042	Ng et al. (1968)
Cadmium	0.3	Ng et al. (1968)
Cobalt	0.03	Ng et al. (1982)
Copper	0.25	Ng et al. (1982)
Lead	0.068	Ng et al. (1968)
Molybdenum	0.13	Ng et al. (1968)
Nickel	0.033	Ng et al. (1982)
Selenium	1.3	Ng et al. (1968)
Thallium	0.46	Dolgner et al. (1983); Gough et al. (1979); Ng et al. (1968); Kaplan et al. (1990)
Uranium	0.0025	Ng et al. (1968)
PAHs	0.33	Agency for Toxic Substances and Disease Registry (1990)
Radionuclides		
Actinium	0.0025	Ng et al. (1968)
Lead	0.068	Ng et al. (1968)
Protactinium	0.0025	Ng et al. (1968)
Radium[a]	0.0014	Ng et al. (1968)
Thorium[b]	0.0042	Ng et al. (1968)
Uranium[c]	0.0025	Ng et al. (1968)

[a] Applicable to radium-226 and radium-228.

[b] Applicable to thorium-228, thorium-230, and thorium-232.

[c] Applicable to uranium-234, uranium-235, and uranium-238.

TABLE D.2 Radionuclide Exposure Point Concentrations and Estimated Doses from Ingestion of Homegrown Produce by Current and Future Residents at the St. Louis Site[a]

	Actinium-227+D		Lead-210+D	
Property and Receptor	Plant Concentration (pCi/g)	Dose (mrem)	Plant Concentration (pCi/g)	Dose (mrem)
SLDS future resident[b]	0.050	680	4.6	27,000
SLAPS future resident	0.095	1,300	4.6	28,000
Residential vicinity property current or future resident	0.00078	10	0.042	250
Ballfield future resident	0.0062	84	0.29	1,800
Futura Coatings future resident	0.058	780	3.4	21,000
HISS future resident	0.12	1,600	6.8	41,000

	Protactinium-231		Radium-226+D	
Property and Receptor	Plant Concentration (pCi/g)	Dose (mrem)	Plant Concentration (pCi/g)	Dose (mrem)
SLDS future resident[b]	0.048	470	0.073	72
SLAPS future resident	0.11	1,000	0.057	57
Residential vicinity property current or future resident	0.00088	8.9	0.00043	0.42
Ballfield future resident	0.0068	69	0.0036	3.7
Futura Coatings future resident	0.070	690	0.029	29
HISS future resident	0.14	1,400	0.060	60

	Radium-228+D		Thorium-228+D	
Property and Receptor	Plant Concentration (pCi/g)	Dose (mrem)	Plant Concentration (pCi/g)	Dose (mrem)
SLDS future resident[b]	0.0081	8.8	0.031	21
SLAPS future resident	0.0011	1.1	0.0097	6.5
Residential vicinity property current or future resident[c]	-	-	0.00018	0.11
Ballfield future resident	0.00070	0.76	0.0063	4.3
Futura Coatings future resident	0.00025	0.27	0.0097	6.8
HISS future resident	0.00024	0.26	0.0088	6

TABLE D.2 (Cont.)

	Thorium-230		Thorium-232	
Property and Receptor	Plant Concentration (pCi/g)	Dose (mrem)	Plant Concentration (pCi/g)	Dose (mrem)
SLDS future resident[b]	0.50	240	0.030	76
SLAPS future resident	1.8	860	0.011	29
Residential vicinity property current or future resident	0.18	88	0.00018	0.42
Ballfield future resident	0.097	48	0.0076	19
Futura Coatings future resident	0.46	220	0.0097	24
HISS future resident	0.67	320	0.0088	22

	Uranium-234		Uranium-235+D	
Property and Receptor	Plant Concentration (pCi/g)	Dose (mrem)	Plant Concentration (pCi/g)	Dose (mrem)
SLDS future resident[b]	0.45	110	0.021	4.7
SLAPS future resident	0.083	19	0.0038	0.84
Residential vicinity property current or future resident[c]	0.0013	0.29	-	-
Ballfield future resident	0.019	4.3	0.00085	0.19
Futura Coatings future resident	0.068	16	0.0030	0.68
HISS future resident	0.14	32	0.0063	1.4

	Uranium-238+D		
Property and Receptor	Plant Concentration (pCi/g)	Dose (mrem)	Total Dose (mrem)
SLDS future resident[b]	0.45	100	29,000
SLAPS future resident	0.083	19	31,000
Residential vicinity property current or future resident	0.0013	0.28	360
Ballfield future resident	0.019	4.2	2,000
Futura Coatings future resident	0.068	15	23,000
HISS future resident	0.14	30	44,000

[a] Based on soil data for a depth of 0-3 ft; however, for HISS, thorium-230 data for 1-3 ft were used because no thorium-230 data were available for 0-1 ft.

[b] Data for the city property were incorporated into the SLDS data to estimate soil concentrations.

[c] A hyphen indicates that plant concentrations were not projected from soil data because soil concentrations were below background.

TABLE D.3 Chemical Exposure Point Concentrations for Ingestion of Homegrown Produce by Future Residents at the St. Louis Site[a]

	Exposure Point Concentration[b] (mg/kg)				
Contaminant	SLDS	SLAPS	Ballfield	Futura	HISS
Metals					
Antimony	1.3	0.062	0.29	-	0.62
Arsenic	0.32	0.28	0.78	0.71	2.1
Beryllium	0.00037	0.00063	0.0010	0.0020	0.0031
Cadmium	0.93	0.51	0.72	-	2.5
Cobalt	0.39	22	0.75	84	26
Copper	-	120	-	450	-
Lead	88	8.8	2.8	9.5	18
Molybdenum	-	-	11	26	31
Nickel	0.92	30	1.1	120	30
Selenium	-	-	110	270	260
Thallium	22	5.1	40	5.5	92
Uranium	1.3	0.24	-	0.20	0.40
PAHs	150	-	-	-	-

[a] Contaminant concentrations in plants were calculated by multiplying the soil UL_{95} values given in Table 3.15 by the appropriate soil-to-plant transfer factors given in Table D.1. All values are rounded to two significant figures. Data are not available for the residential vicinity property.

[b] A hyphen indicates that the substance is not a contaminant of concern for that property.

TABLE D.4 Estimated Daily Intake of Chemicals from Ingestion of Homegrown Produce by Future Residents at the St. Louis Site[a]

	Estimated Daily Intake for Future Resident Averaged over Exposure Period[b] (mg/kg-d)				
Contaminant	SLDS	SLAPS	Ballfield	Futura	HISS
Metals					
Antimony	1.4×10^{-3}	6.8×10^{-5}	3.1×10^{-4}	-	6.8×10^{-4}
Arsenic	3.5×10^{-4}	3.1×10^{-4}	8.5×10^{-4}	7.8×10^{-4}	2.3×10^{-3}
Beryllium	4.0×10^{-7}	6.9×10^{-7}	1.1×10^{-6}	2.2×10^{-6}	3.4×10^{-6}
Cadmium	1.0×10^{-3}	5.6×10^{-4}	7.9×10^{-4}	-	2.8×10^{-3}
Cobalt	4.3×10^{-4}	2.4×10^{-2}	8.2×10^{-4}	9.2×10^{-2}	2.8×10^{-2}
Copper	-	1.3×10^{-1}	-	4.9×10^{-1}	-
Lead	9.7×10^{-2}	9.7×10^{-3}	3.1×10^{-3}	1.0×10^{-2}	1.9×10^{-2}
Molybdenum	-	-	1.2×10^{-2}	2.8×10^{-2}	3.4×10^{-2}
Nickel	1.0×10^{-3}	3.3×10^{-2}	1.2×10^{-3}	1.3×10^{-1}	3.3×10^{-2}
Selenium	-	-	1.2×10^{-1}	3.0×10^{-1}	2.8×10^{-1}
Thallium	2.4×10^{-2}	5.5×10^{-3}	4.4×10^{-2}	6.0×10^{-3}	1.0×10^{-1}
Uranium	1.5×10^{-3}	2.7×10^{-4}	-	2.2×10^{-4}	4.4×10^{-4}
PAHs	1.6×10^{-1}	-	-	-	-

	Estimated Daily Intake for Future Resident Averaged over Lifetime[b,c] (mg/kg-d)				
Contaminant	SLDS	SLAPS	Ballfield	Futura	HISS
Metals					
Arsenic	1.5×10^{-4}	1.3×10^{-4}	3.7×10^{-4}	3.3×10^{-4}	9.9×10^{-4}
Beryllium	1.7×10^{-7}	3.0×10^{-7}	4.7×10^{-7}	9.5×10^{-7}	1.5×10^{-6}
Lead	4.2×10^{-2}	4.2×10^{-3}	1.3×10^{-3}	4.5×10^{-3}	8.3×10^{-3}
PAHs	6.9×10^{-2}	-	-	-	-

[a] Data are not available for the residential vicinity property. See Table D.3 for exposure point concentrations and Section D.3 for equation used to calculate intake.

[b] A hyphen indicates that the substance is not a contaminant of concern for that property.

[c] Estimated for carcinogenic contaminants only.

TABLE D.5 Radiological Carcinogenic Risk from Ingestion of Homegrown Produce by Current and Future Residents at the St. Louis Site[a]

	Carcinogenic Risk			
Property and Receptor	Actinium-227+D	Lead-210+D	Protactinium-231	Radium-226+D
SLDS future resident	4.1×10^{-4}	1.6×10^{-2}	2.8×10^{-4}	4.3×10^{-5}
SLAPS future resident	7.8×10^{-4}	1.7×10^{-2}	6.0×10^{-4}	3.4×10^{-5}
Residential vicinity property current or future resident	6.0×10^{-6}	1.5×10^{-4}	5.3×10^{-6}	2.5×10^{-7}
Ballfield future resident	5.0×10^{-5}	1.1×10^{-3}	4.1×10^{-5}	2.2×10^{-6}
Futura Coatings future resident	4.7×10^{-4}	1.3×10^{-2}	4.1×10^{-4}	1.7×10^{-5}
HISS future resident[b]	9.6×10^{-4}	2.5×10^{-2}	8.4×10^{-4}	3.6×10^{-5}

	Carcinogenic Risk			
Property and Receptor	Radium-228+D	Thorium-228+D	Thorium-230	Thorium-232
SLDS future resident	5.3×10^{-6}	1.3×10^{-5}	1.4×10^{-4}	4.6×10^{-5}
SLAPS future resident	6.6×10^{-7}	3.9×10^{-6}	5.2×10^{-4}	1.7×10^{-5}
Residential vicinity property current or future resident[c]	0	6.6×10^{-8}	5.3×10^{-5}	2.5×10^{-7}
Ballfield future resident	4.6×10^{-7}	2.6×10^{-6}	2.9×10^{-5}	1.1×10^{-5}
Futura Coatings future resident	1.6×10^{-7}	4.1×10^{-5}	1.3×10^{-4}	1.4×10^{-5}
HISS future resident[b]	1.6×10^{-7}	3.6×10^{-6}	1.9×10^{-4}	1.3×10^{-5}

	Carcinogenic Risk			Total Carcinogenic Risk
Property and Receptor	Uranium-234	Uranium-235+D	Uranium-238+D	
SLDS future resident	6.6×10^{-5}	2.8×10^{-6}	6.0×10^{-5}	1.7×10^{-2}
SLAPS future resident	1.1×10^{-5}	5.0×10^{-7}	1.1×10^{-5}	1.9×10^{-2}
Residential vicinity property current or future resident[c]	1.7×10^{-7}	0	1.7×10^{-7}	2.2×10^{-4}
Ballfield future resident	2.6×10^{-6}	1.1×10^{-7}	2.5×10^{-6}	1.2×10^{-3}
Futura Coatings future resident	9.6×10^{-6}	4.1×10^{-7}	9.0×10^{-6}	1.4×10^{-2}
HISS future resident[b]	1.9×10^{-5}	8.4×10^{-7}	1.8×10^{-5}	2.6×10^{-2}

[a] The risk estimates presented in this table are derived from exposure point concentrations and estimated doses given in Table D.2.

[b] See Table D.6 for additional estimated risks from the contribution of contaminants in the HISS storage piles.

[c] A zero indicates that the soil concentrations (which were used to derive the plant concentrations) were less than background levels and would result in an insignificant risk.

TABLE D.6 Estimated Dose and Risk from the HISS Pile

Radionuclide[a]	Exposure Point Concentration[b] (pCi/g)	Dose (mrem)	Risk
Actinium-227+D	200	6,800	4.1×10^{-3}
Protactinium-231	120	3,000	1.7×10^{-3}
Radium-226+D	57	79	4.7×10^{-5}
Radium-228+D	1.9	2.9	1.7×10^{-6}
Thorium-228+D	2.1	6	3.6×10^{-6}
Thorium-230	8,900	18,000	1.1×10^{-2}
Thorium-232	1.9	20	1.2×10^{-5}
Uranium-235+D	4	2.3	1.4×10^{-6}
Uranium-238+D	72	41	2.5×10^{-5}
Total		28,000	1.7×10^{-2}

[a] Radionuclide groups in this table are based on the results presented in Table 2.4.

[b] Based on radiological data taken from the pile existing in 1981 (Oak Ridge Associated Universities 1981).

TABLE D.7 Chemical Carcinogenic Risk from Ingestion of Homegrown Produce by Future Residents at the St. Louis Site[a]

Contaminant	Carcinogenic Risk[b]				
	SLDS[c]	SLAPS	Ballfield	Futura[d]	HISS
Metals					
Arsenic	2.6×10^{-4}	2.3×10^{-4}	6.4×10^{-4}	5.8×10^{-4}	1.7×10^{-3}
Beryllium	7.4×10^{-7}	1.3×10^{-6}	2.0×10^{-6}	4.1×10^{-6}	6.3×10^{-6}
PAHs	4.0×10^{-1}	-	-	-	-
Total carcinogenic risk	4.0×10^{-1}	2.3×10^{-4}	6.4×10^{-4}	5.8×10^{-4}	1.7×10^{-3}

[a] The risk estimates presented in this table are derived from exposure point concentrations given in Table D.3 and estimated daily intakes given in Table D.4.

[b] A hyphen indicates that the substance is not a contaminant of concern for that property.

[c] Includes the SLDS main site, SLDS vicinity properties, and city property.

[d] Represents all commercial/municipal/industrial vicinity properties.

TABLE D.8 Chemical Hazard Quotients for Ingestion of Homegrown Produce by Future Residents at the St. Louis Site[a]

	Hazard Quotient[b]				
Contaminant	SLDS[c]	SLAPS	Ballfield	Futura[d]	HISS
Metals					
Antimony	3.6	0.17	0.78	-	1.7
Arsenic	1.2	1.0	2.8	2.6	7.7
Beryllium	0.00008	0.00014	0.00022	0.00044	0.00068
Cadmium	1	0.56	0.79	-	2.8
Cobalt	NQ	NQ	NQ	NQ	NQ
Copper	-	3.5	-	13	-
Molybdenum	-	-	3.0	7.1	8.5
Nickel	0.050	1.7	0.061	6.3	1.6
Selenium	-	-	24	60	57
Thallium	340	79	630	86	1,400
Uranium[d]	0.50	0.090	-	0.073	0.15
PAHs	NQ	-	-	-	-
Hazard index	350	86	660	180	1,500

[a] The hazard quotients presented in this table are derived from exposure point concentrations given in Table D.3 and estimated daily intakes given in Table D.4.

[b] NQ indicates not quantified because no oral reference doses (RfDs) are available; a hyphen indicates that the substance is not a contaminant of concern for that property. All values are rounded to two significant figures.

[c] Includes the SLDS main site, SLDS vicinity properties, and city property.

[d] Represents all commercial/municipal/industrial vicinity properties.

TABLE D.9 Radiological and Chemical Carcinogenic Risk from Ingestion of Homegrown Produce

	Carcinogenic Risk		
Property	Radiological[a]	Chemical[b]	Total
SLDS	1.7×10^{-2}	4.0×10^{-1}	4.2×10^{-1}
SLAPS	1.9×10^{-2}	2.3×10^{-4}	1.9×10^{-2}
Residential vicinity property	2.2×10^{-4}	-[c]	2.2×10^{-4}
Ballfield	1.2×10^{-3}	6.4×10^{-4}	1.8×10^{-3}
Futura Coatings	1.4×10^{-2}	5.8×10^{-4}	1.5×10^{-2}
HISS[d]	2.6×10^{-2}	1.7×10^{-3}	2.8×10^{-2}

[a] Doses are presented in Table D.2.

[b] Based on intake values presented in Table D.4.

[c] No data available.

[d] The HISS property has an additional radiological risk of 1.7×10^{-2} from exposure to the HISS pile; estimates for the HISS pile are presented in Table D.6.

D.6 REFERENCES

Agency for Toxic Substances and Disease Registry, 1990, *Toxicological Profile for Polycyclic Aromatic Hydrocarbons*, ATSDR/TP-90/20, prepared by Clement International Corporation for U.S. Public Health Service, Dec.

Dolgner, R., et al., 1983, *Repeated Surveillance of Exposure to Thallium in a Population Living in the Vicinity of a Cement Plant Emitting Dust Containing Thallium*, International Archives of Occupational and Environmental Health, *51*(1):79-94.

EPA: see U.S. Environmental Protection Agency

Gilbert, T.L., et al., 1989, *A Manual for Implementing Residual Radioactive Material Guidelines*, ANL/ES-160 (DOE/CH/8901), prepared by Argonne National Laboratory, Energy and Environmental Systems Division, Argonne, Ill., for U.S. Department of Energy, Assistant Secretary for Nuclear Energy, June.

Gough, L.P., et al., 1979, *Element Concentrations Toxic to Plants, Animals, and Man*, U.S. Geological Survey Bulletin 1466.

Kaplan, D.I., et al., 1990, *Thallium Toxicity in Bean*, Journal of Environmental Quality, *19*(3):359-365.

Ng, Y.C., et al., 1968, *Prediction of the Maximum Dosage to Man from the Fallout of Nuclear Devices; IV. Handbook for Estimating the Maximum Internal Dose from Radionuclides Released to the Biosphere*, TID-4500, Lawrence Radiation Laboratory, Livermore, Calif.

Ng, Y.C., et al., 1982, *Soil-to-Plant Concentration Factors for Radiological Assessments*, NUREG/CR-2975, Lawrence Livermore National Laboratory, Livermore, Calif.

Oak Ridge Associated Universities, 1981, *Radiological Survey of the Mallinckrodt Chemical Works, St. Louis, Missouri*, DOE/EV-0005/27 (ORNL-5715), Oak Ridge, Tenn., Dec.

U.S. Environmental Protection Agency, 1991, *Risk Assessment Guidance for Superfund, Volume I, Human-Health Evaluation Manual, Supplemental Guidance, "Standard Default Exposure Factors," Interim Final*, OSWER Directive 9285.6-03, Office of Emergency and Remedial Response, Washington, D.C., March 25.

08 01
Reports

9810161060

00-1415

SL-1283

Formerly Utilized Sites Remedial Action Program (FUSRAP)

ADMINISTRATIVE RECORD

for the St. Louis Site, Missouri

U.S. Department of Energy

14-1070.2