U.S. Army
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Engineers

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Luckey Site
Luckey, Ohio

FINAL
Remedial Investigation Report
Volume I (Text)

Prepared for:
U.S. Army Corps of Engineers
Buffalo District

Prepared by:
Science Applications International Corporation
Dublin, Ohio

Managed by:
Montgomery Watson

Total Environmental Restoration Contract
DACW27-97-D-0015 Task Order 0009
U.S. Army Corps of Engineers
Louisville District

September 2000

MONTGOMERY WATSON
Serving The World's Environmental Needs

SAIC
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SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

contributed to the preparation of this document and should not be considered an eligible contractor for its review.

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ACRONYMS AND ABBREVIATIONS

AASHO	American Association of State Highway Officials
ACGIH	American Conference of Governmental Industrial Hygienists
ADD	average daily dose
AEC	Atomic Energy Commission
AMSL	above mean sea level
ANL	Argonne National Laboratories
ANSI	American National Standards Institute
ARAR	Applicable or Relevant and Appropriate Requirement
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances Disease Registry
ATV	all terrain vehicle
AUF	area use factor
BAF	bioaccumulation factor
BBC	Brush Beryllium Company
BCF	bioaccumulation concentration
BeOH	beryllium hydroxide
bgs	below ground surface
bls	below land surface
BMW	background monitoring well
BNI	Bechtel National, Inc
BRA	baseline risk assessment
BZ	breathing zone
CBD	chronic beryllium desease
CDC	Centers for Disease Control and Prevention
CEC	cation exchange capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cm^2	square centimeters
COCs	constituents of concern
COPCs	constituents of potential concern
CPECs	constituents of potential ecological concern
cpm	counts per minute
CSF	cancer slope factor
CT	central tendency
DACs	derived air concentrations
DAD	dermal absorbed dose
DAF	dilution attenuation factor
DCF	dose conversion factor
DCGL	Derived Concentration Guidance Level
DOD	Department of Defense
DOE	Department of Energy
DPC	Defense Plant Corporation
dpm	disintegrations per minute
DQA	data quality assessment
DQI	data quality indicators
DQO	Data Quality Objective
EDD	electronic data deliverable
EDQL	Ecological Data Quality Level
EEQ	environmental effects quotient
Eh	redox potential
ELCR	excess lifetime cancer risk

ACRONYMS AND ABBREVIATIONS

EM	electromagnetic
EPA	Environmental Protection Agency
EPC	exposure point concentration
EPI	Environmental Physics Incorporated
ERA	ecological risk assessment
ESA	Endangered Species Act
EU	exposure unit
FA	functional area
FBI	family biotic index
FID	flame-ionization detector
FIDLER	field instrument for detecting low-energy radiation
foc	fraction of organic carbon
FOV	fields of view
FP	Field Procedure
FS	Feasibility Study
ft	foot or feet
FUSRAP	Formerly Utilized Sites Remedial Action Program
GEL	General Engineering Laboratories
GI	gastrointestinal
GPS	Global Positioning System
GPR	ground penetrating radar
GSA	General Services Administration
H&S	Health and Safety
ha	hectares
HEAST	Health Effects and Assessment Summary Tables
HELP	Huron/Erie Lake Plain
HEPA	High Efficiency Particulate Air
HHRA	Human Health Risk Assessment
HI	hazard index
HQ	hazard quotient
HVAC	heating, ventilating, and air conditioning
IA	Investigation Area
IAEA	International Atomic Energy Agency
IDL	instrument detection limit
IEUBK	Integrated Exposure Uptake Biokinetic Model
ILCRs	incremental lifetime cancer risk
IRIS	Integrated Risk Information System
ISGS	in situ gamma-ray spectroscopy
kg	kilograms
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
LIBS	Laser Induced Breakdown Spectroscopy
LOAEL	lowest observed adverse effects level
LOSA	Lake Ontario Storage Area
m^2	square meters
MARRSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MCE	mixed cellulose ester
MCL	maximum contaminant level
MED	Manhattan Engineering District
mg/kg	milligrams/kilogram
mm	millimeter

ACRONYMS AND ABBREVIATIONS

MOA	Memorandum of Agreement
MS/MSD	matrix spike/matrix spike duplicate
MW	monitoring well
NARA	National Archive and Records Administration
NCEA	National Center for Environmental Assessment
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NESHAPS	National Emissions Standards for Hazardous Air Pollutants
NIOSH	National Institute for Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observed adverse effect level
NPDES	National Pollution Discharge Elimination System
NRC	Nuclear Regulatory Commission
NYCRR	New York Central Railroad
Ohio DOH	Ohio Department of Health
ODNR	Ohio Department of Natural Resources
Ohio EPA	Ohio Environmental Protection Agency
OMW	off-site monitoring well
ORNL	Oak Ridge National Laboratory
OSHA	Occupation Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
OVA	Organic Vapor Analyzer
PACM	presumed asbestos-containing material
PAH	polyaromatic hydrocarbon
PCBs	polychlorinated biphenyls
PCE	tetrachloroethene
PCOC	potential constituent of concern
pCi	picocuries
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PE	performance evaluation
PEL	Permissible Exposure Limits
PID	photoionization detector
ppb	parts per billion
PPE	Personal Protective Equipment
ppm	parts per million
PRGs	Preliminary Remediation Goals
PRP	potentially responsible party
PVC	polyvinyl chloride
PZ	piezometer
QA	Quality Assurance
QC	Quality Control
QAPP	quality assurance project plan
Ra	radium
RAGS	Risk Assessment Guidance for Superfund
RBCs	risk-based concentrations
RBP	rapid bioassessment protocol
RCRA	Resource Conservation and Recovery Act
RESRAD	residual radiation computer code
RfD	reference dose factor
RHTG	Records Holding Technical Group

ACRONYMS AND ABBREVIATIONS

RI	Remedial Investigation
RME	reasonable maximum exposure
RPD	relative percent difference
RPM	radiation protection manager
SAFER	Streamlined Approach for Environmental Restoration
SAIC	Science Applications International Corporation
SAP	sampling and analysis
SI	Site Investigation
SOP	standard operating procedure
SQL	sample quantitation limit
STP	sewage treatment facility
SVOCs	semi-volatile organic compounds
SWSD	surface water and sediment
T&E	threatened and endangered
TAL	target analyte list
TBC	to be considered
TCE	trichloroethene
TCL	target compound list
TDS	total dissolved solids
Th	thorium
TIC	tentatively identified compound
TLV	Threshold Limit Value
TM	Technical Memorandum
TOC	total organic carbon
TRACER	Transportable Remote Analyzer for Characterization and Environmental Remediation
TRPH	total recoverable petroleum hydrocarbons
TRV	toxicity reference values
TRW	Technical Review Workgroup
TSS	total suspended solids
TUF	temporal use factor
TW	test well
TWA	time-weighted average
U	uranium
UCL	upper confidence limit
USACE	United States Army Corps of Engineers
USAF	United States Air Force
USCS	Unified Soil Classification Service
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UST	underground storage tank
UTL	upper tolerance limit
VFT	vinyl floor tile
VOCs	Volatile Organic Compounds
WP	Work Plan
WWII	World War II
µg	micrograms
µg/dL	micrograms per deciliter
$\mu g/ft^2$	micrograms per square feet

ACRONYMS AND ABBREVIATIONS

µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µg/m^3	micrograms per meter cubed
µrem	microrem
µrem/hr	microrem per hour
µR/h	microRoentgen per hour

EXECUTIVE SUMMARY

The Luckey site is located just north of Luckey, Ohio approximately 22 miles southeast of Toledo, Ohio. The site consists of a large production building and warehouse, several smaller process and ancillary buildings, two abandoned railroad spurs, and several former disposal areas (three lagoons in the southeastern portion of the site and an area in the northeastern portion) and covers approximately 40 acres. The area surrounding the site to the west, north, and east is primarily residential farmland. An abandoned New York Central Railroad bed runs along the eastern boundary. A former quarry and municipal dump border the site to the south.

Brush Beryllium Company (BBC) contracted with the Atomic Energy Commission (AEC) to produce beryllium at the Luckey site from 1949 through the early 1960s. BBC transferred all beryllium production operations to a new facility in Elmore, Ohio in 1958. Sintering and powder blending operations, established at the Luckey facility in 1957, continued through the early 1960s and were subsequently shut down. Hayes Lemmerz International, Incorporated now owns the Luckey site. Uretech International, Inc. currently leases and operates the facility to manufacture urethane parts for the automotive and health care industries.

In 1988, a “designation” survey was performed. The information collected in this survey was used in the Department of Energy (DOE) designation process to justify the inclusion of the Luckey site in the Formerly Utilized Site Remedial Action Program (FUSRAP). FUSRAP was established to remediate sites impacted by activities of the Manhattan Engineering District (MED), or the AEC in the early years of the nation's atomic energy program. At the Luckey site, it specifically addresses beryllium, materials associated with the beryllium production process, and radioactive residuals.

In 1996, DOE performed a preliminary site evaluation to evaluate risk from beryllium and radionuclides at the Luckey site. This study indicated there might be an unacceptable risk to potential receptors at the site. Site characterization activities began in 1997. Characterization activities included the collection and analysis of various media to assess the nature and extent of chemical and radiological constituents at the site, referred to as the phase II field sampling activities.

In October 1997, Congress transferred authority for FUSRAP from DOE to the U.S. Army Corps of Engineers (USACE). In 1998, the USACE developed a Remedial Investigation/Feasibility Study (RI/FS) Work Plan to detail the collection of data of sufficient quantity and quality to evaluate risk posed by current site conditions to human health and the surrounding environment. The Ohio Environmental Protection Agency (Ohio EPA) and the Ohio Department of Health (Ohio DOH) reviewed the Work Plan. This work, also known as Phase IV, commenced in June of 1998. Phase II and Phase IV sampling activities focused on determining the nature and extent of AEC-related constituents: arsenic, barium, beryllium, lead, ammonia, fluoride, and radionuclides (particularly radium, thorium, and uranium).

The Phase IV RI was performed in strict accordance with the RI/FS Work Plan. Field activities were conducted from June 1998 to December 1999. On-site and off-site media were investigated: groundwater, surface water, soil, and sediment. Samples also were collected in the on-site buildings. Ambient and personal air monitoring were conducted during all sampling activities. Samples were analyzed for parameters specified in the RI/FS Work Plan using analytical methods and data quality objectives described in the Quality Assurance Project Plan (QAPP) for each laboratory.

Three types of sample groupings were generally collected during the RI: beryllium screening, risk or full suite, and nature and extent. The difference between sample groupings is the list of analytes associated with the sample type. Samples collected for beryllium screening were analyzed for beryllium. Samples collected for risk determination were generally analyzed for target analyte list (TAL) metals,

radionuclides, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), anions, and ammonia. This list varied slightly according to media. Samples collected for nature and extent were analyzed for AEC-related constituents (arsenic, barium, beryllium, lead, radionuclides, fluoride, and ammonia). Analytical results from all three types were used to evaluate nature and extent and as input to the risk assessment.

Several objectives were presented in the RI/FS Work Plan to define the purpose and scope of the RI. Each concerns the collection of adequate data. The primary focus of the RI is to acquire, analyze, and interpret data in order to meet the following objectives. Each objective and a discussion of how the objective has been achieved is presented below.

1) determine the nature and extent of AEC-related contamination on site:

The nature (constituents and concentrations), and vertical and horizontal extent of AEC-related constituents was determined. The following table presents the number of samples collected in various on-site media:

Media	No. of samples
soils	957
sediment & surface water	15
groundwater	102
swipes	~ 500
dust	113
building materials	83

Beryllium was detected above background across the site. Radionuclides also were detected in a similar pattern, but to a lesser extent. Beryllium was detected above background in all surface water and sediment samples collected from on-site drainage ditches. Groundwater at the site has been impacted by beryllium at a few locations, but there does not appear to be a well-defined plume. The nature and extent has been sufficiently characterized to support engineering studies required during an FS.

2) verify the presence or absence, and determine the nature and extent of potential AEC-related contamination at adjacent properties:

The presence of AEC-related constituents has been verified at properties to the north and east of the site. The nature and extent of AEC-related contamination on these properties has been determined for all media. Additional wells will be installed north of the site to understand the water balance between Toussaint Creek and groundwater. Soil and groundwater samples along the eastern edge of the property and on the railroad embankment do not indicate that contamination is migrating to the farm field east of the site. The absence of AEC-related constituents has been verified on the property west of the site. It does not appear that the Quarry (located South of the site) or the Troy Township Dump were impacted.

The possible presence of AEC-related material at two residential properties more than a mile from the site is being addressed separately from the Luckey RI.

3) determine the nature and extent of contamination in Toussaint Creek:

The gross nature and extent of AEC-related constituents in Toussaint Creek has been determined. Samples collected from a 15-mile stretch of the creek provide sufficient information to assess the

magnitude of contamination in the creek, but do not clearly define the detailed nature or specific extent of the contamination. If further action is determined to be appropriate at Toussaint Creek, as a result of the BRA, additional samples will be required.

4) determine the presence or absence of groundwater contamination, and determine the nature and extent of any detected AEC-related contaminants:

Groundwater samples collected during five sampling events from 41 monitoring wells (including six background wells), two production wells, and four taps were analyzed and evaluated to determine the nature and extent of AEC-related constituents. Manganese, uranium-234, uranium-235, and uranium-238 are the constituents detected in groundwater that pose risk under current land use conditions. Beryllium was detected in five samples above the MCL but there does not appear to be a distinct plume nor does beryllium pose unacceptable risk. Beryllium was detected above the drinking water standard in one sample collected from the residence located north of the site, but not in five subsequent samples collected from that location. Samples collected from twelve monitoring wells installed in the farm field have contained no detectable beryllium with the exception of one sample, which contained beryllium at a concentration less than background.

5) define the natural subsurface stratigraphy, depth to bedrock, depth to groundwater, groundwater flow direction and gradient, and the distribution of contaminants within the subsurface units:

Aquifer and groundwater characteristics were defined using information obtained from the installation and sampling of 41 monitoring wells and six piezometers. A groundwater flow model was developed to assist in interpreting groundwater flow characteristics. Information on this model and its construction is detailed in the Draft Groundwater Model Report (SAIC 2000).

6) acquire information to define the fate and transport of contaminants from the site:

The results of chemical and physical data collection efforts provide data sufficient to determine the fate and transport of contaminants from the site for purposes of assessing the potential future nature and extent of constituents. The nature and extent of contamination in the various media have been determined. The hydrogeologic characteristics governing the fate and transport of constituents at the site have been quantified. The presence or absence of contaminants in media and pathways to that media from contaminant sources define the transport of contaminants. In other words, the fate of the contaminants is tied to the media in which they are found.

7) gather sufficient information to complete a baseline risk assessment (BRA) including an assessment of human health and ecological risks:

All of the analytical samples collected at the site were analyzed at a DQO level sufficient for risk assessment purposes (i.e. beryllium screening, nature and extent, and full suite). The following table lists the number of full suite samples that were collected per media. The full suite analysis was used to gather additional analytical information to support a BRA that could evaluate the effects of all constituents detected at the site and not just AEC-related constituents.

Media	No. of samples
Soils	77
Sediment	19
Surface water	16
Groundwater	30

In addition, air, soil, groundwater, surface water, and sediment samples were collected for determining background. The results of the analytical analysis of these samples provide a data set sufficient for performing a BRA at Luckey.

8) determine whether contaminants present a threat to human health or the environment:

The data collected in on- and off-site media were evaluated in a baseline risk assessment. Table ES.1 summarizes the RME risk for human health and ecological risk in each exposure unit evaluated at the Luckey site.

9) if required, support an FS to develop, identify, and recommend alternatives to address AEC-related contamination that poses unacceptable risks to human health or the environment:

The data and results of the RI provide the foundation for an FS, if required. Data regarding the nature and extent of contamination in environmental media and buildings, and the environmental setting of the facility (including geology/hydrogeology and groundwater flow characteristics) were collected during the sampling events. Geotechnical data were obtained: moisture content, dry density, specific gravity, grain size analysis, Atterburg limits, and total organic carbon. This combination of geologic/hydrogeologic and geotechnical data will be used to evaluate remedial technologies performed as part of an FS.

10) evaluate the impacts of beryllium and radionuclides on the site buildings:

Several surveys were conducted in the on-site buildings to investigate the possibility contaminants may have accumulated as a result of AEC activities. A radiological survey was performed in all site buildings. Approximately 80% of the Annex and 5% of the remaining buildings were surveyed. A beryllium swipe survey also was performed in all site buildings to measure removable beryllium. Several samples of building materials were collected in the larger buildings. Most of these were analyzed for beryllium. A few were analyzed for radionuclides. These surveys indicated beryllium was present in dust that had settled in the buildings; thus a bulk dust survey was conducted in all the buildings. Bulk dust samples were collected from “functional areas” using a HEPA vacuum. The results of these surveys are summarized below:

- The direct radiation reading data clearly show that there are several areas within the Annex and two isolated locations in the Production Building that have activity slightly above NRC guidelines for release to the public. However the majority of the elevated activity is in the beams.

- Dose rate measurements taken at the level where the worker activities usually take place show levels consistent with naturally occurring radioactivities.

- Beryllium swipes show significant removable contamination in the Annex, Production Building, Former Laboratory, and Maintenance Building. Lower concentrations of beryllium are found in the Former Melting, Alloying, and Shipping Building, Shack, East and West Well Buildings, Fire Pump House, Guard House, Bulk Storage Building, Sewage Treatment Building, and Employee Activity Building.

- Air monitoring results did not exceed the OSHA standard for beryllium during intrusive sampling in the buildings, three values did exceed the proposed guideline. All of these instances occurred during sampling activities in the buildings.

- Bulk dust, sampled in the on-site buildings, has no formal standard. A criteria of 20 mg/kg has been developed based on the American Conference of Government and Industrial Hygienists (ACGIH) nuisance dust guideline of 10 mg/m^3. Bulk dust samples indicate there is potential to exceed the proposed ACGIH guideline for airborne beryllium if dust is re-suspended during disruptive maintenance activities. This is true even if the nuisance dust levels are not exceeded.
- The building materials samples indicate that while there is significant beryllium contamination of the paint, brick, concrete and other materials in the structure of the buildings only a minor amount of radiological contamination seems to be present. Buildings that contain significant concentrations of beryllium within the construction materials include the Former Laboratory, Maintenance Building, Production Building, and Annex.

Table ES.1. Most Likely RME Receptor Risk for Exposure Units Evaluated at the Luckey Site

Exposure Unit & Most Likely Receptor	Media	Hazard Index >1	Cancer Risk	EEQ>1	EEQ>100
Exposure Unit 1 (on-site soils)	Soil (0-2 ft bgs)	NO	YES	YES	YES
Industrial Worker	Groundwater (Exp. Unit 7)	NO	YES	NA	NA
Exposure Unit 2 (on-site soils)	Soil (0-2 ft bgs)	YES[1]	YES	YES	YES
Industrial Worker	Groundwater (Exp. Unit 7)	NO	YES	NA	NA
Exposure Unit 3 (off-site soils)	Surface Soil (0-2 ft bgs)	YES	YES	NA	NA
Resident Farmer (Adult or Child)	Soil (0-10 ft bgs)	NO	YES	YES	NO
	Groundwater (Exp. Unit 7)	YES[2]	YESO	NA	NA
	Surface Water	NO	NO	YES	YES
	Sediment	YES	YES	YES	YES
Exposure Unit 4 (Toussaint Creek)	Soil (0-2 ft bgs)	NO	NO	YES	NO
	Surface Water	NO	NO	YES	NO
Adolescent Trespasser	Sediment	NO	YES	YES	NO
Exposure Unit 5 (Quarry)	Soil (0-2 ft bgs)	NO	NO	YES	NO
Adolescent Trespasser	Surface Water	NO	NO	NO	NO
Exposure Unit 6 (Dump) Adolescent Trespasser	Soil (0-2 ft bgs)	NO	NO	NO	NO

EEQ = environmental effects quotient
NA = not applicable
RME = reasonable maximum exposure assumptions
[1] Lead is the only constituent that poses non-cancer risk, this is based on a comparison to a modeled value not to risk calculations.
[2] Groundwater is considered one contiguous unit. The risk from on-site groundwater would be unacceptable for a resident farmer (child). Current off-site conditions do not pose unacceptable risk; manganese was detected below the exposure point concentration in all off-site monitoring wells.

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1.2 REMEDIAL INVESTIGATION OVERVIEW AND SCOPE 1-2
1.3 REPORT ORGANIZATION 1-3

1.0 INTRODUCTION

The Luckey site is located just north of Luckey, Ohio, which is approximately 22 miles southeast of Toledo, Ohio (Figure 1.1). The site consists of a large production building and warehouse, several smaller process and ancillary buildings, two abandoned railroad spurs, and several disposal areas (three lagoons in the southeastern portion of the site and an area in the northeastern portion) and covers approximately 40 acres. The area surrounding the site to the west, north, and east is primarily residential farmland. An abandoned New York Central Railroad (NYCRR) bed runs along the eastern boundary. A former quarry and municipal dump border the site to the south (Figure 1.2).

In 1942, Defense Plant Corporation (DPC) built a magnesium reduction plant at the site to produce metallic magnesium during World War II (WWII). The magnesium reduction plant was closed in November of 1945 as a war surplus plant. The Brush Beryllium Company (BBC) leased the site in the late 1940s and contracted with the Atomic Energy Commission (AEC) to design, construct, operate, and maintain a plant for the production of beryllium. BBC operated the AEC-owned beryllium production plant through the early 1960s. BBC transferred all beryllium production operations to a new facility in Elmore, Ohio in 1958. Sintering and powder blending operations, established at the Luckey facility in 1957, continued through the early 1960s and were subsequently shut down.

The property was sold several times before the current owner, Hayes Lemmerz International, Incorporated (previously Motor Wheel, Inc.), purchased it in 1988. Motor Wheel used the site to coat steel automotive wheels with polyurethane foam. Since May 1995, Hayes Lemmerz International, Inc. has leased about 23 acres of the site to Uretech International, Inc., which uses the site to manufacture urethane parts for the automotive and health care industries. A detailed operational history of the site is provided in Section 2.1.1.1.

In 1988, a “designation” survey was performed. The information collected in this survey was used in the Department of Energy (DOE) designation process to justify the inclusion of the Luckey site in the Formerly Utilized Site Remedial Action Program (FUSRAP). In October 1997, Congress transferred authority for FUSRAP from the DOE to the U.S. Army Corps of Engineers (USACE). DOE and the USACE subsequently entered into a Memorandum of Agreement (MOA) detailing the responsibilities of each in FUSRAP.

FUSRAP was established to remediate sites impacted by activities of the Manhattan Engineering District (MED) or the AEC in the early years of the nation’s atomic energy program. At the Luckey site, USACE is authorized to specifically address beryllium, materials associated with the beryllium production process, and radioactive residuals. These radioactive residuals are the result of the processing of ores at facilities not licensed by the Nuclear Regulatory Commission (NRC) when the Uranium Mill Tailing Recovery Act was enacted in 1978, or thereafter. Congress has mandated that FUSRAP sites, whether or not they are on the National Priority List, shall be subject to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Congress passed CERCLA in 1980. CERCLA (also known as the Superfund Act) made the U.S. Environmental Protection Agency (EPA) responsible for protecting public health and the environment from the threats that could be posed by uncontrolled or abandoned contaminated sites. It was amended in 1986 to increase state involvement, encourage citizen participation, strengthen enforcement authority, and increase funding.

The Luckey site remedial investigation (RI) has been conducted in accordance with the requirements of CERCLA and will be followed by a feasibility study (FS), which also will meet CERCLA requirements. The FS will describe and evaluate alternatives for remediation and will recommend one preferred alternative.

The remainder of Section 1 presents the purpose and organization of this RI Report. The scope and purpose of the RI and an overview of the RI activities also are included.

1.1 PURPOSE OF THE REMEDIAL INVESTIGATION REPORT

The RI was conducted to characterize the nature and extent of contamination and to evaluate potential risks to human health and the environment at the Luckey site. The primary purpose of the RI Report is to document the data collection and analysis activities conducted in support of this objective. Results of the RI also are evaluated to determine if data are sufficient to develop and evaluate FS alternatives and assess the need for site remediation.

The RI Report will provide various stakeholders (public, regulatory agencies, USACE, current property owners and tenants, etc.) the opportunity to comprehensively review all data collected and recommendations resulting from the RI process. The RI Report specifically presents the following:

- the purpose, scope, and rationale of RI field investigation activities;
- the nature and extent of chemical and radiological constituents;
- the fate and transport of constituents in the environment;
- the site conceptual model;
- the calculation of risk to human health and ecological receptors in a baseline risk assessment;
- summary, conclusions, and recommendations.

If the RI Report determines that the site or portions of the site pose unacceptable risks, an FS will be performed to develop and evaluate alternatives for addressing these areas.

1.2 REMEDIAL INVESTIGATION OVERVIEW AND SCOPE

The primary objective of the comprehensive RI was to collect data of sufficient quantity and quality to evaluate the risk posed by current site conditions to human health and the surrounding environment. Table 1.1 summarizes the activities conducted during the RI. Field sampling and analytical programs implemented to gather data on site characteristics and conditions in support of the RI at the Luckey site were performed in several phases:

- Phase I, the initial planning for the RI at the Luckey site, began in 1996. It consisted of record searches and the development of a sampling and analysis plan (SAP) for the initial field investigation activities. The overall goal of the RI was developed and stated in site-specific data quality objectives (DQOs), which were included in the SAP (SAIC 1997).

- Phase II, a non-intrusive field investigation conducted in 1997, primarily focused on site-wide reconnaissance surveys. Lateral boundaries of surface soil contamination were delineated and mapped using radiological walkover surveys, portable laser induced breakdown spectroscopy (LIBS), and geophysics. In addition to these surveys, a limited environmental sampling program was implemented to establish background concentrations of naturally occurring constituents; to correlate between the reconnaissance surveys and laboratory analyses; and to identify other potential contaminants in soil, surface water, sediments, and air. A cursory (or limited) scoping survey also was performed in a large on-site building (the Annex) to determine the distribution of transferable and fixed radioactive contamination and to determine whether remnant beryllium was present in that building. Reconnaissance surveys and the background sampling program were instrumental in identifying potential on-site and off-site contaminants, and in delineating areas requiring further investigation.

- Phase III assessed the data collected during Phase II. The results of the Phase II investigation are presented in the Phase II characterization report completed in 1998 (BNI 1998). The data were evaluated against the DQOs in order to determine the specific sampling objectives for the second, more intrusive, portion of the field investigation.

- Phase IV, the final phase of the RI sampling program, was completed primarily in 1998. A supplemental effort was performed in 1999. The main purpose of the Phase IV effort was to determine the nature and extent of potential contaminants and collect sufficient data to evaluate the risk associated with those contaminants. This follow-up investigation was extended to off-site areas to determine the possible impact of AEC related contaminants. The investigation focused on groundwater and intrusive soil sampling, but additional samples of surface water, sediment, and air were collected. Background areas representative of natural groundwater conditions were identified and sampled. Additional soil and sediment samples were collected to enhance the background database and improve the statistical power for calculating background values. The cursory radiological and beryllium surveys conducted in 1997 were extended to all on-site buildings in the 1998 sampling event, and more extensive surveys were conducted in the Annex. Composite samples of bulk dust were obtained from many different types of structures in all of the on-site buildings to assess residual levels of beryllium. A wetlands designation survey also was performed.

Activities complementing the RI Report upon completion of the Phase IV field investigation include:

- development of a quality control program and provisions for independent technical review of RI-related tasks being performed in support of the RI Report;
- a records search to gather historical information concerning the former Brush Beryllium plant, AEC activities, and documents pertaining to the Luckey site;
- development of a contaminant fate, transport, and exposure analysis model
- development of a groundwater model to support the conceptual model and the baseline risk assessment (BRA);
- performance of a BRA; and
- assessment of potential vicinity properties.

The results of these activities and all phases of the RI are presented and evaluated in this comprehensive RI Report.

1.3 REPORT ORGANIZATION

This RI Report is prepared in accordance with EPA guidance and the recommended format (EPA 1988). Further direction was provided in the statement of work provided by the USACE, Buffalo District (USACE 1999). The report consists of an executive summary, Sections 1 through 9, and appendices. Section 1 describes the purpose and the organization of this report.

Section 2 presents a description and history of the Luckey site, including previous investigations performed at the site. The objective is to provide a historical perspective to be used in evaluating human health and environmental impacts associated with the Luckey site. The historical summary has been updated with information discovered during the records search. Section 2 also describes the physical characteristics of the Luckey site, including geography, geology, hydrology, and ecology of the study area and vicinity. Data relevant to the physical characteristics of the study area are presented from a regional, local, and site perspective, as appropriate.

The environmental investigations conducted to support the RI are summarized in Section 3. Investigative activities conducted during Phase II and Phase IV are presented according to media "units." These units include on-site soils, off-site soils, groundwater, on-site sediments and Toussaint Creek, and the buildings. Background sampling activities and the methodology used to calculate background values also are detailed. This section presents the specific data objectives and methodology employed for each data collection and analysis activity, as well as a description of the RI laboratory program and the data management approach used for the project.

Section 4 presents the data gathered during the RI and discusses the nature and extent of contamination at the Luckey site and adjacent properties. The nature and extent of contamination is discussed with respect to the environmental media studied (i.e. on-site soils, groundwater, surface water and sediment, buildings, and off-site soils).

An evaluation of the probable fate and transport of the constituents of potential concern (COPC) is presented in Section 5. Physical and chemical characteristics impacting fate and transport are considered, and conceptual models of constituent migration are presented.

Sections 6 and 7 present the BRA for human health and ecological receptors, respectively. Data and evaluations supporting the risk assessments and the uncertainties associated with the BRA are presented. Risk is evaluated using exposure units based on the media "units" presented in Sections 3 and 4.

Section 8 summarizes the results and conclusions drawn from the RI and other data relevant to the Luckey site. Data gaps and general recommendations are presented. Preliminary remedial action objectives also are identified.

Section 9 lists the references used in the preparation of this document.

The appendices contain data relevant to the RI at the Luckey site. Boring logs, well construction diagrams, analytical data tables, a data quality assessment, and risk assessment calculations are provided to support the interpretations made in this RI Report.

SECTION 1: LIST OF TABLES

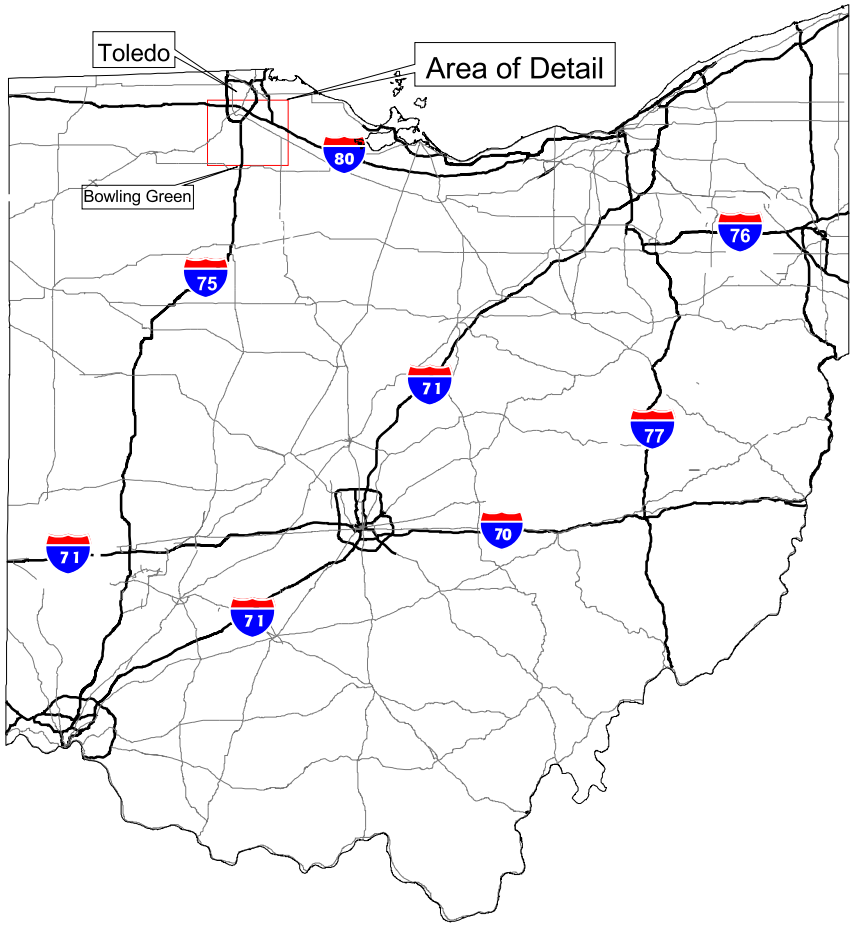
Table 1.1. Activities Comprising the Remedial Investigation at the Luckey Site

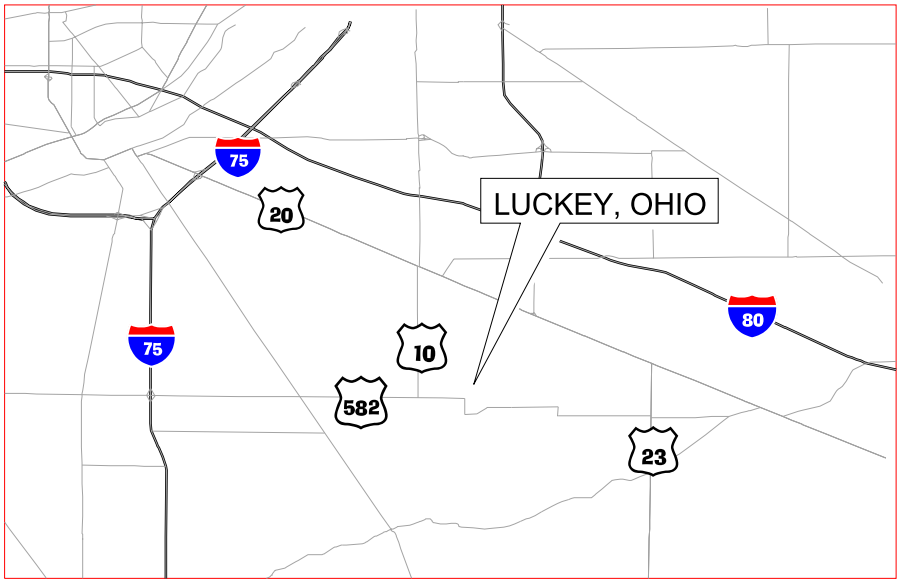
Table 1.1. Activities Comprising the Remedial Investigation at the Luckey Site

Date	RI Phase	Activities
Winter 1996	I	• development of data quality objectives • Phase II Sampling and Analysis Plan (SAIC 1997)
Summer 1997	II	• site-wide reconnaissance surveys for beryllium and radiological activity • soil sampling • surface water and sediment sampling in drainage ditches and Toussaint Creek • background sampling • cursory scoping surveys in the Annex
Fall/Winter 1997	III	• Phase II Characterization Report • evaluation of Phase II data to focus scope of Phase IV field activities • Phase IV Sampling and Analysis Plan (SAIC 1998)
Spring/Summer 1998 Summer 1999	IV	• extensive soil sampling on site and off site • installation of monitoring wells and groundwater sampling activities (including residential wells) • surface water and sediment sampling (including 15-mile downstream stretch of Toussaint Creek) • additional background sampling • sampling (wipes, building materials, and dust) and scoping surveys in all on-site buildings • wetlands designation survey
April 1999 through July 2000	RI Report and complementary activities	• independent technical review • records search • fate, transport, and exposure analysis model • groundwater modeling • baseline risk assessment (BRA) • assessment of potential vicinity properties

SECTION 1: LIST OF FIGURES

Figure 1.1. Site Location
Figure 1.2. Luckey Site near Luckey, Ohio





Primary road with limited access
Primary road

60 0 60 Miles

N W E S

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Site Location

Science Applications International Corporation — Columbus, Ohio

Drawn By	Date	Scale	Project No.	Figure No.
LMA	02/09/00	As Shown	04-1748-801	1.1

S:ARCVIEW LUCKEY/C01748/801/SITE LOCATION MAP

S:ARCVIEW LUCKEY/GIS/PROJECT3.APR LAYOUT AERIAL PHOTO

N
W E
S

0.05 0 0.05 0.1 Miles

U.S. ARMY CORPS OF ENGINEERS
BUFFALO DISTRICT
LUCKEY SITE

Luckey Site near Luckey, Ohio

Science Applications International Corporation Columbus, Ohio

DRAWN BY	DATE	Scale	PROJECT NO.	Figure NO.
LMA	02/09/00	As Shown	04-1748-801	1.2

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2.0 SITE BACKGROUND

The following sub-sections describe historical activities at the site, both operational and investigatory in nature, and the site's physical characteristics pertinent to the RI. The site history has been updated with information acquired during the search of historical archives (Appendix 2A). The description of physical characteristics has been updated with data obtained during the RI pertaining to geologic, hydrogeologic, and ecological features.

2.1 SITE HISTORY

The Luckey site was originally built as a magnesium reduction plant before it was converted by the AEC to process beryllium and eventually sold to a private owner. Table 2.1 chronicles the historical events at the Luckey site. The events summarized in this table are explained in more detail in the following sub-sections.

2.1.1 Site Activities

This section presents a discussion of historic site activities, including those associated with past AEC operations, waste disposal practices, and decontamination of several buildings. Post-AEC operations are discussed to the extent possible.

2.1.1.1 <u>Operational History</u>

In 1942, DPC built a magnesium reduction plant (Plancor 669) at the Luckey site (Figure 1.2). The facility was operated during WWII by a DPC contractor, the Magnesium Reduction Company, as assignee for the National Lead Company. A multiple-retort ferro-silicon, or pigeon process, produced metallic magnesium from dolomitic limestone (PRC 1995). A residue, consisting of iron, silicon, and calcium, also was created (Cline 1990). The government agreed to dispose this residue in a quarry that was operated by Kelly Island Stone and Limestone (Kelly Island and DPC 1943); however, employee interviews indicate that no waste was disposed off site during beryllium operations (Cline 1990). The agreement was terminated when the quarry reached capacity in 1958 (Basic Inc. 1958). The Kelly Island quarry is now known as the Troy Township Dump or Luckey Dump. The magnesium reduction plant was closed in November of 1945 as a war surplus plant. According to employee interviews, production was never reinitiated (Singleton 1990). In 1951, however, plans were made and then canceled to restart production of magnesium.

Custody of the plant was transferred to the Reconstruction Finance Corporation in 1945. In 1946, the Office of Defense Plants leased equipment from the Luckey Plant to BBC. BBC leased the entire site in 1949 and contracted with the AEC to design, construct, operate, and maintain a plant for the production of beryllium. BBC also agreed to maintain the former magnesium plant facilities in standby status (SAIC 1996). The new beryllium capacity was needed to replace capacity lost because of a fire at the privately owned beryllium production plant in Lorain, Ohio. BBC operated the AEC-owned beryllium production plant between 1949 and 1958. Some of the beryllium production may have been in standby mode by 1954 (PRC 1995). BBC records (Powers 1983) indicate that the plant primarily produced beryllium hydroxide throughout the life of the facility. From 1950 through 1953, the plant also produced beryllium metal in vacuum cast billets and some beryllium oxide from beryllium hydroxide. Some of the beryllium hydroxide was sold to BBC's Elmore, Ohio plant to make beryllium copper alloys. BBC transferred beryllium production operations to a new facility in Elmore, Ohio in 1958. Sintering and powder blending operations, established at the Luckey facility in 1957, continued through the early 1960s and were subsequently shut down.

In late 1951, AEC shipped approximately 1,000 tons of scrap steel containing various radionuclides to the Luckey site from the Lake Ontario Storage Area (LOSA). Records indicate plans were made and later dropped to restart magnesium production after hostilities emerged in Korea. The scrap was to be used to scavenge chlorine from a particular step in the magnesium reduction process. However, a former employee indicated the scrap was to be used as structural metal in the setup of the beryllium production line (Cline 1990). The scrap was not used and, according to the same employee, some of the scrap may have been sold to local scrap dealers (Cline 1990).

There have been no state environmental enforcement actions regarding the plant in recent years. In the late 1980's there were a number of notices to provide potable water due to bacterial contamination in the drinking water, however these were short-lived. Potable water is supplied when the water system at the site loses integrity until water test results are received.

2.1.1.2 Air Monitoring and Housekeeping Procedures

An air monitoring program at the facility during BBC operation included ambient air, stack, and duct sampling; however, no historical data have been located. Air emissions were produced:

- during conversion of beryllium hydroxide to beryllium oxide by decomposing crystallized beryllium sulfate in a furnace;
- during conversion of beryllium hydroxide to beryllium metal by decomposing ammonium beryllium fluoride salt in a high-frequency induction furnace to produce beryllium fluoride or by melting beryllium fluoride and magnesium to produce beryllium metal; and
- during production of beryllium hydroxide from beryl ore by first melting the ore in an electric furnace.

According to interviews, air handling and safety procedures were established, and the entire plant, including the ceiling and overhead beams, was washed and scrubbed monthly (OEPA 1997).

2.1.1.3 Waste Disposal Activities

Waste disposal activities by BBC at Luckey are documented in reports from 1950 to 1958 (BBC 1950-1958). According to employee interviews, sludge was removed from the lagoons each summer and was placed in burial pits in the northeast corner of the property. Although not as specific as interviews, waste disposal reports confirm disposal of lagoon sludge in the northeast corner [BBC 1950-58 (BBC to ODH)]. The pits were excavated with a bulldozer and compacted with a spiked roller. The pits, approximately 14 ft wide and 18 ft deep, took approximately two years to fill. Vehicles were reportedly buried in the last pit, which was dug during closure parallel to the north fence and west of the main drainage ditch. In addition, three or four pits excavated in a north-south orientation at the spoils area received sludge from the lagoons. The sludge was transported in drums from the lagoons, and the contents were emptied down a ramp into the pits. Only infrequently and accidentally were drums and their contents buried in the pits. All pits were covered with 4 ft of clay and marked with a 4-ft by 4-ft cross (Singleton 1990). An Ohio Environmental Protection Agency (Ohio EPA) investigation into disposal of drummed wastes reported a re-excavation of drummed waste in a temporary burial pit (Davis 1988).

A 1951 discussion of alternative disposal technologies included a proposed deep injection well and an evaporator (Schwenzfeier 1951). Deep injection, proposed on the basis on U.S. Geologic Survey (USGS) recommendations, identified shortcomings of the lagoon waste disposal system (Eisenbud 1950). Shortcomings include "...the liquid wastes can move through the soil to the permeable limestone (indicated by the rise of water in test hole) and that they may also reach the groundwater through

outcroppings in the bed of Toussaint Creek, although chemical analyses made so far have not shown that the ground or surface water is contaminated." The well was not drilled, and at the request of the Division of Mines, the permit was returned (Schaffner 1952).

Despite the existence of an agreement for disposal at the Kelly Island quarry [in effect from 1943 to 1958 (Basic Inc. 1958)], employee interviews indicate that no waste was disposed off site during beryllium operations (Cline 1990).

Lagoons

Four lagoons, labeled A, B, C, and D, were constructed at the Luckey site. Lagoon A was approximately 3 to 4 ft deep. Lagoon B was constructed in two stages. The first stage, built in 1949, was 3 to 4 ft deep; and the second, built in 1950, was 5 to 6 ft deep. Lagoon C, only 1½ ft deep, was constructed in two stages. The larger eastern-most section was constructed later (Cline 1990). BBC records confirm all lagoons were of shallow construction, approximately 4 ft deep, and were formed by scraping the top layer of soil and constructing the embankment. The liners were reported to be compacted clay. Lagoon D, constructed in 1956, apparently was never used.

During 1950 to 1953, Lagoon A (approximate location is shown in Figure 2.1) received wastes discharged from the conversion of plant-grade beryllium hydroxide (BeOH) to beryllium metal in vacuum cast billets. Beryllium hydroxide was dissolved in ammonium bifluoride solution to form an ammonium beryllium fluoride solution. Calcium carbonate, lead oxide, and sulfides were added to precipitate impurities, which were filtered and pumped to Lagoon A. Crystallized ammonium beryllium fluoride salt was reduced to beryllium metal in two furnaces in two steps involving exchange of the fluoride with magnesium metal. Magnesium fluoride was removed by rinsing with water, and the magnesium fluoride solution was discarded to Lagoon A. The solution also contained ammonium fluoride, ammonium sulfide, and beryllium fluoride. This process produced a smaller amount of liquid and sludge than the BeOH process, thus; one small impoundment provided sufficient storage. Lagoon A never had to be extended because of the limited metal production (Powers 1983).

According to BBC records (Powers 1983), Lagoons B and C received discharges from the conversion of beryl ore (beryllium aluminum silicate) to beryllium hydroxide by the sulfate process. Beryllium sulfate, aluminum sulfate, and silica were formed from the ore. The latter two by-products were discharged to the lagoons. Sulfates, silica, ammonium alum, and iron cake were removed and discarded. Sodium hydroxide was then added to the beryllium sulfate solution to produce beryllium hydroxide. Waste solutions from this conversion contained high levels of dissolved solids, primarily sodium sulfate and sodium hydroxide, and were impounded in Lagoons B and C. The solutions were discharged to Toussaint Creek under an agreement with the Ohio Water Pollution Control Agency. Controlled discharges from the lagoons during periods of adequate flow in Toussaint Creek were reported to Ohio DOH. Also, silica sludge removal to the spoils area in the northeast corner of the plant site was reported [BBC 1950-58 (BBC to ODH) and Cline 1990].

In a 1956 report, low precipitation (assumed to mean inadequate flow in Toussaint Creek), required the construction of a new small lagoon (possibly Lagoon D) for additional storage of wastes; however, there is no indication that Lagoon D was ever used. Conversion of beryllium hydroxide to beryllium oxide resulted in scrubber sludge of oxides of sulfur which were also discharged to Lagoons B and C (Powers 1983).

Water from the lagoons was discharged to Toussaint Creek under a permit issued by the Ohio DOH. From 1993 to 1995, Motor Wheel National Pollution Discharge Elimination System (NPDES)

reports indicate detectable quantities of beryllium in surface water at the 004 storm sewer outfall discharge to the drainage ditch along Luckey Road ranging from less than 5 µg/L to 37 µg/L.

In 1988, Motor Wheel Corporation voluntarily contracted with Consolidated Environmental Services to place a 2-ft thick clay cap on top of Lagoons A and B to hinder wind dispersal of dust (Knutsen 1988). At the same time, the Production Building and the Annex were power-vacuumed (Karsten 2000).

Disposal Area

A specification (BBC 1954a) and subcontract to construct (BBC 1954b) describes a sludge disposal area as a farm-drain tiled impoundment approximately 151 ft east-west by 200 ft north-south in the northeastern section of the Luckey site (Figure 2.1). An accompanying sketch does not locate the lagoon exactly but shows the lagoon to be adjacent to the main drainage ditch (runs north-south) on the west and an existing road on the south. Portions of the specification may have been constructed. The required retaining wall appears to exist on the east and northwest sides of the area; the sump pit, though installed, does not appear to have been lined as required. Although it might be difficult to geophysically differentiate the clay drain tiles, the lack of anomalies would indicate that the clay drain tiles might not have been installed.

A 1958 drawing of the fencing for the "Beryllium Contaminated Burial Area" shows an area, approximately 325 ft by 250 ft, north of the northeast disposal area and a relocation of the existing northern fence line. This burial area was probably never constructed; the disposal area within the existing fence line may have been used for this purpose.

Disposal Trenches

It has been reported that in 1955, a pit for disposal of scrap metal was excavated west of the main drainage ditch and northeast of the sewage plant (Singleton 1990). However, there is no documentation that scrap metal was ever placed in these scrap disposal pits.

There were two scrap disposal trenches, which are reported to have received cracked graphite crucibles with soluble beryllium fluoride and insoluble magnesium fluoride. These trenches were dug by an earthmover to an estimated depth of 6 ft. The bottom of the trenches was not deep enough to reach bedrock. Soil from the excavation of the trenches was used to cover them after they were full. The exact location and orientation of these trenches is unclear. It is reported that the trenches were not re-excavated during site closure (Cline 1990).

2.1.1.4 Decontamination and Disposition

In 1959, the AEC contracted with BBC to close the plant. At plant closing, a burial site (disposal area) was designated in the northeastern corner. Originally 8.5 acres were set aside, but only 2 acres were actually used (Figure 2.1). It is reported that the sludge from all three lagoons was removed and placed in the burial site, and dikes or embankments around the former lagoons were used to fill the lagoons (Cline 1990). Complete removal of sludge from all three lagoons is contradicted by the results of sampling conducted in 1991 during the designation survey. Although analytical results from soil samples collected at depths from zero to 42 inches in Lagoon C indicate that this lagoon was covered with a layer of approximately 24 inches of clean fill, Lagoon C was not excavated to remove sludge prior to the addition of the soil layer (DOE 1991). A 1959 memo mentions a sludge recovery program during disposition of the BBC site. The program produced an accumulation of 9,000 pounds of beryllium contained in crude

ammonium beryllium fluoride salt, which was probably sold to BBC. Land disposal was recommended for the residue from the sludge recovery operation.

Buildings were decontaminated by dismantling equipment, disposing of equipment as surplus, and steam-cleaning the building interiors. The AEC suggested bricks from the demolition of the smokestack could be disposed on site and the lagoons should be drained and covered. Due to the fact Lagoons A and B were still uncovered as of 1988, not all of these steps were taken.

Process piping and ventilation ducts in the beryllium wing were dismantled and either sent to Oak Ridge, Tennessee or disposed on site. Building decontamination emphasized thorough cleaning and painting (using a silicone preparation) to reduce exposure to beryllium via airborne inhalation. Final disposition of the large sintering furnace was deferred (AEC 1958). In 1958, surface decontamination tolerance levels were reported to be 5 $\mu g/ft^2$ of beryllium for materials for sale to the public, 20 $\mu g/ft^2$ of beryllium to the AEC, and 300 $\mu g/ft^2$ of beryllium to the beryllium industry. For equipment with moving parts, decontamination was based on airborne criteria of 0.03 $\mu g/m^3$ of beryllium [BBC 1950-58 (Powers to Bass 1958)].

2.1.1.5 Post AEC Operations

In 1961, the GSA sold the facility to the Aluminum and Magnesium, Inc. division of Vulcan Materials Company. The government reserved the right of ingress and egress to remove beryllium ore. In 1962, Luckey Industries, Inc. purchased the former beryllium facility and proposed to reclaim magnesium from WWII incendiary bombs. The reclamation process failed. (Presumably, the property was sold back to Aluminum and Magnesium, Inc.) By 1966, the facility employed a dozen people recovering zinc from by-products of the steel industry. In 1967, Aluminum and Magnesium, Inc. transferred the property to its parent company, Vulcan Materials.

In 1968, the Goodyear Tire and Rubber Company of Akron, Ohio purchased the site and began producing automotive foam seating products. Other products produced at the facility included styled wheels and mattress cores. A 1975 wastewater study for Goodyear states that the plant manufactured automotive foam seating using flexible urethane foam and other automotive products using rigid urethane foam (SJL 1975). In December of 1983, Motor Wheel, an independent business entity, leased the property from Goodyear and then purchased it in March of 1988. In January 1988, Motor Wheel submitted a Drum Storage Area Closure Plan to Ohio EPA (Chem-Tech 1988). Also during 1988, the Resource Conservation and Recovery Act (RCRA) status of the facility changed from a treatment, storage, and disposal facility to a large quantity generator of hazardous waste. From 1988 to May 1995, Motor Wheel used the site to coat steel automotive wheels with polyurethane foam. Since May 1995, Hayes Lemmerz (the successor company to Motor Wheel) has leased about 23 acres of the site to Uretech International, Inc., which conducts similar operations to those formerly conducted by Motor Wheel. Uretech is a registered large quantity generator of hazardous waste under RCRA.

2.1.2 Site Contaminants

Based on historic AEC operational and processing records, as well as environmental sampling, several potential contaminants have been identified at the Luckey site. These contaminants are grouped in the categories listed below. Their potential sources, nature, and likely impacts on the RI also are discussed.

2.1.2.1 Beryl Ore

According to employee interviews, the beryl ore, purchased from brokers or the AEC, arrived at the Luckey site in bags and drums. The ore particles varied in size, i.e., from large pieces (the size of half a brick) to small gravel-size particles that appeared to have been crushed prior to shipment (Cline 1990). Ore was stored on both sides of the railroad siding near the railroad scales (Singleton 1990) and on runways adjacent to the production buildings (OEPA 1997). Dump trucks on the concrete runways received waste by-products discharged from chutes in the building.

Ground beryl ore was obtained from the former Middlesex Sampling Plant in Middlesex, New Jersey (another AEC facility). The rock grinders that crushed the beryllium ore also were used to grind uranium ores. The beryl ore may have acquired radiological constituents left behind by the uranium grinding operations (DOE 1991). Pegmatites containing beryl ore obtained from South America also may have contained small amounts of naturally occurring radionuclides.

2.1.2.2 Radioactive Scrap

Records indicate that in late 1951, the Luckey site received approximately 1,000 tons of scrap steel from LOSA. By the early 1950s, LOSA had accumulated significant quantities of scrap metal, partly because metal drums were used to ship and store residues from the processing of pitchblende ores. When the pitchblende residues were consolidated into a storage facility at LOSA, the emptied drums were cleaned for reuse or scrapped. These drums contained radioactive residues (TAPR 1951). Most likely these drums would have contained radium-226 (Ra-226), thorium-230 (Th-230), Th-232, uranium-234 (U-234), U-235, and U-238 (as at other FUSRAP sites). The proportion of these radionuclides would vary depending upon the use of the drums prior to being scrapped. The steel, intended to control chlorine gas as a by-product of the magnesium production process, consisted primarily of used, empty steel drums containing radioactive residues (TAPR 1951). Employee interviews indicate the scrap was to be used in setting up the beryllium production process. The scrap steel was reported to contain radioactive materials. The scrap metal was delivered by railroad between December 1951 and early 1952. It was stored in the yard north of the main building along the railroad tracks. Only a small portion of the steel was usable by BBC. Some of the scrap metal may have been sold to local scrap dealers (Cline 1990).

Records also indicate that beryllium scrap from other AEC operations was being sent to Luckey for reprocessing. Indications are that some of this scrap was contaminated with radionuclides (Smith 1950).

2.1.2.3 Other Contaminants

Motor Wheel Corporation manufactured polyurethane parts and wheel covers for the automobile industry and was registered as a storage facility and generator of RCRA hazardous wastes. Uretech currently manages similar operations and paints brake parts for the automotive industry. Motor Wheel submitted a RCRA closure plan for a drum storage area, reporting the following waste streams: toluene diisocyanate waste (U223), dichloromethane (methylene chloride) (F002), a mixture of isobutyl acetate and residual paint (D001), and petroleum naphtha-wax-water (D001). Paint waste and petroleum naphtha are hazardous due to their ignitability characteristic. Toluene diisocyanate decomposes into carbon dioxide and urea. Therefore, indicators for Motor Wheel soil contamination are methylene chloride and ignitability. It is assumed that these indicators are site-wide and not applicable to only the drum storage area located on the north side of the plant immediately north of the main road. However, the USACE only has authority for these wastes when they are intermingled with AEC materials. Characterization of non-AEC indicator compounds was limited to areas where beryllium or radionuclides were thought to be above acceptable limits.

2.1.3 Site Description

The Luckey site consists of a large production building and warehouse, two abandoned railroad spurs, and several smaller process and ancillary buildings. Site features are depicted in Figure 2.1. Filter beds for sewage treatment are located in the north-central portion of the site. Former ore staging and spoils areas are located south and west of the filter beds.

The sewage treatment plant is located west of the filter beds. In the vicinity are the old lime pit or settling basin for the water treatment facility, the back-filled ditch connecting the sewage treatment facility with the lime pit, and the former scrap steel storage site. In the western portion of the Luckey site are the former laboratory building drains, including a sump pit and a 5½ ft by 14-ft septic tank filled with crushed brick (reportedly from the main stack).

There are several areas devoid of vegetation in both old and recent aerial photos: an area adjacent to the sewage treatment facility and immediately north of the circular drive; an area north and east of the filter beds; and an area in the northeastern portion of the site. Disposal areas at the Luckey site include three lagoons in the southeastern portion of the property and a landfill in the northeastern portion of the site. The following sections describe these areas in more detail.

2.1.3.1 <u>Disposal Area</u>

The northeastern corner of the site was formerly used as a disposal area, according to facility records and interviews with former employees (Sections 2.1.1.3 and 2.1.1.4). There are purported to be four large disposal trenches in the northeastern corner of the property. The trenches are approximately 14 ft wide by 18 ft deep and are parallel to the railroad line that ran along the eastern site boundary. Mounds of excavated soil, process materials, and ores compose the spoils mounds. It is possible that the area was used as a landfill and may contain a variety of disposed materials. Groundwater in the area was encountered at a depth of 7 to 14 ft below natural grade. Bedrock is at a depth of approximately 20 ft below natural grade. The majority of the area is stabilized by vegetation, but a portion of the area is bare.

2.1.3.2 <u>Lagoons A, B, and C</u>

Three former process waste lagoons, designated Lagoons A, B, and C are located in the southeastern corner of the site. This area was used to dispose waste process sludge and filter cake in open lagoons. Lagoons A and B appear to have been in use simultaneously and probably contain different waste sludge generated at different stages in the beryllium process. Lagoon C, which was divided into two sections, probably received waste similar to that received by Lagoons A and B. Lagoon A is purported to be 3 to 4 ft deep, Lagoon B 5 to 6 ft deep, and Lagoon C is 1 to 1½ ft deep. Following closure of the lagoons, they were reportedly covered with 3 to 5 ft of clean soils. Former employees describe dredging the lagoons and depositing the dredged sludge in trenches in the Landfill/Spoils Area. North of Lagoons A and B and south of the warehouse is an open area where beryl ores were staged for processing.

2.1.3.3 <u>Lagoon D and Railroad Sidings</u>

The former railroad sidings that enter the property from the east bound an area in the east-central portion of the site. According to facility records and interviews with former employees, this area was used as an ore staging area. Lagoon D, located in the northwestern portion of this area, was excavated but never used. A scrap metal disposal trench was located in the northeastern portion of this area along the northern railroad spur. Ore and gangue materials were probably staged outside the east wall of the

processing building in the western portion of the area. A surface water drainage ditch extends across the area with two tributaries. One drains north from the area of the former process lagoons. The second originates at the southeastern corner of the former process building and runs east. The two drainage ways intersect, flow northeast, and then turn due north toward Toussaint Creek. The eastern portion of the site is low, hummocky ground that is poorly drained.

2.1.3.4 Adjacent Areas

The Luckey site is encompassed on three sides by open agricultural lands that have been used for crop production in the past. Potential impact to this area results from wind-blown and airborne contaminant releases from the smokestack of the production facility. If material from the Luckey site deposited on these lands, it is expected to be isolated in the upper 2 ft of soil. Farming activities (plowing and tilling of the soils) may have mobilized surface deposited constituents and diluted them in the shallow soil matrix. The Troy Township Dump and land surrounding the France Stone Quarry border the Luckey site to the south.

2.1.3.5 Buildings

There are seven large buildings and six smaller structures at the Luckey site. These were built to house or support the magnesium reduction activities and subsequently used during beryllium processing and sintering activities. The larger buildings are of brick and concrete block construction, some with metal sheathing over steel supports. The roof supports in these buildings (except for the Annex) are steel trusses that are generally triangular in shape. In the Annex, the roof is supported by horizontal, steel I-beams. The smaller buildings (guard shacks and pump houses) are a mix of concrete block, brick and wood frame structures.

The two largest buildings, the Production Building and the Annex, are currently used for painting automotive parts and production of urethane foam products for the automotive and health care industries. The rest of the larger buildings are used for administrative activities and storage.

2.1.3.6 Surface Water Features

Surface water features on the site include drainage features entering (e.g., Gilbert Road ditch) and leaving the site (e.g., main drainage ditch) or receiving runoff from the site or discharge from the groundwater (e.g., Toussaint Creek). In addition to drainage, these features include sanitary sewer sumps and drains receiving surface runoff. Surface drainage in the interior of the facility includes NPDES outfalls. Drainage ditches adjacent to roads and railroad drainage along the boundary of the site also are included. Historically, Lagoons B and C discharged first to the main drainage ditch then to Toussaint Creek during periods of high rainfall and stream flow. This main drainage ditch also received runoff from the ore and scrap metal storage sites along the railroad spurs and discharge from the on-site sewage treatment area. Lagoon A drained west into a drainage ditch discharging to the Luckey Road ditch which also received roof stormwater runoff from the Production and Annex buildings.

2.1.4 Summary of Previous Investigations

This section provides a brief summary of previous investigations conducted at the Luckey site. The designation survey and the Phase II RI are predecessors to Phase IV of the comprehensive RI. Several other investigations and activities have been conducted resulting in the accumulation of historical data. Although this historical data cannot be incorporated into the RI data set, it may be used to assess the conclusions of the RI. A listing and brief description of these investigations is presented in Table 2.2.

2.1.4.1 ORNL Preliminary Survey

A preliminary radiological survey of the Luckey site was conducted by Oak Ridge National Laboratory (ORNL) in December 1988. This study was performed over a two-day period and involved conducting gamma walkover surveys over a large portion of the property, collecting surface and subsurface soil samples, and collecting water samples (ORNL 1990).

The walkover surveys were performed using a portable gamma-scintillation meter. Gamma exposure rates over the majority of the property ranged from 5 µR/h to 9 µR/h. Elevated readings were observed over Lagoons A, B, and C, with the highest reading of 1,500 µR/h occurring in Lagoon B. Isolated areas of elevated radioactivity (as high as 800 µR/h) are scattered over most of the property. Soil samples were taken at several of these locations. In addition to the lagoon areas, elevated activity levels were concentrated over the landfill (spoils) area in the northeast corner of the site (12 to 90 µR/h), north of the propane tanks (160 µR/h), south of the propane tanks (800 µR/h), near the pump room (400 µR/h), and at the rubble pile located south of the filter beds (20 to 100 µR/h) (ORNL 1990).

Thirty-six soil samples and three water samples were collected from the site and adjacent property during the ORNL survey (Figure 2.2). Nineteen locations were biased to areas where measured gamma radiation was high. No analyses for alpha activity or Th-230 were collected during this investigation. The analytical results show Ra-226 levels up to 4,000 pCi/g at the site (Table 2.3). Seven stations had Ra-226 activities above 100 pCi/g. The highest activities were located just south of the propane tanks; at the east edge of the bare spot in IA07; north of the propane tanks; and in lagoon B.

Samples for beryllium analysis also were collected during the ORNL survey. Fourteen samples were collected from eight stations. The highest concentration of 6,400 mg/kg was detected in lagoon B. Elevated concentrations also were detected in Lagoon C (5,300 mg/kg), Lagoon A (4,400 mg/kg), and in the field north of the site (3,500 mg/kg).

Detectable concentrations of U-238, Ra-226, and Th-232 were recorded in each water sample, although the reported concentrations were below DOE guidelines. A single sample was taken in the farm field north of the site. Analysis showed beryllium and radiological constituents above background (ORNL 1990).

The information collected in this survey was used in the DOE designation process to justify the inclusion of Luckey in the FUSRAP program. The reasons stated in the designation letter (DOE 1991) were:

- The land was owned by the government at the time that the facility produced beryllium.
- The facility had been controlled by the AEC both directly and indirectly.
- The beryllium ore used at the Luckey site was owned by the government and ground at the AEC-Middlesex facility for shipment to the Luckey facility.
- The site was inspected on many occasions by AEC health and safety staff.

The letter authorizes “remedial action for the observed radioactivity, the beryllium, and chemicals related to the production of beryllium” at the Luckey site under FUSRAP (DOE 1991).

In 1996, a preliminary site evaluation was performed to justify further investigatory action and propose future activities to better define areas of contamination and site characteristics. The preliminary site evaluation report evaluated the risk from beryllium and radionuclides detected during the ORNL survey. The conclusion (based on using the maximum detected values for each constituent of concern)

indicated there might be an unacceptable risk to potential receptors at the site. The report recommended further investigation to properly evaluate risk to human health and ecological receptors (SAIC 1996).

2.1.4.2 Phase II Characterization

DOE designated the Luckey site into the FUSRAP Program in 1992 and began site characterization fieldwork in 1997. Phase II work elements included the following:

- collecting background soil, sediment, and surface water samples to determine concentrations of radionuclides, organic chemicals, and metals, as well as background gamma exposure and ambient air concentrations of beryllium and gross radioactivity;
- collecting and analyzing ambient air samples for beryllium and gross radioactivity;
- collecting external gamma exposure measurements;
- conducting radiological walkover surveys and building radiological surveys;
- conducting systematic site-wide soil sampling survey for beryllium using the LIBS equipment;
- performing a cursory scoping survey in the AEC annex for beryllium;
- collecting correlation samples to calibrate the radiological walkover data and LIBS data;
- collecting soil samples from 15 locations, including the trenches, lagoons, scrap metal pits, spoils piles, and the location of several former underground storage tanks;
- conducting surface geophysical surveys, including magnetometer, Electromagnetic-31 (EM-31) and EM-61, over investigation areas (IAs) 1, 3, 5, 7, and 8 to define the perimeter of the fill and trench areas and to locate buried drums and scrap metal; and
- collecting downstream sediment samples from Toussaint Creek.

Results of the Phase II field efforts are documented in the Phase II Characterization Report (BNI 1998). These results were evaluated to delineate and focus the Phase IV RI activities. The data collected during the Phase II activities also have been incorporated into this comprehensive RI Report. The field activities are described in detail in Section 3, and the results are used to characterize the nature and extent of contamination. Analytical data also are incorporated into the BRA detailed in Sections 6 and 7.

2.1.4.3 Wetlands Designation Survey

In the summer of 1998, the USACE performed a wetlands designation survey at the Luckey site. The field investigation was conducted according to procedures described in the USACE *Wetland Delineation Manual* (USACE 1987). An area immediately north of the abandoned railroad bed and Lagoon C was identified as a delineated federal wetland. A channeled waterway immediately east of the pump house and filter beds technically meets the criteria for a shallow emergent wetland (Figure 2-17). The results of this survey are presented in the *Wetland Delineation Report for the Luckey Site* (USACE 1998b).

2.1.4.4 Historical Investigations and Sampling Activities

This section details previous investigations and sampling activities. In some instances, the following investigations and sampling activities provide additional sources of information. Although data is not currently available for all activities, it may be discovered during subsequent records searches. Although this data cannot be incorporated into the RI data set, it can be compared to the conclusions of the RI Report.

A series of investigations pertaining to the disposal of liquid wastes in the lagoons were conducted in the late 1940s and early 1950s:

- The 1949 Ohio DOH-approval to use lagoons included several conditions (ODH 1949). Requirements for groundwater and surface water monitoring were part of the approval. No records of the monitoring have been found.

- Connectivity of the lagoons with groundwater was tested in shallow drilled wells in December 1953. The wells were drilled to 20 ft around the lagoons using a 2½-inch auger drill by Raymond Concrete Pile Company of Detroit, Michigan. Analyses for pH, sulfate, and ammonia exist for three sample events. Further analyses are not available (Schwenzfeier 1956). All wells were dry except for one drilled on the southeast corner of the "solar evaporation lagoon," which is assumed to mean Lagoon C. Sulfate (4,500 ppm) and beryllium (0.6 ppm) results in the shallow well water indicated some connectivity, but the absence of water in most wells was interpreted to mean that little percolation was occurring (Schwenzfeier 1954).

- In support of alleged groundwater contamination of National Gypsum Company quarry water from the Luckey site, representative values of pH, sulfate, beryllium, and ammonia are reported for the lagoon waste water, Toussaint Creek (upstream and downstream), the Luckey plant "deep well" (There is no indication in the report whether this is the west or east production well.), off-site farm wells, and National Gypsum quarry water (Schaffner 1954). Reported concentrations of beryllium in lagoon water, Toussaint Creek, the plant well, and three farm wells were at or below 0.25 ppm. In connection with this complaint, a radioactive iodine tracer was introduced into the lagoons with the hope that a connection could be documented. No documented results have been found; however, subsequent correspondence indicates that magnesium sludge in the Troy Township Dump may have been the source of the problem (Schwenzfeier 1956).

Over the years, several sampling episodes have occurred involving water wells and other locations on and around the Luckey site:

- A series of water analyses for the potable water supply at the Luckey facility exist for the period from 1985 until 1990. Additional individual reports exist for several years in the 1990s. These results show that with an exception in late 1985 and early 1986, beryllium in the potable water supply at the Luckey facility has been below the detectable levels and/or below the Safe Drinking Water Act maximum contaminant level (MCL). Beryllium was detected at concentrations up to 8.8 µg/L during the late 1985/early 1986 time frame (MASI 1986) prior to the establishment of the MCL.

- A letter (Gilbert 1986) details the removal of a 10,000 gallon Vimpol tank and two 30,000 gallon fuel oil tanks. The description of the removal included a note indicating, "there was no visible oil or chemical sheen on the ground or water in the pit" after removal of the tanks. A visual inspection of the tanks showed them "to be in very good and sound shape" (Gilbert 1986). No sampling information or results pertaining to this activity have been located.

2.1.5 Off-site Residential Properties

While conducting the RI and associated tasks at the Luckey site, background soil and groundwater samples were collected on the property of a local resident. The resident indicated his father had been a residential land developer in the Luckey area in the 1960's and had used soil from the Luckey site as fill material at residential properties. The developer was contacted and interviewed. Two properties were identified and later were the subject of radiological surveys, soil sampling, and tap water sampling. These properties are being addressed separately from the Luckey RI (SAIC 2000a, SAIC 2000b).

2.2 SITE CHARACTERISTICS

2.2.1 Geology

The Luckey site is located in the Eastern Lake Plains section of the Central Lowlands Province. The topography is flat and consists of shallow surface gradients that slope toward Lake Erie at approximately 3 to 4 ft/mile (Glaze 1972). Low sand and dolomite ridges rise 10 ft or so over the low-lying lake plains. Surface elevations range from 580 ft above mean sea level (amsl) in northern Wood County to 705 ft above mean sea level (amsl) in southern Wood County (Bush 1966). At the Luckey site, surface elevations range from 647 to 664 ft amsl. The site is generally higher in the northeast corner of the property due to historical disposal activities. Other important features in the vicinity of the Luckey site include the town of Luckey to the south, which sits upon a topographic high at an elevation of about 680 ft amsl; the inactive France Stone Quarry located directly south of the facility with an estimated total depth of 70 ft; and Toussaint Creek, located north of the facility, with a creek-bed elevation of 634 ft amsl where it passes beneath Lemoyne Road. Figure 2.3 shows topographic contours of the site, along with the northern edge of the quarry south of the site and the Toussaint Creek north of the site.

The Luckey site sits on a mantle of unconsolidated glacial deposits overlying a sequence of relatively flat-lying sedimentary rocks. Roughly 300 ft of the Silurian age Lockport Dolomite compose the upper bedrock unit. This dolomite lies on top of a layer of Rochester Shale that is approximately 20 ft thick through most of the region.

2.2.1.1 <u>Structural Geology</u>

The predominant regional geological feature is the Findlay Arch, which is an anticlinal structure that trends north-northeastward. The structure runs from North Bass Island through eastern Ottawa and Sandusky Counties all the way to the Dayton area. The Luckey site lies just west of the axis of the arch, as shown in Figure 2.4. The older carbonate rocks (Lockport Dolomite) are exposed at the surface or subcrop beneath the glacial drift along the axis of the arch. Younger rocks overlie the Lockport Dolomite to the east and west. On the western flank of the arch, bedrock units dip to the west-northwest at greater than 35 ft/mile (Breen and Dumouchelle 1991).

The Bowling Green fault zone trends roughly north-south through central Wood County, west of the Luckey property. The normal fault occurs on the western flank of the Findlay Arch and has younger, downthrown rocks on the western side of the fault with a reported displacement of 200 ft in central Wood County (Breen and Dumouchelle 1991).

2.2.1.2 <u>Unconsolidated Deposits</u>

The unconsolidated deposits consist of soils and glacial sediments that overly the consolidated bedrock. In the eastern half of Wood County, the unconsolidated deposits are generally less than 30 ft thick, and bedrock highs are exposed at or occur just beneath the surface. Unconsolidated sediments are thickest (60 ft or more) along the Maumee River valley and along preglacial stream valleys in Wood County.

Drilling and sampling at the Luckey site indicate unconsolidated sediments ranging in thickness from 15 to 26½ ft overlying the dolomite bedrock. Generally, the unconsolidated deposits are thinnest to the south and east of the facility, and gradually thicken towards Toussaint Creek to the north.

USDA Soils

Soils present on the site are typically poorly drained clays of the Hoytville series. Most of the site lies on the Hoytville clay, but a small portion of the property near lagoon C lies on the Hoytville clay loam. These soils are almost identical, only varying slightly in clay content. The U.S. Department of Agriculture (USDA) Soil Conservation Service indicates that this soil series (including both the clay and clay loam) has a high shrink swell potential, with up to 93% passing a 0.074 millimeter sieve, a liquid limit for the clay loam of 35,and a plasticity index of 12. According to USDA (1966), the Unified Soil Classification is CH (clay), and the American Association of State Highway Officials (AASHO) classification is A-7 (clayey soils that have low strength when wet). The soil is relatively neutral, with a pH ranging from 6.4 to 7.1.

The Hoytville series is characterized by very poorly drained, dark-colored soils in fine-grained, gritty till on broad flats. Typically the soils are mottled yellowish-brown and grayish brown, firm, and exhibit a blocky structure. Near the surface the soils tend to exhibit a more grayish color. Overall, surface infiltration in the Hoytville soils is very poor. This poor drainage, along with the generally level land surface, results in the need for the extensive network of deep drainage ditches present throughout the region. Prior to the construction of intricate drainage ditches in the area, much of the former glacial lake plain was a swamp. Since the wet, swampy soil was black in color and covered such a large area, it became known as the "Great Black Swamp".

Glacial Sediments

Clay-rich glacial till underlies the Hoytville soil in the area. Within Wood County, this clay-rich till thins to the east but can reach a thickness of 35 ft in some areas. The clay-rich till often covers a pebbly till (Paulson 1981, USDA 1966, and Glaze 1972). According to Paulson (1981), this upper till is often referred to as clay due to its high clay content (40-50%). The lower pebbly till contains more sand and gravel and may contain discontinuous sand and gravel lenses ranging in thickness from 2 to 29 ft. Much of the glacial till in Wood County is overlain by a veneer of lacustrine sediments consisting of sand, silt, and clay that was deposited when melting glaciers caused Lake Erie to flood into northwest Ohio.

Much of the glacial till on site contains varying percentages of clay versus silt. In some areas, the till has a higher percentage of silt than clay; other areas consist more of clays than silt. Much of the till contains at least a trace of sand and gravel, sometimes reaching 20% of the till. The color ranges from dark brown to a dark gray color. Results from the geotechnical analyses classified most soil samples as lean clay (CL) with some fine sand and silt. Samples exhibited moisture contents ranging from 12.2 to 18.6%. Complete results for all geotechnical analyses are presented in Table 2.4.

Drilling and sampling at the site indicate the presence of thin, discontinuous layers of sand and gravel, especially near the bedrock surface. Most of the sand and gravel in the area sits directly on top of the dolomite. In Wood County, these sand and gravel deposits are believed to be derived from glacial outwash (Paulson, 1981). The sand and gravel consists primarily of fine sand with some silt and about 20% fine gravel, although more gravelly deposits have been found at the site. The sand and gravel deposits are either dark brown or gray and tend to be thin (less than 2 ft thick), but have been found to be as thick as 6 ft locally on site.

A total of five cross sections (three south-north sections and two east-west sections) have been constructed along the traverses shown in Figure 2.5. These cross sections (Figures 2.6 through 2.10) depict the unconsolidated sediments overlying the carbonate bedrock at the site. At the Luckey site, the

unconsolidated sediments range from 15 to 20 ft thick and gradually increase in thickness to the north toward Toussaint Creek.

2.2.1.3 Bedrock Geology

The uppermost bedrock in the region consists of the Lockport Dolomite. This formation ranges in thickness from 125 ft to 475 ft (Breen and Dumouchelle 1991). Examination of oil well logs in the area indicates the thickness of the dolomite to be 300 ft. The Lockport Dolomite is massive in structure, open to vesicular in texture, light gray to bluish gray in color, generally poor in fossils, and may be granular or crystalline. Secondary features (dissolution along joints, fractures, and faults) create sufficient porosity in the Lockport Dolomite to make it a significant aquifer for the region. Logs from boreholes drilled on or near the site and from residential wells drilled in the region were used to construct a contour map depicting the top of the Lockport Dolomite (Figure 2.11). Top of bedrock elevations typically range between 630 and 640 ft amsl and decrease to the north-northwest of the site. East of the site, the bedrock is near the surface and is covered by glacial till 5 ft thick or less in many areas. South of the site, the town of Luckey sits on a bedrock high with elevations generally greater than 660 ft amsl and with very thin glacial till cover.

During the installation of bedrock groundwater monitoring wells (MWs), a thin (1 to 2 ft) zone of weathered limestone was noted at the bedrock interface at several locations in the vicinity of the Luckey site. In general, the descriptions of dolomite cores collected during the Phase IV investigation were consistent with previous information.

Below the Lockport Group dolomite lies about a 20 ft layer of Rochester Shale. It is believed that this formation provides a fairly impermeable separation between the bedrock aquifer above and the units occurring below it. Rochester Shale has a very distinctive green color and often contains gray and greenish-gray crinoidal dolomite. Borehole logs from oil wells in the area suggest the top of this layer is located about 300-ft bgs.

2.2.2 Hydrogeology

Two hydrostratigraphic units are present in the vicinity of the Luckey site, one in the overlying unconsolidated material and the other in the carbonate bedrock (Lockport Dolomite). The unconsolidated sediments are not typically used as a source for water supplies. In northwest Ohio, the thick sequence of Silurian and Devonian carbonate bedrock compose a regional aquifer that serves as the primary source of groundwater for much of Wood County's rural population.

The surficial water-bearing unit consists of sand and gravel lenses within the till, but little information regarding the water-yielding characteristics of these deposits is available. Most of the glacial deposits in the Wood County area are poor water-bearing units due to their high clay and silt contents (Smith and Sabol 1994). Paulson (1981) reported water yields up to 20 gal/min in glacial outwash deposits along the preglacial Napleon River valley. A weathered detrital or broken rock zone typically occurs above the competent bedrock. This zone is typically saturated with groundwater and can be a good supply of water for domestic use (Breen and Dumouchelle 1991 after Forsyth 1968).

The carbonate aquifer is good to excellent with typical yields of 10 to 20 gal/min, but it can reach 100 to 500 gal/min (Smith and Sabol 1994). According to Paulson (1981), the Lockport Dolomite supplies water from its entire thickness but is usually tapped at a range of 50 to 80 ft below the surface of the unit. The carbonate water supply is dependent upon a network of interconnected fractures, bedding planes, and joints. Solution along these features enhances secondary porosity and the ability of the dolomite to transmit water (Smith and Sabol 1994). Paulson (1981) noted that the secondary porosity

extends several hundred feet into the bedrock but does not approach the irregularity of an established karst terrain.

The predominant set of fractures, which trends northeast-southwest (Breen and Dumouchelle 1991 after Van Wagner 1988, Glaze 1972, Rowland and Kunkle 1970) can be used to locate potentially high-yielding areas for the drilling of production wells. Wells completed at different depths within the carbonate bedrock were observed to have similar water levels, suggesting that the water-bearing zones appear to be interconnected (Paulson 1981).

Groundwater in the carbonate aquifer is under artesian pressure where the potentiometric surface occurs above the top of the aquifer [above the base of the glacial till (Breen and Dumouchelle 1991)]. The glacial deposits that overly the carbonate aquifer form the confining layer above much of the aquifer. This confining layer is not impermeable, and leakage does occur between the carbonate aquifer and the glacial deposits. As a result, the carbonate aquifer can be characterized as a semiconfined or leaky-confined aquifer.

2.2.2.1 Groundwater Recharge

Recharge to groundwater within the carbonate bedrock occurs through several mechanisms. These mechanisms include leakage of water from precipitation through the glacial till overlying the bedrock, direct infiltration of precipitation in areas where the glacial till is thin or absent, and as a result of infiltration of surface water through streambeds. Breen and Dumouchelle (1991) analyzed tritium levels in groundwater from the carbonate aquifer in Lucas, Wood, and Sandusky counties to identify areas where the groundwater is relatively young—recently recharged by infiltrating precipitation. Results of the investigation indicate that areas where the till is thin (defined as 20 ft thick or less) or absent comprise the areas where most recharge to the carbonate aquifer occur. Areas where the till is thin include Bowling Green, Luckey, Stoney Ridge, and Pemberville (Smith and Sabol 1994). Areas where the till is thicker than 20 ft generally receive very little recharge as a result of precipitation leakage down through the till.

Site-specific estimates of groundwater recharge rates were not determined. However, estimates of aerial groundwater recharge rates were determined through a number of studies completed for the carbonate aquifer system and are summarized in Table 2.5. Locally higher recharge rates may occur in areas where the glacial till is thin or absent. Paulson (1981) noted that recharge to the carbonate aquifer occurred from the months of November through May, with most recharge occurring in May. Based upon examination of precipitation data and water levels in a well, a period of four weeks was estimated between precipitation events and infiltration into the regional groundwater flow system (Paulson 1981). Precipitation and water levels in monitoring wells at the Luckey site have been monitored continuously since July 1999. This data indicates no apparent correlation between groundwater levels and precipitation events. Recharge through tills at the site is not believed to be a major process. It appears most recharge is occurring via the lateral flux of water from the south-bedrock high at Luckey.

2.2.2.2 Groundwater Discharge

Groundwater discharge from the carbonate aquifer occurs through several primary processes that include flow to rivers, streams, lakes and quarries; municipal and domestic supply wells; quarry dewatering; and from springs and flowing wells. Breen and Dumouchelle (1991) state that the Maumee and Portage rivers are discharge areas for groundwater from the carbonate aquifer. Streams may also receive groundwater discharge, especially in western Sandusky and eastern Wood County where the bedrock occurs near the ground surface. In areas where the glacial till is thicker, discharge to streams likely occurs only where the stream is in contact with the carbonate bedrock.

2.2.2.3 Regional Groundwater Flow

The general groundwater flow direction in Wood County is from recharge areas in the south toward discharge zones at Lake Erie and the Maumee River. A potentiometric surface map compiled by Breen and Dumouchelle (1991) shows a groundwater mound beneath the town of Luckey. The mound is associated with the shallow bedrock and higher recharge rates for this area. Radial groundwater flow occurs away from the mound in all directions, with the exception of no flow toward the southwest. Regional groundwater flow is to the north beneath the Luckey site with shallow groundwater gradients of around 5 ft/mile. Steeper gradients likely occur adjacent to the groundwater mound. South of the groundwater mound, flow is to the southeast toward Pemberville and the Portage River. There is also a component of flow to the east toward the Portage River and the large cone of depression associated with quarry dewatering just north of Woodville in western Sandusky County.

2.2.2.4 Site Groundwater

A total of 43 monitoring wells and piezometers have been installed since 1997 to various depths throughout the site and in the field between the Luckey site and Toussaint Creek to the north. The location of each monitoring well and piezometer is shown in Figure 2.5. Table 2.6 provides a list of the monitoring wells and piezometers installed at the site. Monitoring wells were completed as shallow (in the unconsolidated sediments overlying the bedrock), intermediate (within the top 10-ft of the bedrock) and deep (greater than 20 ft beneath the top of bedrock) wells. All of the piezometers were installed in the unconsolidated sediments overlying the bedrock. Figure 2.12 provides a schematic of the depths of the monitoring wells.

Field observations indicate that except in areas where surface water is commonly present there is minimal water in the overburden. Soil borings were not open long enough for water levels to stabilize and be accurately measured. In general water which would have entered the borings was limited by the nature of the overburden. This is born out by the discussions in Section 4 on dry wells and low recharge rates.

Beginning in August 1998, water level data have been collected periodically from all of the monitoring wells and piezometers. Continuous water level recorders have been installed in 20 monitoring wells since July 1999, and they record water level data every two hours. The data are used to construct well hydrographs and water table and potentiometric surface maps for the site. Examples of the hydrographs are included in Figures 2.13 and 2.14. Figure 2.13 shows a hydrograph from data that was collected on a periodic basis, and Figure 2.14 shows a hydrograph from a continuous recording monitor. Hydrographs showing data from all the wells and piezometers are included in the Groundwater Model and Calibration Technical Memorandum (SAIC 2000c).

Analyses of collected water level data have suggested that four out of the six piezometers are providing erratic water levels. Because of the shrink/swell characteristics of the clay in the soils and till, it is possible that precipitation recharge may be migrating down the casing, resulting in misleading data. Therefore, water level maps have been developed, excluding data from all six of the piezometers, because they have all been constructed in the same way.

The hydrographs do not provide a complete record of seasonal water level variations, due to periods in which no water level measurements were recorded. The hydrographs do, however, indicate that the groundwater elevations in all three zones (shallow, intermediate, and deep) can vary significantly on a daily and annual basis. With the exception of two deep wells [OMW-34(B) and MW-39(B)], average daily (0.14 ft/day) and annual fluctuations (1.38 ft) are very similar regardless of the depth of the well. Both deep wells fluctuated just over 7.9 ft annually. Seasonal groundwater levels are generally highest

during the months of August 1998 or July 1999 and lowest during October 1999, based upon our data set. Data from August 1999 most closely matched the average water levels for all wells (based upon the periodic water level measurements) and were used to produce the water level maps. A brief discussion of the groundwater flow conditions at the Luckey site is presented here. A more thorough discussion of groundwater flow conditions is presented in Groundwater Model and Calibration Technical Memorandum (SAIC 2000).

The unconsolidated potentiometric surface map based on water level data collected in August 1999 is shown in Figure 2.15. The primary water bearing zones in the unconsolidated material are the relatively thin zones of sand and gravel present at or near the bedrock interface. Due to the discontinuous nature of these zones across the site, it is unlikely that even the best producing unconsolidated wells would be able to support sustained production of usable quantities of groundwater. In general, the direction of groundwater flow in the unconsolidated material is from south to north across the property. Water levels in the quarry to the south of the site are in contact with the unconsolidated sediments, and therefore have been incorporated into the water table map. Drawdown in the East Well, estimated from the surrounding water level data, results in a large cone of depression in the unconsolidated sediments. Groundwater discharge to Toussaint Creek is implied by the contours in the northeast portion of the map, but no actual field data exists to verify this condition.

The glacial till acts as a semi-confining layer for the bedrock aquifer. Groundwater levels in the bedrock form a higher potentiometric surface than the groundwater table in the unconsolidated zone. The higher potentiometric surface in the bedrock suggests an upward gradient from the bedrock into the unconsolidated zone through most of the site. Near the east production well, the gradient between the bedrock and unconsolidated zone is reversed due to drawdown in the well.

The bedrock aquifer potentiometric surface (based on water level data collected in August 1999) for the intermediate-depth wells is shown in Figure 2.16. Based on the data, the limestone quarry located to the south of the Luckey site acts as a local source for groundwater recharge to the bedrock aquifer. As a result, groundwater in the bedrock aquifer flows from the quarry to the north across the southern portion of the Luckey property. The cone of depression resulting from the Uretech production well (East Well) captures most groundwater beneath the facility. From the north side of the site, groundwater appears to flow south from under the Toussaint Creek. This flow pattern appears to be caused, or at least influenced, by the cone of depression created by Uretech's production well.

2.2.2.5 Slug Test Results

Single well aquifer tests or slug tests were conducted on wells completed within the unconsolidated sediments and bedrock at the site. Six monitoring wells were tested in both the unconsolidated sediments and the carbonate bedrock. Calculated hydraulic conductivities varied between 0.028 ft/day to 126.3 ft/day in the unconsolidated sediments, and between 0.027 ft/day and 18.160 ft/day in bedrock. Table 2.7 summarizes slug test results, well construction details, and geologic material tested for each well.

2.2.3 Surface Drainage

Surface drainage features at the Luckey site include several NPDES outfalls, storm sewers, drainage ditches, and wetland areas (Figure 2.17). Drainage from on-site sources flows to two main channels, the main drainage ditch and the western drainage ditch. The main drainage ditch originates on site, but discharges off site through the adjacent farm field to the north. The western drainage ditch flows northward along Luckey Road, between the road and the property fenceline. The origin of this ditch is

uncertain, but it can be traced to the south beyond the town of Luckey. The ultimate receptor of these two main ditches and most on-site drainage is Toussaint Creek.

The main drainage ditch originates from the south side of the Warehouse or Annex and the southeast corner of the former Melting, Alloying, and Shipping Building near former Lagoon D. Flow from these source areas converges just east of former Lagoon D to form the main drainage ditch, which then courses northward across the adjacent agricultural field and empties into Toussaint Creek approximately 1,100 ft from the site. Historically, Lagoons B and C discharged to this ditch, as did runoff from the ore and scrap metal storage sites along the former railroad spurs. However, direct discharge from these areas ceased when the lagoons were closed and the storage sites were cleaned up. Currently, runoff from roof drains and truck bays at the Production Building, Annex, and several other buildings discharges to this ditch. In addition, sanitary drains from site buildings terminate at the on-site sewage treatment plant (STP), but the treated effluent is discharged into this ditch at a NPDES outfall just east of the filter beds.

The western drainage ditch runs along Luckey Road at the property boundary and empties into Toussaint Creek approximately 900 ft to the north. Runoff from several on-site sources discharges into the ditch at three locations. The southernmost point, NPDES Outfall 004, receives stormwater from roof drains at the former Laboratory Building and the Annex. The flow is conveyed from these sources in an open concrete-lined drainage ditch along the south side of the former Laboratory Building and enters the western drainage ditch at Outfall 004. In the past, runoff from Lagoon A also contributed flow to this ditch, but it has since been closed. A second discharge point, NPDES Outfall 006, is located between Outfall 004 and the Plant entrance. This outfall receives stormwater runoff from asphalt driveways and possibly the roof drains at the Main Office Building via a concrete-lined drainage ditch that runs westward between the Employee Activity Building and the Guard Shack. The northernmost discharge point in the western drainage ditch is a drainage pipe from the former lime pit, which emptied into the ditch near the northern property boundary.

2.2.3.1 Meander Bends and Toussaint Creek

Toussaint Creek is located north of the Luckey site and receives discharge from the facility's western and main central drainage ditches. The creek flows toward the east and is generally bordered by farm fields (Figures 2.18 and 2.19). In its upper reaches, the creek bed is deeply incised in the region's clayey soils and has a minimal flood plain. Downstream, however, the creek meanders and has a more significant flood plain.

Due to poor natural drainage in the adjoining farm fields, the creek is subject to seasonal flooding by heavy storms. Where the creek is narrow and relatively straight, as it is immediately north of the property, a minimal flood plain has developed, and the sediments within the creek bed are periodically scoured and transported by the swiftly moving floodwaters. In some of the broader reaches east of the site, the floodwaters deposit fine-grained silt and clay sediments on the inside of meander bends where the flow rate is significantly reduced. It is unlikely that 40-year-old sediments deposited in the creek during operation of the beryllium processing plant still remain in the straight and narrow reaches. However, some of these older sediments may be present on the meander bends that are active deposition locations during flood events.

2.2.3.2 France Stone Quarry

A quarry directly south of the Luckey site is owned by France Stone Company of Sylvania, Ohio. Luckey, Ohio was an important source of lime many years ago, due to the incredible purity of the dolomite in the Luckey quarry. The lime was produced at the quarry, and barrels were made in town to

package the lime. This lime from the dolomitic limestone was used in mortars, papermaking, plasters, and refractory processes. A representative of France Stone Company, who was recently interviewed, indicated that this quarry is presently inactive, being held in reserve because the company has sufficient active reserves at other quarries. National Gypsum Corporation previously operated the quarry in the 1940s. The dolomite was mined and processed in kilns on site for lime production. After France Stone Company acquired the quarry, it was used to produce crushed stone for aggregate and highway work, as well as for ship ballast and flux stone for the steel industry. This quarry was never used for large stone production. Crushers were located in the floor of the quarry. The maximum depth was about 70 ft.

The France Stone Company representative is unaware of any contamination of the water in the quarry or any previous testing of the water in the quarry. According to a company representative, there is a monitoring well installed by Bechtel in the woods to the east of the quarry. An exact figure for inflow into the quarry and quarry dewatering rates are unknown, but the material is fairly tight compared to other quarries and is easily dewatered during the years of operation. The Luckey quarry has been inactive since the early 1970s, with no plans to resume operations. During a site visit in February 1998, the water level was near the ground surface, with drainage control provided by a ditch along the highway.

2.2.4 Climate and Water Use

The climate in Wood County is temperate. The 30-year mean annual temperature and precipitation recorded at Bowling Green (1961-1990) and Toledo (1955-1986) are shown in Table 2.8. Estimates of evapotranspiration range from 22 inches per year (Harstine 1991) to 24 inches per year (Lyford and Cohen 1988) for Wood County.

National water-use data files maintained by the USGS estimate the population of Wood County at 116, 930 people (USGS 1999). Of these, 67,820 rely on public water supply systems that derive their water from either surface water (59,680 people) or groundwater sources (8,140 people). The remaining 49,110 receive their water from private domestic supply wells or springs. The large population centers including Bowling Green and the suburbs of Toledo in Wood County are supplied by surface water. In the rural areas, groundwater from the carbonate aquifer is the primary source for domestic supply. Breen and Dumouchelle (1991) noted that ten villages in Lucas, Wood, and Sandusky counties used the carbonate aquifer to obtain their public water supply. Pemberville, located south of Luckey in Wood County, and Woodville, located east of Luckey in Sandusky County, are the two nearest villages with public water supply derived from wells completed in the carbonate bedrock. Estimated daily mean groundwater withdrawals for several categories of use are shown in Table 2.9. Estimated daily per capita use of groundwater is just under 75 gal/day for residents obtaining their water supply through private wells completed in the carbonate aquifer. In general, residents in the vicinity of the Luckey site depend on wells drilled into the carbonate aquifer for their water supplies. The fractured bedrock at depths of up to 100 ft is the primary aquifer tapped. Domestic supply wells are typically cased to around 30 ft bgs.

The population residing near the Luckey site uses groundwater as their source of potable water. Data from the U.S. Census Bureau (2000) compiled for the 1990 census provides an estimate of the population living within one mile of the Luckey site. The total estimated population residing within a one-mile radius of the site is estimated at 985 persons and includes 848 residents of the town of Luckey, Ohio. Of this total, 28 people are estimated to live within one quarter mile of the site; 626 within one half mile of the site; and 897 within three-quarters of a mile of the site.

Two production wells are located on the Luckey site. The West Production Well and East Production Well (Well #1 and Well #2, respectively) are capable of yielding water at rates of 186 gal/min and 246 gal/min respectively. Both wells are installed to a depth of 320-ft bgs. The water from these wells is hard, due to the calcium and magnesium-rich nature of the bedrock formation. The West Well

has been taken out of service and is used primarily as a backup supply for fire prevention. The East Well supplies groundwater at an estimated rate of 70 gal/min for activities (including potable water supplies) at the Uretech facility.

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Table 2.1. Timeline of Historical Events at the Luckey Site

Year	Event/Activity
1942	Defense Plant Corporation (DPC) builds magnesium reduction plant.
1945	World War II ends (WWII); magnesium reduction plant is closed.
1949	Brush Beryllium Company (BBC) leases site and contracts with the Atomic Energy Commission (AEC) to construct, operate, and maintain beryllium production facility.
1951	Korean War begins. Plans are made and dropped to restart the magnesium reduction plant.
1951-1952	Scrap metal is received from Lake Ontario Storage Area (LOSA).
1950-?	Contaminated scrap beryllium is received for reprocessing.
1958	Beryllium production operations are discontinued at Luckey.
1959	Buildings decontamination activities are performed.
1957-1960	Sintering and powder metallurgy activities are conducted at the facility.
1961	Facility is sold to Aluminum and Magnesium, Inc.
1962	Luckey Industries purchases beryllium facility portion of site to recover magnesium.
1967	Aluminum and Magnesium, Inc. transfers ownership to its parent company, Vulcan Materials.
1968	Entire property is purchased by Goodyear Tire and Rubber Company (to make automotive urethane foam products).
1983	Motor Wheel leases property (to make urethane auto products).
1988	Motor Wheel purchases property.
1995	Twenty-three acres of the property are leased by Uretech for continued auto products operations.

Table 2.2. Previous Investigations Conducted at the Luckey Site

Date	Investigation
1949	The Ohio Department of Health (Ohio DOH) approved the use of the lagoons at the Luckey site under several conditions. Requirements for monitoring of groundwater and surface water were part of the approval. No records of the monitoring have been found.
1953	Shallow wells were drilled to test the connectivity of the lagoons with groundwater. Analyses for pH, sulfate and ammonia exist for three sample events. Further analyses are not available.
1954	Samples were collected and analyzed to determine if the Luckey site was contaminating groundwater and causing operational problems for the National Gypsum Company at the France Stone Quarry. Representative values of pH, sulfate, beryllium, and ammonia are reported for the lagoon waste water, Toussaint Creek (upstream and downstream), the Luckey Plant "deep" well, offsite farm wells, and National Gypsum quarry water. A radioactive iodine tracer also was introduced into the lagoons to determine connectivity. No documented test results have been found.
1985-1990	A series of water analyses for the potable water supply at the Luckey facility exists for the period from 1985 until 1990. Additional individual reports exist for several years in the 1990s.
1986	Motor Wheel Corporation removed a 10,000 gallon Vimpol tank and two 30,000 gallon fuel oil tanks.
1988	A preliminary radiological survey of the Luckey site was performed by Oak Ridge National Laboratory (ORNL) in December 1988. This study was performed over a 2-day period, and involved performing gamma walkover surveys over a large portion of the property, collecting surface and subsurface soil samples, and collecting water samples. The information collected in this survey was used in the Department of Energy (DOE) designation process to justify the inclusion of Luckey in the Formerly Utilized Sites Remedial Action Program (FUSRAP) program
1992	DOE designated the Luckey site into the FUSRAP Program.
1996	A preliminary site evaluation was performed by Science Applications International Corporation (SAIC) to justify further investigatory action and propose future activities to better define areas of contamination and site characteristics. Existing data were evaluated – additional data were not generated.
1997	The first phase (Phase II) of field activities for the remedial investigation was conducted by Bechtel National, Inc (BNI). The activities and results are documented in the Phase II Characterization Report. These activities also are included in this comprehensive Remedial Investigation (RI) Report.
1998	United States Army Corps of Engineers (USACE) performed a wetlands delineation survey of the Luckey site.

Table 2.3. Analytical Results of ORNL Historical Investigation (1988)

Station	Sample ID	Radium-226 (pCi/g)	Thorium-232 (pCi/g)	Uranium-238 (pCi/g)	Beryllium (mg/kg)
B1	B1A	230	0.33	120	--
B1	B1B	25	0.31	16	--
B1	B1C	51	0.3	47	--
B10	B10A	8.4	1.84	11	1,300
B10	B10B	2.3	1.2	2.9	120
B11	B11	70	0.45	24	--
B12	B12	150	0.62	27	--
B13	B13A	100	0.99	67	1,300
B13	B13B	83	1	51	1,600
B13	B13C	49	1	27	--
B14	B14A	12	1.4	12	--
B14	B14B	15	1.3	24	--
B14	B14C	17	1.7	280	--
B15	B15A	68	0.41	73	--
B15	B15B	63	0.53	59	--
B15	B15C	59	0.63	51	--
B16	B16	760	1.6	250	--
B17	B17	4,000	3.5	98	310
B18	B18	230	1	160	--
B19	B19	11	0.95	12	3,500
B2	B2	150	0.21	78	--
B3	B3	90	0.32	43	--
B4	B4	42	0.27	29	--
B5	B5A	54	0.4	53	--
B5	B5B	42	0.28	41	--
B6	B6	2.1	0.93	2.6	--
B7	B7	16	2.2	21	6,400
B8	B8	73	0.34	42	--
B9	B9A	9.6	4.3	53	4,400
B9	B9B	7.8	1.7	52	--
B9	B9C	19	1.1	61	--
S1	S1	1.3	0.89	1.5	6.8
S2	S2A	1.9	0.98	2.2	110
S2	S2B	1.8	1.1	2.8	60
S2	S2C	17	0.72	17	1,600
S2	S2D	12	0.28	17	4,200
S2	S2E	20	0.34	49	5,300

-- sample not analyzed for beryllium

Table 2.4. Geotechnical Data for the Luckey Site

ASTM Method:			D2116	D1188	D854	D4318		D422				D698A/B		Visual Classification
						Atterburg Limits		Grain Size Distribution				Proctor		
Sample Station	Sample ID	Depth[1] (ft bgs)	Moisture Content (%)	Dry Density (lb/ft^3)	Specific Gravity	LL (%)	PL (%)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	MDD (lb/ft^3)	OMC (%)	
IA03-SB0004	LUSB1044	15.0-15.7	7.1	124.1	2.709	19	9	9	44	28	19	115.7	15.8	Clayey Sand (SC)
IA03-SB0017	LUSB1049	11.0-12.0	15.5	119.9	2.725	22	10	7	33	31	29	119.5	13.8	Sandy Lean Clay (CL)
IA01-SB0018	LUSB0251	14.0-14.4	8.0	136.5	2.702	13	2	5	55	29	11	111.8	15.8	Silty Sand (SM)
IA01-SB0011	LUSB0252	9.0-11.2	18.6	114.4	2.711	31	14	1	10	34	55	108.5	17.0	Lean Clay (CL)
IA01-SB0019	LUSB0253	7.0-8.2	16.8	116.4	2.729	35	17	2	14	28	56	94.0	26.0	Lean Clay with Sand (CL)
IA01-SB0020	LUSB0254	7.0-8.2	15.3	119.7	2.725	33	16	1	15	30	54	104.9	19.5	Lean Clay with Sand (CL)
IA02-SB0002	LUSB1045	8.2-9.2	12.2	120.9	2.701	25	11	6	31	33	30	112.3	15.8	Sandy Lean Clay (CL)
IA02-SB0003	LUSB1046	9.0-9.8	12.8	121.4	2.710	23	10	4	28	36	32	112.5	15.3	Sandy Lean Clay (CL)
IA02-SB0004	LUSB1047	10.0-11.7	17.8	110.2	2.815	33	14	1	10	25	64	85.3	30.0	Lean Clay (CL)
IA03-SB0001	LUSB1048	10.5-11.3	16.3	116.6	2.710	32	16	2	18	36	44	112.3	15.8	Lean Clay with Sand (CL)
IA05-SB0019	LUSB1050	10.0-11.0	15.9	117.6	2.702	19	5	7	35	42	16	113.7	15.3	Sandy Silty Clay (CL-ML)
IA05-SB0003	LUSB1051	10.0-11.0	14.3	122.5	2.734	32	16	2	17	38	43	104.4	18.2	Lean Clay with Sand (CL)
IA07-SB0005	LUSB1052	7.0-7.8	15.1	119.8	2.732	36	19	1	17	30	52	112.4	15.5	Lean Clay with Sand (CL)
IA06-SD0035	LUSD0175	0.0-0.5	--	--	2.65	--	--	10.5	85.1	0.9	3.5	--	--	Poorly Graded Sands (SP)
IA06-SD0036	LUSD0176	0.0-0.5	--	--	2.65	--	--	9.0	87.2	2.3	1.5	--	--	Poorly Graded Sands (SP)
IA06-SD0037	LUSD0177	0.0-0.5	--	--	2.65	--	--	12.9	62.1	13.8	11.2	--	--	Silty Clayey Sand (SM-SC)
IA06-SD0038	LUSD0178	0.0-0.5	--	--	2.45	--	--	2.2	43.3	27.0	27.5	--	--	Sandy Clayey Silt (ML-CL)
IA06-SD0039	LUSD0179	2.0-2.5	--	--	2.65	--	--	17.5	44.4	21.6	16.5	--	--	Clayey Sand (SC)
IA06-SD0035	LUSD9622	0.0-0.5	--	--	2.65	--	--	13.7	81.1	0.0	5.2	--	--	Poorly Graded Sands (SP)

[1]depth of shelby tube sample
ASTM -- American Society for Testing and Materials
bgs -- below ground surface
-- not measured
LL -- liquid limit
MDD -- maximum dry density
OMC -- optimum moisture content
PL -- plastic limit

Table 2.5. Estimated Recharge Rates to the Carbonate Aquifer in Wood County

Source	Recharge Rate (inches/year)
Pettyjohn and Henning, 1977	4.1
Rowland and Kunkle, 1970	0.14 to 1.6
Winegardner, 1971	0.29

Table 2.6. Monitoring Wells and Piezometers at the Luckey Site

Monitoring Well ID	Location			
	Easting (ft)	Northing (ft)	Surface Elevation (ft)	Well Bottom (ft)
MW-01(I)	1697509.4386	654799.7349	647.88	617.88
MW-02(S)	1697495.7800	654793.7296	647.85	628.85
MW-03(I)	1697057.4343	653858.9710	649.33	622.33
MW-04(S)	1697041.9934	653859.7723	649.16	631.96
MW-05(I)	1698188.0426	654307.2644	650.68	620.68
MW-06(S)	1698187.1600	654322.9701	650.46	632.46
MW-07(I)	1698132.0026	654675.6136	648.6	617.6
MW-08(S)	1698138.8486	654662.4507	648.66	628.36
MW-13(S)	1697939.3016	654811.0356	648.75	630.75
MW-14(S)	1697028.6385	654000.3239	649.51	632.01
MW-17(S)	1698018.1442	654341.8833	649.82	629.79
MW-18(I)	1696732.2910	654599.6176	647.88	614.88
MW-19(I)	1697954.1195	654806.6200	648.62	618.62
MW-20(S)	1697853.9878	654097.6144	650.54	636.54
MW-21(I)	1697394.4970	654513.6371	649.25	621.25
MW-22(I)	1697743.3728	654798.8183	647.82	620.32
MW-23(S)	1697755.7772	653841.1278	650.06	634.51
MW-24(S)	1697302.7405	654031.9662	650.91	627.91
MW-25(I)	1697030.1492	654797.3753	647.25	616.75
MW-26(S)	1697694.9323	654802.2052	647.78	620.28
OMW-27(I)	1697272.7700	654832.8454	647.7	592.7
OMW-28(B)	1697264.1500	654832.8824	647.67	592.67
OMW-29(I)	1696546.9202	655130.6620	646.85	612.85
OMW-30(B)	1696547.0502	655139.7640	646.73	589.73
OMW-31(I)	1697191.3503	655223.1144	646.47	615.47
OMW-32(B)	1697200.0603	655222.8654	646.52	590.52
OMW-33(I)	1696857.1905	655512.8327	646.29	591.29
OMW-34(B)	1696865.5605	655512.4257	646.38	550.38
OMW-35(I)	1697852.2105	655497.0959	646.38	614.98
OMW-36(B)	1697852.1905	655506.3229	646.42	591.22
OMW-37(I)	1696779.3508	655884.6858	641.34	606.24
OMW-38(B)	1696786.3308	655886.9478	641.37	586.37
MW-39(B)	1697509.2499	654812.2982	647.87	553.87
MW-40(B)	1697500.4799	654812.5412	647.85	591.65
MW-41(B)	1697371.8800	653846.6120	650.33	594.33
TW-42(S)	1697071.0300	653859.6880	649.3	634.3
TW-43(S)	1696694.7500	653848.8410	649.35	634.35
PZ01	1696809.8572	654485.2251	647.68	629.11
PZ02	1697294.1739	654783.8674	647.29	630.39
PZ03	1697650.9977	654306.1664	648.7	632.7
PZ04	1696695.6358	653841.8728	648.9	630.99
PZ05	1698263.3528	653836.5070	650.06	637.56
PZ06	1697110.7569	654632.3612	647.41	629.25

BMW - background monitoring well
MW - monitoring well
OMW - off-site monitoring well
TW - test well
PZ - piezometer

Table 2.7. Aquifer Test Summary

Monitoring Well (MW)	Location	Screened Interval (ft bgs)	Total Depth (ft bgs)	Hydraulic Conductivity (ft/day)
Wells Screened in Sand and Gravel				
MW-02(S)	IA05	14.2 - 19.2	19.5	35.690
MW-06(S)	IA01	13.1 - 18.1	18.3	37.080
MW-08(S)	IA01	15.0 - 20.0	20.3	126.300
MW-17(S)	IA03	14.7 - 19.7	20.0	4.269 4.411
Wells Screened in Silt and Clay				
MW-04(S)	IA02	10.3 - 15.3	15.6	0.028
MW-23(S)	IA02	23.6 - 28.6	28.8	0.057
Wells Screened in Competent Bedrock				
MW-01(I)	IA05	24.6 - 29.6	29.9	18.160
MW-03(I)	IA02	21.7 - 26.7	27.0	4.635 3.949
MW-05(I)	IA01	24.6-29.6	29.8	0.401
MW-07(I)	IA01	25.9 - 30.9	31.2	9.746
MW-25(I)	IA07	25.2 – 30.3	30.5	0.027
Well Screened in Weathered Bedrock				
MW-24(S)	IA02	18.1 – 23.1	23.5	21.310 3.971

bgs – below ground surface

Table 2.8. Average Temperature and Precipitation Data from Bowling Green and Toledo, Ohio

Month	Average Temperature (°F)		Average Precipitation (inches)		1999 Site Precipitation (inches)
	Bowling Green	Toledo	Bowling Green	Toledo	
Jan	31.0	29.5	1.56	1.82	NA
Feb	34.2	33.3	1.51	1.78	NA
Mar	46.1	44.5	2.46	2.57	NA
Apr	59.2	59.0	3.01	3.05	NA
May	71.4	70.6	3.42	2.87	NA
Jun	80.9	79.5	3.59	3.66	NA
Jul	84.6	83.4	3.98	3.29	1.54
Aug	81.9	81.3	2.95	3.26	1.03
Sep	75.9	74.1	2.71	2.73	2.25
Oct	63.6	62.2	2.24	2.06	2.50
Nov	49.6	47.6	2.80	2.76	NA
Dec	36.3	35.1	2.54	2.67	NA
Annual	59.5	58.3	32.77	32.52	NA

NA: Site data are not available prior to July 1999, not yet reported for November or December 1999.

Table 2.9. Groundwater Withdrawals for Several Categories of Use in Wood County, Ohio

Category of Use	Withdrawal (million gallons per day)
Public Supply, Population served = 8,140	0.40
Domestic Self-Supplied, Population served = 49,110	3.68
Mining	1.89
Livestock	0.04
Irrigation	0.14
Golf Course Irrigation[a]	0.46
Industrial[b]	0.21

(Data are compilations for the 1995 calendar year on file with U.S. Geological Survey (USGS) (1999) except where noted.)

[a] Data from Black 1983, in Breen and Dumouchelle 1991.

[b] Data from Breen and Dumouchelle 1991, based upon 1985 calender year.

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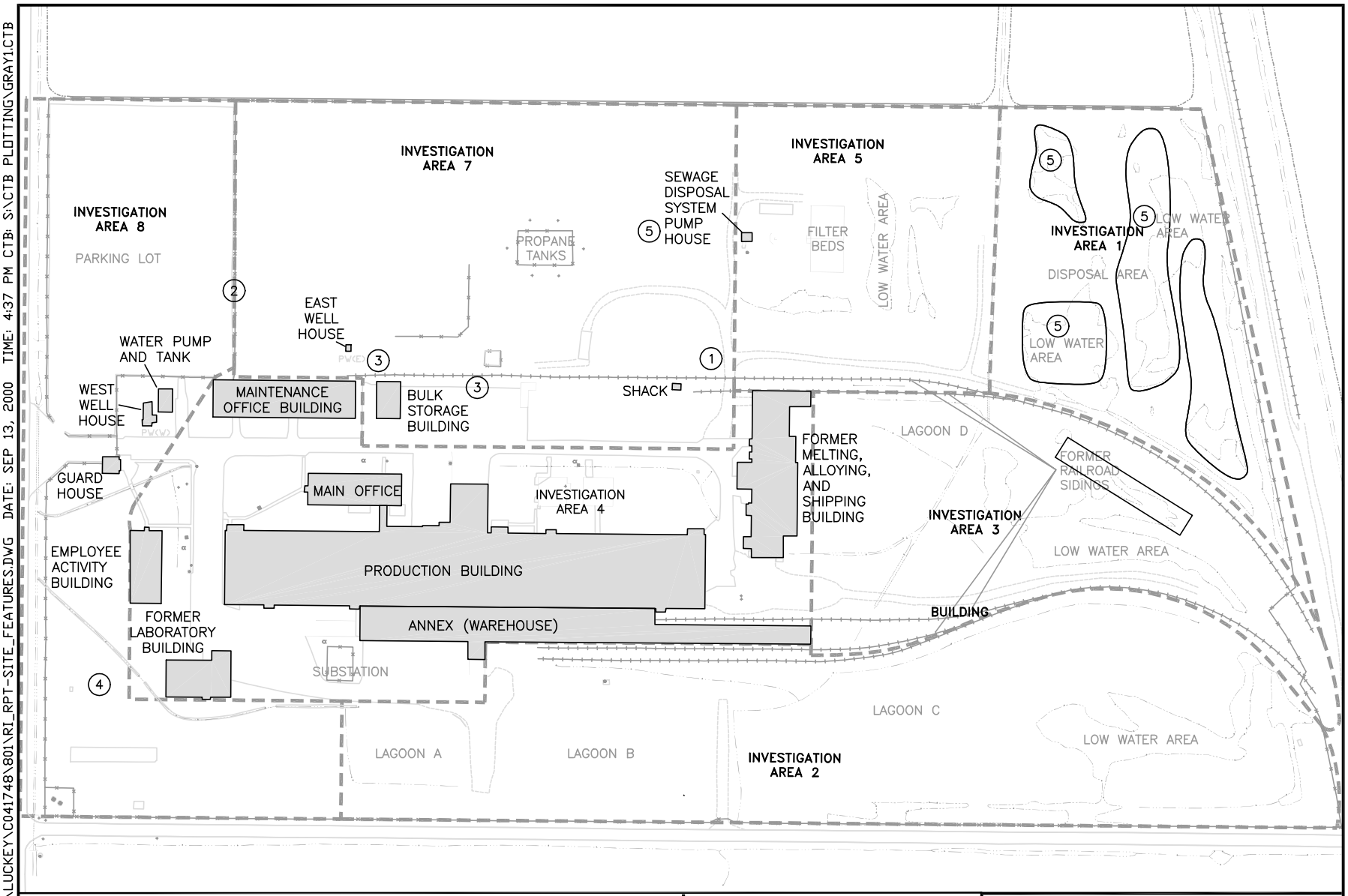

BUILDING
LOW LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE

1 FORMER ORE STAGING AREA
2 FORMER LIME PIT
3 FORMER SCRAP STEEL STORAGE SITES
4 FORMER LABORATORY BLDG. DRAINS
5 AREAS DEVOID OF VEGETATION

N True North

100 0 100 200
FEET

31 0 31 62
METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Features at the Luckey Site

Science Applications International Corporation
Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
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BUILDING
LOW LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE
SOIL SAMPLE LOCATIONS
WATER SAMPLE LOCATIONS

N
True North

0 130 260
FEET

0 40 80
METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

ORNL Historical Investigation (1988)

SAIC. Science Applications International Corporation Columbus, Ohio

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BUILDINGS

LOW-LYING AREAS

FENCE LINE

STREAMS & CREEKS

ABANDONED RAILROAD GRADE

N
True North

0 110 220
FEET

0 360 720
METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Site Specific Topographic Contours

Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	02/09/00	AS SHOWN	04-1748-801	2.3

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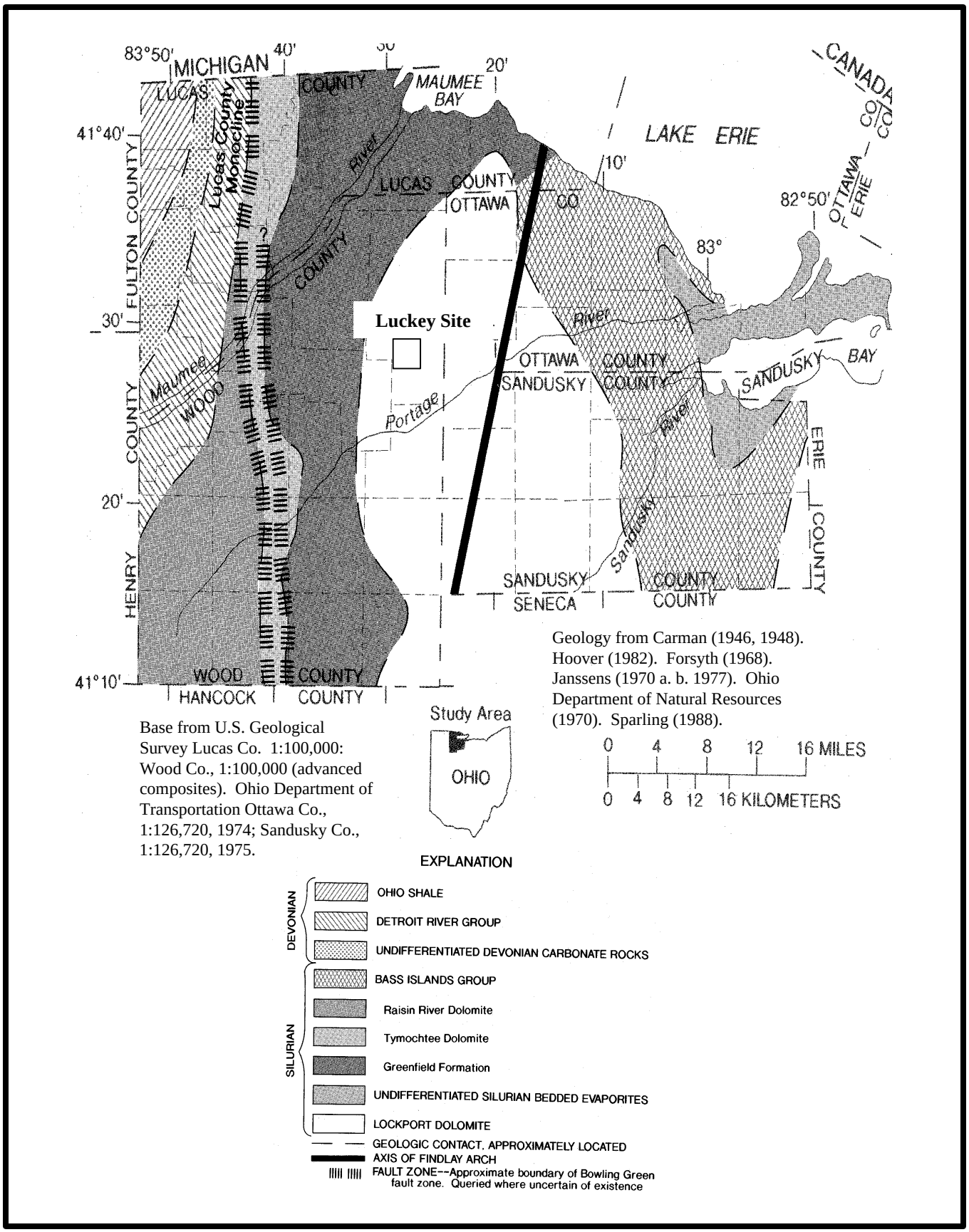
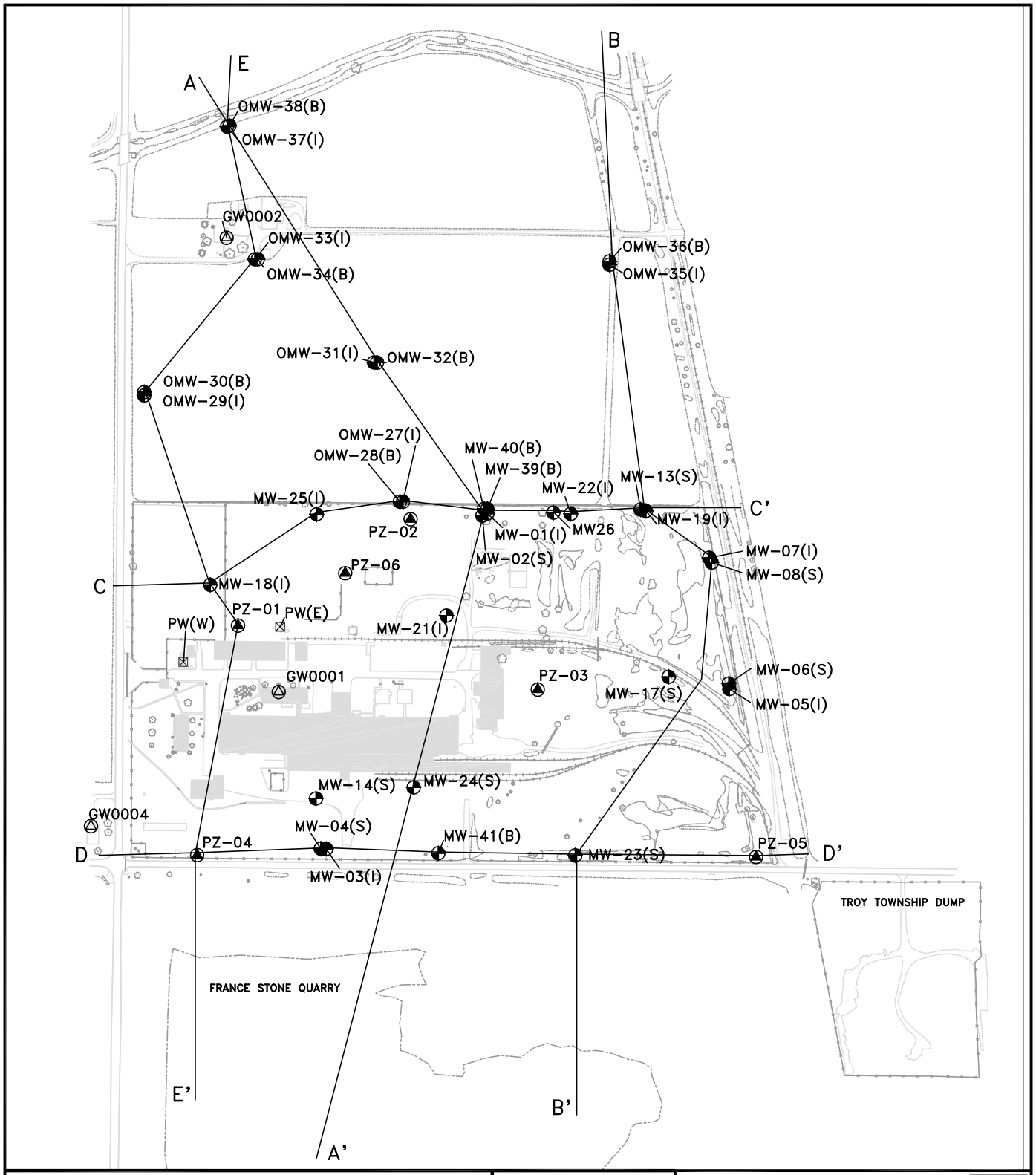


Base from U.S. Geological Survey Lucas Co. 1:100,000: Wood Co., 1:100,000 (advanced composites). Ohio Department of Transportation Ottawa Co., 1:126,720, 1974; Sandusky Co., 1:126,720, 1975.

Geology from Carman (1946, 1948). Hoover (1982). Forsyth (1968). Janssens (1970 a. b. 1977). Ohio Department of Natural Resources (1970). Sparling (1988).

Figure 2.4 Generalized Geology of the Area Surrounding Luckey Site (Modified from Breen and Dumouchelle 1991)



BUILDINGS
LOW-LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE
MONITORING WELL
PIEZOMETER
RESIDENTIAL WELL/ TAP WATER
N True North

0 200 400 FEET
0 60 120 METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Location of Cross-Section Traverses

SAIC Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	02-04-00	AS SHOWN	04-1748-801	2.5

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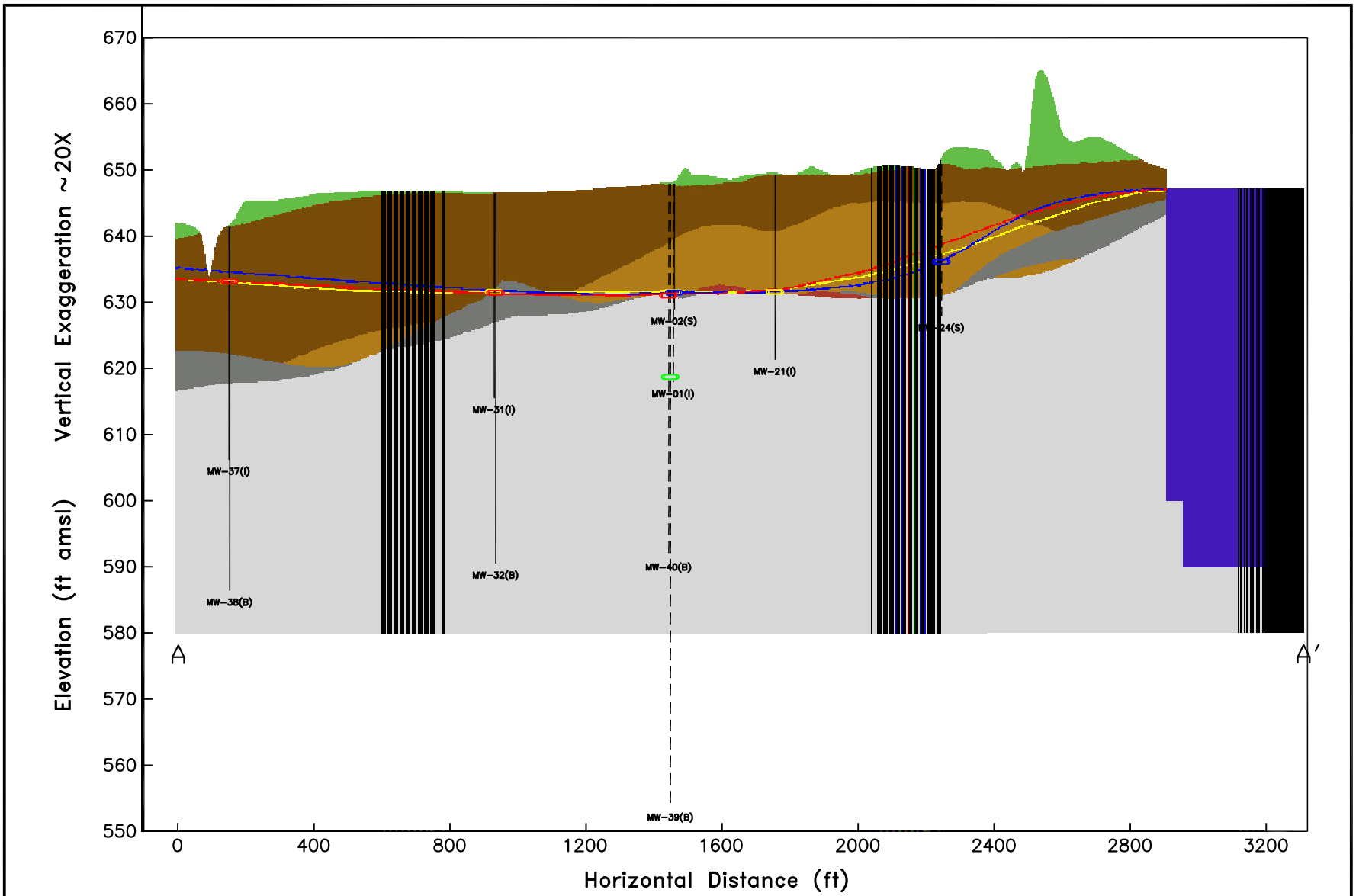

Groundwater Elevation in Shallow Well
Groundwater Elevation in Intermediate Well
Groundwater Elevation in Deep Well
Groundwater Elevation in Very Deep Well

Shallow Groundwater Potentiometric Surface
Intermediate Groundwater Potentiometric Surface
Deep Groundwater Potentiometric Surface

Fill
Silty Clay
Silt
Sandy/Gravelly Silt
Clay
Bedrock
Quarry Water
Trench

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Cross-Section A-A'

Science Applications International Corporation
Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
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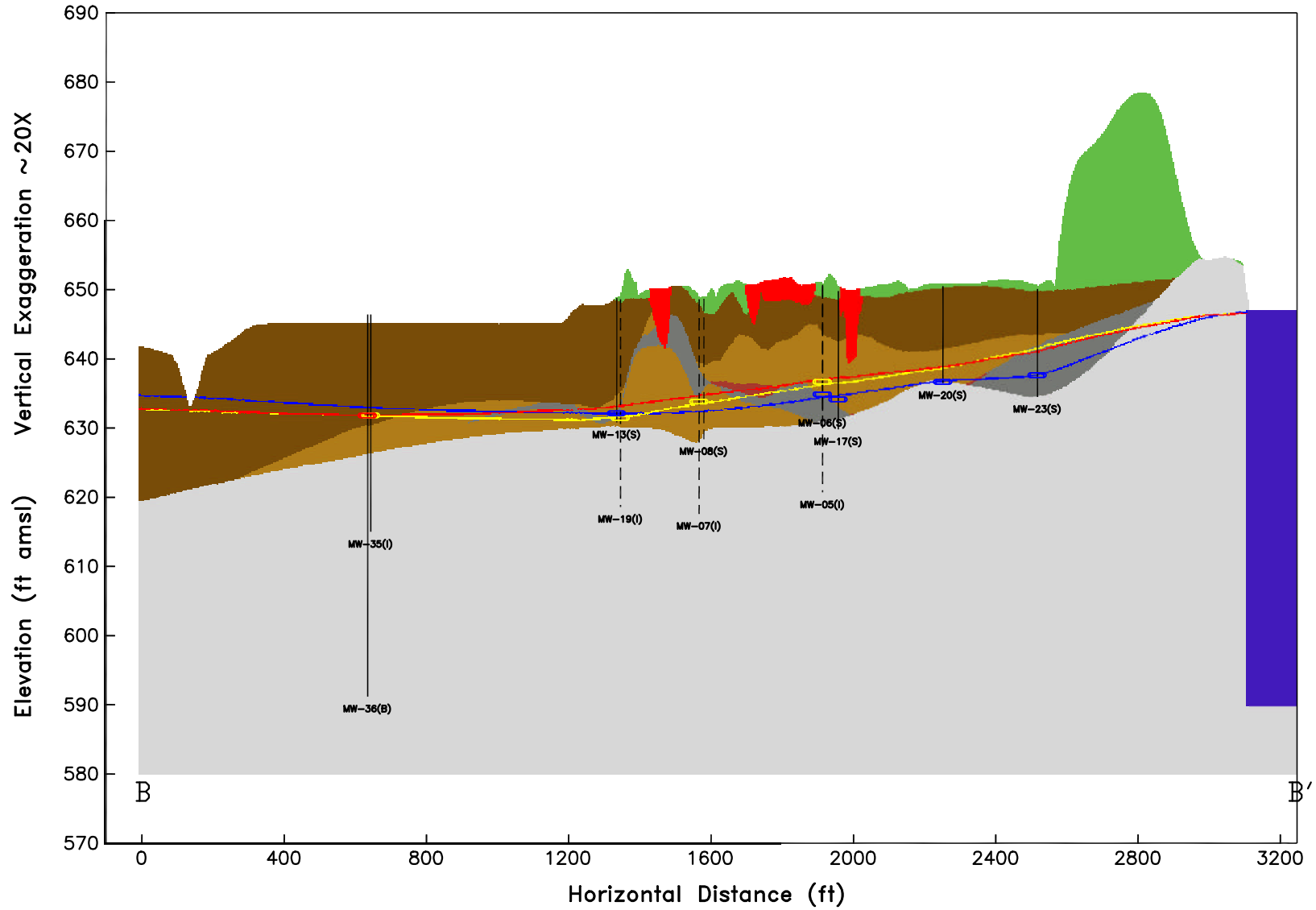

Groundwater Elevation in Shallow Well
Groundwater Elevation in Intermediate Well
Groundwater Elevation in Deep Well
Groundwater Elevation in Very Deep Well

Shallow Groundwater Potentiometric Surface
Intermediate Groundwater Potentiometric Surface
Deep Groundwater Potentiometric Surface

Fill
Silty Clay
Silt
Sandy/Gravelly Silt

Clay
Bedrock
Quarry Water
Trench

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Cross-Section B-B'

Science Applications International Corporation
Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
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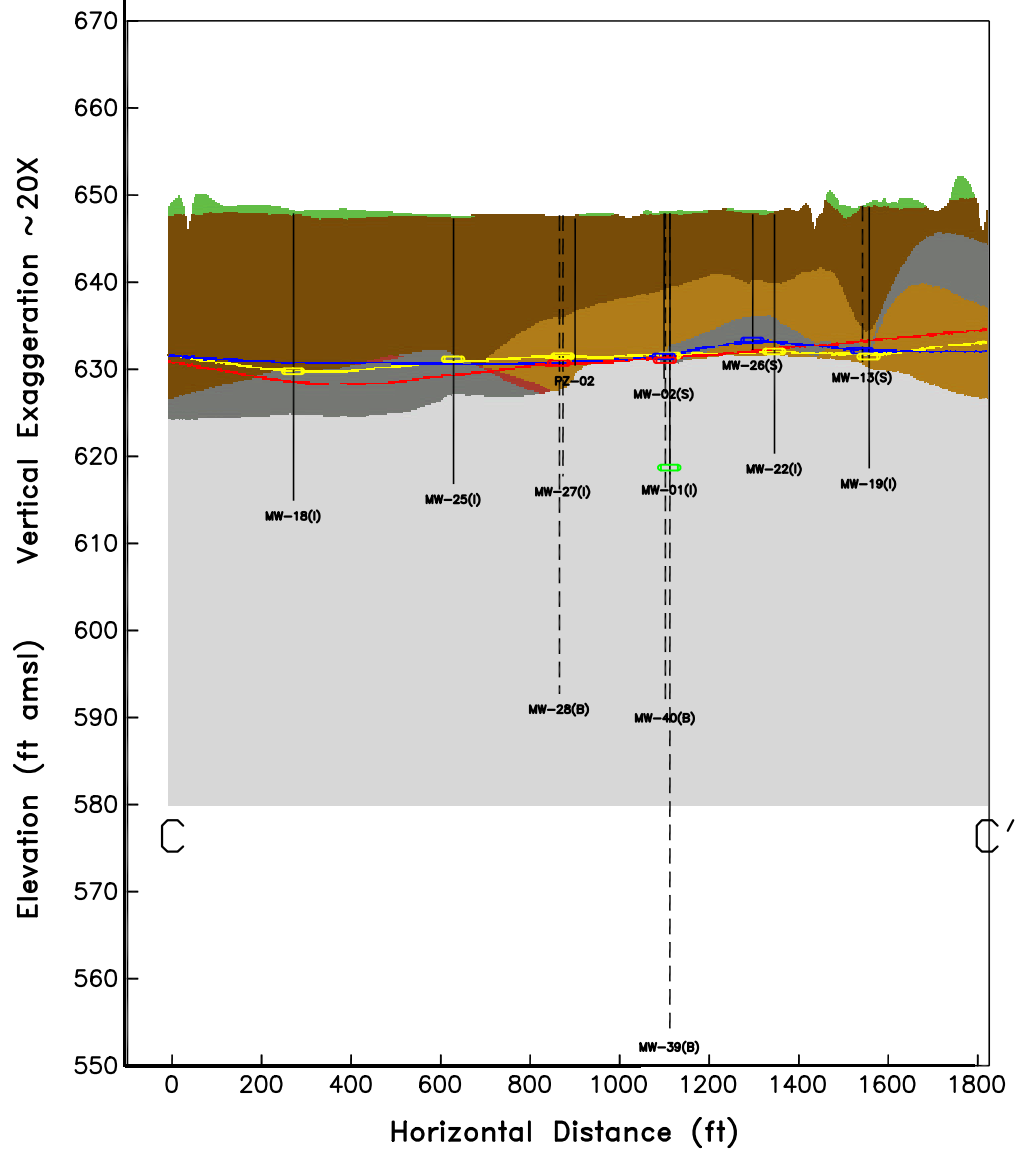


Groundwater Elevation in Shallow Well
Groundwater Elevation in Intermediate Well
Groundwater Elevation in Deep Well
Groundwater Elevation in Very Deep Well

Shallow Groundwater Potentiometric Surface
Intermediate Groundwater Potentiometric Surface
Deep Groundwater Potentiometric Surface

Fill
Silty Clay
Silt
Sandy/Gravelly Silt
Clay
Bedrock
Quarry Water
Trench

U.S. Army Corps of Engineers
Buffalo District

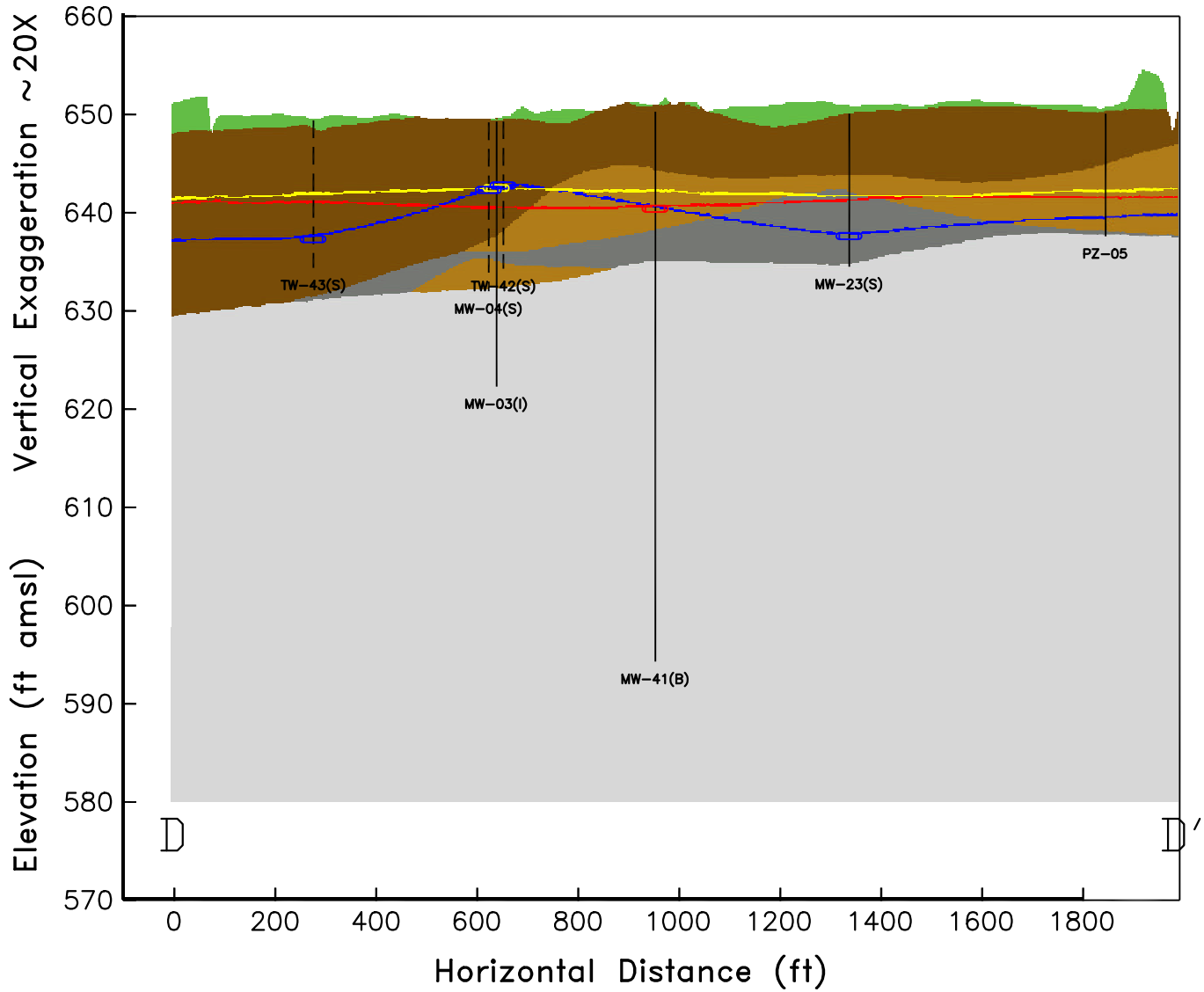
LUCKEY SITE
RI REPORT

Cross-Section C-C'

Science Applications International Corporation
Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	02-01-00	AS SHOWN	04-1748-801	2.8

NAME: N-S:\LUCKEY\C041748\801\RIRPT_D-D'-GW-XSECT-.DWG DATE: APR 13, 2000 TIME: 2:55 PM PCP: S:\PCP\FULLCOLR.PCP



Groundwater Elevation in Shallow Well
Groundwater Elevation in Intermediate Well
Groundwater Elevation in Deep Well
Groundwater Elevation in Very Deep Well

Shallow Groundwater Potentiometric Surface
Intermediate Groundwater Potentiometric Surface
Deep Groundwater Potentiometric Surface

Fill
Silty Clay
Silt
Sandy/Gravelly Silt

Clay
Bedrock
Quarry Water
Trench

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Cross-Section D-D'

Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	02-01-00	AS SHOWN	04-1748-801	2.9

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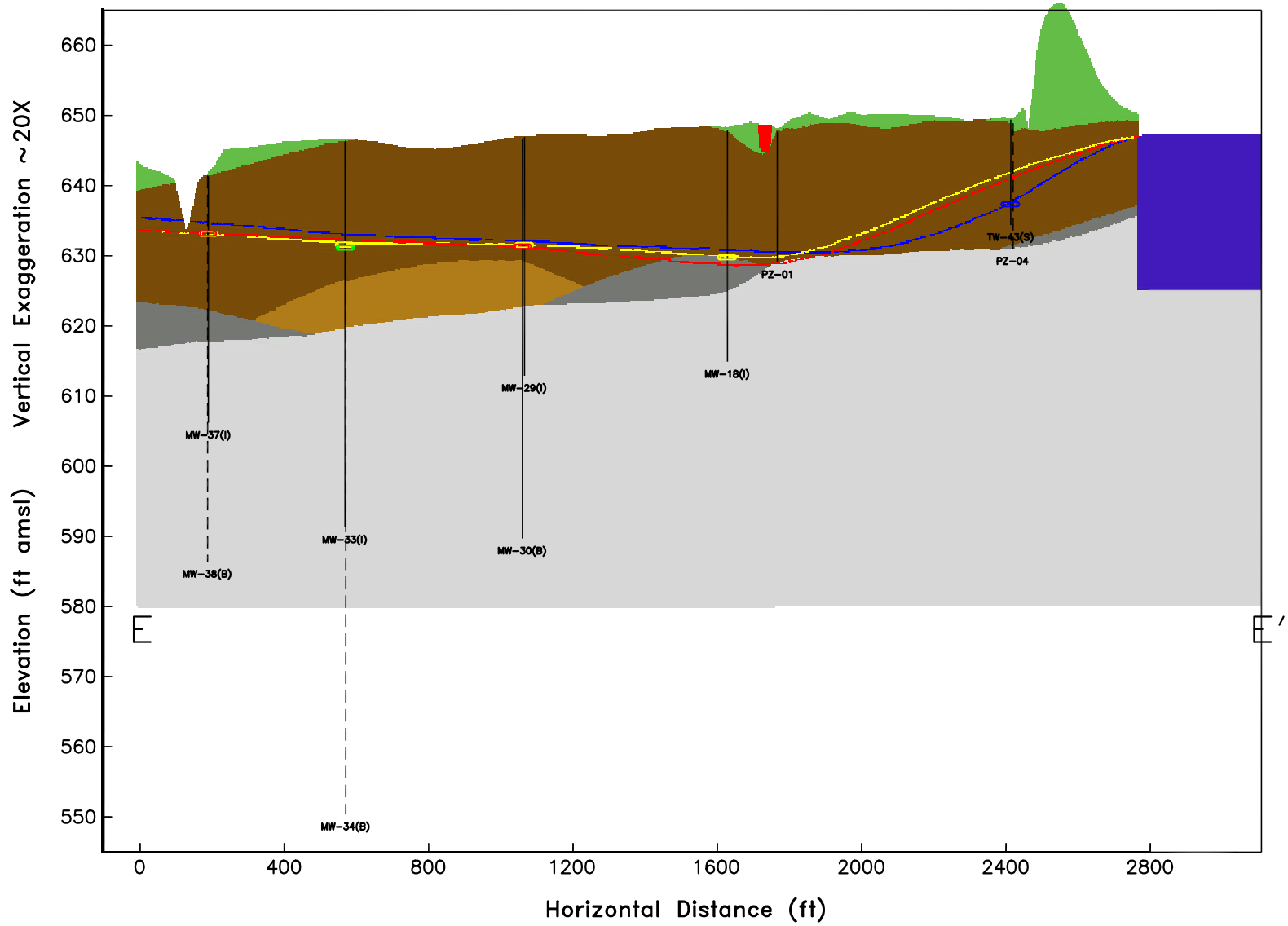


Groundwater Elevation in Shallow Well
Groundwater Elevation in Intermediate Well
Groundwater Elevation in Deep Well
Groundwater Elevation in Very Deep Well

Shallow Groundwater Potentiometric Surface
Intermediate Groundwater Potentiometric Surface
Deep Groundwater Potentiometric Surface

Fill
Silty Clay
Silt
Sndy/Gravelly Silt

Clay
Bedrock
Quarry Water
Trench

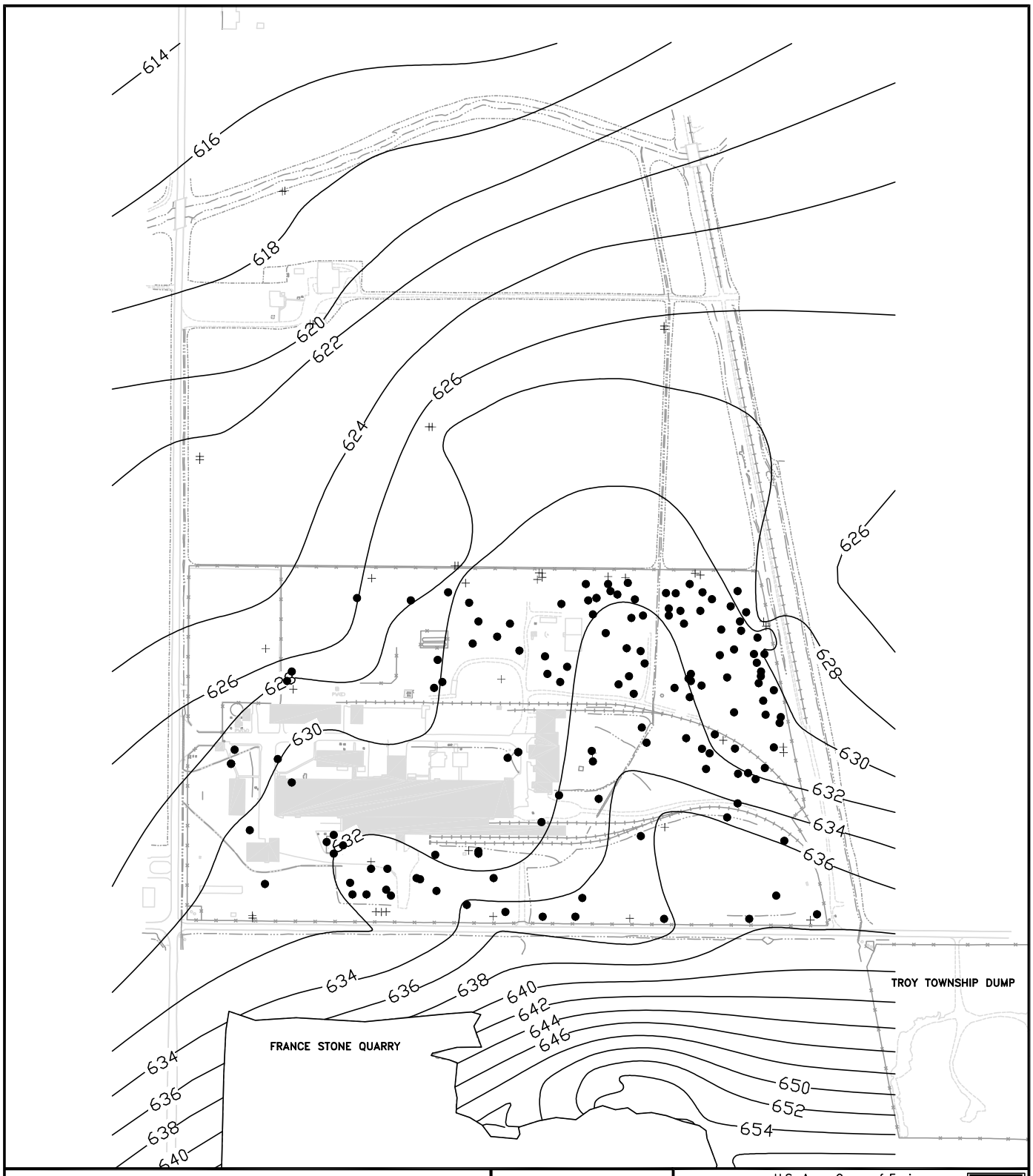
U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Cross-Section E-E'

Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	02-01-00	AS SHOWN	04-1748-801	2.10



BUILDINGS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE
WELL / PIEZOMETER LOCATION
SOIL BORING LOCATION
N True North

In addition to survey data from well piezometer and soil boring locations shown, data from residential wells constructed near the site also were used.

0 200 400 FEET

0 60 120 METERS

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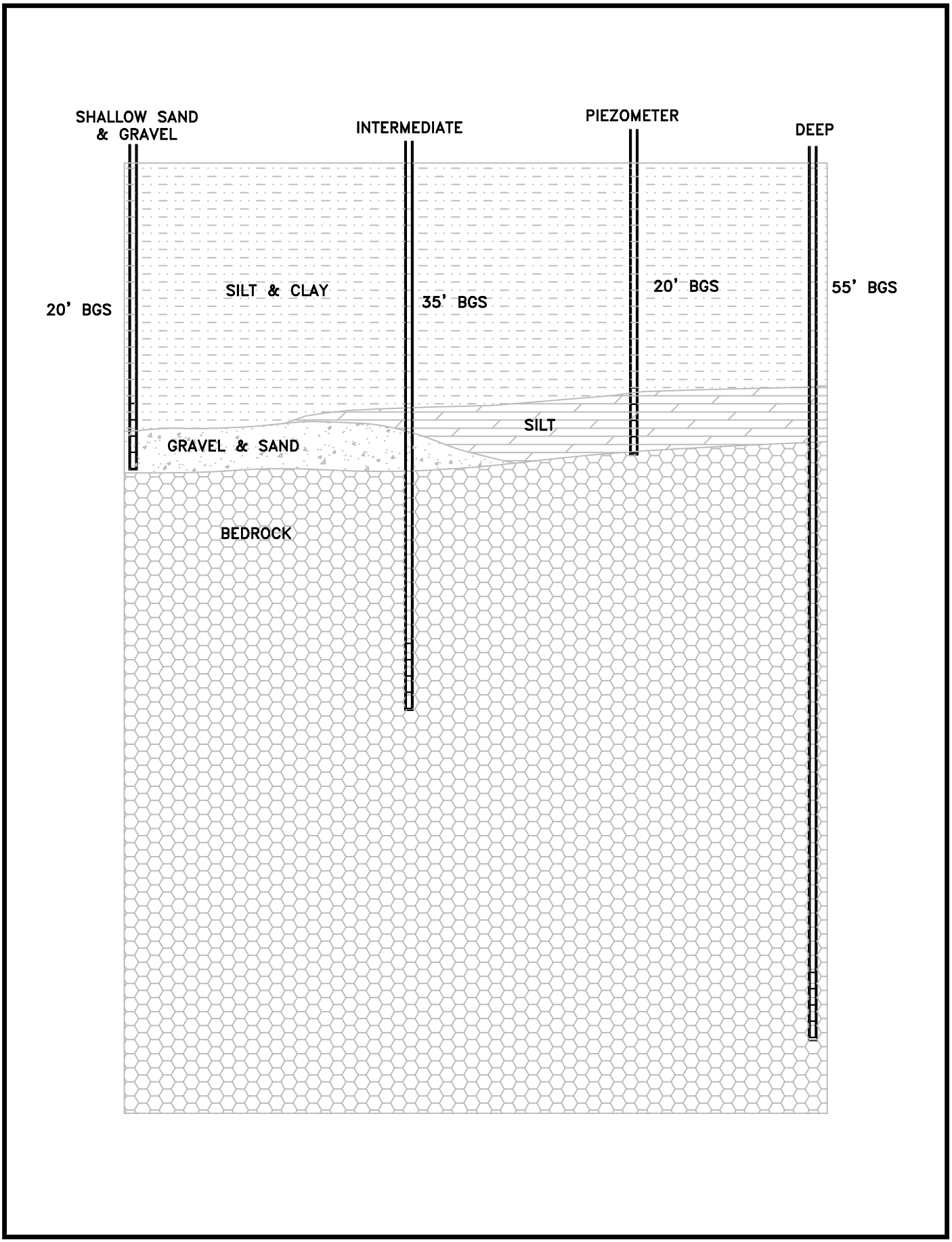
LUCKEY SITE
RI REPORT

Site-Specific Bedrock Surface Contours

Science Applications International Corporation — Columbus, Ohio

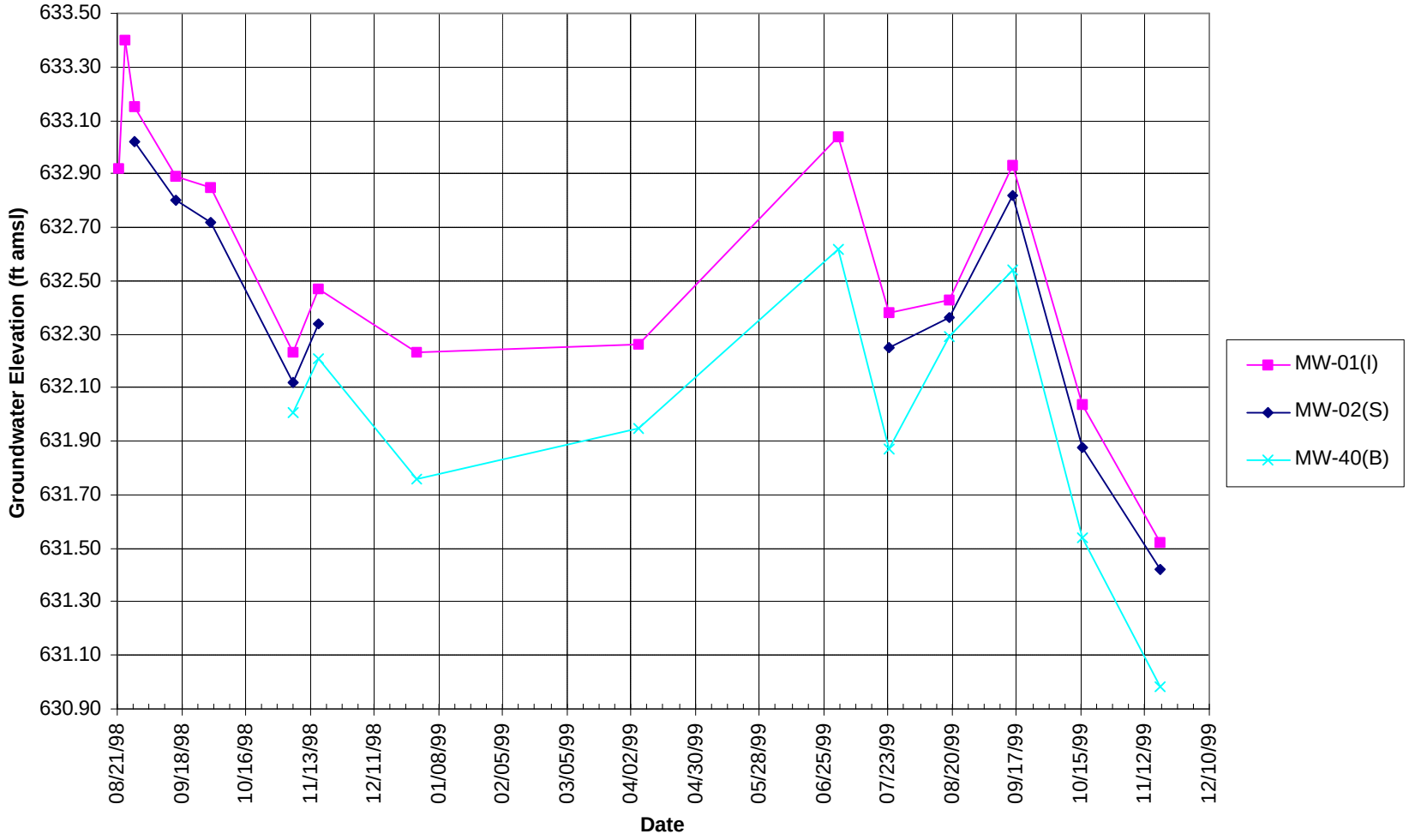
DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	02-04-00	AS SHOWN	04-1748-801	2.11

NAME: S:\LUCKEY\C041748\801\RIRPT_BEDROCK-CONTOURS.DWG DATE: APR 13, 2000 TIME: 8:31 AM PCP: S:\PCP\GREY1.PCP



U:\3D\Luckey\RIReport\RIReportFigures\Depthofwells.pdf

Figure 2.12 Schematic of Well Depths on the Luckey Site



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LUCKEY SITE
RI REPORT

Periodic Data
MW-01(I), MW-02(S), and MW-40(B)

Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	DRAWING NO.
BJW	01-19-00	AS SHOWN	04-1748-801	2.13

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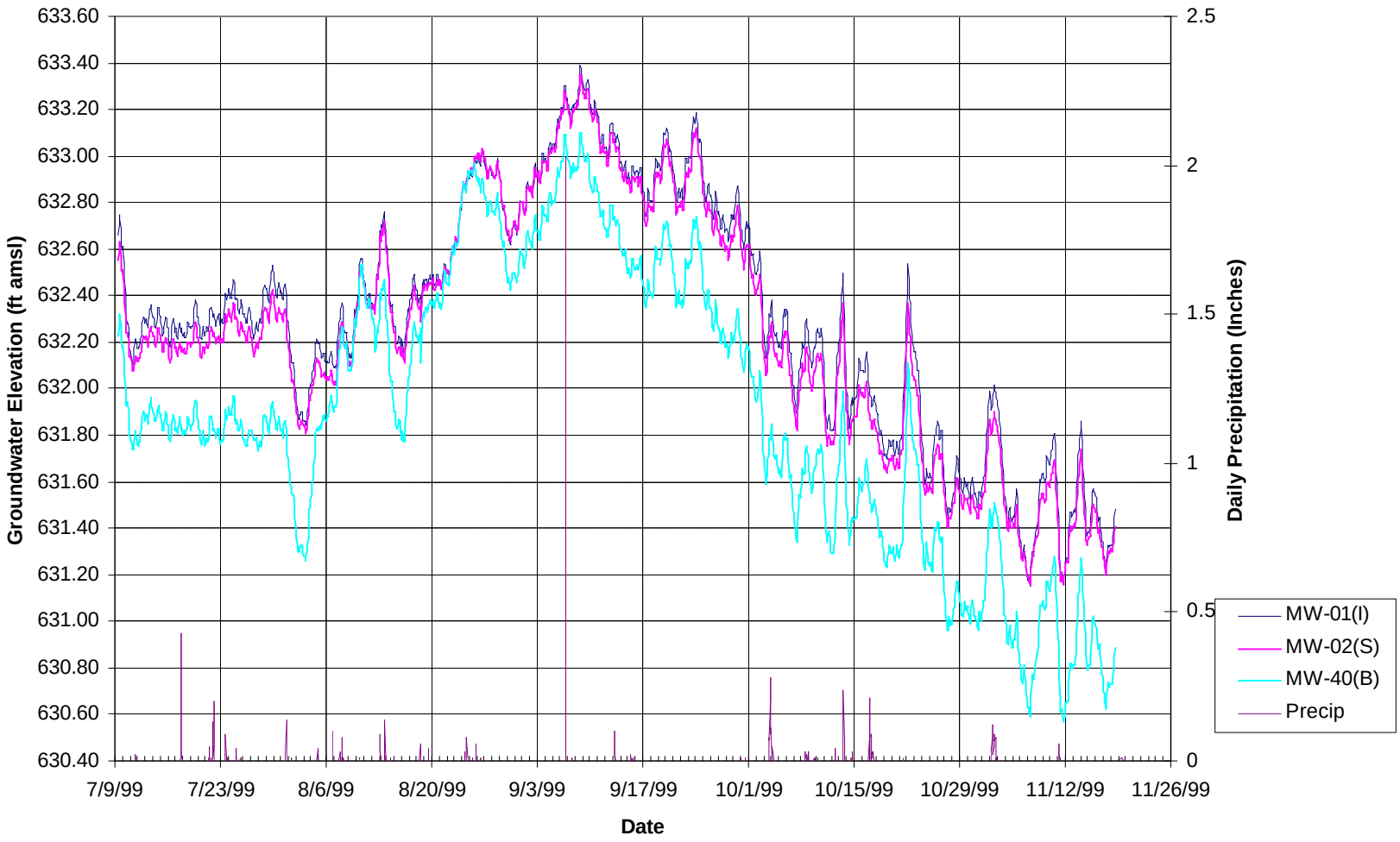

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LUCKEY SITE
RI REPORT

Continuous Data
MW-01(I), MW-02(S), and MW-40(B)

Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	DRAWING NO.
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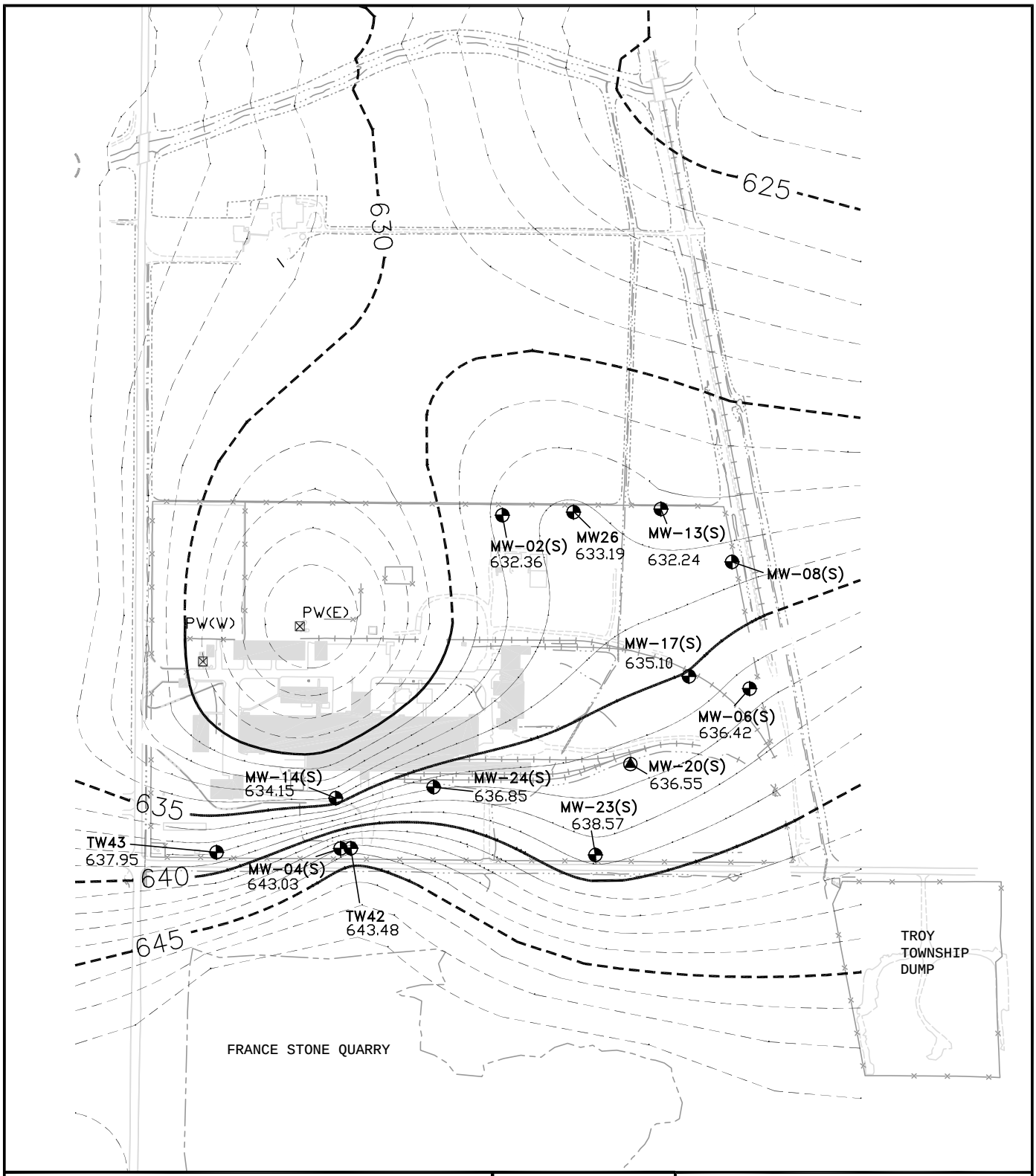

BUILDINGS
LOW-LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE
GROUNDWATER CONTOUR
ESTIMATED GROUNDWATER CONTOURS

Shallow wells predrilled to approximately 20ft bgs with the bottom of the screened interval roughly 1 to 2ft above top of bedrock.

N True North

0 200 400 FEET

0 60 120 METERS

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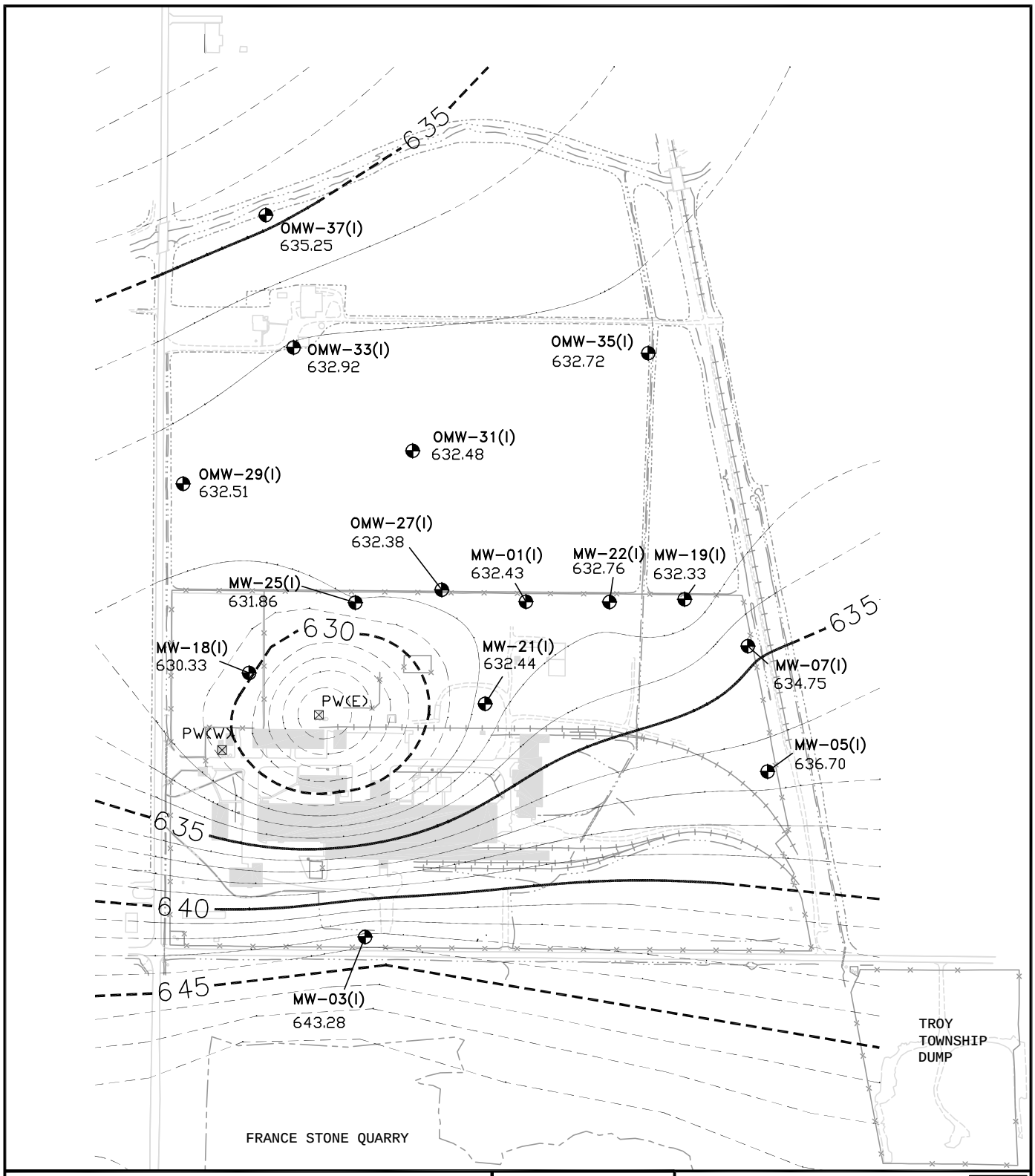
LUCKEY SITE
RI REPORT

Groundwater Contours for Shallow Wells
Data Collected 18 August 1999

SAIC. Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	02-05-00	AS SHOWN	04-1748-801	2.15

NAME: S:\LUCKEY\C041748\801\RIRPT_GROUNDH2O-CONT-SHALLOW.DWG DATE: APR 17, 2000 TIME: 4:27 PM PCP: S:\PCP\GREY1.PCP



BUILDINGS
LOW-LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE
GROUNDWATER CONTOUR
ESTIMATED GROUNDWATER CONTOURS

Intermediate wells are drilled to approximately 30ft bgs and screened in the top 10ft of bedrock.

N True North

0 200 400 FEET

0 60 120 METERS

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LUCKEY SITE
RI REPORT

Groundwater Contours for Intermediate Wells
Data Collected 18 August 1999

SAIC. Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	02-05-00	AS SHOWN	04-1748-801	2.16

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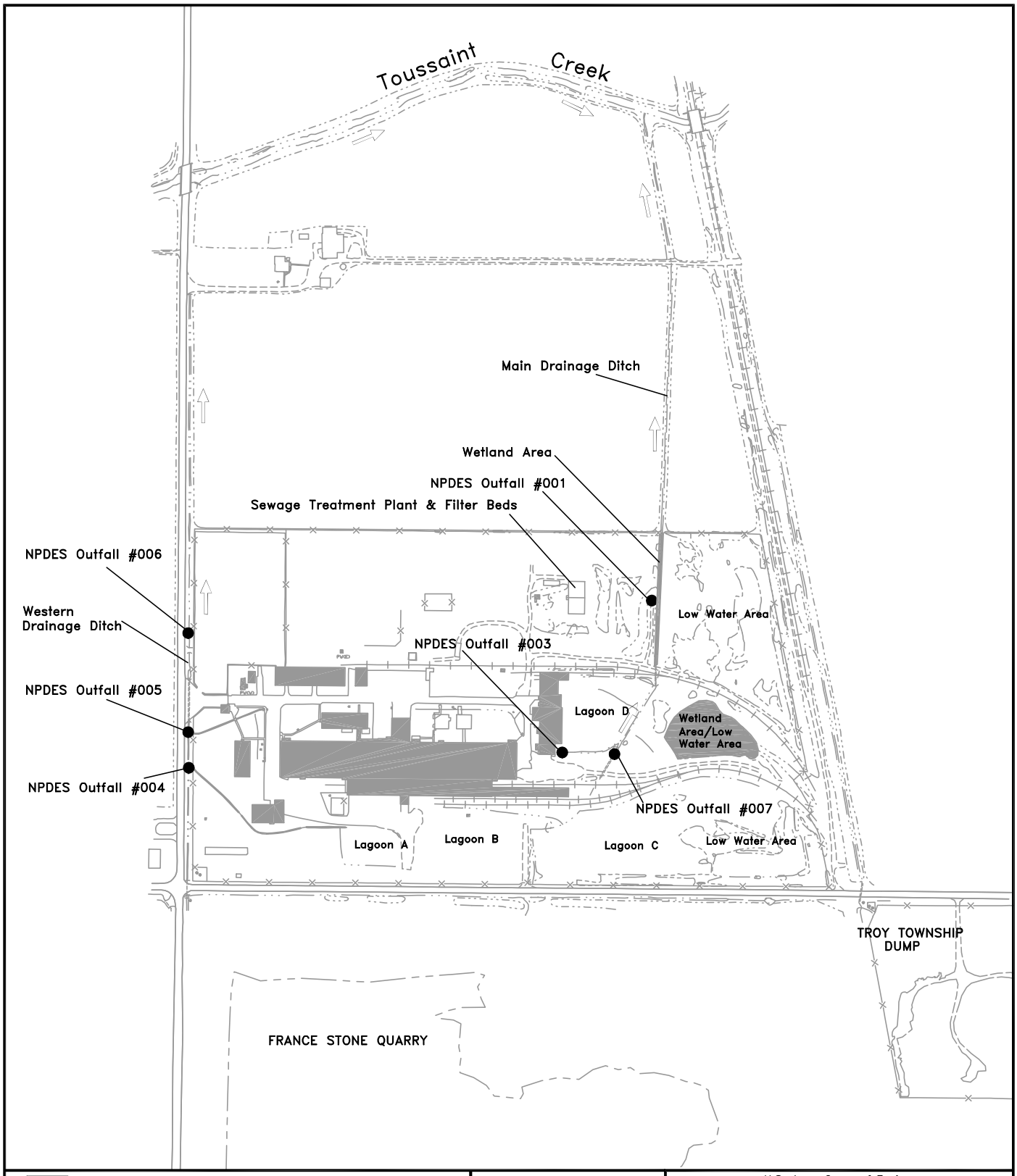

BUILDINGS
LOW-LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE
DIRECTION OF FLOW IN DITCHES AND STREAMS

N True North

0 394 FEET

0 60 120 METERS

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LUCKEY SITE
RI REPORT

Surface Drainage Features

SAIC. Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	02/10/00	AS SHOWN	04-1748-801	2.17

Figure 2.18. Toussaint Creek Upstream of the Luckey Site at Luckey Road

Figure 2.19. Toussaint Creek Downstream of the Luckey Site at LeMoyne Road

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3.0 REMEDIAL INVESTIGATION ACTIVITIES

The efforts and results of two major studies have been combined to form a comprehensive RI of the Luckey site. This section describes the field sampling and analytical programs that were implemented to gather data on site characteristics and conditions in support of the RI. The primary objective of the investigation is to collect data of sufficient quantity and quality to evaluate the risk posed by current site conditions to human health and the surrounding environment. In the event that an unacceptable risk is calculated for the site, the data must be adequate to support an assessment of alternative actions.

Achieving these objectives required that representative samples of various site environmental media, including groundwater, surface water, sediment, soil, dust, and air, be collected across the entire site. Samples also were collected from off-site areas in order to assess the potential environmental impact from past operational practices or the migration of site contaminants. The on-site and off-site environmental media were evaluated using a combination of systematic and biased sampling strategies depending on the specific objectives and data quality requirements. The investigative elements described in this section were designed to fulfill the DQOs presented in the RI Work Plan and to address information needs identified by previous site investigations.

The RI activities were conducted in accordance with several site-specific guidance documents, including:

- *Final Sampling and Analysis Plan for the Luckey Site* (SAIC 1997),
- *Public Review Draft Remedial Investigation/Feasibility Study Work Plan for the Luckey Site at Luckey, Ohio* (SAIC 1998a),
- *Sampling and Analysis Plan for Remedial Investigation at the Luckey Site* (SAIC 1998b), and
- *Sampling and Analysis Plan Addendum for the Remedial Investigation at the Luckey Site* (SAIC 1999c).

The Phase II field sampling activities were conducted using standard field procedures, which were developed specifically for the FUSRAP program. These procedures are listed in the Phase II SAP (SAIC 1997). Additional standard field procedures were developed for the Phase IV sampling event and are referenced in the following sections of this report. The actual procedures are presented in Appendix B of the Phase IV SAP (SAIC 1998b). Both sets of field procedures were reviewed by Ohio EPA, and comments were addressed before fieldwork commenced. These field procedures have not been reproduced in this document; however, supplemental information and any deviations have been noted where appropriate. Adherence to these procedures ensured that all samples were collected in a consistent manner and were representative of site conditions. Furthermore, consistency in the sample collection procedures improved the comparability of the analytical results.

As a part of the planning for the Phase II investigation, technical personnel divided the comprehensive study area into IAs. Each IA represented a portion of the site to be addressed as an independent study area. The following areas were used in Phase II to group data collection activities (Figure 2.1):

- IA01: disposal area;
- IA02: Lagoons A, B, and C;
- IA03: Lagoon D (included railroad sidings);
- IA04: buildings (interior and exterior);
- IA05: filter bed area;
- IA06: drainage ditches, storm sewers, and Toussaint Creek;
- IA07: northwest portion of site (includes propane tanks, filled ditches, and baseball diamond);

- IA08: western portion of site;
- IA09: site-wide Groundwater;
- IA10: off-site areas (adjacent properties, France Stone Quarry, Troy Township Dump, and floodplains); and
- BKG: background locations.

These same IAs were used to organize Phase IV sampling activities. For nature and extent and risk discussion purposes, these areas have been rearranged into units based on environmental media (on-site and off-site soils, groundwater, surface water, sediment, and buildings).

The remainder of Section 3 provides detailed discussions on the specific RI activities that were accomplished in order to acquire the data necessary to make risk-based decisions and guide the future environmental management of the site. For ease of discussion, this section has been divided into the following subsections:

- on-site investigation activities,
- off-site investigation activities,
- background concentrations in environmental media,
- laboratory testing and analyses, and
- data evaluation process.

The objectives, rationale, and collection methods associated with the field sampling activities are presented for each of the on-site, off-site, and background sampling programs. The respective media-specific sample locations are shown on site-wide maps. An overview of the project DQOs and details of the laboratory testing program is provided. In addition, the validation procedures and data quality assessment (DQA) for the laboratory analyses are discussed. The last subsection presents the data evaluation process, which includes the identification of background values and a comparison of the data to background and established regulatory guidance levels. Analytical results and their implications, such as the nature and extent of potential contaminants, are discussed in Section 4.

3.1 SUMMARY OF ON-SITE INVESTIGATION ACTIVITIES

Investigative activities performed on the Luckey site were concerned with identifying potential source areas, testing the various environmental media to determine if they have been impacted by past operations, delineating the extent of the impacted areas, and determining if the site-related contaminants have migrated off site. The testing of all environmental media, as well as certain building materials, was required to fully address these concerns. This was accomplished by implementing a comprehensive sampling and analysis program consisting of the following:

- general survey methods,
- surface and subsurface soil sampling,
- monitoring well installation and groundwater sampling,
- surface water and sediment sampling,
- ambient air monitoring, and
- building surveys.

A discussion of each of these work elements is provided below.

3.1.1 General Survey Methods

Several survey methods were employed as reconnaissance tools to identify the distribution of contaminants across the site and locate areas in which to focus the intrusive sampling effort. Levels of detectable radioactivity were mapped using portable gamma detection equipment in walkover surveys. Concentrations of beryllium in the shallow soils were mapped using laser spectroscopy methods and portable as well as field laboratory equipment. These two surveys were semi-quantitative in the sense that they revealed widespread areas or hotspots of relatively elevated concentrations or levels of activity. Geophysical surveys were conducted primarily to locate subsurface features such as waste disposal trenches or buried metallic objects. In addition, the geophysical surveys were used to identify buried underground utilities, underground storage tanks, and remnant foundations of former buildings, in order to optimize the placement of soil borings. The areas defined by these methods were used to select soil sample locations that will support risk analyses of the site contaminants.

3.1.1.1 <u>Gamma Walkover Surveys</u>

Radiological walkover surveys were performed over the Luckey site, including paved areas, to identify and delineate locations of elevated radioactivity. The surveys were designed to show the areal distribution of elevated radioactivity across the surface of the site and detect target objects as small as two square meters. The surveys were non-intrusive and were unable to provide information on subsurface conditions. However, hotspots detected by the surveys were used to pinpoint areas for further investigation or collect confirmatory environmental samples (BNI 1998).

Two types of radiological instruments were used to conduct the surveys. A Bicron field instrument for detecting low-energy radiation (FIDLER) equipped with a 5-inch diameter sodium iodide crystal was used to detect low-energy gamma radiation. High-energy gamma radiation was detected using an Eberline SPA-3 equipped with a 2-inch by 2-inch sodium iodide crystal. As gamma activity data were recorded in the field, the station locations were determined and recorded using Global Positioning System (GPS) receivers. All data were electronically recorded in the field and downloaded to a computer to produce graphic presentations of the results.

Calibration of the FIDLER and SPA-3 instruments was checked daily before and after usage. After completing the initial daily calibration check, a walkover survey was performed over a 15-m by 15-m grid to test the equipment and to compensate for changing environmental conditions, such as soil moisture. The calibration check grid was located in an uncontaminated area at the northwest corner of the site. The same grid was used each day for this calibration test. The activity readings in the area of the calibration check grid were comparable to those taken in the background areas.

The site was divided into approximately fifty-two 50-m by 50-m grids, excluding areas that could not be walked over, such as buildings and rubble piles. Each grid was then subdivided into 25 transects that were spaced 2 m apart. Each transect was walked over at a rate of 1 m every two seconds while the survey instrument was moved from side to side. Surveying along transects in this manner covered about a 1-meter swath with each stride and provided approximately 50% coverage of each grid.

Data generated from both the FIDLER and the SPA-3 were recorded on their respective GPS data loggers. Twice daily the data were transferred from the data loggers to a computer for processing and storage. Data processing involved computing a location-correction factor and then linking the location data to values for the FIDLER and SPA-3 data. The data processing yielded gamma activity values with corresponding X and Y location coordinates, which were then compiled into high-resolution maps using graphic visualization software. Site-wide maps of the low-level and high-level gamma activity were created to identify and delineate boundaries of surface contamination. The maps were used as a guide to

direct the efforts of a more intensive environmental sampling program (Figures 3.1 and 3.2) (BNI 1998). Background for each survey was measured at the background locations established for the site (Figure 3.13). The average background established for the FIDLER survey was 10,234 counts per minute (cpm). Because the SPA data had to be normalized [as explained in the Phase II report (BNI 1998)] the measured background cannot be directly compared to the site values.

3.1.1.2 Laser Induced Breakdown Spectroscopy (LIBS) Surveys

A systematic survey using a LIBS probe was performed over the entire site to identify the boundaries of beryllium contamination in the surface soils. Multiple readings were taken at each sampling location to determine the average concentration at that location. Surface soil samples were taken at selected LIBS sampling locations to correlate LIBS results to soil beryllium concentrations. The LIBS technology is a semi-quantitative tool that can be used to determine approximate or relative levels of contamination and to make field decisions for selecting samples to submit for more definitive laboratory analyses. It does not replace the need for laboratory analyses.

Two types of LIBS units were used to determine surface beryllium concentrations across the site. Both LIBS units determine beryllium concentrations in soil using induced laser emissions to excite atoms of beryllium present in the soil matrix. As they return to their rest state, the excited beryllium atoms emit a quantity of light that is measured and recorded by the instrument. A mobile backpack unit was used to produce a non-intrusive direct reading of beryllium concentration in the soil. The backpack unit consisted of a pulsed laser mounted in the lower portion of a hand-held probe. The probe also housed an optical lens system to focus the laser beam at the surface of the soil. The laser induces the beryllium atoms to produce an emission of light, which is detected and recorded by a spectrometer contained in the unit.

The second instrument used for the LIBS survey was a Transportable Remote Analyzer for Characterization and Environmental Remediation unit, or TRACER unit. A field laboratory was established to house the TRACER instrument, and a portion of the laboratory was dedicated to sample preparation. The TRACER system used a significantly more powerful laser and a higher resolution spectrometer than the backpack. Because it operates over a broader range of sample concentrations, it was used to analyze a sample if the concentration fell outside the reliable operating range of the backpack. Unlike the backpack unit that evaluated soil in-situ (in place), the TRACER system required that a sample of soil be extracted from the ground and placed in a glass vial before being inserted into the unit for analysis.

Based on replicate studies of Luckey background soil that was spiked with a trace level standard of beryllium nitrate, the backpack unit had an instrument detection limit (IDL) of 50 ppm, whereas that of the TRACER unit was 20 ppm. The Practical Quantitation Limits of the instruments were approximately three times their IDLs, or 150 ppm and 60 ppm, respectively.

A total of 558 survey points were analyzed using the backpack system, and 786 samples were analyzed using the TRACER unit. The resultant data were used to generate a contour map of surface beryllium concentrations across the site (Figure 3.3) (BNI 1998). The distribution of beryllium indicated on the map was an important factor in locating intrusive samples to better define the extent of contamination in the site soils.

3.1.1.3 Geophysical Surveys

Geophysical investigations were employed at the Luckey site as an integral part of the RI. The surveys were conducted using several complementary geophysical methods: electromagnetic, magnetic, ground penetrating radar (GPR), and line tracing. The objectives of the surveys were to locate areas of

potential contamination and identify relevant subsurface features. The principal targets included buried waste disposal trenches and buried scrap metal. Secondary targets included subsurface utilities, underground storage tanks, and a septic tank. Approximately 15 acres of the site were investigated using geophysics. Specific objectives of the surveys included:

- defining the perimeter of the fill areas;
- locating buried drums and scrap metal;
- estimating the depth of disturbed soils; and
- identifying underground utilities or obstructions before locating soil borings.

A Geonics EM-31 electromagnetic survey instrument was used to measure contrasts in electromagnetic conductivity within the ground. The variations in electromagnetic conductivity can be caused by zones of disturbed soil, increased moisture content, and buried metallic and non-metallic objects (e.g., concrete). When detected in the subsurface, these features may represent likely source areas of contamination. The EM-31 is a frequency-domain instrument that uses a transmitter coil to produce a primary magnetic field and induce an electric current into the ground. A secondary magnetic field is generated within the ground that can be measured by a receiver coil on the instrument. The ratio of the strength of the secondary to primary magnetic fields is directly proportional to the ground conductivity. The effective depth of investigation can be adjusted from about 3 m to about 6 m, depending on how the instrument is physically oriented.

A Geonics EM-61 electromagnetic survey instrument was used to locate buried metallic objects. The EM-61 is a high-resolution time-domain metal detector consisting of a powerful transmitter coil that generates a pulsed primary magnetic field, which induces eddy currents in nearby metallic objects in the ground. Two horizontal receiver coils spaced 16-inches apart measure the secondary field generated by the decay of these eddy currents. The relative response from the two coils allows an estimate of the depth of a detected object. The measured response is independent of the electrical conductivity of the ground. The EM-61 is capable of detecting a single 55-gallon drum at a depth greater than 10 ft, yet it is relatively insensitive to interference from nearby surface metal, such as fences, buildings, or cars. The instrument is also relatively insensitive to overhead power lines. Due to the horizontal coil arrangement, the response curve of the instrument peaks directly above the metal object, simplifying the determination of the object's location.

Magnetic survey methods are capable of detecting measurable changes in the earth's magnetic field caused by ferromagnetic bodies, such as metal drums, tanks, or accumulations of ferrous metal. Several historic site drawings indicate that there were two steel 30,000-gallon fuel oil tanks buried just south of the fenced propane tank compound near the center of the property. If present, these tanks would produce a significant magnetic anomaly compared to the surrounding undisturbed soils. A brief magnetic survey was conducted over a limited portion of the site to test for the presence of these two tanks. The survey, performed using a Geometrics G-858 magnetometer, required only 1½ hours to obtain sufficient measurements to determine the tanks were no longer buried underground.

The resultant data from the EM-31, EM-61, and magnetic geophysical surveys were compiled into a series of maps. A composite EM-31 survey map was prepared for the entire site, and more detailed maps of the different survey results were prepared for individual investigative areas. In addition, some of the EM-61 data were presented as vertical profiles along selected traverse lines to show the depth and magnitude of various subsurface anomalies. All of these maps are presented in Section 3 of the Phase II Characterization Report (BNI 1998).

A limited geophysical survey was performed prior to conducting any intrusive sampling activities at several sites where structures previously existed. According to historical records, there were three

structures at the former Brush Beryllium facility used for the storage or handling of petroleum products. These structures included a Transformer Room, an Oil House, and a Pump House. None of these structures currently exists, and there is no indication of their former locations on the present ground surface. They were constructed with the rest of the buildings in the early 1940's but the duration of their use is unknown. The objective of the surveys was to locate active or abandoned utility lines, remnant foundations, and underground piping that may have been left in-place after the former structures were razed. Due to the nature of these limited surveys, no elaborate grid system was established, and no maps of the resultant data were produced.

The geophysical surveys conducted at these sites consisted of electromagnetic EM-61 and GPR. The EM-61 was operated in the wheel mode and collected a data point at every 0.643 ft of line distance. The GPR unit was a Geophysical Survey Systems, Inc. model SIR-2 with a 500-megahertz antenna. The GPR collected a continuous data set along a survey line. During collection of the GPR data, distance markers were placed in the record allowing the operator to reestablish a position along the survey line when necessary.

At the former Oil House, located just west of the Main Office Building, four potential borehole sites were staked in the field. For each of the borings, a 15-ft by 15-ft bi-directional survey grid was measured and marked with spray paint. EM-61 and GPR data were collected along traverses spaced 5 ft apart in two directions, north to south and east to west. At the eastern boring, a buried building foundation was detected by the GPR, and the boring location was moved approximately 5 ft to the southeast. Four prospective boreholes were staked around the former Pump House. Because this area was more open, a 65-ft (north-south) by 50-ft (east-west) grid encompassing the entire footprint of the former building was measured and marked with spray paint. EM-61 and GPR data were collected along traverses spaced 5 ft apart in both directions at this site. At the former Transformer Room, a 10-ft by 10-ft bi-directional grid was established at each prospective borehole. EM-61 and GPR data were collected along two north-south and two east-west traverses, each spaced 5 ft apart.

In addition to the EM-61 and GPR surveys, each grid was screened with three different line-locator instruments, a Metrotech 810, a RadioDetection RD400, and a Metrotech 50/60-megahertz locator. The 810 and RD400 units are utility locators used to detect the presence of underground pipes and utilities. The 50/60 unit was used to scan for active underground electrical lines. Any utilities detected by these locators were marked on the ground surface with spray paint, and an estimated depth to the top of the utility was painted next to the mark.

3.1.2 Surface and Subsurface Soil Sampling

3.1.2.1 Phase II Soil Sampling

Although no formal program for an intensive soil sampling effort existed in the Phase II RI field investigation, a limited number of samples were collected for several reasons. Samples of surface soil were collected on site to confirm the results of the LIBS and gamma walkover surveys, and a few surface and subsurface samples were obtained from waste disposal features to help refine the list of potential site contaminants. Additional samples were collected to quantify results of the radiological walkover surveys.

LIBS Confirmatory Sampling

In order to determine the accuracy of the LIBS survey, surface soil samples were collected from 50 of the LIBS survey points and analyzed by an off-site laboratory (Table 3.1, Figure 3.4). The laboratory results then were compared to the LIBS survey results to develop a correlation between the field and laboratory data. These correlation samples were analyzed for beryllium, after being prepared

using a standard digestion method and an "aggressive" digestion method. The two sets of data (standard and aggressive) also provided information on beryllium solubility issues.

Radiological Correlation Sampling

Discrete surface soil samples were collected at 40 locations across the Luckey site and were analyzed by DOE-approved laboratories for the following radionuclides (Table 3.1, Figure 3.4):

Actinium-227	Ra-226 & daughters
Americium-241	Th-230
Cesium-137	Th-232 & daughters
Potassium-40	U-235
Protactinium-231	U-238

Sampling locations were selected following completion of the gamma walkover surveys to insure that they were representative of the full range of activity levels reported by the walkover instrumentation. In most cases, the sampling locations were positioned along transects that started in areas of elevated radioactivity and terminated in areas at or near background levels. The soil samples were collected from zero to ½ ft using hand augers.

Real-time in-situ gamma-ray spectroscopy (ISGS) analyses also were performed at 29 locations (Table 3.1). ISGS analyses provide isotope-specific quantitative data that are comparable in quality to laboratory analyses over a wide range of activity levels. The primary objective of the ISGS was to provide real-time isotopic data to establish a relationship between the gamma walkover results and actual radionuclide activity levels. The ISGS results were compared to the discrete sample laboratory analytical results to evaluate the correlation of the two analytical techniques.

The ISGS analyses were conducted using a portable Canberra high purity germanium (HPGe) Inspector system. Uncollimated (unrestricted field of view (FOV)) measurements were made at 27 of the 29 locations, while collimated (restricted field of view) measurements with different FOVs were made at 20 locations. The collimated measurements were obtained for FOV areas of 25, 50, 75, and 157 square meters (m^2). A FOV of 25-m^2 was used to provide isotopic analyses of the smaller hotspots identified by the gamma walkover survey. The larger FOVs were used to evaluate larger hotspots and, when combined with multiple FOV measurements, to estimate the size of the hotspot. A description of the ISGS procedures, the measurement results, and evaluation of the data are presented in Appendix G of the Phase II Characterization Report (BNI 1998).

Supplemental COPC Sampling

An initial listing of contaminants related to AEC activities at the Luckey facility was established before startup of the RI. This list was based on knowledge of past processing operations, waste disposal practices, and previous limited sampling by ORNL (1990). Previous sampling focused primarily on beryllium and radiological contamination over a relatively restricted area. In order to develop a preliminary list of COPCs, a limited amount of additional soil sampling was included in the Phase II RI SAP. This sampling effort was not intended to define the vertical extent of contamination, but the results can be used to help delineate the extent.

Soil samples were collected in areas where contamination was known or suspected to exist based on previous investigations, site history, surface contamination identified by the walkover surveys, or indications of subsurface burial sites detected by the geophysical surveys. Site features specifically targeted by the COPC sampling included waste disposal trenches, scrap metal burial pits, lagoons, debris

piles, and general areas with significantly elevated levels of beryllium or radiological activity in the surface soils. The samples were obtained at the depth interval of known or suspected contamination in order to identify the widest possible array of contaminants and perhaps the highest concentrations. Sampling was not performed in the vicinity of the buildings or on the western side of the property because minimal contamination was detected by the reconnaissance surveys in those areas.

The results of the radiological and beryllium walkover surveys were used to select the prospective COPC sampling sites. Twenty-one soil sampling locations were established, as listed in Table 3.2 and shown in Figure 3.4. Four surface soil samples and 25 subsurface soil samples (including two duplicates) were collected at the 21 locations in October 1997. The samples were collected in accordance with the FUSRAP standard field operating procedures outlined in the Phase II SAP (SAIC 1997). In general, the surface soil samples were collected from a depth of zero to ½ ft using stainless steel trowels, while the subsurface samples were collected at various depths using stainless steel hand augers.

The COPC samples were analyzed for both radiological and chemical parameters. Radiological parameters included gamma spectroscopy, radium, isotopic thorium, and isotopic uranium. Chemical parameters included metals, beryllium by "aggressive" digestion, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), anions, and pH. The anions included chloride, fluoride, nitrate, phosphate, and sulfate. Soil moisture content was recorded for all samples and soil temperature was recorded for samples analyzed for pH. Not all analyses were performed for each sample. For instance, surface samples were not analyzed for VOCs, and only selected samples were analyzed for beryllium using both digestion methods. Table 3.2 lists the specific parameters analyzed for each of the soil samples.

3.1.2.2 Phase IV Soil Sampling

Based on results of the Phase II field sampling activities, much of the northeastern portion of the site, as well as isolated areas in the northern and southern portions, were shown to be impacted by beryllium and radiological contaminants. As a result, a more intensive sampling scheme was devised to further define the nature and extent of contamination and calculate the associated risk to human health and the environment. In response to these findings, a SAP was developed (SAIC 1998b), outlining a biased sampling technique for acquiring additional intrusive soil samples.

The biased soil sampling program was implemented to meet the following primary objectives:

- define the horizontal boundaries of impacted areas,
- define the vertical boundaries of impacted areas,
- provide data on concentrations of chemical and radiological COPCs for risk assessment; and
- determine whether soil contaminants are present as mixed waste.

Three types of soil samples were collected to meet these objectives: samples to determine risk, samples to define the nature and extent of contamination, and screening samples. In general, risk samples were analyzed for radioactivity and a wide range of chemical parameters, while the nature and extent samples were analyzed for AEC-related COPCs. Selected screening samples from many soil borings were analyzed for beryllium by the laboratory with rapid turnaround time for reporting the results (within 24 to 48 hours). The screening results were used in the field to determine if the soil borings and samples (installed as planned) adequately defined the extent of contamination at a certain feature. If they did not, then additional borings were installed until the sampling sufficiently characterized the contaminant boundary.

Several sampling protocols for sampling the boreholes were developed, depending on whether the borings were installed to determine risk or nature and extent. Typically, one or more risk borings were drilled into each target feature. A risk sample was collected from a 1-ft interval at the depth where the highest level of contamination was expected in the target feature. This interval was selected based on organic vapor field screening values, radiological field screening values, visual contamination or staining, and olfactory sensing. If none of these techniques were successful in identifying contaminated zones, then the risk sample was collected from the approximate center of the feature. Risk samples were analyzed for target analyte list (TAL) metals, radionuclides, VOCs, SVOCs, fluoride, and ammonia. In addition, samples collected from every other 1-ft interval in the risk borings were screened in the field for radiological activity and sent to the laboratory for beryllium analysis.

Additional borings were installed to collect samples to determine nature and extent i.e., define the maximum depth of contamination as well as the maximum level of contaminants. Within major target features such as trenches and pits, four laboratory samples per boring were collected to determine nature and vertical extent. The samples were collected in 1-ft intervals and generally came from depths of 1 to 2 ft, the middle of the target feature, the bottom 1-ft of the feature, and from 1 to 2 ft beneath the feature in native soil. In addition, boreholes were drilled outside of target features to determine the lateral extent of contamination. In these borings, laboratory samples were collected at the same depths as the samples taken from the middle and bottom of the adjacent feature. Soil samples collected from each 1-ft interval in the nature and extent borings were screened in the field for radiological activity. All nature and extent laboratory samples were analyzed for arsenic, barium, beryllium, lead, radionuclides, fluoride, and ammonia.

Soil borings were placed in and around previously identified target features such as waste disposal trenches, scrap metal pits, lagoons, debris piles, areas of stressed vegetation, and general areas with elevated levels of beryllium and/or radioactivity. The locations of these borings are shown in Figure 3.4. The soil borings were installed using a combination of rotosonic, hollow-stem auger, and Geoprobe direct-push drilling techniques, depending on the sample volume required and site accessibility. All borings were abandoned using either a bentonite/Portland cement grout (e.g., hollow stem auger & rotosonic boreholes) or bentonite pellets (e.g., Geoprobe boreholes).

Rotosonic drilling was accomplished with a truck-mounted Superdrill 150 drill rig. The rotosonic boreholes were drilled and cored by simultaneously advancing two lines of drill pipe, a 4-inch inside diameter inner core barrel and a 6-inch inside diameter outer drive casing. A drill bit consisting of a hardened steel ring with tungsten carbide inserts was fastened to both the inner core barrel and the outer drive casing. This allowed the core barrel and casing to be advanced as a single unit. After drilling a 10-ft interval, the outer casing was held in place within the boring while the inner core barrel was removed. A 4-inch diameter continuous core of soil or rock was extruded from the core barrel, sealed in a plastic sleeve, and laid out on a working tray for field screening, visual description, and sampling. The process was repeated by adding successive 10-ft lengths of casing and drill pipe until the bottom of the boring or desired depth was reached.

Each 2-ft section of the 10-ft long core samples was screened in the field for organic vapors and radiological activity. After retrieving a core sample small slits were made, at 2-ft intervals, in the plastic sleeve encasing the sample. The probe tip of a Photovac Micro Tip photoionization detector (PID) was inserted into the slits and the organic vapor content was recorded. Next the entire plastic sleeve was cut open, and the core was scanned with an Eberline Model E-600 Digital Survey Instrument and a SHP-380 probe. Measurements of both alpha and beta-gamma radiation were recorded for each core sample.

Hollow-stem auger drilling was accomplished using a CME 55 all-terrain rig with 4½-inch inside diameter augers. Continuous soil samples were obtained using 24 inch-long, 3-inch inside diameter

stainless steel split-spoon samplers. After the augers were advanced 2 ft, the center rod and pilot bit assembly were removed from the hollow axis of the auger column. A split-spoon sampler was then lowered to the bottom of the borehole, and the sampler was driven ahead of the augers to the desired sample depth using a 140-pound hydraulic hammer. For some boreholes, the sampler was advanced using the drill rig hydraulics to push the sampler to the desired depth. This method was used during adverse weather conditions (rain, excessive heat) to minimize safety risks to workers that resulted from driving the sampler with the drop-hammer/cathead method. After retrieving the sampler, the center drill rod and pilot bit were re-inserted into the auger column and another 5-ft section of auger and center rod was added. This process continued until the desired depth of the boring was reached.

The split-spoon sampling was performed in accordance with Field Procedure (FP) 3.3 and American Society for Testing and Materials (ASTM) test method D1586-84. Upon opening the sampler, the soil core was screened for organic vapors and radiological activity using the same instruments employed for screening the rotosonic samples. Measurements of organic vapor content and alpha and beta-gamma radiation were recorded, samples for VOC analyses were quickly retained, and the sample was described based on visual inspection in accordance with FP4.2. After collecting sufficient sample for VOC analyses, the remaining sample portion was homogenized in a stainless steel bowl before filling containers for the rest of the sample analyses.

Several soil borings were installed using a Geoprobe Systems Model 5400 unit and direct-push sampling methods. Continuous cores were obtained in 4-ft intervals by hydraulically pressing a two-inch diameter stainless steel microcore tube through the soil. The microcore tube contained an acetate liner in which the soil core was retained. After each 4-ft interval was cored, the acetate liner was removed from the core barrel and cut open to expose the soil sample. Samples for VOC analyses were quickly retained and sealed in their respective containers. The soil core was described according to the gross composition, texture, moisture, and other observable properties, and the remaining soil samples were collected after homogenizing the sample in a stainless steel bowl.

The core samples obtained by these three drilling methods were described based on visual inspection in accordance with FP4.2. The descriptions included characteristics such as grain size, Unified Soil Classification System (USCS) criteria, color, moisture content, and other pertinent field observations. Descriptive logs of the soil borings are contained in Appendix 3A. Samples were collected from the soil borings in accordance with field procedure FP3.2, and homogenization of the soil samples was performed according to FP3.3.

Soil samples designated for VOC analyses were collected and preserved in Encore® samplers. The samples were obtained by peeling away the outer ½-inch layer from the appropriate 1-ft core interval, quickly pressing the sampler into the soil core at several places within the sample interval, and sealing the sampler with the airtight cap provided by the manufacturer. The sampler was enclosed in a re-sealable waterproof pouch, labeled, and placed on ice while awaiting processing and shipment to the laboratory. If contamination was identified, by either visual examination or field screening, in a relatively thin discrete zone within the selected sample interval, the VOC sample was collected from only that discrete zone instead of the entire 1-ft interval.

Discussions of off-site and background soil sampling are provided in Sections 3.2.2 and 3.3.1, respectively. Results of all soil sampling efforts are discussed in Section 4.1 (on-site soils) and 4.5 (off-site soils) of this report and are presented in detail in Appendix 4A.1.

3.1.3 Monitoring Well Installation and Groundwater Sampling

Prior to this RI, little information existed regarding the occurrence or quality of groundwater beneath the Luckey site. Other than the two production wells used by the Uretech facility for their operational and drinking water needs, no other water wells were known to exist on the site. Bedrock was estimated to be at depths of 20 to 40 ft bgs. Based on logs of surrounding residential wells, groundwater was known to occur within the bedrock, but it also was assumed to occur above the bedrock in the unconsolidated deposits. Many of the historical on-site waste disposal features (e.g., lagoons and trenches) were reported to have penetrated considerable depths in the subsurface soils and unconsolidated deposits. Because these features could have been in contact with or in close proximity to zones of saturation, groundwater represented a potential pathway for the off-site migration of contaminants. A program consisting of monitoring well (MW) installation and groundwater sampling was implemented to evaluate this pathway and identify potential impacts to water quality.

A total of 43 groundwater monitoring wells were installed as part of the RI of the Luckey site. Twenty-five of the monitoring wells were located within the confines of the property boundaries, 12 were located in the farm fields immediately north of the site, and six were located at three background sites. This section discusses the installation and placement rationale of the on-site wells. Discussions of the off-site and background monitoring wells are provided in Sections 3.2.3 and 3.3.2, respectively.

Twenty-five groundwater monitoring wells were installed on the site between June 19 and November 3 1998. The locations of these 25 wells are shown in Figure 3.5. Since no site-specific information existed on subsurface conditions deeper than approximately 10 ft prior to the RI, the wells were installed in several stages. An initial set of four exploratory well pairs was installed to define the subsurface conditions and locate water-bearing zones that could have been impacted by past waste disposal practices at the site. These first eight wells were designated MW-01(I) through MW-08(S) and were placed along the north, east, and south boundaries of the Luckey site. At each location, a shallow well was completed at the base of the unconsolidated deposits just above the bedrock surface, and a second well was completed at a depth of 10 ft into the bedrock. These eight wells were placed with the following objectives in mind:

- confirm depth to bedrock across the site,
- determine the direction of groundwater flow across the site,
- determine if there was a shallow groundwater zone existed above the local bedrock that was sufficient to sample,
- evaluate vertical gradients between shallow and deep zones, and
- identify the target zones for additional monitoring wells.

The eight wells were developed and sampled to obtain an initial assessment of the groundwater quality at the site. In addition, the static water levels were measured in these wells several times and preliminary groundwater contour maps were developed to establish the likely direction of groundwater flow.

Based on information gained from the installation and sampling of these initial wells, another 12 wells were located on site. The locations of these wells were selected in consultation with the Ohio EPA. Most of the wells were placed around current or historic site features that could impact groundwater quality. Such features include lagoons, trenches and pits, bare spots, debris piles, or areas of suspected contamination based on site history.

Several wells were located to better define the local groundwater flow, to test different depth intervals in the bedrock, or to evaluate the impacts of the two production wells used by the Uretech

facility. Additional rationale for the placement of the on-site monitoring wells is summarized in Table 3.3. The 12 wells were developed and groundwater samples were collected to obtain a broader view of water quality across the Luckey site.

As more water quality information was obtained and data gaps were identified, three additional on-site monitoring wells were installed in deeper bedrock zones. Two of these wells, MW-39(B) and MW-40(B), were located immediately adjacent to the MW-01(I)/MW-02(S) well pair. The need to test the deeper bedrock zones in this area was realized after beryllium was detected in water samples from both MW-01(I) and MW-02(S). Wells MW-39(B) and MW-40(B) were completed at depths of approximately 92 ft and 56 ft, respectively. The intermediate target depth of 50 to 55 ft was selected in order to determine if beryllium had migrated deeper in the bedrock aquifer. A depth of approximately 90 ft was selected as a second target zone because available well records indicate that the domestic well at the first residence immediately north of the site, as well as many of the surrounding residential wells, are completed near that depth. The third well, MW-41(B), was installed on the south side of the property and completed at a depth of 56 ft. This well, placed south of Lagoon B, served as the upgradient well for the intermediate bedrock zone.

At the request of Ohio EPA, two final wells were installed on site in relatively shallow sand units. Both of these wells, TW-42 and TW-43, were located along the south side of the site and were completed at a depth of 15 ft. The purpose of these wells was to test the thin sand units in the shallow soils that were encountered during drilling but believed to be less significant with respect to the more extensive and permeable target zone on top of the bedrock. The two wells were used to evaluate the capability of the thin sands to transmit sufficient quantities of groundwater. They were not installed for the purpose of water quality sampling.

3.1.3.1 Well Drilling Activities

The following sections describe the drilling, installation, and sampling of the on-site monitoring wells. A discussion of off-site monitoring wells is provided in Section 3.2.3. The borings for the on-site monitoring wells were drilled using rotosonic and hollow-stem auger drilling techniques. All of the bedrock borings and most of the borings for the shallow wells completed on top of the bedrock were drilled with a rotosonic rig. Several of the shallow borings were drilled with an all-terrain hollow-stem auger rig where site accessibility was a concern.

The rotosonic drilling was accomplished with either a truck-mounted Superdrill 150 or a Nodwell tracked drill rig. The rotosonic borings for the monitoring wells were drilled employing the same techniques that were used to advance the regular soil borings. Each 2-ft section of the 10-ft-long core samples was screened in the field for organic vapors and radiological activity. The coring process was continued until the anticipated well depth was reached and the continuous core sample was used to develop a descriptive well log. Once drilling was completed, the core barrel was removed and a monitoring well was installed within the 6-inch diameter casing.

Hollow-stem auger drilling was accomplished using a CME 55 all-terrain rig with 4½-inch inside diameter augers. Continuous soil samples were obtained using 24-inch long, 3-inch inside diameter stainless steel split-spoon samplers, in accordance with field procedure FP3.3 and ASTM test method D1586-84. After drilling was completed and the last sampler was removed from the auger string, a monitoring well was installed through the hollow-stem augers. Descriptive logs of the soil borings for all of the monitoring wells are contained in Appendix 3A.

3.1.3.2 Monitoring Well Completion

All monitoring wells were designed and installed in accordance with field procedure FP5.0. In general, they were constructed with 2-inch inside diameter schedule 40 polyvinyl chloride (PVC) riser pipe and well screen. Each section of the pipe was joined with flush-threaded couplings. All of the on-site monitoring wells were equipped with a 5-ft length of factory slotted screen. The wells were completed with an artificial filter pack consisting of quartz silica sand that was placed around the screen from the bottom of the borehole to approximately 2 ft above the screen. Bentonite pellets were used to seal the annular space above the filter pack section. The minimum seal thickness was 2 ft, but some of the deeper bedrock wells had seals that were as much as 15 ft thick. The remaining open annulus from the top of the well seal to the ground surface was filled with a Portland cement/bentonite grout mixture. At the surface, the PVC well casing was protected with a locking outer steel casing or a steel vault that was encased in a 3 by 3-ft square concrete pad. The pad was sloped away from the well to promote drainage. Well construction and completion diagrams are provided in Appendix 3A.

3.1.3.3 Monitoring Well Development

After installation, the monitoring wells were developed so that representative groundwater samples could be collected. Well development was performed in accordance with field procedure FP5-1. All but two of the on-site wells were developed by removing water with a submersible pump. Monitoring wells MW-13(S) and MW-14(S) were developed using dedicated Teflon bailers because of the low volume of water in the wells and the slow rate of recharge. Development activities continued until stable readings of pH, specific conductance, and temperature were obtained, and the water was visibly silt-free. The water quality parameters measured upon completion of well development records are included in Appendix 3B.

Wells MW-20(S) and MW-26(S) could not be fully developed after numerous exhaustive efforts with dedicated Teflon bailers. These two wells consistently contain only ¼ to ¾ ft of water, and are extremely slow to recharge. Both are shallow wells that had to be drilled twice to find sufficient saturated deposits for screen placement. Although some sand and gravel layers were encountered in the second borings, the saturated deposits were minor in comparison to the predominantly fine silts and clays penetrated in the boreholes. During development, the wells quickly bailed dry and recharged less than 1 foot of water after one to two days. To test the well screens, approximately ½ gal of deionized water was poured into each well, which produced a rise in the static water level of about 3 ft. The elevated water level within the wells was dissipated within a few minutes. This indicated that the well screens were not clogged and that there was little recharge available to the wells. Since the yield from these wells was inadequate to fill the required sample containers, they could not be used as part of the sampling network. However, because the screens are not clogged and there has been noticeable fluctuation in the water levels in these wells, they have been retained as water level monitoring points.

3.1.3.4 Groundwater Sampling Methodology

Representative groundwater samples were collected with dedicated Teflon bailers and submersible pumps. Monitoring wells MW-13(S) and MW-14(S) were sampled using dedicated Teflon bailers because of the low volume of water in the wells and the slow rate of recharge. The remaining 19 wells were equipped with dedicated submersible bladder pumps, which were manufactured by QED and constructed of PVC with a Teflon bladder.

Prior to sample collection, the wells were purged to remove stagnant water. Wells MW-13(S) and MW-14(S) were purged with a Teflon bailer. Because these wells recharged very slowly, they were bailed dry twice, and samples were collected when sufficient water volume existed to fill a sample

container. Even with this modified purging scheme, it still required two days to collect enough water from these two wells to fill all the sample containers.

The micropurge technique was used to remove stagnant water from the wells containing submersible pumps. This low-flow, low-volume purging technique is described in field procedure FP5.2. Water temperature, pH, and specific conductance were continuously monitored during purging with an in-line flow-through cell. Groundwater samples were collected when these parameters stabilized. The field parameters measured at sample collection are included in Appendix 3B.

Samples collected for analysis of dissolved constituents such as metals, radionuclides, and solids were filtered in the field before they were preserved in the sample containers. The field filtration was performed in accordance with field procedure FP5.5. If wells contained submersible pumps, the samples were collected from dedicated in-line filter capsules. A hand-operated vacuum pump attached to a sample collection container and filtration apparatus was used at wells that required a bailer for sample acquisition. These filtration devices also were dedicated to the individual wells. Both techniques employed filters with a 0.45-µm pore size.

In conjunction with the on-site monitoring well installation and sampling program, two on-site production wells and an interior tap were sampled (GW0001). Samples were obtained from spigots in accordance with standard field procedure FP5.4. The water spigot/tap was turned on and allowed to flow prior to sample collection. Water quality readings were collected before and after sample collection. The production wells and tap water are being sampled on a regular basis for metals and radionuclides.

3.1.3.5 Groundwater Sample Analyses

The Phase IV SAP specified that the on-site monitoring wells be sampled twice to evaluate the groundwater quality across the Luckey site. The wells were sampled during a seasonally wet period and during a dry period to obtain the maximum variation in water quality. Twenty-one of the 25 wells installed on site were incorporated in the groundwater sampling network. Wells MW-20(S) and MW-26(S) were not sampled due to insufficient water volume. Wells TW-42 and TW-43 were constructed as test wells and were not sampled. General Engineering Laboratories (GEL) of Charleston, South Carolina was contracted to analyze all groundwater samples.

The initial four pair of wells were sampled in July 1998 for nitrate, anions, total and dissolved radionuclides, total and dissolved metals, VOCs, SVOCs, total dissolved solids (TDS), and total suspended solids (TSS). This first set of samples was analyzed with a two-week data-reporting schedule. The expedited turn-around time was requested in order to identify potential areas of contamination and to assist in the placement of additional monitoring wells at the site. The results indicated that detectable concentrations of beryllium were present in samples from wells MW-01(I) and MW-02(S). These two wells were sampled a second time in July 1998, for beryllium only, to confirm the results.

Groundwater samples also were collected in August and November 1998 as new monitoring wells were added to the network. All of the on-site monitoring wells were sampled as a single group in April 1999. Table 3.4 provides a listing of the on-site monitoring wells, the date they were sampled, and the chemical and radiological parameters that were tested in each sampling event. The analytical results from each of the sampling events are provided in Appendix 4A.4 and discussed in detail in Section 4.2.2.

3.1.4 Surface Water and Sediment Sampling

Surface drainage features at the Luckey site include several NPDES outfalls, storm sewers, drainage ditches, and wetland areas. Drainage from on-site sources flows to two main channels, the main

drainage ditch and the western drainage ditch. The main drainage ditch originates on site, but discharges off site through the adjacent farm field to the north. The western ditch flows northward along Luckey Road, between the road and the property fenceline. The origin of this ditch is uncertain, but it can be traced to the south beyond the town of Luckey. The ultimate receptor of these two main ditches and most on-site drainage is Toussaint Creek.

Past operational practices and runoff from sparsely vegetated areas and waste disposal sites may have released site-related contaminants to the various on-site drainage paths. To determine if contaminants were being transported off site by these drainage features, a surface water and sediment sampling program was implemented as part of the RI. Samples were obtained initially in the fall of 1997 (Phase II) and again during the summer of 1998 (Phase IV).

In the Phase II sampling event, eleven surface water and sediment samples were collected to identify potential source areas that may have contributed to the off-site migration of contaminants. The sample locations are shown on Figure 3.6, as a four-digit number with a "SWSD" prefix. A second sampling event occurred in July 1998, in which four additional sets of surface water/sediment samples were collected to supplement the initial sampling data and to more closely examine potential source areas. These four sample stations are identified on Figure 3.6 as a four-digit number with the prefix "IA06-SD." The rationale for the placement of these surface water and sediment samples is presented in Table 3.5.

3.1.4.1 Surface Water and Sediment Sampling Methodologies

The Phase II field sampling activities were conducted in accordance with the *Sampling and Analysis Plan (SAP) for the Luckey Site* (SAIC 1997) and the Ohio EPA guidance document *Sediment Sampling Guide and Methodologies* (OEPA 1996). Sample locations were selected based on field observations of site drainage patterns and proximity to known areas of former waste handling activities. Representative surface water samples were obtained prior to sediment sampling at a particular location where conditions allowed. The sediment samples were obtained as grab samples from shallow surficial deposits (zero to ½ ft). Fine-grained sediments were preferentially sampled and identified by best professional judgement.

Samples collected in Phase IV were obtained in accordance with field procedure FP7.0, which is contained in the *Sampling and Analysis Plan for Remedial Investigation at the Luckey Site* (SAIC 1998b). Since the surface water was less than 1 ft deep at each location, samples were collected either by directly filling the appropriate glass sample containers or by using a glass transfer vessel. Sediment samples were collected using an 18 inch-long by 2-inch diameter stainless steel sediment corer that was advanced with a hand-operated slide hammer. The samples were obtained from the surface of the sediment to a depth of 1 ft. As specified in the SAP, the original plan was to sample the sediments in 1-ft increments to a total depth of 3 ft. However, in all locations the sediments were generally only 1 ft thick or less. Where the sediment thickness was inadequate for the corer, as in the concrete-lined ditches, a stainless steel scoop was used to collect the sample. Typically, these sediments were less than 6 inches thick, and the sample had to be collected from a wider surface area to obtain sufficient for analysis.

3.1.4.2 Surface Water and Sediment Sample Analyses

Surface water samples obtained in Phase II were analyzed for metals, radionuclides, SVOCs, VOCs, and anions. In addition, selected samples were analyzed for alkalinity, TDS, and TSS. All sediment samples were analyzed for metals, radionuclides, and SVOCs. Selected samples were analyzed for VOCs and anions.

The Phase IV surface water and sediment samples were analyzed for metals, radionuclides, fluoride, and in some cases VOCs and SVOCs. Field measurements of pH, specific conductance, water temperature, and dissolved oxygen also were recorded for the surface water samples at the time of collection. Results of the surface water and sediment sample analyses are presented in Appendix 4A.2 and 4A.3. A detailed discussion of the results is provided in Section 4.4.2.

3.1.5 Building Surveys

There are several buildings on the Luckey site that housed beryllium processing operations, associated activities (including administration), and storage (Figure 3.7). These include a large production building and warehouse, as well as several smaller process and ancillary buildings (Former Melting, Alloying, and Shipping building, office buildings, and the Maintenance building). Transferable surface contamination in building interiors may have been minimized by washing and painting surfaces. However, original levels of residual contamination from radiological constituents and beryllium may still be present beneath coats of paint on walls and floors in buildings.

Cursory beryllium and radiological scoping surveys were performed during the Phase II RI. More extensive surveys were continued during the Phase IV RI. The purpose of these surveys was to measure residual levels of beryllium and direct, as well as removable, radiological contamination. Direct measurements are conducted prior to collection of a swipe. Therefore, direct readings measure the contribution of both fixed and removable radioactivity at a specific location. The Phase II surveys focused on the Annex. The data were evaluated in the Phase II Characterization Report (BNI 1998), and as a result, during Phase IV, scoping surveys were performed in all of the on-site buildings. The following subsections explain the sampling and scoping activities in the buildings. A more detailed presentation is provided in Appendix 3C.

3.1.5.1 Phase II Scoping Survey of Annex

Scoping surveys (beryllium and radiological) were performed in the Annex during the Phase II RI. The beryllium survey was limited to the ceiling I-beam trusses. Not all I-beam trusses were surveyed because much of the building was inaccessible to the survey crew. All scoping survey data were collected from the top of the lower horizontal surface of the I-beam. The radiological survey was more complete and included the floor and walls, in addition to the ceiling beams. These data are presented in the Phase II Characterization Report (BNI 1998) and are discussed in Section 4.3.

Beryllium Survey

A limited survey of the interior of the Annex was conducted to determine whether beryllium contamination was present. No paint chips were taken from the walls for analysis. Swipes were taken to determine transferable beryllium content from surfaces of the overhead trusses only. No swipes were taken from the floors or walls. It was believed that the floors and walls had been painted several times subsequent to the completion of all beryllium-related work at the Luckey site. The swipes were taken from an area measuring approximately 100 cm^2. Forty-eight swipes and two blanks were taken from the ceiling I-beam trusses.

Radiological Survey

During the radiological survey, both direct and removable (smear) measurements were taken. The smears were taken from an area measuring approximately 100 cm^2; the direct alpha measurements were taken from an area of approximately 50 cm^2; and the direct beta-gamma measurements were taken

from an area of approximately 15½ cm^2. Direct alpha and beta-gamma measurements were documented in the active instrument area and have been translated to 100 cm^2.

The smears (removable contamination) were analyzed on site for alpha contamination using an Eberline Scintillation Alpha Counter Four (SAC-4). Direct alpha measurements were taken using an Eberline AC-3 alpha detector. Both direct and removable beta-gamma measurements were taken using a Geiger-Mueller Detector (Eberline HP-360).

The floor of the Annex was surveyed utilizing a 1-meter by 1 m grid, taking direct measurements in the probe area (corrected to 100 cm^2) and smears from a 100 cm^2 area. Only the grid nodes were surveyed. The wall of the Annex was surveyed by measuring a series of points approximately ½ m above the floor.

3.1.5.2 Phase IV Scoping Surveys

As a result of the scoping surveys conducted in the Annex during Phase II, additional surveys were planned for Phase IV. Beryllium and radiological surveys were conducted in the Annex and six other on-site buildings during the summer of 1998. An extensive survey was conducted in the Annex, where 80% of 1-m grids established on accessible surfaces of the floor, the bottom meter of all walls, and overhead structures were surveyed for direct and removable contamination. Much of the space in several buildings, including the Annex, is currently occupied by active production lines or product storage. As a result, only 80% of the Annex could be surveyed and survey coverage in the remaining buildings may have been biased.

A 5% cursory survey of accessible grids was conducted in six other buildings. These buildings were not directly involved in the processing of beryllium. The objective of the 5% survey was to determine if beryllium was present in any of these structures and if contamination is prevalent throughout the structure. The cursory survey was performed in the following buildings:

- Production Building;
- Former Laboratory Building;
- Maintenance Building;
- Bulk Storage Building;
- Former Melting, Alloying, and Shipping Building; and
- Employee Activity Building (beryllium scoping survey).

The surveys consisted of recording direct measurements of direct or total alpha and beta-gamma radioactivity and taking smear and swipe samples to test for transferable contamination. Discrete samples of building materials also were collected. In most cases, these were analyzed for beryllium. Some building materials samples collected in the Annex were analyzed for radionuclides. The cursory survey in the Employee Activity Building was extended to 10% coverage, as this building was considered to represent background (Section 3.3.4).

Results from this initial phase of laboratory analysis indicated that measurable concentrations of beryllium in settled dust were present in all buildings investigated. Elevated radiological readings also were detected in small isolated areas of the Annex and Production Building. Testing of the remaining on-site buildings was determined to be warranted based on the radiological field testing and the laboratory results of swipe samples for beryllium and radiological constituents. Swipe samples for beryllium and radionuclide testing, as well as direct reading measurements, were collected from the following seven smaller buildings in a subsequent phase during the summer of 1999:

- Employee Activity Building (beryllium scoping survey and radiological scoping survey),
- Guard House,
- Building Housing West Production Well,
- Building Housing East Production Well,
- Building Housing Water Pump and Tank,
- Sewage Disposal System Pump House, and
- Shack.

Beryllium swipes and samples of building materials were collected in the Employee Activity Building during the initial Phase IV effort. Dust samples and additional swipes were collected, and radiological scoping surveys were performed during the subsequent field activities conducted in the buildings in 1999. The results of Phase IV activities are discussed in Section 4.3 and are presented in Appendix 4B.

Scoping Surveys – Grid Layout

In order to complete the scoping surveys, the buildings were individually measured and sectioned off in a manner to locate sampling points within a square meter area. Each square meter was labeled in x-axis and y-axis coordinates for horizontal surfaces. Z-axis coordinates were provided when elevated structures in a building were sampled. The grid layouts in each surveyed building are detailed in Appendix 3C. Swipes and/or smears were collected from 100 cm^2 areas within a grid to measure removable concentrations of beryllium or radiological activity.

Beryllium Survey

Swipe samples were collected from surfaces where either high levels of visible debris were present, or areas where dust had settled due to other factors. Other factors (influencing the settling of dust particles) considered were static forces, mechanical forces, natural forces, and building settling. Due to the structure, age, and use of this facility, areas of high visible dust were readily identified. All of the surfaces inspected show elevated levels of visible dust, specifically on horizontal surfaces 8 ft or greater above floor level. Swipe sampling locations are depicted in figures contained in Appendix 3C.

Specific sampling procedures were followed to collect the dust. These procedures are guidelines provided in the Occupational Safety and Health Administration (OSHA) Technical Manual, Section I-Chapter 2 (Sampling for Surface Contamination), and are detailed in Appendix 3C of this RI Report.

Radiological Survey

Each grid area was scanned with a portable radiation detection instrument to locate an area of highest activity. The detector was kept as close to the surface as possible and moved in a serpentine pattern while advancing approximately ½ m per second for beta-gamma detectors and at a rate of one detector-width per second for alpha detectors.

Within the selected grid, the point of highest activity was surveyed with a one-minute count. If that point exceeded the Nuclear Regulatory Commission's (NRC) Regulatory Guide 1.86 criteria, then five points were surveyed and averaged to determine if the grid exceeded guidelines. The five point measurements were averaged for a grid measurement and compared to transferable surface activity criteria (average and maximum) in NRC Regulatory Guide 1.86. If guidelines were exceeded, then smears of 100 cm^2 were collected for a measurement of transferable or removable contamination.

Smears were obtained by wiping an area of approximately 100 cm^2 using a dry filter paper, (Whatman 50 or equivalent) while applying moderate pressure. A 47-mm diameter filter was typically used, although cotton swabs also were used to swipe holes or cracks. These smears were counted for gross activity to determine decontamination potential and for comparison with removable criteria of NRC Regulatory Guide 1.86. Approximately 10% of smears collected were sent off site for analysis.

The floor of the Annex was scanned using an automated system. This system uses a floor monitor coupled to a laser ranging system to record the position and alpha or beta/gamma activity of each location. The system operates in a near continuous mode taking readings every few seconds. The system produced a detailed map showing activity on the floor (Appendix 4B.3).

3.1.5.3 Building Materials Samples

Building materials samples were collected during the Phase IV surveys to test for "fixed" beryllium and radiological constituents. Building materials sample locations are presented in figures contained in Appendix 3C. These samples consisted of paint scrapings and bulk materials (concrete, cinder blocks, etc.). The paint was scraped to expose the bare metal surface of the beam and collected to test for fixed beryllium, which may have been absorbed through porous paint material or painted over as layers were added. Bulk materials were collected from various building substrates. The substrates included cinder block walls and concrete floor. Materials were selected from areas where previous damage was already present or in areas where foundation settling cracks were observed. Building material samples were collected by lightly tapping the material with a rock hammer to dislodge not more than the outside two centimeters of the surface. Surface samples of steel or wood building material generally were not collected.

3.1.5.4 Bulk Dust Collection

During the Phase IV scoping surveys performed in 1998, an extensive accumulation of dust was discovered on horizontal areas inside each building. Based on the findings of the scoping surveys, a total of 110 bulk composite dust samples were collected in all of the on-site buildings in 1999.

The majority of the dust samples were analyzed for beryllium. One bulk composite dust sample (collected throughout the Annex and Production Building) was analyzed for SVOCs and TAL metals to provide additional information on the nature of the dust for the purpose of dust disposal. A bulk composite dust sample also was collected in each of the following buildings for quantitative beryllium speciation (which is considered useful information for industrial hygiene purposes):

- Annex,
- Production Building – First Floor, and
- Production Building – Second Floor.

Sampling Procedure

Each building was divided into Functional Areas (FAs). Functional areas are areas within which similar activities occur. Examples would be hallways where the primary activity is movement of people and goods or and an office area where the primary activity is paperwork and meetings. The FAs are described and depicted in Appendix 3C. Two samples were collected in each functional area - one sample from zero to 2 m above the floor and one sample above 2 m. Samples were collected using a High Efficiency Particulate Air (HEPA) vacuum equipped with lightweight, non-conductive tubular extensions. The dust collection device was a fibrous bag filter fitted inside the tip of the vacuum hose wand. The bag

filter consisted of an all natural, chemically inert, fibrous material generally used for sampling biological spores and allergens. The filter pore size was approximately 0.22 microns.

Dust was collected from as many different structures (biased and unbiased) in each FA as possible. The structures included the following:

- floors, walls, and ceilings;
- heating, ventilating, and air conditioning (HVAC) systems (interior and exterior) and HVAC filters;
- trusses;
- pipe surfaces and pipe hangers;
- machinery surfaces;
- product surfaces;
- lighting fixtures;
- tops of lockers, partitions, other overhead structures; and
- other generic structures.

The results of the bulk dust analyses are presented in Appendix 4B.1, and discussed in Section 4.3.

3.1.6 Dose Rate Measurements

General area dose rate surveys were performed and documented inside buildings where elevated radioactive contamination was detected during Phase II and Phase IV characterization activities. These measurements were determined to be a result of direct radiological contamination. Contact and 30 cm dose rate surveys were performed where a localized area of elevated activity may pose a significant external radiation exposure hazard. These areas were identified by the site radiation protection manager (RPM) in consultation with the USACE-Buffalo District health physicist.

Elevated radiological measurements were recorded in several areas within the Annex and Production Building during the Phase IV RI. The areas containing elevated measurements included floors, walls, and overhead ceiling beams in the Annex, as well as two small areas on overhead ceiling beams in the Production Building. The ceiling beams, as high as 30 ft are accessible only by a mechanical lift. Dose rate measurements in these overhead areas are of limited use, since any potential exposure is limited by accessibility constraints. Therefore, the dose rate measurement surveys focused primarily on the floor and walls in the Annex.

Dose rate measurements were performed in high-traffic areas in the Annex and Production Building. Dose rate measurements also were collected in areas on the site where gamma walkover data collected in Phase II had indicated higher levels of gamma radiation. At each area a gamma meter was used to predefine the area to be walked with the dose meter. The following areas were measured:

- north of the propane tanks;
- south of the propane tanks;
- along the gravel drive;
- immediately surrounding boring IA05-SB0009;
- a small area near lagoon C and the origin of the main drainage ditch;
- an area overlying a trench in the northeastern portion of the site; and
- two areas outside the fence, north and east of the site.

The results of the dose rate survey are presented in Appendix 4C and are discussed in Sections 4.1.8 and 4.3.5.

3.1.6.1 Dose Rate Survey Methods

Dose rates were measured at waist level while walking a serpentine pattern at approximately ½ m per second outdoors and straight lines at 1 m per second indoors. If an area of elevated activity was identified, a dose rate was measured at waist level, knee level, and just above ground surface. If the source of the elevated measurement was identified as material other than the ground, a contact (one inch) and general area (12 inches or 30 cm) dose rate were measured.

A gamma sensitive Geiger Mueller exposure rate instrument (Bicron MicroR meter) was used to measure the dose rates. The instrument had a current annual calibration, and the instrument response to a source was verified each day prior to work. Dose rates were performed by an American National Standards Institute (ANSI) 3.1 qualified Senior Health Physics Technician, and recorded in units of microrem/hour (µrem/hr). Dose rates were described or recorded on a survey diagram (sketched) representing an overhead view of the area. When the meter needle stabilized between two readings on the meter scale, the higher number was recorded on the survey.

3.1.7 Air Monitoring

An air monitoring program was conducted during the investigation to monitor ambient air conditions and personnel breathing zone levels for radiological parameters and beryllium. The monitoring program also gauged the effectiveness of engineering and administrative controls. Investigation activities potentially producing dust included intrusive soil disturbances, drill rig operations, hand auguring, and trenching. The objectives of the air monitoring were to:

- identify the presence of radiological COPCs and beryllium particulates in ambient air;
- assess the need for, or effectiveness of, engineering controls to minimize dust generation due to on-site activities or high wind activity;
- estimate the potential movement of wind-borne contaminants from the site;
- verify compliance with limits for hazardous air pollutants (NESHAPS); and
- verify compliance with OSHA Permissible Exposure Limits (PEL).

On September 2, 1999 the OSHA issued a *Hazard Information Bulletin on Preventing Adverse Health Effects from Exposure to Beryllium on the Job*. In this bulletin OSHA states that their current PEL of 2µg/m^3 eight-hour time-weighted average (TWA) may not be adequate to prevent the occurrence of chronic beryllium disease (CBD). The American Conference of Governmental Industrial Hygienists (ACGIH) published a Notice of Intended change for its Threshold Limit Value (TLV) for beryllium that would lower the TLV to 0.2µg/m^3 averaged over an eight-hour work shift. The 0.2µg/m^3 is currently a proposed standard; however all of the Phase II and Phase IV data presented in the following sections are evaluated using both the current standard of 2 µg/m^3 and the proposed standard of 0.2µg/m^3.

3.1.7.1 Phase II Air Monitoring Program

During Phase II field activities, ambient air samples were collected from eight locations on the Luckey Site (Figure 3.8). Two of the locations were within buildings at the site. Samples were analyzed for gross alpha radioactivity, radionuclides, and beryllium. Ambient air samples for beryllium analysis were collected using an Anderson Impactor (PM-10 particle size impactor), which used Whatman 41 filters of pore sizes 7.2 µm, 3 µm, 1.5 µm, 0.95 µm, 0.49 µm, and less than 0.49 µm. Radiological ambient air samples were collected on cellulose ester filters using a high-volume (approximately 50 L/min) sampler. The duration of collection was approximately 500 minutes (about eight-hours) in each case. The radiological sample filters were analyzed on site using an SAC-4. No correction factor was applied for self-absorption. Previous program experience has shown that self-absorption is not a

significant problem for FUSRAP radiological air samples (BNI 1998). The results of these analyses are summarized here, with the complete results reported in Appendix 3D.

Eight of the nine samples analyzed for gross alpha activity were below background. Results for the ninth sample were equal to background. Six samples were analyzed for radioisotopes: three samples were analyzed individually and three as composite samples. Five of the six were analyzed by gamma spectroscopy to provide qualitative data on the isotopic distribution of radionuclides. The sixth sample, a composite of all samples collected, was analyzed by alpha spectroscopy. Air samples at eight on-site locations were analyzed for beryllium. Different filter sizes were used in an attempt to determine distribution of beryllium with particle size. Beryllium was detected in only a single sample.

The results from the area (stationary) and personnel samplers were well below the air effluent concentration guidelines set forth in 10 CFR 20 Appendix B for gross alpha radiation. The calculated air concentrations for a composite air sample were below the derived air concentrations (DACs) listed in 10 CFR 20 Appendix B for all radionuclides reported. The DACs have been used for comparison purposes in place of the Derived Concentration Guidance Levels (DCGLs) as the appropriate regulatory guideline for use under the USACE administration of FUSRAP. The maximum beryllium concentration detected did not exceed 20% of the permissible exposure limit (2µg/m^3).

3.1.7.2 Phase IV Ambient Air Monitoring Program

During Phase IV field activities, locations of the high volume air sampling pumps were chosen daily through consideration of the prevailing wind direction and the location of investigative activities. Prevailing wind direction was monitored by the use of a windsock mounted at the site. Figure 3.8 shows the locations of these air monitoring stations. Two sets of pumps, one set upwind and another set downwind of field activities, were used on a daily basis during field activities. Samples were analyzed for gross alpha radioactivity, radionuclides, and beryllium.

Ambient air samples for beryllium analysis and radiological parameters were collected using a high volume air sampling pump (set at approximately 50 L/min) and a cellulose ester filter to collect the sample. The sampling pumps were started prior to the commencement of any field activity and were allowed to run the entire shift (approximately eight- hours). Sample pumps were turned off only after verification that all field activities were complete for the day.

Information such as the date, sample time, the flow rate, calculated air volume, and the associated sample ID number was recorded in a log (Appendix 3D). One filter was sent for off-site beryllium analysis, utilizing National Institute for Occupational Safety and Health (NIOSH) method 7102, and one was counted on site for gross alpha activity. Ten percent of the samples counted on site were sent off site for confirmatory analysis and radiation speciation.

Ambient air monitoring within the buildings utilizing a high volume pump was not conducted during Phase IV activities. Instead, personnel breathing zone air monitoring was conducted daily and used as an indicator of potential exposures due to removable beryllium contamination in dust on roof trusses reported in Phase II.

The results of the ambient air monitoring program are summarized here, with the complete results reported in Appendix 3D. Actual results for beryllium are presented as well as a TWA value. Concentrations of beryllium were converted into a TWA for comparison to the OSHA PEL of 2µg/m^3 and the proposed ACGIH TLV of 0.2µg/m^3 TWA. The maximum concentration reported for beryllium as a TWA was 0.03µg/m^3, which is well below the proposed ACGIH standard. The results from the ambient

air samplers were well below the air effluent concentration guidelines set forth in 10 CFR 20 Appendix B for gross alpha radiation.

3.1.7.3 Phase IV Personnel Air Monitoring

The identification of airborne contaminants in the breathing zone and selection of appropriate personal protective equipment (PPE) for remediation workers during field activities was the responsibility of Health and Safety (H&S) personnel. The PEL for occupational exposure to beryllium is 2 $\mu g/m^3$. Engineering controls, such as the use of respirators, were implemented if air concentrations of beryllium reached 0.09 $\mu g/m^3$. Occupational criteria were assumed protective for public exposures. Personnel radiation uptake also was monitored through the use of personal breathing zone air sampling to ensure the selection of PPE was appropriate for site tasks. Real-time monitoring of dust by H&S personnel was used as an immediate indicator of potential exposure to airborne contaminants. Results of both ambient air and personal breathing zone monitoring were used to decide the appropriate level of PPE for site workers.

Approximately 77% of the personal air monitoring data collected during additional field activities (June 16, 1999 through July 15, 1999) were determined to be invalid. These samples were analyzed by the laboratory using NIOSH Method 7300 instead of the required NIOSH Method 7102 as specified in written direction provided to the laboratory by USACE and SAIC. Due to differences in sample preparation between the two methods (primarily sample digestion) and insufficient sample volumes as required by the method, data obtained using the NIOSH 7300 method were determined to be invalid. Valid air monitoring data were collected during sampling activities in the Maintenance Building, Annex, and the Production Building.

Results of the personal air monitoring are presented in Appendix 3D. Again, beryllium results were converted into a time-weighted average for comparison with the OSHA PEL and the proposed ACGIH TLV. The highest concentration of beryllium (0.831 $\mu g/m^3$) was detected during dust sampling activities conducted in the buildings. This value is below the OSHA PEL, but exceeds the proposed ACGIH TLV of 0.2$\mu g/m^3$. On three occasions beryllium was reported above the proposed TLV value of 0.2$\mu g/m^3$. All of these instances occurred during sampling activities in the buildings while personnel were wearing air-purifying respirators equipped with HEPA cartridges.

During Phase IV field activities, results of both ambient and personal air monitoring were posted daily for the remediation worker's information. Laboratory analysis of airborne beryllium were available within 24 hours of laboratory receipt of the sample/filter to ensure timely posting of this information.

3.2 SUMMARY OF OFF-SITE INVESTIGATION ACTIVITIES

As part of the RI of the Luckey site, various environmental media were sampled in adjacent off-site areas to evaluate the potential impact from site-related contaminants. The off-site activities consisted of the following work elements:

- General Survey Methods;
- Surface and Subsurface Soil Sampling;
- Monitoring Well Installation and Groundwater Sampling;
- Surface Water and Sediment Sampling; and
- Meander Bend Sampling in Toussaint Creek.

3.2.1 General Survey Methods

A gamma walkover survey was performed on properties adjacent to the Luckey site as a general reconnaissance tool to delineate areas of elevated radioactivity. The most likely sources of such contaminants on these properties are historic smokestack emissions and wind-blown dust from bare spots on the site. Because air dispersion is the transport mechanism for these potential sources, the contamination is expected to be in the surficial or relatively shallow soils and detectable with general survey instruments. Although the gamma survey cannot detect beryllium, it may be useful as a possible indicator since the sources and transport mechanisms are similar. The survey was used to identify areas for further investigation and locate sites for environmental sampling.

The survey was conducted in two separate events due to the presence of crops in some of the adjacent farm fields. The initial survey was conducted in July 1998 and covered three areas: (1) a 200-ft wide stretch of the northern farm field immediately north of the Luckey site, (2) the former railroad immediately east of the site, and (3) a small strip along the public right-of-way along the south side of Gilbert Road. A follow-up survey was performed in August 1998 after the crops in the farm field west of the site were harvested. This survey covered a 200ft wide swath of the western farm field. The survey was not extended onto the France Stone quarry property or the farm field east of the Luckey site because right-of-entry agreements were not in place at the time.

Two different sodium iodide scintillation probes were utilized in performing the survey. A high-gamma sensitivity detector with a 2-inch by 2-inch sodium iodide crystal was used for detecting high-energy gamma emissions. A FIDLER with a 5-inch diameter thin crystal was used for the detection of low-energy gamma emissions. Individual station locations were determined with a GPS as the readings were recorded. The detectors and GPS were connected to a data processing system that allowed both real-time and post processing capabilities, and the entire system was capable of capturing a minimum of 60 readings per minute.

Calibration of the detection instruments was checked daily against a known source. In addition, background was re-established each day prior to surveying activities. The detection instruments and GPS were mounted on a Kawasaki 4-wheel drive ATV. The unit was operated at an appropriate speed to locate and identify hotspots of elevated activity, which were defined as areas that were two times background levels. For each hotspot, a 1-minute bias count was performed for confirmation. Maps of gamma activity detected by each instrument were created to identify areas of elevated activity contamination. These maps were used as a guide in locating points for confirmatory environmental sampling (Figures 3.9 and 3.10).

3.2.2 Surface and Subsurface Soil Sampling

Properties adjacent to the Luckey site were sampled using *the Multi-Agency Radiation Survey and Site Investigation Manual (MARRSIM)* as guidance (DOD 1997). Accordingly, the adjacent properties are considered as Class 3 impacted areas. As defined in this guidance document, Class 3 sites include any impacted areas that are not expected to contain any residual radioactivity, or are expected to contain levels of residual radioactivity at a small fraction of the Derived Concentration Guidance Level DCGL, based on site operating history and previous radiological surveys. For Class 3 sites, MARSSIM recommends random sampling supplemented with “professional judgement” or biased sampling. The biased samples should be located where contaminants would most likely accumulate.

The focus of the investigation in off-site areas was the first 200 ft of land immediately bordering the property. This distance, chosen based on the likely contaminant transport mechanisms, represents a hypothetical residential subdivision on the adjacent properties. The gamma walkover surveys and at least

seven sampling sites were located within the 200-ft investigation zones. The results of the gamma walkover survey were used to locate biased sampling points, where possible, by identifying hotspots of elevated gamma activity. Soil samples were collected from these locations to confirm the results of the gamma survey and to quantify the concentrations of potential contaminants by laboratory analyses. The remaining samples within this zone were located randomly. On three adjoining properties, seven discretionary samples also were randomly located beyond the 200-ft zone to test the entire property. Where no elevated activity was detected by the gamma survey in an adjacent property, all samples within and beyond the 200-ft zone were located randomly.

Adjacent properties that were considered Class 3 impact areas and evaluated by intrusive soil sampling in the RI include:

- the farm field immediately north of the site,
- former railroad line east of the site (NYCRR),
- France Stone Quarry to the south,
- the farm field west of the site, and
- Troy Township dump to the south and east.

Samples were obtained from all properties except the Troy Township dump using stainless steel hand augers in accordance with standard procedure FP3.2. Since the borings installed at the dump were drilled to bedrock, they were advanced using truck-mounted drill rigs. The soil collected from each hand-augured sample interval was homogenized by thorough mixing in a stainless steel bowl according to standard procedure FP3.3. However, samples obtained for VOC analyses were collected with Encore® samplers immediately after the soil was brought to the surface and prior to homogenizing. The sample locations for each of the off-site properties are shown in Figure 3.11.

3.2.2.1 Northern Farm Field

In the farm field north of the Luckey site, the gamma walkover survey identified two small areas of elevated gamma activity. Both areas were near the main ditch just after it leaves the Luckey site. Based on the survey, three biased sample stations were located in areas of the highest measured gamma activity. Soil boring IA10-SB0023 was located approximately 20 ft northeast of the intersection of the main ditch with the fence line at the northern property boundary. This boring was advanced to a depth of 5 ft using stainless steel hand augers, and soil samples were collected from each 1-ft interval. Stations IA10-SB0042 and IA10-SB0043 were located along the eastern side of the ditch approximately 120 ft and 170 ft north of the fence line. Soil samples were obtained from the top 1½ ft at these two sampling stations. Twelve additional sample points were randomly selected by computer and located in the field using the GPS instrumentation. Five sample stations were located within the 200-ft-wide gamma survey grid immediately north of the property boundary, while the remaining seven were located in the field north of the survey area. Soil samples were collected from zero to 1½ ft at each of these locations. All soil samples collected in the northern farm field were analyzed for arsenic, barium, beryllium, lead, and radionuclides, except for the 3 to 4 ft and 4 to 5 ft interval samples from IA10-SB0023, which were analyzed only for beryllium.

3.2.2.2 New York Central Railroad Property

The gamma walkover survey detected several areas of elevated activity along the former NYCRR bed east of the Luckey site. Most of these areas were located in the low-lying wooded strip of land at the northeast corner of the property, between the property fence line and the former NYCRR bed. Two biased sampling points (IA10-SB0048 and IA10-SB0051) were located in this area based on the gamma survey results. The exact sample locations were pinpointed by scanning the ground surface with handheld

field radiological instruments. In addition, seven random sample stations were generated by computer and located along the railroad bed using the GPS unit. Most samples were obtained from the top ½ ft of soil. However, some samples were obtained from zero to 1½ ft if a large amount of cobbles and rocks were encountered in the borings. At IA10-SB0052, samples were collected from both the zero to ½ ft and 1 to 1½-ft intervals bgs. All samples were collected using stainless steel hand augers and analyzed for metals and radionuclides.

The sample results obtained from the northern farm field and the former railroad bed indicated that beryllium was present at elevated concentrations in several areas at both properties and that radionuclides were present at elevated concentrations along the railroad bed. To confirm these results and further define the extent of impacted soils, an additional 27 systematic soil samples were collected in the northern farm field and along the former railroad bed. Eleven of the borings, IA10-SB0109 through IA10-SB0119, were hand-augured in the farm field along the northern property line. They were spaced about 150 ft apart. Borings IA10-SB0120 through IA10-SB0126 were hand-augured in the northern farm field along the eastern side of the open main ditch. These borings were spaced approximately 150 ft apart and extended from near the northern edge of the 200-ft survey area north to Toussaint Creek. Nine borings, IA10-SB0089 through IA10-SB0097, were randomly located on top of and along the eastern side of the former railroad bed. Samples were collected from the top 6 inches or 1 ft of soil depending on the amount of cobbles or rocks encountered in the borings. The additional samples collected in the northern farm field were analyzed for beryllium, while those collected along the NYCRR bed were analyzed for beryllium and radionuclides.

Access to the farm field east of the railroad bed could not be negotiated therefore samples could not be collected. However as explained in Section 4.5.2, the concentrations of beryllium and radionuclides detected in soil samples drops off significantly across the railroad right-of-way.

3.2.2.3 France Stone Quarry

No activity above background was detected in the limited gamma survey performed in the right-of-way along Gilbert Road at the northern edge of the France Stone Quarry property. Due to the lack of information on the distribution of possible contaminants on the property, 14 random sampling locations were generated by computer and plotted on an aerial photograph of the quarry site. The aerial photograph was used to pinpoint the sample locations in the field. Seven of the sample stations were located within a 200-ft wide strip along the northern property boundary, and the other seven were located in the remaining property south of this strip. At 13 of the stations, soil samples were collected from the top 1 ft using stainless steel hand augers. In several places, however, shallow bedrock or cobbles limited the sampling to the top ½ ft or less. At the last station, soil boring IA10-SB0025 was augured to a depth of 3 ft and samples were collected in 1-ft intervals. All soil samples from the quarry were analyzed for arsenic, barium, beryllium, lead, fluoride, and radionuclides. The 1 to 2-ft interval sample from IA10-SB0025 also was analyzed for VOCs.

3.2.2.4 Western Farm Field

The gamma walkover survey did not detect any activity greater than background with either the FIDLER or sodium iodide instruments on the farm field west of the Luckey site. Since no hotspots were identified, fourteen random sample stations were generated by computer and located using the GPS unit. Seven of the sample stations were located within the 200-ft walkover survey area, and the remaining seven were located beyond the survey area. At 13 of the stations, soil samples were collected from zero to 1½ ft using stainless steel hand augers. These samples were analyzed for arsenic, barium, beryllium, lead, and radionuclides. Soil boring IA10-SB0024, located within the 200-ft survey area, was hand-augured to a depth of 5 ft and soil samples were collected in 1-ft intervals. The zero to 1 ft and 2 to 3 ft

samples were analyzed for arsenic, barium, beryllium, lead, and radionuclides. The 1 to 2 ft interval sample was analyzed for metals, VOCs, SVOCs, and radionuclides, while the 3 to 4 ft and 4 to 5 ft interval samples were analyzed only for beryllium.

3.2.2.5 Troy Township Dump

The Troy Township Dump, located southeast of the Luckey site, encompasses approximately 6 acres. There is no documented evidence that the dump was used for the disposal of AEC-related materials. However, the dump was open during the beryllium production operations and an agreement that allowed the disposal of material from the plant was apparently in place at that time. Based on the possibility that AEC-related material could have been disposed there, the entire dumpsite was considered for investigation.

Because the dump remained open for 20 years after beryllium production ceased, it was expected that any material disposed at that time would now be deeply buried. To test for the presence of site-related materials, the Phase IV Sampling and Analyses Plan specified that two borings would be drilled at the dump to determine the nature and extent of potential contaminants. Soil samples were supposed to be collected from the middle of the fill material, from the base of the fill material, and from 3 ft below the base of the dump. In addition, it was planned that seven borings be advanced to a depth of 40 ft and that the two samples from each boring with the highest gamma activity be sent for further laboratory analyses. This plan was modified in the field since bedrock was encountered at depths ranging between 10 and 27 ft and the fill material was encountered down to the bedrock in several places.

As shown in Figure 3.11, seven borings were installed during the investigation of the dump. The borings were located to represent as much of the dumpsite as possible, but coverage was limited by accessibility. Four borings were drilled on the elevated plateau in the southern half of the dump using a rotosonic drill rig. A fifth boring was drilled along the sloped driveway approximately 100 ft south of Gilbert Road using a rotosonic rig. The two remaining borings were drilled in low areas in the northwest section of the dump using a hollow-stem auger drill rig. A boring could not be installed in the northeast corner of the site due to the heavy vegetative cover and the presence of more than a foot of standing water.

Continuous soil samples were provided by the rotosonic rig, which advanced a 10-ft-long core barrel and yielded a 4-inch diameter core. Continuous samples were obtained with the hollow-stem auger rig by driving a 3 inch inside diameter by 24 inch-long split-spoon sampler in accordance with standard field procedure FP3.2. Descriptive logs were compiled for each boring based on visual observations. These logs are provided in Appendix 3A.

Each 1-ft increment of the core samples was screened in the field with an organic vapor detector and radiological field instruments. The organic vapor detector was used primarily for health and safety concerns. Measurements that were provided by the alpha and beta-gamma radiological detection instruments were used to select soil samples for further laboratory analyses.

Borings IA10-SB0026 and IA10-SB0027 were installed to determine the nature and extent of possible AEC-related contaminants in the dumpsite. These were both drilled using the rotosonic rig and were the most extensively sampled borings at the dump. Soil samples were collected from the middle of the fill and base of the fill in these two borings, as well as from the two highest radiological field screening measurements in each boring. All of these samples were collected for laboratory analyses of arsenic, barium, beryllium, lead, fluoride, nitrogen-nitrate, and radionuclides. A number of samples also were obtained from the borings for analyses of beryllium only. These supplemental beryllium samples were collected to delineate the vertical extent or stratification of beryllium, if present.

Two samples were collected in each of the five other borings drilled at the dump. The samples were selected based on the highest radiological field screening measurements. If the measurements within a particular boring were not significantly different, then the samples from the approximate middle and base of the fill material were selected for analyses. All of these samples were analyzed for arsenic, barium, beryllium, lead, fluoride, nitrogen-nitrate, and radionuclides.

3.2.3 Monitoring Well Installation and Groundwater Sampling

Results of the initial sampling of the 25 on-site monitoring wells indicated that low concentrations of beryllium were present in two wells located near the northern boundary of the site. The water levels measured periodically in all 25 wells indicated that the direction of groundwater flow was toward the north. Several farms and residential houses dependent on water well supplies are located north of the site, the nearest being approximately 500 ft away. To further evaluate the potential for the off-site migration of site-related contaminants in groundwater, the USACE decided that additional monitoring wells should be installed between the site and the domestic water wells. In response to this concern, 12 additional wells were installed off site in the farm fields immediately north of the site. These wells were drilled in October 1998, several months after completing the initial on-site wells, because right-of-entry and access agreements between the property owner and the USACE had to be negotiated and signed.

The locations of these wells were selected based on groundwater flow maps developed using data from the initial 25 wells and in consultation with the Ohio EPA. The following objectives were identified to guide the placement of wells:

- better define the local groundwater flow,
- determine the influence of Toussaint Creek on groundwater flow,
- test different depth intervals in the bedrock; and
- use as an early warning detection system for the downgradient residential wells.

The locations of the 12 wells are shown in Figure 3.5. As shown in the figure, the wells were installed in pairs with a shallow and deep well at each location. The shallow wells were completed approximately 10 ft into bedrock, while all but one of the deeper wells were completed at about 35 ft into the bedrock. Monitoring well OMW-34(B) was completed at a depth of 90 ft to match the depth of the nearby residential well.

All borings for the off-site monitoring wells were advanced using a rotosonic drill rig that cored a 6 inch diameter hole. The wells were completed with flush threaded 2-inch diameter PVC casing and a 5-ft length of slotted PVC screen. The well design and installation procedures were accomplished in accordance with standard field procedure FP5.0. Descriptive boring logs and well completion diagrams for the 12 off-site monitoring wells are contained in Appendix 3A.

After installation, the monitoring wells were developed in accordance with standard field procedure FP5.1. Well development was accomplished by removing a minimum of five well volumes of groundwater from each well using a submersible pump. Development continued until stable readings of pH, temperature, and specific conductance were achieved and the turbidity values were as low as practicable. Final water quality measurements measured during well development are provided in Appendix 3B. After development was complete, each of the 12 wells was equipped with a submersible QED bladder pump for the collection of representative groundwater samples.

Groundwater samples were collected from the off-site wells in November 1998 and April 1999. All the wells were purged and sampled using low-flow micro-purge techniques in accordance with

standard field procedures FP5.2 and FP5.3. The water quality measurements recorded during the groundwater sampling events are contained in Appendix 3B. All of the off-site groundwater samples were analyzed for metals and radionuclides. Samples collected for analyses of dissolved constituents were filtered in the field according to standard procedure FP5.5.

In conjunction with the off-site monitoring well installation and sampling program, three nearby residential wells were sampled to characterize the quality of water currently being consumed (Figure 3.5). Samples were obtained from outside spigots in accordance with standard field procedure FP5.4. The spigots were carefully selected so that only samples of raw untreated water were obtained. Residential well locations, GW0002 and GW0003, located north of the site, were sampled in July and November 1998 and in April, July, and October 1999. Residential well, GW0004, located immediately west of the site, was sampled in July and November 1998. The samples were analyzed for metals and radionuclides.

3.2.4 Surface Water and Sediment Sampling

Surface water and sediment were sampled in off-site drainage features to evaluate the potential impact of site-related contaminants beyond the Luckey site boundaries. The sampling was conducted in October 1997, June to July 1998, and June 1999. The objective of the Phase II sampling event was to determine if the off-site media had been impacted by site-related contaminants. To satisfy this objective, off-site samples were obtained from the western ditch, the main drainage ditch near Toussaint Creek, along the NYCRR bed east of the site, and in Toussaint Creek. The rationale for the placement of these surface water and sediment samples is presented in Table 3.6.

Sediment samples also were obtained at four transects (BH0017, BH0018, BH0019 and BH0020) on Toussaint Creek to evaluate the nature and distribution of potential contaminants within the streambed. A transect was established by locating sampling stations across the Creek perpendicular to the flow. Three samples were collected at each transect: one came from sediments along the north bank of the Creek, one from sediments along the south bank, and one from sediments near the center of the stream. Twelve sediment transect samples were collected (three at each location).

Although not considered a current drainage feature of the site, the railroad right-of-way along the eastern property boundary also was sampled during the Phase II field investigation. Swales along both sides of the railroad bed were evaluated as possible former collection areas or drainage conduits for runoff from the site. It is unknown whether the two swales are, or were previously, hydraulically connected.

All of the surface water samples collected in Phase II were analyzed for metals, radioisotopes, VOCs, and SVOCs. With the exception of the transect samples collected along Toussaint Creek, sediment samples were analyzed for metals, radioisotopes, and SVOCs. Many of the sediment samples were analyzed for VOCs as well. The sediment transect samples from Toussaint Creek were analyzed only for metals and radioisotopes.

Results of the Phase II sampling indicated that site-related contaminants were present in the Toussaint Creek sediments as far as two miles downstream of the site. Although this sampling program was successful in defining the nature of the contaminants, the extent had not been fully delineated, because beryllium was detected in samples collected furthest downstream. A more intensive sampling program was conducted in June and July 1998 to determine the downstream extent and depth of these contaminants.

Beginning about 2½ miles downstream of the Luckey site, sediment samples were collected in the creek at approximately ½ mile intervals to a distance of 15 miles. Because much of Toussaint Creek is bordered by private land, the sampling was conducted at cross roads and sites that were accessible by

foot. Several USGS 7½-minute topographic maps were used to identify prospective sampling stations. The sites selected appear in Figure 3.12. Specific location coordinates of the sample points were determined in the field using a hand-held GPS unit.

At each sample station, professional judgment was used to choose sites within the stream that contained relatively thick accumulations of sediments. The original plan called for collection of sediment samples in 1-ft intervals to a depth of 3 ft at each location. At all sites, however, natural clay or sample refusal due to large rocks was encountered in the zero to 1 or 1 to 2 ft intervals. Because the natural clay was glacial till and not representative of streambed sediments, sampling was terminated when the clay was encountered.

The sediment sampling was performed in accordance with field procedure FP7.0. Samples were obtained using a 2 inch diameter by 18inch-long stainless steel sediment corer that was advanced with a hand-operated slide hammer. Before removing the core sampler from the zero to 1 ft interval, a 3 inch diameter by 2-ft-long steel shelby tube was pressed into the sediments around the sampler to a depth of 1 ft. This prevented loose wet sediments from collapsing into the hole after the corer was pulled, possibly compromising the integrity of successively deeper samples.

A total of 42 sediment samples were collected at 29 stations along Toussaint Creek in the Phase IV sampling event. All samples were analyzed for metals and radionuclides.

In addition to the sediment samples, a surface water sample was collected from Toussaint Creek on a weekly schedule over the duration of the 1998 field sampling program. A sampling station (IA06-SW0002) was established approximately 200 ft west of the bridge over Lemoyne Road (Figure 3.12). Samples were collected either by directly filling the sample containers in the stream or by using a transfer vessel in accordance with standard procedure FP7.0. The eight surface water samples were analyzed for metals, fluoride and radionuclides. Field measurements of pH, temperature, specific conductivity, dissolved oxygen, and turbidity were recorded at the time of sample collection.

In August 1998, one sediment sample and four surface water samples were collected at two locations within the France Stone Quarry. The two sample locations are shown on Figure 3.3. Horizontal coordinates of the sample locations were determined with a hand-held GPS unit. At both locations surface water was sampled at depths of 10 ft and 60 ft using a Kemmerer point source sampler, in accordance with standard procedure FP7.0. A sediment sample was collected at station IA10-SD0006 using a stainless steel petite Ponar sampler. A sediment sample also was planned for the other station, but no sediment was encountered on the quarry bottom at that location. Attempts to retrieve sediment from four separate spots in that area yielded only a few pieces of rock. All samples were analyzed for metals, radionuclides, VOCs, and SVOCs. In addition, field measurements of pH, temperature, specific conductivity, and dissolved oxygen were recorded for each water sample collected. Results of the surface water and sediment sample analyses are presented in Appendix 4A.2 and 4A.3. A detailed discussion of the results is provided in Section 4.4.

3.2.5 Meander Bend Sampling in Toussaint Creek

Toussaint Creek, located north of the Luckey site, receives discharge from the site's western and main drainage ditches. The creek flows toward the east and is generally bordered by farm fields. In its upper reaches, the creek bed is deeply incised in the region's clayey soils and has a minimal flood plain. Downstream, however, the creek meanders and has a more significant flood plain.

The sediments and soils on three meander bends located north of the site were evaluated as part of the RI. The locations of the three meander bends are shown in Figure 3.12. The objective of the

sampling was to determine the nature and extent of potential site-related contaminants. To accomplish this, five shallow soil borings were hand-augured on each of the meander bends. The boring sites were selected based on field observations of likely flood deposits and a cursory radiological survey. After delineating obvious depositional areas, the surface soils were scanned with hand-held alpha and beta-gamma detection instruments, and borings were augured at the five sites exhibiting the highest activity.

Each of the soil borings was augured to a depth of 5 ft or auger refusal, and a sample was collected from each 1-ft interval. A total of 46 samples were collected from the 15 soil borings. The sampling was performed in accordance with field technical procedures FP3.2 and FP3.3. A clean stainless steel auger bucket was used to sample each interval, and the samples were homogenized in a stainless steel bowl before dividing them into the appropriate sample containers. All samples were described based on visual examination in accordance with FP4.2. The field descriptions included characteristics such as grain size, USCS criteria, color, moisture content, and other pertinent observations. Descriptive logs of the meander bend borings are contained in Appendix 3A.

Each sample was scanned in the field with the alpha and beta-gamma detectors. Most of the meander bend samples were submitted for laboratory analysis of metals and radionuclides, but some were analyzed for beryllium only. In general, the upper two samples from each boring were analyzed for metals and radionuclides, while successively deeper samples were analyzed only for beryllium. Additionally, one sample from each meander bend site was analyzed for a full suite of chemical parameters including metals, radionuclides, VOCs, and SVOCs. Results of the meander bend sampling are presented in Section 4.4.2.

3.3 BACKGROUND SAMPLING

As part of the RI, a background sampling program was conducted to evaluate the natural or ambient concentrations of chemical constituents in the various environmental media at the site and in surrounding areas. Representative samples of surface soil, subsurface soil, groundwater, surface water, sediment, and air were collected and analyzed for selected chemical constituents to determine background conditions. Background samples were located in areas that were least likely to be influenced by past operations at the Luckey site. In addition, the samples were obtained from locations that were not impacted by other potential off-site sources of contamination. Background sampling locations are shown in Figure 3.13. The following major tasks were conducted during the RI background sampling program:

- collection and analysis of 23 surface soil samples,
- collection and analysis of 46 subsurface soil samples from 23 soil borings,
- collection and analysis of 17 groundwater samples from 6 monitoring wells,
- collection and analysis of two surface water and 11 sediment samples, and
- collection and analysis of two ambient air samples.

Background samples were collected from all environmental media in accordance with procedures presented in the Phase II or the Phase IV SAPs (SAIC 1997, 1998b). The selection of background sampling sites was consistent with the EPA guidance document *Determination of Background Concentrations of Inorganics in Soils and Sediments at Hazardous Waste Sites* (EPA 1995a), which recommends that the constituent, physical, and biological characteristics of the sites be considered in the selection process. Background samples were collected in the same manner and analyzed by the same laboratories as the other environmental samples collected for the RI.

This section discusses how the background data set for the RI was established. Locations of the background sampling sites are identified, and discussions of the number of samples, the methods of

sample collection, and sample analysis are provided for each environmental medium. A presentation of the calculation for specific background analyte concentrations is provided in Section 3.5.

3.3.1 Background Soil Sampling

Suitable areas for sampling background soils were identified using Ohio Department of Natural Resources (ODNR) soil maps of Wood County. The primary consideration was to locate areas with the same Hoytville Clay soil as that found at the Luckey site. The background locations consisted of a lightly wooded area, grassland, and a lawn. The final three locations were selected in concurrence with the Ohio EPA (Figure 3.13).

In 1997, three soil borings were installed at each of the OFFBKG 2 and OFFBKG 3 locations, and six borings were installed at the OFFBKG 1 location. The initial three borings at the OFFBKG 1 location were determined by ODNR to be in an unmapped inclusion of Rimer soils. Subsequently, three additional borings were installed at the same property but in the Hoytville Clay soil. The samples from the three borings in the Rimer soil series were not used in the background data set. In an effort to supplement the number of background soil samples and improve the statistical power of the data set, three additional soil borings were installed at all three locations during Phase IV (OFFBKG 1, OFFBKG 2, and OFFBKG 3).

A total of 69 soil samples were collected and used to determine background concentrations. The soil samples represent three depth intervals from 26 soil borings. Most of the borings were sampled in the intervals zero to ½ ft bgs, ½ to 1½ ft bgs, and 1½ to 2½ ft bgs. At each depth interval the sample was composited across the interval. Five additional soil borings completed in 1998 were sampled in the intervals zero to 1 ft bgs, 1 to 2 ft bgs, and 2 to 3 ft bgs. Because the background soils were collected from the same soil type and were obtained from depth intervals that are primarily considered as surface soils for risk assessment purposes, the samples were not segregated by depth for background determinations. This increased the statistical power of the background data set.

The sampling procedures were performed in accordance with the standard field technical procedures FP3.2 and FP3.3 contained in Appendix B of the Phase IV RI SAP (SAIC 1998b). After removing the sod layer or any foreign debris, a surface soil sample was collected from a depth of zero to ½ ft bgs using a stainless steel spoon or scoop. Samples for VOC analyses were obtained first using an Encore® sampler. The soil samples were described in the field based on visual inspection in accordance with FP4.2. The descriptions included characteristics such as grain size USCS criteria, color, moisture content, and other pertinent field observations. Descriptive logs of the background soil borings are contained in Appendix 3A.

The 33 background soil samples collected in Phase II were analyzed in an off-site laboratory for radionuclides, metals, anions, and SVOCs. In addition, at least one surface soil sample from each site was analyzed for pesticides and polychlorinated biphenyls (PCBs), and at least one subsurface sample per site was analyzed for VOCs. All of the background soil samples collected in Phase IV were analyzed for radionuclides, metals, VOCs, SVOCs, and PCBs.

3.3.2 Upgradient Groundwater Sampling

In July 1998, six monitoring wells were installed at three locations upgradient of the Luckey site to evaluate the background or ambient groundwater quality. A pair of wells, consisting of one shallow and one deep well, was completed at the same locations used for collecting background soils. These background locations were the only sites where permission was granted for access. Monitoring wells

BMW-09(I) and BMW-10(S) were located at OFFBKG 3, wells BMW-11(I) and BMW-12(S) at OFFBKG 2, and BMW-15(I) and BMW-16(S) at OFFBKG 1.

All boreholes for the monitoring wells were advanced using a rotosonic drill rig that cored a 6-inch diameter hole. The shallow wells were completed in unconsolidated deposits on top of the local bedrock, while the deeper wells were completed at a depth approximately 10 ft below the bedrock surface. The wells were completed with flush-threaded 2-inch diameter PVC casing and a 5 ft length of slotted PVC screen. Because bedrock was encountered at a depth of only 6½ ft bgs at the OFFBKG 2 location, the construction of shallow well BMW-12(S) was modified slightly. For this well, the screened length was reduced to 3½ ft to accommodate the bentonite seal and grout collar. The well designs and installation procedures were accomplished in accordance with standard field procedure FP5.0. Descriptive boring logs and well completion diagrams for the six background monitoring wells are contained in Appendix 3A.

After installation, the monitoring wells were developed in accordance with standard field procedure FP5.1. Well development was accomplished by removing a minimum of five well volumes of groundwater from each background well using a submersible pump or Teflon bailer. Development continued until stable readings of pH, temperature, and specific conductance were achieved. The water quality parameter measurements recorded upon completion of well development are provided in Appendix 3B. After development was complete, five of the six wells were equipped with QED bladder pumps in order to provide representative groundwater samples. Due to the low water level and the shallow depth of well BMW-12(S) at the OFFBKG 2, a Teflon bailer was dedicated to this well for sampling purposes.

Groundwater samples were collected from the background wells in August and November of 1998 and in April of 1999. All of the wells were purged and sampled using low-flow micro-purge techniques in accordance with standard field procedures FP5.2 and FP5.3. The three rounds of seasonal groundwater sampling yielded a total of 17 background samples. A sample was not collected from the shallow well at the OFFBKG 2 during the November 1998 sampling event because the well was dry.

Groundwater samples collected from the background wells in August 1998 were analyzed for total metals, dissolved metals, and radionuclides. In November 1998, groundwater samples were analyzed for these same chemical parameters plus fluoride and nitrogen-ammonia. Groundwater samples collected from the background wells in the April 1999 event were analyzed for an extensive list of chemical parameters. In addition to the tests performed in the two previous sampling events, the April 1999 samples were analyzed for alkalinity, chloride, nitrite/nitrate, sulfate, VOCs, SVOCs, TSS, TDS, gasoline range organics, and diesel range organics. The gasoline and diesel range organics were added by the USACE based on a newly acquired list of compounds likely used in past operations at the site (USACE 1999). The list was provided by a representative of Brush Wellman, Incorporated who indicated the compounds "were likely used for the purpose of producing beryllium at the Luckey plant." Samples collected for analysis of dissolved constituents were filtered in the field according to standard procedure FP5.5.

3.3.3 Upgradient Surface Water and Sediment Sampling

Two sediment and two surface water samples were collected from background locations during the Phase II field investigation. Nine additional background sediment samples were collected in Phase IV. All samples were collected from Toussaint Creek or its tributaries upstream from the site and located in relatively thick depositional areas. Ohio EPA actively participated in the selection and sampling of the Phase II background locations. All of the background samples were located in areas unaffected by potential contaminant sources from the Luckey site and are assumed to be representative of natural

conditions. The background values were compared to results from on site and downstream samples to identify potential site-related contaminants and evaluate the impact of contaminants that may have migrated off site.

In 1997, one set of surface water and sediment samples was collected from Toussaint Creek approximately 2 miles upstream of the site. The sampling point was located just upstream of the bridge where Layman Road crosses Toussaint Creek. A second set was collected on a tributary to Toussaint Creek, approximately 3½ miles upstream of the site. This sample location was just east of the bridge where State Route 199 crosses the tributary. Sample station locations are depicted in Figure 3.13. Topographic coordinates for these sample locations were not established.

In Phase IV, nine additional upstream sediment samples were collected to supplement the background data set. Seven of these samples were located along Toussaint Creek to a distance of approximately 5 miles. The other two samples were obtained on a tributary to Toussaint Creek. Accessibility to the sample points was achieved by selecting sites at local road or railroads crossings. The Dunkirk USGS 7½-minute topographic map and a hand-held GPS unit were used to determine the coordinates of the sampled locations, which are shown in Figure 3.13.

The Phase II sediment collection activities were performed in accordance with the *Sampling and Analysis Plan (SAP) for the Luckey Site* (SAIC 1997), standard operating procedure 191-IG-028, and the Ohio EPA's *Sediment Sampling Guide and Methodologies* (OEPA 1996). Sediment samples obtained in 1998 were collected at a depth interval of zero to 1 ft using a 2 inch-diameter stainless steel core barrel attached to a hand-operated slide hammer. The remaining sample was homogenized in the stainless steel bowl in accordance with FP3-3 and divided into the appropriate sample containers.

The two surface water background samples collected in Phase II were analyzed for metals, radionuclides, VOCs, SVOCs, anions, TDS, TSS, and alkalinity. The two sediment samples were analyzed for metals, radionuclides, VOCs, SVOCs, anions, pesticides, PCBs, total organic carbon (TOC), and pH. Background sediment samples collected in Phase IV were analyzed for metals, radionuclides, anions, VOCs, and SVOCs. Results of the background surface water and sediment analyses are presented Section 3.5.2.

3.3.4 Other Background Measurements

3.3.4.1 <u>Building Surveys</u>

Selection of a suitable background location for the sampling activities conducted in the buildings was problematic. No similar off-site buildings constructed in the same timeframe are known to exist in the Luckey area. The Employee Activity Building was therefore designated as the background building because it was constructed at the same time as the rest of the site buildings and had never been used for beryllium- or radiological-related activities. Originally, it was an office with minimal or no exposure to the processes in the rest of the complex. Beryllium and radiological scoping surveys were performed in this building to determine approximate background values for evaluating the remainder of the buildings. A grid was laid out using the northwest corner of the building as the origin (resulting in 360 grids). A 10% survey was performed in this building; therefore, 36 grids were selected.

Beryllium swipe samples were collected from the selected grids and floor cracks or areas where dust had settled. A total of 53 beryllium swipes were collected. In addition, nine building materials samples were collected and analyzed for beryllium. The average concentration of beryllium swipe samples was calculated at 0.15 $\mu g/100cm^2$, with a maximum value of 3.7 $\mu g/100cm^2$. The second highest concentration was measured at 0.55 $\mu g/100cm^2$. Without the maximum value, the average falls to 0.08

$\mu g/100cm^2$. The average beryllium concentration detected in building materials samples was 7.85 mg/kg with a maximum detected concentration of 18.2 mg/kg.

A smear was collected in each grid to measure transferable radioactivity. Two smears were sent for analysis of radionuclides at the off-site laboratory. All of the smears were below NRC Regulatory Guide 1.86 transferable criteria (20 disintegrations/minute (dpm) for alpha activity and 1,000 dpm for beta-gamma). Each grid was scanned for direct alpha and beta-gamma activity in cpm. None of the grids exceeded twice the established reference value for this building (3 to 6 cpm alpha and 274 to 302 cpm beta-gamma). Th-230 and U-238 were the only two radionuclides detected in the smears. Both concentrations were below 1 $pCi/100cm^2$ and flagged as estimated values.

3.3.4.2 Ambient Air

Air samples were obtained at two background locations during Phase II to determine the ambient air quality during non-intrusive field activities at the Luckey site. Samples for beryllium analyses were collected at background locations OFFBKG1 and OFFBKG3, while radiological air samples were collected only at OFFBKG3 (Figure 3.13).

Samples for beryllium analyses were collected using an Anderson Impactor (PM-10 particle size) with Whatman 41 cellulose-ester filters. The filter pore sizes included 7.2µm, 3µm, 1.5µm, 0.95µm, 0.49µm, and <0.49µm. Samples for radiological analyses were collected on cellulose-ester filters with a high-volume sampler (approximately 50 L per minute). The duration of collection was approximately 500 minutes (eight-hours). The radiological sample filters were analyzed on site using SAC-4.

The concentration of beryllium in the background air samples collected at OFFBKG1 and OFFBKG3 were below the laboratory detection limit of 3.4×10^{-4} mg/m^3. Gross alpha concentrations in the air samples collected at OFFBKG3 also were less than the minimum detection limit (9.93×10^{-16} µCi/mL). The results are presented in their entirety in Appendix 3D.

3.4 ANALYTICAL PROGRAM

The sampling and analysis programs conducted under the RI at the Luckey site included the collection and analysis of soil, sediment, surface water, groundwater, swipes, building materials, dust, and ambient and personal air monitoring samples. Field screening of samples was conducted primarily for health and safety reasons but also to select sample collection intervals.

Samples were collected and analyzed according to the requirements of two different quality assurance programs. Phase II was conducted under the requirements of the FUSRAP Quality Assurance Program Plan (QAPP) developed by the DOE. Project specific requirements were detailed in the Phase II SAP (SAIC 1997).

Phase IV was conducted under the requirements of the Luckey QAPP (SAIC 1998c). This QAPP was prepared in accordance with EPA QAPP and USACE guidance documents, *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans* (EPA 1991e), *EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations* (EPA 1994c), and *Requirements for the Preparation of Sampling and Analysis Plans* (USACE 1994).

The QAPPs outline the project organization, DQOs, intended data uses, quality assurance/quality control (QA/QC) activities, and specific protocols to achieve the desired DQOs and maintain defensibility of the data. Specific protocols detailed in the QAPP include field and sample documentation, sample

collection, sample preservation, handling and storage, sample packaging and shipping, chain of custody, laboratory analytical procedures for all media sampled, and QA/QC requirements.

The project DQOs delineate the goals of the RI for the field activities and analytical program. DQOs were developed prior to the initiation of Phase II RI field activities to focus the phased field efforts and assure data quality. Specific analytical parameters and methods are detailed. The quality of the data is assessed in terms of accuracy, precision, sensitivity, completeness, representativeness, and comparability.

The following subsections present the program DQOs, field screening methods, an overview of the analytical program, and a summary of the DQA.

3.4.1 Data Quality Objectives

The project DQOs for the Luckey site RI were developed using DOE's Streamlined Approach for Environmental Remediation (SAFER) approach, in conjunction with the EPA DQO process (EPA 1994a). SAFER focuses on the data needed to define and evaluate site conditions based on a source/pathway/receptor evaluation. The EPA DQO process focuses on the need/decision/action evaluation for a site. The DQOs were developed and presented in the SAP prepared for the Phase II portion of the RI. Upon completion of Phase II, the data were evaluated against the DQOs and the remaining data necessary to fulfill the DQOs were identified for collection during Phase IV of the RI.

Quality assurance objectives were developed to support the project DQOs. The primary goal of the quality assurance objectives is to ensure the collected data supporting the conclusions of the RI are legally defensible.

3.4.1.1 <u>SAFER Approach</u>

The SAFER approach assesses the site's "probable conditions" based on available data. It is SAFER's intent that the probable conditions be understood to the extent necessary to meet the DQOs (i.e., evaluating site risk and selecting the preferred remedial alternative).

Under the SAFER approach, a detailed conceptual model was developed based on the current understanding of conditions at the Luckey site. The overall conceptual model developed for this site is detailed in Section 5 of this report. The conceptual model is presented in tabular and graphical form with narrative descriptions. The conceptual model of the Luckey site takes into consideration the following parameters:

- primary sources (e.g., surface storage areas, ore-processing operations, waste disposal areas, etc.);
- primary release mechanisms (e.g., erosion, wind-blown dust, surface water runoff, stack emissions, etc.);
- secondary sources (e.g., surface water, sediments, groundwater, dust settled on building features, etc.);
- secondary release mechanisms (e.g., sediment deposition, stormwater runoff, fugitive dust, etc.);
- pathway of migration (e.g., ditches and creeks, groundwater flow, wind, etc);
- exposure routes (e.g., inhalation of dust, ingestion of soil, surface water, groundwater, etc.); and
- potential receptors (e.g., residential farmer/child, industrial worker, teenage trespassers, etc.).

3.4.1.2 Data Quality Objectives

EPA's DQO process (EPA 1994a) was used in conjunction with the SAFER process to develop the DQOs for the Luckey site RI. This process as it pertains to the development of DQOs at the Luckey site is presented in both the Phase II SAP (SAIC 1997) and the Phase IV SAP (SAIC 1998b). There are several objectives of this RI, and each concern the collection of sufficient data. One primary objective is to collect data of sufficient quality and quantity to evaluate the risk posed by the site to human health and the surrounding environment under current and future planned land uses. If an unacceptable risk is calculated for the site, an additional objective will be to acquire sufficient data to develop and evaluate alternatives for possible remedial actions. Both of these objectives require a definition of the three-dimensional distribution of COPCs.

The primary DQOs developed for the RI at the Luckey site are listed below. Each primary objective is subdivided into more specific DQOs:

1) Determine if constituents of concern (COCs) are present in the various media at the Luckey site at concentrations posing risk to human health (site workers and surrounding public) and the environment. More specifically:

   - Determine the nature and extent of radiological and chemical constituents of potential concern (COPCs).
   - Determine the nature and extent of radiological or chemical COPCs migrating off site through surface water and sediment.
   - Determine if radiological or chemical COPCs are present in groundwater at the site and, if so, determine the nature and extent.
   - Determine if ecological receptors present at the site are being affected by COPCs.
   - Determine the physical conditions of the site media that promote or retard the mobility of COPCs.
   - Determine if current workers are being exposed to gamma radiation at levels exceeding regulatory guidelines.
   - Determine if current workers are being exposed to airborne radiological and chemical COPCs at levels exceeding regulatory guidelines.
   - Determine if current workers are being exposed to building surface radiological activity levels (fixed and removable) exceeding regulatory guidelines and, if so, determine the nature and extent.

2) Determine and collect the type and quality of data required to evaluate a broad range of remedial action alternatives that will minimize or eliminate public health risks and impact to the environment. More specifically:

   - Determine the volume of impacted soil at the site with radiological activity levels exceeding action levels.
   - Determine if soil exceeding radiological guidelines also qualifies as a RCRA hazardous waste (volume of mixed waste present at the site).
   - Determine the total volume of soil at the site with beryllium concentrations and other potential AEC constituents above respective criteria.
   - Determine the soil geotechnical properties and depth to groundwater conducive to on-site remedial solutions.
   - Determine the conduciveness of the site to treatment options such as soil washing and groundwater treatment.

- Determine if dust in the buildings qualifies as a RCRA hazardous waste in the event that building remediation and dust disposal is determined to be necessary.
- Support potentially responsible party (PRP) cost recovery for contaminants inter-mixed with AEC related contaminants but not a result of AEC activities.

3.4.2 Field Screening Methods

During the 1998 field investigative effort, a large number of soil samples were collected on the Luckey site as part of the RI. Each of the soil samples, collected on site, was screened in the field for organic vapor content and radiological activity using hand-held instruments. The semi-quantitative field measurements were used mainly for health and safety concerns, but they also were used to select samples for more extensive laboratory, chemical, and radiological characterization. Results of these field measurements were recorded in dedicated logbooks or on standard sample forms at the time of sample collection.

Most of the surface and subsurface soil samples were screened for organic vapor content using a PhotoVac Micro Tip PID. This instrument was used to measure the combined concentration of a wide array of organic compounds in the parts per million range. It was not capable of discriminating between concentrations of individual organic compounds, but it was useful as a general survey tool to locate areas of elevated organic contamination. Each 1-ft core of soil was scanned with the PID immediately after the sampling device was opened and the soil was exposed. The readings were used to upgrade or downgrade the levels of PPE as necessary, but they also were used to decide when to collect samples for laboratory VOC analyses.

A Foxboro Century 128 Organic Vapor Analyzer (OVA) with a flame-ionization detector (FID) was used to screen soil samples from the 10 boreholes installed at the former oil handling facilities. Experience with both FID and PID instruments at the site indicated that the FID was more sensitive to petroleum-based hydrocarbon contaminants. Soils obtained from the borings at the oil handling facilities were scanned with the OVA as soon as the core tube was opened as an initial test for contamination. Additionally, a portion from each 1-ft section of the core sample was contained in a zip-lock bag and stored away from potential sources of fugitive contamination. After a period of 10 to 15 minutes, the bag was opened slightly and the tip of the OVA was inserted. The sustained organic vapor concentration was recorded on the log sheet. The samples with the highest measurements detected by the OVA in each of these borings were selected for further laboratory analyses.

Alpha and beta-gamma radiation field screenings were conducted on all soil cores obtained from on-site areas. The scans were performed immediately after the sampling device was opened, exposing the soil, and prior to placing the samples in containers. The instruments typically used to measure radiological activity included a Ludlum 2224 scaler/ratemeter with a 43-89 alpha/beta probe, a Ludlum 2929 dual scaler, and a Bicron microrem meter. These tools were used as qualitative indicators of contamination and as a guide for directing further sampling activities when contamination was detected. Upon completion of sampling at each location, total and removable alpha and beta-gamma contamination surveys were performed on sampling equipment and materials, sample containers, and personnel. In addition, smears of sampling equipment and sample containers were collected and analyzed in the field office using an Eberline RO-2 ion chamber.

Calibrations of the FID, PID, and radiological instruments were field checked each day prior to use. The field calibrations were performed according to directions provided by the instrument manufacturers and were recorded in calibration logbooks. If an instrument could not be successfully calibrated, it was taken out of service and repaired. A sufficient number of instruments were maintained on site as replacements while instruments were being repaired.

3.4.3 Overview of Laboratory Analytical Parameters and Methods

Samples were analyzed by independent laboratories under contract for each phase of the investigation. The analytical laboratories, parameters, and methods are listed according to sample media in Tables 3.7 through 3.14. Strict adherence to the requirements set forth in the QAPP was required of the analytical laboratories so that conditions adverse to quality would not arise. Laboratory standard operating procedures are based on the methods as published by the EPA in Test Methods for Evaluating Solid Waste, *Physical/Chemical Methods SW846*, Third Edition (November 1986; Revision 1, July 1992; Revision 2, November 1992; and Updates 1, 2, and 3).

Analytical data were validated according to the guidelines and procedures described in these documents:

- *National Functional Guidelines for Organic Data Review, Multi-Media, Multi-Concentration*, December 1990, Revised June 1991;
- *Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analyses*, February 1988, Revised January 1993; and
- *SAIC Quality Assurance Technical Procedures; Volume I, Data Management: Data Validation Procedure, Revision 3*, September 1996.

Approximately 10% of the data were validated as specified in the Luckey QAPP (SAIC 1998c). The validators were responsible for (1) reviewing laboratory data packages and applying required control limits (2) using professional judgment where specific limits were not specified, (3) qualifying affected data points on applicable results forms, and (4) preparing a data validation report for actions taken.

Analytical validation results were reviewed before incorporating validation qualifiers into the Luckey RI electronic database (Tables 3.15 and 3.16). The validation results were reviewed for consistency and completeness to resolve any questions. After the validation qualifiers were incorporated into the database an output report was printed and compared to the input data. All changes were documented and incorporated into the Luckey RI database as the final qualifiers.

3.4.4 Analytical Data Quality Assessment

The DQA describes the evaluation of the data quality indicators (DQIs) that were used to assess the quality of the analytical data collected for the USACE Luckey RI. The DQIs (accuracy, precision, completeness, representativeness, and comparability) are assessed with respect to the project DQOs. Project DQOs establish the data end uses and end users and provide objective criteria by which the data quality can be measured. More importantly, the DQO process identifies the up-front protocols, processes, procedures, and methods by which the DQOs can be met. With the appropriate planning for project DQOs, their achievement provides the basis for concluding that the acquired investigation data are scientifically sound, legally defensible, and adequate for their intended use. An overview of the results of the DQA follows:

(1) the data validation process found no systematic problem and produced minor qualifications of the results,
(2) completeness for the Luckey RI data is > 99%,
(3) overall project accuracy (all matrices/all parameters) is 96.7%,
(4) overall analytical precision (all matrices/all parameters) is 97.7%,
(5) overall field duplicate precision (all matrices/all parameters) is 84.8%,
(6) documented representativeness was achieved for the Luckey RI, and
(7) documented comparability was achieved for the Luckey RI.

DQIs were found to be sufficiently in control. All project DQOs were met. A breakdown of DQIs by matrix and parameter is addressed in the Luckey RI DQA, Appendix 3E.

QA/QC samples were collected during the field effort to assist in the data quality assessment. QC samples include field trip blanks, field duplicates, laboratory method blanks, laboratory control samples, laboratory duplicates, rinsate blanks, field blanks, and matrix spike/matrix spike duplicate (MS/MSD). QC samples were analyzed by the primary laboratory (GEL). QA samples are split samples analyzed by an independent laboratory (Argonne National Laboratory). Table 3.17 lists the primary samples and associated split and field duplicate samples.

3.5 REMEDIAL INVESTIGATION EVALUATION PROCESS

3.5.1 Overview of the Evaluation Process

A major step in evaluating the RI data is to distinguish between constituents that are likely related to past waste handling and/or disposal practices at the site, and those that may be present at naturally occurring or background levels. As part of the RI, background samples were acquired from all environmental media. This data set was evaluated to establish concentrations of chemical constituents that could be considered as background for each of the media tested. Results of the environmental sampling conducted on site and off site were compared to the background concentrations to identify areas possibly impacted by site-related contaminants.

The nature and extent of site-related contaminants identified for the Luckey site and adjacent properties were evaluated for each medium. This evaluation was performed to help delineate the boundaries of the contaminants and determine whether their occurrence was localized or widespread. The calculated background concentrations and the extent of contamination were then used in a BRA to evaluate the potential risk to human health and the environment.

As an initial step in the risk assessment, chemical and radiological elements identified as site-related contaminants were compared to relevant regulatory standards, risk-based guidelines, and preliminary remediation goals (PRGs) to quantify the significance of their occurrence. In addition, contaminants detected above the 95% UTL were screened using weight-of-evidence techniques and EPA Region 9 risk-based PRGs. Elements that were determined to be below these guidelines were eliminated from further consideration in the risk assessment. Site-related contaminants that failed the initial screening were designated as COPCs and were examined more critically to evaluate the risk to human and ecological receptors. An exposure and toxicity assessment was performed for each of the COPCs to determine the actual COCs. COCs were identified as those COPCs that exceed acceptable risk criteria established by EPA for each receptor and pathway. The COCs represent the main contributors to human health and ecological risk that will need to be addressed during potential remedial actions.

3.5.2 Background Statistics and Comparisons

The 95% upper tolerance limit (UTL) was used to identify which chemical and radiological constituents detected at the site were present above naturally occurring background levels. The UTL is an upper confidence limit for a given percentile of the background data set. It represents the concentration below which 95% of the background sample data fall with 95% certainty. This method is recommended in *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities* (EPA 1989b) and in other EPA guidance (EPA 1995a and EPA 1992a). Background values were established for each appropriate inorganic analyte (e.g., metals and radioisotopes).

Background data for all media were evaluated for reasonableness of results. This is particularly applicable to radionuclides where secular equilibrium should prevail. A variance was identified for uranium in one background soil sample. The concentrations of uranium isotopes were significantly different than known natural ratios of U-234, U-235 and U-238. When evaluated the U-235 value was determined to be a statistical outlier in the U-235 data set. In addition, it was not in agreement with the U-234 and U-238 concentrations measured in the sample. That value was eliminated from the data set used to calculate background for U-235.

The calculation of the 95% UTL is dependent on the distribution of each analyte in the background data set. The Shapiro-Wilk W-statistic was used to determine whether the background data set was most like a normal or lognormal distribution. If the distribution was considered lognormal, log-transformed data were used to calculate the UTL; otherwise, untransformed data were used. Results less than the detection limit were set to one-half the quantitation limit. However, if there were fewer than 50% detects, or fewer than 10 total samples, the UTL was not calculated. The maximum concentration above the detection limit was used as the background criterion if a UTL could not be calculated or for distributions that were neither normal nor lognormal.

The equation used to calculate the 95% UTL for analytes with a normal distribution was:

$$UTL = \bar{x} + k(s),$$

For lognormal distributions, the equation used to calculate the 95% UTL with log transformed data was:

$$UTL = e^{\bar{x} + k(s)},$$

where:

$\bar{x}$	=	sample arithmetic mean,
k	=	k statistic table-value, dependent on the sample size (Gilbert 1987),
s	=	sample standard deviation, and
e	=	exponential conversion for lognormal data.

Data collected from the Luckey site were compared to the 95% UTL of the background data set. To apply the background 95% UTLs to the site-related data, all results in a given media, and aggregate where applicable, were compared to the constituent-specific 95% UTL. If the concentration of an analyte from the site data was larger than the calculated background 95% UTL, the site data was determined to be above background and designated as a site-related COPC. If the concentration of an analyte from the site data fell below the 95% UTL, the data were considered to be indistinguishable from background. Specific analytes that were not detected at concentrations greater than the 95% UTL were considered naturally occurring and, therefore, not related to industrial operations at the site. On the other hand, if the concentration of a specific analyte from the environmental samples was greater than the calculated 95% UTL, the sample data was considered above background and designated as a site-related contaminant.

Tables of background values for each environmental media were developed using the methods outlined above. The background values are listed in Tables 3.18 and 3.19. Tables of related statistical values such as the maximum, minimum, and average detected concentrations, as well as the 95% UTL values appear in Appendix 3F. Analytes were placed in the following categories: (1) analytes sampled for but never detected, (2) analytes detected but always at concentrations less than the background values, and (3) analytes detected above background criteria. Analytes in the third category were considered as constituents that may be of concern. A discussion of the nature and extent of the identified constituents is provided in Section 4.

3.5.3 Preliminary Remediation Goals and Regulatory Guidance Levels

Constituent-specific PRGs are acceptable concentration values for individual chemicals for specific medium and land use combinations. PRG values may be used for preliminary evaluation of the nature and extent of contamination. PRGs may be risk-based, based on applicable or relevant and appropriate requirements (ARARs), or background concentrations for naturally occurring constituents. PRGs are typically developed during project scoping (DQOs development) or concurrently with early RI and feasibility study activities in order to facilitate the development of appropriate detection limits and potential remedial alternatives.

PRGs for the COPCs related to past AEC activities at the site are presented in this RI report. These PRGs consist of human health risk-based values developed by EPA Region 9, National Primary Drinking Water MCLs, 10 CFR 20, 10 CFR 40, and 40 CFR 192 for radiological contamination in soil, and background concentrations for naturally occurring constituents. The following types of PRGs are available for each medium:

- *Soil PRGs*: EPA Region 9 PRGs, 10 CFR 20, 10 CFR 40, 40 CFR 192, and background values
- *Groundwater PRGs:* MCLs, EPA Region 9 PRGs, and background values
- *Sediment PRGs*: Background values
- *Surface water PRGs*: Background values, Ohio Water Quality Criteria
- *Building surfaces PRGs:* Background values, NRC guidelines, DOE "housekeeping" guidelines
- *Bulk Dust PRGs:* Calculated comparison to OSHA guidelines for air.

For some chemicals, more than one PRG is available for a given medium. In these cases, the basis for the PRG was considered in determining the appropriate PRG to use. For example, where background concentrations exceed risk-based concentrations, the background values should be used as the basis for evaluating site data. However, it should be emphasized that PRGs are not intended to be used as final cleanup values. Final cleanup values will be developed after the BRA has been completed. In addition, note that the revised PRGs are developed in the BRA to assist with remedial alternative development.

The various PRGs for inorganic and radiological constituents in soil and groundwater are presented in the risk assessment contained in Sections 6 and 7 of this report. The PRGs for soil include industrial, residential and agricultural land use scenarios. Groundwater PRGs also are included for these scenarios and MCLs, where appropriate. These PRGs were used in together with site-specific background values to identify potential site-related contaminants for further evaluation in the risk assessment. For surface water and sediment, upstream data were used to provide the necessary quantitative values for comparison.

3.5.3.1 <u>Risk-based Preliminary Remediation Goals</u>

Risk-based PRGs have been developed by EPA Region 9 in accordance with EPA's *Risk Assessment Guidance for Superfund* methodology (EPA 1991b). These risk-based PRGs are not site-specific; rather, they are based on default values that are believed to represent average site conditions and conservative exposure assumptions. Risk-based PRGs set concentration limits using both carcinogenic and non-carcinogenic toxicity values based on risk from multiple exposure pathways. Risk-based PRGs are derived from a specified acceptable excess lifetime cancer risk (ELCR) or non-cancer hazard quotient (HQ). Cancer risk levels typically are based on the National Contingency Plan (NCP) target risk range of 1×10^{-6} to 1×10^{-4} ELCR. Non-cancer risk goals are based on a target HQ of one (1.0). Some constituents have PRGs based on both cancer and non-cancer risks, and PRGs are calculated for both types of risks. For these constituents, the lower PRG is used.

3.5.3.2 ARAR-Based PRGs

ARAR-based PRGs include promulgated standards that may be considered as cleanup goals for a particular site. Two ARAR-based PRGs were considered in the Luckey RI: National Primary Drinking Water MCLs, and EPA and DOE soil standards for radiological contamination. MCLs are constituent-specific maximum concentration limits established as enforceable drinking water regulations. Standards set forth in 40 CFR 192.12 establish Ra-226 criteria at 5 pCi/g above background for soil zero to 15 cm (6 inches) bgs and 15 pCi/g above background for soil below 15 cm (6 inches).

3.5.3.3 Background-Based PRGs

Site-specific background concentrations of naturally occurring constituents in a wide range of environmental media were determined during the RI. The background evaluation included soil, groundwater, surface water, and sediment and is discussed in detail in Section 3.5.2 above.

Building data is difficult to compare to background since the age of the building and the materials used in construction can affect the results of all surveys. The employee activity building was not used in the production process and therefore presents a possible background location for comparison with the other buildings. It was constructed at the same time as the rest of the buildings and of similar materials.

3.5.3.4 Building Surfaces PRGs

There are several ARAR-based PRGs that can be used to make comparisons with building data. For radiological constituents the NRC Regulatory Guide 1.86 identifies standards for surface contamination criteria. No similar standards exist for beryllium on building surfaces. OSHA has a standard for beryllium in air but the concentrations on building surfaces can not be related directly to an air concentration. DOE and various parts of the DOE complex have been engaged for several years in examining standards to be used to prevent chronic beryllium disease.

DOE has developed a guideline for beryllium on surfaces of 1 $\mu g/100cm^2$ beryllium for dry swipes and 5 $\mu g/100cm^2$ for wet swipes. This is not a promulgated standard. The only current legal standard is the OSHA standard, which establishes an exposure limit in air. The surface contamination guidelines are considered "housekeeping" guidelines rather than strict standards. The DOE "housekeeping" guidelines are recognized as goals that can reasonably be attained rather than risk-based PRGs. DOE's proposal, of 1 $\mu g/100cm^2$ beryllium for dry swipes and 5 $\mu g/100cm^2$ for wet swipes is used for comparison in this report.

NRC guidance levels for the unrestricted release of equipment have been selected to evaluate the results of the radiological survey in the buildings (NRC 1974 and 1982). A conservative approach would be to compare the values to the most restrictive NRC 1.86 guidelines, which are the guidelines for alpha activity, associated with Ra-226 and Th-230. The guidelines for beta-gamma activities are less stringent. However they are included for comparison purposes. The guidelines for alpha and beta-gamma activities are:

	Ra-226 & Th-230 (alpha)	Uranium (beta-gamma)
average activity:	100 dpm/100 cm^2	5,000 dpm/100 cm^2
maximum fixed activity:	300 dpm/100 cm^2	15,000 dpm/100 cm^2
removable alpha activity:	20 dpm/100 cm^2	1,000 dpm/100 cm^2

3.5.3.5 Bulk Dust PRGs

Bulk dust, sampled in the on-site buildings, also has no formal standard. A criterion of 20 mg/kg has been developed based on the American Conference of Government and Industrial Hygienists (ACGIH) nuisance dust guideline of 10 mg/m^3. The ACGIH proposed guideline for a maximum 8-hour, time-weighted average (TWA) concentration for airborne beryllium in an occupational setting is 0.0002 mg Be/m^3. It can be related to the nuisance dust guideline by the following relationship:

$$10 \text{ mg building dust/m}^3 \times Y = 0.0002 \text{ mg Be/m}^3$$

$$Y = [0.0002 \text{ mg Be/m}^3] / [10 \text{ mg building dust/m}^3]$$

$$Y = 0.00002 \text{ mg Be/mg building dust}$$

$$[0.00002 \text{ mg Be/mg building dust}] \times [1\text{x}10^6 \text{ mg/kg}] = 20 \text{ mg/kg}$$

This calculation shows that if the concentration of total beryllium in settled dust does not exceed 20 mg/kg and if the ACGIH nuisance dust guideline of 10 mg/m^3 is not exceeded, then the proposed ACGIH TWA will not be exceeded.

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Table 3.1. LIBS and Radiological Survey Correlation Samples

LIBS Correlation Samples				Radiological Correlation Samples					
Analytical Samples				*Analytical Samples*		*ISGS Samples*			
Station ID	**Sample ID**	**Station ID**	**Sample ID**	**Station ID**	**Sample ID**	**Station ID**	**Sample ID**	**Station ID**	**Sample ID**
04EY00	LU00178	10CQ01	LU00231	05FR01	LU00241	03FW01	030927	07EV02	101726
04EZ00	LU00179	10CR00	LU00232	05FS00	LU00242	03FW01	041702	09CM00	061358
05EV00	LU00180	10CL01	LU00233	05FL02	LU00243	03FW01	060748	09CM00	061341
05EV01	LU00181	10CM00	LU00234	05EN01	LU00244	03FW01	061717	09CX00	061121
05EW00	LU00182	10CH01	LU00235	06EU01	LU00245	03FW01	101850	09CX00	061140
05EW01	LU00183	10CI00	LU00236	07EV01	LU00246	03FW01	110913	09DA03	060931
05EX00	LU00184	10CI01	LU00237	07FA00	LU00247	03FW01	111716	09DA03	061016
05EX01	LU00185	10CJ00	LU00238	07FF00	LU00248	03FW01	060812	09DA03	060950
05EY00	LU00186	10CJ01	LU00239	07FK00	LU00249	03FW01	291737	09DH00	061041
05EZ00	LU00187	05EI00	LU00240	07AW01	LU00250	03FW01	301132	09DH00	061059
06EV00	LU00188			07AW02	LU00251	03FW02	060837	10AW02	061431
05EB00	LU00189			07AX02	LU00252	03FW03	060901	10AW02	061451
05EC00	LU00190			07AY01	LU00253	04AX00	110959	10BB02	061512
05ED00	LU00191			07AY02	LU00254	04AX00	111654	10BG02	061600
05EE00	LU00192			07AZ01	LU00255	05BE00	111153	10BG02	061626
06EA00	LU00193			08AV01	LU00256	05EN02	041500	11DN02	101426
06EB00	LU00194			10AW02	LU00257	05ET01	041030	11EI02	101351
06EC00	LU00195			10BB01	LU00258	05ET01	041621	11FC02	101305
06ED00	LU00196			10BB02	LU00259	05ET01	041103	11FC02	101326
06EE00	LU00197			10BG01	LU00260	05ET01	041135	11FH02	101119
05DY00	LU00198			10BG02	LU00261	05ET01	041358	11FH02	101140
05DT00	LU00199			10CX01	LU00262	05FR02	301432	11FR02	101059
05DN00	LU00200			10CS01	LU00263	05FR02	301452	11FW02	101037
05DI00	LU00201			10CM01	LU00264	06BK01	111452	11GB02	100953
01AX00	LU00210			09DA02	LU00265	06BK01	111523		
01BD00	LU00211			09DB01	LU00266	06FV00	301210		
01BJ00	LU00212			09DC01	LU00267	06FV00	301300		
05EC00	LU00213			09DC02	LU00268	06FX00	301324		
08FI01	LU00217			09DC03	LU00269	06FX00	301401		
08GD00	LU00218			08ED01	LU00270	06FY01	301550		
08FI01	LU00219			08EI01	LU00271	06FY01	031013		
08FY00	LU00220			08EI02	LU00272	07AP00	111131		
08FT01	LU00221			08EH01	LU00273	07AP00	111113		
08FT01	LU00222			10EF01	LU00274	07AZ00	111031		
08FT00	LU00223			10EF00	LU00275	07AZ00	111054		
08FN01	LU00224			09EJ01	LU00276	07BE00	031108		
08FN00	LU00225			09EJ02	LU00277	07BE00	031127		
08FI00	LU00226			09EI01	LU00278	07EL01	101806		
09DI00	LU00227			09EI02	LU00279	07EL01	101750		
09DE00	LU00228			09EH01	LU00280	07EV02	101646		
09CZ01	LU00229			10BG02	LU00281	07EV02	101828		
10CV00	LU00230			09EH01	LU00282	07EV02	101704		

ISGS - in situ gamma-ray spectroscopy
LIBS - Laser Induced Breakdown Spectroscopy

Table 3.2. Phase II COPC Samples and Analyses

Investigation Area (IA)	Sample Station	Sample ID	Sample Type	Collection Date	Radionuclides	Metals	Beryllium by HF Digestion	VOCs	SVOCs	Anions	pH
IA01	09EZ01	LU00148	surface	07-OCT-97	yes	yes	yes	no	yes	yes	yes
	10FD01	LU00149	surface	07-OCT-97	yes	yes	no	no	yes	yes	yes
IA02	04AX00	LU00150	subsurface	21-OCT-97	yes	yes	yes	yes	yes	yes	yes
		LU00151	subsurface	21-OCT-97	yes	yes	no	yes	yes	no	yes
	05BE00	LU00152	subsurface	21-OCT-97	yes	yes	yes	yes	yes	yes	yes
		LU00153	subsurface	21-OCT-97	yes	yes	no	yes	yes	no	yes
	08AW00	LU00154	subsurface	22-OCT-97	yes	yes	yes	yes	yes	yes	yes
		LU00155	subsurface	22-OCT-97	yes	yes	no	yes	yes	no	no
	10AX00	LU00156	subsurface	22-OCT-97	yes	yes	no	no	yes	no	no
		LU00157	subsurface	22-OCT-97	yes	yes	yes	yes	yes	yes	yes
IA05	07FR00	LU00158	subsurface	23-OCT-97	yes	yes	yes	yes	yes	yes	yes
	08EX00	LU00159	subsurface	23-OCT-97	yes	yes	no	yes	yes	no	no
	08FE00	LU00160	subsurface	23-OCT-97	yes	yes	yes	yes	yes	yes	yes
	BH0015	LU00161	subsurface	23-OCT-97	yes	yes	no	yes	yes	no	no
	08FS01	LU00162	subsurface	27-OCT-97	yes	yes	yes	yes	yes	no	no
	08FS02	LU00163	subsurface	27-OCT-97	yes	yes	yes	yes	yes	yes	yes
IA03	09DI00	LU00166	subsurface	29-OCT-97	yes	yes	yes	yes	yes	no	no
		LU00167	subsurface	29-OCT-97	yes	yes	yes	yes	yes	yes	yes
	10DD00	LU00168	subsurface	29-OCT-97	yes	yes	yes	yes	yes	no	no
IA07	05EI00	LU00172	subsurface	29-OCT-97	yes	yes	yes	yes	yes	no	no
	03EQ01	LU00174	subsurface	29-OCT-97	yes	yes	yes	yes	yes	yes	yes
		LU00175	subsurface	29-OCT-97	yes	yes	yes	yes	yes	yes	yes
		LU00176	subsurface	29-OCT-97	yes	yes	yes	yes	yes	no	no
	06FD00	LU00177	subsurface	29-OCT-97	yes	yes	yes	no	yes	yes	yes
IA01	09FU01	LU00202	subsurface	30-OCT-97	yes	yes	yes	yes	yes	yes	yes
	09EJ01	LU00206	subsurface	30-OCT-97	yes	yes	yes	yes	yes	yes	yes
	10FI01	LU00204	subsurface	30-OCT-97	yes	yes	yes	yes	yes	yes	yes
	11EV01	LU00208	subsurface	30-OCT-97	yes	yes	yes	yes	yes	yes	yes
		LU00214	subsurface	30-OCT-97	yes	yes	yes	yes	yes	yes	yes

COPC – constituent of potential concern
HF – hydrofluoric acid
SVOCs – semivolatile organic compounds
VOCs – volatile organic compounds

Table 3.3. Rationale for Placement of On-site Groundwater Monitoring Wells

Monitoring Well (MW)	Well Depth (ft – bgs)	Features of Interest	Rationale For Monitoring Well Placement
MW-01(I) MW-02(S) MW-39(B) MW-40(B)	29.90 19.50 92.00 56.22	Sewage Treatment Plant and Filter bed in IA05, Bare Spot in IA07, and local groundwater flow	This 4-well cluster was placed at the northern boundary of the site between the filter bed of the Sewage Treatment Plant and the Bare Spot in IA07 to evaluate off-site migration in shallow unconsolidated deposits and in shallow, intermediate, and deep zones within the bedrock.
MW-03(I) MW-04(S)	27.00 17.00	Lagoons A and B	Evaluate quality of shallow and deep groundwater on the upgradient side of Lagoons A and B.
MW-05(I) MW-06(S)	29.75 18.30	Trenches and Pits at the northeast corner of the Luckey site	Assess off-site groundwater migration east of IA01 along northeast side of Luckey property.
MW-07(I) MW-08(S)	31.20 20.30	Trenches and Pits at the northeast corner of the Luckey site	Assess off-site groundwater migration east of IA01 along northeast side of Luckey property.
MW-13(S) MW-19(I)	17.20 29.00	Trenches and Pits at the northeast corner of the Luckey site	Evaluate quality of shallow and deep groundwater zones downgradient of Trenches and Pits in IA01.
MW-14(S)	17.01	Lagoon A	Evaluate quality of shallow groundwater zone downgradient of Lagoon A.
MW-17(S)	20.03	Lagoon C and Trench in IA03	Evaluate quality of shallow groundwater zone downgradient of Trench in IA03 and Lagoon C. Well is also located on upgradient side of IA01.
MW-18(I)	33.00	Local groundwater flow	Define local groundwater flow along west side of the Luckey site and evaluate affects of West Production Well.
MW-20(S)	14.50	Lagoon C	Evaluate quality of shallow groundwater zone downgradient of Lagoon C.
MW-21(I)	28.00	Bare Spot in IA07 and effects of East Production Well	Evaluate quality of groundwater upgradient of Bare Spot in IA07 and assess the effects of the east production well.
MW-22(I) MW-26(S)	27.44 15.07	Debris piles and trench in IA05 and filter bed of Sewage Treatment Plant.	Evaluate quality of shallow and deep groundwater zones downgradient of features in IA05 and assess off-site migration toward north.
MW-23(S)	15.55	Lagoon C	Evaluate quality of shallow groundwater zone upgradient of Lagoon C.
MW-24(S)	23.42	Lagoon B	Evaluate quality of shallow groundwater zone downgradient of Lagoon B.
MW-25(I)	30.50	Local groundwater flow and off-site migration	Define local groundwater flow along north side of Luckey site and evaluate affects of West Production Well.
MW-41(B)	56.00	Lagoon B	Evaluate quality of groundwater in intermediate bedrock zone upgradient of Lagoon B.
TW-42	15.00	Shallow sand unit	Test well (TW) requested by Ohio EPA to evaluate shallow sand unit.
TW-43	15.00	Shallow sand unit	Test well requested by Ohio EPA to evaluate shallow sand unit.

(S) – shallow well (I) – intermediate well (B) – bedrock well bgs – below ground surface

Table 3.4. Monitoring Well Sampling Events at the Luckey Site (Page 1 of 2)

Well Number	Summer 1998	Fall 1998	Spring 1999	Summer 1999	October 1999
BMW-09(I)	COPC	COPC	Full Suite	--	--
BMW-10(S)	COPC	COPC	Full Suite	--	--
BMW-11(I)	COPC	COPC	Full Suite	--	--
BMW-12(S)	COPC	--	Full Suite	--	--
BMW-15(I)	COPC	COPC	Full Suite	--	--
BMW-16(S)	COPC	COPC	Full Suite	--	--
MW-01(I)	Full Suite (7/14/98) Beryllium (7/23/98)	Beryllium	Full Suite	--	--
MW-02(S)	Full Suite (7/14/98) Beryllium (7/23/98)	Beryllium	Full Suite	--	--
MW-03(I)	Full Suite	--	Full Suite	--	--
MW-04(S)	Full Suite	--	Full Suite	--	--
MW-05(I)	Full Suite	--	Full Suite	--	--
MW-06(S)	Full Suite	--	Full Suite	--	--
MW-07(I)	Full Suite	--	Full Suite	--	--
MW-08(S)	Full Suite	--	Full Suite	--	--
MW-13(S)	Full Suite	--	Full Suite	--	--
MW-14(S)	Full Suite	--	COPC	--	--
MW-17(S)	Full Suite	--	Full Suite	--	--
MW-18(I)	COPC	--	COPC	--	--
MW-19(I)	Full Suite	--	Full Suite	--	--
MW-21(I)	Full Suite	--	COPC	--	--
MW-22(I)	COPC	--	Full Suite	--	--
MW-23(S)	Full Suite	--	COPC	--	--
MW-24(S)	Full Suite	--	COPC	--	--
MW-25(I)	COPC	--	COPC	--	--
MW-39(B)	O	COPC	Full Suite	--	--
MW-40(B)	O	COPC	Full Suite	--	--
MW-41(B)	O	Full Suite	Full Suite	--	--

Table 3.4. Monitoring Well Sampling Events at the Luckey Site (Page 2 of 2)

Well Number	Summer 1998	Fall 1998	Spring 1999	Summer 1999	October 1999
OMW-27(I)	O	COPC	Full Suite	--	--
OMW-28(B)	O	COPC	Full Suite	--	--
OMW-29(I)	O	COPC	COPC	--	--
OMW-30(B)	O	COPC	COPC	--	--
OMW-31(I)	O	COPC	COPC	--	--
OMW-32(B)	O	COPC	COPC	--	--
OMW-33(I)	O	COPC	COPC	--	--
OMW-34(B)	O	COPC	COPC	--	--
OMW-35(I)	O	COPC	COPC	--	--
OMW-36(B)	O	COPC	COPC	--	--
OMW-37(I)	O	COPC	COPC	--	--
OMW-38(B)	O	COPC	COPC	--	--
PW(E)	COPC	COPC	COPC	COPC	COPC
PW(W)	COPC	COPC	Full Suite	COPC	Beryllium (28ft)[A] Beryllium (81ft)[A] Beryllium (110ft)[A] Beryllium (175ft)[A] Beryllium (185ft)[A]
GW001	COPC	Beryllium	COPC	COPC	COPC
GW002	COPC (7/29/98) Beryllium (8/10/98)	COPC	Full Suite	COPC	COPC
GW003	COPC	COPC	Full Suite	COPC	COPC
GW004	COPC	--	Full Suite	--	--

-- well not sampled
O – well not yet installed
(S) – Shallow Well
(I) – Intermediate Well
(B) – Bedrock Well
(E) – East
(W) – West
BMW – Background Monitoring Well
MW – Onsite Monitoring Well
OMW – Offsite Monitoring Well
PW – Production Well
GW – Residential Well

[A] – Beryllium samples collected during a packer test conducted on 10/14/99 to 10/15/99 in the production well at the depth indicated.
COPC analyses – Arsenic; Barium; Beryllium; Lead; Ammonia; Fluoride; Radionuclides (filtered & total)
Full Suite analyses – VOCs; SVOCs; Metals (filtered & total); Radionuclides (filtered & total); Anions; Ammonia; Nitrate/Nitrite; TSS; TDS; DRO/GRO

Table 3.5. Rationale for Location of On-site Surface Water and Sediment Sampling

Station	Media	Station Location	Rationale For Sample Station Location
Phase II - Fall 1997			
SWSD0004	surface water sediment	northeast ditch at northern property boundary	Represents the downstream sampling point for combined on-site contributions to the northeast ditch. When compared to the upstream sample SWSD0005, can be used to evaluate effects of runoff to the ditch from the spoils piles and nearby waste disposal areas.
SWSD0005	surface water sediment	northeast ditch, northeast corner of Lagoon D	Strategically located to separate the potential effects of contaminants from Lagoons B and C, the railroad spurs, and the former Melting, Alloying, and Shipping Building.
SWSD0006	surface water sediment	northeast ditch, between Lagoons D and C	
SWSD0007	surface water sediment	NPDES outfall 004	Located to evaluate runoff from the southwestern portion of the Luckey site.
SWSD0009	surface water sediment	western drainage ditch approximately 100 feet downstream of SWSD0010	A drainage pipe, possibly from the former lime pit, empties into the drainage ditch between sample locations SWSD0009 and SWSD0010. The SWSD0009 samples represent the on-site contributions to the western drainage ditch.
SWSD0010	surface water sediment	western drainage ditch at northern property boundary	
SWSD0018	sediment	NPDES outfall 006	Located to evaluate runoff from the west-central portion of the Luckey site. A surface water sample could not be obtained at Outfall 006 because the concrete-lined ditch leading to the outfall was dry at the time of sampling.
SWSD0019	surface water sediment	northeast ditch, drain pit at the souheast corner of the former Melting, Alloying, and Shipping Building	Strategically located to separate the potential effects of contaminants from Lagoons B and C, the railroad spurs, and the former Melting, Alloying, and Shipping Building.
SWSD0020	surface water	inside Production Building	Located to evaluate the Production Building as a potential source area. The sediment sample at SWSD0020 could not be collected due to a lack of sediment.
SWSD0021	surface water sediment	inside Production Building	
SWSD0022	surface water sediment	open sump east of ditch near spoil piles and waste disposal features in northeast corner of property	The exact nature of the sump is unknown. It is a prefabricated concrete pipe approximately 5 foot in diameter and may be associated with a subsurface drainage system beneath the trenches in the adjoining waste disposal area. The pipe contains water year-round the level of which level varies a few feet seasonally.
SWSD0023	surface water sediment	southwest side of Production Building near truck dock	Located to evaluate the Production Building as a potential source area.

Table 3.5. Rationale for Location of On-site Surface Water and Sediment Sampling

Station	Media	Station Location	Rationale For Sample Station Location
Phase IV - Summer 1998 & 1999			
IA06-SD0001	surface water sediment	northeast ditch, upstream of STP outfall	Located to separate the effects of the STP effluent and the runoff from nearby waste disposal areas.
IA06-SD0002	surface water sediment	concrete-lined ditch leading to Outfall 004	Located to evaluate runoff from the western portion of the Luckey Site. These samples were located closer to the source areas (i.e., the Annex and former Laboratory Building) to determine flow contributing to the outfall.
IA06-SD0003	surface water sediment	between NPDES outfalls 004 and 006	
IA06-SD0005	surface water sediment	storm drain along driveway northeast of Production Building	This drain feeds into the headwaters of the northeast ditch located at the southeast corner of the former Melting, Alloying, and Shipping Building. This sample, which is upstream of the building, may be compared to samples obtained downstream of the building during Phase II.

Table 3.6. Rationale for Location of Off-site Surface Water and Sediment Sampling

Station	Media	Location	Rationale For Sample Station Location
Phase II - Fall 1997			
SWSD0008	surface water sediment	confluence of the western drainage ditch with Toussaint Creek	Represent the combined effects of discharge from Outfalls 004 and 006, the drainage pipe from the former lime pit, and runoff from the farm field immediately north of the site.
SWSD0011	surface water sediment	western drainage ditch approximately 0.25 miles south of NPDES outfall 004	Measure quality of surface water and sediments in ditch upstream of Luckey Site. These samples provided a baseline data point to evaluate upstream sources that may contribute contaminants to the ditch before reaching Outfall 004.
SWSD0012	surface water sediment	southeast corner of the property, upgradient of the site, downgradient of the Troy Township dump.	Determine the impact of the Troy Township dump on downstream activities.
SWSD0013	surface water sediment	confluence of the main central drainage ditch and Toussaint Creek	Represent the cumulative effects from numerous on-site sources. This is the ultimate discharge point of the main ditch.
SWSD0014	surface water sediment	Toussaint Creek approximately 0.25 miles downstream of the confluence with main central drainage ditch	Evaluate the downstream extent of site-related contaminants.
SWSD0015	surface water sediment	Toussaint Creek approximately 0.50 miles downstream of the confluence with main central drainage ditch	
SWSD0016	surface water sediment	swales on eastern and western sides (respectively) of railroad right-of-way (eastern property boundary)	Evaluate possible former collection areas or drainage conduits for runoff from the site. It is unknown whether the two swales are, or were previously, hydraulically connected. No surface water was present at SWSD0017.
SWSD0017	sediment		
BH0017	3 sediment samples	upstream side of Lemoyne Road	Evaluate the nature and distribution of potential contaminants within the streambed.
BH0018	3 sediment samples	downstream side of Lemoyne Road	
BH0019	3 sediment samples	upstream side of Pemberville Road	
BH0020	3 sediment samples	downstream side of Pemberville Road	

Table 3.6. Rationale for Location of Off-site Surface Water and Sediment Sampling

Station	Media	Location	Rationale For Sample Station Location
PHASE IV - summer 1998 & 1999			
IA06-SD0004	surface water sediment	farm bridge over main central drainage ditch	Evaluate the effects of runoff from the adjacent farm fields
IA10-SD0002	sediment	ditch east of railroad bed	Evaluate the migration of contaminants across the railroad embankment.
IA10-SD0003	sediment		
IA06-SD0006 through IA06-SD0034	sediment samples in 1-foot intervals to a depth of 3	located every ½ mile in Toussaint Creek - 2½ miles to 15 miles downstream of the Luckey site	Determine the downstream extent and depth of contaminants.
IA06-SD0037	sediment	Lemoyne Road	Collect TOC and grain size data with respect to concentrations of suspected site-related contaminants at each of these locations to be evaluated in the ecological risk assessment.
IA06-SD0038	sediment	collocated with station BH0017	
IA06-SD0039	sediment	Pemberville Road	

Table 3.7. Soil Samples - Parameters and Analytical Methods

Parameters	**Analytical Method**
PHASE II	
Chemistry	
Volatile Organic Compounds (VOCs)	SW846 8260/8260A
Semivolatile Organic Compounds (SVOCs)	SW846 8270/8270B
Metals	SW 846 6010A
Mercury	SW 846 7471/7471A
Pesticides	EPA 8081A
Polychlorinated biphenyls (PCBs)	SW846 8082
Anions	SW846 300.0/9056
pH	SW 846 150.1/9045
Radiochemistry	
Actinium-227, Radium-226/228, Thorium-227/228/230/232, Uranium-234/235/238	Alpha Spectroscopy
Actinium-227, Americium-241, Cesium-137, Potassium-40, Protactinium-231, Radium-226/228, Thorium-228/230/232, Uranium-235/238	Gamma Spectroscopy
PHASE IV	
Chemistry	
VOCs	SW846 8260B
SVOCs	SW846 8270C
Metals	EPA6010A/6010B
Mercury	EPA7471/7471A
Herbicides	EPA 8151B
Pesticides	EPA 8081A
PCBs	SW846 8082
Nitrogen, Ammonia	EPA 350.1 modified
Anions	SW846 9056
Diesel Range Organics	SW-846 8015, Modified
Total Recoverable Petroleum Hydrocarbons	EPA 418.1 Modified
Radiochemistry	
Uranium-234,235,238	Alpha Spectroscopy
Thorium-228,230,232 including Actinium-227	Alpha Spectroscopy
Cesium-137, Actinium-228, Cobalt-60, Potassium-40, Protactinium-231, Radium-226&228, Thorium-234, Uranium-235	Gamma Spectroscopy
geotechnical analyses	ASTM

ASTM – American Society for Testing and Materials

Table 3.8. Sediment Samples – Parameters and Analytical Methods

Parameters	**Analytical Methods**
PHASE II	
Chemistry	
Volatile Organic Compounds (VOCs)	SW846 8260A
Semivolatile Organic Compounds (SVOCs)	SW846 8270/8270B
Pesticides/Polychlorinated biphenyls (PCBs)	SW846 8080A
Metals	SW846 6010A
Mercury	SW 846 7471/7471A
Anions	SW846 9056
Total Organic Carbon	SW846 9060
pH	150.1 1982
% Moisture	SW846 3550
Temperature & pH	SW846 9045
Radiochemistry	
Actinium-227, Radium-226/228, Thorium-227/228/230/232, Uranium-234/235/238	Alpha Spectroscopy
Actinium-227, Americium-241, Cesium-137, Potassium-40, Protactinium-231, Radium-226/228, Thorium-228/230/232, Uranium-235/238	Gamma Spectroscopy
PHASE IV	
Chemistry	
VOCs	EPA 8260B
SVOCs	EPA 8270C
Arsenic, Barium, Beryllium, Lead	EPA 6010A/6010B
Metals	EPA6010B/7471
Nitrogen, Ammonia	EPA 350.1 modified
Anions	SW846 9056
Total Organic Carbon	SW846 9060
Radiochemistry	
Uranium-234,235,238	Alpha Spectroscopy
Thorium-228,230,232 including Actinium-227	Alpha Spectroscopy
Cesium-137, Actinium-228, Cobalt-60, Potassium-40, Protactinium-231, Radium-226&228, Thorium-234, Uranium-235	Gamma Spectroscopy

Table 3.9. Surface Water Samples – Parameters and Analytical Methods

Parameter	**Analytical Method**
PHASE II	
Chemistry	
Volatile Organic Compounds (VOCs)	SW846 8260A
Semivolatile Organic Compounds (SVOCs)	SW846 8270B
Metals	SW846 6010A
Mercury	SW846 7470A
Alkalinity	310.1/310.1 1978
Ammonia	350.1/350.1 1978
Anions	SW846 9056
Total Dissolved Solids	160.1/160.1 1971
Total Suspended Solids	160.2/160.2 1971
Radiochemistry	
Actinium-227, Radium-226/228, Thorium-227/228/230/232, Uranium-234/235/238	Alpha Spectroscopy
Actinium-227, Americium-241, Cesium-137, Potassium-40, Protactinium-231, Radium-226/228, Thorium-228/230/232, Uranium-235/238	Gamma Spectroscopy
PHASE IV	
Chemistry	
VOCs	SW846 8260B
SVOCs	EPA 8270C
Arsenic, Barium, Beryllium, Lead	EPA6010A
Metals	EPA6010B7470
Fluoride	SW846 9056
Nitrogen, Ammonia	EPA 350.1
Radiochemistry (total & filtered)	
Uranium-234,235,238	Alpha Spectroscopy
Thorium-228,230,232 including Actinium-227	Alpha Spectroscopy
Radium-226,228	Radon Emanation
Cesium-137, Actinium-228, Cobalt-60, Potassium-40, Protactinium-231 Thorium-234, Uranium-235	Gamma Spectroscopy
Gross Alpha/Beta	EPA 900.0

Table 3.10. Groundwater & Tap Water Samples - Parameters and Analytical Methods

Parameters	**Analytical Method**
PHASE IV	
Chemistry	
Volatile Organic Compounds (VOCs)	SW846 8260B
Semivolatile Organic Compounds (SVOCs)	EPA 8270C
Metals (total & filtered)	SW846 6010B/7470/7470A
Chloride	SW846 9056/EPA 300.0
Fluoride	SW846 9056
Sulfate	SW846 9056/EPA 300.0
Nitrogen, Ammonia	EPA 350.1
Nitrate/Nitrite	EPA 353.1
Total Recoverable Petroleum Hydrocarbons	EPA 418.1
Diesel Range Organics/Gasoline Range Organics	SW-846 8015, Modified
Alkalinity	EPA 310.1
Total Dissolved Solids	EPA 160.1
Total Suspended Solids	EPA 160.2
Radiochemistry (total & filtered)	
Uranium-234,235,238	Alpha Spectroscopy
Thorium-228,230,232 including Actinium-227	Alpha Spectroscopy
Radium-226,228	Radon Emanation
Cesium-137, Actinium-228, Cobalt-60, Potassium-40, Protactinium-231, Thorium-234, Uranium-235	Gamma Spectroscopy
Gross Alpha/Beta	EPA 900.0

Table 3.11. Swipe Samples – Parameters and Analytical Methods

Parameter	**Analytical Method**
Chemistry	
Beryllium	SW846 6010A/E6010B
Radiochemistry	
Gross Alpha	EPA 900.0
Nonvolatile Beta	EPA 900.0
Radium-226,228	Radon Emanation
Radium-228	EPI A-009
Uranium-233/234/235/238	Alpha Spectroscopy
Thorium-228/230/232, Actinium-227	Alpha Spectroscopy
Actinium-227, Actinium-228, Cesium-137, Cobalt-60, Potassium-40, Protactinium-231, Thorium-234, Uranium-235	Gamma Spectroscopy

Table 3.12. Building Materials Samples – Parameters and Analytical Methods

Parameter	**Analytical Method**
Chemistry	
Beryllium	SW846 6010A/E6010B
Radiochemistry	
Uranium-233/234/235/238	Alpha Spectroscopy
Thorium-228/230/232, Actinium-227	Alpha Spectroscopy
Actinium-228, Cesium-137, Cobalt-60, Potassium-40, Protactinium-231, Radium-226/228, Thorium-234, Uranium-235	Gamma Spectroscopy

Table 3.13. Dust Samples – Parameters and Analytical Methods

Parameter	**Analytical Method**
Chemistry	
Beryllium	SW846 6010B
Metals	SW846 6010B/7471
Semivolatile Organic Compounds (SVOCs)	SW846 8270C

Table 3.14. Personal & Ambient Air Monitoring – Parameters and Analytical Methods

Parameter	**Analytical Method**
PHASE IV	
Chemistry	
Beryllium	NIOSH 7102
Radiochemistry	
Radium-226,228	Radon Emanation
Uranium-233, 234, 235, 238	Alpha Spectroscopy
Thorium-228, 230, 232 Actinium-227	Alpha Spectroscopy
Actinium-228, Cesium-137, Cobalt-60, Potassium-40, Protactinium-231, Thorium-234, Uranium-235	Gamma Spectroscopy

Table 3.15. Data Qualifiers for Inorganic Analyses

Qualifier	Explanation
E	This qualifier is used when the percent difference between the parent sample and its serial dilution's concentrations exceed 10%. The sample's concentration must be greater than 50 times the IDL/MDL for ICP (6010B/ILMO 3.0) or 100 times the absolute value of the preparation blank's concentration (6020).
J	This qualifier indicates the analyte concentration is estimated. This qualifier is applied during the data validation process.
*	This qualifier indicates the duplicate sample analysis for an analyte is out of control.
B	This qualifier indicates the reported result fell above the IDL/MDL but below the laboratory's RDL.
N	This qualifier indicates the matrix or pre-digested spike sample recovery for an analyte is not within the specified control limit.
R	Data qualified as unusable.
U	The analyte's result was less than the IDL/MDL.
UJ	Analyte was not detected and the RDL is estimated. This qualifier is applied during the data validation process.

RDL – reporting detection limit
IDL – instrument detection limit
ICP – inductively coupled plasma
MDL – method detection limit

Table 3.16. Data Qualifiers for Organic Analyses

Qualifier	Explanation
E	Identifies compounds whose concentrations exceed the upper level of the calibration range of the instrument for that specific analysis.
J	This qualifier indicates an estimated value concerning either, (1) analyte detected at a level less than the RDL or PQL and greater than or equal to the MDL or (2) qualified during the data validation process.
N	Presumptive evidence based upon a mass spectral library search to make a tentative identification of the analyte.
NJ	Analyte has been "tentatively identified" and the associated numerical value is estimated based upon 1:1 response factor to the nearest eluting internal standard.
P	Pesticide/PCB target analyte is greater than 25% difference for the detected concentrations between the two GC columns.
R	Data qualified as unusable.
U	Compound analyzed for but not detected (sample quantitation limit has been adjusted to reflect dilutions and percent moisture).
UJ	Compound was not detected and the RDL is estimated. This qualifier is applied during the data validation process.

GC – gas chromatograph
PCB – polychlorinated biphenyl
RDL – reporting detection limit
MDL – method detection limit
PQL – practical quantitation limit
TIC – tentatively identified compounds

Table 3.17. Quality Assurance/Quality Control (QA/QC) Sample Correlation

Sample ID	Duplicate Sample ID	Split Sample ID	Analytical Parameters
LUGW0006	--	LUGW9686	full suite
LUGW0017	LUGW9188	LUGW9688	metals and radiochemical parameters
LUGW0035	--	LUGW9690	metals and radiochemical parameters
LUGW0040	LUGW9191	LUGW9691	full suite
LUGW0041	--	LUGW9692	metals and radiochemical parameters
LUGW0042	--	LUGW9693	metals and radiochemical parameters
LUGW0061	--	LUGW9694	metals
LUGW0061	--	LUGW9694	radiochemical parameters
LUGW0094	--	LUGW9697	full suite
LUGW0116	--	LUGW9699	full suite
LUGW0117	--	LUGW9698	full suite
LUGW0149	--	LUGW9701	metals and radiochemical parameters
LUGW0150	--	LUGW9700	metals and radiochemical parameters
LUSB0003	--	LUSB9508	full suite
LUSB0009	--	LUSB9502	metals and radiochemical parameters
LUSB0137	LUSB9014	LUSB9514	beryllium
LUSB0258	--	LUSB9526	full suite
LUSB0338	LUSB9035	LUSB9535	beryllium
LUSB0388	--	LUSB9540	metals and radiochemical parameters
LUSB0449	LUSB9047	LUSB9547	beryllium
LUSB0504	--	LUSB9553	PCBs
LUSB0521	LUSB9055	LUSB9555	beryllium
LUSB0544	--	LUSB9558	full suite
LUSB0550	--	LUSB9559	metals and radiochemical parameters
LUSB0630	LUSB9067	LUSB9567	beryllium
LUSB0741	LUSB9078	LUSB9578	beryllium
LUSB0762	LUSB9080	LUSB9580	metals and radiochemical parameters
LUSB0816	--	LUSB9582	full suite
LUSB0908	--	LUSB9596	metals and radiochemical parameters
LUSB0998	--	LUSB9602	full suite
LUSB1180	--	LUSB9605	metals and radiochemical parameters
LUSB1198	--	LUSB9606	metals and radiochemical parameters

-- no corresponding field duplicate

Table 3.18 Background Values for Metals (95% UTL)

Compound	Soil (mg/kg)	Sediment (mg/kg)	Surface Water (µg/L)	Groundwater (µg/L)	
				total	Filtered
Aluminum	23,700	12,000	733	2,960	32.4
Antimony	0.9	0.88	O	2.9	4
Arsenic	24.1	12.1	O	4.7	6.2
Barium	209	94.3	38.80	105	93.1
Beryllium	1.13	0.69	O	0.79	O
Boron	13.4	15.5	O	--	--
Cadmium	0.98	0.51	O	1	0.36
Calcium	55,100	109,000	89,400	119,000	112,000
Chromium	29.6	17.6	1.20	21.3	O
Cobalt	19.1	10	O	1.2	O
Copper	42	23	4.60	5.6	40.8
Iron	38,600	20,500	871	4,330	1,060
Lead	23.2	14.3	1.20	7.2	1.8
Magnesium	17,100	18,900	27,000	72,700	55,300
Manganese	2,340	563	19.70	144	91.6
Mercury	0.19	O	--	0.1	O
Molybdenum	11.3	2.60	11.10	--	--
Nickel	46.1	25.30	O	5.5	6.4
Phosphorus	808	680	O	177	218
Potassium	3,410	2,390	1,570	16,200	16,100
Selenium	2.33	1.8	O	O	7.5
Silicon	595	567	3,620	--	--
Silver	0.51	O	O	2.2	O
Sodium	285	373	18,500	28,100	27,400
Strontium	75.6	98.3	1,450	--	--
Thallium	2.1	3.4	O	6.7	5
Tin	O	O	O	--	--
Vanadium	42.8	24.80	2.2	6.3	1.4
Zinc	110	108	O	122	13.9

Note "O" indicates the analyte was not detected in the background data set.
"--" indicates the analyte was not analyzed in the background data set.
UTL - upper tolerance limit

Table 3.19. Background Values for Radionuclides (95% UTL)

Compound	Soil (pCi/g)	Sediment (pCi/g)	Surface Water (pCi/L)	Groundwater (pCi/L)	
				Total	Filtered
Actinium-227	1.76	0.4	0.36	0.35	O
Actinium-228	1.35	0.76	--	O	O
Americium-241	O	O	O	--	--
Cesium-137	0.72	0.16	O	5.29	O
Cobalt-60	O	O	--	O	O
Gross Alpha	--	16.50	--	6.03	5.48
Nonvolatile Beta	--	20.80	--	12.1	3.81
Potassium-40	27.2	18.1	O	39	31.8
Protactinium-231	O	O	O	O	O
Radium-226	2.97	1.63	0.24	1.86	2.63
Radium-228	1.48	1.11	O	1.57	1.3
Thorium-227	1.76	0.4	0.36	--	--
Thorium-228	1.60	1.19	O	0.65	O
Thorium-230	3.20	1.89	0.57	14.7	0.99
Thorium-232	1.48	0.84	O	O	O
Thorium-234	3.07	2.27	--	O	O
Uranium-233/234	2.01	1.23	--	1.62	0.999
Uranium-234	2.61	1.8	0.78	--	--
Uranium-235	0.25	0.06	O	O	O
Uranium-238	2.63	2.08	1.02	1.4	0.998

Note "O" indicates the analyte was not detected in the background data set.
"--" indicates the analyte was not analyzed in the background data set.
UTL - upper tolerance limit

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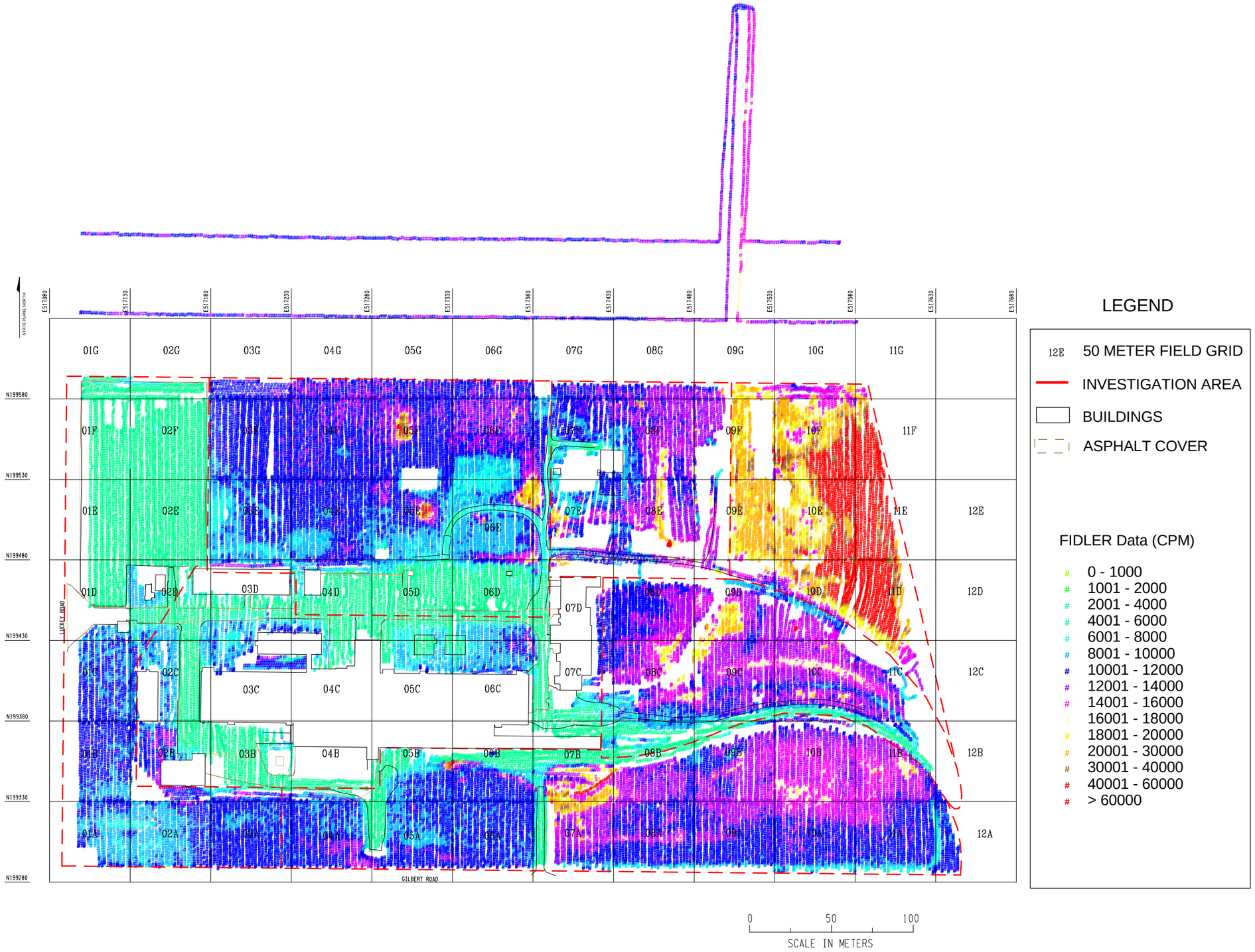

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Figure 3-1
Luckey Site
Gamma Walkover Survey Results (FIDLER) Site Wide

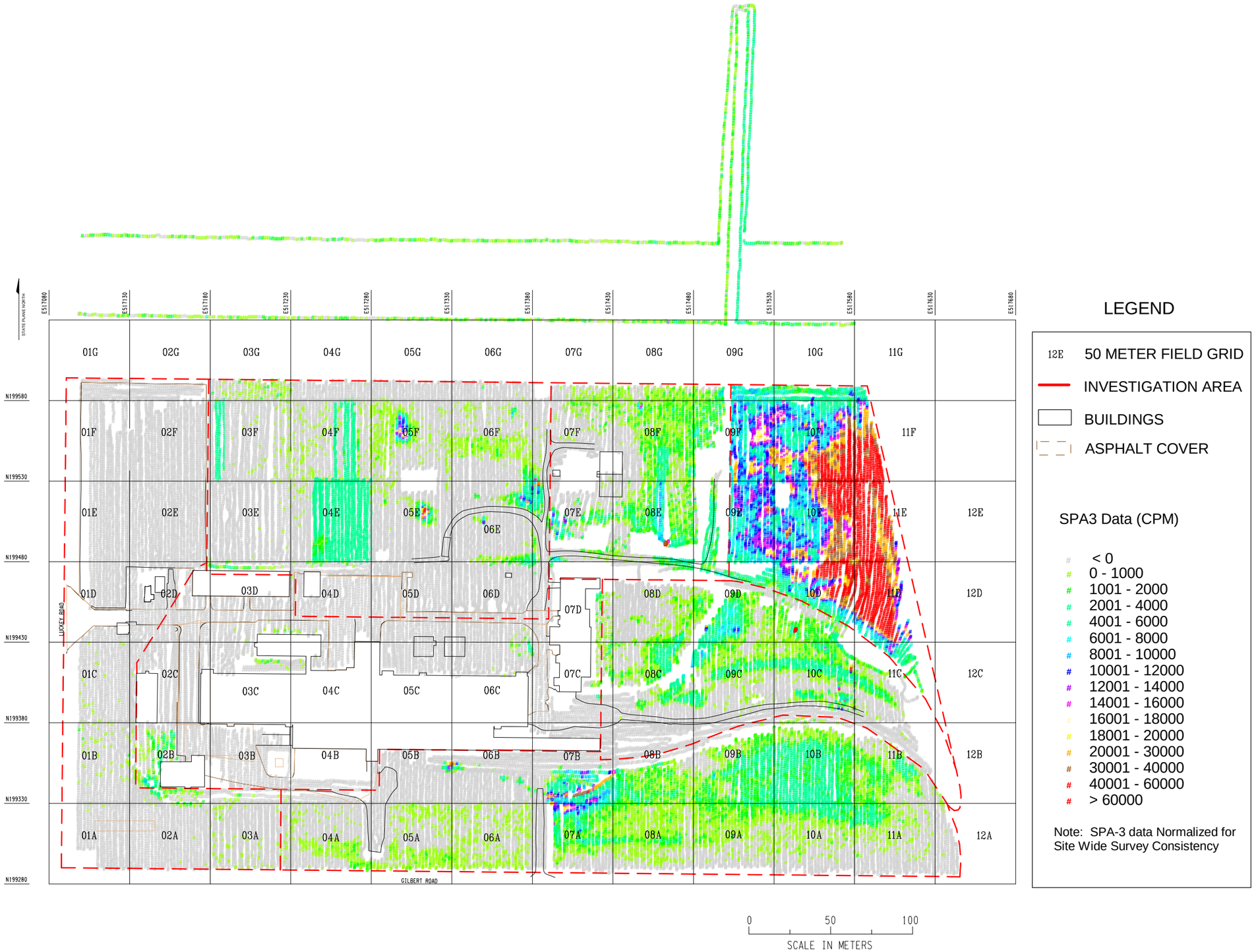

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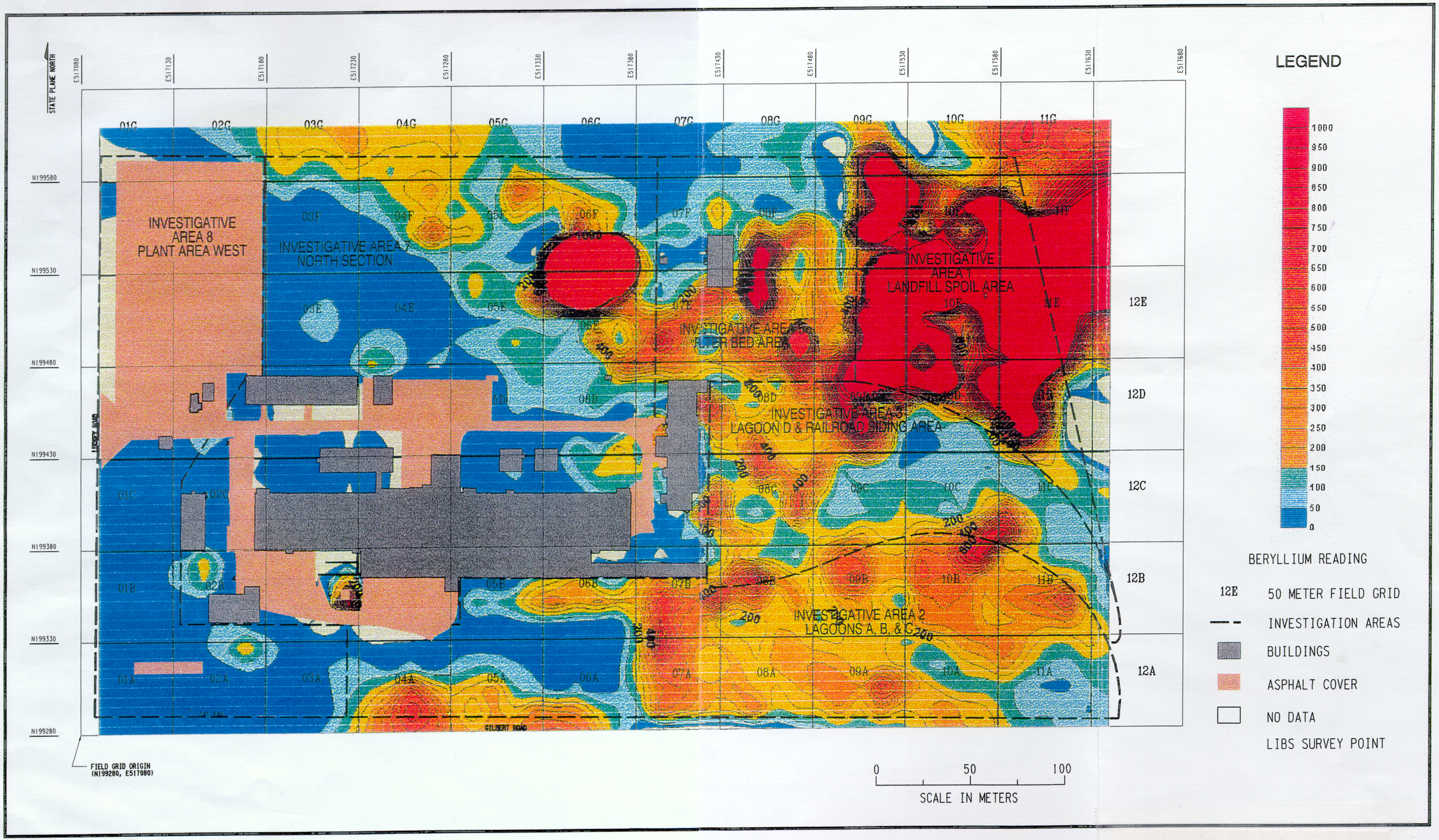
Figure 3-2
Luckey Site
Gamma Walkover Survey Results (SPA-3) Site Wide



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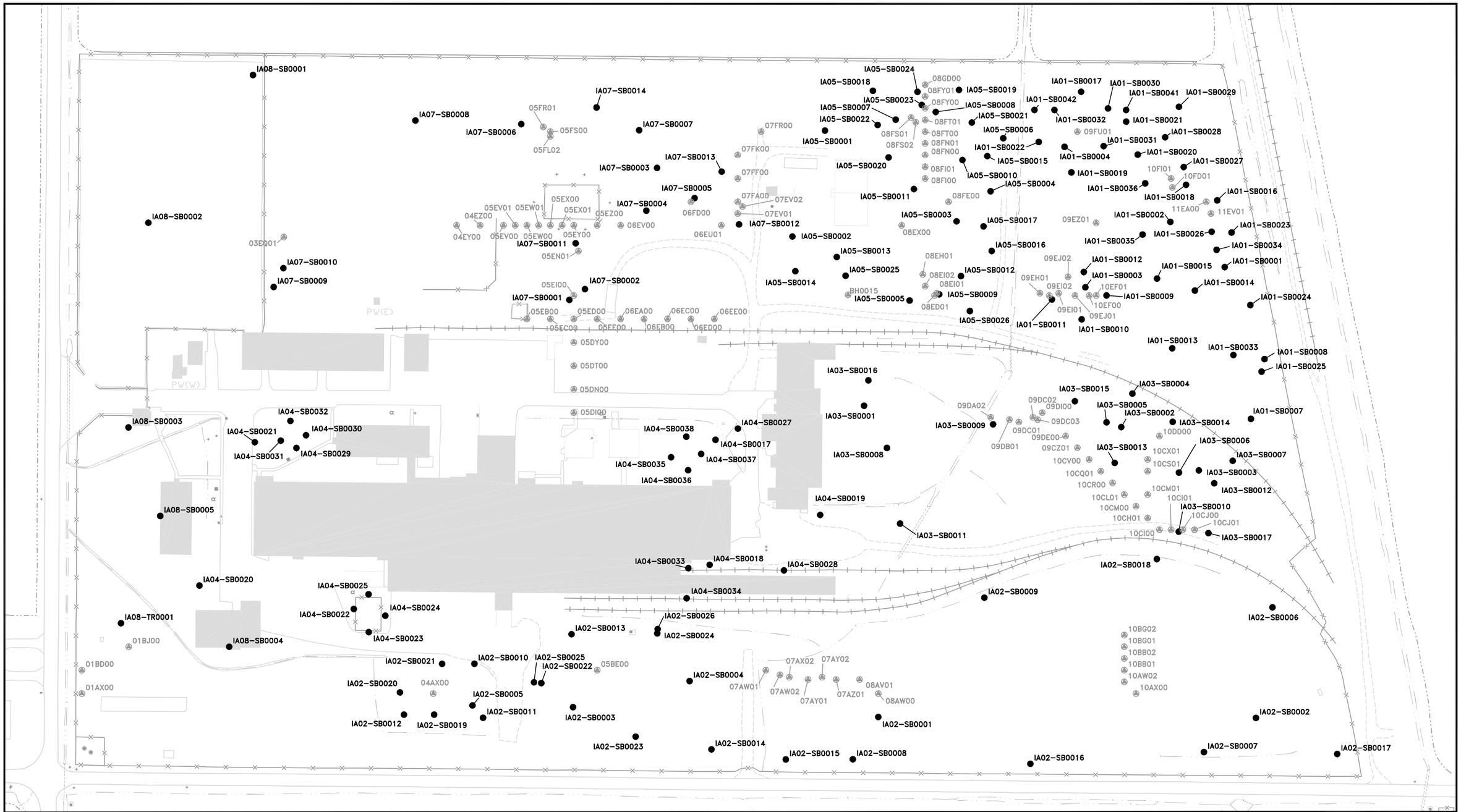
12/8/97

Figure 3.3.
Luckey, Ohio
LIBS Walkover Survey Results



U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Phase II and Phase IV
On-site Soil Sample Locations

Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	11-16-99	AS SHOWN	04-1748-801	3.4

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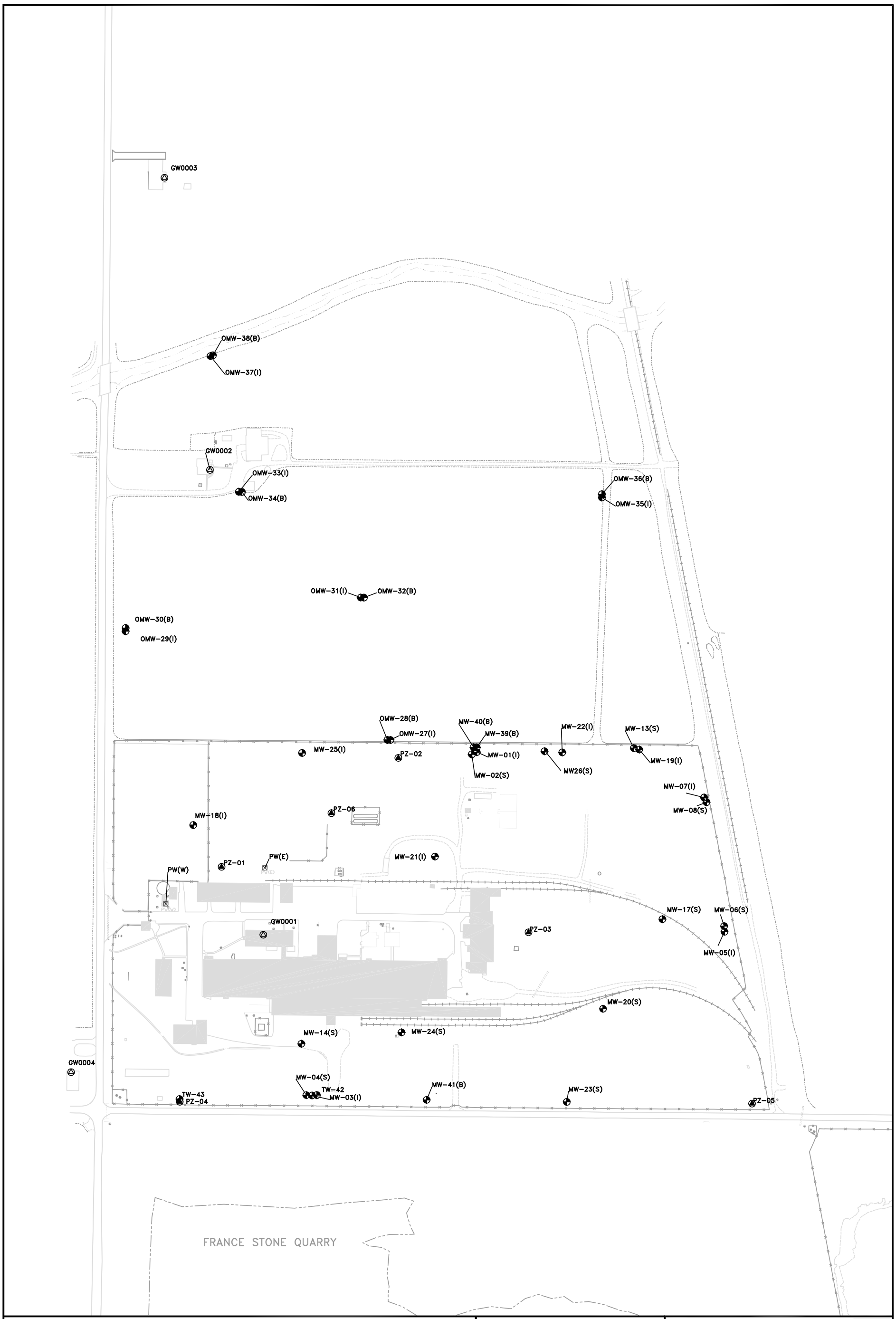


BUILDINGS
LOW-LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE
PIEZOMETER
GROUNDWATER MONITORING WELLS
RESIDENTIAL WELLS/TAP WATER

N
True North

250 0 125 250
FEET

76 0 38 76
METERS

U.S. Army Corps of Engineers
Buffalo District

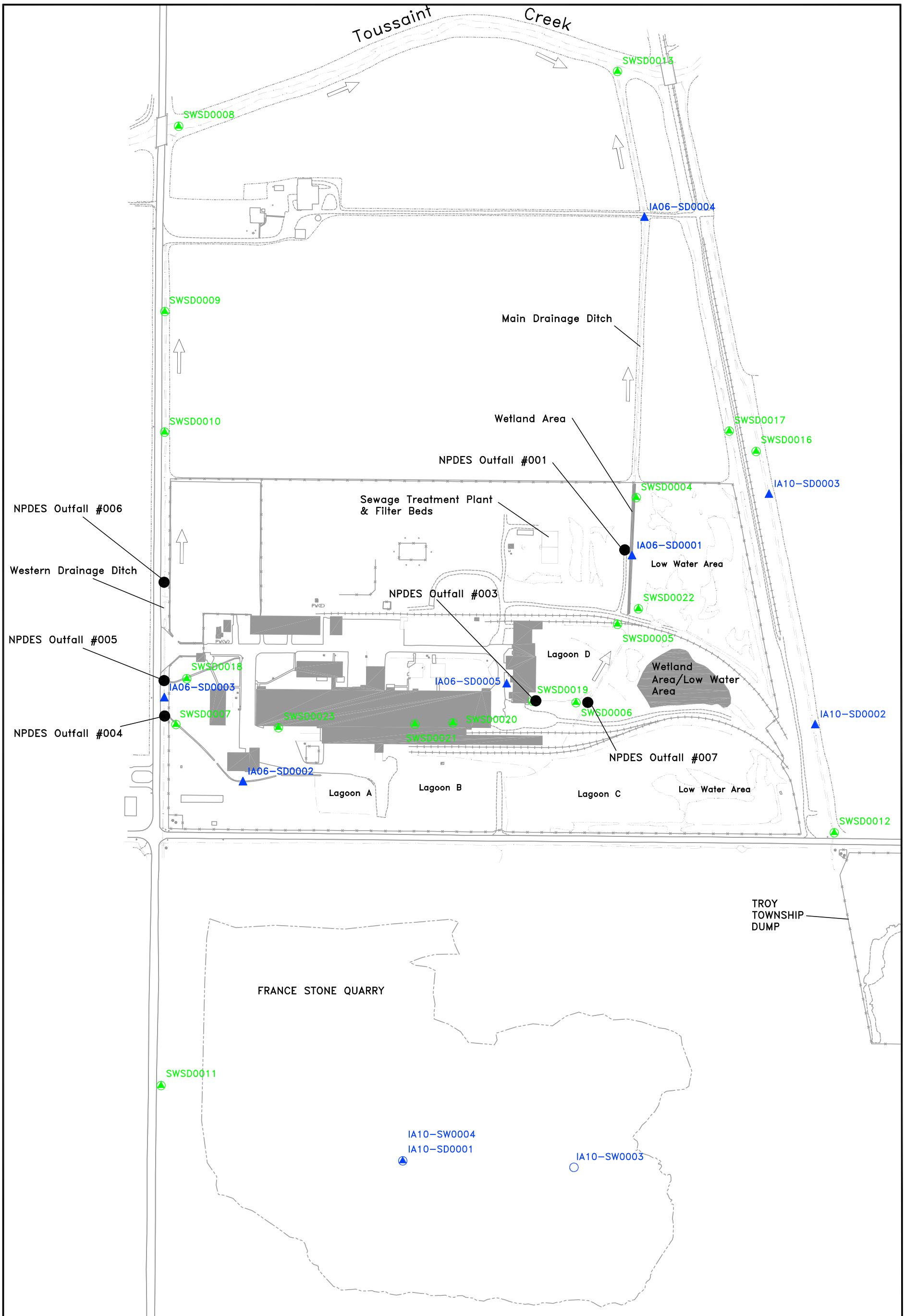
LUCKEY SITE
RI REPORT

Phase IV Groundwater Sample Locations

Science Applications International Corporation
Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
LMA	11-16-99	AS SHOWN	04-1748-801	3.5

NAME: S:\LUCKEY\C041748\801\RIRPT_PHASEII&IVGW.DWG DATE: APR 13, 2000 TIME: 7:12 AM PCP: S:\PCP\GREY1.PCP



BUILDINGS
LOW-LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE
DIRECTION OF FLOW ON DITCHES & STREAMS
SEDIMENT/SURFACE WATER SAMPLE LOCATION
SEDIMENT SAMPLE LOCATION
SURFACE WATER SAMPLE LOCATION
NPDES Outfalls
N True North

NOTE: GREEN DENOTES PHASE II SAMPLE LOCATIONS; BLUE DENOTES PHASE IV SAMPLE LOCATIONS

131 0 131 262
FEET

40 0 40 80
METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Phase II and Phase IV Sediment and
Surface Water Sample Locations

SAIC. Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	11-16-99	AS SHOWN	04-1748-801	3.6

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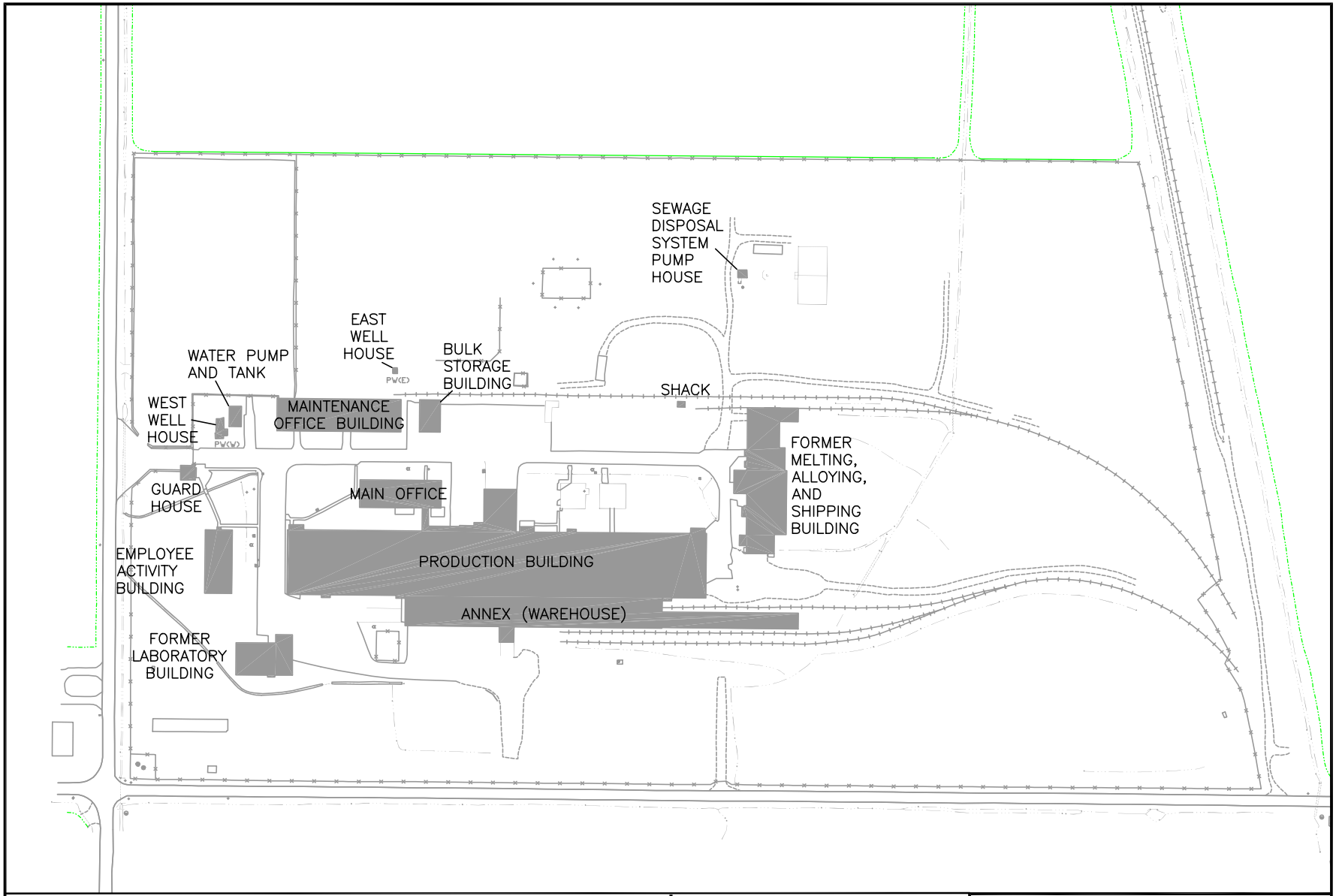

BUILDINGS

LOW-LYING AREAS

FENCE LINE

STREAMS & CREEKS

ABANDONED RAILROAD GRADE

N
True North

115 0 115 230
FEET

35 0 35 70
METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Buildings Targeted for Scoping Surveys

SAIC. Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
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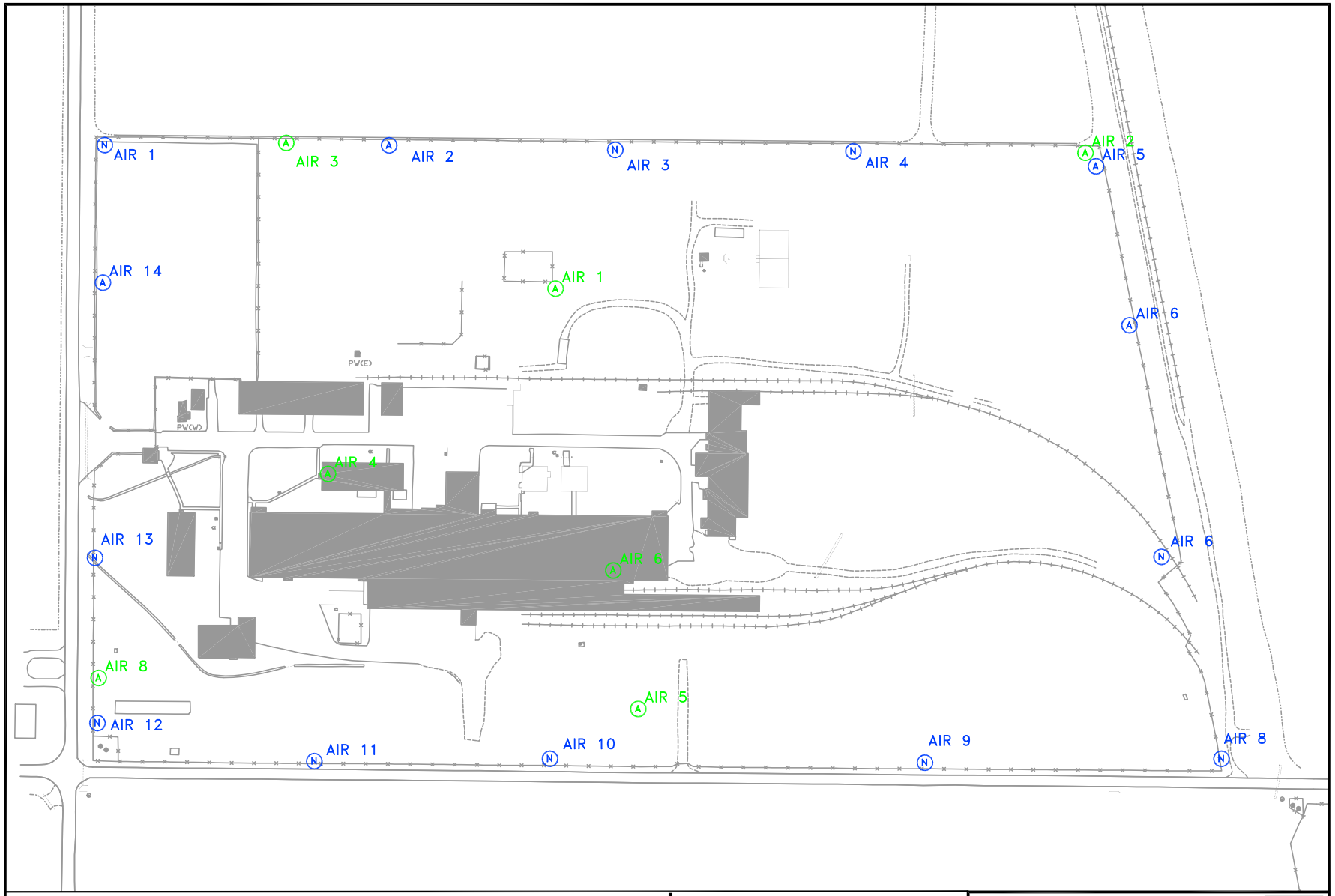

BUILDING
LOW LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE

PHASE II AIR SAMPLE STATIONS
PHASE IV AIR SAMPLE STATIONS
SAMPLE STATIONS NOT UTILIZED

N True North

115 0 115 230
FEET

35 0 35 70
METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Phase II and Phase IV
Air Sampling Stations

SAIC Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
LMA	01-10-00	AS SHOWN	04-1748-801	3.8

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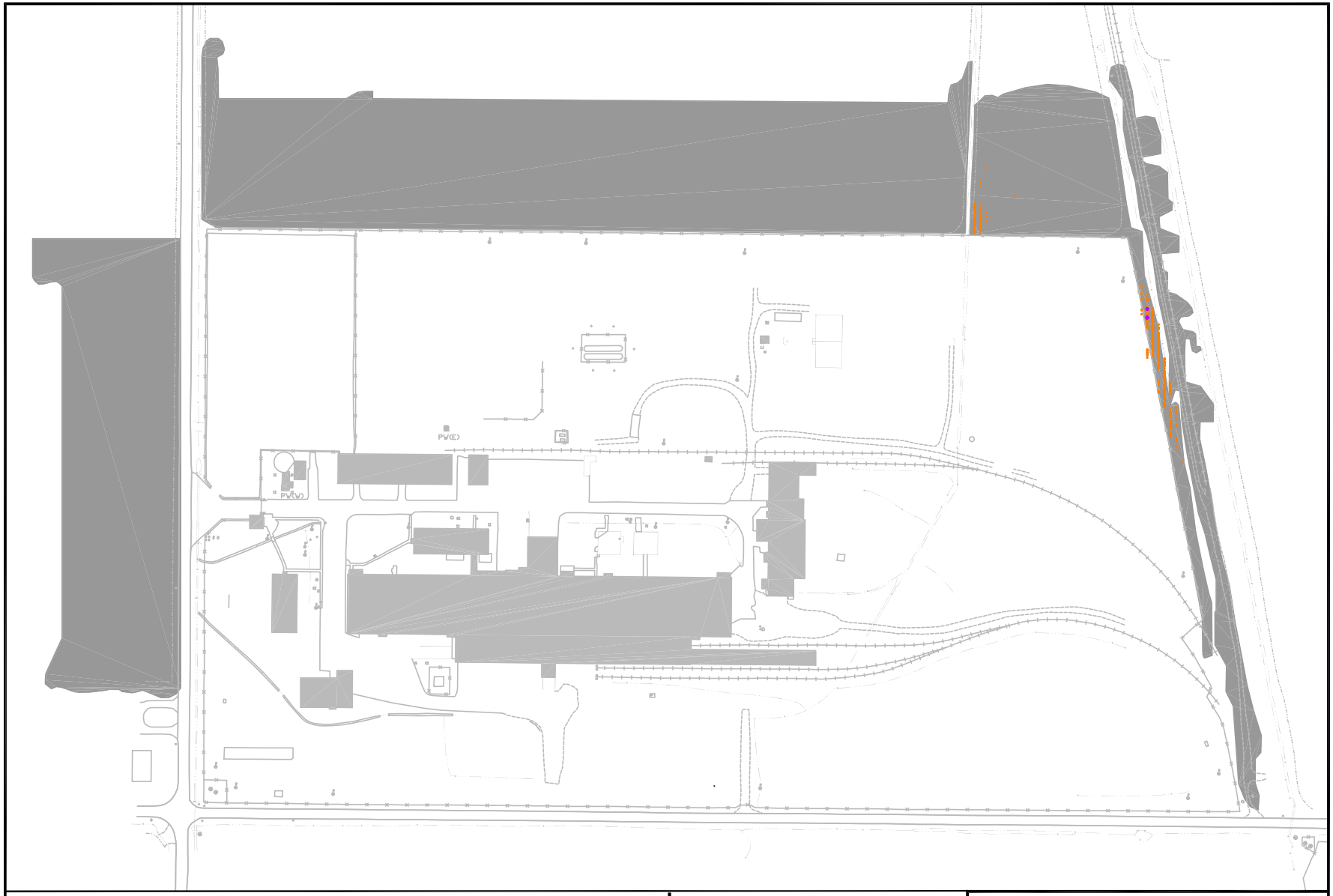

BUILDINGS
LOW-LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE

50,000–99,999 UNITS
22,000–49,999 UNITS
11,000–21,999 UNITS

N
True North

125 0 125 250
FEET

38 0 38 76
METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Gamma Walkover Survey Results (FIDLER)
Adjacent Properties

SAIC. Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	12-10-99	AS SHOWN	04-1748-801	3.9

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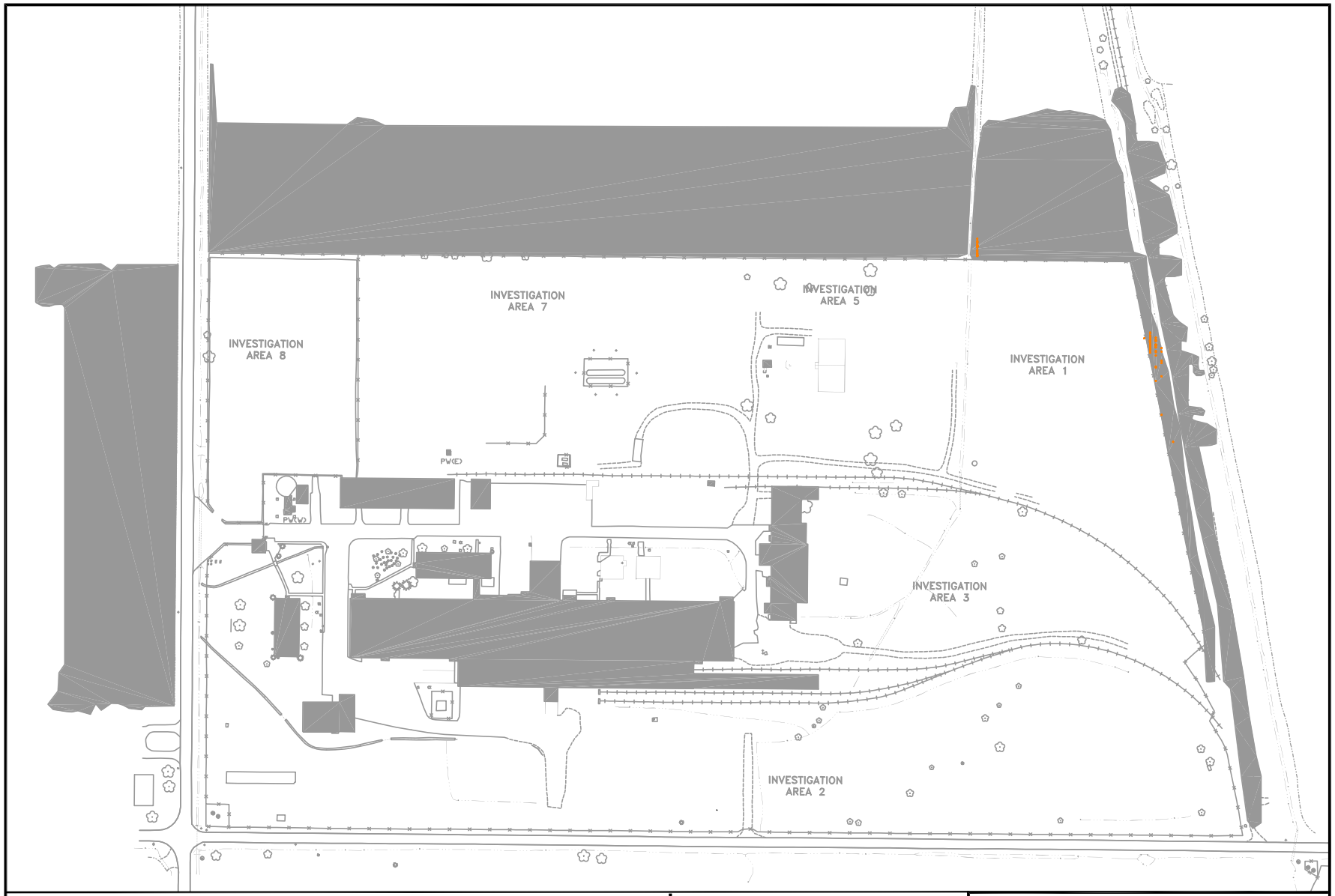


BUILDINGS
LOW-LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE

22,000–49,999 UNITS
11,000–21,999 UNITS

N
True North

125 0 125 250
FEET

38 0 38 76
METERS

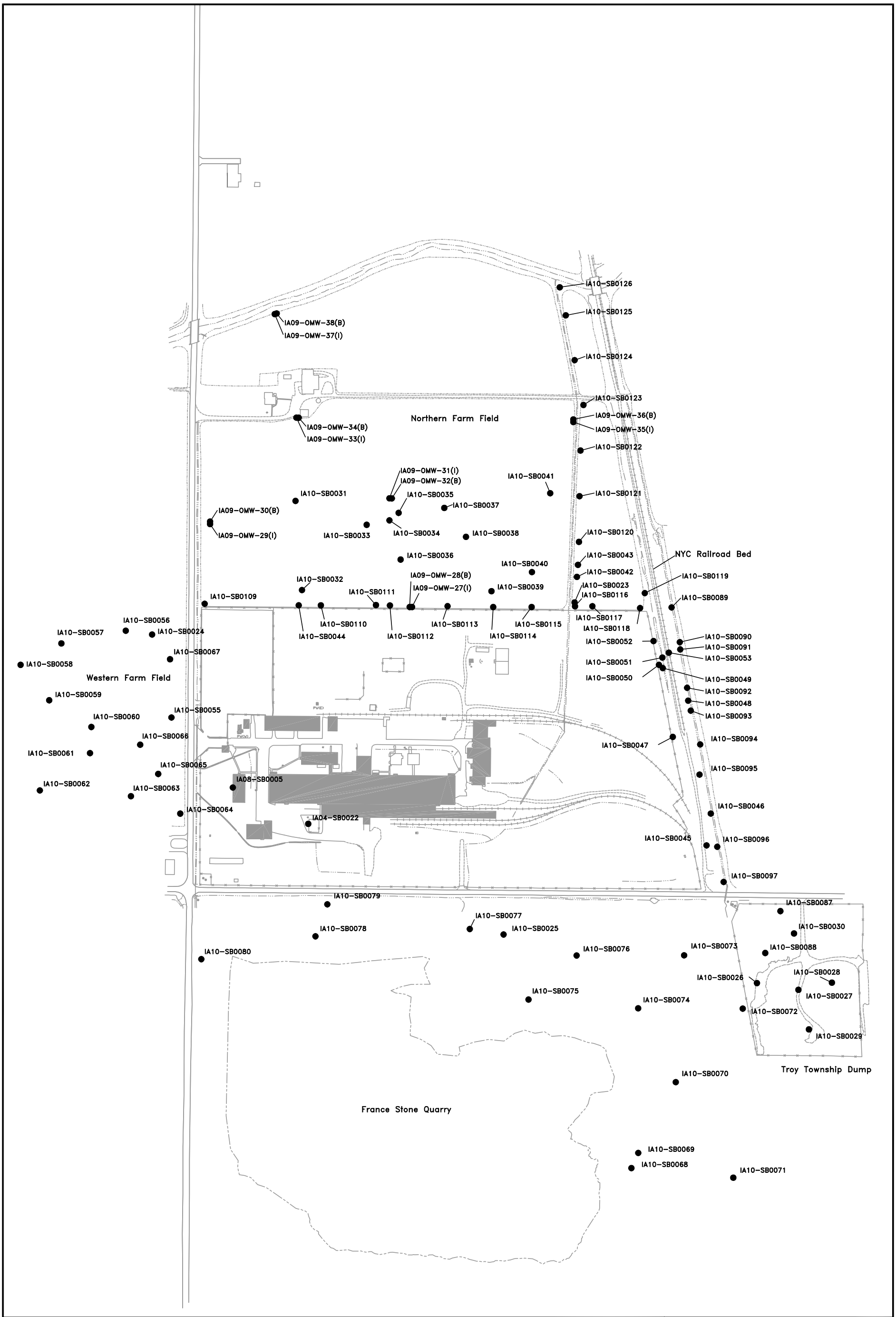
U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Gamma Walkover Survey Results (NaI)
Adjacent Properties

SAIC. Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	12-10-99	AS SHOWN	04-1748-801	3.10



BUILDINGS
LOW-LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE
PHASE IV SOIL BORING

N
True North

164 0 164 328
FEET

50 0 50 100
METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Phase II and Phase IV Off-site
Soil Sample Locations

Science Applications International Corporation
Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
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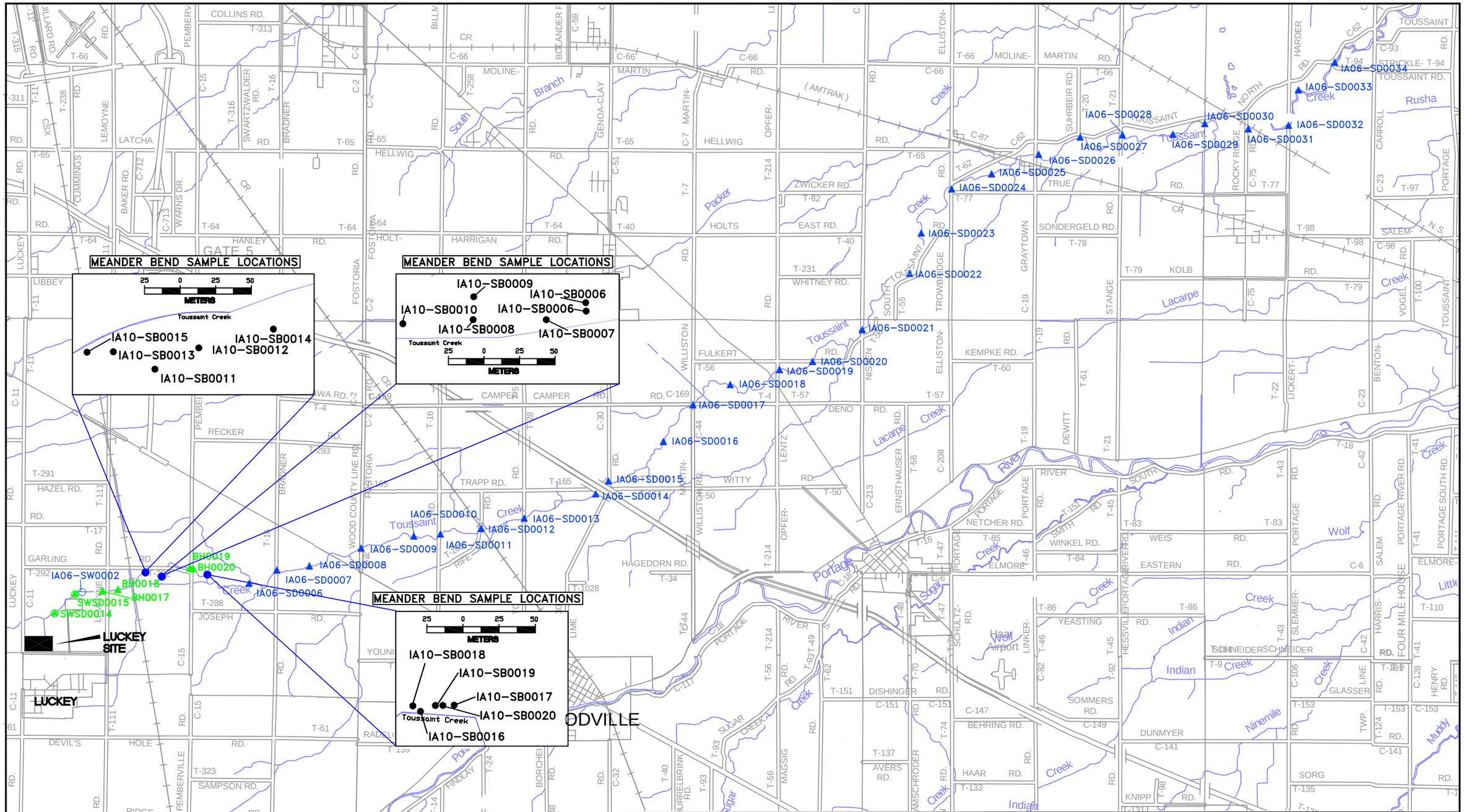
MEANDER BEND SAMPLE LOCATIONS
IA10-SB0015
IA10-SB0014
IA10-SB0013
IA10-SB0012
IA10-SB0011
Toussaint Creek
MEANDER BEND SAMPLE LOCATIONS
IA10-SB0009
IA10-SB0006
IA10-SB0010
IA10-SB0006
IA10-SB0008
IA10-SB0007
Toussaint Creek
MEANDER BEND SAMPLE LOCATIONS
IA10-SB0018
IA10-SB0019
IA10-SB0017
IA10-SB0020
IA10-SB0016
Toussaint Creek
LUCKEY SITE
LUCKEY
IA06-SW0002
BH0018
BH0017
SWSD0015
SWSD0014
BH0019
BH0020
IA06-SD0006
IA06-SD0007
IA06-SD0008
IA06-SD0009
IA06-SD0010
IA06-SD0011
IA06-SD0012
IA06-SD0013
IA06-SD0014
IA06-SD0015
IA06-SD0016
IA06-SD0017
IA06-SD0018
IA06-SD0019
IA06-SD0020
IA06-SD0021
IA06-SD0022
IA06-SD0023
IA06-SD0024
IA06-SD0025
IA06-SD0026
IA06-SD0027
IA06-SD0028
IA06-SD0029
IA06-SD0030
IA06-SD0031
IA06-SD0032
IA06-SD0033
IA06-SD0034
Toussaint Creek
Lacarpe Creek
Portage River
Wolf Creek
Indian Creek
Ninemile Creek
Muddy Creek
Rusha Creek
Haar Airport
GATE 5
ODDVILLE
STREAMS & CREEKS
SEDIMENT/SURFACE WATER SAMPLE LOCATION
SEDIMENT SAMPLE LOCATION
SURFACE WATER SAMPLE LOCATION
MEANDER BEND SOIL SAMPLE LOCATIONS
NOTE: GREEN DENOTES PHASE II SAMPLE LOCATIONS; BLUE DENOTES PHASE IV SAMPLE LOCATIONS
N
True North
2953 0 2953 5906
FEET
900 0 900 1800
METERS
U.S. Army Corps of Engineers
Buffalo District
LUCKEY SITE
RI REPORT
Phase II and Phase IV Off-site
Sediment and Surface Water Sample Locations
Science Applications International Corporation
Columbus, Ohio
DRAWN LA
DATE 11-16-99
SCALE AS SHOWN
PROJECT NO. 04-1748-801
FIGURE NO. 3.12
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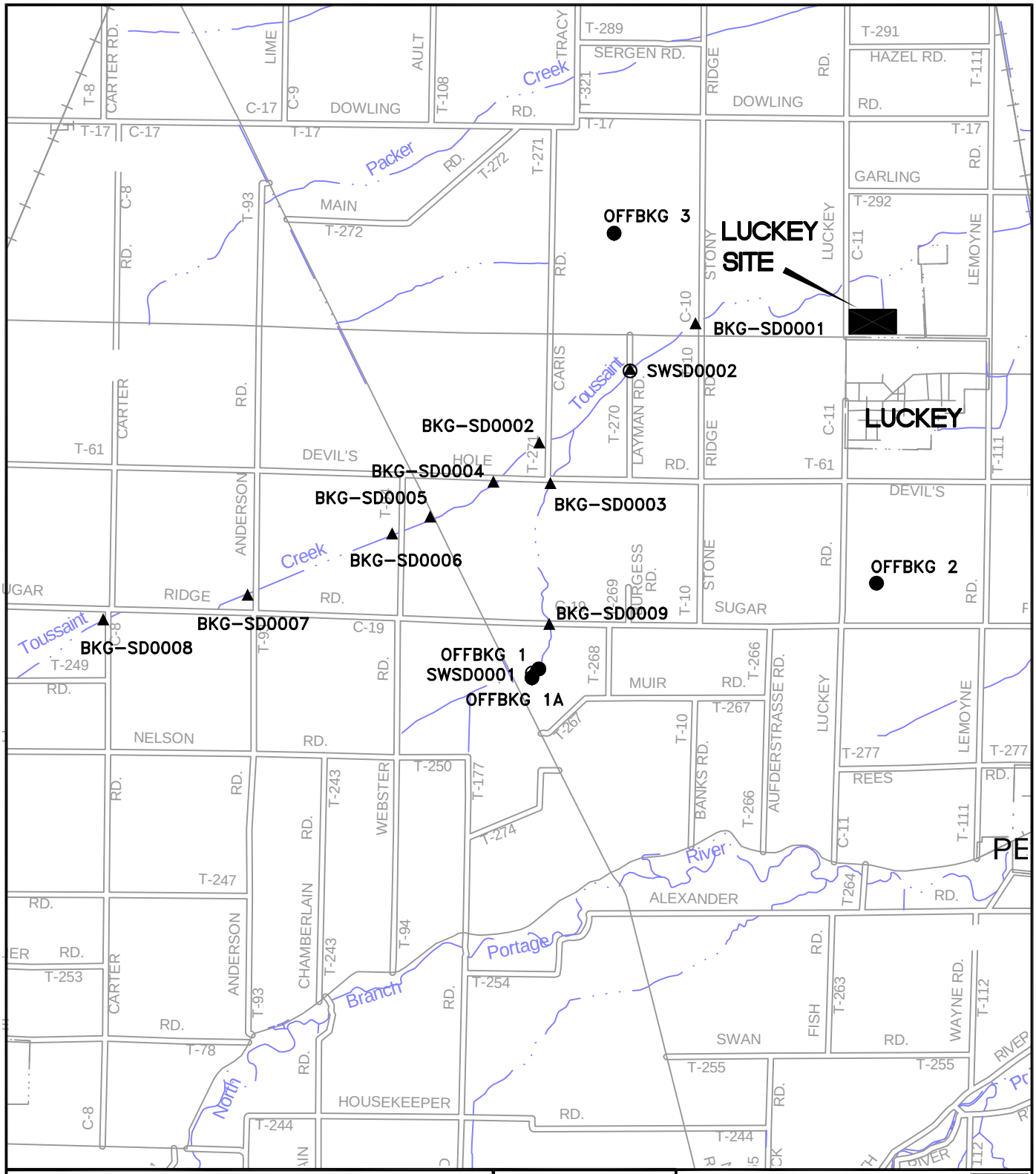

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COUNTY ROADS
CITY STREET
RAILROAD
STREAMS

BACKGROUND SOIL SAMPLE LOCATION
SEDIMENT SAMPLE LOCATION
SEDIMENT/SURFACE WATER SAMPLE LOCATION

N True North

0 2625 5250 FEET

0 800 1600 METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

BACKGROUND SAMPLING LOCATIONS

SAIC. Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
LMA	11-17-99	AS SHOWN	04-1748-801	3.13

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4.0 REMEDIAL INVESTIGATION RESULTS: NATURE AND EXTENT

The results of the chemical and radiological analyses conducted by off-site laboratories are used in this section to identify potential site-related constituents. Chemical and radiological concentrations in the various media were compared to the background data set in order to quantify the significance of chemical occurrences. The constituents found at concentrations above background are presented and evaluated for all environmental media investigated in the RI. For presentation purposes, the evaluation was divided into the following operable units:

- Unit 1: On-site soils
- Unit 2: Groundwater
- Unit 3: Buildings
- Unit 4: Sediments and Surface Water
- Unit 5: Off-site soils

The nature and extent of site-related constituents are described for each of these units. These discussions rely on comparisons with background PRGs to establish constituents that may be a potential concern. Background sampling of the environmental media at the Luckey site is presented in Section 3.3. Calculated background values and media specific PRGs are presented in Section 3.5.2 and 3.5.3, respectively. Chemical and radiological elements detected above background are presented in summary tables. The distributions of the various constituents identified for each unit are displayed on site diagrams to permit further evaluation of their nature and extent. Essential nutrients are included in the summary tables but are not discussed for nature and extent.

Each unit concludes with a brief synopsis of the nature and extent of contamination associated with the Luckey site. Results from the Phase II investigation have been integrated into the discussion. A general discussion of the constituents identified on site and off site is provided, with emphasis on those constituents believed to be of primary concern. All constituents detected above the respective background will be further evaluated in the BRA in sections 6 and 7. A complete listing of all sample analytical results is provided in Appendix 4A.

4.1 UNIT 1: ON-SITE SOILS

The soils contained within the Luckey site boundaries were evaluated in the RI by collecting intrusive samples from strategically placed borings and submitting the samples for laboratory testing of a wide array of chemical and radiological parameters. In the Phase II investigation, four surface and 25 subsurface soil samples were collected from sample locations designated as potential constituents of concern (PCOCs). The PCOC samples were analyzed for radionuclides, metals, VOCs, SVOCs, and anions. Ra-226 and total uranium were the primary radionuclides detected above background. Beryllium was the primary metal detected above background with a maximum concentration of 9,970 mg/kg. Three VOCs (dichloromethane, toluene, and total xylenes) also were widely detected. SVOCs were detected near the former UST and in the filter bed area. The results of the Phase II investigation identified impacted areas at the Luckey site. Phase IV sampling efforts were designed to determine the nature and extent of soil contamination in these areas.

Three types of borings and associated soil samples were collected during the Phase IV RI. These borings are referred to as beryllium screening borings, risk borings, and nature and extent borings. The only difference between the borings is the list of analytes reported for samples collected from the borings. Soil samples collected from the beryllium screening borings were analyzed for beryllium. Soil samples collected from risk borings were analyzed for target analyte list (TAL) metals, radionuclides, VOCs, SVOCs, fluoride, and ammonia. In addition, samples collected from every other 1-ft interval in the risk

borings were screened in the field for radiological activity and analyzed for beryllium. Soil samples collected from the nature and extent borings were analyzed for AEC-related constituents (arsenic, barium, beryllium, lead, radionuclides, fluoride, and ammonia). Analytical results from all three types of borings were used to evaluate nature and extent and as input to the risk assessment.

Typically, one or more risk borings were drilled into each target feature. The risk samples were collected from a 1-ft interval at the depth where the highest level of contamination was expected based on field screening for organic vapors and radionuclides or visual observation of contamination or staining. Four laboratory samples per boring were collected to determine nature and vertical extent within major target features such as trenches and pits. The samples were collected in 1-ft intervals and generally came from the top, middle, and bottom of the target feature, and from 1 to 2 ft beneath the feature. In addition, boreholes were drilled outside of target features to determine the lateral extent of contamination. In these borings, laboratory samples were collected at the same depths as the samples taken from the middle and bottom of the adjacent feature. A more thorough discussion of the soil sampling and analysis methodology is presented in Section 3.1.2 for the on-site soils. The results of the laboratory analyses of these soil samples are summarized in this section.

In earlier investigations, the Luckey site was divided into 10 Investigative Areas (IAs) based on the suspected contaminants and the likely source. However, the results of the RI sampling program indicated that the pattern of contamination was not adequately defined by IA boundaries. Further, the investigation of on-site soils was more closely related to site features such as lagoons and waste disposal trenches rather than specific IAs. For these reasons, limited references to specific IAs are used in this section. The IA designations have been retained to better describe certain locations and not to define features of interest. The principle features of interest for the investigation of on-site soils include:

- trenches and pits (used for disposal of sludge, scrap metal, and lime);
- lagoons;
- former petroleum handling buildings and underground storage tank (UST) area;
- electrical transformer areas (past and present);
- bare spots and areas of stressed vegetation;
- filter bed area and debris piles; and
- existing buildings.

4.1.1 Trenches and Pits

Based on historic operational records and personal communications with past employees, numerous trenches and pits were excavated on the Luckey site for the disposal of waste materials. Much of the sludge dredged from the lagoons was deposited in trenches and pits that were excavated in the northeast corner of the property (Waste Disposal Trenches and Pits in Northeast Corner). This area was formerly designated as IA01. Two other trenches were excavated on site for the disposal of metal and other waste. One of these trenches was located south of the rail spur in the east-central portion of the property formerly designated as IA03 (Scrap Metal Disposal Trench). The other was located just northeast of the sewage treatment filter beds in the area formerly designated as IA05 (Disposal Trench Northeast of Filter Beds). In addition, a lime pit or settling basin associated with the water treatment plant was located near the northwestern corner of the site in former area IA07 (Lime Pit).

Tables 4.1a through 4.1d provide a summary of the detected constituents in the trenches and pits that includes a list of analytes detected, their frequency of detection, minimum and maximum detected values and locations, average concentration, background, and PRGs for the soil samples. Several figures also have been created to illustrate the nature and extent of contamination associated with trenches and pits. The distribution of beryllium detected above background in the soil borings from the trenches and

pits is shown in Figure 4.1. The distributions of lead, barium, arsenic, and fluoride are shown in Figure 4.2. The distributions of radionuclides are shown in Figure 4.3. Each figure lists concentrations detected above background at each soil boring location.

4.1.1.1 Waste Disposal Trenches and Pits in Northeast Corner (IA01)

An area of approximately 3.8 acres in the northeast corner of the Luckey site was used in the past for on-site disposal of sludge and solid waste. Several trenches and pits were excavated for disposal of the waste materials. Six PCOC locations were sampled in the Phase II investigation to evaluate surface and subsurface soils in the Waste Disposal Trenches and Pits. During Phase IV, 36 borings were installed in the northeast disposal area to determine the magnitude and extent of constituents in these soils as indicated below:

- 4 risk borings, 2 through the disposal trenches(IA01-SB0001 and IA01-SB0002) and one each in the disposal pits (IA01-SB0003 and IA01-SB0004)
- 16 nature and extent borings in and adjacent to the trenches and pits
- 16 beryllium screening borings near disposal trenches and pits

Table 4.1a summarizes the analytical results of all soil samples collected in the evaluation of the disposal trenches and pits in the northeast corner of the property during Phase II and Phase IV sampling activities.

Based on descriptive logs of the two borings drilled through the trenches, a black or gray sludge was encountered to a depth of approximately six feet bgs. Fill material was encountered in the two pits to a depth of approximately eight feet. The fill consisted of metal debris, wood, brick, woven fabric, black sand, and concrete fragments. Eight samples were collected from the four risk borings drilled through these features. Beryllium, lead, chromium, and zinc were the metals most commonly detected above background in these samples. Beryllium was detected above background in a few samples collected from beneath the fill material. In the two borings through the trenches, beryllium was detected above background to depths of six and nine ft. Beryllium was detected above background to depths of seven and nine feet in the two borings through the disposal pits. Other metals that were detected above background in one to four samples include arsenic, antimony, aluminum, barium, cadmium, copper, mercury, molybdenum, phosphorus, selenium, silver, strontium, thallium and zinc.

Seven PAHs totaling 10,420 µg/kg were detected in the 1 to 2 ft sample from IA01-SB0003. PAHs were detected at low levels in two other samples. These plus diesel range organics and bis(2-ethylhexyl)pthalate were the only SVOCs detected in any of the samples collected from the trenches or pits in this area. Several organic constituents were detected in one or more of the samples collected from the trenches and pits. Bromodichloromethane, 2-hexanone, and 2-butanone were detected in one sample each at very low, estimated concentrations. The most commonly detected VOCs included benzene, ethylbenzene, toluene, total xylenes, methlyene chloride and carbon disulfide. These constituents also were detected at very low or estimated concentrations. These same VOCs were detected in many other locations across the Luckey site at comparable concentrations. Because these VOCs are few in number, low in concentration, and found in other areas of the site, their presence is not believed to be a result of impact from past disposal operations.

Radionuclides were detected above background in seven of the eight soil samples collected from the risk borings in the trenches and pits. The most common radionuclides detected above background included Ra-226, Th-230, Th-234, U-233/234, U-235 and U-238. Actinium-227 and Th-238 also were detected above background in 10% or less of the samples.

Beryllium, fluoride, and lead were the main constituents detected above background in the soil samples collected from this area. Beryllium was detected above background in more than 120 samples. Concentrations ranged from 0.36 mg/kg to 8760 mg/kg. Generally, it was detected in at least one subsurface sample in each boring in this area. In borings where it was detected in more than one sample, the highest concentrations were usually found in the samples nearest the surface. In several borings, beryllium was detected to a depth of approximately 16 ft. Fluoride was detected in 60 soil samples at concentrations that ranged from 1.02 mg/kg to 576 mg/kg. Lead was detected above background in 43 samples. Nine samples exceeded the Region 9 PRG of 400mg/kg. The maximum lead concentration (28,900 mg/kg) was detected in a crystalline exudate on the soil surface in one of the un-vegetated areas. Radionuclides were detected above background in 26 subsurface soil samples. The radionuclides most commonly detected above background included Ra-226, Th-230, Th-234, U-233/234, U-235 and U-238. The elevated radionuclides were detected mainly in the 1 to 2 ft samples. However, they were detected at levels greater than three times background in the 6 to 7 ft sample from IA01-SB0004.

4.1.1.2 Scrap Metal Disposal Trench (IA03)

Historical on-site waste disposal practices involved the excavation of a trench in the east-central portion of the Luckey site for the disposal of scrap metal. The trench location was identified along the south side of a former rail spur using geophysical surveys (Section 3.1.1.3). One PCOC location was sampled at this disposal trench during Phase II. During Phase IV, thirteen borings were installed in and adjacent to the scrap metal trench as indicated below:

- 2 risk borings through the disposal trench
- 7 nature and extent borings in and adjacent to the trench
- 4 beryllium screening borings near the disposal trench

Table 4.1b summarizes the analytical results for Phase II and Phase IV borings.

Two borings were drilled through the disposal trench and were advanced until bedrock was encountered at a depth of 18 ft. Samples were collected from the middle of the fill material to determine the magnitude of contamination. Seven borings were installed in areas around the trench to determine the extent of contamination in the trench. Two of the borings were drilled to a depth of 10 ft and the other five were drilled to approximately 15 ft. Four soil borings were drilled in the vicinity of the disposal trench to determine the horizontal and vertical extent of beryllium.

Based on descriptive logs of the two borings drilled through the trench and the single sample taken on top of the trench, the fill material was encountered between 1½ and 4 ft bgs. Samples from the fill consisted of metal debris and black sand. Both samples collected from 3 to 4 ft contained beryllium, copper, and toluene. Other analytes detected in at least one of the samples included lead (780 mg/kg), 2-methylnaphthalene (246J µg/kg), benzene (2J µg/kg), chloroform (0.84J µg/kg), toluene (442J µg/kg) total xylenes (35.8 µg/kg), and three PAH compounds (2,409 µg/kg). U-233/234 (2.8 pCi/g) and U-238 (2.7 pCi/g) were detected in the 3 to 4 ft sample from IA03-SB0003, at activities slightly above background.

An exploratory trench, TR0002, was excavated in a north-south direction across the scrap metal disposal trench to more closely examine the contents and to better define the depth. The excavation reached a depth of 13 ft with a rubber-tire backhoe. Soil samples were collected from the excavation at depths of zero to ½ ft, 1 to 2 ft, 3 to 4 ft, and 12 to 13 ft and analyzed for beryllium. Fill material consisting of steel and fiberboard drums, blocks of metal, wood, brick, black sand, and glass fragments was encountered to a depth of approximately 12 ft bgs.

Beryllium was detected above background in all four samples collected from the exploratory trench. The highest concentration detected was 1,300 mg/kg in the 1 to 2 ft sample. At the bottom of the trench, beryllium was detected in the 12 to 13 ft sample at 274 mg/kg. It is believed that the concentrations detected in the samples from borings IA03-SB0002 and IA03-SB0003 are more representative of the true levels of beryllium at this depth. The excavation was difficult to keep open due to the loose fill material and also was full of water. As a result, high-quality discrete samples could not be collected.

Outside of the scrap trench, beryllium was the main constituent detected above background in the soil. Beryllium was detected in most of these borings to a depth of 3 or 4 ft. Fluoride was detected in the 1 to 2 ft sample from IA03-SB0004 and in two subsurface samples from IA03-SB0009, but each occurrence was less than two times the background value. Radionuclides were detected above background in the 1 to 2 ft sample from IA03-SB0005, the 12 to 13½ ft sample from IA03-SB0007, and in two subsurface samples from IA03-SB0009. In each case, however, the radionuclides were detected at a level less than 1½ times their respective background activities.

4.1.1.3 Disposal Trench Northeast of Filter Beds (IA05)

Historical on-site waste disposal practices involved the excavation of a trench northeast of the filter beds for the disposal of scrap metal. Two PCOC locations were sampled on top of the disposal trench and two outside the trench during the Phase II investigation. During Phase IV, nine borings were installed in and adjacent to the scrap metal trench as indicated below:

- 2 risk borings through the disposal trench (IA05-SB0007 and IA05-SB008)
- 4 nature and extent borings in and adjacent to the trench
- 3 beryllium screening borings near the disposal trench

Table 4.1c summarizes the analytical results for the Phase II and Phase IV borings.

Samples from risk borings were collected from depths of 1 to 2 ft bgs and the middle of the fill material in both borings. Since the fill in IA05-SB0007 was slightly thicker than in IA05-SB0008, a second sample was collected from the fill and analyzed for these same parameters. Four borings were installed around the perimeter of the trench to determine the nature and extent of contamination. Three additional borings were installed near the disposal trench to determine the horizontal and vertical extent of beryllium.

Based on descriptive logs of the two borings drilled through the trench, the fill material was encountered between 3 and 6½ ft bgs. The fill consisted of metal debris, wood, ash, brick, woven fabric, black sand, and glass fragments. Samples collected from zero to 1 ft bgs contained fluoride, beryllium, and lead above background. Beryllium and four organic constituents were detected in the 1 to 2 ft samples from both borings drilled through the trench. Beryllium also was detected above background in all four of the surface samples collected in Phase II. The four organic constituents were detected at very low or estimated concentrations and included benzene, ethylbenzene, methylene chloride, and toluene.

Numerous metals were detected above background in samples collected from the fill material. Beryllium, chromium, copper, lead, mercury, nickel, and zinc were detected above background in both samples. Beryllium and lead also were detected above background in the surface samples. Antimony, aluminum, selenium, and vanadium were detected above background in one of the two fill samples. The same four organic constituents detected in the 1 to 2 ft samples were detected at low or estimated concentrations in the samples from the fill as well. The fill also contained low concentrations of 10 PAHs, methylene bromide, and bis(2-ethylhexyl)phthalate in at least one of the samples. U-233/234 was

detected above background in both fill samples, while Ra-226, Th-230, Th-234, U-235 and U-238 were detected in at least one of the samples.

Beneath the fill material fluoride and beryllium were the analytes most frequently detected above background. Barium was detected in one sample at a concentration of 789 mg/kg. Ra-226 also was detected in one sample beneath the fill material slightly above the background activity. Beryllium was detected to a depth of 9½ ft bgs in both borings, at concentrations of 40.5 mg/kg and 109 mg/kg.

Fluoride and beryllium were detected above background to a depth of approximately 5 ft bgs in the four nature and extent borings outside the trench. Lead was detected in one of the 1 to 2 ft samples at a concentration of 51.9 mg/kg. Potassium-40 was detected slightly above background in two samples. Beryllium was detected in the 9 to 10 ft samples from IA05-SB0018 and IA05-SB0019, but the maximum concentration was 1.9 mg/kg. Beryllium was not detected below a depth of 5 ft in the other two borings. Beryllium also was detected above background in borings IA05-SB0022 and IA05-SB0024 to a depth of 4 ft. In boring IA05-SB0023, it was detected to a depth of 6 ft.

4.1.1.4 Lime Pit (IA07)

The old lime pit or settling basin is located in the northwest portion of the site. During the Phase II investigation, one PCOC location was sampled at the lime pit. Two additional borings were installed through the lime pit during Phase IV activities as indicated below:

- 2 nature and extent borings (IA07-SB0009 and IA07-SB0010) in and adjacent to the trench

Boring IA07-SB0009 was drilled to a depth of 7½ ft and four soil samples were collected for chemical analyses. Boring IA07-SB0010 was drilled to 6 ft and three subsurface samples were collected for laboratory analyses. Boring IA07-03EQ01 was augured to 3½ ft and three subsurface samples were collected.

Barium, beryllium, and lead were detected above background concentrations in the ½ to 1½ ft samples from two borings. The highest concentrations of beryllium and lead were 13.7 mg/kg and 442 mg/kg, respectively. Beryllium also was detected in the 2.2 to 3.3 ft sample from IA07-SB0010, but the concentration was 1.9 mg/kg. Barium, Boron, magnesium, and strontium were detected above background in samples from IA07-03EQ01. Potassium-40 and Th-228 were detected once in each phase IV boring at levels slightly exceeding the background activities. Table 4.1d summarizes the analytical results for the Phase II and Phase IV borings.

4.1.2 Lagoons

Lagoons A, B, and C were constructed to contain waste sludge generated as part of the beryllium processing. Lagoon D was excavated just east of the former Shipping & Receiving Building but reportedly was never used. During Phase II investigations, five PCOC locations (1 each at Lagoons A and B, 2 in Lagoon C, and 1 to evaluate surface soils near Lagoon D) were sampled to evaluate surface and subsurface soils in the lagoons. Soils in and around each of the lagoons were further evaluated during Phase IV activities by installing borings and collecting soil samples as indicated below:

- 6 risk borings (2 each in Lagoons B and C, and one each in Lagoons A and D)
- 10 nature and extent borings (4 at Lagoon C, 3 at Lagoon A, 2 at Lagoon B, and 1 at Lagoon D)
- 12 beryllium screening borings (3 at Lagoons A and B, 4 at Lagoon C, and 2 at Lagoon D)

Tables 4.2a through 4.2d summarize the analytes detected, their frequency of detection, minimum and maximum detected values and locations, average concentration, background and PRGs for soil samples collected from the Lagoons. Several figures were created to graphically display the results of the sampling efforts at the lagoons. The distributions of inorganic constituents and radionuclides in the soils at the Lagoons are shown in Figures 4.4 and 4.5, respectively.

In the risk borings, samples were collected from either the 1 to 2 ft interval or the middle of the sludge material, if present. Two additional subsurface samples were collected from these borings for analyses of nature and extent constituents. Samples for analysis of beryllium also were collected in each of these borings. In the nature and extent borings, the first subsurface samples were generally collected from these borings at ½ to 1½ ft. The second sample was collected at a depth near the base of sludge or fill material as determined from the risk borings. A third sample was collected from natural soils beneath the sludge or fill. The beryllium screening borings were drilled to depths of 8 to 10 ft and samples were collected at intervals of every other foot.

A trench was excavated through the suspected location of Lagoon D to investigate the presence of buried metallic objects identified in the geophysical surveys, to define the depth of the lagoon, and to determine the nature of the fill material. The investigative trench was approximately 12 ft long and 8 ft deep. Soil samples were collected from the walls of the trench at intervals of 1 to 2 ft, 3 to 4 ft, and 5 to 6 ft, and from 7 to 8 ft at the bottom of the trench. All samples were analyzed for beryllium.

4.1.2.1 Organic Constituents

One SVOC was detected in the soil samples collected at the lagoons. Fluoranthene was detected at an estimated concentration of 2010J µg/kg in the 1 to 2 ft sample from IA02-SB0003. Low or estimated concentrations of five VOCs were detected in each of the six 1 to 2 ft depth samples from the risk borings. Benzene and toluene were present in six samples. Carbon disulfide and total xylenes were detected in three samples. Chloroform and ethylbenzene were detected in one sample. These same VOCs were detected in many other locations across the Luckey site at comparable concentrations. Because the organic constituents are few in number, low in concentration, and found in other areas of the site, their presence is not believed to be a result of impact from past operations at the lagoons.

4.1.2.2 Lagoon A

Beryllium was the metal most commonly detected above background at Lagoon A (Table 4.2a). It was detected above background in the upper samples from all borings except IA02-SB0010. The concentrations in all samples ranged from 2 mg/kg to 7880 mg/kg. In the lagoon, it was found at a depth of 4.8 ft bgs, while along the northern edge of the lagoon, it was detected at a maximum depth of 6 ft.

Fluoride was detected above background in four samples. It was detected at a concentration of 231 mg/kg in the 2½ to 3½ ft sample from IA02-04AX00. It also was detected in the 1½ to 2½ ft sample in IA02-SB0010 at a concentration of 53.2 mg/kg. Barium and cobalt were detected above background in the 1 to 2 ft sample from IA02-SB0005. Potassium-40, Ra-226,Th-228, Th-230, U-234, U-235 and U-238 were detected in one or two samples each at levels ranging from slightly above their respective background to 52.3 pCi/g for U-234 at IA02-04AX00.

4.1.2.3 Lagoon B

Beryllium was the metal most commonly detected in soil samples from Lagoon B (Table 4.2b). It was found above background in all borings except IA02-SB0025 and IA02-SB0026. The concentrations ranged from 1.7 mg/kg to 2,920 mg/kg. The highest concentrations were detected in the 2½ to 3½ ft

sample from IA02-05BE00 and in the 4½ to 5½ ft interval from IA02-SB0004. It was detected above background to a depth of 8 ft, both inside and around Lagoon B.

Fluoride was detected above background in four samples, and the concentration ranged from 7.14 mg/kg to 92.1 mg/kg. The highest concentration was detected in the 7 to 8 ft sample from IA02-SB0004. Lead was detected above background in three samples. It was found in the 1 to 2 ft sample from IA02-SB0003 at 29 mg/kg, in the 4 to 5½ ft sample from IA02-05BE00 and in the 2½ to 3½ ft sample from IA02-SB0013 at 122 mg/kg.

Ra-226, Th-234, U-233/234, and U-238 were each detected in the 7 to 8 ft sample from IA02-SB0004. Th-234 also was detected in the 2½ to 3½ ft sample from IA02-SB0013. Potassium-40 was detected in two samples at 27.4 pCi/g and 28.7 pCi/g. These are slightly above the background activity of 27.2 pCi/g. Thorium-230 (24.6 pCi/g), U-234 (6.8 and 13.1 pCi/g) and U-235 (0.53 and 0.27 pCi/g) also were detected at location IA02-05BE00. Ra-226 and Th-230 were elevated to nearly 10 times background.

4.1.2.4 Lagoon C

Beryllium and lead were the metals most commonly detected above background at Lagoon C (Table 4.2c). Fluoride was the only anion detected above background. Beryllium was encountered above background in all borings except IA02-SB0016 and IA02-SB0017. The concentrations ranged from 1.2 mg/kg to 3,840 mg/kg, and the highest levels were found in the 1 to 3½ ft interval in boring IA02-SB0001. Beryllium was detected to a maximum depth of 7 ft in this boring, but only to 5 ft in other borings. Fluoride was detected in eleven samples, with concentrations ranging from 0.19 mg/kg to 27.4 mg/kg. Lead was detected above background in eight samples, but none were deeper than 4 ft bgs. The highest concentration was 88.5 mg/kg. Numerous other metals were detected in the 1 to 2 ft samples from IA02-SB0001 and IA02-SB0002 including aluminum, antimony, cadmium, chromium, and zinc. Many of these also were detected in the 3 to 4 ft sample at IA02-08AW00.

Six radionuclides were detected at elevated activities in two samples from the 1 to 3½ ft interval in boring IA02-SB0001. These included Ra-226, Th-230, Th-234, U-233/234, U-235, and U-238. Some of the detected activities were as much as 12 times background. Radionuclides also were detected in the 1 to 2 ft sample in IA02-SB0002, the 2½ to 3½ ft sample in IA02-SB0009, and the 2 to 3 ft sample of IA02-08AW00, but they were fewer in number and had significantly lower activities. In addition, potassium-40 was detected in four subsurface samples, with a maximum activity of 30.2 pCi/g.

4.1.2.5 Lagoon D

Beryllium, lead, and fluoride were detected above background in soil samples collected at Lagoon D (Table 4.2d). Beryllium was detected in the 1 to 2 ft and 5 to 6 ft samples from IA03-SB0001 at 15.1 mg/kg and 1.9 mg/kg, respectively. Lead also was detected above background in the 1 to 2 ft sample. Fluoride, beryllium, and lead were detected above background in the 1 to 2 ft sample from IA03-SB0008. No constituents were detected above background in the 3 to 4 ft and 6 to 7 ft samples. Beryllium was detected in the 1 to 2 ft and 3 to 4 ft samples from Trench TR0001. The highest concentration was 26.6 mg/kg.

Potassium-40 was detected at 28.9 pCi/g in the 9 to 10 ft sample from boring IA03-SB0008. This is slightly above the background activity of 27.2 pCi/g. Actinium-228 at 1.45 pCi/g was the only other radionuclide detected above background at Lagoon D.

4.1.3 Former Petroleum Handling Buildings and UST Area

According to historical documentation, three former on-site facilities were used for the storage or handling of petroleum products. An Oil House once existed just west of the current Main Office, and an Oil Pump House was located just north of the east end of the Production Building (as shown in Figure 3.7 of Section 3). Old schematic drawings also show what appear to be two tanks associated with the Oil Pump House. It is uncertain whether these were above-ground or underground tanks, or if they even existed. However, it is known that two underground petroleum storage tanks were once located in the north central portion of the site between the main buildings and the above-ground propane tanks. The two 30,000-gal USTs previously held fuel oil. One PCOC location was sampled at the former UST area during Phase II. As part of the Phase IV RI, soils around these former facilities were tested to determine if they have been impacted by past releases of petroleum products.

Because the contaminants in the vicinity of the Oil house and the Oil Pump House were expected to consist mainly of hydrocarbons, the sampling strategy was targeted at these compounds. Therefore, the terminology of risk boring, nature and extent boring, and beryllium screening boring do not apply here.

Four soil borings were installed at the former Oil House and four at the Oil Pump House using a direct-push Geoprobe unit. Two subsurface samples were collected from each boring for analysis. The first subsurface sample in each boring was selected based on the highest organic vapor field screen reading or visual signs of contamination such as odor or soil discoloration. If the field instrumentation detected no organic vapors and there was no obvious sign of contamination in the soils, then the sample was collected from the 5 to 6 ft interval. The second subsurface sample in each boring was collected from the bottom 1 ft interval. All samples were analyzed for total recoverable petroleum hydrocarbons (TRPH) and SVOCs. In addition, the sample with the highest FID field screen reading at each site was analyzed for VOCs.

Two soil borings were drilled in the former UST area located just south of the propane tanks using a hollow-stem auger rig or hand augur. Subsurface soil samples were collected from two borings at 9 to 10 ft and one at 4 to 4.3 ft for chemical analyses. The deeper depth was selected because it was believed to be below the bottom of the former USTs and, therefore, a likely horizon in which to detect potential contamination. These samples were analyzed for 23 metals, SVOCs, VOCs, and radionuclides. Additional subsurface samples were collected from each boring for analysis of beryllium. Boring IA04-SB0002 was augured to a depth of 18½ ft before bedrock was encountered. At IA04-SB0001, auger refusal was encountered at a depth of 12 ft bgs and at several other locations spaced about 5 ft apart. The obstruction was believed to be a concrete slab associated with the former USTs. This is further supported by the geophysical surveys, which detected a magnetic and weak EM-61 anomaly at this location, but no corresponding EM-31 anomaly. These findings suggest the presence of a remnant base foundation consisting of reinforced concrete.

Table 4.3 summarizes analytes detected, their frequency of detection, minimum and maximum detected values and locations, average concentration, background, and PRGs for soil samples collected from former petroleum handling buildings and UST area. The distribution of organic constituents and beryllium detected at the former petroleum handling buildings and UST area are displayed in Figure 4.6. Results from the former Oil House, former Oil Pump House, and the former UST Area are discussed below.

4.1.3.1 <u>Former Oil House</u>

TRPH was the only constituent detected in all but one of the eight subsurface soil samples collected at the former Oil House. The highest concentration of TRPH detected in these seven samples

was 35.6 mg/kg. TRPH was detected in the 3 to 4 ft sample from IA04-SB0030 at 6,190 mg/kg. This sample also contained the SVOC 2-methylnaphthalene (4,100 µg/kg) and four VOCs. The VOCs included acetone (36.4 µg/kg), carbon disulfide (1.9J µg/kg), toluene (1.2J µg/kg), and total xylenes (22.3 µg/kg). No other organic constituents were detected in any of the samples collected at the former Oil House.

4.1.3.2 Former Oil Pump House

TRPH was detected above the instrument detection limits in five of the eight subsurface soil samples collected at the Former Oil Pump House. The concentrations of TRPH ranged from 14.6J mg/kg to 69.5 mg/kg. Two SVOCs were detected in the 10 to 11 ft sample from IA04-SB0037 at low estimated concentrations. The level of chrysene was reported as 31.5J µg/kg, and that for pyrene was 44.7J µg/kg. Both these values are below their respective PRGs. Vinyl chloride was detected in the 5 to 6 ft sample in IA04-SB0036 at 3.8 µg/kg.

4.1.3.3 Former UST Area

Beryllium was detected above background in all five subsurface samples collected from IA07-SB0001. The concentrations ranged from 1.9 mg/kg to 20.1 mg/kg and generally decreased with depth. At IA07-SB0002, beryllium was detected above background in four samples to a depth of 8 ft bgs. The highest concentration detected was 4.6 mg/kg in the 1 to 1½ ft sample. The maximum beryllium concentration was at location IA07-05EI00 at 27.2 mg/kg in the 0 to 0.1 ft sample. Beryllium was below background in the five samples collected between 9 ft and 18 ft bgs. Calcium was the only other metal detected above background in either sample. Uranium-235 was the only radionuclide detected above background. Its concentration (0.33J pCi/g) was an estimated value slightly above background

Five VOCs were detected at low or estimated concentrations in the 9 to 10 ft sample from IA07-SB0001. These constituents included benzene (4.4J µg/kg), carbon disulfide (20.7 µg/kg), ethylbenzene (3.3J µg/kg), toluene (10.7 µg/kg), and total xylenes (10.4 µg/kg). In the 9 to 10 ft sample from IA07-SB0002, the only VOCs detected were carbon disulfide (26 µg/kg) and total xylenes (1.1J µg/kg). The VOCs 2-methylnapthalaene, methylene chloride, acetone and four PAHs were detected in the 4 to 4.3 ft sample at location IA07-05EI00. One, acenapthene, was below its background concentration. The rest, although above background, are well below their respective PRGs.

4.1.4 Electrical Transformer Areas

Historically, two areas on the Luckey site contained electrical transformers, a former Transformer Room and an electrical substation. The former Transformer Room (constructed in 1949) was identified on a 1950s plant drawing, and was located at the east end of the Annex, or present-day warehouse (Figure 3.7 of Section 3). The transformers no longer exist and the building has since been extended almost 200 feet beyond the former Transformer Room. An electrical substation, which first appears on drawings from the 1950's, is located at the southwest corner of the Annex. The substation is enclosed with a 40-ft by 40-ft chain-link fence and contains several transformers that are currently used by Uretech International Inc. It is possible that this transformer was added to supply the induction furnace used in the beryllium production process.

Six borings were drilled at these two sites to test the surface and subsurface soils for potential contamination associated with the electrical transformers. The sampling strategy was targeted at these constituents. Therefore, the terminology of risk boring, nature and extent boring, and beryllium screening boring do not apply here.

Table 4.4 summarizes analytes detected, their frequency of detection, minimum and maximum detected values and locations, average concentration, backgrounds and PRGs for the soil samples collected from the electrical transformer areas. The distribution of organic constituents and beryllium detected above background at the former Transformer Room and the electrical substation are shown in Figure 4.7. Results from the former Transformer Room and the Electrical Substation are discussed below.

4.1.4.1 Former Transformer Room

Two soil borings were installed at the former Transformer Room. Both borings were advanced to a depth of 10 ft using a direct-push Geoprobe unit. One surface soil sample and two subsurface samples were collected at each boring for analysis. The first subsurface sample in each boring was selected based on the highest organic vapor field screen reading or visual signs of contamination such as odor or soil discoloration. The second subsurface sample was collected from the bottom 1 ft interval of the boring. All samples were analyzed for TRPH, PCBs, and SVOCs. In addition, one sample from each boring was analyzed for VOCs.

The analytical results for these samples are summarized in Table 4.4. Since the analyses are all organic, there are no associated background values for comparison. Therefore, the summary table lists all parameters that were detected above the instrument detection limit and qualified as either an actual or an estimated value.

The surface sample collected from IA04-SB0033 on the north side of the former Transformer Room contained TRPH at 418 mg/kg and PCB-1254 at 3,200 µg/kg. SVOCs were detected in this sample, including bis(2-ethylhexyl)phthalate at 459 µg/kg and 15 PAHs totaling 24,222 µg/kg. Seven PAHs were detected above background but below the Region 9 PRG. Five were detected above the region 9 PRG. The first subsurface sample was selected from the 1½ to 2½ ft interval based on visual inspection. This sample consisted of black sand and dark gray clay. None of the samples produced a response on the FID organic vapor detector greater than 0.1 ppm. TRPH was detected in this subsurface sample at 39.3 mg/kg and PCB-1254 was detected at 10100 µg/kg. No SVOCs were detected in this sample. The sample from 9 to 10 ft bgs at the bottom of the boring contained no detectable concentrations of TRPH, SVOC, or PCB compounds.

In the surface soil sample from IA04-SB0034 located at the south side of the former Transformer Room, TRPH and the PCB-1254 were detected at concentrations of 141 mg/kg and 2270 µg/kg, respectively. SVOCs detected in this sample include 13 PAH compounds at a combined concentration of 10,817 µg/kg and bis(2-ethylhexyl)phthalate at 2,360 µg/kg. The first subsurface sample was collected from 1½ to 2½ ft bgs based on a FID field screen response of 3 ppm. Organic vapors were not detected in any of the other subsurface samples. The 1½ to 2½ ft sample contained low estimated concentrations of benzene (0.61J µg/kg), carbon disulfide (4.1J µg/kg), and toluene (0.65J µg/kg). Only TRPH (11.5J mg/kg) was detected in the 9 to 10 ft sample collected from the bottom of boring IA04-SB0034. Neither of the subsurface samples contained detectable concentrations of PCBs or SVOCs.

4.1.4.2 Electrical Substation

At the southwest corner of the Annex stands an electrical substation with a number of transformers. The earliest maps, circa 1942, show an electrical substation at this location however it may have been upgraded. Four 5-ft soil borings were placed around this outdoor transformer area. Three of the borings were advanced using a direct-push Geoprobe unit, while the fourth (IA04-SB0025) was hand-augured due to space limitations. Beginning at a depth of 1 ft, four subsurface samples were collected at 1 ft intervals from each boring. Boring IA04-SB0025 was hand-augured a second time to obtain additional samples from the 4 to 5 ft and 5 to 6 ft depth intervals. At least one sample from each boring

was analyzed for PCBs, and the remaining samples were analyzed for beryllium. The 2 to 3 ft and 3 to 4 ft samples from IA04-SB0023 were analyzed for PCBs.

PCBs were detected in each of the four borings. PCB-1260 was detected in the 1 to 2 ft sample from IA04-SB0022 at a concentration of 23.1 µg/kg. PCBs were not detected in the 2 to 3 ft sample from IA04-SB0023, but four PCB congeners were detected in the 3 to 4 ft sample at a combined concentration of 31.9 µg/kg. In IA04-SB0024, five PCB congeners were detected in the 3 to 4 ft sample. Their combined concentration was approximately 357 µg/kg. Three were detected in the 4 to 5 ft sample from IA04-SB0025 at a total concentration of 54 µg/kg. Although PCBs were detected in the soils at the electrical substation, the total concentration of all samples was below 500 µg/kg. In accordance with the EPA "PCB Mega Rule" (40 CFR 761.61) for PCB remediation, generally no further action is required when levels are below 1,000 µg/kg.

Beryllium was detected in the 1 to 2 ft, 2 to 3 ft, and 4 to 5 ft intervals in boring IA04-SB0023; concentrations ranged from 2.2 mg/kg to 6.4 mg/kg. At IA04-SB0025, beryllium was detected in all five of the subsurface samples at concentrations ranging from 13.1 mg/kg to 55.6 mg/kg. Beryllium was not detected above background in any of the samples from IA04-SB0022 or IA04-SB0024.

The organic constituents and beryllium detected at the former Transformer Room and the electrical substation are shown in Figure 4.7. The greatest concentrations of organic constituents were detected in the surface soil samples from the north and south sides of the former Transformer Room. PCBs were detected at significant concentrations on the north side at a depth of 1½ to 2½ ft. Based on the field screening results and the descriptive log for this boring (IA04-SB0033), the contamination is not expected to be deeper than 2½ ft bgs. The black sand and dark gray clay encountered in this boring terminated at that depth and the deeper soils consist of natural silty clays. TRPH and SVOCs were not detected at significant quantities below the surface soils.

Beryllium was detected above background values in two of the borings installed at the electrical substation to a depth of 5 ft. The highest beryllium concentrations were found in IA04-SB0025. It was difficult to prevent some of the loose sand and gravel encountered during hand-auguring from caving into the boring.

4.1.5 Bare Spots and Stressed Vegetation Areas

A large area devoid of vegetation and several smaller areas of stressed vegetation are visible in historic and recent aerial photographs of the site. These areas are located mainly in the north central portion of the facility in the area previously designated as IA07. The large bare spot covers approximately 80 ft by 110 ft and is situated between the propane tanks and the sewage treatment plant. The surface is covered with cobbles, pieces of refractory brick, and scattered metallic debris to a depth of 6 inches to 1 ft. One PCOC location within the bare spot was sampled during the Phase II investigation. A series of low areas with stressed vegetation are visible north and northwest of the propane tanks. This area is covered with native grasses, and except for the stressed vegetation, there are no other extraordinary surface characteristics. As part of the Phase IV RI, each of these features was evaluated by collecting subsurface soil samples from soil borings as indicated below:

- 6 risk borings (3 in the bare spot and 1 each in the areas of stressed vegetation)
- 2 beryllium screening borings

All six risk borings were advanced to a depth of approximately 7 ft bgs using a hollow-stem auger rig. Subsurface samples were collected from depths of approximately 1 to 2 ft. In a few cases, these sample depths were adjusted slightly depending on the amount of sample recovery in the split

spoons. Samples also were collected from 3 to 4 ft, and 4 to 5 ft bgs in the six borings and analyzed for nature and extent constituents. In addition, samples collected from 5 to 6 ft and 6 to 7 ft in each boring were collected for expedited analyses of beryllium. Based on the results, the vertical extent of beryllium was not defined in two borings. Therefore, two beryllium screening borings (IA07-SB0003 and IA07-SB0004) were re-drilled within 2 ft of the original boreholes to collect additional samples for beryllium. Samples were collected from 8 to 9 and 9 to 10 ft bgs in these second borings using a direct-push Geoprobe unit.

Tables 4.5a and 4.5b provide a list of analytes detected, their frequency of detection, minimum and maximum detected values and locations, average concentration, background, and PRGs for the soil samples collected from the bare spot and stressed vegetation areas. The chemical elements that were detected most extensively in the soil samples from across the bare spot and areas of stressed vegetation were beryllium and fluoride. These two metals also exhibited the widest contrast with their respective background. The distributions of inorganic constituents in this area are displayed in Figure 4.8. Results from the former bare spot and stressed vegetation areas are discussed below.

4.1.5.1 Bare Spot

Ten metals were detected above background in the three 1 to 2 ft samples collected in the bare spot. Aluminum, barium, cobalt, and nickel were detected in one sample concentrations slightly above background. Thallium was detected in two samples, while beryllium, chromium, lead, and vanadium were detected in all three samples. Elevated concentrations of fluoride and beryllium were detected in each of the 3 to 4 ft and 4 to 5 ft samples from the three borings. Concentrations of nitrogen-ammonia ranged from 20.4 mg/kg to 765 mg/kg. Beryllium was detected above background to a depth of 9 ft in IA07-SB0003, to about 7 ft in IA07-SB0004, and to 6 ft in IA07-SB0005.

Low levels of six radionuclides, Ra-226, Th-228, Th-230, U-233/234, and U-235 were detected in several samples. Except for Ra-226 and Th-230, each occurrence slightly exceeded the respective background activity. Ra-226 was present in the zero to ½ ft sample in boring IA07-06FD00. The maximum measured activity was 6.96 pCi/g. Th-230 was detected above background in the zero to ½ ft sample from boring IA07-06FD00 at a measured activity of 30.6 pCi/g. U-233/234 was detected in the 1 to 2 ft sample in boring IA07-SB0004 and the 3 to 4 ft and 4 to 5 ft samples in boring IA07-SB0005. The maximum measured activity was 3.14 pCi/g.

SVOCs were found in one sample collected from the bare spot. Six PAHs were detected well below PRGs in the 1 to 2 ft sample from boring IA07-SB0003. These included benzo(a)anthracene, benzo(k)fluoranthene, chrysene, fluoranthene, phenanthrene, and pyrene at a combined estimated concentration of 691J µg/kg. VOCs were detected in each of the three 1 to 2 ft samples. Carbon disulfide was detected in all three, with concentrations ranging from 15 µg/kg to 34.2 µg/kg. Toluene was detected in the 1 to 2 ft sample from IA07-SB0004 at 9.6 µg/kg. Benzene and total xylenes were detected in each sample at low estimated concentrations. The maximum detected concentration for each was 3.6J µg/kg and 5.3J µg/kg, respectively. Estimated concentrations of toluene also were detected in IA07-SB0003 and IA07-SB0005, and the maximum value was 2.3J µg/kg. A low estimated concentration of acetone was detected in the 1 to 2 ft sample from IA07-SB0005 at a level of 9J µg/kg.

4.1.5.2 Stressed Vegetation Areas

Beryllium was detected above background in four of the five subsurface samples collected from IA07-SB0006. The concentrations ranged from 1.9 mg/kg to 25.3 mg/kg and the greatest concentration was found in the 1 to 2 ft sample. The concentration of beryllium in the bottom sample from 6 to 7 ft was

below background. Fluoride was detected in the 3 to 4 ft and 4 to 5 ft samples at a concentration of 12.3 mg/kg. The only radionuclide detected above background in IA07-SB0006 was potassium-40 (27.6 pCi/g), which was found in the 1 to 2 ft sample. This value is slightly above the background activity of 27.2 pCi/g. Two VOCs, benzene (0.83J µg/kg) and carbon disulfide (55 µg/kg), also were detected in this same sample. SVOCs were not detected in any of the samples.

Fluoride and beryllium were detected above background in the samples from boring IA07-SB0007. Fluoride was detected in the 3 to 4 ft sample at 40.4 mg/kg and in the 4 to 5 ft sample at 16.5 mg/kg. Beryllium was detected in four subsurface samples at concentrations that ranged from 24 mg/kg to 70.1 mg/kg. In general, the concentrations decreased with depth and the concentration in the bottom sample from 6 to 7 ft bgs was below background. The only organic constituents detected in the samples from this boring were benzene (0.69J µg/kg) and carbon disulfide (14.5 µg/kg). These were detected in the 1 to 2 ft sample. No radionuclides were detected above background and SVOCs were not found above the instrument detection limits in any sample.

No metals or radionuclides were detected at IA07-SB0008 above background. The only organic constituents detected in this boring were two VOCs, benzene and carbon disulfide. Benzene was detected in the 1 to 1½ ft sample at a low estimated concentration of 1J µg/kg, and carbon disulfide was detected in the same sample at 61.5 µg/kg.

Three borings were completed in the stressed vegetation area during Phase II. These samples were collected to confirm high readings on the gamma walkover. Two locations show elevated activities of Ra-226, Th-230, U-234, U-235 and U-238. IA07-05FS00 and IA07-05FL02 show: Ra-226 at 8.09 and 12.1 pCi/g respectively, Th-230 at 8.39 and 12.4 pCi/g respectively, U-234 at 14.2 and 25.8 pCi/g respectively, U-234 at 1.02 and 0.633 pCi/g respectively and U-238 at 13.8 and 26.1 pCi/g respectively. Both samples were taken in the upper ½ ft of the soil.

4.1.6 Filter Bed Area and Debris Piles

Filter beds for the sewage treatment plant and numerous debris piles are contained in a 3.3-acre area in the north central portion of the site. The debris piles are remnants of ore staging and disposal activities. Four PCOC locations in the filter bed and debris pile area were sampled during the Phase II investigation. During Phase IV, the surface and subsurface soils in this area were evaluated using samples collected from 17 borings as indicated below:

- 7 risk borings
- 8 nature and extent borings
- 2 beryllium screening borings

In each risk borehole, one sample was obtained from the fill material. Additional samples were collected below this sample for beryllium analyses. In the nature and extent boreholes, samples were collected from approximate depths of 1 to 2 ft, 3 to 4 ft, and 4 to 5 ft. Boreholes installed for beryllium screening were located between the debris piles. Four subsurface samples were collected from each screening boring for analysis of beryllium.

Table 4.6 summarizes analytes detected, their frequency of detection, minimum and maximum detected values and locations, average concentration, background, and PRGs for the soil samples collected from the debris piles and filter beds. Figure 4.9 shows the distribution of inorganic constituents and fluoride above background in the borings associated with the debris piles and filter beds. The distribution of organic constituents detected in the soils is displayed in Figure 4.10.

Boring IA05-SB0001 was hand-augured through a mound just northwest of the filter beds. Low or estimated concentrations of five VOCs were detected in this sample. These included benzene, (3.3J µg/kg), carbon disulfide (16.9 µg/kg), ethylbenzene (1.1J µg/kg), toluene (6.8 µg/kg), and total xylenes (4J µg/kg). Samples for beryllium analyses were collected near the bottom of the fill at 5 to 6 ft bgs and in the native soil below the fill at 7 to 8 ft bgs. Beryllium was not detected above background in either sample.

Five borings were installed in and around the construction debris piles located southwest of the filter beds. Low concentrations of 10 PAHs and BTEX compounds were detected in the 1 to 2 ft sample at IA05-SB0002. Fluoride and beryllium were detected above background in several samples from borings IA05-SB0013 and IA05-SB0014. Fluoride concentrations ranged from 8.4 mg/kg to 46.7 mg/kg in these two borings and were present in all but the 4 to 5 ft sample at IA05-SB0014. Barium was detected in the ½ to 1 ft sample of IA05-BH0015 at a concentration of 234 mg./kg. Beryllium was present in the 3 to 4 ft and 4 to 5 ft samples in IA05-SB0013, the 1 to 2 ft sample in IA05-SB0014 and the ½ to 1 ft sample of IA05-BH0015. The concentrations ranged from 8.42 mg/kg to 94.9 mg/kg. Additionally, beryllium was detected above background in all four subsurface samples at IA05-SB0025; the concentrations ranged from 22.8 mg/kg to 147 mg/kg. Lead was detected in the 1 to 2 ft sample from IA05-SB0014 at a concentration of 80.3 mg/kg and in the ½ to 1 ft sample from IA05-BH0015 at a concentration of 215 mg/kg. U-233/234 and potassium-40 were detected slightly above background in one sample in boring IA05-SB0014.

Twelve borings were installed in and around the debris piles along the southern and eastern portions of the area. Overall, fluoride, beryllium, and lead were the most common metals detected above background. PAHs were detected in three of the borings, and low concentrations of VOCs were detected in five. Maximum PAH concentrations in these samples exceeded background and in four instances exceeded their respective PRG. In general, the borings installed in the debris piles contained the greatest concentration of constituents. For example, borings IA05-SB0003, IA05-SB0004, and IA05-SB0005 contained from six to 10 metals in the 1 to 2 ft samples. Numerous PAH compounds also were detected in the 1 to 2 ft samples from borings IA05-SB0003 and IA05-SB0005.

Although IA05-SB0009 was not installed in a debris pile, the surface sample collected at that boring contained 12 metals and nine radionuclides above background concentrations. This same sample also contained seven PAHs and low levels of benzene, ethylbenzene, and total xylenes. Beryllium was detected to a depth of 10 ft in this boring. The highest beryllium concentration was 13,300 mg/kg. It was detected in the sample from 4 to 5 ft bgs. The highest radionuclide activity (Th-230 at 88.5 pCi/g) was detected in the surface sample at this boring.

Boring IA05-SB0011 was located in a low area just east of the filter beds. Beryllium was the only metal detected above background in the 1 to 2 ft sample. The concentration was 3.8 mg/kg. No metals or radionuclides were detected above background in the samples from 3 to 4 ft and 4 to 5 ft in this boring.

4.1.7 Existing Buildings and Associated Areas

Thirteen borings and one exploratory trench were sampled around the existing on-site buildings to determine if subsurface soils have been impacted by historic site operations. The borings were placed in areas likely to accumulate contamination, such as drip lines under the eaves of buildings, near loading docks, in high-traffic areas, and around drainage features. The borings included the following:

- 7 risk borings

- 6 nature and extent borings

Five risk borings were drilled to 5-ft bgs and subsurface samples were collected from the 1 to 2 ft interval. Additional samples were collected from each 1 ft interval from 2 to 5 ft bgs and analyzed for beryllium. Two risk borings were installed in the parking lot at the northwest corner of the site to investigate the possibility that elevated levels of site-related constituents existed in the shallow soils before it was paved. This lot was paved sometime in the 1960s. The two borings were drilled to depths of 3 ft bgs using a direct-push Geoprobe rig. Soil samples were collected just beneath the pavement at depths of zero to 1 ft. Additional samples were obtained from depths of 1 to 2 ft and 2 to 3 ft and analyzed for beryllium.

Six nature and extent borings were located around the outside of the buildings. Three borings were placed around the eastern side of the Production Building and Annex. The other three were located near the former Laboratory Building, the Employee Activity Building, and the Guard Shack. These six borings were advanced to depths of 5 to 7 ft, and three subsurface samples were collected from each boring.

An exploratory trench (TR0001) was excavated in an abandoned septic tank located west of the former Laboratory Building. The tank was reportedly filled with brick from the main smokestack used by the beryllium production facility after the stack was dismantled. The concrete tank was unearthed and the contents were removed using a backhoe. A soil sample was collected at a depth of approximately 6½ ft near the bottom of the tank and was analyzed for 24 metals, SVOCs, VOCs, and radionuclides.

Table 4.7 summarizes analytes detected, their frequency of detection, minimum and maximum detected values and locations, average concentration, background, and PRGs for the soil samples collected from the existing buildings and associated areas. Figure 4.11 shows the distribution of organic and inorganic constituents detected in the soil samples collected from around the existing buildings and associated areas. Results for the building areas, parking lot and former septic tank are presented below.

4.1.7.1 Building Areas

Risk boring IA04-SB0017 was installed just north of the eastern end of the Production Building. Low levels of two VOCs, benzene (0.57J µg/kg) and toluene (5.6 µg/kg), were detected in the 1 to 2 ft sample. No other chemical or radiological parameters were detected above background in this sample. Beryllium was not detected above background in any of the three deeper subsurface samples. Nature and extent boring IA04-SB0027 was installed in this same area. The only constituent detected above background in this boring was protactinium-231. It was detected at 1.37 pCi/g in the 3 to 4 ft sample, which is slightly above the background activity of 1.2 pCi/g.

Risk boring IA04-SB0018 and nature and extent boring IA04-SB0028 were augured on the north side of the Annex along a former rail spur. IA04-SB0018 was installed between a former Transformer Room at the Annex and an open doorway to a large compressor in the Production Building. The 1 to 2 ft sample contained beryllium, cadmium, and lead at concentrations above background. Organic constituents detected in this sample included 11 PAHs totaling approximately 36,600 µg/kg, benzene (2J µg/kg), chloroform (0.62J µg/kg), ethylbenzene (1.3J µg/kg), and toluene (9 µg/kg). Th-234 was detected at an estimated 3.11 pCi/g. Three deeper subsurface samples were analyzed for beryllium, which was not detected above background. IA04-SB0028 was installed adjacent to a loading dock near the eastern end of the Annex. Three metals were detected above background in the 1 to 2 ft sample. These included barium (563 mg/kg), beryllium (13.3 mg/kg), and lead (24.5 mg/kg). Potassium-40 was detected in the 5 to 6 ft sample at 27.6 pCi/g, which is slightly above background.

On the east side of the former Shipping and Receiving Building at risk boring IA04-SB0019, low levels of four VOCs were detected in the 1 to 2 ft sample. These included 1,1,1 trichloroethane (7.3 µg/kg), trichloroethylene (1.3J µg/kg), benzene (0.69J µg/kg), and toluene (10.8 µg/kg). No metals, SVOCs, or radionuclides were detected in this sample. Beryllium was not detected above background in any of the four subsurface samples collected in this boring.

Boring IA04-SB0020 was located between the former Laboratory Building and the Employee Activity Building at a beryllium hotspot identified in the walkover survey. Estimated concentrations of benzene and carbon disulfide were detected in the 1 to 2 ft sample at 0.84 µg/kg and 0.69 µg/kg, respectively. No other chemical or radiological constituents were detected in this sample. Beryllium was not detected above background in any of the four subsurface samples collected in this boring.

Numerous organic constituents and metals were detected in the 1 to 2 ft sample collected from risk boring IA04-SB0021. This boring was installed along the driveway north of the Production Building and west of the Main Office in the area of a former Oil House. The organic constituents included 10 PAHs, 4-methyl-2-pentanone (21.4 µg/kg), ethylbenzene (9.1 µg/kg), and total xylenes (26 µg/kg). Low estimated concentrations of benzene and carbon disulfide also were detected in this sample. The metals detected above background included beryllium (18.8 mg/kg), cadmium (1.6 mg/kg), lead (106 mg/kg), and zinc (136 mg/kg). Beryllium was not detected above background in the three deeper soil samples from this boring.

Soils on the south side of the Annex were investigated with nature and extent boring IA04-SB0026. Beryllium was the only metal detected above background in this boring. It was detected in the 1 to 2 ft sample (11.2 mg/kg) and the 6 to 7 ft sample (19.4 mg/kg), but not in the 3 to 4 ft sample. No radionuclides were detected above background in any of the samples.

Boring IA08-SB0005 was hand-augured under the eave on the west side of the Employee Activity Building. Lead was the only chemical parameter detected above background in the ½ to 1½ ft sample. It was detected at 48.6 mg/kg. All constituents analyzed in the 1½ to 2½ ft and 4 to 5 ft samples were below background. The lead present in the surface sample could be associated with past usage of lead-based paints on the buildings.

At the Guard Shack, lead was detected above background in the ½ to 1½ ft and 1½ to 2½ ft samples from boring IA08-SB0003. The concentrations were 72.9 mg/kg and 31.2 mg/kg and decreased with depth. Lead was detected in the 4 to 5 ft sample, but below background. Th-232 was detected in the 1½ to 2½ ft sample and Th-228 was detected in the ½ to 1½ ft and 1½ to 2½ ft samples slightly above the background activity.

Soil boring IA08-SB0004 was hand-augured along the south side of the former Laboratory Building. Fluoride (8.04 mg/kg) and beryllium (54.8 mg/kg) were detected above background in the ½ to 1½ ft sample. Beryllium (29.2 mg/kg) and lead (30.9 mg/kg) were detected above background in the 1½ to 2½ ft sample. Potassium-40 also was detected in this intermediate depth sample slightly above background. No chemical or radiological parameters were detected above background in the 4 to 5 ft sample.

4.1.7.2 Parking Lot

Three metals were detected above background in the zero to 1 ft samples collected in the parking lot: beryllium, lead, and vanadium. Beryllium was detected in IA08-SB0001at 7.3 mg/kg. Vanadium also was detected in IA08-SB0001 at 51.1 mg/kg. Lead was detected at 55.8 mg/kg in the sample from IA08-SB0002.

Beryllium was detected above background in the two deeper subsurface samples from IA08-SB0001 as well. The concentration in the 1 to 2 ft sample was 6.6 mg/kg, while that in the 2 to 3 ft sample was 4.2 mg/kg. It was not detected above background in any of the subsurface samples collected from IA08-SB0002.

Four VOCs were detected in the 1 to 2 ft samples at low concentrations. Acetone (11.7 µg/kg) and toluene (1.1J µg/kg) were detected in the sample from IA08-SB0001, while benzene (2.3J µg/kg), toluene (1.9J µg/kg), and total xylenes (1.2J µg/kg) were detected in the sample from IA08-SB0002. SVOCs were not reported above the instrument detection limits in either sample.

4.1.7.3 Former Septic Tank

The former septic tank contained broken concrete, masonry bricks, and soil. The bricks were similar to those used in the construction of the site buildings and were not a high-temperature firebrick. Organic vapors were not detected while field screening any of the excavated materials. Four metals were detected above background in the soil sample obtained from the bottom of the tank. These included lead (42.1 mg/kg), mercury (2.7 mg/kg), phosphorus (1,160 mg/kg), and zinc (152 mg/kg). In addition, low estimated concentrations of toluene and total xylenes were detected in this sample.

4.1.8 Dose Rate Measurement Results

General area dose rate surveys were performed and documented where elevated radioactive contamination on site was detected during Phase II and Phase IV characterization activities (Figure 4.12). Contact and 30-cm dose rate surveys were performed to measure the external radiation exposure hazard.

Background dose rate measurements were collected in the farm field north of the site, approximately 50 m east of the central drainage ditch. Readings at that location ranged between 6 and 8 µrem/hr. Measurements at the three areas in IA07 ranged from 13 to 22 µrem/hr for the area north of the propane tanks, 10 to 130 µrem/hr for the area south of the propane tanks, and 8 to 17 µrem/hr for the area near the gravel drive. These areas represent dose levels of one to 16 times background. The measurement of 130 µrem/hr is the highest value recorded at the site.

The area surrounding IA05-SB0009 was measured at 15 to 19 µrem/hr. The small area near lagoon C and the origin of the central drainage ditch measured 9 to 14 µrem/hr. These are one to slightly more than two times background.

The area overlying the trench in IA01 measured 20 to 50 µrem/hr. The area north of the fence and east of the central ditch registered 10 to 12 µrem/hr. The area east of the fence between the old railroad bed measured 14 to 25 µrem/hr. These latter two are between one and three times background while the area inside the fence is 2½ to 6¼ times background.

4.1.9 Summary

This section provides a brief summary of the sampling results for the on-site soils. The on-site soils were investigated by focusing on features known or believed to have been impacted by past AEC activities at the site. These features include:

- trenches and pits
- lagoons

- former petroleum handling building and UST area
- electrical transformer areas
- bare spots and stressed vegetation areas
- filter bed area and debris piles
- existing buildings and associated areas

Summary tables listing the detected constituents, including minimum, maximum, frequency of detection above background and soil PRGs have been included in the preceding discussions for each of the features. In addition, maps showing the locations and concentrations of constituents detected above background for each feature also have been included in the preceding discussions. The most significantly impacted areas for the on-site soils includes the trenches and pits, the lagoons, and the filter bed area and debris piles. Constituents were detected above background at the other features investigated, but usually at much lower levels.

Three inorganics (beryllium, lead and fluoride) and five radionuclides (Ra-226, Th-230, Th-234, U-233/234, and U-238) were the most commonly detected AEC-related constituents above background in soil samples from the disposal trenches and pits. Detections above background at depths greater than a few feet were generally encountered within and beneath the trench and pit fill materials. Contamination between the trenches and pits is generally confined to the surface soils. In addition to the constituents noted above, several metals, PAHs, and VOCs also were detected above background within the disposal trenches and pits. The metals include arsenic, cadmium, chromium, copper, mercury, nickel, selenium, and zinc. Typically, these metals have a low frequency of detection above background within the soils from the disposal trenches and pits. PAHs were detected in one sample from the northeast corner pits and trenches, and from samples collected in the scrap metal and disposal trenches. Because these are not definitively associated with current sources of PAHs, these concentrations will be considered as potentially associated with AEC activities on the site. Low levels of several VOCs also were detected in each of the trenches and pits investigated.

Three inorganics (beryllium, lead, and fluoride) and four radionuclides (Ra-226, Th-234, U-233/234, and U-238) were the most commonly detected AEC-related constituents above background in soil samples from the lagoons. Lead was not detected above background at Lagoon A. The radionuclides appear to be primarily associated with soils at Lagoon B. Several other metals were identified above background at lower frequencies of detection above background. Barium and cobalt were detected above background at Lagoon A. Antimony, cadmium (location of highest measured value in on-site soils), chromium, and zinc were detected above background at Lagoon C.

At the former Petroleum Handling Building And UST Area, the primary constituents detected above background included TRPHs, several VOCs (vinyl chloride, benzene, carbon disulfide, ethyl benzene, toluene, and total xylenes) at low levels, and several PAHs. Beryllium also was detected above background in the soils, but the concentrations were significantly less than other areas on site.

At the Electrical Transformer Areas the primary constituents detected above background included TRPHs several PAHs and aroclor-1254. Elevated levels of these constituents were generally limited to the shallow surface soils. Beryllium also was detected above background in the soils, but the concentrations were significantly less than other areas on site. Because this area was the terminus of one of the rail spurs, PAHs from the railroad ties would be expected.

The on-site soils at the bare spot and stressed vegetation areas had a number of constituents detected above background, but the concentrations do not appear to be high enough to cause vegetative stress. Measured concentrations are similar to those detected at other areas on site that do not exhibit stressed vegetation. Beryllium, chromium, lead, and vanadium were detected above background at the

Bare Spot. Several radionuclides (Th-228, Th-232, and U-234) PAHs and VOCs also were detected above background.

At the filter bed area and debris piles, beryllium and lead were the metals that most commonly exceeded background. Other metals detected above background, but to a lesser magnitude include barium, cadmium, nickel, and zinc. Five radionuclides (Ra-226, Th-230, Th-234, U-233/234, and U-238) also were detected above background. Low levels of PAHs and VOCs were detected in the soils here as well. PAHs in this area are most likely related to buildings demolished in the 1960s. Since the debris could include roofing materials, and asphalt, PAHs would be expected and are not necessarily related to beryllium production activities.

Around the existing buildings, PAHs were the primary constituents detected in the shallow soils. There is currently asphalt and considerable truck traffic in these areas. PAHs are likely related to current activities. Beryllium, lead, and cadmium were the metals that most commonly exceeded background. Several radionuclides and VOCs were detected in the soils at low levels or levels slightly exceeding background.

4.2 UNIT 2: GROUNDWATER

Groundwater sampling was conducted during the Phase IV RI. Prior to Phase IV, very little information was available on the groundwater quality beneath the Luckey site. A brief summary of the groundwater sampling activities is presented, followed by a description of the nature and extent of contamination in groundwater at the facility.

4.2.1 Phase IV Groundwater Sampling Activities

Monitoring well installation and groundwater sampling are described in Sections 3.1.3 and 3.2.3. A network of 43 monitoring wells [25 on-site (21 were sampled), 12 off-site, six background] were installed and sampled to evaluate the groundwater pathway as a potential off-site transport mechanism and to determine the presence, nature, and extent of potential groundwater contamination from historical waste disposal practices at the Luckey site. Groundwater samples also were collected from the east (PW[E]) and west(PW[W]) production wells, from tap water at the Uretech facility (GW0001), and from three nearby residential wells (GW0002, GW0003, and GW0004) (Figure 3.5).

Two primary sampling rounds were conducted to evaluate groundwater quality beneath the Luckey site and adjacent areas. The first round consisted of samples collected during the summer and fall of 1998 at seasonally low groundwater levels. The second round consisted of samples collected during the spring of 1999 at seasonally high groundwater levels. The Uretech production wells, water supply, and the three nearby residential wells were sampled more frequently to monitor for potential contaminants in the groundwater. Table 3.4 in Section 3.1.3 lists monitoring well sampling events conducted during the RI and the constituents analyzed in each sample.

4.2.2 Nature and Extent

This nature and extent discussion focuses on those constituents initially identified as most likely occurring in groundwater based upon AEC-related activities at the Luckey site. These included arsenic, barium, beryllium, lead, ammonia, fluoride and radionuclides. As shown in Table 3.4, many of the groundwater samples were analyzed for this list of constituents. For other groundwater samples, full suite analyses were performed. Table 4.8 provides a summary of all analytes detected in at least one groundwater sample collected during the RI. The table provides calculated background (if available) for each constituent, frequency of detection, the location and magnitude of the maximum measured value,

and the groundwater PRGs for each detected constituent. Groundwater PRGs consist of MCLs, EPA Region 9 PRGs, and background values. Appendix 4A.4 provides the analytical results for groundwater samples collected during the RI.

Background for naturally occurring constituents in groundwater were determined from groundwater samples collected from the background monitoring wells (Section 3.5.2). Groundwater PRGs are presented in Section 3.5.3. For metals and radionuclides, both filtered and unfiltered groundwater samples were analyzed. Filtering of the groundwater samples was performed in an attempt to quantify the mobile fraction of each constituent within the groundwater, particularly in the unconsolidated zone.

As indicated in Table 4.8, a number of constituents were detected above background in one or more samples. Rather than discussing all constituents detected above background, only those that "significantly exceeded" the groundwater PRGs or significantly contribute to risk are discussed. Here, significantly exceeded means that the 95% UCL of the mean for the detected constituent exceeded the groundwater PRGs. Beryllium and the radionuclides gross alpha, uranium-233/234, and uranium-238 exceeded their respective groundwater PRGs. A groundwater PRG is not available for ammonia. However, the EPA (1996) lists a lifetime drinking water health advisory of 30 mg/L for ammonia in groundwater. Since the maximum detected value for ammonia was 22.1 mg/L, no further discussion of the nature and extent of ammonia in groundwater is included here. In addition, gross alpha activity is a measure of alpha radiation emitted from all alpha-emitting isotopes. While the specific radionuclide(s) responsible for the gross alpha activity has not been determined, there does appear to be a correlation between elevated uranium isotopes and gross alpha activity. Therefore, gross alpha activity is included by reference with the discussion for the uranium isotopes that exceeded their groundwater PRGs.

In addition, nickel and manganese were detected above background during the groundwater sampling and analysis. Neither compound was originally identified as an AEC-related constituents. Both have been retained for discussion of their nature and extent in the groundwater at the Luckey site. No VOCs or SVOCs have been retained for discussion of nature and extent. VOCs and SVOCs were infrequently detected (one or two detects in 38 samples) and typically at concentrations well below their respective PRGs.

This discussion focuses on those constituents, having the greatest potential for requiring some sort of remedial action. A thorough screening of all detected constituents is presented as part of the baseline risk assessment in Section 6. The following sections discuss the nature and extent for constituents noted above. Maps showing the location and magnitude of each constituent above background also have been included. The spring 1999 sampling round provides the most comprehensive snapshot of AEC-related constituents in the groundwater at the facility and has been used primarily in the discussion of nature and extent. Overall, seasonal trends are not evident in the data.

4.2.2.1 Metals

A total of 18 metals were detected above their respective background in at least one sample. Of these, beryllium, manganese, and nickel were found to be significantly higher than their PRGs. Both filtered (analytical results for groundwater samples passed through a filter to remove suspended solids) and unfiltered (total) results are presented in Table 4.8 for metals. As one would expect, filtered results tend to have lower concentrations than unfiltered results. However, examination of results above background indicates minor differences between filtered and unfiltered levels. As a result, the discussion here focuses on the unfiltered results. A brief discussion of their nature and extent is provided below.

Beryllium

Beryllium was detected in 35 of 104 unfiltered groundwater samples. Values ranged from 0.13µg/L at GW0002 to 39.5 µg/L at MW-01(I). Twenty-three samples from seven locations [MW-01(I), MW-02(S), MW-13(S), MW-19(I), Uretech tap water (GW0001), west production well (PW(W)), and one off-site residential well (GW0002)] had reported beryllium concentrations above background (0.79 µg/L). Beryllium in groundwater above background is shown in Figure 4.13. Reported beryllium concentrations from the shallow, intermediate, and bedrock monitoring wells, residential wells, and the west production well also are posted on the map.

Beryllium was detected above background in one of seven samples collected from residential well GW0002 located just east of Luckey Road and just south of Toussaint Creek. All groundwater samples collected from residential wells GW0003 and GW0004 were below background for beryllium. At GW0002, the first sample collected (July 1998) had a reported beryllium concentration of 7.7 µg/L. One other sample (October 1999) detected beryllium (0.13J µg/L). All other groundwater samples collected from GW0002 were below detection limits for beryllium.

One tap water sample collected in April 1999 from the Uretech facility had beryllium at 2 µg/L. Analysis of another sample (October 1999) detected beryllium at 0.19 µg/L. Three remaining tap water samples collected from the Uretech facility were below detection limits for beryllium.

Nine of nine groundwater samples collected from the west production well, PW(W), had reported beryllium concentrations above background. Beryllium concentrations ranged between 9.3 and 13.2 µg/L at PW(W). In October 1999, a borehole video survey and geophysical logging of the west production well was completed to show depth-discrete sampling zones in an attempt to identify the source of beryllium in the well. Five intervals were tested (depths of 28, 81, 110, 175, 185 ft bgs) using a packer assembly to isolate the zones of interest. The most likely source of beryllium entering the well appeared to be an open fracture at 28 to 29 ft bgs. However, sampling results from each interval were very similar (ranging from 10.6 to 13.2 µg/L) and did not permit the identification of the source of beryllium in the west production well. Instead, the results suggest that the well may be contaminated to a depth of 185 ft bgs, or that the packers were unable to obtain a good seal in the open borehole, or a combination of the two.

The highest concentration of beryllium was consistently reported in samples collected from MW-01(I), located at the northern boundary of the Uretech property. MW-01(I) is completed within the upper 10 ft of the dolomite bedrock. The shallow well MW-02(S) completed immediately above the bedrock and adjacent to MW-01(I) also exhibited elevated concentrations of beryllium. Two deeper monitoring wells, MW-39(B) and MW-40(B), were installed near MW-01(I). Beryllium levels were below detection limits in samples collected from these two monitoring wells, suggesting that elevated beryllium concentrations are limited to the shallow overburden and upper 10 ft of bedrock at this location.

The beryllium in the groundwater at the northern boundary of the site in MW-01(I) and MW-02(S) occur just to the north and west of the elevated levels of beryllium in the soils associated with the filter bed area and debris piles. No soil samples were collected during the installation of these wells, and as a result, the beryllium levels in the soils above the wells are not known. However, it is likely that the elevated groundwater levels along the northern boundary have their source from the soils immediately adjacent to the wells or from the filter bed and debris piles just to the south and west. Groundwater contours in the shallow and intermediate depth wells indicate a potential flow path from beneath the filter bed and debris piles areas to the area of the monitoring wells before turning back southward within the cone of influence of the Uretech production wells.

A similar situation occurs just over 400 ft to the east of MW-01(I). Monitoring wells MW-13(S) and MW-19(I) exhibit elevated levels of beryllium in the shallow overburden and upper 10 ft of bedrock. Beryllium above background was reported in two rounds of samples collected from these two monitoring wells. Elevated beryllium levels at MW-13(S) and MW-19(I) are thought to be associated with the beryllium detected a depth in the soils of the trenches and pits in the northeast portion of the site.

Manganese

Manganese was detected in all 41 unfiltered groundwater samples. Values ranged from 3.9 µg/L at GW0002 to 2,160 µg/L at MW-14(S). Nine samples from seven locations [MW-02(S), MW-04(S), MW-08(S), MW-13(S), MW-14(S), MW-22(I), and the west production well (PW(W)] had reported manganese concentrations above background (144µg/L).

Manganese detected above background in groundwater is shown in Figure 4.13. Reported manganese levels from the shallow, intermediate, and bedrock monitoring wells, residential wells, and the west production well also are posted on the map. Manganese was not originally identified as and an AEC-related constituent therefore was not sampled for as frequently.

Manganese was not detected above background in the residential wells. One sample was collected from each of the wells. Results ranged from 3.9 µg/L to 16.4 µg/L. One of two groundwater samples collected from the west production well, PW(W), had reported manganese concentrations above background. Manganese concentrations were 114 and 217 µg/L at PW(W). One sample, collected from the east production well, PW(E), had a measured manganese concentration of 5.2 µg/L. Tap water samples collected at the Uretech facility were not analyzed for manganese.

The highest concentration of manganese (2,160 µg/L) was reported in the only sample collected from MW-14(S), located between the current manufacturing facilities and the southern boundary of the Uretech property. MW-14(S) is completed in the shallow overburden immediately above the bedrock surface. Five of the seven locations where background was exceeded occur in the shallow groundwater monitoring wells. MW-04(S), located immediately south of MW-14(S), had a reported manganese level of 536 µg/L and may be associated with the same source, possibly from the former lagoons.

Manganese also exceeds background in the northeast corner of the facility beneath the northeast disposal area. Two shallow monitoring wells (MW-08(S) at 156 µg/L and MW-13(S) at 897 µg/L) and one intermediate depth monitoring well (MW-22(I) at 291 µg/L) exceed background for manganese. MW-02(S) and PW(W), which had exceeded manganese background in the summer of 1998, were below background in the spring of 1999.

Manganese was rarely reported above background (2,340 mg/kg) in the soils at the site. The locations of manganese above background in the groundwater appear to be associated with Lagoons A and B in the southern portion of the site and the disposal area in the northeast corner of the site.

Nickel

Nickel was detected in 38 of 41 unfiltered groundwater samples. Values ranged from 1.2 µg/L at MW-41(B) to 2,430 µg/L at MW-14(S). Twenty-nine samples from 21 locations had reported nickel concentrations above background (5.5 µg/L). Reported nickel levels from the shallow, intermediate, and bedrock monitoring wells, residential wells, and the production wells are posted on (Figure 4.13). Nickel

was not originally identified as a constituent associated with past operations at the Luckey site, and therefore was not sampled for as frequently as the original list of AEC-related constituents.

Nickel was not detected above background in the residential wells. One sample was collected from each of the wells. Results were below detection limits for GW0002 and GW0003, and 2.3 µg/L at GW0004. Both groundwater samples collected from the west production well, PW(W), had reported nickel concentrations (74.4 and 116µg/L) above background. One sample, collected from the east production well, PW(E), had a measured nickel concentration of 40.9 µg/L Tap water samples collected at the Uretech facility were not analyzed for nickel.

As was the case for manganese, the highest concentration of nickel (2,430 µg/L) was reported in the only sample collected from MW-14(S), located between the current manufacturing facilities and the southern boundary of the Uretech property. MW-04(S) [located immediately south of MW-14(S)] contained a reported nickel level of 80.1 µg/L and may be associated with the same source, possibly from the former lagoons. The same may be true for MW-24(S) (nickel concentration of 69.1 µg/L) located east of MW-14(S).

Nickel also exceeds background in nearly all other monitoring wells at the site. MW-41(B) along the southern Uretech property boundary, and MW-39(B) along the northern Uretech property boundary were below background during the spring of 1999. At MW-21(I), located immediately north of the manufacturing facilities, nickel was reported at 313 µg/L. Nickel was rarely reported above background (46.1 mg/kg) in the soils at the site. Despite the ubiquitous nature of nickel above background in the groundwater, only three samples were detected above its MCL (100 µg/L). In addition, it is possible that the three background sampling locations have anomalously low concentrations of nickel in the groundwater.

4.2.2.2 Radionuclides

Three radioactive constituents were determined to exceed their respective background or PRG activities and contribute significantly to risk. The constituents include U-233/234, U-235 and U-238 isotopes. As was the case for metals, the discussion here focuses on the unfiltered groundwater sample results.

Uranium-233/234

U-233/234 was detected in 68 of 90 unfiltered groundwater samples. Activities ranged from 0.139 pCi/L at GW0002 to 129 pCi/L at MW-24(S). Eighteen samples from ten locations had reported U-233/234 activities above background (1.62 pCi/L). U-233/234 activities above background the shallow, intermediate, and bedrock monitoring wells, residential wells, and the production wells are posted on Figure 4.14.

U-233/234 was not detected above background in the residential wells. Five samples were collected from GW0002 and GW0003, and two samples were collected from GW0004. Results ranged from below detection limits to 0.517J pCi/L. All three groundwater samples collected from the west production well, PW(W), had reported U-233/234 activities (ranging from 2.67J to 3.81 pCi/L) that slightly exceeded background. Four samples each were collected from the east production well, PW(E), and the tap water at the Uretech facility. U-233/234 activities were below background at both of these locations for all groundwater samples collected.

As illustrated in Figure 4.14, the extent of U-233/234 above background is spotty across the site. The highest activity of U-233/234 (129 pCi/L) was detected at MW-24(S), located just north of Lagoon B. MW-14(S) (at 3.36 pCi/L), located to the west of MW-24(S), and MW-23(S) (at 3.43 pCi/L), located to the east along the southern boundary of the facility, also exceeded background. In the northern half of the facility, MW-13(S) at 14.9 pCi/L and MW-21(I) at 6.25 pCi/L have the highest measured activities for U-233/234. Three other locations, MW-01(I), MW-02(S), and PW(W) slightly exceed background for U-233/234.

Uranium-235

Uranium-235 was detected in 11 of 90 unfiltered groundwater samples. Values ranged from 0.073 pCi/l in MW-01(I) to 6.39 pCi/l in MW-24(S) (Table 4-8). U-235 was not detected in background groundwater samples.

U-235 was not detected in the residential wells, the Uretech tap, or the east production well. It was detected in wells along the east side of the site (MW-06(S), MW-07(I), MW-08(S), and MW-13(S)), both north and south of the buildings (MW-14(S), MW-24(S) and MW-21(I)) and in the west production well. It also was detected in MW-01(I) and MW-02(S) along the north central boundary of the site. All detects except for those in MW-24(S) are estimated quantities.

Uranium-238

U-238 was detected in 64 of 90 unfiltered groundwater samples. Values ranged from 0.087 pCi/L at GW0002 to 129 pCi/L at MW-24(S). Eighteen samples from 10 locations [MW-02(S), MW-04(S), MW-06(S), MW-07(I), MW-13(S), MW-14(S), MW-21(I), MW-23(S), MW-24(S), and the west production well] had reported U-238 activities above background (1.4 pCi/L).

The approximate extent of U-238 in groundwater above background from samples collected during the spring of 1999 is shown in Figure 4.14. Reported U-238 levels from the shallow, intermediate, and bedrock monitoring wells, residential wells, and the production wells also are posted on the map.

U-238 was not detected above background in the residential wells. Five samples were collected from GW0002 and GW0003, and two samples were collected from GW0004. Results ranged from below detection limits to 0.77J pCi/L. All three groundwater samples collected from the west production well, PW(W), had reported U-238 activities (range 2.86J to 3.47 pCi/L) that slightly exceeded background. Four samples were collected from the east production well, PW(E), and the tap water at the Uretech facility. U-238 activities were below background at both of these locations for all groundwater samples collected.

As illustrated in Figure 4.14, the extent of U-238 above background is spotty across the site and similar to the distribution of U-233/234 during the spring of 1999. The highest activity of U-238 (129 pCi/L) was detected at MW-24(S), located just north of Lagoon B. Other locations exceeding background in the southern half of the facility include MW-04(S) at 2.93 pCi/L, MW-14(S) at 2.94 pCi/L, and MW-23(S) at 2.74 pCi/L. In the northern half of the facility, MW-13(S) at 8.58 pCi/L and MW-21(I) at 6.04 pCi/L have the highest measured activities for U-238. Three other locations, MW-02(S), MW-06(S), and PW(W) slightly exceed the background for U-238.

4.2.3 Summary of Groundwater Sampling Results

Results and findings based on the groundwater sampling results for the Luckey site are briefly summarized below:

- AEC-related constituents identified in groundwater are beryllium, uranium-233/234, and uranium-238. Beryllium and the radionuclides in the groundwater correlate to elevated levels in the soils in most cases. In addition, nickel and manganese were detected above background in the groundwater.
- The elevated levels reported for the west production well are likely the result the movement of constituents in the shallow bedrock or immediately above the bedrock surface into the production well over time.
- Nickel and manganese are not associated with past AEC activities. The sources of nickel and manganese in groundwater are less well defined as limited detections above background were noted in the soils at the Luckey site. The nature and extent of nickel and manganese in groundwater is less well defined as these constituents were sampled less frequently. Both are elevated in MW-14(S), which is a shallow, low-yielding monitoring well. Sampling of this well typically requires several days to permit collection of sufficient sample volume for analysis.
- Constituents do not appear to be migrating off site in the groundwater, nor are there any well developed plumes within the groundwater. Contamination is spotty—consists of a few locations with elevated detections.
- There is very little apparent seasonal variation in constituent levels based on comparison of summer and fall 1998 sample results with spring 1999 sample results.
- Highest concentrations are typically in the shallow wells immediately above the bedrock or the intermediate wells completed in the upper ten feet of bedrock.
- Bedrock at depth does not appear to have been impacted.
- Nickel background may be anomalously low—all but two sample concentrations on site were detected above background. However, average concentrations reported by Breen and Dumouchelle (1991) for nickel in the carbonate aquifer were 2 ± 2.6 μg/L suggesting that activities at the site may have contributed to nickel in the shallow groundwater.
- Analysis for metals and radionuclides were presented for both filtered and unfiltered (total) levels. Generally, filtered levels were lower than unfiltered. However, for the AEC-related constituents, there does not appear to be significant differences in the filtered and unfiltered results for detections above background.

4.3 UNIT 3: BUILDINGS

The nature and extent of contamination in the buildings was evaluated over several years and through two phases of field activities. Sampling activities were initially conducted in the Annex, during the Phase II RI sampling activities. These activities consisted of beryllium and radiological surveys, the details of which are presented in Section 3.1.5. In summary, dry swipes for both beryllium and radiological constituents were taken, as were direct alpha and beta-gamma measurements. As a result of these surveys, sampling activities were continued in Phase IV of the RI and expanded to encompass all 13 on-site buildings (Figure 3.7). Phase IV sampling activities also were expanded from beryllium and radiological surveys to include sampling of building materials (paint, brick, concrete, and dust) and dose rate measurements. The sampling activities are summarized in Section 3.1.5 and discussed in detail in Appendix 3C. The results are presented in this section. The results of sampling activities performed in the on-site buildings are compared (where appropriate) to the guidelines detailed in Section 3.5.3.

During Phase IV, 13 locations were scanned with the alpha meter and then rescanned with a sheet of paper between the surface and the alpha meter. The purpose of this exercise was to check for crosstalk. Crosstalk is a term used to indicate that an unwanted signal is being registered on the instrument. The paper will block alpha radiation. The second reading (shielded) then indicates “non-alpha” counts. After evaluation of this crosstalk, on average, alpha readings of 434 dpm and lower will be below the 100 dpm NRC guideline. A more detailed discussion is presented in Appendix 4B.2.

The radiological results presented in the following sections are incorporated into the calculations of radiological dose within the buildings contained in Section 6. The risk assessment does not evaluate the risk from beryllium contamination within the buildings. This is due to the lack of recognized standards for beryllium in building materials and on surfaces. Standards only currently exist for concentrations in air for occupational workers.

The subsequent sections discuss the radiological survey results for fixed and removable contamination, nature and extent of beryllium contamination in swipes, dust sampling results, radiological constituents and beryllium in building materials, dose rate surveys, and air sampling results.

4.3.1 Radiological Survey Results

4.3.1.1 Annex

A cursory survey of the Annex was conducted during Phase II to determine if additional surveys might be warranted. The Phase IV surveys were more extensive. Both phases included readings of fixed and removable radiation.

Phase II

The Phase II radiological survey included an evaluation of ceiling beams, walls, and floors. The beam survey results are summarized in Table 4.9 and presented in Figure 4.15. Results of the direct measurements showed fixed surface alpha and beta-gamma activities up to 1,186 and 89,748 dpm/100 cm^2, respectively. Results of the smears showed removable surface alpha and beta-gamma activities up to 6 and 657 dpm/100 cm^2, respectively. Some areas on the beams exceeded the NRC guidelines for fixed radioactivity.

Figure 4.16 shows survey results from the floor of the AEC Annex for direct beta-gamma. Direct alpha survey values ranged up to 57 dpm /100 cm^2 and removable alpha survey values ranged up to 9 dpm /100 cm^2. Removable beta-gamma survey values on the floor ranged up to 71 dpm /100 cm^2 (with one area surveyed at 953 dpm /100 cm^2) and direct beta-gamma floor survey values ranged up to 14,264 dpm/100 cm^2 (BNI 1998).

Results of the direct measurements on the walls showed fixed surface alpha and beta-gamma activites up to 50 and 605 dpm/100 cm^2, respectively. Results of the smears from the walls showed removable surface alpha and beta-gamma activites up to 2 and 49 dpm/100 cm^2, respectively (BNI 1998). When compared to NRC criteria, neither the average nor removable limits were exceeded.

Since isotopic analysis was not performed during Phase II, the nature of the contamination present on the AEC Annex surfaces could not be determined. A significant number of smears and readings exceeded the NRC guidelines in the Phase II data. As a result, a more comprehensive survey was conducted in the Annex during Phase IV.

Phase IV

Phase IV, like Phase II, covered ceiling beams, walls, and floors, and additionally covered some other surfaces like duct work, pipes, and light fixtures. Results of the Phase IV survey confirm several areas in the annex and production buildings with elevated radioactivity.

Accessible areas of the Annex floor were scanned with an automated floor monitor system. More than 240 points were identified as having alpha radiation above the 100 dpm guideline. This floor survey also identified 12 areas where readings exceeded 300 dpm alpha. Seven of these were eliminated after one-minute scans were completed. Sample teams did not have access to the north wall of the Annex due to manufacturing activities in the building. All of these elevated areas were found along the south side of the Annex. It is possible that additional areas of elevated radioactivity might exist in areas of the floor that were not accessible. All of these points (240) have been included in Figure 4.17. The field survey report (TNU 1998) identified no points above the 15,000 dpm maximum for beta-gamma activity, and the two highest points in the range of 3,826 dpm were below the 5,000 dpm average for the NRC guidelines.

Removable alpha radioactivity above 20 dpm is presented in Table 4.10. The highest value is 35 dpm. This is less than two times the guideline of 20 dpm and is from a sample that had considerable beta-gamma emissions (1,455 dpm). Given the amount of cross talk detected while measuring fixed alpha activity, it is likely that the actual alpha emissions are below the 20 dpm guideline.

4.3.1.2 Remaining Buildings

The remaining buildings were surveyed in a cursory manner (approximately 5% coverage) to determine residual levels of radiological activity. These surveys were performed in 1998 and 1999 during the Phase IV RI. The radiological survey data are presented in Appendix 4B.3. The Employee Activity Building was surveyed as a potential background comparison to other buildings. It is well below the NRC guidelines in radiological terms.

Figure 4.18 depicts all of the grid locations in the Production Building where instrument readings exceeded the NRC guidelines for fixed alpha and/or beta-gamma activity. A shielded count was taken at each location (except one) where alpha readings exceeded the NRC guidelines. Comparing the shielded alpha readings to the unshielded alpha readings results in three readings with differences greater than 100 dpm. As a result, four locations potentially exceed the fixed alpha activity guidelines of the NRC. Those locations where beta-gamma readings exceed the 5,000 dpm NRC guideline coincide with locations where high alpha readings also were measured. All of the readings above NRC guidelines were measured on beams. The three locations are in grids Y27, Y28, and H23. These locations are all in the eastern 32 m of the production building near the south wall.

Removable activity was measured using a dry smear of a 100 cm^2 area. In the Production Building, four locations potentially exceed the removable radioactivity guidelines for alpha. The readings were 36 dpm/100 cm^2 or less at each of these locations. One of the readings was just 21 dpm/100 cm^2 unshielded. If just alpha activity were counted, it most likely would not exceed the guidelines. Two other locations were counted at 26 dpm/100 cm^2. At one of those locations, 68% of its direct reading is attributable to crosstalk. Attributing a similar amount of crosstalk to the removable fraction would reduce the activity below the guideline. This leaves one reading of 36 dpm. At that location 84% of the direct reading is attributed to crosstalk. This same reduction would reduce the removable reading to well below the guideline of 20 dpm. All removable beta-gamma activity in the Production Building was measured below the NRC guideline of 1,000 dpm.

The Production building is the only building in addition to the Annex where alpha and beta-gamma activity exceeded the NRC guidelines. The surveys conducted at the remaining buildings indicate that fixed and removable activity were below the NRC guidelines.

4.3.2 Beryllium Swipe Survey

A limited survey of the interior of the Annex was conducted to determine whether residual beryllium was present. Swipes were collected to determine transferable beryllium concentrations from surfaces in the buildings.

Phase II

A limited beryllium survey of the interior of the Annex was conducted during Phase II sampling activities. During Phase II, dry swipes were collected from the overhead I-beams. No swipes were taken from the floors or walls. It was believed that the floors and walls had been painted several times subsequent to the completion of all beryllium-related work at the Luckey site. In addition, a portion of the floor had been replaced. Table 4.11 presents the Phase II results. The maximum beryllium content detected for a 100 cm^2 area was 10.8 μg, well above the DOE housekeeping guideline of 1 $\mu g/100cm^2$ for dry swipes. The DOE housekeeping guideline is included here for comparative purposes since regulatory standards currently do not exist for beryllium on building surfaces.

Phase IV

In Phase IV a more thorough survey of the Annex and the rest of the site buildings was performed. Beryllium swipes collected in Phase IV were wet swipes rather than dry. Wet swipes are more efficient at picking up dust and dirt from surfaces; thus, the results are expected to be higher than those from Phase II. DOE's housekeeping guideline also increases to 5 $\mu g/100cm^2$ for wet swipes. In all of the buildings, wet swipes were collected for removable beryllium as described in Section 3.1.5. The Employee Activity Building also was surveyed as a potential background comparison. It is below the DOE "housekeeping" guideline for all beryllium swipes. With one exception all the swipes in the Employee Activity Building are below 1 $\mu g/100cm^2$ which is one fifth of the DOE proposed release to the public guideline for wet swipes.

Table 4.12 shows the average and maximum results for swipes taken from the buildings. The analytical results for all of the swipes collected in Phase IV are presented in Appendix 4B.1. Figures 4.19, 4.20, and 4.21 show the location of swipes taken and a color-coded range of results.

In seven of the 13 buildings, the maximum value exceeds the housekeeping guideline of 5 $\mu g/100cm^2$. Only four of the buildings had average values above this guideline. Roughly half of the results exceed the housekeeping guideline.

4.3.3 Dust Sampling

The results from the swipe sampling prompted a program of dust sampling in the buildings. This resulted in 110 analyses of dust samples collected from functional areas in the buildings. The procedures used for this sampling are summarized in section 3.1.5 and detailed in Appendix 3C. Complete results for these samples are presented in Appendix 4B.1. Figures 4.22, 4.23, and 4.24 present the results of the dust sampling in the functional areas for the Production Building and Annex. Table 4.13 lists the results of the beryllium analysis for dust samples collected in the functional areas of each building.

As a general guide, results of the composite dust samples tested for total beryllium were compared to 20 mg/kg. In the Annex, Production Building, Former Laboratory, Maintenance Building, and the sewage disposal building the average bulk dust concentration of beryllium exceeds this calculated value (Table 4.14). The highest values are in the Annex and Production Building, although the old

Maintenance Building and the Sewage Pump house have significant levels as well. The dust samples collected at elevations greater than 2 m in the Annex and the smaller buildings, including the employee activities building, seem to contain more beryllium than those samples collected at lower elevations. This relationship does not follow for the Production Building, Former Laboratory, and former Melting, Alloying, and Shipping building. For these buildings, the beryllium concentrations seem to be equally distributed between the lower and higher elevations. It does not necessarily follow that concentrations between the two elevation ranges within each functional area are equal. Some FAs have higher concentrations at lower levels and others at higher elevations.

Dust samples and swipe samples do not seem to correlate well; in all cases the bulk dust average for a building is higher than the average of the swipes. In some cases, like the Former Laboratory and the former Melting, Alloying, Shipping, and Receiving Building, individual, FA bulk dust results are greater than the maximum swipe result for the same building. In the Production Building and Annex, the maximum swipe exceeds the maximum bulk dust result from any FA in the same building. In the Maintenance Building, Shipping and Receiving Building, Bulk Storage Building, Employee Activity Building, Guard House, West Production well house, and the Sewage Building the average bulk dust result exceeded the maximum swipe result.

4.3.3.1 Beryllium Speciation Testing

Beryllium speciation testing was conducted on three bulk composite dust samples collected on the first and second floors of the Production Building and in the Annex. This testing consisted of several analyses. Besides beryllium speciation, testing also was preformed to determine the particle size distribution and to evaluate lead.

The testing confirmed beryllium oxide is present in settled dust. However, this identification does not rule out the possibility that beryllium metal and beryllium hydroxide also are present. The identification of beryllium oxide also does not indicate that beryllium oxide is the most prevalent form in which beryllium exists in the buildings.

Analysis of lead indicates the source of lead is consistent with lead-based paint for the following reasons:

- The samples analyzed for lead were consistent with a redistribution of a liquid phase, such as paint.
- The lead was detected at trace levels which also suggests that the lead exists as small inclusions consistent with composite or paint materials rather than sources such as minerals.

A particle size analysis showed beryllium-containing particles range from 7 to about 60 micrometers across with an average particle size of 19 micrometers. A total of 106 particles were measured from the three composite samples with the following percentages centered at the respective sizes:

- 75% at 15 micrometers
- 20% at 30 micrometers
- 5% at 50 micrometers
- 1% at 65 micrometers

The above data must be interpreted with caution in evaluating the respirable fraction of beryllium particles and potential health risks for the following reasons:

1) Since the particles are likely to be aggregates, the actual size is unknown;
2) Particles in the micrometer and less range will not be imaged by the analytical technique utilized; and
3) There is no assurance that the sizes of particles observed during the testing will reflect the actual sizes either in airborne or settled dust.

4.3.4 Building Materials Sampling

Building material and paint samples were collected from floors and walls within the seven major buildings. Seventy-five samples were collected, including three from the Employee Activity Building. All of these were analyzed for beryllium. Five samples from the Annex were analyzed for radionuclides. The complete results for these samples are presented in Appendix 4B.1. Table 4.15 shows the average and maximum beryllium result for each building, as well as the differences between paint samples and other samples.

The high averages in the Production Building and the Annex are expected. A single high sample in the Former Laboratory Building skews the result for that building. The next highest value is 16 mg/kg. The same is true of the Maintenance Building, where the maximum value is nearly an order of magnitude larger than the next highest value.

Radionuclides were analyzed in five building material samples from the Annex. The samples were chosen because of elevated readings from the direct radiation survey discussed in Section 4.3.1. Table 4.16 shows the activities found in each sample.

4.3.5 Dose Rate Surveys

Dose rate surveys were performed in three buildings. The Annex and Production Building were surveyed at seven grid locations. An additional walking survey was performed along the major aisles of the Annex and both floors of the Production Building. The results are presented in Appendix 4C. A survey also was conducted in the Employee Activity Building. The results ranged from 4 to 6 μrem/hr. Results of a background survey in the eastern portion of the northern farm field (grid 10H) ranged from 6 to 8 μrem/hr.

All building results are between 4 and 7 μrem/hr. Based on the assumption that 1 μR/hr is approximately equal to 1 μrem/hr, this is in the same range as the off-site background measured in 1997 of 9.7 μR/hr (BNI 1998).

4.3.6 Air Sampling

A summary of personnel and ambient air monitoring results is presented in section 3.1.7. In evaluating the potential for beryllium in air samples to exceed the proposed OSHA standard, bulk dust results were compared to a calculated level of 20 mg beryllium/kg of total settled dust. Levels exceeding this value show it is theoretically possible that the proposed ACGIH TWA for beryllium could be exceeded if the settled dust becomes airborne. This is substantiated by the fact that three personal air monitoring results for sampling technicians collecting dust samples from building surfaces did exceed the proposed TWA. The air samples were collected while sampling technicians were collecting samples of settled dust from various building surfaces including overhead piping, ductwork, and lighting fixtures. Technicians also collected chip samples of building materials and dragged direct-reading radiation instrumentation over building surfaces. All of these tasks are considered intrusive sampling activities because dust was necessarily disturbed in order to conduct the building characterization. The intrusive

nature of the investigation must be taken into account when evaluating the air monitoring results.

4.3.7 Summary Discussion

The following findings are evident from the foregoing discussion:

- The direct radiation reading data clearly show that there are several areas within the Annex and two isolated locations in the Production Building that have activity above NRC guidelines for release to the public. However the majority of the elevated activity is in the beams. Dose rate measurements taken at the level where the worker activities usually take place are at background.

- Beryllium swipes show significant contamination in the Annex, Production Building, Former Laboratory, and Maintenance Building. Lower concentrations are found in the Melting, Alloying, and Shipping Building, Shack, and Sewage Treatment Building.

- Bulk dust samples results indicate that there is a significant possibility to exceed the proposed ACGIH beryllium guideline for airborne beryllium if dust is re-suspended by maintenance activities. This is true even if the nuisance dust levels are not exceeded.

- The building materials samples indicate that there is significant concentrations of beryllium in the paint, brick, concrete and other materials in the structure of the buildings. Only a minor amount of radiological contamination seems to be present. Those buildings whose structure are significantly contaminated with beryllium include the Former Laboratory, the Maintenance Building, the Production Building, and the Annex.

Several possible sources exist for the radioactivity in the buildings. It is known that scrap steel contaminated with radionuclides was shipped to the site. However the steel was not used in the magnesium process as intended and there was no reason to use it in the beryllium production process. A small amount of natural radioactivity is associated with the beryllium ore and this may account for minor amount of the radioactivity found on the site and in the buildings. Scrap beryllium contaminated with radionuclides was reprocessed at Luckey (section 2.1.2.2). This may have provided a major source for radioactivity in the buildings. The activity may have been left in the buildings after production ceased or it may have been reintroduced into the buildings through dust blown from the uncapped Lagoons A and B. In the process of sealing the surfaces, previous occupants of the building may have sealed in levels of radioactivity that would account for activities detected in the building materials.

Interpretation of the radiological results should be done with the knowledge that there is considerable “crosstalk” between the beta-gamma and alpha channels of the survey meters. A comparison of the “shielded” and “unshielded” alpha readings with the beta-gamma counts for 13 locations indicates that an average of 2.2% of the beta-gamma counts was erroneously counted on the alpha channel (Appendix 4B.2). Because of the relatively low alpha readings, this amounts to an average of 80% of the alpha counts or 77% of the dpms. As a practical matter this means that, on average, alpha readings of 434 dpm and lower would be below the 100 dpm NRC guideline.

Beryllium is clearly present in the building dust and in building materials from the Former Laboratory, Maintenance Building, Production Building, Annex, and Bulk Storage Building. Although it is thought that some decontamination of the buildings may have occurred after production ceased in 1958 it is unclear if decontamination was done again after the end of all beryllium operations in 1962. Former employees have indicated that several times in the last 30 years there have been episodes of power washing or other decontamination (Karsten 2000). The largest concentrations of beryllium found in the

buildings today are in areas not normally used under current operations. These occurrences could be relics of past operations or could represent dust blown in from the uncapped lagoons.

4.4 UNIT 4: SEDIMENTS AND SURFACE WATER

Sediment and surface water samples were collected from the ditches in and around the site, from building drains and sumps, and from Toussaint Creek to assess current on-site conditions and the transport of constituents off site (Figures 3.6 and 3.12). Samples also were collected upstream of the site to address the potential for non-site related sources of constituents contributing to current off-site conditions in the downstream drainage system (Figure 3.13). Sampling was conducted in accordance with the field procedures detailed in Section 3.1.4.

During Phase II, sediment samples were collected from all the on-site ditches, including the central drainage ditch and both ditches leading to Luckey Road. Samples also were collected from sumps inside the Production Building and Annex. Additional samples were taken in the ditch along Luckey Road, in the ditch east of the railroad embankment, and along Toussaint Creek as far as Pemberville Road (about 1½ miles downstream). Samples were analyzed for metals, radionuclides, and organic constituents. During Phase IV, additional sediment samples were collected in the on-site drainage ditches leading to Toussaint Creek. Samples also were collected along Toussaint Creek approximately 15 miles downstream of the site. These samples were analyzed for arsenic, barium, beryllium, lead, fluoride, and radionuclides.

During Phase II and Phase IV, surface water samples were collected on site and downstream in Toussaint Creek for 1½ miles. Twenty surface water samples were taken in Phase II and 19 in Phase IV. Most of the Phase II samples are on site or immediately adjacent to the site. A number of the Phase IV samples were collected from Toussaint Creek at Lemoyne Road, which was sampled weekly during the field effort in 1998.

4.4.1 Inorganics

This discussion focuses primarily on the distribution of beryllium in sediment and surface water. Beryllium was detected above background in all but one of the sediment samples collected in Toussaint Creek downstream of the site. It also was detected above background in all downstream surface water samples.

There are three drainage pathways from the Luckey site. The largest is the central drainage ditch. At times this drained Lagoons B and C, as well as the area between the rail spurs, and portions of the disposal area and the debris piles. It also receives the outfall from the sewage treatment plant. This ditch can be divided into two sections. The first section is a reedy ditch containing mostly stagnant water that ends at a siphon leading under the northern-most rail spur. The sample station SWSD0005 is located at the siphon. The second section starts at the siphon and flows north to the site boundary and through the farm fields to Toussaint Creek. Although SWSD0022 appears to be in this section it is actually in a concrete sump that may have been installed as a part of a proposed drainage system for IA01. The sump is not connected to the drainage ditch. Aside from SWSD0022, the first section, south of the siphon, contains beryllium values up to 297 mg/kg. The more northerly section contains four samples. The first, taken near the outflow from the sewage treatment plant, detected beryllium at 376 mg/kg; and the second, taken at the northern end of the site, has 25.1 mg/kg of beryllium. In the farm field to the north of the site, this increases to 83.8 mg/kg and to 97.6 mg/kg by the time Toussaint Creek is reached. Since background for beryllium is below 1 mg/kg, this indicates beryllium is being transported off site in sediments. Figure 4.25 presents beryllium concentrations detected in the immediate vicinity of the site.

Concentrations of beryllium in surface water samples taken in the main drainage ditch and the storm drain that leads to it range from 2.2 to 83.6 µg/L. The larger value occurs in the main drainage ditch at the farm bridge north of the site. Background concentrations were less than 0.2 µg/L. It should be noted that this sample was collected where the ditch is very muddy. It is possible the elevated concentrations are the result of increased suspended solids collected with the water sample at this location. The concentrations of beryllium in other samples collected in this stretch of ditch ranged from 2.2 to 19.6 µg/l.

The Luckey Road drainage ditch is located along the east side of Luckey Road and receives surface water runoff from the west and southwest portions of the Luckey site. The Luckey Road ditch receives surface water from two smaller on-site drainage ditches located in the southwestern portion of the Luckey site. Beryllium concentrations in the two sediment samples collected from the ditch originating south of the Annex are 150 and 108 mg/kg. The concentration of beryllium in the sample collected from the drainage ditch originating near the northwest corner of the Production Building is 17.5 mg/kg. Samples were collected in several additional locations along this ditch prior to the confluence at Toussaint Creek. Concentrations tend to decrease in a downstream direction (Figure 4.26). However, a sample collected immediately downstream of an unidentified drain pipe breaks this trend. The drain pipe appears to originate on the Luckey site. Surface water samples collocated with these samples show concentrations of 1.3 to 10.9 µg/L of beryllium. The higher concentration was observed north of the site in the Luckey Road ditch just downstream of the drain pipe.

Sediments collected in Toussaint Creek upstream of the site contain beryllium at concentrations up to 0.69 mg/kg. At the confluence of the Luckey Road ditch and Toussaint Creek, beryllium was detected at 3.3 mg/kg. The concentrations detected at the next three locations downstream are 97.6, 43.4 and 223 mg/kg. The last sample was taken about a quarter-of-a-mile up Toussaint Creek from Lemoyne Road and represents the highest beryllium concentration found in sediments off-site. Figure 4.27 shows the concentrations of beryllium in sediments downstream of the site. Concentrations drop to approximately 1 mg/kg in the last mile sampled.

A limited number of surface water samples were collected from Toussaint Creek downstream of the Luckey site during the RI. A total of nine samples were collected from one location (IA06-SW0002) on a weekly basis for nine weeks (Figure 3.12). The concentrations of analytes at this station varied widely, as shown by beryllium. Analytical results indicated a maximum beryllium concentration of 5.1 µg/L and a minimum of 0.39 µg/L. Beryllium was not detected in background surface water samples.

Sediment and surface water samples collected during Phase II were analyzed for TAL metals. During Phase IV, samples were analyzed for arsenic, barium, beryllium, and lead, which were considered to be possibly site-related.

In sediments, the site-related metals arsenic and lead exceed their respective background values. Arsenic is roughly 2.6 times background, and lead is almost 152 times background. The maximum detects for the non-site-related metals aluminum, cadmium, calcium, copper, magnesium, mercury, silicon, strontium, and zinc all exceed their respective background values (Table 4.17). This however does not indicate that there is a problem associated with these results. Some such as mercury had no background detects, and others such as aluminum and calcium were 30% above background. Cadmium is 5.2 times background, and copper is ten times background.

Surface water analytical results show that for site related analytes such as arsenic, barium, and lead, the maximum concentrations exist on site and they are much reduced by the time samples are collected at Lemoyne Road. Lemoyne Road is the farthest downstream any surface water samples were

collected. When comparing the maximum detects for site-related metals in surface water taken from Toussaint Creek to background values (Table 4.18), all the values are significantly above background. However, there are two background surface water samples, and except for lead, the values are below EPA's MCLs for drinking water as well as surface water quality criteria established for the Lake Erie Basin (Table 4.18). On-site surface water does exceed the surface water quality criteria for cadmium, copper, lead, nickel, methylene chloride and zinc. However, except for copper and lead, the samples where these exceedances are located were taken from sewers and drains inside the main building. For copper and lead the highest results are from the same locations with a few from the ditches and storm sewers on site exceeding the water quality criteria (Table 4.19). Complete surface water analytical results are in Appendix 4A.3.

Surface water analyses for non-site related analytes show that all analytes for which background was measured exceed background except for Th-230. However, for those that have a drinking water MCL, only thallium exceeds the MCL (Tables 4.18 and 4.19).

4.4.1.1 Meander Bend Samples

Soil samples were collected from meander bends along Toussaint Creek to determine the nature and extent of potential site-related constituents as a result of sediment deposition during flooding events. These samples were collected at three locations relatively close to the site. Two of the locations are between Lemoyne and Pemberville Roads, and one is east of Pemberville Road (Figure 3.12). Five shallow soil borings were hand-augured at each of the meander bends. The boring sites were selected based on field observations of likely flood deposits and a cursory radiological survey. Each of the soil borings was augured to a depth of 5 ft or auger refusal, and a sample was collected from each 1 ft interval. A total of 46 samples were collected from 15 soil borings. The number of samples collected per location varied based on soil conditions and the total depth reached. Sampling was performed in accordance with field technical procedures FP3.2 and FP3.3.

Two potentially site-related constituents, beryllium and lead, were consistently detected above background in the meander bend samples (Table 4.20). Background soil concentrations for beryllium and lead are 1.13 mg/kg and 23.2 mg/kg, respectively. Beryllium was detected at a maximum concentration of 89.7 mg/kg and was present at a concentration exceeding background in at least one sample from every location. No consistent vertical distribution of beryllium concentrations is apparent in the results from eight sample locations where at least three intervals were sampled (zero to 1 ft, to 1 to 2 ft, and 2 to 3 ft bgs). No radionuclides were detected at concentrations above background.

4.4.2 Radionuclides

Analyses of radionuclides in sediments can be evaluated using Ra-226 as a representative of all radionuclides. Table 4.21 shows the activities of Ra-226 above background in sediment samples from both Phase II and Phase IV.

Those samples that exceed 2 pCi/g are all on-site samples or at locations immediately adjacent to the site. Because the background concentration for Ra-226 is 1.63 pCi/g, very little radioactivity is likely being transported off site in sediments. Other site-related radionuclides show this same pattern of nothing greater than 2 pCi/g in the main ditches or in Toussaint Creek.

The maximum detect of Ra-226 in surface water in ditches leading from the site or in Toussaint Creek is 2.52 pCi/L. This is slightly elevated above the maximum background detect of 2.25 pCi/L. The only two surface water samples that had higher Ra-226 values were collected from the concrete sump

(9.56 pCi/L) and an exploratory trench in a scrap metal disposal area (15.9 pCi/L). Complete analytical results for surface water appear in Appendix 4A.3.

4.4.3 Organic Constituents and Anions

Other parameters analyzed in sediments include VOCs, SVOCs, and anions. Complete results for all sediment analyses are contained in Appendix 4A.2. Table 4.17 shows the maximum detect of the organic compound and anion analyses and the number of detects for sediments. The VOCs were detected in locations either on site or in the ditches immediately around the site. The SVOCs were detected in samples on site or in the first mile of Toussaint Creek. This includes all PAHs. The maximum values of most of the anions and miscellaneous analytes are on site or immediately off site in ditches. Only a few were analyzed at off-site locations.

4.4.4 Summary

Analytical results from sediment sampling conducted during the Phase II and IV RI at the Luckey site suggest that beryllium contamination has been transported off site via surface water and sediment. The highest concentrations in sediment are found either on or directly adjacent to the Luckey site. However, beryllium is detected above background in sediment samples for 13 miles downstream and in soils of Toussaint Creek meander bends. Beryllium concentrations in Toussaint Creek tend to decrease in a downstream direction moving away from the potential source drainage ditches noted above. Beryllium concentrations exceeded background in nearly all sediment samples analyzed (on-site and off-site) except for those between 13 and 15 miles down Toussaint Creek. Other metals such as arsenic and lead, although elevated, do not appear to have the same clear relationship to the site. The irregular distribution could lead to the conclusion that there may be other sources. A reasonable conclusion regarding the source of the beryllium would be that it comes from on-site soils and trench and pit fill material. This would seem to be particularly true of the northeast corner of the site and the main drainage ditch. The beryllium concentration in sediments grades from there into Toussaint Creek.

Ra-226 sediment concentrations do not suggest any apparent trend in distribution along Toussaint Creek. Although the highest concentrations are located either on site or directly adjacent to the Luckey site, the downstream concentrations do not noticeably decrease along the portion of the creek that was sampled. The concentrations, however, are within the range of background throughout the creek. Ra-226 concentrations exceeded background at five off-site locations (out of more than 60 sediment samples analyzed) sampled for this RI. With one exception, these locations are all within a mile of the site. The lone exception is a location nearly 15 miles downstream, with a concentration 10% above background.

4.5 UNIT 5: OFF-SITE SOILS

As part of the RI, surface and subsurface soil samples were collected from properties adjacent to the Luckey site and analyzed for chemical and radiological constituents. The sample locations were based, in part, on the results of the gamma walkover surveys. Samples were located to investigate the relatively few hotspots identified by the walkover surveys (Section 3.2.1). Additional samples were randomly placed to provide representative coverage. Maps of the FIDLER and SPA-3 instrument measurements collected on the off-site properties are illustrated in Figures 3.9 and 3.10.

The results of the chemical and radiological testing conducted by the analytical laboratories were used to identify potential constituents on these off-site properties. Chemical and radiological concentrations detected in the soils were compared to the background data set to quantify the significance of their occurrence. Constituents detected at concentrations above background were designated as possible contaminants.

This section discusses the nature and extent of potential contaminants detected in the soils of the off-site properties. The off-site properties investigated include the northern and western farm fields, the former NYCRR tracks, the France Stone Quarry, and the Troy Township Dump. The analytical data is presented in summary tables that show the elements detected above background. The distribution or extent of constituents detected in the off-site soils is displayed on maps where appropriate.

4.5.1 Northern Farm Field

This property adjoins the Luckey site immediately to the north. Fourteen surface soil samples were collected from this property and analyzed for arsenic, barium, beryllium, lead, and radionuclides. Another 18 surface soil samples were collected and analyzed for beryllium. Elevated concentrations of beryllium were detected above background in 26 of these samples and ranged from 1.2 mg/kg to 744 mg/kg. Lead was detected in three samples from 40.7 mg/kg to 174 mg/kg. Th-230, Th-234, U-233/234, and U-238 were detected in two samples at levels less than 2½ times background. Table 4.22 provides a summary of constituents detected above background for all samples collected in the Northern Farm Field.

One soil boring, IA10-SB0023, was completed to a depth of 5 feet bgs. Beryllium and lead were detected in the 0 to 1 ft sample at 447 mg/kg and 168 mg/kg, respectively. Levels of Th-230, Th-234, Ra-226, U-233/234, and U-238 were detected in this sample. Beryllium was detected in each of the four subsurface samples at concentrations ranging from 4.9 mg/kg to 81.2 mg/kg. Lead was detected in one of the subsurface samples (2 to 3 ft) at 39.6 mg/kg. Actinium-228 was found in the 1 to 2 ft sample above background, while Th-230 and U-233/234 were found in the 2 to 3 ft sample above background. In each case, the radionuclide activities were slightly above background.

An additional 12 soil samples were obtained from the borings that were drilled for the installation of off-site monitoring wells OMW-27 through OMW-38. Eight of the samples were collected from zero to ½ ft, while the remaining four samples were collected from depths of 2 to 2½ ft bgs. The samples were analyzed for beryllium. Elevated concentrations of beryllium were detected in surface samples from OMW27, OMW28, OMW-29, OMW-30, OMW-37, and OMW38. The concentrations ranged from 1.6 to 3.1 mg/kg, which are slightly above background.

The distribution of beryllium and lead are shown in Figure 4.28. As indicated in this figure, elevated levels of both metals are located along the eastern side of the open ditch that leads to Toussaint Creek. The east side of the ditch was targeted as a result of the Phase II LIBS survey which showed only the eastern side to have high beryllium values (BNI 1998). The highest concentrations are located within 250 feet of the Luckey site property line, and the levels generally decrease toward Toussaint Creek. This contaminant trend supports the hypothesis that the ditch was periodically dredged to maintain a good flow, and the dredged spoils were deposited along the ditch.

A second area with elevated levels of beryllium is located along the fence line, just north of the Luckey site. Slightly elevated levels are present along most of the fence line, with concentrations generally below 10 mg/kg. Two localized areas of elevated concentrations of beryllium are evident. The first localized area occurs near IA10-SB0044 and IA10-SB0110, located approximately 400 ft east of Luckey Road. Beryllium ranges from approximately 14 mg/kg to 21 mg/kg in this area. Lead is also present at this spot (sample IA10-SB0044), at levels slightly greater than background. The second localized area occurs near the eastern side of the property between the ditch and the former railroad line. Levels of beryllium approach 50 mg/kg along the fence line and the railroad bed in this area.

Based on this nature and extent evaluation, it is apparent that a portion of the soils in the northern farm field has been impacted by constituents related to the Luckey site. These constituents, consisting

predominantly of beryllium and lead, are found in two main areas. Constituents detected along the open ditch are probably a result of past dredging operations to maintain free flow from the Luckey site to Toussaint Creek. Sources for the constituents located along the fence line and in the two localized areas described above could be from windblown deposits or from storm water runoff from the Luckey site and portions of the railroad bed.

4.5.2 Former New York Central Railroad Tracks

A former rail line for the NYCRR adjoins the Luckey site along its eastern border. The line was abandoned several years ago, and the steel rails and wooden ties were pulled up and laid along the eastern side of the railroad bed. The property has since been sold to one of the local farmers. The elevated gravel roadbed and the discarded wooden ties are the features that remain. Low-lying narrow strips of land thickly covered with shrubs and small saplings border the east and west sides of the roadbed. Eighteen surface soil samples and one subsurface soil sample were collected and analyzed to determine the presence of AEC-related materials. Table 4.23 summarizes the results of the laboratory analyses for all detected constituents in samples collected along the former railroad tracks. Figure 4.29 shows the distribution of metals and radionuclides detected above background.

Nine surface soil samples, IA10-SB0045 through IA10-SB0053, were collected along the former railroad tracks immediately east of the Luckey site. Most of the samples were obtained from the heavily vegetated strip of land lying between the tracks and the property fence line. However, a few were collected on the roadbed and on the eastern slope. In addition to the surface sample collected at IA10-SB0052, a subsurface sample was collected from 1 to 1½ ft bgs. Each of these samples was analyzed for arsenic, barium, beryllium, lead, and radionuclides.

Arsenic was not detected above background in any of the samples, while barium was detected above background in sample IA10-SB0045. The concentration of barium was 479 mg/kg, compared to the background (209 mg/kg). Lead was detected above background in seven of the nine surface soil samples, and the concentrations ranged from 48.2 mg/kg to 338 mg/kg. Beryllium was found above background in all nine surface soil samples and in the one subsurface soil sample. Concentrations ranged from 2.2 mg/kg to 2,560 mg/kg. The highest concentration (2,560 mg/kg) was found in the sample from IA10-SB0051; all other concentrations were below 148 mg/kg. The concentration of beryllium in the subsurface sample collected at IA10-SB0052 was 3.8 mg/kg.

Radionuclides were detected above background in eight samples. U-233/234, U-235 and Th-234 were detected in five samples each, while Ra-226 and U-238 were detected in four samples. Seven radionuclides were detected in sample IA10-SB0051. No radionuclides were detected in samples IA10-SB0046, IA10-SB0048, and IA10-SB0053, which are located either on top of or along the eastern side of the roadbed.

An additional nine samples (IA10-SB0089 through IA10-SB0097) were collected from on top of the bed and along the eastern side of the tracks and analyzed for beryllium and radionuclides. Beryllium was detected above background in each of these samples, with concentrations ranging from 3.8 mg/kg to 38.1 mg/kg. Radionuclides were not detected above background in any of these samples.

Based on the elevated levels of beryllium and radionuclides, it is apparent that materials associated with the Luckey site have impacted a portion of this adjacent property. As shown in Figure 4.29, elevated levels of beryllium were found in all samples collected along the former railroad. The concentrations of beryllium were below 100 mg/kg, except for IA10-SB0049, IA10-SB0050, and IA10-SB0051. The highest activities of radionuclides were detected in these three samples as well. In general, IA10-SB0051 contained the largest number of constituents above background and the highest levels.

These three borings are contained in a rather localized cluster in the low-lying area between the roadbed and the Luckey site property boundary. They are located just east of the waste disposal trenches at the northeast corner of the site. Constituents may have been deposited there by wind blowing across the bare areas at the disposal trenches or from storm water runoff that collects in the low-lying area.

4.5.3 France Stone Quarry

The France Stone Quarry is located immediately south of the Luckey site between Gilbert Road and the town of Luckey. Thirteen surface soil samples were collected from this property and were analyzed for arsenic, barium, beryllium, fluoride, lead, and radionuclides. Beryllium was detected above background in two samples at concentrations of 2.1 mg/kg and 2.5 mg/kg. Lead was detected in six samples at concentrations ranging from 25 mg/kg to 233 mg/kg. Uranium-235 was detected in one of 16 samples slightly above background. The remaining detections of radionuclides were below background. Table 4.24 summarizes the detected constituents for all samples collected at the quarry.

Soil boring IA10-SB0025 was completed to a depth of 3 ft before encountering bedrock. A soil sample was collected from each 1 ft depth interval and analyzed for arsenic, barium, beryllium, fluoride, lead, and radionuclides. In addition, a sample from the 1 to 2 ft interval was analyzed for VOCs. No metals or radionuclides were detected above background in any sample from this boring. Low concentrations of 2-hexanone, benzene, ethylbenzene, toluene and total xylenes were detected in the sample from 1 to 2 ft bgs. All of these VOC concentrations were estimated and ranged from 1 µg/kg to 9.9 µg/kg.

Figure 4.30 shows the distribution of lead and beryllium that was detected above background. None of the samples containing elevated lead is located within the first 200 ft immediately south of the Luckey site. Instead, these samples are clustered near the eastern portion of the property where the former stone processing structures were located. Construction debris from the razing of these structures still exists in this area. It is likely that the elevated levels of lead are artifacts of this debris.

Both occurrences of beryllium were slightly above background (1.7 mg/kg). The samples were taken from the northwest corner and the eastern portions of the property, so there is no distinctive trend in the data. Based on the sample results and the nature and extent evaluation, the soils at the quarry property do not appear to have been significantly impacted by past operations at the Luckey site. The elevated concentrations of lead and beryllium, and the estimated levels of VOCs, are addressed further in the BRA.

4.5.4 Western Farm Field

This farm field is located across Luckey Road immediately west of the Luckey site. Thirteen surface soil samples were collected from this property and were analyzed for arsenic, barium, beryllium, lead, and radionuclides. Beryllium was detected above background in three samples; the concentration in each case was 1.2 mg/kg. Lead was detected above background in one sample. The sample from location IA10-SB0064 contained lead at 23.6 mg/kg, which is slightly above the background of 23.2 mg/kg. Samples from seven locations contained very low levels of radioactivity. The isotopes detected above background include actinium-228, potassium-40, Th-228, Th-234 and U-235. Potassium-40 was the most prevalent isotope found and was detected in four samples. The greatest activity associated with this isotope was 28.7 pCi/g, which is slightly above the background of 27.2 pCi/g. The other four isotopes were detected in one sample each. Table 4.25 provides a summary of the detected constituents for all samples collected in the western farm field.

Soil boring IA10-SB0024 was completed to a depth of 5 feet. Soil samples from the zero to 1 ft and 2 to 3 ft depth intervals were analyzed for arsenic, barium, beryllium, lead, and radionuclides. Soil

from the 1 to 2 ft interval was analyzed for 24 metals, radionuclides, VOCs, and SVOCs, while samples from the 3 to 4 ft and 4 to 5 ft intervals were analyzed for beryllium. Two metals were detected in the 1 to 2 ft sample, and both were slightly above background. Antimony was detected at 0.31 mg/kg, and selenium was detected at 2.7 mg/kg. Three VOCs were detected in this same sample acetone (19.3B µg/kg), chloroform (0.58JB µg/kg), and toluene (0.9J µg/kg). However, these were either low estimated concentrations qualified with a J, or were found in associated blank samples and qualified with a B (Table 3.16). Potassium-40 was detected in the sample from 1 to 2 ft and Th-232 was detected in the sample from 2 to 3 ft bgs. Both occurrences were essentially the same level as the respective background.

Figure 4.31 shows the distribution of inorganic constituents and radionuclides that were detected above background. No trends or significant hotspots can be identified in the data. Potassium-40, the most widespread constituent, was detected in several samples close to Luckey Road as well as several samples located farthest from the road. Other constituents occur infrequently at concentrations near background. Based on this evaluation, the western farm field does not appear to have been impacted by past operations at the Luckey site. The significance of the three metals, five radionuclides, and three VOCs detected in the soil samples are addressed further in the baseline risk assessment.

4.5.5 Troy Township Dump

Although its not strictly considered an adjacent site, this dump is located within ¼ mile of the Luckey site. Seven borings were drilled through the dump at strategic locations to determine whether it contained AEC-related materials. Eighteen subsurface soil samples were collected and analyzed for arsenic, barium, beryllium, fluoride, lead, nitrate-nitrogen, and radionuclides. An additional 14 subsurface samples were collected and analyzed for beryllium. Table 4.26 provides a summary of the detected constituents for all samples collected in the Township dump.

Beryllium was detected above background in the samples collected from 1 to 2 ft, 2 to 3 ft, and 3 to 4 ft in boring IA10-SB0026. The concentrations ranged from 1.9 mg/kg to 46.7 mg/kg. Fluoride and lead were detected in the 2 to 3 ft sample from this boring at concentrations of 9.83 mg/kg and 114 mg/kg, respectively.

At boring IA10-SB0027, lead was detected in the 3 to 4 ft sample at a concentration of 33.6 mg/kg. Beryllium was detected at 1.5 mg/kg in the 5 to 5½ ft sample. In the 11 to 12 ft sample, barium and fluoride were detected at 1,220 mg/kg and 7.74 mg/kg, respectively. Barium was detected in the 15 to 16 ft sample at 1,920 mg/kg. The sample collected from just above the bedrock (22 to 23 ft) contained barium at 2,640 mg/kg and fluoride at 10.7 mg/kg.

Barium and fluoride were detected in the 13 to 14 ft sample from boring IA10-SB0028 at concentrations of 2,740 mg/kg and 10.9 mg/kg, respectively.

At boring IA10-SB0029, lead was detected in the 3 to 4 ft sample at 61.3 mg/kg, and barium was detected in the 23½ to 24½ ft sample at 3,460 mg/kg.

Potassium-40 was the only radionuclide detected in the samples from the dump. It was detected in the 2 to 3 ft sample from boring IA10-SB0087. The concentration of 29.9 pCi/g was slightly above background (27.2 pCi/g). This was the only constituent detected in this boring above background. No analytes were detected above background in boring IA10-SB0030 or IA10-SB0088.

Figure 4.32 shows the distribution of inorganic constituents and radionuclides that were detected above background. As indicated in the figure, most of the constituents detected above background were contained in the borings located on the south side of the dump. This part of the dump contains the

thickest fill deposits and the oldest spoils are likely buried there. Based on the results of the chemical analyses and the concentrations of barium, beryllium, and fluoride, it is not apparent that AEC-related materials were deposited in the dump. The constituents are evaluated further in the BRA.

4.5.6 Summary of Off-site Soil Sampling

Soil sampling was conducted at five adjacent properties to determine if past AEC activities have impacted them. The properties investigated include:

- Northern Farm Field – adjoins the site to the north
- Former New York Central Railroad Tracks – adjoins the site to the east
- France Stone Quarry – immediately south of the site and south of Gilbert Road
- Western Farm Field – immediately west of the site and west of Luckey Road
- Troy Township Dump – within ¼ mile southeast of the site

Of the properties investigated, the Northern Farm Field and the former New York Central Railroad Tracks appear to have been impacted by AEC related constituents. Both the France Stone Quarry and the Western Farm Field appear not to have been impacted by AEC-related constituents. Analytical results from all detected constituents are further evaluated in the human health and ecological risk assessments presented in Sections 6 and 7 of this report. A brief summary of the constituents detected at the impacted properties is presented below.

Sampling results indicate that soils in the northern farm field have been impacted by constituents related to the Luckey site. The primary constituents are beryllium and lead. They occur in two main areas, along the main ditch that flows north towards Toussaint Creek, and along the northern property boundary of the Luckey site. Constituents along the open ditch are probably a result of past dredging operations to maintain free flow from the Luckey site to Toussaint Creek. Sources for the constituents located along the northern property boundary could be from windblown deposits or from storm water runoff from the Luckey site and portions of the railroad bed.

Elevated levels of beryllium and radionuclides were detected in samples collected from the former New York Central Railroad Tracks. Elevated levels of beryllium were detected in all samples collected from this property. The highest levels of beryllium and radionuclides were detected in the same three samples (IA10-SB0049, IA10-SB0050, and IA10-SB0051). The three borings are contained in the low-lying area between the roadbed and the Luckey site property boundary. They are located just east of the waste disposal trenches at the northeast corner of the site. Constituents may have been deposited there by wind blowing across the bare areas at the disposal trenches or from storm water runoff that collects in the low-lying area.

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Table 4.1a. Disposal Trenches and Pits - Northeast Corner (IA01): Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Metals									
Aluminum	15/15	12500	IA01-SB0003	64700	IA01-SB0001	23700	3/15	76142	mg/kg
Antimony	6/15	0.45 B	IA01-SB0003	1.4 J	09EJ01	0.9	2/6	31	mg/kg
Arsenic	69/73	1.5	IA01-SB0007	33.5	IA01-SB0004	24.1	2/69	4	mg/kg
Barium	68/68	12.4	IA01-SB0001	301	IA01-SB0007	209	1/68	5375	mg/kg
Beryllium	192/192	0.17 B	IA01-SB0002	8760	IA01-SB0035	1.13	123/192	154	mg/kg
Boron	4/7	16.3	10FD01	31.8 J	09EJ01	13.4	4/4	5497	mg/kg
Cadmium	8/15	0.29	IA01-SB0002	3.9	09EJ01	0.98	3/8	37	mg/kg
Calcium	15/15	792	IA01-SB0001	91700	IA01-SB0003	55100	2/15	--	mg/kg
Chromium	15/15	17.9	10FI01	97.3	09EJ01	29.6	7/15	210.7	mg/kg
Cobalt	15/15	0.92 B	IA01-SB0001	17.3	09FU01	19.1	0/15	4693	mg/kg
Copper	15/15	8 J	10FI01	181	IA01-SB0003	42	3/15	2905	mg/kg
Iron	15/15	2210	IA01-SB0001	54400	IA01-SB0002	38600	1/15	23463	mg/kg
Lead	68/68	4.9 *	IA01-SB0011	28900 J	10FD01	23.2	26/68	400	mg/kg
Magnesium	15/15	435	IA01-SB0001	18200	IA01-SB0003	17100	1/15	--	mg/kg
Manganese	15/15	31.5	IA01-SB0001	544	09FU01	2340	0/15	1762	mg/kg
Mercury	15/15	0.04	IA01-SB0002	1.4	09EJ01	0.19	4/15	2.3	mg/kg
Molybdenum	7/7	0.63 B	10FI01	12.7	09EJ01	11.3	1/7	391	mg/kg
Nickel	15/15	17.3	10FI01	84.6	09EJ01	46.1	3/15	1564	mg/kg
Phosphorus	6/6	57.1	IA01-SB0001	863	IA01-SB0004	808	1/6	--	mg/kg
Potassium	15/15	324	IA01-SB0001	4070 J	09FU01	3410	3/15	--	mg/kg
Selenium	13/15	0.34 B	IA01-SB0001	2.8 B	10FD01	2.33	2/13	391	mg/kg
Silicon	7/7	1100 J	11EV01	4710 J	10FD01	595	7/7	11.3	mg/kg
Silver	5/15	0.2 B	09EZ01	0.63 B	10FD01	0.51	1/5	391	mg/kg
Sodium	14/14	329	IA01-SB0004	22300	09EZ01	285	14/14	--	mg/kg
Strontium	7/7	0.125 J	10FD01	160	09EZ01	75.6	3/7	46924	mg/kg
Thallium	8/15	0.95 B	IA01-SB0004	3.6 B	09EJ01	2.1	2/8	0.6	mg/kg
Vanadium	15/15	1.5 B	IA01-SB0001	42.2	IA01-SB0002	42.8	0/15	547	mg/kg
Zinc	15/15	6.5	IA01-SB0001	1830	10FD01	110	7/15	23463	mg/kg
Indicator Parameters									
Chloride	6/7	7.76 J	09EJ01	320	09EZ01	--	--	--	mg/kg
Fluoride	60/60	1.02	IA01-SB0018	576	10FD01	6.94	45/60	3666	mg/kg
Nitrate, as N	7/7	1.06	09EJ01	521	09EZ01	--	--	11.3	mg/kg
Nitrogen, Ammonia	52/53	1.6	IA01-SB0011	135	IA01-SB0020	--	--	--	mg/kg
Sulfate	7/7	42.7	09FU01	24800	09EZ01	--	--	--	mg/kg

*USEPA Region 9 PRG

Table 4.1a. Disposal Trenches and Pits - Northeast Corner (IA01): Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Semivolatile Organics									
Benzo(a)anthracene	2/16	166 J	10FD01	896 J	IA01-SB0003	--	--	0.6	ug/kg
Benzo(a)pyrene	3/16	187 J	10FD01	874 J	IA01-SB0003	--	--	0.1	ug/kg
Benzo(b)fluoranthene	3/16	275 J	10FD01	1190 J	IA01-SB0003	--	--	0.6	ug/kg
Chrysene	3/16	200 J	10FD01	1060 J	IA01-SB0003	--	--	62.1	ug/kg
Diesel Range Organics	1/1	2.8 B	IA01-SB0023	2.8 B	IA01-SB0023	--	--	--	mg/kg
Fluoranthene	3/16	387	10FD01	2670	IA01-SB0003	--	--	2294	ug/kg
Phenanthrene	1/16	1900	IA01-SB0003	1900	IA01-SB0003	--	--	230.9	ug/kg
Pyrene	2/16	231 J	10FD01	1830	IA01-SB0003	--	--	2309	ug/kg
bis(2-ethylhexyl)phthalate	2/16	242 J	09EJ01	246 J	09EZ01	--	--	34.7	ug/kg
Volatile Organics									
2-Butanone	1/13	3.8 J	IA01-SB0002	3.8 J	IA01-SB0002	--	--	7325	ug/kg
2-Hexanone	1/13	1.1 J	IA01-SB0003	1.1 J	IA01-SB0003	--	--	--	ug/kg
Benzene	8/13	1.1 J	IA01-SB0001	5.4 J	IA01-SB0003	--	--	0.7	ug/kg
Bromodichloromethane	1/5	1.2 J	10FI01	1.2 J	10FI01	--	--	1.0	ug/kg
Carbon disulfide	3/13	2 J	IA01-SB0003	13	IA01-SB0002	--	--	355	ug/kg
Chloroform	2/13	1.6 J	IA01-SB0001	7.9 J	10FI01	--	--	0.2	ug/kg
Ethylbenzene	6/13	0.5 J	IA01-SB0003	49.7	IA01-SB0002	--	--	230	ug/kg
Methylene chloride	3/13	2.8 J	11EV01	7.8	09FU01	--	--	8.9	ug/kg
Toluene	13/13	3.6 B	IA01-SB0003	162 J	09EJ01	--	--	520	ug/kg
Xylenes (total)	4/13	1.4 J	IA01-SB0003	26.9	IA01-SB0003	--	--	210	ug/kg
Radiological Parameters									
Actinium-227	36/76	0.143 J	IA01-SB0002	2.08	10FI01	1.76	4/36	--	pCi/g
Actinium-228	58/61	0.541 J	IA01-SB0018	1.42	IA01-SB0007	1.35	1/58	--	pCi/g
Cesium-137	10/76	0.0363	IA01-SB0013	0.495	09EI01	0.72	0/10	--	pCi/g
Potassium-40	75/76	3.11	IA01-SB0001	31.3	IA01-SB0007	27.2	3/75	--	pCi/g
Radium-226	76/76	0.891 J	IA01-SB0022	193 J	10FI01	2.97	28/76	--	pCi/g
Radium-228	73/76	0.0945	10FI01	1.42	IA01-SB0007	1.48	0/73	--	pCi/g
Thorium-227	14/15	0.338	11EV01	2.08	10FI01	1.76	2/14	11.3	pCi/g
Thorium-228	76/76	0.0945	10FI01	2.11	IA01-SB0003	1.6	4/76	--	pCi/g
Thorium-230	76/76	1.06	IA01-SB0011	60.3	09EJ01	3.2	28/76	--	pCi/g
Thorium-232	76/76	0.104	10FI01	1.46	IA01-SB0011	1.48	0/76	--	pCi/g
Thorium-234	41/61	1.08 J	IA01-SB0021	43.3	IA01-SB0018	3.07	14/41	--	pCi/g
Uranium-233/234	61/61	0.554 J	IA01-SB0022	43.2	IA01-SB0018	2.01	15/61	--	pCi/g
Uranium-234	15/15	2.4	11EV01	31.1	09EJ01	2.61	14/15	11.3	pCi/g
Uranium-235	42/76	0.0492	IA01-SB0014	2.29	IA01-SB0018	0.25	21/42	--	pCi/g
Uranium-238	76/76	0.708 J	IA01-SB0009	41.5	IA01-SB0018	2.63	27/76	--	pCi/g

*USEPA Region 9 PRG

Table 4.1b. Disposal Trenches and Pits - Scrap Metal Disposal Trench (IA03): Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Metals									
Aluminum	6/6	8900	IA03-SB0002	39500	10DD00	23700	2/6	76142	mg/kg
Arsenic	33/33	2.6	IA03-SB0002	39.4	10DD00	24.1	1/33	4	mg/kg
Barium	30/30	19.9 N	IA03-SB0007	218 J	10DD00	209	1/30	5375	mg/kg
Beryllium	84/84	0.19 B	IA03-SB0007	1300	IA03-TR0002	1.13	36/84	154	mg/kg
Boron	1/1	21.5	10DD00	21.5	10DD00	13.4	1/1	5497	mg/kg
Cadmium	3/3	0.31	IA03-SB0003	5.7 B	10DD00	0.98	1/3	37	mg/kg
Calcium	3/3	2530	IA03-SB0002	126000	10DD00	55100	1/3	--	mg/kg
Chromium	3/3	23.7	IA03-SB0003	153 J	10DD00	29.6	1/3	210.7	mg/kg
Cobalt	3/3	10	IA03-SB0002	35.3	10DD00	19.1	1/3	4693	mg/kg
Copper	3/3	63.8	IA03-SB0003	1970	IA03-SB0002	42	3/3	2905	mg/kg
Iron	3/3	24500	IA03-SB0002	119000 J	10DD00	38600	1/3	23463	mg/kg
Lead	33/33	5.2 E	IA03-SB0007	780	10DD00	23.2	5/33	400	mg/kg
Magnesium	6/6	2870 *	IA03-SB0002	25300	10DD00	17100	1/6	--	mg/kg
Manganese	3/3	187	IA03-SB0002	1720	10DD00	2340	0/3	1762	mg/kg
Mercury	3/3	0.07 B	IA03-SB0002	0.79	10DD00	0.19	1/3	2.3	mg/kg
Molybdenum	1/1	15.8	10DD00	15.8	10DD00	11.3	1/1	391	mg/kg
Nickel	3/3	36.8	IA03-SB0003	194	10DD00	46.1	1/3	1564	mg/kg
Phosphorus	2/2	311	IA03-SB0002	431	IA03-SB0003	808	0/2	--	mg/kg
Potassium	3/3	1300	IA03-SB0002	7520 J	10DD00	3410	1/3	--	mg/kg
Selenium	2/3	1.2 B	IA03-SB0002	1.6	IA03-SB0003	2.33	0/2	391	mg/kg
Silicon	1/1	5150 J	10DD00	5150 J	10DD00	595	1/1	11.3	mg/kg
Silver	1/3	1.2 B	10DD00	1.2 B	10DD00	0.51	1/1	391	mg/kg
Sodium	3/3	174	IA03-SB0002	577	10DD00	285	1/3	--	mg/kg
Strontium	1/1	214	10DD00	214	10DD00	75.6	1/1	46924	mg/kg
Thallium	3/3	0.64 B	IA03-SB0002	5.4 B	10DD00	2.1	1/3	0.6	mg/kg
Vanadium	3/3	35.7	IA03-SB0003	71	10DD00	42.8	1/3	547	mg/kg
Zinc	3/3	64.9	IA03-SB0003	262	10DD00	110	1/3	23463	mg/kg
Indicator Parameters									
Fluoride	27/27	0.93	IA03-SB0006	10.5	IA03-SB0009	6.94	4/27	3666	mg/kg
Nitrogen, Ammonia	27/27	1.12	IA03-SB0005	48	IA03-SB0017	--	--	--	mg/kg
Semivolatile Organics									
2-Methylnaphthalene	1/3	246 J	IA03-SB0002	246 J	IA03-SB0002	--	--	230.9	ug/kg
Fluoranthene	1/3	811	IA03-SB0002	811	IA03-SB0002	--	--	2294	ug/kg
Phenanthrene	1/3	866	IA03-SB0002	866	IA03-SB0002	--	--	230.9	ug/kg
Pyrene	1/3	732	IA03-SB0002	732	IA03-SB0002	--	--	2309	ug/kg

*USEPA Region 9 PRG

Table 4.1b. Disposal Trenches and Pits - Scrap Metal Disposal Trench (IA03): Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Volatile Organics									
Benzene	1/3	2 J	IA03-SB0002	2 J	IA03-SB0002	--	--	0.7	ug/kg
Chloroform	1/3	0.84 J	IA03-SB0002	0.84 J	IA03-SB0002	--	--	0.2	ug/kg
Chloromethane	1/1	115 J	10DD00	115 J	10DD00	--	--	1.2	ug/kg
Ethylbenzene	1/3	7.3 J	IA03-SB0002	7.3 J	IA03-SB0002	--	--	230	ug/kg
Toluene	3/3	4.7	IA03-SB0003	422 J	10DD00	--	--	520	ug/kg
Xylenes (total)	1/3	35.8	IA03-SB0002	35.8	IA03-SB0002	--	--	210	ug/kg
Radiological Parameters									
Actinium-227	3/33	0.163	10DD00	0.327	10CX01	1.76	0/3	--	pCi/g
Actinium-228	27/29	0.489 J	IA03-SB0006	1.22	IA03-SB0010	1.35	0/27	--	pCi/g
Cesium-137	3/33	0.0375	IA03-SB0002	0.704	10CX01	0.72	0/3	--	pCi/g
Potassium-40	33/33	2.19	IA03-SB0002	28.1	IA03-SB0005	27.2	2/33	--	pCi/g
Radium-226	33/33	0.878 J	IA03-SB0010	2.12	IA03-SB0005	2.97	0/33	--	pCi/g
Radium-228	31/33	0.489 J	IA03-SB0006	1.22	IA03-SB0010	1.48	0/31	--	pCi/g
Thorium-227	3/4	0.163	10DD00	0.327	10CX01	1.76	0/3	11.3	pCi/g
Thorium-228	33/33	0.255 J	IA03-SB0002	2.1	IA03-SB0009	1.6	2/33	--	pCi/g
Thorium-230	33/33	0.827	10CM01	2.88	10DD00	3.2	0/33	--	pCi/g
Thorium-232	33/33	0.183 J	IA03-SB0002	1.75	IA03-SB0009	1.48	1/33	--	pCi/g
Thorium-234	20/29	0.676 J	IA03-SB0010	3.33 J	IA03-SB0007	3.07	1/20	--	pCi/g
Uranium-233/234	29/29	0.654 J	IA03-SB0017	2.8	IA03-SB0003	2.01	1/29	--	pCi/g
Uranium-234	4/4	0.51	10DD00	1.03	10CX01	2.61	0/4	11.3	pCi/g
Uranium-235	9/33	0.0594	10CS01	0.13 J	IA03-SB0010	0.25	0/9	--	pCi/g
Uranium-238	33/33	0.533	10DD00	2.7	IA03-SB0003	2.63	1/33	--	pCi/g

*USEPA Region 9 PRG

Table 4.1c. Disposal Trenches and Pits - NE of Filter Beds (IA05): Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Metals									
Aluminum	11/11	11400	08FT00	24300	IA05-SB0008	23700	1/11	76142	mg/kg
Antimony	3/6	0.47 B	IA05-SB0007	9.1	IA05-SB0007	0.9	2/3	31	mg/kg
Arsenic	34/34	4	IA05-SB0007	20.8 *	IA05-SB0020	24.1	0/34	4	mg/kg
Barium	29/29	23.1	IA05-SB0007	789	IA05-SB0008	209	1/29	5375	mg/kg
Beryllium	52/52	0.3	IA05-SB0022	8620 N	IA05-SB0007	1.13	40/52	154	mg/kg
Boron	2/2	11 J	08FS01	15.3 J	08FS02	13.4	1/2	5497	mg/kg
Cadmium	5/6	0.45	IA05-SB0007	1 B	08FS02	0.98	1/5	37	mg/kg
Calcium	6/6	22600	IA05-SB0007	50900	IA05-SB0008	55100	0/6	--	mg/kg
Chromium	6/6	19.7	IA05-SB0007	61.8	IA05-SB0007	29.6	2/6	210.7	mg/kg
Cobalt	6/6	9.6	IA05-SB0007	19	08FS01	19.1	0/6	4693	mg/kg
Copper	6/6	24.9	IA05-SB0007	154	IA05-SB0007	42	3/6	2905	mg/kg
Iron	6/6	26000	IA05-SB0007	80600	IA05-SB0008	38600	2/6	23463	mg/kg
Lead	34/34	9.2	IA05-SB0007	627	IA05-SB0007	23.2	13/34	400	mg/kg
Magnesium	11/11	5810	IA05-SB0007	15000	08FT01	17100	0/11	--	mg/kg
Manganese	6/6	222	IA05-SB0007	864	08FS01	2340	0/6	1762	mg/kg
Mercury	4/6	0.06	08FS02	0.7	IA05-SB0008	0.19	2/4	2.3	mg/kg
Molybdenum	2/2	5.3 B	08FS01	6.7 J	08FS02	11.3	0/2	391	mg/kg
Nickel	6/6	31.6	IA05-SB0007	61.2	IA05-SB0008	46.1	3/6	1564	mg/kg
Phosphorus	4/4	423	IA05-SB0008	600	IA05-SB0007	808	0/4	--	mg/kg
Potassium	6/6	1780	IA05-SB0007	5060	IA05-SB0008	3410	1/6	--	mg/kg
Selenium	3/6	0.7 B	IA05-SB0007	3.4	IA05-SB0008	2.33	1/3	391	mg/kg
Silicon	2/2	884 J	08FS01	892 J	08FS02	595	2/2	11.3	mg/kg
Silver	2/6	0.26 B	08FS01	0.37 B	IA05-SB0007	0.51	0/2	391	mg/kg
Sodium	6/6	102	IA05-SB0007	308	IA05-SB0008	285	1/6	--	mg/kg
Strontium	2/2	102	08FS02	136 *	08FS01	75.6	2/2	46924	mg/kg
Vanadium	6/6	26.8	IA05-SB0007	51.1	IA05-SB0008	42.8	1/6	547	mg/kg
Zinc	6/6	70	IA05-SB0007	363	IA05-SB0008	110	2/6	23463	mg/kg
Indicator Parameters									
Fluoride	24/24	1.77	IA05-SB0019	68.4	IA05-SB0018	6.94	19/24	3666	mg/kg
Nitrate, as N	1/1	0.769 J	08FS02	0.769 J	08FS02	--	--	11.3	mg/kg
Nitrogen, Ammonia	23/23	0.65 J	IA05-SB0007	31.8	IA05-SB0020	--	--	--	mg/kg
Phosphorus	1/1	1.84 J	08FS02	1.84 J	08FS02	808	0/1	--	mg/kg
Sulfate	1/1	36.8	08FS02	36.8	08FS02	--	--	--	mg/kg

*USEPA Region 9 PRG

Table 4.1c. Disposal Trenches and Pits - NE of Filter Beds (IA05): Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Semivolatile Organics									
Anthracene	1/6	75.3 J	IA05-SB0007	75.3 J	IA05-SB0007	--	--	21896	ug/kg
Benzo(a)anthracene	1/6	211 J	IA05-SB0007	211 J	IA05-SB0007	--	--	0.6	ug/kg
Benzo(a)pyrene	1/6	232 J	IA05-SB0007	232 J	IA05-SB0007	--	--	0.1	ug/kg
Benzo(b)fluoranthene	1/6	461	IA05-SB0007	461	IA05-SB0007	--	--	0.6	ug/kg
Benzo(ghi)perylene	1/6	176 J	IA05-SB0007	176 J	IA05-SB0007	--	--	230.9	ug/kg
Chrysene	1/6	316 J	IA05-SB0007	316 J	IA05-SB0007	--	--	62.1	ug/kg
Dibenz(a,h)anthracene	1/6	51.6 J	IA05-SB0007	51.6 J	IA05-SB0007	--	--	0.1	ug/kg
Fluoranthene	1/6	422 J	IA05-SB0007	422 J	IA05-SB0007	--	--	2294	ug/kg
Indeno(1,2,3-c,d)pyrene	1/6	183 J	IA05-SB0007	183 J	IA05-SB0007	--	--	0.6	ug/kg
Phenanthrene	1/6	271 J	IA05-SB0007	271 J	IA05-SB0007	--	--	230.9	ug/kg
Pyrene	1/6	385 J	IA05-SB0007	385 J	IA05-SB0007	--	--	2309	ug/kg
bis(2-ethylhexyl)phthalate	1/6	219 J	IA05-SB0007	219 J	IA05-SB0007	--	--	34.7	ug/kg
Volatile Organics									
Benzene	4/6	0.7 J	IA05-SB0007	5.7 J	IA05-SB0007	--	--	0.7	ug/kg
Ethylbenzene	4/6	0.78 J	IA05-SB0008	1.8 J	IA05-SB0008	--	--	230	ug/kg
Methyl Bromide	1/4	6.7 J	IA05-SB0008	6.7 J	IA05-SB0008	--	--	4	ug/kg
Methyl Chloride	1/4	5.9 J	IA05-SB0008	5.9 J	IA05-SB0008	--	--	1.2	ug/kg
Methylene chloride	5/6	0.7 BJ	IA05-SB0007	5 J	08FS02	--	--	8.9	ug/kg
Toluene	5/6	0.46 J	08FS01	18.9	IA05-SB0007	--	--	520	ug/kg
Radiological Parameters									
Actinium-227	6/29	0.122 J	IA05-SB0008	1.34 J	IA05-SB0007	1.76	0/6	--	pCi/g
Actinium-228	27/27	0.293 J	IA05-SB0007	1.33	IA05-SB0020	1.35	0/27	--	pCi/g
Cesium-137	5/29	0.0483	IA05-SB0021	0.19	IA05-SB0008	0.72	0/5	--	pCi/g
Potassium-40	29/29	8.51	IA05-SB0007	28.4	IA05-SB0019	27.2	2/29	--	pCi/g
Radium-226	29/29	1.06	IA05-SB0007	9.71	IA05-SB0007	2.97	3/29	--	pCi/g
Radium-228	29/29	0.293 J	IA05-SB0007	1.33	IA05-SB0020	1.48	0/29	--	pCi/g
Thorium-228	29/29	0.51 J	IA05-SB0007	1.47	IA05-SB0020	1.6	0/29	--	pCi/g
Thorium-230	29/29	0.928 J	IA05-SB0021	15.7	IA05-SB0007	3.2	2/29	--	pCi/g
Thorium-232	29/29	0.237 J	IA05-SB0007	1.27	IA05-SB0018	1.48	0/29	--	pCi/g
Thorium-234	15/27	1.08 J	IA05-SB0021	6.61	IA05-SB0007	3.07	2/15	--	pCi/g
Uranium-233/234	27/27	0.54 J	IA05-SB0021	7.98	IA05-SB0007	2.01	3/27	--	pCi/g
Uranium-234	2/2	0.742	08FS01	0.968	08FS02	2.61	0/2	11.3	pCi/g
Uranium-235	11/29	0.0672	IA05-SB0021	0.545 J	IA05-SB0007	0.25	1/11	--	pCi/g
Uranium-238	29/29	0.816 J	IA05-SB0020	8.11	IA05-SB0007	2.63	2/29	--	pCi/g

*USEPA Region 9 PRG

Table 4.1d. Disposal Trenches and Pits - Lime Pit (IA07): Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Metals									
Aluminum	3/3	7310	03EQ01	11400	03EQ01	23700	0/3	76142	mg/kg
Arsenic	10/10	1 B	IA07-SB0009	11.1	IA07-SB0009	24.1	0/10	4	mg/kg
Barium	10/10	47.9	IA07-SB0009	243	IA07-SB0009	209	2/10	5375	mg/kg
Beryllium	10/10	0.26 B	IA07-SB0009	13.7	IA07-SB0010	1.13	3/10	154	mg/kg
Boron	2/3	12.2	03EQ01	15.9	03EQ01	13.4	1/2	5497	mg/kg
Cadmium	3/3	0.5 B	03EQ01	0.57 B	03EQ01	0.98	0/3	37	mg/kg
Calcium	3/3	78300	03EQ01	87800	03EQ01	55100	3/3	--	mg/kg
Chromium	3/3	14.3 J	03EQ01	18.5 J	03EQ01	29.6	0/3	210.7	mg/kg
Cobalt	3/3	6.8	03EQ01	9.3	03EQ01	19.1	0/3	4693	mg/kg
Copper	3/3	25 J	03EQ01	29.1 J	03EQ01	42	0/3	2905	mg/kg
Iron	3/3	15500 J	03EQ01	21600 J	03EQ01	38600	0/3	23463	mg/kg
Lead	10/10	2.2	IA07-SB0009	442	IA07-SB0010	23.2	3/10	400	mg/kg
Magnesium	3/3	10800	03EQ01	22600	03EQ01	17100	1/3	--	mg/kg
Manganese	3/3	247	03EQ01	358	03EQ01	2340	0/3	1762	mg/kg
Mercury	3/3	0.04 B	03EQ01	0.08	03EQ01	0.19	0/3	2.3	mg/kg
Molybdenum	3/3	2.8 B	03EQ01	4.1 B	03EQ01	11.3	0/3	391	mg/kg
Nickel	3/3	22.8	03EQ01	26	03EQ01	46.1	0/3	1564	mg/kg
Potassium	3/3	1290 J	03EQ01	2430 J	03EQ01	3410	0/3	--	mg/kg
Silicon	3/3	1050 J	03EQ01	2500 J	03EQ01	595	3/3	11.3	mg/kg
Silver	3/3	0.17 B	03EQ01	0.25 B	03EQ01	0.51	0/3	391	mg/kg
Sodium	3/3	153	03EQ01	173	03EQ01	285	0/3	--	mg/kg
Strontium	3/3	444	03EQ01	2980	03EQ01	75.6	3/3	46924	mg/kg
Thallium	1/3	0.49 B	03EQ01	0.49 B	03EQ01	2.1	0/1	0.6	mg/kg
Vanadium	3/3	15.3	03EQ01	26.5	03EQ01	42.8	0/3	547	mg/kg
Zinc	3/3	57.8	03EQ01	68.5	03EQ01	110	0/3	23463	mg/kg
Indicator Parameters									
Chloride	2/2	43	03EQ01	43.3	03EQ01	--	--	--	mg/kg
Fluoride	9/9	2.28	IA07-SB0009	6.83	IA07-SB0009	6.94	0/9	3666	mg/kg
Nitrate, as N	2/2	0.173 J	03EQ01	0.214 J	03EQ01	--	--	11.3	mg/kg
Nitrogen, Ammonia	7/7	1.77	IA07-SB0009	35.5	IA07-SB0009	--	--	--	mg/kg
Sulfate	2/2	149	03EQ01	348	03EQ01	--	--	--	mg/kg
Volatile Organics									
Chloroform	1/3	2.7 J	03EQ01	2.7 J	03EQ01	--	--	0.2	ug/kg
Chloromethane	1/3	60.6 J	03EQ01	60.6 J	03EQ01	--	--	1.2	ug/kg
Methylene chloride	2/3	2.8 J	03EQ01	4.4 J	03EQ01	--	--	8.9	ug/kg
Toluene	3/3	33.2 J	03EQ01	127	03EQ01	--	--	520	ug/kg

*USEAP Region 9 PRG

Table 4.1d. Disposal Trenches and Pits - Lime Pit (IA07): Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Radiological Parameters									
Actinium-228	5/7	0.649 J	IA07-SB0010	1.17	IA07-SB0009	1.35	0/5	--	pCi/g
Cesium-137	3/10	0.14	IA07-SB0009	0.151	IA07-SB0010	0.72	0/3	--	pCi/g
Potassium-40	9/10	2.24	IA07-SB0010	29.6	IA07-SB0009	27.2	2/9	--	pCi/g
Radium-226	10/10	0.884 J	IA07-SB0009	1.67	IA07-SB0009	2.97	0/10	--	pCi/g
Radium-228	8/10	0.428	03EQ01	1.17	IA07-SB0009	1.48	0/8	--	pCi/g
Thorium-228	9/10	0.428	03EQ01	1.67	IA07-SB0010	1.6	2/9	--	pCi/g
Thorium-230	10/10	0.162 J	IA07-SB0009	2.33	IA07-SB0009	3.2	0/10	--	pCi/g
Thorium-232	8/10	0.404	03EQ01	1.47	IA07-SB0010	1.48	0/8	--	pCi/g
Thorium-234	2/7	1.18 J	IA07-SB0009	1.78 J	IA07-SB0010	3.07	0/2	--	pCi/g
Uranium-233/234	7/7	0.122 J	IA07-SB0009	1.4	IA07-SB0010	2.01	0/7	--	pCi/g
Uranium-234	3/3	0.359	03EQ01	0.553	03EQ01	2.61	0/3	11.3	pCi/g
Uranium-235	1/10	0.0679	03EQ01	0.0679	03EQ01	0.25	0/1	--	pCi/g
Uranium-238	10/10	0.0977	IA07-SB0009	1.41	IA07-SB0009	2.63	0/10	--	pCi/g

*USEAP Region 9 PRG

Table 4.2a. Lagoon A: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Metals									
Aluminum	3/3	12100	04AX00	179000	04AX00	23700	1/3	76142	mg/kg
Arsenic	12/13	2.1	IA02-SB0010	11.4	IA02-SB0005	24.1	0/12	4	mg/kg
Barium	13/13	35.2 B	04AX00	292	IA02-SB0005	209	1/13	5375	mg/kg
Beryllium	27/27	0.43	IA02-SB0020	7880	04AX00	1.13	13/27	154	mg/kg
Boron	1/2	10.5 B	04AX00	10.5 B	04AX00	13.4	0/1	5497	mg/kg
Cadmium	2/3	0.2 B	IA02-SB0005	0.2 B	04AX00	0.98	0/2	37	mg/kg
Calcium	3/3	9110 *	04AX00	81300	IA02-SB0005	55100	1/3	--	mg/kg
Chromium	3/3	18.1	IA02-SB0005	172	04AX00	29.6	1/3	210.7	mg/kg
Cobalt	3/3	5.5 B	04AX00	21.4	IA02-SB0005	19.1	1/3	4693	mg/kg
Copper	3/3	15.1	04AX00	51.8	04AX00	42	1/3	2905	mg/kg
Iron	3/3	11100	04AX00	24600	IA02-SB0005	38600	0/3	23463	mg/kg
Lead	13/13	5.9	IA02-SB0010	135 B	04AX00	23.2	1/13	400	mg/kg
Magnesium	3/3	4820	04AX00	16500	04AX00	17100	0/3	--	mg/kg
Manganese	3/3	311	04AX00	2150	IA02-SB0005	2340	0/3	1762	mg/kg
Mercury	1/3	0.02 B	IA02-SB0005	0.02 B	IA02-SB0005	0.19	0/1	2.3	mg/kg
Nickel	3/3	19.9	04AX00	44.1 B	04AX00	46.1	0/3	1564	mg/kg
Phosphorus	1/1	416	IA02-SB0005	416	IA02-SB0005	808	0/1	--	mg/kg
Potassium	3/3	844 B	04AX00	2570	IA02-SB0005	3410	0/3	--	mg/kg
Selenium	1/3	1.6	IA02-SB0005	1.6	IA02-SB0005	2.33	0/1	391	mg/kg
Silicon	2/2	1120 J	04AX00	1320 J	04AX00	595	2/2	11.3	mg/kg
Silver	1/3	3.6 B	04AX00	3.6 B	04AX00	0.51	1/1	391	mg/kg
Sodium	3/3	673	IA02-SB0005	37000	04AX00	285	3/3	--	mg/kg
Strontium	2/2	50.4	04AX00	641	04AX00	75.6	1/2	46924	mg/kg
Thallium	1/3	0.73 B	IA02-SB0005	0.73 B	IA02-SB0005	2.1	0/1	0.6	mg/kg
Vanadium	3/3	9.2 B	04AX00	28.4	IA02-SB0005	42.8	0/3	547	mg/kg
Zinc	3/3	41	04AX00	127	04AX00	110	1/3	23463	mg/kg
Indicator Parameters									
Chloride	1/1	72.6 J	04AX00	72.6 J	04AX00	--	--	--	mg/kg
Fluoride	11/11	1.01	IA02-SB0005	231	04AX00	6.94	4/11	3666	mg/kg
Nitrate, as N	1/1	3.6	04AX00	3.6	04AX00	--	--	11.3	mg/kg
Nitrogen, Ammonia	10/10	2.63	IA02-SB0005	232	IA02-SB0010	--	--	--	mg/kg
Phosphorus	1/1	2.44 J	04AX00	2.44 J	04AX00	808	0/1	--	mg/kg
Sulfate	1/1	7785	04AX00	7785	04AX00	--	--	--	mg/kg

*USEPA Region 9 PRG

Table 4.2a. Lagoon A: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Volatile Organics									
Benzene	1/3	1.2 J	IA02-SB0005	1.2 J	IA02-SB0005	--	--	0.7	ug/kg
Carbon disulfide	1/3	14	IA02-SB0005	14	IA02-SB0005	--	--	355	ug/kg
Ethylbenzene	1/3	0.28 J	04AX00	0.28 J	04AX00	--	--	230	ug/kg
Toluene	2/3	1.7 J	IA02-SB0005	53.6	04AX00	--	--	520	ug/kg
Xylenes (total)	1/3	0.71 J	04AX00	0.71 J	04AX00	--	--	210	ug/kg
Radiological Parameters									
Actinium-227	2/13	0.162 J	IA02-SB0005	0.957 J	04AX00	1.76	0/2	--	pCi/g
Actinium-228	10/11	0.841 J	IA02-SB0011	1.2	IA02-SB0005	1.35	0/10	--	pCi/g
Cesium-137	1/13	0.0499	IA02-SB0005	0.0499	IA02-SB0005	0.72	0/1	--	pCi/g
Potassium-40	13/13	6.23	04AX00	28.6	IA02-SB0011	27.2	1/13	--	pCi/g
Radium-226	13/13	1.05 J	04AX00	22.4 J	04AX00	2.97	1/13	--	pCi/g
Radium-228	12/13	0.41	04AX00	1.2	IA02-SB0005	1.48	0/12	--	pCi/g
Thorium-227	1/2	0.957 J	04AX00	0.957 J	04AX00	1.76	0/1	11.3	pCi/g
Thorium-228	13/13	0.41	04AX00	1.67	IA02-SB0011	1.6	1/13	--	pCi/g
Thorium-230	13/13	0.876	04AX00	25.6 J	04AX00	3.2	1/13	--	pCi/g
Thorium-232	13/13	0.268	04AX00	1.23 J	04AX00	1.48	0/13	--	pCi/g
Thorium-234	3/11	1.47 J	IA02-SB0012	1.77 J	IA02-SB0011	3.07	0/3	--	pCi/g
Uranium-233/234	11/11	0.828 J	IA02-SB0005	1.68	IA02-SB0011	2.01	0/11	--	pCi/g
Uranium-234	2/2	4.86	04AX00	52.3	04AX00	2.61	2/2	11.3	pCi/g
Uranium-235	7/13	0.0524	IA02-SB0012	0.559 J	04AX00	0.25	2/7	--	pCi/g
Uranium-238	13/13	0.949 J	IA02-SB0012	51.1	04AX00	2.63	2/13	--	pCi/g

*USEPA Region 9 PRG

Table 4.2b. Lagoon B: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Metals									
Aluminum	4/4	10500	IA02-SB0004	41000	05BE00	23700	2/4	76142	mg/kg
Arsenic	15/15	3.3	IA02-SB0014	12.7 B	05BE00	24.1	0/15	4	mg/kg
Barium	15/15	17.8	05BE00	171	05BE00	209	0/15	5375	mg/kg
Beryllium	38/38	0.51 J	IA02-SB0025	2920	05BE00	1.13	22/38	154	mg/kg
Boron	2/2	4 B	05BE00	28.3	05BE00	13.4	1/2	5497	mg/kg
Cadmium	3/4	0.25	IA02-SB0004	0.91	IA02-SB0003	0.98	0/3	37	mg/kg
Calcium	4/4	3400 *	05BE00	84500	IA02-SB0004	55100	2/4	--	mg/kg
Chromium	4/4	16.5	IA02-SB0004	66.7	05BE00	29.6	2/4	210.7	mg/kg
Cobalt	4/4	0.99 B	05BE00	18.5	05BE00	19.1	0/4	4693	mg/kg
Copper	4/4	8.9	05BE00	35.6	05BE00	42	0/4	2905	mg/kg
Iron	4/4	3900	05BE00	44700	05BE00	38600	1/4	23463	mg/kg
Lead	15/15	6.8	IA02-SB0014	122	IA02-SB0013	23.2	3/15	400	mg/kg
Magnesium	4/4	1270	05BE00	21700	IA02-SB0003	17100	1/4	--	mg/kg
Manganese	4/4	94.9	05BE00	1400 N	IA02-SB0004	2340	0/4	1762	mg/kg
Mercury	1/4	0.12	IA02-SB0003	0.12	IA02-SB0003	0.19	0/1	2.3	mg/kg
Molybdenum	1/2	5.6 B	05BE00	5.6 B	05BE00	11.3	0/1	391	mg/kg
Nickel	4/4	27.1	IA02-SB0004	62.5	05BE00	46.1	2/4	1564	mg/kg
Phosphorus	2/2	441	IA02-SB0004	475	IA02-SB0003	808	0/2	--	mg/kg
Potassium	4/4	595	05BE00	4750	05BE00	3410	1/4	--	mg/kg
Selenium	3/4	0.59 B	05BE00	1.5	IA02-SB0004	2.33	0/3	391	mg/kg
Silicon	2/2	1650 J	05BE00	1680 J	05BE00	595	2/2	11.3	mg/kg
Sodium	4/4	86.1	IA02-SB0004	14100	05BE00	285	3/4	--	mg/kg
Strontium	2/2	53	05BE00	180	05BE00	75.6	1/2	46924	mg/kg
Thallium	2/4	1.1 B	IA02-SB0004	2.1	IA02-SB0003	2.1	0/2	0.6	mg/kg
Vanadium	4/4	2.7 B	05BE00	64	05BE00	42.8	1/4	547	mg/kg
Zinc	4/4	17.4	05BE00	129	05BE00	110	1/4	23463	mg/kg
Indicator Parameters									
Chloride	1/1	20.6 J	05BE00	20.6 J	05BE00	--	--	--	mg/kg
Fluoride	12/12	0.97	IA02-SB0014	92.1	IA02-SB0004	6.94	5/12	3666	mg/kg
Nitrogen, Ammonia	10/11	1.17	IA02-SB0004	46.2	IA02-SB0004	--	--	--	mg/kg
Sulfate	1/1	2110	05BE00	2110	05BE00	--	--	--	mg/kg
Semivolatile Organics									
Fluoranthene	1/4	2010 J	IA02-SB0003	2010 J	IA02-SB0003	--	--	2294	ug/kg

*USEPA Region 9 PRG

Table 4.2b. Lagoon B: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Volatile Organics									
Benzene	2/4	2.1 J	IA02-SB0003	2.5 J	IA02-SB0004	--	--	0.7	ug/kg
Carbon disulfide	2/4	4.5 J	IA02-SB0004	43.2	IA02-SB0003	--	--	355	ug/kg
Ethylbenzene	1/4	0.62 J	IA02-SB0004	0.62 J	IA02-SB0004	--	--	230	ug/kg
Methylene chloride	1/4	13.7 J	05BE00	13.7 J	05BE00	--	--	8.9	ug/kg
Toluene	4/4	3.4	IA02-SB0003	221	05BE00	--	--	520	ug/kg
Xylenes (total)	2/4	0.96 J	IA02-SB0003	1.2 J	IA02-SB0004	--	--	210	ug/kg
Radiological Parameters									
Actinium-227	3/15	0.204 J	IA02-SB0004	1.56	05BE00	1.76	0/3	--	pCi/g
Actinium-228	13/13	0.63 J	IA02-SB0003	1.22	IA02-SB0014	1.35	0/13	--	pCi/g
Cesium-137	2/15	0.0362	IA02-SB0013	0.0779	IA02-SB0003	0.72	0/2	--	pCi/g
Potassium-40	14/15	18.7	IA02-SB0003	28.7	IA02-SB0014	27.2	2/14	--	pCi/g
Radium-226	15/15	1.08	IA02-SB0014	37.4 J	05BE00	2.97	3/15	--	pCi/g
Radium-228	15/15	0.171	05BE00	1.22	IA02-SB0014	1.48	0/15	--	pCi/g
Thorium-227	2/2	0.294	05BE00	1.56	05BE00	1.76	0/2	11.3	pCi/g
Thorium-228	15/15	0.171	05BE00	1.51	IA02-SB0014	1.6	0/15	--	pCi/g
Thorium-230	15/15	1.16	IA02-SB0013	24.6	05BE00	3.2	1/15	--	pCi/g
Thorium-232	15/15	0.253	05BE00	1.3	IA02-SB0004	1.48	0/15	--	pCi/g
Thorium-234	10/13	1.2 J	IA02-SB0004	4.06 J	IA02-SB0004	3.07	2/10	--	pCi/g
Uranium-233/234	13/13	0.843 J	IA02-SB0013	3.29	IA02-SB0004	2.01	1/13	--	pCi/g
Uranium-234	2/2	6.8	05BE00	13.1	05BE00	2.61	2/2	11.3	pCi/g
Uranium-235	8/15	0.0496	IA02-SB0014	0.527 J	05BE00	0.25	2/8	--	pCi/g
Uranium-238	15/15	0.808 J	IA02-SB0014	14.6	05BE00	2.63	3/15	--	pCi/g

*USEPA Region 9 PRG

Table 4.2c. Lagoon C: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Metals									
Aluminum	6/6	16600	10AX00	80900	IA02-SB0001	23700	4/6	76142	mg/kg
Antimony	2/6	0.26 J	10AX00	3.1 J	08AW00	0.9	1/2	31	mg/kg
Arsenic	26/26	2.3 B	08AW00	98.7	08AW00	24.1	2/26	4	mg/kg
Barium	21/21	24	08AW00	2250	08AW00	209	1/21	5375	mg/kg
Beryllium	46/46	0.31	IA02-SB0016	3840	IA02-SB0001	1.13	23/46	154	mg/kg
Boron	4/4	3.2 J	08AW00	56.8 J	08AW00	13.4	1/4	5497	mg/kg
Cadmium	6/6	0.62 B	10AX00	438	IA02-SB0001	0.98	4/6	37	mg/kg
Calcium	6/6	2800	10AX00	24800	08AW00	55100	0/6	--	mg/kg
Chromium	6/6	23.6	10AX00	111	08AW00	29.6	3/6	210.7	mg/kg
Cobalt	6/6	2 B	08AW00	59.2	08AW00	19.1	1/6	4693	mg/kg
Copper	6/6	20.1 J	10AX00	104 J	08AW00	42	1/6	2905	mg/kg
Iron	6/6	7060 J	08AW00	159000 J	08AW00	38600	1/6	23463	mg/kg
Lead	21/21	9	IA02-SB0002	88.5	IA02-SB0007	23.2	8/21	400	mg/kg
Magnesium	6/6	26.8	08AW00	31700	08AW00	17100	1/6	--	mg/kg
Manganese	6/6	144	08AW00	858	10AX00	2340	0/6	1762	mg/kg
Mercury	6/6	0.03 B	08AW00	0.06 B	08AW00	0.19	0/6	2.3	mg/kg
Molybdenum	3/4	3.2 J	10AX00	16.5 J	08AW00	11.3	1/3	391	mg/kg
Nickel	6/6	33.1	IA02-SB0002	143	08AW00	46.1	1/6	1564	mg/kg
Phosphorus	2/2	243	IA02-SB0001	596	IA02-SB0002	808	0/2	--	mg/kg
Potassium	6/6	808	IA02-SB0001	9920	08AW00	3410	1/6	--	mg/kg
Selenium	5/6	0.37 B	10AX00	5.1 B	08AW00	2.33	1/5	391	mg/kg
Silicon	4/4	680 J	10AX00	3350 J	08AW00	595	4/4	11.3	mg/kg
Silver	3/6	0.13 B	10AX00	1.1 B	08AW00	0.51	1/3	391	mg/kg
Sodium	6/6	952	IA02-SB0002	7990 J	08AW00	285	6/6	--	mg/kg
Strontium	4/4	17.8	10AX00	159	08AW00	75.6	2/4	46924	mg/kg
Thallium	1/6	19.3 B	08AW00	19.3 B	08AW00	2.1	1/1	0.6	mg/kg
Vanadium	6/6	7.3	08AW00	186	08AW00	42.8	1/6	547	mg/kg
Zinc	6/6	71.6	10AX00	1840	IA02-SB0001	110	3/6	23463	mg/kg
Indicator Parameters									
Chloride	2/2	3.92 J	08AW00	10.2 J	10AX00	--	--	--	mg/kg
Fluoride	17/17	0.19 J	10AX00	27.4	IA02-SB0009	6.94	10/17	3666	mg/kg
Nitrate, as N	2/2	1.64 J	08AW00	2.56 J	10AX00	--	--	11.3	mg/kg
Nitrogen, Ammonia	15/15	5.26	IA02-SB0009	38.9	IA02-SB0007	--	--	--	mg/kg
Sulfate	2/2	407	08AW00	526	10AX00	--	--	--	mg/kg

*USEPA Region 9 PRG

Table 4.2c. Lagoon C: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Volatile Organics									
Benzene	2/6	0.92 J	IA02-SB0002	2.1 J	IA02-SB0001	--	--	0.7	ug/kg
Chloroform	1/6	1.9 J	IA02-SB0001	1.9 J	IA02-SB0001	--	--	0.2	ug/kg
Ethylbenzene	3/6	0.34 J	10AX00	0.61 J	10AX00	--	--	230	ug/kg
Methylene chloride	4/6	4 J	10AX00	37.1 B	08AW00	--	--	8.9	ug/kg
Toluene	6/6	0.44 J	08AW00	23.4 J	10AX00	--	--	520	ug/kg
Xylenes (total)	3/6	1.3 J	08AW00	2.1 J	10AX00	--	--	210	ug/kg
Radiological Parameters									
Actinium-227	20/34	0.099 J	IA02-SB0009	1 J	IA02-SB0001	1.76	0/20	--	pCi/g
Actinium-228	14/17	0.804 J	IA02-SB0009	1.35	IA02-SB0007	1.35	0/14	--	pCi/g
Cesium-137	11/34	0.0655	IA02-SB0002	0.447	07AX02	0.72	0/11	--	pCi/g
Potassium-40	34/34	2.93	IA02-SB0001	30.2	IA02-SB0007	27.2	5/34	--	pCi/g
Radium-226	34/34	1.31	IA02-SB0009	32.1 J	08AW00	2.97	14/34	--	pCi/g
Radium-228	33/34	0.227	08AW00	1.35	IA02-SB0007	1.48	0/33	--	pCi/g
Thorium-227	13/17	0.162	10AX00	0.749	07AX02	1.76	0/13	11.3	pCi/g
Thorium-228	34/34	0.227	08AW00	1.4	IA02-SB0006	1.6	0/34	--	pCi/g
Thorium-230	34/34	0.872	10AX00	15.2	IA02-SB0001	3.2	6/34	--	pCi/g
Thorium-232	34/34	0.162 J	IA02-SB0001	1.04	IA02-SB0009	1.48	0/34	--	pCi/g
Thorium-234	10/17	1.03 J	IA02-SB0006	27.6	IA02-SB0001	3.07	3/10	--	pCi/g
Uranium-233/234	17/17	0.962 J	IA02-SB0007	24.2	IA02-SB0001	2.01	5/17	--	pCi/g
Uranium-234	17/17	0.738	10AX00	9.43	08AW00	2.61	4/17	11.3	pCi/g
Uranium-235	24/34	0.0426	10BB01	1.89	IA02-SB0001	0.25	3/24	--	pCi/g
Uranium-238	34/34	0.658	10AX00	27.8	IA02-SB0001	2.63	8/34	--	pCi/g

*USEPA Region 9 PRG

Table 4.2d. Lagoon D: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Metals									
Aluminum	2/2	12100	IA03-SB0001	13300	IA03-SB0001	23700	0/2	76142	mg/kg
Arsenic	6/6	7.3	IA03-SB0001	12.7	IA03-SB0008	24.1	0/6	4	mg/kg
Barium	6/6	89	IA03-SB0008	149	IA03-SB0008	209	0/6	5375	mg/kg
Beryllium	18/18	0.36	IA03-SB0016	26.6 *	IA03-TR0001	1.13	6/18	154	mg/kg
Cadmium	2/2	0.31	IA03-SB0001	0.35	IA03-SB0001	0.98	0/2	37	mg/kg
Calcium	2/2	29400	IA03-SB0001	97000	IA03-SB0001	55100	1/2	--	mg/kg
Chromium	2/2	20.2	IA03-SB0001	20.5	IA03-SB0001	29.6	0/2	210.7	mg/kg
Cobalt	2/2	12.3	IA03-SB0001	14.8	IA03-SB0001	19.1	0/2	4693	mg/kg
Copper	2/2	21.1	IA03-SB0001	24.3	IA03-SB0001	42	0/2	2905	mg/kg
Iron	2/2	22000	IA03-SB0001	25200	IA03-SB0001	38600	0/2	23463	mg/kg
Lead	6/6	10.2	IA03-SB0001	51.9	IA03-SB0008	23.2	2/6	400	mg/kg
Magnesium	2/2	14600	IA03-SB0001	17300	IA03-SB0001	17100	1/2	--	mg/kg
Manganese	2/2	521	IA03-SB0001	622	IA03-SB0001	2340	0/2	1762	mg/kg
Mercury	1/2	0.04	IA03-SB0001	0.04	IA03-SB0001	0.19	0/1	2.3	mg/kg
Nickel	2/2	33.4	IA03-SB0001	33.5	IA03-SB0001	46.1	0/2	1564	mg/kg
Phosphorus	2/2	406 E	IA03-SB0001	457	IA03-SB0001	808	0/2	--	mg/kg
Potassium	2/2	1580	IA03-SB0001	2940	IA03-SB0001	3410	0/2	--	mg/kg
Selenium	2/2	1.2 B	IA03-SB0001	1.6	IA03-SB0001	2.33	0/2	391	mg/kg
Silver	1/2	0.36 B	IA03-SB0001	0.36 B	IA03-SB0001	0.51	0/1	391	mg/kg
Vanadium	2/2	27.5	IA03-SB0001	28.2	IA03-SB0001	42.8	0/2	547	mg/kg
Zinc	2/2	56	IA03-SB0001	86.5	IA03-SB0001	110	0/2	23463	mg/kg
Indicator Parameters									
Fluoride	4/4	1.6	IA03-SB0008	20.1	IA03-SB0008	6.94	1/4	3666	mg/kg
Nitrogen, Ammonia	4/4	0.92 J	IA03-SB0008	21.7	IA03-SB0008	--	--	--	mg/kg
Volatile Organics									
Benzene	2/2	1.1 J	IA03-SB0001	2.3 J	IA03-SB0001	--	--	0.7	ug/kg
Ethylbenzene	1/2	1.3 J	IA03-SB0001	1.3 J	IA03-SB0001	--	--	230	ug/kg
Toluene	2/2	1.9 JB	IA03-SB0001	4.9 B	IA03-SB0001	--	--	520	ug/kg
Xylenes (total)	2/2	0.83 J	IA03-SB0001	2.4 J	IA03-SB0001	--	--	210	ug/kg

*USEPA Region 9 PRG

Table 4.2d. Lagoon D: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Radiological Parameters									
Actinium-228	6/6	0.85 J	IA03-SB0001	1.45	IA03-SB0008	1.35	1/6	--	pCi/g
Cesium-137	1/6	0.0679	IA03-SB0008	0.0679	IA03-SB0008	0.72	0/1	--	pCi/g
Potassium-40	6/6	24.3	IA03-SB0001	28.9	IA03-SB0008	27.2	1/6	--	pCi/g
Radium-226	6/6	1.31	IA03-SB0008	1.76	IA03-SB0001	2.97	0/6	--	pCi/g
Radium-228	6/6	0.85 J	IA03-SB0001	1.45	IA03-SB0008	1.48	0/6	--	pCi/g
Thorium-228	6/6	0.945 J	IA03-SB0008	1.44	IA03-SB0008	1.6	0/6	--	pCi/g
Thorium-230	6/6	1.59	IA03-SB0008	2.1	IA03-SB0008	3.2	0/6	--	pCi/g
Thorium-232	6/6	0.617 J	IA03-SB0001	1.13	IA03-SB0008	1.48	0/6	--	pCi/g
Thorium-234	5/6	0.542 J	IA03-SB0008	2.2 J	IA03-SB0001	3.07	0/5	--	pCi/g
Uranium-233/234	6/6	0.905 J	IA03-SB0008	1.35	IA03-SB0008	2.01	0/6	--	pCi/g
Uranium-235	2/6	0.0728	IA03-SB0001	0.214 J	IA03-SB0008	0.25	0/2	--	pCi/g
Uranium-238	6/6	0.833 J	IA03-SB0008	1.6	IA03-SB0008	2.63	0/6	--	pCi/g

*USEPA Region 9 PRG

Table 4.3. Former Petroleum Buildings and UST Areas: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Metals									
Aluminum	4/4	1730	IA07-SB0001	14100	IA07-SB0002	23700	0/4	76142	mg/kg
Arsenic	4/4	1.3	IA07-SB0001	7.4 B	05EI00	24.1	0/4	4	mg/kg
Barium	3/3	25.7 N	IA07-SB0001	216	IA07-SB0002	209	1/3	5375	mg/kg
Beryllium	16/16	0.25	IA07-SB0002	27.2	05EI00	1.13	11/16	154	mg/kg
Boron	1/1	11.4 B	05EI00	11.4 B	05EI00	13.4	0/1	5497	mg/kg
Cadmium	2/3	0.35	IA07-SB0002	0.51 B	05EI00	0.98	0/2	37	mg/kg
Calcium	3/3	26900	IA07-SB0001	94900	IA07-SB0002	55100	2/3	--	mg/kg
Chromium	3/3	5.2 *	IA07-SB0001	22.2	IA07-SB0002	29.6	0/3	210.7	mg/kg
Cobalt	3/3	1.2	IA07-SB0001	10	05EI00	19.1	0/3	4693	mg/kg
Copper	3/3	3.7 *	IA07-SB0001	23.5 J	05EI00	42	0/3	2905	mg/kg
Iron	3/3	4230	IA07-SB0001	24700	IA07-SB0002	38600	0/3	23463	mg/kg
Lead	4/4	10.1 J	IA07-SB0002	72.8	05EI00	23.2	2/4	400	mg/kg
Magnesium	4/4	4200	IA07-SB0001	42400 J	05EI00	17100	1/4	--	mg/kg
Manganese	3/3	99 *	IA07-SB0001	439	05EI00	2340	0/3	1762	mg/kg
Mercury	1/3	0.04	05EI00	0.04	05EI00	0.19	0/1	2.3	mg/kg
Molybdenum	1/1	4.2 B	05EI00	4.2 B	05EI00	11.3	0/1	391	mg/kg
Nickel	3/3	4.3 *	IA07-SB0001	29.7	IA07-SB0002	46.1	0/3	1564	mg/kg
Phosphorus	2/2	221	IA07-SB0001	484	IA07-SB0002	808	0/2	--	mg/kg
Potassium	3/3	235	IA07-SB0001	3200	IA07-SB0002	3410	0/3	--	mg/kg
Silicon	1/1	1880 J	05EI00	1880 J	05EI00	595	1/1	11.3	mg/kg
Silver	1/3	0.2 B	05EI00	0.2 B	05EI00	0.51	0/1	391	mg/kg
Sodium	2/3	69.2 N	IA07-SB0001	175	IA07-SB0002	285	0/2	--	mg/kg
Strontium	1/1	122	05EI00	122	05EI00	75.6	1/1	46924	mg/kg
Thallium	2/3	0.84 B	05EI00	1.2 B	IA07-SB0002	2.1	0/2	0.6	mg/kg
Vanadium	3/3	6.3	IA07-SB0001	28.9	IA07-SB0002	42.8	0/3	547	mg/kg
Zinc	3/3	12.7 *	IA07-SB0001	63.8	IA07-SB0002	110	0/3	23463	mg/kg
Semivolatile Organics									
2-Methylnaphthalene	2/19	887	05EI00	4100	IA04-SB0030	--	--	230.9	ug/kg
Acenaphthene	1/19	377 J	05EI00	377 J	05EI00	--	--	3682	ug/kg
Chrysene	1/19	31.5 J	IA04-SB0037	31.5 J	IA04-SB0037	--	--	62.1	ug/kg
Diesel Range Organics	2/2	2.3 B	IA07-SB0002	5.3 B	IA07-SB0001	--	--	--	mg/kg
Fluoranthene	1/19	565	05EI00	565	05EI00	--	--	2294	ug/kg
Phenanthrene	1/19	1330	05EI00	1330	05EI00	--	--	230.9	ug/kg
Pyrene	2/19	44.7 J	IA04-SB0037	907	05EI00	--	--	2309	ug/kg

*USEPA Region 9 PRG

Table 4.3. Former Petroleum Buildings and UST Areas: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Volatile Organics									
Acetone	2/5	36.4	IA04-SB0030	493 J	05EI00	--	--	1570	ug/kg
Benzene	2/5	1.1 J	IA07-SB0002	4.4 J	IA07-SB0001	--	--	0.7	ug/kg
Carbon disulfide	3/5	1.9 J	IA04-SB0030	26	IA07-SB0002	--	--	355	ug/kg
Ethylbenzene	2/5	3.3 J	IA07-SB0001	14.4 J	05EI00	--	--	230	ug/kg
Methylene chloride	1/5	6 J	05EI00	6 J	05EI00	--	--	8.9	ug/kg
Toluene	3/5	1.2 J	IA04-SB0030	586 J	05EI00	--	--	520	ug/kg
Vinyl chloride	1/5	3.8	IA04-SB0036	3.8	IA04-SB0036	--	--	--	ug/kg
Xylenes (total)	4/5	1.1 J	IA07-SB0002	22.3	IA04-SB0030	--	--	210	ug/kg
cis-1,2-Dichloroethene	1/1	3.9 J	IA04-SB0036	3.9 J	IA04-SB0036	--	--	11.3	ug/kg
Radiological Parameters									
Actinium-228	2/2	0.338 J	IA07-SB0001	0.735 J	IA07-SB0002	1.35	0/2	--	pCi/g
Cesium-137	1/3	0.0783	IA07-SB0001	0.0783	IA07-SB0001	0.72	0/1	--	pCi/g
Potassium-40	3/3	11.1	IA07-SB0001	22.7	IA07-SB0002	27.2	0/3	--	pCi/g
Radium-226	3/3	0.551 J	IA07-SB0001	1.28	IA07-SB0002	2.97	0/3	--	pCi/g
Radium-228	3/3	0.338 J	IA07-SB0001	0.735 J	IA07-SB0002	1.48	0/3	--	pCi/g
Thorium-228	3/3	0.316 J	IA07-SB0001	0.655 J	IA07-SB0002	1.6	0/3	--	pCi/g
Thorium-230	3/3	0.588	05EI00	0.889 J	IA07-SB0002	3.2	0/3	--	pCi/g
Thorium-232	3/3	0.325 J	IA07-SB0001	0.714 J	IA07-SB0002	1.48	0/3	--	pCi/g
Thorium-234	1/2	0.524 J	IA07-SB0001	0.524 J	IA07-SB0001	3.07	0/1	--	pCi/g
Uranium-233/234	2/2	0.856 J	IA07-SB0002	1.16	IA07-SB0001	2.01	0/2	--	pCi/g
Uranium-234	1/1	0.35	05EI00	0.35	05EI00	2.61	0/1	11.3	pCi/g
Uranium-235	1/3	0.332 J	IA07-SB0001	0.332 J	IA07-SB0001	0.25	1/1	--	pCi/g
Uranium-238	3/3	0.492 J	IA07-SB0002	0.932 J	IA07-SB0001	2.63	0/3	--	pCi/g
Wet Chemistry									
Total Rec. Petro. Hydrocarbons	11/16	12.1 J	IA04-SB0029	6190	IA04-SB0030	--	--	--	mg/kg

*USEPA Region 9 PRG

Table 4.4. Electrical Transformer Area: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Metals									
Beryllium	14/14	0.63	IA04-SB0022	55.6	IA04-SB0025	1.13	9/14	154	mg/kg
Semivolatile Organics									
Acenaphthene	1/6	82.3 J	IA04-SB0033	82.3 J	IA04-SB0033	--	--	3682	ug/kg
Acenaphthylene	2/6	90.8 J	IA04-SB0033	91.9 J	IA04-SB0034	--	--	230.9	ug/kg
Anthracene	2/6	179 J	IA04-SB0034	734	IA04-SB0033	--	--	21896	ug/kg
Benzo(a)anthracene	2/6	685	IA04-SB0034	2210	IA04-SB0033	--	--	0.6	ug/kg
Benzo(a)pyrene	2/6	1450	IA04-SB0034	1790	IA04-SB0033	--	--	0.1	ug/kg
Benzo(b)fluoranthene	2/6	2430	IA04-SB0033	2600	IA04-SB0034	--	--	0.6	ug/kg
Benzo(ghi)perylene	2/6	865	IA04-SB0033	1050	IA04-SB0034	--	--	230.9	ug/kg
Benzo(k)fluoranthene	2/6	1040	IA04-SB0034	1650	IA04-SB0033	--	--	6.2	ug/kg
Chrysene	2/6	1050	IA04-SB0034	1830	IA04-SB0033	--	--	62.1	ug/kg
Dibenz(a,h)anthracene	2/6	428	IA04-SB0034	458	IA04-SB0033	--	--	0.1	ug/kg
Fluoranthene	2/6	530	IA04-SB0034	6260 D	IA04-SB0033	--	--	2294	ug/kg
Fluorene	1/6	160 J	IA04-SB0033	160 J	IA04-SB0033	--	--	2644	ug/kg
Indeno(1,2,3-c,d)pyrene	2/6	891	IA04-SB0034	893	IA04-SB0033	--	--	0.6	ug/kg
Phenanthrene	2/6	189 J	IA04-SB0034	2290	IA04-SB0033	--	--	230.9	ug/kg
Pyrene	2/6	633	IA04-SB0034	4000	IA04-SB0033	--	--	2309	ug/kg
bis(2-ethylhexyl)phthalate	2/6	459	IA04-SB0033	2360	IA04-SB0034	--	--	34.7	ug/kg
Volatile Organics									
Benzene	1/1	0.61 J	IA04-SB0034	0.61 J	IA04-SB0034	--	--	0.7	ug/kg
Carbon disulfide	1/1	4.1 J	IA04-SB0034	4.1 J	IA04-SB0034	--	--	355	ug/kg
Toluene	1/1	0.64999	IA04-SB0034	0.64999	IA04-SB0034	--	--	520	ug/kg
PCBs									
Aroclor-1016	1/10	14.1 P	IA04-SB0024	14.1 P	IA04-SB0024	--	--	4	ug/kg
Aroclor-1221	1/10	290 EP	IA04-SB0024	290 EP	IA04-SB0024	--	--	0.2	ug/kg
Aroclor-1248	2/10	15.4 P	IA04-SB0025	15.6 P	IA04-SB0024	--	--	0.2	ug/kg
Aroclor-1254	6/10	9.8	IA04-SB0033	10100	IA04-SB0033	--	--	0.2	ug/kg
Aroclor-1260	3/10	13.3	IA04-SB0024	23.1 P	IA04-SB0022	--	--	0.2	ug/kg
Wet Chemistry									
Total Rec. Petro. Hydrocarbons	4/6	11.5 J	IA04-SB0034	418	IA04-SB0033	--	--	--	mg/kg

*USEAP Region 9 PRG

Table 4.5a. Bare Spot: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Metals									
Aluminum	4/4	13200	06FD00	25000	IA07-SB0003	23700	1/4	76142	mg/kg
Antimony	1/4	5.1 J	06FD00	5.1 J	06FD00	0.9	1/1	31	mg/kg
Arsenic	10/10	7.9	IA07-SB0005	21.8	IA07-SB0004	24.1	0/10	4	mg/kg
Barium	10/10	55.1 N	IA07-SB0005	2440 J	06FD00	209	2/10	5375	mg/kg
Beryllium	20/20	0.66	IA07-SB0005	2510	06FD00	1.13	16/20	154	mg/kg
Boron	1/1	43.1	06FD00	43.1	06FD00	13.4	1/1	5497	mg/kg
Cadmium	1/4	3.2	06FD00	3.2	06FD00	0.98	1/1	37	mg/kg
Calcium	4/4	5520	IA07-SB0005	68300	06FD00	55100	1/4	--	mg/kg
Chromium	4/4	30.9 *	IA07-SB0004	91.5 J	06FD00	29.6	4/4	210.7	mg/kg
Cobalt	4/4	15.4	06FD00	29.4	IA07-SB0004	19.1	1/4	4693	mg/kg
Copper	4/4	23.4 *	IA07-SB0004	133 J	06FD00	42	1/4	2905	mg/kg
Iron	4/4	33500	IA07-SB0003	118000 J	06FD00	38600	3/4	23463	mg/kg
Lead	10/10	10.1 J	IA07-SB0003	9380	06FD00	23.2	4/10	400	mg/kg
Magnesium	4/4	6980	IA07-SB0004	34800	06FD00	17100	1/4	--	mg/kg
Manganese	4/4	751	06FD00	2030 *	IA07-SB0004	2340	0/4	1762	mg/kg
Mercury	4/4	0.03 B	IA07-SB0005	0.22	06FD00	0.19	1/4	2.3	mg/kg
Molybdenum	1/1	9.2	06FD00	9.2	06FD00	11.3	0/1	391	mg/kg
Nickel	4/4	41.2 *	IA07-SB0003	160	06FD00	46.1	2/4	1564	mg/kg
Phosphorus	3/3	525 B	IA07-SB0005	584	IA07-SB0003	808	0/3	--	mg/kg
Potassium	4/4	3450	IA07-SB0005	4860	IA07-SB0003	3410	4/4	--	mg/kg
Selenium	1/4	1.8 B	IA07-SB0005	1.8 B	IA07-SB0005	2.33	0/1	391	mg/kg
Silicon	1/1	4580 J	06FD00	4580 J	06FD00	595	1/1	11.3	mg/kg
Silver	1/4	0.7 B	06FD00	0.7 B	06FD00	0.51	1/1	391	mg/kg
Sodium	4/4	98.9 B	IA07-SB0005	564	06FD00	285	1/4	--	mg/kg
Strontium	1/1	141	06FD00	141	06FD00	75.6	1/1	46924	mg/kg
Thallium	4/4	2 B	IA07-SB0005	4.8	IA07-SB0003	2.1	3/4	0.6	mg/kg
Vanadium	4/4	28.5	06FD00	55.1	IA07-SB0004	42.8	3/4	547	mg/kg
Zinc	4/4	85.5 B	IA07-SB0005	295	06FD00	110	1/4	23463	mg/kg
Indicator Parameters									
Fluoride	7/7	15.6	IA07-SB0005	302	IA07-SB0003	6.94	7/7	3666	mg/kg
Nitrate, as N	1/1	9.22 J	06FD00	9.22 J	06FD00	--	--	11.3	mg/kg
Nitrogen, Ammonia	6/6	20.4	IA07-SB0005	765	IA07-SB0003	--	--	--	mg/kg
Phosphorus	1/1	0.391 J	06FD00	0.391 J	06FD00	808	0/1	--	mg/kg
Sulfate	1/1	124	06FD00	124	06FD00	--	--	--	mg/kg

*USEPA Region 9 PRG

Table 4.5a. Bare Spot: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Semivolatile Organics									
Benzo(a)anthracene	1/4	73.3 J	IA07-SB0003	73.3 J	IA07-SB0003	--	--	0.6	ug/kg
Benzo(k)fluoranthene	1/4	94.1 J	IA07-SB0003	94.1 J	IA07-SB0003	--	--	6.2	ug/kg
Chrysene	1/4	66.7 J	IA07-SB0003	66.7 J	IA07-SB0003	--	--	62.1	ug/kg
Fluoranthene	1/4	181 J	IA07-SB0003	181 J	IA07-SB0003	--	--	2294	ug/kg
Phenanthrene	1/4	129 J	IA07-SB0003	129 J	IA07-SB0003	--	--	230.9	ug/kg
Pyrene	1/4	147 J	IA07-SB0003	147 J	IA07-SB0003	--	--	2309	ug/kg
Volatile Organics									
Acetone	1/3	9 J	IA07-SB0005	9 J	IA07-SB0005	--	--	1570	ug/kg
Benzene	3/3	1.3 J	IA07-SB0005	3.6 J	IA07-SB0004	--	--	0.7	ug/kg
Carbon disulfide	3/3	15	IA07-SB0004	34.2	IA07-SB0003	--	--	355	ug/kg
Ethylbenzene	1/3	3.1 J	IA07-SB0004	3.1 J	IA07-SB0004	--	--	230	ug/kg
Methyl Pentane Isomer	1/1	22.4 J	IA07-SB0004	22.4 J	IA07-SB0004	--	--	--	ug/kg
Toluene	3/3	1.8 J	IA07-SB0003	9.6	IA07-SB0004	--	--	520	ug/kg
Xylenes (total)	2/3	0.91 J	IA07-SB0003	5.3 J	IA07-SB0004	--	--	210	ug/kg
Radiological Parameters									
Actinium-227	8/10	0.355 J	IA07-SB0005	0.879	06FD00	1.76	0/8	--	pCi/g
Actinium-228	9/9	0.857 J	IA07-SB0003	1.17	IA07-SB0003	1.35	0/9	--	pCi/g
Cesium-137	1/10	0.827	06FD00	0.827	06FD00	0.72	1/1	--	pCi/g
Potassium-40	10/10	10.9	06FD00	26.8	IA07-SB0005	27.2	0/10	--	pCi/g
Radium-226	10/10	1.13	IA07-SB0004	6.96 J	06FD00	2.97	1/10	--	pCi/g
Radium-228	10/10	0.636	06FD00	1.17	IA07-SB0003	1.48	0/10	--	pCi/g
Thorium-227	1/1	0.879	06FD00	0.879	06FD00	1.76	0/1	11.3	pCi/g
Thorium-228	10/10	0.636	06FD00	1.63	IA07-SB0005	1.6	1/10	--	pCi/g
Thorium-230	10/10	1.82 J	IA07-SB0004	30.6	06FD00	3.2	1/10	--	pCi/g
Thorium-232	10/10	0.53	06FD00	1.44	IA07-SB0003	1.48	0/10	--	pCi/g
Thorium-234	5/9	1.49 J	IA07-SB0003	2.44 J	IA07-SB0005	3.07	0/5	--	pCi/g
Uranium-233/234	9/9	1.84	IA07-SB0003	3.14	IA07-SB0005	2.01	4/9	--	pCi/g
Uranium-234	1/1	9.27	06FD00	9.27	06FD00	2.61	1/1	11.3	pCi/g
Uranium-235	7/10	0.167 J	IA07-SB0004	0.429	06FD00	0.25	3/7	--	pCi/g
Uranium-238	10/10	1.86	IA07-SB0003	8.5	06FD00	2.63	1/10	--	pCi/g

*USEPA Region 9 PRG

Table 4.5b. Stressed Vegetation: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Metals									
Aluminum	3/3	13700 J	IA07-SB0006	17200 J	IA07-SB0007	23700	0/3	76142	mg/kg
Antimony	1/3	0.3 J	IA07-SB0008	0.3 J	IA07-SB0008	0.9	0/1	31	mg/kg
Arsenic	9/9	4.3	IA07-SB0008	15.2	IA07-SB0007	24.1	0/9	4	mg/kg
Barium	9/9	62	IA07-SB0008	115	IA07-SB0008	209	0/9	5375	mg/kg
Beryllium	15/15	0.61	IA07-SB0007	70.1	IA07-SB0007	1.13	9/15	154	mg/kg
Cadmium	3/3	0.24	IA07-SB0006	0.51	IA07-SB0008	0.98	0/3	37	mg/kg
Calcium	3/3	4170	IA07-SB0008	5260	IA07-SB0006	55100	0/3	--	mg/kg
Chromium	3/3	20.3	IA07-SB0006	23.6	IA07-SB0007	29.6	0/3	210.7	mg/kg
Cobalt	3/3	7.7	IA07-SB0006	12.9	IA07-SB0008	19.1	0/3	4693	mg/kg
Copper	3/3	9.6	IA07-SB0006	20.6	IA07-SB0008	42	0/3	2905	mg/kg
Iron	3/3	22100	IA07-SB0006	28700	IA07-SB0007	38600	0/3	23463	mg/kg
Lead	9/9	7.4 J	IA07-SB0008	19.7	IA07-SB0006	23.2	0/9	400	mg/kg
Magnesium	3/3	5260	IA07-SB0006	6140	IA07-SB0007	17100	0/3	--	mg/kg
Manganese	3/3	194 J	IA07-SB0006	677 J	IA07-SB0008	2340	0/3	1762	mg/kg
Mercury	3/3	0.03 B	IA07-SB0006	0.04 B	IA07-SB0008	0.19	0/3	2.3	mg/kg
Nickel	3/3	22.6	IA07-SB0006	34.9	IA07-SB0008	46.1	0/3	1564	mg/kg
Phosphorus	3/3	409	IA07-SB0006	450	IA07-SB0008	808	0/3	--	mg/kg
Potassium	3/3	1450	IA07-SB0006	1710	IA07-SB0007	3410	0/3	--	mg/kg
Sodium	3/3	53.5 J	IA07-SB0008	120 J	IA07-SB0007	285	0/3	--	mg/kg
Vanadium	3/3	27.5	IA07-SB0006	34.5	IA07-SB0007	42.8	0/3	547	mg/kg
Zinc	3/3	72.1	IA07-SB0006	84	IA07-SB0007	110	0/3	23463	mg/kg
Indicator Parameters									
Fluoride	6/6	4.04	IA07-SB0008	40.4	IA07-SB0007	6.94	4/6	3666	mg/kg
Nitrogen, Ammonia	6/6	1.62	IA07-SB0008	6.13	IA07-SB0006	--	--	--	mg/kg
Volatile Organics									
Benzene	3/3	0.69 J	IA07-SB0007	1 J	IA07-SB0008	--	--	0.7	ug/kg
Carbon disulfide	3/3	14.5	IA07-SB0007	61.5	IA07-SB0008	--	--	355	ug/kg

*USEPA Region 9 PRG

Table 4.5b. Stressed Vegetation: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Radiological Parameters									
Actinium-227	3/11	0.37	05FS00	1.07	05FR01	1.76	0/3	--	pCi/g
Actinium-228	9/9	0.787 J	IA07-SB0006	1.18	IA07-SB0008	1.35	0/9	--	pCi/g
Cesium-137	3/12	0.0497	IA07-SB0008	0.39	05FR01	0.72	0/3	--	pCi/g
Potassium-40	12/12	19.7	IA07-SB0006	27.6	IA07-SB0006	27.2	1/12	--	pCi/g
Radium-226	12/12	1.07	IA07-SB0006	21 J	05FR01	2.97	3/12	--	pCi/g
Radium-228	12/12	0.5	05FR01	1.18	IA07-SB0008	1.48	0/12	--	pCi/g
Thorium-227	3/3	0.37	05FS00	1.07	05FR01	1.76	0/3	11.3	pCi/g
Thorium-228	12/12	0.5	05FR01	1.56 J	IA07-SB0008	1.6	0/12	--	pCi/g
Thorium-230	12/12	1.51 J	IA07-SB0006	19.2	05FR01	3.2	3/12	--	pCi/g
Thorium-232	12/12	0.528	05FL02	1.27 J	IA07-SB0007	1.48	0/12	--	pCi/g
Thorium-234	4/9	0.925 J	IA07-SB0007	1.82 J	IA07-SB0007	3.07	0/4	--	pCi/g
Uranium-233/234	9/9	0.707 J	IA07-SB0008	1.48 J	IA07-SB0007	2.01	0/9	--	pCi/g
Uranium-234	3/3	14.2	05FS00	25.8	05FL02	2.61	3/3	11.3	pCi/g
Uranium-235	3/12	0.633	05FS00	1.02	05FL02	0.25	3/3	--	pCi/g
Uranium-238	12/12	0.738 J	IA07-SB0006	26.6	05FR01	2.63	3/12	--	pCi/g

*USEPA Region 9 PRG

Table 4.6. Debris Piles and Filter Bed Area: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Metals									
Aluminum	15/15	4940	IA05-SB0002	19200	08FI01	23700	0/15	76142	mg/kg
Antimony	4/8	0.27 J	IA05-SB0003	0.62 BN	IA05-SB0001	0.9	0/4	31	mg/kg
Arsenic	39/39	2.5	IA05-SB0011	18.1	IA05-SB0010	24.1	0/39	4	mg/kg
Barium	34/34	48.6	IA05-SB0002	322	IA05-SB0005	209	5/34	5375	mg/kg
Beryllium	65/65	0.07 B	IA05-SB0001	13300	IA05-SB0009	1.13	52/65	154	mg/kg
Boron	3/3	9.8 B	08EX00	13.5	08FE00	13.4	1/3	5497	mg/kg
Cadmium	8/10	0.23	IA05-SB0002	14.5	IA05-SB0004	0.98	6/8	37	mg/kg
Calcium	10/10	18200	08FE00	206000	IA05-SB0004	55100	6/10	--	mg/kg
Chromium	10/10	8	IA05-SB0002	42.2	IA05-SB0004	29.6	2/10	210.7	mg/kg
Cobalt	10/10	3	IA05-SB0002	19.3	IA05-SB0009	19.1	1/10	4693	mg/kg
Copper	10/10	8	IA05-SB0002	57.6	IA05-SB0009	42	3/10	2905	mg/kg
Iron	10/10	7990	IA05-SB0002	34900	IA05-SB0009	38600	0/10	23463	mg/kg
Lead	41/41	6.9 B	08EX00	2670 N*	IA05-SB0017	23.2	18/41	400	mg/kg
Magnesium	15/15	5930	08FI01	53700	BH0015	17100	3/15	--	mg/kg
Manganese	10/10	169 N	IA05-SB0002	2670	IA05-SB0009	2340	1/10	1762	mg/kg
Mercury	8/10	0.03 B	IA05-SB0001	1.8	BH0015	0.19	4/8	2.3	mg/kg
Molybdenum	3/3	1.3 J	08FE00	2.7 J	BH0015	11.3	0/3	391	mg/kg
Nickel	10/10	8.9	IA05-SB0002	63.6	IA05-SB0009	46.1	2/10	1564	mg/kg
Phosphorus	7/7	197	IA05-SB0002	866	IA05-SB0003	808	1/7	--	mg/kg
Potassium	10/10	978	IA05-SB0002	3770	IA05-SB0009	3410	2/10	--	mg/kg
Selenium	8/10	0.35 B	08EX00	2.7 B	IA05-SB0009	2.33	1/8	391	mg/kg
Silicon	3/3	865 J	08EX00	1460 J	08FE00	595	3/3	11.3	mg/kg
Silver	1/10	0.08 B	08EX00	0.08 B	08EX00	0.51	0/1	391	mg/kg
Sodium	10/10	60.3 J	IA05-SB0003	447 J	08EX00	285	1/10	--	mg/kg
Strontium	3/3	25.3	08EX00	1180	BH0015	75.6	2/3	46924	mg/kg
Thallium	6/10	0.44 B	IA05-SB0005	2.2 B	IA05-SB0004	2.1	1/6	0.6	mg/kg
Vanadium	10/10	12.1	IA05-SB0002	34.4	IA05-SB0006	42.8	0/10	547	mg/kg
Zinc	10/10	30.5 *	IA05-SB0002	539	BH0015	110	6/10	23463	mg/kg
Indicator Parameters									
Fluoride	25/25	0.97	IA05-SB0014	126	IA05-SB0017	6.94	17/25	3666	mg/kg
Nitrate, as N	1/1	2.98	08FE00	2.98	08FE00	--	--	11.3	mg/kg
Nitrogen, Ammonia	24/24	3.29	IA05-SB0012	64	IA05-SB0017	--	--	--	mg/kg

*USEPA Region 9 PRG

Table 4.6. Debris Piles and Filter Bed Area: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Semivolatile Organics									
Anthracene	2/10	975 J	IA05-SB0005	1100 J	BH0015	--	--	21896	ug/kg
Benzo(a)anthracene	5/10	499 J	IA05-SB0003	3170	BH0015	--	--	0.6	ug/kg
Benzo(a)pyrene	5/10	572 J	IA05-SB0003	3230	BH0015	--	--	0.1	ug/kg
Benzo(b)fluoranthene	5/10	1000	IA05-SB0003	4050	BH0015	--	--	0.6	ug/kg
Benzo(ghi)perylene	3/10	714 J	IA05-SB0002	1680	BH0015	--	--	230.9	ug/kg
Benzo(k)fluoranthene	2/10	944 J	IA05-SB0002	1630	BH0015	--	--	6.2	ug/kg
Chrysene	5/10	679 J	IA05-SB0003	2890 J	BH0015	--	--	62.1	ug/kg
Fluoranthene	5/10	1480	IA05-SB0003	6980	BH0015	--	--	2294	ug/kg
Indeno(1,2,3-c,d)pyrene	4/10	421 J	IA05-SB0003	1980 J	BH0015	--	--	0.6	ug/kg
Phenanthrene	5/10	801	IA05-SB0003	3870	BH0015	--	--	230.9	ug/kg
Pyrene	5/10	1050	IA05-SB0003	6920	BH0015	--	--	2309	ug/kg
Volatile Organics									
Benzene	5/10	1.5 J	IA05-SB0006	3.5 J	IA05-SB0003	--	--	0.7	ug/kg
Carbon disulfide	1/10	16.9	IA05-SB0001	16.9	IA05-SB0001	--	--	355	ug/kg
Ethylbenzene	9/10	0.52 J	IA05-SB0006	3.8 J	08EX00	--	--	230	ug/kg
Methylene chloride	4/10	0.55 BJ	IA05-SB0009	4.7 J	BH0015	--	--	8.9	ug/kg
Toluene	9/10	1.3 J	IA05-SB0006	79.3 J	08EX00	--	--	520	ug/kg
Xylenes (total)	9/10	1.1 J	IA05-SB0006	16.4 J	08EX00	--	--	210	ug/kg
Radiological Parameters									
Actinium-227	13/37	0.13 J	IA05-SB0015	3.37 J	IA05-SB0009	1.76	1/13	--	pCi/g
Actinium-228	31/31	0.314 J	IA05-SB0002	1.6	IA05-SB0009	1.35	2/31	--	pCi/g
Cesium-137	18/37	0.0456	IA05-SB0012	0.621	08EI01	0.72	0/18	--	pCi/g
Potassium-40	37/37	6.48	IA05-SB0004	27.7	IA05-SB0010	27.2	2/37	--	pCi/g
Radium-226	37/37	0.504 J	IA05-SB0002	41.4	IA05-SB0009	2.97	5/37	--	pCi/g
Radium-228	37/37	0.314 J	IA05-SB0002	1.6	IA05-SB0009	1.48	1/37	--	pCi/g
Thorium-227	4/6	0.167	08EH01	1.45	08ED01	1.76	0/4	11.3	pCi/g
Thorium-228	37/37	0.483	08EI01	1.56 J	IA05-SB0001	1.6	0/37	--	pCi/g
Thorium-230	37/37	0.727 J	IA05-SB0002	88.5	IA05-SB0009	3.2	4/37	--	pCi/g
Thorium-232	36/37	0.405 J	IA05-SB0011	1.19	IA05-SB0012	1.48	0/36	--	pCi/g
Thorium-234	14/31	1.19 J	IA05-SB0006	25.3	IA05-SB0009	3.07	3/14	--	pCi/g
Uranium-233/234	31/31	0.69 J	IA05-SB0004	30.3 J	IA05-SB0009	2.01	4/31	--	pCi/g
Uranium-234	6/6	0.475	08FE00	10.2	08ED01	2.61	2/6	11.3	pCi/g
Uranium-235	18/37	0.0425	08FE00	2.88 J	IA05-SB0009	0.25	3/18	--	pCi/g
Uranium-238	37/37	0.396	08EX00	28.7 J	IA05-SB0009	2.63	4/37	--	pCi/g

*USEPA Region 9 PRG

Table 4.7. Existing Buildings and Associated Areas: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Metals									
Aluminum	8/8	8660	IA04-SB0021	22100	IA08-SB0001	23700	0/8	76142	mg/kg
Antimony	4/8	0.31 BN	IA08-TR0001	0.71 B	IA08-SB0002	0.9	0/4	31	mg/kg
Arsenic	24/26	1.6	IA04-SB0028	13.8	IA04-SB0028	24.1	0/24	4	mg/kg
Barium	26/26	1.6	IA04-SB0026	563	IA04-SB0028	209	1/26	5375	mg/kg
Beryllium	45/45	0.47	IA04-SB0027	57.1	IA04-SB0018	1.13	15/45	154	mg/kg
Cadmium	6/7	0.28	IA08-SB0002	1.6	IA04-SB0021	0.98	2/6	37	mg/kg
Calcium	7/7	3610	IA04-SB0017	132000	IA04-SB0021	55100	2/7	--	mg/kg
Chromium	8/8	13.4	IA08-TR0001	27	IA08-SB0001	29.6	0/8	210.7	mg/kg
Cobalt	8/8	4.5	IA04-SB0021	10.3	IA08-SB0001	19.1	0/8	4693	mg/kg
Copper	8/8	15.4	IA04-SB0017	41.4	IA04-SB0019	42	0/8	2905	mg/kg
Iron	8/8	12500	IA08-TR0001	30500	IA08-SB0001	38600	0/8	23463	mg/kg
Lead	26/26	6.5	IA04-SB0026	106	IA04-SB0021	23.2	9/26	400	mg/kg
Magnesium	7/7	3940	IA08-TR0001	77500	IA04-SB0021	17100	3/7	--	mg/kg
Manganese	8/8	96.1 N*	IA08-TR0001	324	IA04-SB0020	2340	0/8	1762	mg/kg
Mercury	5/8	0.02 B	IA04-SB0019	2.7	IA08-TR0001	0.19	1/5	2.3	mg/kg
Nickel	8/8	15.8	IA04-SB0021	27.5	IA04-SB0019	46.1	0/8	1564	mg/kg
Phosphorus	8/8	290	IA04-SB0021	1160 *	IA08-TR0001	808	1/8	--	mg/kg
Potassium	8/8	1640	IA04-SB0017	3860	IA08-SB0001	3410	1/8	--	mg/kg
Selenium	8/8	0.97 B	IA04-SB0021	2.1	IA04-SB0019	2.33	0/8	391	mg/kg
Silver	4/8	0.22 B	IA08-TR0001	0.5 B	IA04-SB0021	0.51	0/4	391	mg/kg
Sodium	6/6	58.9	IA04-SB0019	340 E	IA08-TR0001	285	1/6	--	mg/kg
Thallium	4/8	0.98 B	IA08-SB0002	1.7 B	IA04-SB0018	2.1	0/4	0.6	mg/kg
Vanadium	8/8	18.2 N	IA08-TR0001	51.1	IA08-SB0001	42.8	1/8	547	mg/kg
Zinc	8/8	63.3	IA04-SB0020	152 *	IA08-TR0001	110	2/8	23463	mg/kg
Indicator Parameters									
Fluoride	18/18	0.75	IA04-SB0026	8.04	IA08-SB0004	6.94	1/18	3666	mg/kg
Nitrogen, Ammonia	16/18	3.17	IA04-SB0027	40.4	IA08-SB0005	--	--	--	mg/kg
Semivolatile Organics									
Anthracene	2/8	1910	IA04-SB0018	249000 J	IA04-SB0021	--	--	21896	ug/kg
Benzo(a)anthracene	2/8	3730	IA04-SB0018	236000 J	IA04-SB0021	--	--	0.6	ug/kg
Benzo(a)pyrene	2/8	3350	IA04-SB0018	195000 J	IA04-SB0021	--	--	0.1	ug/kg
Benzo(b)fluoranthene	2/8	4740	IA04-SB0018	299000 J	IA04-SB0021	--	--	0.6	ug/kg
Benzo(ghi)perylene	1/8	1810	IA04-SB0018	1810	IA04-SB0018	--	--	230.9	ug/kg
Benzo(k)fluoranthene	1/8	1750	IA04-SB0018	1750	IA04-SB0018	--	--	6.2	ug/kg
Chrysene	2/8	4220	IA04-SB0018	237000 J	IA04-SB0021	--	--	62.1	ug/kg
Fluoranthene	3/8	197 J	IA04-SB0019	762000	IA04-SB0021	--	--	2294	ug/kg
Fluorene	2/8	901 J	IA04-SB0018	216000 J	IA04-SB0021	--	--	2644	ug/kg

*USEPA Region 9 PRG

Table 4.7. Existing Buildings and Associated Areas: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Semivolatile Organics (continued)									
Indeno(1,2,3-c,d)pyrene	1/8	2010	IA04-SB0018	2010	IA04-SB0018	--	--	0.6	ug/kg
Naphthalene	1/8	99999.9 J	IA04-SB0021	230000 J	IA04-SB0021	--	--	56	ug/kg
Phenanthrene	2/8	5500	IA04-SB0018	891000	IA04-SB0021	--	--	230.9	ug/kg
Pyrene	2/8	5590	IA04-SB0018	513000	IA04-SB0021	--	--	2309	ug/kg
bis(2-ethylhexyl)phthalate	1/8	408 J	IA08-SB0002	408 J	IA08-SB0002	--	--	34.7	ug/kg
Volatile Organics									
1,1,1-Trichloroethane	1/8	7.3	IA04-SB0019	7.3	IA04-SB0019	--	--	768	ug/kg
4-Methyl-2-pentanone	1/8	21.4	IA04-SB0021	21.4	IA04-SB0021	--	--	787	ug/kg
Acetone	1/8	11.7	IA08-SB0001	11.7	IA08-SB0001	--	--	1570	ug/kg
Benzene	6/8	0.57 J	IA04-SB0017	4.4 J	IA04-SB0021	--	--	0.7	ug/kg
Carbon disulfide	2/8	0.69 J	IA04-SB0020	1.7 J	IA04-SB0021	--	--	355	ug/kg
Chloroform	3/8	0.62 J	IA04-SB0018	343 J	IA08-TR0001	--	--	0.2	ug/kg
Ethylbenzene	2/8	1.3 J	IA04-SB0018	9.1	IA04-SB0021	--	--	230	ug/kg
Methylene chloride	2/8	0.56 JB	IA04-SB0018	498 J	IA08-TR0001	--	--	8.9	ug/kg
Toluene	7/8	1.1 J	IA08-SB0001	36.4 B	IA04-SB0021	--	--	520	ug/kg
Trichloroethene	1/8	1.3 J	IA04-SB0019	1.3 J	IA04-SB0019	--	--	2.8	ug/kg
Xylenes (total)	3/8	1.2 J	IA08-SB0002	26	IA04-SB0021	--	--	210	ug/kg
Radiological Parameters									
Actinium-227	2/26	0.286 J	IA04-SB0028	0.322 J	IA04-SB0028	1.76	0/2	--	pCi/g
Actinium-228	23/26	0.589 J	IA04-SB0028	1.25	IA04-SB0017	1.35	0/23	--	pCi/g
Cesium-137	6/26	0.0698	IA08-SB0004	0.118	IA08-SB0003	0.72	0/6	--	pCi/g
Potassium-40	26/26	0.627 J	IA04-SB0026	28.7	IA08-SB0004	27.2	2/26	--	pCi/g
Radium-226	26/26	0.0887	IA04-SB0026	2.31	IA04-SB0018	2.97	0/26	--	pCi/g
Radium-228	23/26	0.589 J	IA04-SB0028	1.25	IA04-SB0017	1.48	0/23	--	pCi/g
Thorium-228	23/26	0.629 J	IA04-SB0028	2.72	IA08-SB0003	1.6	2/23	--	pCi/g
Thorium-230	25/26	0.522 J	IA04-SB0026	2.75	IA04-SB0018	3.2	0/25	--	pCi/g
Thorium-232	23/26	0.382 J	IA04-SB0028	1.5	IA08-SB0003	1.48	1/23	--	pCi/g
Thorium-234	15/26	0.393 J	IA04-SB0026	3.22 J	IA04-SB0019	3.07	2/15	--	pCi/g
Uranium-233/234	25/26	0.137 J	IA04-SB0026	1.75	IA04-SB0018	2.01	0/25	--	pCi/g
Uranium-235	9/26	0.0611	IA08-TR0001	0.122 J	IA04-SB0028	0.25	0/9	--	pCi/g
Uranium-238	26/26	0.181 J	IA04-SB0026	2	IA04-SB0018	2.63	0/26	--	pCi/g

*USEPA Region 9 PRG

Table 4.8. Summary of Groundwater Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	GW PRG*	MCL
Metals									
Aluminum	28/41	7.7 B	GW0003	10800 J	MW-13(S)	2960	3/28	36499	--
Aluminum (Filtered)	5/32	7.7 B	MW-22(I)	41.5 B	MW-07(I)	32.4	2/5	36499	--
Antimony	6/41	2.1 B	MW-06(S)	3.9 B	MW-13(S)	2.9	4/6	15	6
Antimony (Filtered)	6/32	2.6 B	MW-24(S)	4.9 B	MW-21(I)	4	2/6	15	6
Arsenic	22/91	2.8 B	GW0003	16.8	MW-14(S)	4.7	9/22	--	50
Arsenic (Filtered)	17/65	2.7 B	OMW-30(B)	11.7	MW-07(I)	6.2	8/17	--	50
Barium	91/91	13.2	MW-21(I)	562	OMW-34(B)	105	10/91	2555	2000
Barium (Filtered)	65/65	12.6	MW-21(I)	493	OMW-34(B)	93.1	13/65	2555	2000
Beryllium	35/104	0.12999	GW0002	39.5	MW-01(I)	0.79	23/35	73	4
Beryllium (Filtered)	10/65	0.17 B	MW-24(S)	33.5	MW-01(I)	--	--	73	4
Cadmium	6/41	0.35 B	MW-22(I)	3.4	MW-07(I)	1	3/6	18	5
Calcium	41/41	37100	MW-24(S)	420000	MW-14(S)	119000	26/41	--	--
Calcium (Filtered)	32/32	34800	MW-24(S)	388000	MW-14(S)	112000	22/32	--	--
Chromium	24/41	0.47 B	MW-06(S)	18.3	MW-13(S)	21.3	0/24	--	100
Chromium (Filtered)	5/32	0.53 B	MW-08(S)	1.8 B	MW-24(S)	--	--	--	100
Cobalt	15/41	0.54 B	OMW-27(I)	41.8	MW-14(S)	1.2	12/15	2190	--
Cobalt (Filtered)	12/32	0.51 B	MW-01(I)	38.7	MW-14(S)	--	--	2190	--
Copper	27/41	0.84 B	OMW-28(B)	35	MW-13(S)	5.6	4/27	1356	--
Copper (Filtered)	27/32	1.1 B	MW-39(B)	37.3 J	MW-06(S)	40.8	0/27	1356	--
Iron	40/40	70.7	MW-05(I)	27500	MW-13(S)	4330	3/40	10950	--
Iron (Filtered)	30/32	21.2	MW-41(B)	3590	MW-08(S)	1060	8/30	10950	--
Lead	60/91	1.4 B	MW-19(I)	47	MW-21(I)	7.2	10/60	--	--
Lead (Filtered)	30/65	1.5 B	MW-14(S)	46.2	MW-21(I)	1.8	24/30	--	--
Magnesium	41/41	24900	GW0003	219000	MW-14(S)	72700	13/41	--	--
Magnesium (Filtered)	32/32	35600	MW-39(B)	209000	MW-14(S)	55300	20/32	--	--
Manganese	41/41	3.9 B	GW0002	2160	MW-14(S)	144	9/41	876	--
Manganese (Filtered)	32/32	11.4	MW-39(B)	1860	MW-14(S)	91.6	14/32	876	--
Mercury	1/39	0.19 B	MW-41(B)	0.19 B	MW-41(B)	0.1	1/1	1.1	--
Mercury (Filtered)	1/32	0.19 B	MW-41(B)	0.19 B	MW-41(B)	--	--	1.1	--
Nickel	38/41	1.2 B	MW-41(B)	2430	MW-14(S)	5.5	29/38	730	100
Nickel (Filtered)	29/32	1.7 B	MW-07(I)	2570	MW-14(S)	6.4	22/29	730	100
Phosphorus	21/32	5.7 B	MW-08(S)	4570	MW-13(S)	177	2/21	--	--
Phosphorus (Filtered)	18/26	6 B	MW-08(S)	98.1 E	OMW-28(B)	218	0/18	--	--
Potassium	41/41	889	MW-39(B)	19700	MW-06(S)	16200	3/41	--	--
Potassium (Filtered)	32/32	969	MW-39(B)	20800	MW-06(S)	16100	3/32	--	--
Selenium	6/41	1.9 B	OMW-28(B)	3.7 B	MW-13(S)	--	--	183	50
Selenium (Filtered)	8/32	2.3 B	MW-22(I)	11.6	OMW-28(B)	7.5	4/8	183	50
Silver	2/41	1.5 B	PW(W)	2.4 B	MW-08(S)	2.2	1/2	183	--
Silver (Filtered)	3/32	2.2 B	MW-08(S)	3 B	MW-41(B)	--	--	183	--

*USEPA Region 9 PRG

Table 4.8. Summary of Groundwater Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	GW PRG*	MCL
Metals (continued)									
Sodium	41/41	4260	MW-39(B)	698000	MW-14(S)	28100	22/41	--	--
Sodium (Filtered)	32/32	4850	MW-39(B)	691000	MW-14(S)	27400	18/32	--	--
Thallium	6/41	4.9 B	MW-04(S)	9 B	MW-14(S)	6.7	4/6	0.3	2
Thallium (Filtered)	3/32	4.5 B	MW-07(I)	5.6 B	MW-19(I)	5	2/3	0.3	2
Vanadium	7/41	0.9 B	OMW-27(I)	18.9	MW-13(S)	6.3	3/7	256	--
Vanadium (Filtered)	2/32	0.62 B	MW-08(S)	1 B	MW-24(S)	1.4	0/2	256	--
Zinc	31/40	0.73 B	MW-04(S)	95.8	PW(W)	122	0/31	10950	4700
Zinc (Filtered)	20/31	0.95 B	MW-19(I)	49.1	MW-08(S)	13.9	6/20	10950	4700
Indicator Parameters									
Alkalinity	38/38	95.6	MW-03(I)	771	MW-14(S)	--	--	--	--
Chloride	38/38	5.17	MW-39(B)	255	MW-14(S)	--	--	365.0	--
Fluoride	84/84	0.13	MW-13(S)	2.49	MW-24(S)	1.24	7/84	2190	4000
Nitrate/Nitrite	33/38	0.01 J	MW-03(I)	0.86	OMW-28(B)	--	--	1000.0	10000
Nitrogen, Ammonia	62/73	0.03 J	MW-23(S)	22.1	MW-06(S)	0.21	28/62	--	--
Sulfate	38/38	44.8	MW-39(B)	2170	MW-14(S)	--	--	--	--
Total Dissolved Solids	27/27	340	MW-39(B)	1930	MW-04(S)	--	--	--	--
Total Rec. Petro. Hydrocarbons	1/1	0.82 J	MW-21(I)	0.82 J	MW-21(I)	--	--	--	--
Total Suspended Solids	26/27	1 J	PW(E)	75.3	MW-03(I)	--	--	--	--
Volatile Organics									
1,1,2,2-Tetrachloroethane	1/38	0.64 J	MW-04(S)	0.64 J	MW-04(S)	--	--	0.1	--
1,1,2-Trichloroethane	1/38	0.61 J	MW-04(S)	0.61 J	MW-04(S)	--	--	0.2	5
1,1-Dichloroethane	1/38	0.56 J	MW-04(S)	0.56 J	MW-04(S)	--	--	811	7
1,2-Dichloroethylene	2/38	1 J	MW-04(S)	4.5 J	MW-41(B)	--	--	61	70
1,2-Dichloropropane	1/38	0.62 J	MW-04(S)	0.62 J	MW-04(S)	--	--	0.2	5
2-Butanone	1/38	18.5	MW-08(S)	18.5	MW-08(S)	--	--	1904	8600
Benzene	1/38	0.72 J	MW-04(S)	0.72 J	MW-04(S)	--	--	0.4	5
Carbon disulfide	3/38	0.81 J	MW-41(B)	1.2 J	MW-07(I)	--	--	1043	--
Chlorobenzene	1/38	0.84 J	MW-04(S)	0.84 J	MW-04(S)	--	--	106	--
Chloroform	1/38	0.64 J	MW-04(S)	0.64 J	MW-04(S)	--	--	0.2	--
Ethylbenzene	1/38	0.84 J	MW-04(S)	0.84 J	MW-04(S)	--	--	1340	700
Methyl Bromide	2/38	0.68 J	MW-04(S)	0.82 J	MW-21(I)	--	--	9	--
Methylene chloride	2/38	1.6 JB	MW-07(I)	2 BJ	MW-08(S)	--	--	4.3	5
Styrene	1/38	0.83 J	MW-04(S)	0.83 J	MW-04(S)	--	--	1641	100
Toluene	1/38	0.76 J	MW-04(S)	0.76 J	MW-04(S)	--	--	723	1000
Trichloroethene	2/38	0.77 J	MW-04(S)	2.6 J	MW-41(B)	--	--	1.6	5

*USEPA Region 9 PRG

Table 4.8. Summary of Groundwater Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	GW PRG*	MCL
Radiological Parameters									
Actinium-227	2/88	0.269 J	MW-05(I)	0.308 J	MW-40(B)	0.35	0/2	--	--
Actinium-227 (Filtered)	2/33	0.123 J	OMW-31(I)	0.124 J	OMW-30(B)	--	--	--	--
Cesium-137	1/88	4.95 J	MW-06(S)	4.95 J	MW-06(S)	5.29	0/1	--	--
Cesium-137 (Filtered)	1/33	44.1	OMW-36(B)	44.1	OMW-36(B)	--	--	--	--
Cobalt-60 (Filtered)	1/33	63.2	OMW-36(B)	63.2	OMW-36(B)	--	--	--	--
Gross Alpha	66/88	1.59 J	OMW-35(I)	111	MW-04(S)	6.03	12/66	0.6	--
Gross Alpha (Filtered)	28/33	0.931 J	MW-17(S)	22.8	MW-24(S)	5.48	9/28	0.6	--
Nonvolatile Beta	71/88	1.57 J	MW-17(S)	46.4	OMW-34(B)	12.1	13/71	0.6	--
Nonvolatile Beta (Filtered)	30/33	1.7 J	MW-18(I)	34	OMW-34(B)	--	--	0.6	--
Potassium-40	9/88	26.41 J	OMW-34(B)	68.2 J	MW-13(S)	39	6/9	--	--
Potassium-40 (Filtered)	3/33	49.4 J	MW-06(S)	62.4 J	MW-21(I)	31.8	3/3	--	--
Radium-226	72/90	0.37 J	MW-02(S)	4.12	OMW-37(I)	1.86	17/72	--	--
Radium-226 (Filtered)	32/33	0.49 J	MW-06(S)	2.38	MW-40(B)	2.63	0/32	--	--
Radium-228	5/90	0.905 J	MW-41(B)	1.71	MW-13(S)	1.57	1/5	--	--
Radium-228 (Filtered)	2/33	1.21	MW-14(S)	1.21	MW-25(I)	1.3	0/2	--	--
Thorium-228	44/88	0.117 J	MW-01(I)	1.49	MW-05(I)	0.65	4/44	--	--
Thorium-228 (Filtered)	9/33	0.125 J	MW-06(S)	0.363 J	MW-01(I)	--	--	--	--
Thorium-230	23/88	0.0533	GW0003	0.699 J	MW-14(S)	14.7	0/23	--	--
Thorium-230 (Filtered)	11/33	0.0507	OMW-31(I)	0.835 J	MW-18(I)	0.99	0/11	--	--
Thorium-232	4/88	0.151 J	OMW-37(I)	0.294 J	MW-14(S)	--	--	--	--
Thorium-234	6/88	69.6 J	PW(W)	232 J	OMW-35(I)	--	--	--	--
Uranium-233/234	68/90	0.139 J	GW0002	129	MW-24(S)	1.62	18/68	--	--
Uranium-233/234 (Filtered)	27/33	0.261 J	OMW-33(I)	87.1	MW-24(S)	--	--	--	--
Uranium-235	11/90	0.0729	MW-01(I)	6.39	MW-24(S)	--	--	--	--
Uranium-235 (Filtered)	7/33	0.0751	MW-08(S)	4.37	MW-24(S)	--	--	--	--
Uranium-238	64/90	0.0877	GW0002	129	MW-24(S)	1.4	18/64	--	--
Uranium-238 (Filtered)	27/33	0.184 J	OMW-28(B)	81.5	MW-24(S)	1	11/27	--	--
Wet Chemistry									
Fluoride	4/4	0.469	GW0002	0.78799	GW0003	1.24	0/4	2190	4000
Nitrogen, Ammonia	3/4	0.10999	GW0003	1.55	PW(E)	0.21	2/3	--	--

*USEPA Region 9 PRG

Table 4.9. Summary of Radiological Survey Data – Annex (Phase II)[1]

Beam Number	Direct α Surface Contamination (dpm/100 cm^2)	Direct β/γ Surface Contamination (dpm/100 cm^2)	Removable α Surface Contamination (dpm/100 cm^2)	Removable β/γ Surface Contamination (dpm/100 cm^2)
1	-28 to 17	-222 to 156	-1 to 3	-9 to 68
3	-28 to 17	-200 to 311	-1 to 3	-21 to 23
4	-28 to 28	-133 to 400	-1 to 6	-31 to 30
5	-28 to -6	-311 to 222	-1 to 3	-5 to 17
8	-28 to -6	-267 to 222	-1 to 6	-15 to 30
9	-6 to -28	-200 to 267	-1 to 3	-19 to 25
10	-28 to -6	-156 to 156	-1 to 3	-16 to 13
11	-28 to -6	-178 to 133	-1 to 3	-16 to 16
16	-14 to 28	-50 to 806	-1 to 3	-38 to 657
17	-14 to 69	-50 to 1260	-1 to 3	-32 to 32
18	-14 to 97	-252 to 2571	-1 to 6	-22 to 29
19	-14 to 97	-403 to 554	-1 to 3	41 to -13
20	-14 to 83	-202 to 1915	-1 to 6	-34 to 29
21	0 to 166	-50 to 1512	-1 to 6	-31 to 30
22	14 to 262	353 to 2823	-1 to 9	-85 to 26
23	110 to 593	1512 to 13911	-1 to 2	-24 to 45

[1]*Phase II Characterization Report for the Luckey Site* (BNI 1998)
α – alpha
β/γ – beta-gamma
dpm – disintegrations per minute

Table 4.10. Summary of Transferable Alpha Activity – Annex (Phase II) [1]

Building	Grid Reference	dpm
Production Building	AD 18 Beam E. Shoulder	26
	AL 18 Cross Member	26
	Y 26 Beam E. Shoulder	36
Annex	H5 Beam E. Shoulder	27
	N21 Beam Top	27
	M5 Beam W. Shoulder	22
	L5 Beam Top	35
	L5 Beam W. Shoulder	27
	E16 Beam Top	22
	L11 Beam Top	25

[1] *Phase II Characterization Report for the Luckey Site* (BNI 1998)
dpm – disintegrations per minute

Table 4.11. Summary of Transferable Beryllium Data – Annex (Phase II)[1]
Page 1 of 2

Station ID	Sample ID	Location	Collection Date	Result*
ANX0001	LUC2001	Beam 1 E5N6	11-NOV-97	3.3 μg/100 cm^2
ANX0001	LUC2002	Beam 1 E5N7	11-NOV-97	2.64 μg/100 cm^2
ANX0001	LUC2003	Beam 1 W5N6	11-NOV-97	2.58 μg/100 cm^2
ANX0001	LUC2004	Beam 1 W5N7	11-NOV-97	8.09 μg/100 cm^2
ANX0001	LUC2005	Beam 3 E15N5	11-NOV-97	0.81 μg/100 cm^2
ANX0001	LUC2006	Beam 3 E15N6	11-NOV-97	10.8 μg/100 cm^2
ANX0001	LUC2007	Beam 3 W15N5	11-NOV-97	0.7 μg/100 cm^2
ANX0001	LUC2008	Beam 3 W15N6	11-NOV-97	2.2 μg/100 cm^2
ANX0001	LUC2009	Beam 4 E20N6	11-NOV-97	0.81 μg/100 cm^2
ANX0001	LUC2010	Beam 4 E20N5	11-NOV-97	4.19 μg/100 cm^2
ANX0001	LUC2011	Beam 4 W20N5	11-NOV-97	0.8 μg/100 cm^2
ANX0001	LUC2012	Beam 4 W20N6	11-NOV-97	8.24 μg/100 cm^2
ANX0001	LUC2013	Beam 5 E25N5	11-NOV-97	1.81 μg/100 cm^2
ANX0001	LUC2014	Beam 5 E25N6	11-NOV-97	0.33 μg/100 cm^2
ANX0001	LUC2015	Beam 5 W25N5	11-NOV-97	0.65 μg/100 cm^2
ANX0001	LUC2016	Beam 5 W25N6	11-NOV-97	7.32 μg/100 cm^2
ANX0001	LUC2017	Beam 8 E41N5	11-NOV-97	0.87 μg/100 cm^2
ANX0001	LUC2018	Beam 8 E41N6	11-NOV-97	0.96 μg/100 cm^2
ANX0001	LUC2019	Beam 8 W41N5	11-NOV-97	1.47 μg/100 cm^2
ANX0001	LUC2020	Beam 8 W41N6	11-NOV-97	1.92 μg/100 cm^2
ANX0001	LUC2021	Beam 9 E46N5	11-NOV-97	0.51 μg/100 cm^2
ANX0001	LUC2022	Beam 9 E46N6	11-NOV-97	0.73 μg/100 cm^2
ANX0001	LUC2023	Beam 9 W46N5	11-NOV-97	0.38 μg/100 cm^2
ANX0001	LUC2024	Beam 9 W46N6	11-NOV-97	2.99 μg/100 cm^2
ANX0001	LUC2025	Beam 10 E51N5	11-NOV-97	0.69 μg/100 cm^2
ANX0001	LUC2026	Beam 10 E51N6	11-NOV-97	0.53 μg/100 cm^2
ANX0001	LUC2027	Beam 10 W51N5	11-NOV-97	0.53 μg/100 cm^2
ANX0001	LUC2028	Beam 10 W51N6	11-NOV-97	0.16 μg/100 cm^2
ANX0001	LUC2029	Beam 11 E56N5	11-NOV-97	0.6 μg/100 cm^2
ANX0001	LUC2030	Beam 11 E56N6	11-NOV-97	0.43 μg/100 cm^2

Table 4.11. Summary of Transferable Beryllium Data – Annex (Phase II)[1]
Page 2 of 2

Station ID	Sample ID	Location	Collection Date	Result*
ANX0001	LUC2031	Beam 11 W56N5	11-NOV-97	1.24 µg/100 cm^2
ANX0001	LUC2032	Beam 11 W56N6	11-NOV-97	0.21 µg/100 cm^2
ANX0002	LUC2033	Beam 16 E82N8	12-NOV-97	0.28 µg/100 cm^2
ANX0002	LUC2034	Beam 16 E82N9	12-NOV-97	1.15 µg/100 cm^2
ANX0002	LUC2035	Beam 16 W82N8	12-NOV-97	0.65 µg/100 cm^2
ANX0002	LUC2036	Beam 16 W82N9	12-NOV-97	0.38 µg/100 cm^2
ANX0002	LUC2037	Beam 17 E87N7	12-NOV-97	2.55 µg/100 cm^2
ANX0002	LUC2038	Beam 17 E87N8	12-NOV-97	1.19 µg/100 cm^2
ANX0002	LUC2039	Beam 17 W87N7	12-NOV-97	3.81 µg/100 cm^2
ANX0002	LUC2040	Beam 17 W87N8	12-NOV-97	1.36 µg/100 cm^2
ANX0002	LUC2041	Beam 18 E93N1	12-NOV-97	0.56 µg/100 cm^2
ANX0002	LUC2042	Beam 18 W93N2	12-NOV-97	0.64 µg/100 cm^2
ANX0002	LUC2043	Beam 19 E98N1	12-NOV-97	0.48 µg/100 cm^2
ANX0002	LUC2044	Beam 19 W98N2	12-NOV-97	1.24 µg/100 cm^2
ANX0002	LUC2045	Beam 20 E103N1	12-NOV-97	2.06 µg/100 cm^2
ANX0002	LUC2046	Beam 21 E108N1	12-NOV-97	1.01 µg/100 cm^2
ANX0002	LUC2047	Beam 22 E113N3	12-NOV-97	2.33 µg/100 cm^2
ANX0002	LUC2048	Beam 23 E119N7	12-NOV-97	2.35 µg/100 cm^2
BZ0033	LU40459	BLANK	30-OCT-97	0.02 µg/100 cm^2
ESM0019	LU40517	BLANK	12-NOV-97	0.05 µg/100 cm^2

Notes:

[1] *Phase II Characterization Report for the Luckey Site (BNI 1998)*

* Data are expressed as µg/100cm^2, results were in mg and smear was taken from a 100 cm^2 area.
The matrix code for each sample was: SOL (solid).
The detection limit for each sample was: 0.2 mg.
The sample type for each sample was: REG (regular).
The method code was: 6010A-BE

Table 4.12. Summary of Building Swipe Results (Phase IV)

Building	Detection Frequency Detects/Total	Average ($\mu g/100cm^2$)	Maximum ($\mu g/100cm^2$)	Maximum > DOE housekeeping guideline[a]
Annex	207/210	24.9	640	Yes
Production Building	95/97	6.96	201	Yes
Former Laboratory	11/11	7.62	40.2	Yes
Maintenance Building	26/26	3.78	25.7	Yes
Melting, Alloying, and Shipping Building	19/20	1.40	7.1	Yes
Bulk Storage Building	4/4	0.535	0.76	No
Employee Activity Building	45/48	0.162	3.7	No
Guard House	4/4	0.470	1.3	No
West Production Well House	2/2	0.454	0.87	No
East Production Well House	1/1	0.15	0.15	No
Pump and Tank House	4/4	0.217	0.389	No
Sewage Treatment Building	2/2	4.1	7	Yes
Shack	1/1	26.6	26.6	Yes

[a] The DOE housekeeping guideline is included here for comparative purposes since regulatory standards currently do not exist for beryllium on building surfaces.

Table 4.13. Analytical Results for Dust Samples (Phase IV)

		DATE	SAMPLE NO	PARAMETER	RESULTS		UNITS
Annex Building							
Functional Area 6	0 - 2 meters	7/12/99	LUDU0065	Beryllium	46.7		mg/kg
Functional Area 5	0 - 2 meters	7/12/99	LUDU0066	Beryllium	20.1		mg/kg
Functional Area 4	0 - 2 meters	7/12/99	LUDU0067	Beryllium	31.2		mg/kg
Functional Area 4	> 2 meters	7/12/99	LUDU0068	Beryllium	11.4		mg/kg
Functional Area 6	> 2 meters	7/13/99	LUDU0071	Beryllium	148		mg/kg
Functional Area 5	> 2 meters	7/13/99	LUDU0072	Beryllium	124		mg/kg
Functional Area 2	0 - 2 meters	7/20/99	LUDU0086	Beryllium	48.1	J	mg/kg
Functional Area 1	0 - 2 meters	7/20/99	LUDU0087	Beryllium	71.8	J	mg/kg
Functional Area 1	> 2 meters	7/20/99	LUDU0088	Beryllium	196	J	mg/kg
Functional Area 1	HVAC vent	7/20/99	LUDU0089	Beryllium	52.7	J	mg/kg
Functional Area 3	> 2 meters	7/20/99	LUDU0090	Beryllium	113	J	mg/kg
Functional Area 3	0 - 2 meters	7/20/99	LUDU0085	Beryllium	46.9	J	mg/kg
Functional Area 2	> 2 meters	7/21/99	LUDU0091	Beryllium	116	J	mg/kg
Production Building							
Functional Area 13	0 - 2 meters	7/6/99	LUDU0038	Beryllium	56.6	J	mg/kg
Functional Area 11	0 - 2 meters	7/6/99	LUDU0039	Beryllium	87.7	J	mg/kg
Functional Area 9	0 - 2 meters	7/6/99	LUDU0040	Beryllium	8.6	J	mg/kg
Functional Area 10	0 - 2 meters	7/8/99	LUDU0047	Beryllium	13.3	E	mg/kg
Functional Area 18	0 - 2 meters	7/9/99	LUDU0048	Beryllium	62.2	E	mg/kg
Functional Area 15	0 - 2 meters	7/9/99	LUDU0049	Beryllium	61.5	E	mg/kg
Functional Area 17	0 - 2 meters	7/9/99	LUDU0050	Beryllium	97.5	E	mg/kg
Functional Area 16	0 - 2 meters	7/9/99	LUDU0051	Beryllium	18.2	E	mg/kg
Functional Area 5	0 - 2 meters	7/10/99	LUDU0052	Beryllium	58.1	E	mg/kg
Functional Area 3	0 - 2 meters	7/10/99	LUDU0053	Beryllium	45.6	E	mg/kg
Functional Area 4	0 - 2 meters	7/10/99	LUDU0054	Beryllium	19.5	E	mg/kg
Functional Area 4	> 2 meters	7/10/99	LUDU0055	Beryllium	29	E	mg/kg
Functional Area 11	> 2 meters	7/10/99	LUDU0056	Beryllium	37.4	E	mg/kg
Functional Area 3	> 2 meters	7/10/99	LUDU0057	Beryllium	42.5	E	mg/kg
Functional Area 5	> 2 meters	7/11/99	LUDU0058	Beryllium	48.3	E	mg/kg
Functional Area 18	> 2 meters	7/11/99	LUDU0059	Beryllium	32.2	E	mg/kg
Functional Area 14	0 - 2 meters	7/11/99	LUDU0060	Beryllium	19.3	E	mg/kg
Functional Area 14	> 2 meters	7/11/99	LUDU0061	Beryllium	6.9	E	mg/kg
Functional Area 17	> 2 meters	7/11/99	LUDU0062	Beryllium	29.4	J	mg/kg
Functional Area 16	> 2 meters	7/11/99	LUDU0063	Beryllium	9.7	J	mg/kg
Functional Area 15	> 2 meters	7/11/99	LUDU0064	Beryllium	37	J	mg/kg
Functional Area 10	> 2 meters	7/12/99	LUDU0069	Beryllium	8.5		mg/kg
Functional Area 12	0 - 2 meters	7/12/99	LUDU0070	Beryllium	32.6		mg/kg
Functional Area 12	> 2 meters	7/13/99	LUDU0073	Beryllium	41.7		mg/kg
Functional Area 13	> 2 meters	7/13/99	LUDU0074	Beryllium	41.3		mg/kg
Functional Area 9	> 2 meters	7/14/99	LUDU0075	Beryllium	57.9		mg/kg
Functional Area 8	0 - 2 meters	7/14/99	LUDU0076	Beryllium	59.4		mg/kg
Functional Area 8	> 2 meters	7/14/99	LUDU0077	Beryllium	117		mg/kg
Functional Area 7	0 - 2 meters	7/14/99	LUDU0078	Beryllium	65.8		mg/kg
Functional Area 7	> 2 meters	7/14/99	LUDU0079	Beryllium	65.7		mg/kg
Functional Area 6	0 - 2 meters	7/15/99	LUDU0080	Beryllium	125	J	mg/kg
Functional Area 6	> 2 meters	7/15/99	LUDU0081	Beryllium	336	J	mg/kg
Functional Area 2	0 - 2 meters	7/15/99	LUDU0082	Beryllium	32.9	J	mg/kg
Functional Area 2	> 2 meters	7/15/99	LUDU0083	Beryllium	14.2	J	mg/kg
Functional Area 20	0 - 2 meters	7/15/99	LUDU0084	Beryllium	28.6	J	mg/kg
Functional Area 19	HVAC vent	7/21/99	LUDU0092	Beryllium	40	J	mg/kg
Functional Area 19	0 - 2 meters	7/21/99	LUDU0093	Beryllium	146	J	mg/kg
Functional Area 20	> 2 meters	7/21/99	LUDU0094	Beryllium	41.7	J	mg/kg
Functional Area 19	> 2 meters	7/21/99	LUDU0095	Beryllium	106	J	mg/kg
Functional Area 15	HVAC vent	7/22/99	LUDU0096	Beryllium	3.1		mg/kg
Functional Area 16&17	HVAC vent	7/22/99	LUDU0097	Beryllium	13.5		mg/kg
Functional Area 23	HVAC vent	7/22/99	LUDU0098	Beryllium	5		mg/kg
Functional Area 21	0 - 2 meters	7/22/99	LUDU0099	Beryllium	15.5		mg/kg
Functional Area 21	HVAC vent	7/22/99	LUDU0100	Beryllium	15.9		mg/kg
Functional Area 21	> 2 meters	7/22/99	LUDU0101	Beryllium	27.2		mg/kg
Functional Area 1	0 - 2 meters	7/23/99	LUDU0102	Beryllium	20.2		mg/kg
Functional Area 1	> 2 meters	7/23/99	LUDU0103	Beryllium	13.9		mg/kg

Table 4.13. Analytical Results for Dust Samples (Phase IV)

		DATE	SAMPLE NO	PARAMETER	RESULTS		UNITS
Production Building (continued)							
Functional Area 23	0 - 2 meters	7/23/99	LUDU0104	Beryllium	13.2		mg/kg
Functional Area 23	> 2 meters	7/23/99	LUDU0105	Beryllium	13.4		mg/kg
Functional Area 22	0 - 2 meters	7/23/99	LUDU0106	Beryllium	13.7		mg/kg
Functional Area 22	> 2 meters	7/24/99	LUDU0107	Beryllium	13.5		mg/kg
Functional Area 22	HVAC vent	7/24/99	LUDU0108	Beryllium	9.5		mg/kg
Functional Area 22	HVAC vent	7/24/99	LUDU0109	Beryllium	14		mg/kg
Laboratory Building							
Functional Area 2	0 - 2 meters	6/30/99	LUDU0023	Beryllium	54.2		mg/kg
Functional Area 1	0 - 2 meters	6/30/99	LUDU0024	Beryllium	13.4		mg/kg
Functional Area 3	0 - 2 meters	6/30/99	LUDU0025	Beryllium	5.9		mg/kg
Functional Area 2	> 2 meters	7/1/99	LUDU0026	Beryllium	47.3	J	mg/kg
Functional Area 1	> 2 meters	7/1/99	LUDU0027	Beryllium	6.4	J	mg/kg
Functional Area 3	> 2 meters	7/1/99	LUDU0028	Beryllium	26.7	J	mg/kg
Maintenance Building							
Functional Area 1	0 - 2 meters	6/16/99	LUDU0002	Beryllium	18		mg/kg
Functional Area 2	0 - 2 meters	6/16/99	LUDU0003	Beryllium	10.3		mg/kg
Functional Area 1	> 2 meters	6/17/99	LUDU0004	Beryllium	22.6		mg/kg
Functional Area 2	> 2 meters	6/17/99	LUDU0005	Beryllium	11.4		mg/kg
Functional Area 3	0 - 2 meters	6/17/99	LUDU0006	Beryllium	185		mg/kg
Functional Area 4	0 - 2 meters	6/17/99	LUDU0007	Beryllium	22.8		mg/kg
Functional Area 4	> 2 meters	6/17/99	LUDU0008	Beryllium	28.2		mg/kg
Functional Area 3	> 2 meters	6/17/99	LUDU0009	Beryllium	48.9		mg/kg
Functional Area 4	HVAC vent	7/24/99	LUDU0110	Beryllium	7.2		mg/kg
Melting, Alloying, and Shipping Building							
Functional Area 1	0 - 2 meters	6/28/99	LUDU0012	Beryllium	24.6		mg/kg
Functional Area 2	0 - 2 meters	6/28/99	LUDU0013	Beryllium	11.1		mg/kg
Functional Area 3	0 - 2 meters	6/28/99	LUDU0014	Beryllium	14.5		mg/kg
Functional Area 4	0 - 2 meters	6/29/99	LUDU0015	Beryllium	71.7		mg/kg
Functional Area 1	> 2 meters	6/29/99	LUDU0016	Beryllium	12		mg/kg
Functional Area 2	> 2 meters	6/29/99	LUDU0017	Beryllium	16.2		mg/kg
Functional Area 4	> 2 meters	6/29/99	LUDU0018	Beryllium	30.6		mg/kg
Functional Area 6	0 - 2 meters	6/29/99	LUDU0019	Beryllium	16.4		mg/kg
Functional Area 5	0 - 2 meters	6/29/99	LUDU0020	Beryllium	10.2		mg/kg
Functional Area 6	> 2 meters	6/29/99	LUDU0021	Beryllium	3.8		mg/kg
Functional Area 3	> 2 meters	6/30/99	LUDU0022	Beryllium	2.8		mg/kg
Bulk Storage Building							
Functional Area 1	0 - 2 meters	6/18/99	LUDU0010	Beryllium	15.4		mg/kg
Functional Area 1	> 2 meters	6/18/99	LUDU0011	Beryllium	12.4		mg/kg
Employee Activity Building							
Functional Area 2	0 - 2 meters	7/7/99	LUDU0041	Beryllium	8.3	J	mg/kg
Functional Area 2	> 2 meters	7/7/99	LUDU0042	Beryllium	18.2	J	mg/kg
Functional Area 1	0 - 2 meters	7/8/99	LUDU0043	Beryllium	5.8	E	mg/kg
Functional Area 1	> 2 meters	7/8/99	LUDU0044	Beryllium	9	E	mg/kg
Functional Area 3	0 - 2 meters	7/8/99	LUDU0045	Beryllium	11.1	E	mg/kg
Functional Area 3	> 2 meters	7/8/99	LUDU0046	Beryllium	5.3	E	mg/kg
Guard House							
Functional Area 1	0 - 2 meters	7/2/99	LUDU0035	Beryllium	9.8	J	mg/kg
Functional Area 1	> 2 meters	7/2/99	LUDU0036	Beryllium	14.2	J	mg/kg
Building Housing West Production Well							
Functional Area 1	0 - 2 meters	7/1/99	LUDU0031	Beryllium	5.7	J	mg/kg
Functional Area 1	> 2 meters	7/1/99	LUDU0032	Beryllium	9.5	J	mg/kg
Building Housing Water Pump and Tank							
Functional Area 1	0 - 2 meters	7/1/99	LUDU0029	Beryllium	4.1	J	mg/kg
Functional Area 1	> 2 meters	7/1/99	LUDU0030	Beryllium	2.5	J	mg/kg
Sewage Disposal System Pump House							
Functional Area 1	0 - 2 meters	7/2/99	LUDU0033	Beryllium	36.5	J	mg/kg
Functional Area 1	> 2 meters	7/2/99	LUDU0034	Beryllium	107	J	mg/kg
Shack							
Functional Area 1	All Areas	7/8/99	LUDU0037	Beryllium	81.8	E	mg/kg

Table 4.14. Averaged Dust Sample Results in Buildings (Phase IV)

Building	Average Result (mg/kg)
Annex	78.92
Production Building	46.70
Employee Activity Building	9.62
Former Laboratory	25.65
Melting, Alloying, and Shipping Building	19.44
Maintenance Building	43.40
Bulk Storage Building	13.90
Guard House	12.00
Building House West Production Well	7.60
Building Housing Water Pump and Tank	3.30
Sewage Disposal System Pump House	71.75

Table 4.15. Summary of Beryllium Results in Building Materials Samples (Phase IV)

Station	Number of Samples	Average for "non-paint" samples (mg/kg)	Average for paint samples (mg/kg)	Overall Average (mg/kg)	Maximum (mg/kg)
Annex	33	115	148	132	1,020
Production Building	17	114	92.4	105	500
Former Laboratory	3	541	8.09	186	541
Maintenance Building	8	5.93	40.8	17.9	97.3
Melting, Alloying, and Shipping Building	10	1.96	2.8	2.13	8.1
Tank Building	1	23.5	23.5	23.5	23.5

Table 4.16. Radionuclides Detected in Building Materials - Annex (Phase IV)

PARAMETER	LUBM0043 (pCi/g)	LUBM0068 (pCi/g)	LUBM0093 (pCi/g)	LUBM0098 (pCi/g)	LUBM0099 (pCi/g)
Actinium-227	0.314 U ± 0.34	0.832 J ± 0.4	0.245 J ± 0.21	0.0866 U ± 0.14	-0.0279 U ± 0.028
Actinium-228	0.582 J ± 0.18	0.292 U ± 0.3	0.0965 U ± 0.16	0.198 U ± 0.16	0.0 U ± 0.14
Cesium-137	0.0346 U ± 0.031	0.0099 U ± 0.066	-0.0009 U ± 0.039	0.0 U ± 0.027	0.0144 U ± 0.022
Cobalt-60	0.0198 U ± 0.026	-0.0261 U ± 0.082	0.0106 U ± 0.033	0.0084 U ± 0.021	-0.0187 U ± 0.021
Potassium-40	3.47 ± 0.86	1.76 ± 1.4	0.652 U ± 0.44	9.03 ± 1.1	7.34 ± 1.2
Protactinium-231	0.324 U ± 1.1	-0.0813 U ± 3.1	-0.774 U ± 1.5	-0.0385 U ± 0.75	-0.29 U ± 0.82
Radium-226	2.69 ± 0.35	21.5 ± 2.4	4.4000 ± 0.52	0.752 J ± 0.15	0.444 J ± 0.095
Radium-228	0.582 J ± 0.18	0.292 U ± 0.3	0.0965 U ± 0.16	0.198 J ± 0.16	0.316 J ± 0.14
Thorium-228	0.742 J ± 0.4	0.0846 U ± 0.088	0.255 J ± 0.16	0.308 J ± 0.17	0.273 J ± 0.16
Thorium-230	7.3 ± 1.9	19.1 ± 4.4	7.28 ± 1.9	0.519 J ± 0.23	0.533 J ± 0.23
Thorium-232	0.592 J ± 0.34	0.145 J ± 0.11	0.123 J ± 0.11	0.137 J ± 0.11	0.14 J ± 0.11
Thorium-234	1.43 U ± 1.5	19.5 ± 5	1.85 U ± 2.3	7.06 ± 1.5	13.6 ± 3.3
Uranium-233/234	2.39 J ± 0.99	22.2 ± 3	5.48 ± 0.93	3.42 ± 0.69	11.3 ± 1.6
Uranium-235	0.152 U ± 0.25	1.35 ± 0.35	0.26 J ± 0.14	0.358 J ± 0.19	0.567 J ± 0.22
Uranium-235	0.191 U ± 0.17	1.84 ± 0.73	0.443 J ± 0.34	0.457 J ± 0.21	0.707 J ± 0.24
Uranium-238	1.77 J ± 0.84	21.6 ± 3	4.92 ± 0.86	4.1 ± 0.78	10.9 ± 1.6

Table 4.17. Toussaint Creek, Onsite and Adjacent Areas: Summary of Sediment Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Units
Metals								
Aluminum	33/33	573	SWSD0023	30200	SWSD0021	12000	4/33	mg/kg
Antimony	3/19	0.47 J	SWSD0017	0.7 J	SWSD0016	0.88	0/3	mg/kg
Arsenic	84/84	2.2 J	SWSD0007	31.3	IA06-SD0012	12.1	3/84	mg/kg
Barium	71/71	15.3	IA06-SD0015	378 J	SWSD0023	94.3	14/71	mg/kg
Beryllium	86/86	0.43	IA06-SD0016	2020 J	SWSD0022	0.69	82/86	mg/kg
Boron	15/20	7.3 B	SWSD0015	47.2 J	SWSD0022	15.5	5/15	mg/kg
Cadmium	19/20	0.11 B	SWSD0017	56.8	SWSD0005	0.51	18/19	mg/kg
Calcium	20/20	9290	SWSD0017	166000 J	SWSD0022	109000	4/20	mg/kg
Chromium	20/20	9.8	SWSD0012	45.5	SWSD0023	17.6	10/20	mg/kg
Cobalt	20/20	2.9	SWSD0012	30.5	SWSD0021	10	2/20	mg/kg
Copper	20/20	14.6 J	SWSD0014	228 J	SWSD0016	23	15/20	mg/kg
Iron	20/20	6540 J	SWSD0022	119000	SWSD0023	20500	5/20	mg/kg
Lead	84/84	6.2 J	IA06-SD0013	2170 *	BH0018	14.3	35/84	mg/kg
Magnesium	33/33	5010	SWSD0017	72400 J	SWSD0022	18900	11/33	mg/kg
Manganese	20/20	137 J	SWSD0012	1380	SWSD0021	563	1/20	mg/kg
Mercury	20/20	0.03 B	SWSD0008	0.67 J	SWSD0016	--	--	mg/kg
Molybdenum	20/20	1.4 B	SWSD0019	8.6 J	SWSD0021	2.6	10/20	mg/kg
Nickel	20/20	10.2	SWSD0012	61.4	SWSD0021	25.3	6/20	mg/kg
Potassium	19/20	719 J	SWSD0012	3740	SWSD0021	2390	4/19	mg/kg
Selenium	8/20	0.42 B	SWSD0015	3.2 J	SWSD0016	1.8	2/8	mg/kg
Silicon	19/20	602 J	SWSD0015	3930 J	SWSD0022	567	19/19	mg/kg
Silver	5/20	0.27 B	SWSD0013	9.8	SWSD0019	--	--	mg/kg
Sodium	20/20	155	SWSD0014	3110 J	SWSD0007	373	10/20	mg/kg
Strontium	20/20	44.5 J	SWSD0017	3400 J	SWSD0007	98.3	18/20	mg/kg
Thallium	7/20	0.95 B	SWSD0009	4.2 B	SWSD0023	3.4	1/7	mg/kg
Vanadium	20/20	4.8 B	SWSD0023	60.5	SWSD0021	24.8	4/20	mg/kg
Zinc	20/20	52	SWSD0008	1450	SWSD0023	108	14/20	mg/kg
Indicator Parameters								
Chloride	8/8	14.6	SWSD0019	3670 J	SWSD0007	--	--	mg/kg
Fluoride	58/59	0.58 J	IA06-SD0017	163	IA06-SD0001	5.35	12/58	mg/kg
Nitrate, as N	8/8	0.163 J	SWSD0010	7.29 J	SWSD0004	--	--	mg/kg
Nitrogen, Ammonia	3/3	27.3	IA06-SD0037	73.9	IA06-BH0017	8.1	3/3	mg/kg
Phosphorus	5/5	1.14 J	SWSD0019	2.68 J	SWSD0013	680	0/5	mg/kg
Sulfate	8/8	76.7 J	SWSD0019	4100 J	SWSD0022	--	--	mg/kg
Total organic carbon	19/19	10700 J	SWSD0019	89600 J	SWSD0017	--	--	mg/kg

Table 4.17. Toussaint Creek, Onsite and Adjacent Areas: Summary of Sediment Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Units
Semivolatile Organics								
3,3'-Dichlorobenzidine	2/25	420 J	IA06-SD0005	885 J	IA06-SD0002	--	--	ug/kg
Acenaphthene	1/25	48.9 J	SWSD0015	48.9 J	SWSD0015	--	--	ug/kg
Anthracene	2/25	116 J	SWSD0015	243 J	IA06-SD0003	--	--	ug/kg
Benzo(a)anthracene	6/25	74.5 J	SWSD0014	5640 J	SWSD0018	--	--	ug/kg
Benzo(a)pyrene	8/25	34 J	SWSD0013	7330 J	SWSD0018	--	--	ug/kg
Benzo(b)fluoranthene	9/25	52.5 J	SWSD0013	10700 J	SWSD0018	--	--	ug/kg
Benzo(ghi)perylene	6/25	44.6 J	SWSD0014	4880 J	SWSD0018	--	--	ug/kg
Benzo(k)fluoranthene	4/25	48.6 J	SWSD0014	4370 J	SWSD0018	--	--	ug/kg
Butylbenzylphthalate	1/25	17700 J	SWSD0021	17700 J	SWSD0021	--	--	ug/kg
Carbazole	1/25	164 J	SWSD0015	164 J	SWSD0015	--	--	ug/kg
Chrysene	8/25	45.3 J	SWSD0013	6130 J	SWSD0018	--	--	ug/kg
Di-n-octylphthalate	1/25	479 J	IA06-SD0005	479 J	IA06-SD0005	--	--	ug/kg
Dibenz(a,h)anthracene	2/25	9.2 J	SWSD0015	1880 J	SWSD0018	--	--	ug/kg
Dibenzofuran	1/25	18.9 J	SWSD0015	18.9 J	SWSD0015	--	--	ug/kg
Diethyl phthalate	3/25	25.5 J	SWSD0015	48.2 J	SWSD0014	--	--	ug/kg
Fluoranthene	11/25	59.6 J	SWSD0013	12400 J	SWSD0018	--	--	ug/kg
Fluorene	1/25	64 J	SWSD0015	64 J	SWSD0015	--	--	ug/kg
Indeno(1,2,3-c,d)pyrene	6/25	14 J	SWSD0013	5470 J	SWSD0018	--	--	ug/kg
Phenanthrene	9/25	81 J	SWSD0014	5250 J	SWSD0018	--	--	ug/kg
Pyrene	9/25	62.7 J	SWSD0013	12300 J	SWSD0018	--	--	ug/kg
bis(2-ethylhexyl)phthalate	10/25	56.8 J	SWSD0013	195000 J	SWSD0021	--	--	ug/kg
Volatile Organics								
2-Butanone	8/14	4.3 J	IA06-SD0004	34.8	IA06-SD0002	--	--	ug/kg
Acetone	12/14	21.5 J	SWSD0010	1020	IA06-SD0002	--	--	ug/kg
Benzene	5/14	0.83 J	IA06-SD0005	5.2 J	IA06-SD0004	--	--	ug/kg
Carbon disulfide	5/14	3.6 J	IA06-SD0001	155	IA06-SD0002	--	--	ug/kg
Chlorobenzene	1/14	1.3 J	IA06-SD0003	1.3 J	IA06-SD0003	--	--	ug/kg
Chloroethane	1/14	32.4	IA06-SD0001	32.4	IA06-SD0001	--	--	ug/kg
Chloroform	1/14	1.5 J	IA06-SD0002	1.5 J	IA06-SD0002	--	--	ug/kg
Ethylbenzene	5/14	0.67 J	IA06-SD0005	3.2 J	IA06-SD0004	--	--	ug/kg
Methyl Pentane Isomer	1/1	10.9 J	IA06-SD0001	10.9 J	IA06-SD0001	--	--	ug/kg
Methylene chloride	4/14	0.58 BJ	IA06-SD0001	2.4 BJ	IA06-SD0002	--	--	ug/kg
Toluene	13/14	0.76 J	SWSD0012	111 J	SWSD0011	--	--	ug/kg
Xylenes (total)	5/14	0.77 J	IA06-SD0005	11	IA06-SD0003	--	--	ug/kg

Table 4.17. Toussaint Creek, Onsite and Adjacent Areas: Summary of Sediment Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Units
Radiological Parameters								
Actinium-227	14/86	0.133	IA06-SD0039	0.313	SWSD0006	0.4	0/14	pCi/g
Actinium-228	52/53	0.154 J	IA06-SD0005	1.8	IA06-SD0010	0.76	13/52	pCi/g
Cesium-137	43/86	0.0329	IA06-SD0030	0.688	IA10-SD0003	0.16	19/43	pCi/g
Gross Alpha	3/3	13.3	IA06-SD0039	14.7	IA06-BH0017	16.5	0/3	pCi/g
Nonvolatile Beta	3/3	14.1	IA06-SD0037	24.6	IA06-SD0039	20.8	2/3	pCi/g
Potassium-40	84/86	1.87	SWSD0023	24	IA06-SD0001	18.1	22/84	pCi/g
Radium-226	80/81	0.431 J	IA06-SD0005	9.09 J	SWSD0006	1.63	14/80	pCi/g
Radium-228	83/86	0.154 J	IA06-SD0005	1.8	IA06-SD0010	1.11	1/83	pCi/g
Thorium-227	9/32	0.135	SWSD0004	0.313	SWSD0006	0.4	0/9	pCi/g
Thorium-228	81/86	0.186	SWSD0021	1.97 J	IA06-SD0024	1.19	5/81	pCi/g
Thorium-230	86/86	0.0921	SWSD0023	3.35	SWSD0022	1.89	10/86	pCi/g
Thorium-232	85/86	0.0265	SWSD0023	1.09	IA06-SD0027	0.84	7/85	pCi/g
Thorium-234	30/53	0.791 J	IA06-SD0005	2.28 J	IA06-SD0027	2.27	1/30	pCi/g
Uranium-233/234	53/53	0.398 J	IA06-SD0010	12.6	IA06-SD0029	1.23	10/53	pCi/g
Uranium-234	32/33	0.168 J	SWSD0023	3.84	SWSD0022	1.8	3/32	pCi/g
Uranium-235	14/86	0.03319	IA06-SD0037	0.443 J	IA06-SD0029	0.06	7/14	pCi/g
Uranium-238	85/86	0.25 J	SWSD0023	13	IA06-SD0029	2.08	3/85	pCi/g
Wet Chemistry								
Total Organic Carbon	3/3	20200	IA06-SD0039	28600	IA06-BH0017	--	--	mg/kg

Table 4.18. Toussaint Creek: Summary of Surface Water Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Water Quality Criteria[1]	MCL	Units
Metals										
Aluminum	5/6	194	SWSD0014	1700	IA06-SW0002	733	1/5	--		ug/l
Arsenic	5/14	2.7 B	SWSD0015	8.7	IA06-SW0002	--	--	150	50	ug/l
Barium	14/14	41.4	IA06-SW0002	109	IA06-SW0002	38.8	14/14	--	2000	ug/l
Beryllium	11/14	0.39	IA06-SW0002	5.1	IA06-SW0002	--	--	--	4	ug/l
Boron	5/5	76.4 J	SWSD0013	160 J	SWSD0014	--	--	--		ug/l
Cadmium	3/6	0.43 B	SWSD0015	1 B	SWSD0013	--	--	5.3	5	ug/l
Calcium	6/6	61600	IA06-SW0002	96500	SWSD0013	89400	3/6	--		ug/l
Chromium	2/6	0.86 B	SWSD0008	0.89 B	SWSD0008	1.2	0/2	180	100	ug/l
Cobalt	5/6	0.7 B	SWSD0014	1.6	IA06-SW0002	--	--	--		ug/l
Copper	1/6	8.4	IA06-SW0002	8.4	IA06-SW0002	4.6	1/1	23		ug/l
Iron	6/6	205	SWSD0013	1960	IA06-SW0002	871	3/6	--		ug/l
Lead	6/14	2	IA06-SW0002	10.3 B	SWSD0015	1.2	6/6	21		ug/l
Magnesium	6/6	13900	IA06-SW0002	48100	SWSD0013	27000	5/6	--		ug/l
Manganese	6/6	28.4	IA06-SW0002	720	SWSD0008	19.7	6/6	--		ug/l
Molybdenum	3/5	6.4 B	SWSD0015	16.4 B	SWSD0008	11.1	2/3	--		ug/l
Nickel	6/6	4.8	IA06-SW0002	36.4	SWSD0013	--	--	130	100	ug/l
Phosphorus	1/1	287	IA06-SW0002	287	IA06-SW0002	--	--	--		ug/l
Potassium	6/6	4080	IA06-SW0002	7430	SWSD0015	1570	6/6	--		ug/l
Silicon	5/5	1820	SWSD0008	4160	SWSD0013	3620	1/5	--		ug/l
Sodium	6/6	6270	IA06-SW0002	162000	SWSD0014	18500	5/6	--		ug/l
Strontium	5/5	3110	SWSD0008	7820	SWSD0013	1450	5/5	--		ug/l
Thallium	1/6	5.3	IA06-SW0002	5.3	IA06-SW0002	--	--	--	2	ug/l
Vanadium	4/6	1.2 B	SWSD0013	5.5	IA06-SW0002	2.2	1/4	--		ug/l
Zinc	2/6	11.8	SWSD0015	14.4	IA06-SW0002	--	--	300	4700	ug/l
Indicator Parameters										
Alkalinity	5/5	187	SWSD0008	298 J	SWSD0014	--	--	--		mg/l
Ammonia	4/5	0.04 J	SWSD0008	5.55	SWSD0014	--	--	--		mg/l
Chloride	1/1	63.3	SWSD0013	63.3	SWSD0013	--	--	--		mg/l
Fluoride	10/10	0.18	IA06-SW0002	0.979	SWSD0013	0.18	9/10	--	4000	mg/l
Nitrate, as N	1/1	1.31	SWSD0013	1.31	SWSD0013	--	--	--		mg/l
Phosphorus	1/1	0.134 J	SWSD0013	0.134 J	SWSD0013	--	--	--		mg/l
Sulfate	1/1	355	SWSD0013	355	SWSD0013	--	--	--		mg/l
Total dissolved solids	5/5	622	SWSD0008	920	SWSD0014	--	--	--		mg/l
Total suspended solids	5/5	9.67	SWSD0014	18.3	SWSD0008	--	--	--		mg/l
Semivolatile Organics										
bis(2-ethylhexyl)phthalate	1/5	35.9	SWSD0008	35.9	SWSD0008	--	--	--	6	ug/l

Table 4.18. Toussaint Creek: Summary of Surface Water Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Water Quality Criteria[1]	MCL	Units
Volatile Organics										
Acetone	1/5	4.4 J	SWSD0008	4.4 J	SWSD0008	--	--	--		ug/l
Chloroform	1/5	0.16 J	SWSD0008	0.16 J	SWSD0008	--	--	--		ug/l
Toluene	1/5	1 J	SWSD0015	1 J	SWSD0015	--	--	--	1000	ug/l
Radiological Parameters										
Actinium-227	3/14	0.426	SWSD0013	0.523	SWSD0015	0.36	3/3	--		pCi/l
Gross Alpha	3/3	2.02 J	IA06-SW0002	10.2	IA06-SW0002	--	--	--		pCi/l
Nonvolatile Beta	3/3	4.21 J	IA06-SW0002	84.4	IA06-SW0002	--	--	--		pCi/l
Potassium-40	2/14	36.7 J	IA06-SW0002	451	SWSD0008	--	--	--		pCi/l
Radium-226	9/14	0.198	SWSD0008	1.1	IA06-SW0002	0.24	7/9	--		pCi/l
Radium-228	1/14	1.31	IA06-SW0002	1.31	IA06-SW0002	--	--	--		pCi/l
Thorium-227	3/5	0.426	SWSD0013	0.523	SWSD0015	0.36	3/3	--		pCi/l
Thorium-228	4/14	0.14 J	IA06-SW0002	0.326 J	IA06-SW0002	--	--	--		pCi/l
Thorium-230	5/14	0.0793	IA06-SW0002	0.438 J	IA06-SW0002	0.57	0/5	--		pCi/l
Uranium-233/234	9/9	0.276 J	IA06-SW0002	2.86	IA06-SW0002	--	--	--		pCi/l
Uranium-234	5/5	0.286	SWSD0013	0.672	SWSD0008	0.78	0/5	--		pCi/l
Uranium-235	1/9	0.3 J	IA06-SW0002	0.3 J	IA06-SW0002	--	--	--		pCi/l
Uranium-238	12/14	0.144 J	IA06-SW0002	3.19	IA06-SW0002	1.02	1/12	--		pCi/l

1 - Lake Erie Basin water quality criteria (Ohio Administrative Code 3745-1-33)

Table 4.19. On Site Surface Water: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Water Quality Criteria[1]	MCL	Units
Metals										
Aluminum	9/15	38.5 B	SWSD0021	3340	SWSD0009	733	2/9	--		ug/l
Arsenic	3/20	2.6 B	SWSD0022	8.4	IA06-SD0004	--	--	150	50	ug/l
Barium	20/20	13.4	SWSD0022	233	SWSD0020	38.8	14/20	--	2000	ug/l
Beryllium	16/20	0.23 B	SWSD0019	83.6	IA06-SD0004	--	--	--	4	ug/l
Boron	15/15	53.8	SWSD0022	748	SWSD0021	--	--	--		ug/l
Cadmium	6/15	0.43 B	SWSD0007	3.7 B	SWSD0020	--	--	5.3	5	ug/l
Calcium	14/15	30800	SWSD0021	158000	SWSD0010	89400	8/14	--		ug/l
Chromium	9/15	0.63 B	SWSD0007	42.8	SWSD0021	1.2	6/9	180	100	ug/l
Cobalt	7/15	0.95 B	SWSD0012	5 B	SWSD0021	--	--	--		ug/l
Copper	14/15	4.3 B	SWSD0022	1940	SWSD0020	4.6	13/14	23		ug/l
Iron	13/15	165	SWSD0007	9610	SWSD0020	871	6/13	--		ug/l
Lead	10/20	1.8	IA06-SD0001	416	SWSD0020	1.2	10/10	21		ug/l
Magnesium	15/15	615	SWSD0022	104000	SWSD0009	27000	10/15	--		ug/l
Manganese	14/15	2.6 B	SWSD0022	248	SWSD0006	19.7	9/14	--		ug/l
Mercury	5/15	0.11 B	SWSD0011	0.65	SWSD0020	--	--	0.0013		ug/l
Molybdenum	3/15	5.4 B	SWSD0011	49	SWSD0022	11.1	2/3	--		ug/l
Nickel	14/15	3.9 B	SWSD0012	124	SWSD0021	--	--	130	100	ug/l
Potassium	15/15	2440	SWSD0023	62600	SWSD0021	1570	15/15	--		ug/l
Selenium	1/15	4.3 B	SWSD0021	4.3 B	SWSD0021	--	--	4.6	50	ug/l
Silicon	15/15	2340	SWSD0022	39100	SWSD0021	3620	12/15	--		ug/l
Silver	1/15	1.2 B	SWSD0023	1.2 B	SWSD0023	--	--	--		ug/l
Sodium	15/15	38500	SWSD0020	1730000 J	SWSD0021	18500	15/15	--		ug/l
Strontium	15/15	409	SWSD0012	16800	SWSD0009	1450	9/15	--		ug/l
Vanadium	7/15	0.47 B	SWSD0019	12.5	SWSD0021	2.2	4/7	--		ug/l
Zinc	15/15	12.2	SWSD0022	592	SWSD0020	--	--	300	4700	ug/l
Indicator Parameters										
Alkalinity	15/15	69	SWSD0022	1850 J	SWSD0021	--	--	--		mg/l
Ammonia	15/15	0.08	SWSD0007	26.8	SWSD0012	--	--	--		mg/l
Chloride	7/7	12.8	SWSD0022	961	SWSD0010	--	--	--		mg/l
Fluoride	10/12	0.31	IA06-SD0003	9.11	SWSD0022	0.18	10/10	--	4000	mg/l
Nitrate, as N	5/7	0.015 J	SWSD0022	1.47 J	SWSD0004	--	--	--		mg/l
Phosphorus	6/7	0.036 J	SWSD0007	5.96	SWSD0016	--	--	--		mg/l
Sulfate	7/7	50.2	SWSD0016	378	SWSD0022	--	--	--		mg/l
Total dissolved solids	15/15	341	SWSD0020	4860	SWSD0021	--	--	--		mg/l
Total suspended solids	14/15	3.2 J	SWSD0023	518	SWSD0020	--	--	--		mg/l

Table 4.19. On Site Surface Water: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Water Quality Criteria[1]	MCL	Units
Semivolatile Organics										
Di-n-octylphthalate	1/20	10.8	SWSD0016	10.8	SWSD0016	--	--	--		ug/l
Diethyl phthalate	2/20	5.1 J	SWSD0012	8.3 J	SWSD0011	--	--	--		ug/l
Phenol	2/17	5.8 J	SWSD0011	6.4 J	SWSD0012	--	--	--	9400	ug/l
bis(2-ethylhexyl)phthalate	3/20	8.5 J	SWSD0011	25.4	SWSD0004	--	--	--	6	ug/l
m,p-cresol	2/12	17.3	SWSD0012	21.3	SWSD0011	--	--	--		ug/l
Volatile Organics										
1,1,1-Trichloroethane	1/20	0.31 J	SWSD0023	0.31 J	SWSD0023	--	--	--	200	ug/l
1,1-Dichloroethane	1/20	31.9 J	SWSD0021	31.9 J	SWSD0021	--	--	--	7	ug/l
2-Butanone	1/20	9.1 J	IA06-SD0004	9.1 J	IA06-SD0004	--	--	--	8600	ug/l
Acetone	5/15	4.4 J	SWSD0006	254 J	SWSD0021	--	--	--		ug/l
Bromodichloromethane	3/15	0.33 J	SWSD0005	0.78 J	SWSD0023	--	--	--		ug/l
Carbon disulfide	2/20	0.7 J	IA06-SD0003	1 J	IA06-SD0002	--	--	--		ug/l
Chloroform	3/20	0.23 J	SWSD0007	0.76 J	SWSD0005	--	--	--		ug/l
Dibromochloromethane	3/15	0.22 J	SWSD0005	3.4 J	SWSD0019	--	--	--		ug/l
Methylene chloride	2/20	6.6 J	SWSD0023	8230 B	SWSD0021	--	--	--	5	ug/l
Tetrachloroethene	1/20	1.3 J	IA06-SD0001	1.3 J	IA06-SD0001	--	--	--	5	ug/l
Toluene	3/20	0.73 J	IA06-SD0003	1280	SWSD0021	--	--	--	1000	ug/l
Tribromomethane	2/15	6 J	SWSD0019	12.5 J	SWSD0023	--	--	--		ug/l
Trichloroethene	1/20	118 J	SWSD0021	118 J	SWSD0021	--	--	--	5	ug/l
Xylenes (total)	1/20	8 J	SWSD0021	8 J	SWSD0021	--	--	--	10000	ug/l
cis-1,2-dichloroethene	1/15	37.9 J	SWSD0021	37.9 J	SWSD0021	--	--	--		ug/l
Radiological Parameters										
Actinium-227	1/20	0.598	SWSD0005	0.598	SWSD0005	0.36	1/1	--		pCi/l
Potassium-40	4/20	257 J	SWSD0021	519	SWSD0012	--	--	--		pCi/l
Radium-226	14/20	0.239	SWSD0012	2.52	IA06-SD0004	0.24	13/14	--		pCi/l
Radium-228	3/20	0.324	SWSD0009	0.792 J	IA06-SD0003	--	--	--		pCi/l
Thorium-227	1/15	0.598	SWSD0005	0.598	SWSD0005	0.36	1/1	--		pCi/l
Thorium-228	2/20	0.246 J	IA06-SD0004	0.324	SWSD0009	--	--	--		pCi/l
Thorium-230	6/20	0.18 J	IA06-SD0002	0.459 J	IA06-SD0001	0.57	0/6	--		pCi/l
Thorium-232	1/20	0.105 J	IA06-SD0004	0.105 J	IA06-SD0004	--	--	--		pCi/l
Uranium-233/234	2/5	0.18 J	IA06-SD0001	0.874 J	IA06-SD0003	--	--	--		pCi/l
Uranium-234	7/15	0.308	SWSD0022	2.54	SWSD0006	0.78	1/7	--		pCi/l
Uranium-238	9/20	0.31	SWSD0010	3.27	SWSD0006	1.02	2/9	--		pCi/l

1 - Lake Erie Basin water quality criteria (Ohio Administrative Code 3745-1-33)

Table 4.20. Summary of Analytical Results in Meander Bend Samples

Station	Sample ID	Depth (ft bgs)	Beryllium (mg/kg)	Lead (mg/kg)
IA10-SB0006	LUSB0776	0.0-1.0	11.3	--
IA10-SB0006	LUSB0777	1.0-2.0	7.5	--
IA10-SB0006	LUSB0827	1.0-2.0	17.3	--
IA10-SB0007	LUSB0778	0.0-1.0	24	27.5
IA10-SB0008	LUSB0780	0.0-1.0	17.8	31.2
IA10-SB0008	LUSB0781	1.0-2.0	24.2	25.5
IA10-SB0008	LUSB0771	2.0-2.6	1.4	--
IA10-SB0009	LUSB0782	0.0-1.0	11.2	24
IA10-SB0009	LUSB0783	1.0-2.0	10.1	--
IA10-SB0010	LUSB0784	0.0-1.0	14.5	29.2
IA10-SB0010	LUSB0785	1.0-1.9	43.9	34.7
IA10-SB0011	LUSB0786	0.0-1.0	24.5	26.5
IA10-SB0011	LUSB0787	1.0-2.0	89.7	24.6
IA10-SB0011	LUSB0832	2.0-3.0	3.2	--
IA10-SB0012	LUSB0788	0.0-1.0	10.9	25.3
IA10-SB0012	LUSB0789	1.0-2.0	26.4	--
IA10-SB0012	LUSB0835	2.0-3.0	1.7	--
IA10-SB0012	LUSB0837	4.0-5.0	1.8	--
IA10-SB0013	LUSB0790	0.0-1.0	11.1	--
IA10-SB0013	LUSB0791	1.0-2.0	2.4	--
IA10-SB0014	LUSB0792	0.0-1.0	9.8	24.5
IA10-SB0014	LUSB0793	1.0-2.0	41.5	24.4
IA10-SB0014	LUSB0839	2.0-3.0	6.2	--
IA10-SB0015	LUSB0772	0.0-1.0	55.5	28
IA10-SB0015	LUSB0794	1.0-2.0	38.2	--
IA10-SB0015	LUSB0842	2.0-3.0	3.5	--
IA10-SB0015	LUSB0843	3.0-4.0	1.9	--
IA10-SB0016	LUSB0796	0.0-1.0	15.9	23.7
IA10-SB0016	LUSB0797	1.0-2.0	27.6	--
IA10-SB0017	LUSB0798	0.0-1.0	12.9	27.6
IA10-SB0017	LUSB0801	1.0-2.0	40	27.2
IA10-SB0017	LUSB0845	2.0-3.0	13.2	--
IA10-SB0018	LUSB0799	0.0-1.0	14.4	--
IA10-SB0018	LUSB0800	1.0-2.0	21.2	28.2
IA10-SB0018	LUSB0844	2.0-3.0	31.8	--
IA10-SB0019	LUSB0802	0.0-1.0	27.7	30.5
IA10-SB0019	LUSB0803	1.0-2.0	29	30.9
IA10-SB0020	LUSB0773	0.0-1.0	18.5	27.4

-- Parameter not detected above background.
bgs - below ground surface

Table 4.21. Concentrations of Radium-226 above Background in Sediments

Station	Sample ID	Radium-226 (pCi/g)
IA06-SD0001	LUSD0005	1.95
IA06-SD0004	LUSD0002	1.87
IA06-SD0033	LUSD0097	1.79
SWSD0004	LU00071	1.91 J
SWSD0004	LU00071	1.66
SWSD0005	LU00073	4.77 J
SWSD0006	LU00075	9.09 J
SWSD0013	LU00089	1.85
SWSD0015	LU00093	1.69
SWSD0016	LU00095	2.31 J
SWSD0022	LU00107	2.76 J
SWSD0022	LU00125	2.97 J

Table 4.22. Northern Farm Field: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Metals									
Arsenic	17/17	5	IA10-SB0031	14.8	IA10-SB0023	24.1	0/17	4	mg/kg
Barium	17/17	79.8	IA10-SB0033	129	IA10-SB0023	209	0/17	5375	mg/kg
Beryllium	49/49	0.63 B	IA09-OMW-32(B)	744	IA10-SB0043	1.13	37/49	154	mg/kg
Lead	17/17	12.9 *	IA10-SB0031	174	IA10-SB0043	23.2	5/17	400	mg/kg
Radiological Parameters									
Actinium-227	3/17	0.207 J	IA10-SB0044	0.243 J	IA10-SB0023	1.76	0/3	--	pCi/g
Actinium-228	17/17	0.919 J	IA10-SB0044	1.4	IA10-SB0023	1.35	1/17	--	pCi/g
Cesium-137	15/17	0.105	IA10-SB0037	0.322	IA10-SB0043	0.72	0/15	--	pCi/g
Potassium-40	17/17	22.5	IA10-SB0035	26.1	IA10-SB0023	27.2	0/17	--	pCi/g
Radium-226	17/17	1.45	IA10-SB0035	6.56	IA10-SB0023	2.97	3/17	--	pCi/g
Radium-228	17/17	0.919 J	IA10-SB0044	1.4	IA10-SB0023	1.48	0/17	--	pCi/g
Thorium-228	17/17	0.878 J	IA10-SB0034	1.5	IA10-SB0040	1.6	0/17	--	pCi/g
Thorium-230	17/17	1.39	IA10-SB0035	9	IA10-SB0023	3.2	4/17	--	pCi/g
Thorium-232	17/17	0.6 J	IA10-SB0036	1.32	IA10-SB0038	1.48	0/17	--	pCi/g
Thorium-234	13/17	1.26 J	IA10-SB0031	6.18	IA10-SB0043	3.07	3/13	--	pCi/g
Uranium-233/234	17/17	0.937 J	IA10-SB0039	5.83	IA10-SB0023	2.01	4/17	--	pCi/g
Uranium-235	8/17	0.0516	IA10-SB0039	0.374 J	IA10-SB0023	0.25	1/8	--	pCi/g
Uranium-238	17/17	0.918 J	IA10-SB0033	5.75	IA10-SB0023	2.63	3/17	--	pCi/g

*USEPA Region 9 PRG

Table 4.23. NYC Railroad Area: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Metals									
Arsenic	10/10	2.4 N	IA10-SB0051	15.6 N	IA10-SB0045	24.1	0/10	4	mg/kg
Barium	10/10	25.4	IA10-SB0053	479	IA10-SB0045	209	1/10	5375	mg/kg
Beryllium	18/18	2.2 N	IA10-SB0046	2560 N	IA10-SB0051	1.13	18/18	154	mg/kg
Lead	10/10	8.9 N	IA10-SB0045	338 N	IA10-SB0050	23.2	7/10	400	mg/kg
Radiological Parameters									
Actinium-227	7/18	0.159 J	IA10-SB0092	1.05 J	IA10-SB0051	1.76	0/7	--	pCi/g
Actinium-228	17/18	0.527 J	IA10-SB0049	1.33	IA10-SB0045	1.35	0/17	--	pCi/g
Cesium-137	16/18	0.15	IA10-SB0052	0.984	IA10-SB0047	0.72	2/16	--	pCi/g
Potassium-40	18/18	2.1	IA10-SB0053	26.2	IA10-SB0052	27.2	0/18	--	pCi/g
Radium-226	18/18	1.09	IA10-SB0046	24.7	IA10-SB0051	2.97	4/18	--	pCi/g
Radium-228	17/18	0.527 J	IA10-SB0049	1.33	IA10-SB0045	1.48	0/17	--	pCi/g
Thorium-228	18/18	0.248 J	IA10-SB0053	1.27	IA10-SB0094	1.6	0/18	--	pCi/g
Thorium-230	18/18	0.951 J	IA10-SB0097	14.8	IA10-SB0051	3.2	3/18	--	pCi/g
Thorium-232	17/18	0.508 J	IA10-SB0097	1.15	IA10-SB0045	1.48	0/17	--	pCi/g
Thorium-234	13/18	1.28 J	IA10-SB0090	16.3	IA10-SB0051	3.07	5/13	--	pCi/g
Uranium-233/234	18/18	0.761 J	IA10-SB0095	17.8	IA10-SB0051	2.01	5/18	--	pCi/g
Uranium-235	10/18	0.0813	IA10-SB0046	1.42	IA10-SB0051	0.25	3/10	--	pCi/g
Uranium-238	18/18	0.908 J	IA10-SB0046	16.6	IA10-SB0051	2.63	5/18	--	pCi/g

*USEPA Region 9 PRG

Table 4.24. France Stone Quarry: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Metals									
Arsenic	16/16	1.4	IA10-SB0068	12.5	IA10-SB0072	24.1	0/16	4	mg/kg
Barium	16/16	8.4	IA10-SB0076	160	IA10-SB0072	209	0/16	5375	mg/kg
Beryllium	16/16	0.11 B	IA10-SB0071	2.5	IA10-SB0072	1.13	2/16	154	mg/kg
Lead	16/16	9.2	IA10-SB0025	233	IA10-SB0072	23.2	6/16	400	mg/kg
Indicator Parameters									
Fluoride	15/16	0.5 J	IA10-SB0068	5.47	IA10-SB0076	6.94	0/15	3666	mg/kg
Volatile Organics									
2-Hexanone	1/1	9.9 J	IA10-SB0025	9.9 J	IA10-SB0025	--	--	--	ug/kg
Benzene	1/1	1.4 J	IA10-SB0025	1.4 J	IA10-SB0025	--	--	0.7	ug/kg
Ethylbenzene	1/1	1 J	IA10-SB0025	1 J	IA10-SB0025	--	--	230	ug/kg
Toluene	1/1	1.7 J	IA10-SB0025	1.7 J	IA10-SB0025	--	--	520	ug/kg
Xylenes (total)	1/1	0.66 J	IA10-SB0025	0.66 J	IA10-SB0025	--	--	210	ug/kg
Radiological Parameters									
Actinium-228	8/16	0.173 J	IA10-SB0025	1.04	IA10-SB0072	1.35	0/8	--	pCi/g
Cesium-137	13/16	0.044 J	IA10-SB0069	0.364	IA10-SB0075	0.72	0/13	--	pCi/g
Potassium-40	15/16	0.927 J	IA10-SB0070	20.5	IA10-SB0079	27.2	0/15	--	pCi/g
Radium-226	16/16	0.0861	IA10-SB0076	2.31	IA10-SB0072	2.97	0/16	--	pCi/g
Radium-228	9/16	0.173 J	IA10-SB0025	1.04	IA10-SB0072	1.48	0/9	--	pCi/g
Thorium-228	11/16	0.166 J	IA10-SB0069	1.06	IA10-SB0072	1.6	0/11	--	pCi/g
Thorium-230	14/16	0.231 J	IA10-SB0071	1.97	IA10-SB0078	3.2	0/14	--	pCi/g
Thorium-232	11/16	0.154 J	IA10-SB0069	1.04	IA10-SB0072	1.48	0/11	--	pCi/g
Thorium-234	7/16	0.662 J	IA10-SB0071	2.95 J	IA10-SB0074	3.07	0/7	--	pCi/g
Uranium-233/234	14/16	0.166 J	IA10-SB0068	1.74	IA10-SB0072	2.01	0/14	--	pCi/g
Uranium-235	1/16	0.3 J	IA10-SB0072	0.3 J	IA10-SB0072	0.25	1/1	--	pCi/g
Uranium-238	14/16	0.199 J	IA10-SB0071	1.76	IA10-SB0072	2.63	0/14	--	pCi/g

*USEPA Region 9 PRG

Table 4.25. Western Farm Field: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Metals									
Aluminum	1/1	19900	IA10-SB0024	19900	IA10-SB0024	23700	0/1	76142	mg/kg
Arsenic	16/16	5.8	IA10-SB0059	14.1	IA10-SB0024	24.1	0/16	4	mg/kg
Barium	16/16	99.5 *	IA10-SB0024	133 *	IA10-SB0065	209	0/16	5375	mg/kg
Beryllium	18/18	0.73	IA10-SB0024	1.2	IA10-SB0065	1.13	3/18	154	mg/kg
Calcium	1/1	4650	IA10-SB0024	4650	IA10-SB0024	55100	0/1	--	mg/kg
Chromium	1/1	28.8	IA10-SB0024	28.8	IA10-SB0024	29.6	0/1	210.7	mg/kg
Cobalt	1/1	12.9 *	IA10-SB0024	12.9 *	IA10-SB0024	19.1	0/1	4693	mg/kg
Copper	1/1	25.4	IA10-SB0024	25.4	IA10-SB0024	42	0/1	2905	mg/kg
Iron	1/1	33600	IA10-SB0024	33600	IA10-SB0024	38600	0/1	23463	mg/kg
Lead	16/16	13.7	IA10-SB0058	23.6	IA10-SB0064	23.2	1/16	400	mg/kg
Magnesium	1/1	6400	IA10-SB0024	6400	IA10-SB0024	17100	0/1	--	mg/kg
Manganese	1/1	371 *	IA10-SB0024	371 *	IA10-SB0024	2340	0/1	1762	mg/kg
Mercury	1/1	0.03 B	IA10-SB0024	0.03 B	IA10-SB0024	0.19	0/1	2.3	mg/kg
Nickel	1/1	34.6 *	IA10-SB0024	34.6 *	IA10-SB0024	46.1	0/1	1564	mg/kg
Phosphorus	1/1	514	IA10-SB0024	514	IA10-SB0024	808	0/1	--	mg/kg
Potassium	1/1	2600	IA10-SB0024	2600	IA10-SB0024	3410	0/1	--	mg/kg
Selenium	1/1	2.7	IA10-SB0024	2.7	IA10-SB0024	2.33	1/1	391	mg/kg
Sodium	1/1	77.2 E	IA10-SB0024	77.2 E	IA10-SB0024	285	0/1	--	mg/kg
Thallium	1/1	0.84 B	IA10-SB0024	0.84 B	IA10-SB0024	2.1	0/1	0.6	mg/kg
Vanadium	1/1	41.2	IA10-SB0024	41.2	IA10-SB0024	42.8	0/1	547	mg/kg
Zinc	1/1	91.2	IA10-SB0024	91.2	IA10-SB0024	110	0/1	23463	mg/kg
Volatile Organics									
Acetone	1/1	19.3 B	IA10-SB0024	19.3 B	IA10-SB0024	--	--	1570	ug/kg
Chloroform	1/1	0.58 JB	IA10-SB0024	0.58 JB	IA10-SB0024	--	--	0.2	ug/kg
Toluene	1/1	0.9 J	IA10-SB0024	0.9 J	IA10-SB0024	--	--	520	ug/kg
Radiological Parameters									
Actinium-228	16/16	1	IA10-SB0057	1.42	IA10-SB0058	1.35	1/16	--	pCi/g
Cesium-137	14/16	0.0872	IA10-SB0064	0.214	IA10-SB0056	0.72	0/14	--	pCi/g
Potassium-40	16/16	23.7	IA10-SB0056	28.7	IA10-SB0064	27.2	5/16	--	pCi/g
Radium-226	16/16	1.46	IA10-SB0066	1.86	IA10-SB0064	2.97	0/16	--	pCi/g
Radium-228	16/16	1	IA10-SB0057	1.42	IA10-SB0058	1.48	0/16	--	pCi/g
Thorium-228	16/16	0.766 J	IA10-SB0060	4.09	IA10-SB0067	1.6	1/16	--	pCi/g
Thorium-230	16/16	1.49	IA10-SB0065	2.96	IA10-SB0067	3.2	0/16	--	pCi/g
Thorium-232	16/16	0.744 J	IA10-SB0060	1.46	IA10-SB0024	1.48	0/16	--	pCi/g
Thorium-234	10/16	1.61 J	IA10-SB0024	3.18 J	IA10-SB0063	3.07	1/10	--	pCi/g
Uranium-233/234	16/16	0.996 J	IA10-SB0055	1.53	IA10-SB0024	2.01	0/16	--	pCi/g
Uranium-235	3/16	0.0909	IA10-SB0060	0.12 J	IA10-SB0057	0.25	0/3	--	pCi/g
Uranium-238	16/16	0.982 J	IA10-SB0063	1.52	IA10-SB0024	2.63	0/16	--	pCi/g

*USEPA Region 9 PRG

Table 4.26. Troy Township Dump: Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Metals									
Arsenic	17/18	0.96 B	IA10-SB0028	18.3	IA10-SB0088	24.1	0/17	4	mg/kg
Barium	18/18	30.4	IA10-SB0027	3460	IA10-SB0029	209	5/18	5375	mg/kg
Beryllium	31/32	0.08	IA10-SB0026	46.7	IA10-SB0026	1.13	4/31	154	mg/kg
Lead	17/18	1.1	IA10-SB0027	114	IA10-SB0026	23.2	3/17	400	mg/kg
Indicator Parameters									
Fluoride	17/18	0.7	IA10-SB0087	10.9	IA10-SB0028	6.94	4/17	3666	mg/kg
Nitrogen, Ammonia	18/18	2.38	IA10-SB0026	81.7	IA10-SB0026	--	--	--	mg/kg
Radiological Parameters									
Actinium-227	4/18	0.362 J	IA10-SB0088	1.15 J	IA10-SB0088	1.76	0/4	--	pCi/g
Actinium-228	12/18	0.283 J	IA10-SB0027	1.19	IA10-SB0087	1.35	0/12	--	pCi/g
Cesium-137	4/18	0.0589	IA10-SB0026	0.349	IA10-SB0029	0.72	0/4	--	pCi/g
Potassium-40	11/18	0.486 J	IA10-SB0029	29.9	IA10-SB0087	27.2	1/11	--	pCi/g
Radium-226	17/18	0.0744	IA10-SB0026	2.22	IA10-SB0087	2.97	0/17	--	pCi/g
Radium-228	13/18	0.283 J	IA10-SB0027	1.19	IA10-SB0087	1.48	0/13	--	pCi/g
Thorium-228	13/18	0.17 J	IA10-SB0027	1.04	IA10-SB0088	1.6	0/13	--	pCi/g
Thorium-230	16/18	0.187 J	IA10-SB0027	2.21	IA10-SB0088	3.2	0/16	--	pCi/g
Thorium-232	12/18	0.0943	IA10-SB0028	1.23	IA10-SB0087	1.48	0/12	--	pCi/g
Thorium-234	8/18	0.97 J	IA10-SB0027	2.42 J	IA10-SB0088	3.07	0/8	--	pCi/g
Uranium-233/234	17/18	0.0967	IA10-SB0028	1.35	IA10-SB0087	2.01	0/17	--	pCi/g
Uranium-235	3/18	0.0859	IA10-SB0030	0.122 J	IA10-SB0087	0.25	0/3	--	pCi/g
Uranium-238	17/18	0.167 J	IA10-SB0029	1.75	IA10-SB0088	2.63	0/17	--	pCi/g

*USEPA Region 9 PRG

SECTION 4: LIST OF FIGURES

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IA01-SB0001

1.0-2.0	FT	Beryllium	5130 MG/KG
3.0-4.0	FT	Beryllium	1830 MG/KG
5.0-6.0	FT	Beryllium	65.3 MG/KG

IA01-SB0002

1.0-2.0	FT	Beryllium	968 MG/KG
3.0-4.0	FT	Beryllium	29.9 MG/KG
5.0-6.0	FT	Beryllium	156 MG/KG
8.0-9.0	FT	Beryllium	16.4 MG/KG

IA01-SB0003

1.0-2.0	FT	Beryllium	734 MG/KG
3.0-4.0	FT	Beryllium	462 MG/KG
8.0-9.0	FT	Beryllium	1.6 MG/KG
8.5-9.5	FT	Beryllium	8.5 MG/KG
10.0-11.0	FT	Beryllium	2 MG/KG

IA01-SB0004

1.0-2.0	FT	Beryllium	141 N MG/KG
5.0-6.0	FT	Beryllium	127 N MG/KG
6.0-7.0	FT	Beryllium	335 N MG/KG

IA01-SB0007

1.0-2.0	FT	Beryllium	1760 MG/KG
3.0-4.0	FT	Beryllium	179 MG/KG
5.0-6.0	FT	Beryllium	2.4 MG/KG

IA01-SB0008

1.0-2.0	FT	Beryllium	5.5 MG/KG
5.0-6.0	FT	Beryllium	8.9 MG/KG

IA01-SB0009

1.0-2.0	FT	Beryllium	1630 MG/KG
3.0-4.0	FT	Beryllium	5.3 MG/KG
7.0-8.0	FT	Beryllium	11.4 MG/KG

IA01-SB0010

3.0-4.0	FT	Beryllium	1.8 B MG/KG

IA01-SB0011

2.0-3.5	FT	Beryllium	25.5 * MG/KG

IA01-SB0012

1.0-2.0	FT	Beryllium	2350 * MG/KG

IA01-SB0013

3.0-4.0	FT	Beryllium	13.1 MG/KG
5.0-6.0	FT	Beryllium	18.4 MG/KG

IA01-SB0014

1.0-2.0	FT	Beryllium	95.3 N MG/KG
5.0-5.8	FT	Beryllium	9.6 N MG/KG

IA01-SB0015

1.0-2.0	FT	Beryllium	912 N MG/KG
3.0-4.0	FT	Beryllium	879 N MG/KG
5.0-6.0	FT	Beryllium	74.9 N MG/KG
7.0-8.0	FT	Beryllium	41.3 N MG/KG

IA01-SB0016

1.0-2.0	FT	Beryllium	588 N MG/KG

IA01-SB0017

2.0-3.0	FT	Beryllium	243 N* MG/KG
8.0-9.0	FT	Beryllium	1.6 N* MG/KG

IA01-SB0018

1.0-2.0	FT	Beryllium	1420 * MG/KG
6.0-7.0	FT	Beryllium	22.9 * MG/KG
13.0-14.0	FT	Beryllium	3 * MG/KG

IA01-SB0019

1.0-2.0	FT	Beryllium	310 MG/KG
3.0-4.0	FT	Beryllium	47.6 MG/KG
5.0-6.0	FT	Beryllium	93.4 MG/KG
6.0-7.0	FT	Beryllium	108 MG/KG

IA01-SB0020

3.0-4.0	FT	Beryllium	27.6 MG/KG
5.0-6.0	FT	Beryllium	25.1 MG/KG

IA01-SB0021

1.0-2.0	FT	Beryllium	2.6 MG/KG
3.0-4.0	FT	Beryllium	12.1 MG/KG
5.0-6.0	FT	Beryllium	45.2 MG/KG
6.0-7.0	FT	Beryllium	1.3 MG/KG

IA01-SB0022

1.0-2.0	FT	Beryllium	14.2 MG/KG
3.0-4.0	FT	Beryllium	75.5 MG/KG

IA01-SB0023

1.0-2.0	FT	Beryllium	861 MG/KG
3.0-4.0	FT	Beryllium	440 MG/KG
5.0-6.0	FT	Beryllium	112 MG/KG
8.0-9.0	FT	Beryllium	435 MG/KG
10.0-11.0	FT	Beryllium	14.2 MG/KG
12.0-13.0	FT	Beryllium	10.3 MG/KG
14.0-15.0	FT	Beryllium	4.5 MG/KG
16.0-17.0	FT	Beryllium	11.3 MG/KG

IA01-SB0024

1.0-2.0	FT	Beryllium	327 MG/KG
5.0-6.0	FT	Beryllium	5.4 MG/KG
7.0-8.0	FT	Beryllium	17.1 MG/KG
9.0-10.0	FT	Beryllium	1.5 MG/KG
13.0-14.0	FT	Beryllium	1.6 MG/KG

IA01-SB0025

1.0-2.0	FT	Beryllium	19.3 MG/KG

IA01-SB0026

1.0-2.0	FT	Beryllium	3590 MG/KG
3.0-4.0	FT	Beryllium	1740 MG/KG
5.0-6.0	FT	Beryllium	141 MG/KG
7.0-8.0	FT	Beryllium	23.1 MG/KG
9.0-10.0	FT	Beryllium	6.2 MG/KG
11.0-12.0	FT	Beryllium	10.1 MG/KG

IA01-SB0027

1.0-2.0	FT	Beryllium	2350 MG/KG
3.0-3.6	FT	Beryllium	1490 MG/KG
5.0-6.0	FT	Beryllium	8570 MG/KG
9.0-10.0	FT	Beryllium	59.7 MG/KG
11.0-12.0	FT	Beryllium	102 MG/KG
13.0-14.0	FT	Beryllium	3.6 MG/KG
15.0-16.0	FT	Beryllium	7.3 MG/KG

IA01-SB0028

1.0-2.0	FT	Beryllium	470 MG/KG
3.0-4.0	FT	Beryllium	16.8 MG/KG
6.0-8.0	FT	Beryllium	206 MG/KG
9.0-10.0	FT	Beryllium	5.1 MG/KG

IA01-SB0029

1.0-2.0	FT	Beryllium	5010 MG/KG
2.7-3.3	FT	Beryllium	1.5 MG/KG
5.0-6.0	FT	Beryllium	36.3 MG/KG

IA01-SB0030

1.0-2.0	FT	Beryllium	73.3 MG/KG
4.0-6.0	FT	Beryllium	311 MG/KG
9.0-10.0	FT	Beryllium	3.2 MG/KG

IA01-SB0031

1.0-2.0	FT	Beryllium	31.4 MG/KG
3.0-4.0	FT	Beryllium	2.1 MG/KG
5.0-6.0	FT	Beryllium	1.6 MG/KG
9.0-10.0	FT	Beryllium	1.7 MG/KG
11.0-12.0	FT	Beryllium	1.7 MG/KG

IA01-SB0032

1.0-2.0	FT	Beryllium	50.7 MG/KG
3.0-4.0	FT	Beryllium	25.9 MG/KG
5.0-6.0	FT	Beryllium	303 MG/KG
7.0-8.0	FT	Beryllium	90.4 MG/KG
10.0-11.0	FT	Beryllium	1.4 B MG/KG
10.0-12.0	FT	Beryllium	111 MG/KG
11.0-12.0	FT	Beryllium	2.3 B MG/KG
12.0-13.0	FT	Beryllium	1.8 B MG/KG

IA01-SB0033

1.0-2.0	FT	Beryllium	2200 MG/KG
3.0-4.0	FT	Beryllium	17.9 MG/KG
5.0-6.0	FT	Beryllium	1.2 MG/KG

IA01-SB0034

1.0-2.0	FT	Beryllium	3290 MG/KG
3.0-3.5	FT	Beryllium	7.5 MG/KG
5.0-6.0	FT	Beryllium	43.8 MG/KG

IA01-SB0035

1.0-2.0	FT	Beryllium	8700 MG/KG
3.0-4.0	FT	Beryllium	70 MG/KG
5.0-6.0	FT	Beryllium	4.3 MG/KG
7.0-8.0	FT	Beryllium	1.5 MG/KG
9.0-10.0	FT	Beryllium	2.3 MG/KG

IA01-SB0036

1.0-2.0	FT	Beryllium	518 MG/KG
3.0-4.0	FT	Beryllium	220 MG/KG
13.5-14.0	FT	Beryllium	4.4 B MG/KG

IA03-SB0002

1.0-2.0	FT	Beryllium	14.3 MG/KG
3.0-4.0	FT	Beryllium	193 MG/KG
5.0-6.0	FT	Beryllium	4.3 MG/KG
7.0-8.0	FT	Beryllium	3.3 MG/KG
9.0-10.0	FT	Beryllium	28.4 MG/KG
11.0-12.0	FT	Beryllium	18.5 MG/KG
13.0-14.0	FT	Beryllium	3.5 MG/KG
17.0-18.0	FT	Beryllium	5.4 MG/KG

IA03-SB0003

1.0-2.0	FT	Beryllium	9.3 MG/KG
3.0-4.0	FT	Beryllium	134 MG/KG
9.0-10.0	FT	Beryllium	10.9 E MG/KG
11.0-12.0	FT	Beryllium	6.3 MG/KG
13.0-14.0	FT	Beryllium	3.4 E MG/KG
17.0-18.0	FT	Beryllium	1.9 MG/KG

IA03-SB0004

1.0-2.0	FT	Beryllium	3.9 MG/KG

IA03-SB0005

1.0-2.0	FT	Beryllium	1.2 MG/KG

IA03-SB0009

1.0-2.0	FT	Beryllium	3.6 MG/KG
3.0-4.0	FT	Beryllium	1.6 MG/KG

IA03-SB0010

1.0-1.5	FT	Beryllium	1.5 E MG/KG

IA03-SB0012

1.0-2.0	FT	Beryllium	2 MG/KG
3.0-3.8	FT	Beryllium	18.6 MG/KG

IA03-SB0013

3.0-4.0	FT	Beryllium	2 MG/KG
11.0-12.0	FT	Beryllium	2.9 MG/KG

IA03-SB0014

1.0-2.0	FT	Beryllium	2.5 MG/KG
3.0-4.0	FT	Beryllium	3.4 MG/KG
15.0-16.0	FT	Beryllium	6 MG/KG

IA03-SB0015

1.0-2.0	FT	Beryllium	489 MG/KG

IA03-SB0017

6.0-7.0	FT	Beryllium	2.4 MG/KG

IA03-TR0002

0.0-0.5	FT	Beryllium	22.4 MG/KG
1.0-2.0	FT	Beryllium	1300 MG/KG
3.0-4.0	FT	Beryllium	125 MG/KG
12.0-13.0	FT	Beryllium	274 MG/KG

IA05-SB0007

0.0-1.0	FT	Beryllium	10.7 MG/KG
1.0-2.0	FT	Beryllium	4 N MG/KG
3.0-4.0	FT	Beryllium	8620 N MG/KG
5.5-6.5	FT	Beryllium	520 N MG/KG
7.5-8.5	FT	Beryllium	97.6 N MG/KG
8.5-9.5	FT	Beryllium	109 N MG/KG

IA05-SB0008

0.0-1.0	FT	Beryllium	59 MG/KG
1.0-2.0	FT	Beryllium	8.5 MG/KG
2.5-4.0	FT	Beryllium	379 MG/KG
5.0-6.0	FT	Beryllium	3.7 MG/KG
6.0-7.0	FT	Beryllium	13.5 MG/KG
6.0-7.0	FT	Beryllium	30.8 MG/KG
8.0-9.0	FT	Beryllium	64.7 MG/KG
9.0-10.0	FT	Beryllium	40.5 MG/KG

IA05-SB0018

1.0-2.0	FT	Beryllium	104 MG/KG
3.0-3.8	FT	Beryllium	21.2 MG/KG
3.8-4.6	FT	Beryllium	5 MG/KG
9.0-10.0	FT	Beryllium	1.9 MG/KG

IA05-SB0019

1.0-2.0	FT	Beryllium	69.6 * MG/KG
3.0-4.0	FT	Beryllium	195 * MG/KG
4.0-5.0	FT	Beryllium	13.2 * MG/KG
9.0-10.0	FT	Beryllium	1.7 * MG/KG

IA05-SB0020

1.0-2.0	FT	Beryllium	225 * MG/KG
3.0-4.0	FT	Beryllium	5.6 * MG/KG

IA05-SB0021

1.0-2.0	FT	Beryllium	6.1 * MG/KG
3.0-4.0	FT	Beryllium	2.5 * MG/KG
4.0-5.0	FT	Beryllium	6.1 * MG/KG

IA05-SB0022

1.0-2.0	FT	Beryllium	9.8 MG/KG

IA05-SB0023

1.0-2.0	FT	Beryllium	20.1 MG/KG
3.0-4.0	FT	Beryllium	125 MG/KG
5.0-6.0	FT	Beryllium	2.9 MG/KG

IA05-SB0024

1.0-2.0	FT	Beryllium	35.3 MG/KG
3.0-4.0	FT	Beryllium	54 MG/KG

IA07-SB0009

0.5-1.5	FT	Beryllium	9.8 MG/KG

IA07-SB0010

0.5-1.5	FT	Beryllium	13.7 MG/KG
2.2-3.3	FT	Beryllium	1.9 MG/KG

08FS01

2.0-2.5	FT	Beryllium	35.7 MG/KG

08FS02

2.0-2.5	FT	Beryllium	178 MG/KG

08FT00

0.0-0.1	FT	Beryllium	20 MG/KG

dtpb

08FT01

0.0-0.1	FT	Beryllium	67.6 MG/KG
0.0-0.1	FT	Beryllium	81.9 MG/KG

08FY00

0.0-0.1	FT	Beryllium	123 MG/KG

08GD00

0.0-0.1	FT	Beryllium	61.9 MG/KG

09EJ01

0.5-1.5	FT	Beryllium	3920 J MG/KG

09EZ01

0.0-0.2	FT	Beryllium	2610 MG/KG

09FU01

2.5-3.5	FT	Beryllium	321 J MG/KG

10CI01

0.0-0.1	FT	Beryllium	47.7 MG/KG

10CJ00

0.0-0.1	FT	Beryllium	71.6 MG/KG

10CJ01

0.0-0.1	FT	Beryllium	473 MG/KG

10DD00

0.5-1.0	FT	Beryllium	756 MG/KG

10FD01

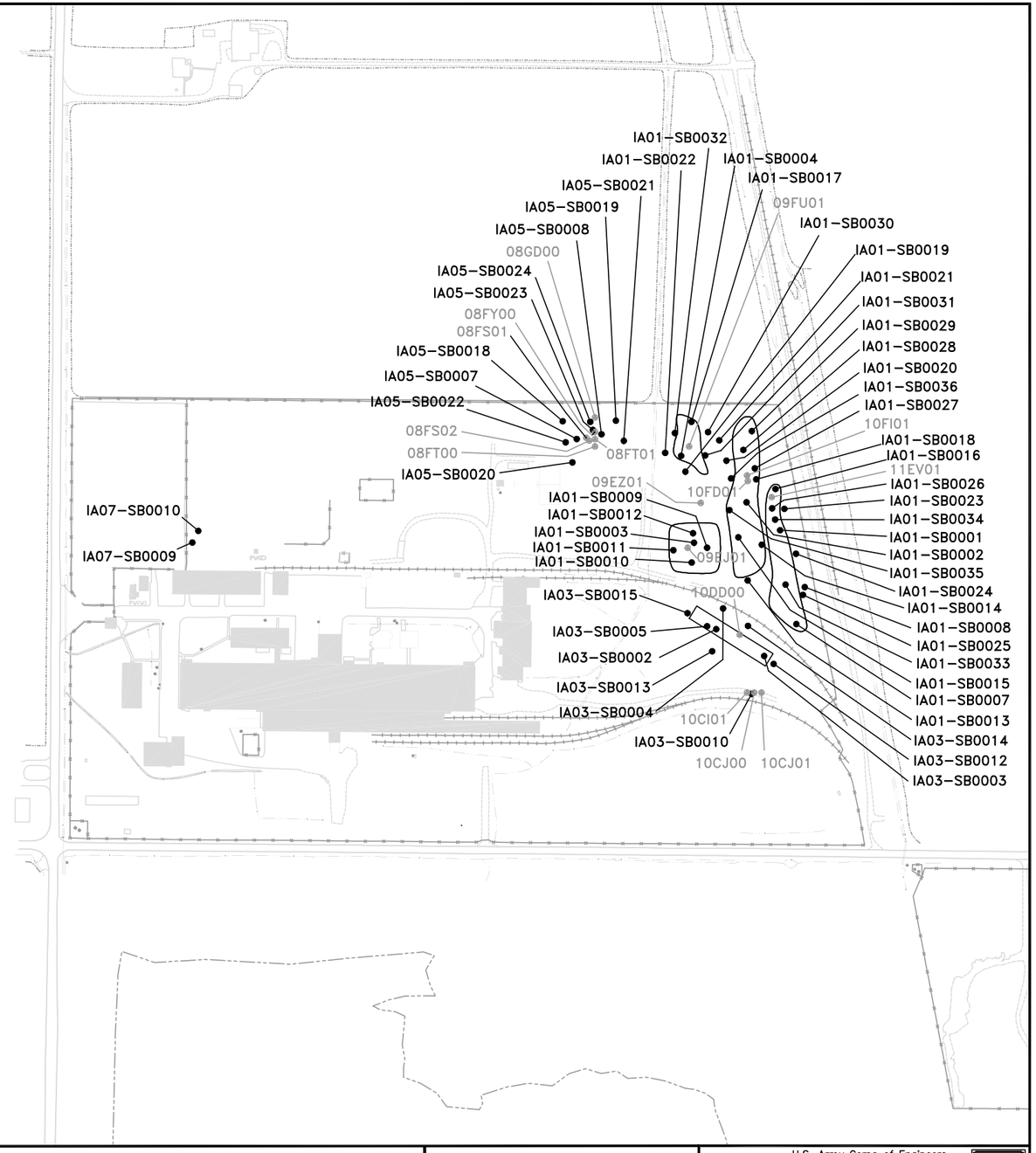
0.0-0.2	FT	Beryllium	5210 MG/KG

10FI01

2.5-3.5	FT	Beryllium	2300 J MG/KG

11EV01

1.5-2.5	FT	Beryllium	819 J MG/KG
1.5-2.5	FT	Beryllium	1270 J MG/KG



BUILDING

LOW LYING AREAS

FENCE LINE

STREAMS & CREEKS

ABANDONED RAILROAD GRADE

PHASE II SOIL BORING

PHASE IV SOIL BORING

TRENCH/PIT BOUNDARY

6.0-7.0 FT Beryllium 2.4 MG/KG — ANALYTICAL RESULTS

N
True North

150 0 150 300
FEET

46 0 46 92
METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Disposal Trenches and Pits
Distribution of Beryllium

Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	02-11-00	AS SHOWN	04-1748-801	4.1

NAME: S:\LUCKEY\C041748\801\RIRPT_DISP-TRENCH-PITS-PB-FL-BA.DWG DATE: APR 12, 2000 TIME: 11:32 AM PCP: S:\PCP\GRAY7,251,252.PCP

IA01-SB0001

1.0-2.0 FT	Lead	70	MG/KG

IA01-SB0002

1.0-2.0 FT	Lead	40.7	MG/KG

IA01-SB0003

1.0-2.0 FT	Lead	1140	MG/KG
8.5-9.5 FT	Lead	40	MG/KG

IA01-SB0004

1.0-2.0 FT	Lead	452 N	MG/KG
6.0-7.0 FT	Arsenic	33.5	MG/KG
6.0-7.0 FT	Lead	80.6 N	MG/KG

IA01-SB0007

1.0-2.0	FT Lead	42.2	MG/KG
1.0-2.0	FT Fluoride	81.4	MG/KG
3.0-4.0	FT Fluoride	29.7	MG/KG
5.0-6.0	FT Fluoride	7.08	MG/KG
9.0-10.0	FT Barium	301	MG/KG

IA01-SB0008

3.0-4.0 FT	Fluoride	9.03	MG/KG
5.0-6.0 FT	Fluoride	21.3	MG/KG

IA01-SB0009

1.0-2.0 FT	Lead	6180	MG/KG
1.0-2.0 FT	Fluoride	161	MG/KG
3.0-4.0 FT	Lead	38.8	MG/KG
7.0-8.0 FT	Lead	66.6	MG/KG

IA01-SB0010

3.0-4.0 FT	Fluoride	26.9	MG/KG

IA01-SB0011

2.0-3.5 FT	Fluoride	48.9	MG/KG

IA01-SB0012

1.0-2.0 FT	Lead	1450 *	MG/KG
1.0-2.0 FT	Fluoride	197	MG/KG
4.0-5.0 FT	Fluoride	26	MG/KG

IA01-SB0013

3.0-4.0 FT	Fluoride	11.3	MG/KG
5.0-6.0 FT	Fluoride	24.2	MG/KG

IA01-SB0014

1.0-2.0 FT	Lead	25.9 N	MG/KG
1.0-2.0 FT	Fluoride	24	MG/KG
3.0-4.5 FT	Fluoride	15.9	MG/KG
5.0-5.8 FT	Lead	49.1 N	MG/KG
5.0-5.8 FT	Fluoride	13.2	MG/KG

IA01-SB0015

1.0-2.0 FT	Lead	289 N	MG/KG
1.0-2.0 FT	Fluoride	168	MG/KG
3.0-4.0 FT	Lead	2110 N	MG/KG
3.0-4.0 FT	Fluoride	187	MG/KG
5.0-6.0 FT	Lead	279 N	MG/KG
5.0-6.0 FT	Fluoride	44.2	MG/KG
7.0-8.0 FT	Fluoride	19.7	MG/KG

IA01-SB0016

1.0-2.0 FT	Lead	54.2 N	MG/KG
1.0-2.0 FT	Fluoride	175	MG/KG

IA01-SB0017

2.0-3.0 FT	Lead	600 N*	MG/KG
2.0-3.0 FT	Fluoride	44.9	MG/KG

IA01-SB0018

1.0-2.0 FT	Lead	120 *	MG/KG
1.0-2.0 FT	Fluoride	156	MG/KG
6.0-7.0 FT	Fluoride	9.28	MG/KG

IA01-SB0019

1.0-2.0 FT	Fluoride	260	MG/KG
3.0-4.0 FT	Fluoride	220	MG/KG
5.0-6.0 FT	Fluoride	83	MG/KG
6.0-7.0 FT	Fluoride	112	MG/KG

IA01-SB0020

1.0-2.0 FT	Lead	47.6 *	MG/KG
1.0-2.0 FT	Fluoride	184	MG/KG
3.0-4.0 FT	Fluoride	47.4	MG/KG
5.0-6.0 FT	Fluoride	47.5	MG/KG
6.0-7.0 FT	Fluoride	17.2	MG/KG

IA01-SB0021

1.0-2.0 FT	Fluoride	11.1	MG/KG
3.0-4.0 FT	Fluoride	21.7	MG/KG
5.0-6.0 FT	Fluoride	27.6	MG/KG
6.0-7.0 FT	Fluoride	14.7	MG/KG

IA01-SB0022

1.0-2.0 FT	Fluoride	53.9	MG/KG
3.0-4.0 FT	Fluoride	89.9	MG/KG
5.0-6.0 FT	Fluoride	11.4	MG/KG

IA03-SB0002

3.0-4.0 FT	Lead	34.2	MG/KG

IA03-SB0004

1.0-2.0 FT	Fluoride	8.15	MG/KG

IA03-SB0009

3.0-4.0 FT	Fluoride	10.5	MG/KG
6.0-7.0 FT	Fluoride	7.97	MG/KG

IA03-SB0017

6.0-7.0 FT	Fluoride	9.67	MG/KG

IA05-SB0007

0.0-1.0 FT	Lead	30	MG/KG
0.0-1.0 FT	Fluoride	12.8	MG/KG
3.0-4.0 FT	Lead	73.9	MG/KG
3.0-4.0 FT	Fluoride	47.5	MG/KG
5.5-6.5 FT	Lead	627	MG/KG
7.5-8.5 FT	Fluoride	17.2	MG/KG
8.5-9.5 FT	Fluoride	17.8	MG/KG

IA05-SB0008

0.0-1.0 FT	Lead	67.9	MG/KG
0.0-1.0 FT	Fluoride	41.5	MG/KG
2.5-4.0 FT	Lead	406	MG/KG
5.0-6.0 FT	Barium	789	MG/KG
5.0-6.0 FT	Fluoride	32.9	MG/KG
6.0-7.0 FT	Fluoride	41.7	MG/KG

IA05-SB0018

1.0-2.0 FT	Fluoride	68.4	MG/KG
3.0-3.8 FT	Fluoride	18.4	MG/KG
3.8-4.6 FT	Fluoride	18	MG/KG

IA05-SB0019

1.0-2.0 FT	Fluoride	10.9	MG/KG
3.0-4.0 FT	Fluoride	22.6	MG/KG
4.0-5.0 FT	Fluoride	31.5	MG/KG

IA05-SB0020

1.0-2.0 FT	Lead	51.9	MG/KG
3.0-4.0 FT	Fluoride	8.33	MG/KG
4.0-5.0 FT	Fluoride	10.5	MG/KG

IA05-SB0021

1.0-2.0 FT	Fluoride	20.2	MG/KG
3.0-4.0 FT	Fluoride	17.8	MG/KG
4.0-5.0 FT	Fluoride	19.8	MG/KG

IA07-SB0009

0.5-1.5 FT	Barium	243	MG/KG
0.5-1.5 FT	Lead	242	MG/KG

IA07-SB0010

0.5-1.5 FT	Barium	225	MG/KG
0.5-1.5 FT	Lead	442	MG/KG

03EQ01

2.5-3.0 FT	Lead	58.9	MG/KG

08FS01

2.0-2.5 FT	Lead	27.3	MG/KG

08FS02

2.0-2.5 FT	Lead	45.6	MG/KG
2.0-2.5 FT	Fluoride	30.3	MG/KG

08FT00

0.0-0.1 FT	Lead	30	MG/KG

08FT01

0.0-0.1 FT	Lead	33.8	MG/KG
0.0-0.1 FT	Lead	39.3	MG/KG

08FY00

0.0-0.1 FT	Lead	69.2	MG/KG

08GD00

0.0-0.1 FT	Lead	47.8	MG/KG

09EJ01

0.5-1.5 FT	Arsenic	28.2	MG/KG
0.5-1.5 FT	Lead	2480	MG/KG
0.5-1.5 FT	Fluoride	206	MG/KG

09EZ01

0.0-0.2 FT	Lead	8490	MG/KG
0.0-0.2 FT	Fluoride	558	MG/KG

09FU01

2.5-3.5 FT	Lead	151	MG/KG
2.5-3.5 FT	Fluoride	190	MG/KG

10CI01

0.0-0.1 FT	Lead	58.3	MG/KG

10CJ00

0.0-0.1 FT	Lead	40.6	MG/KG

10CJ01

0.0-0.1 FT	Lead	47.1	MG/KG

10DD00

0.5-1.0 FT	Arsenic	39.4	MG/KG
0.5-1.0 FT	Barium	218 J	MG/KG
0.5-1.0 FT	Lead	780	MG/KG

10FD01

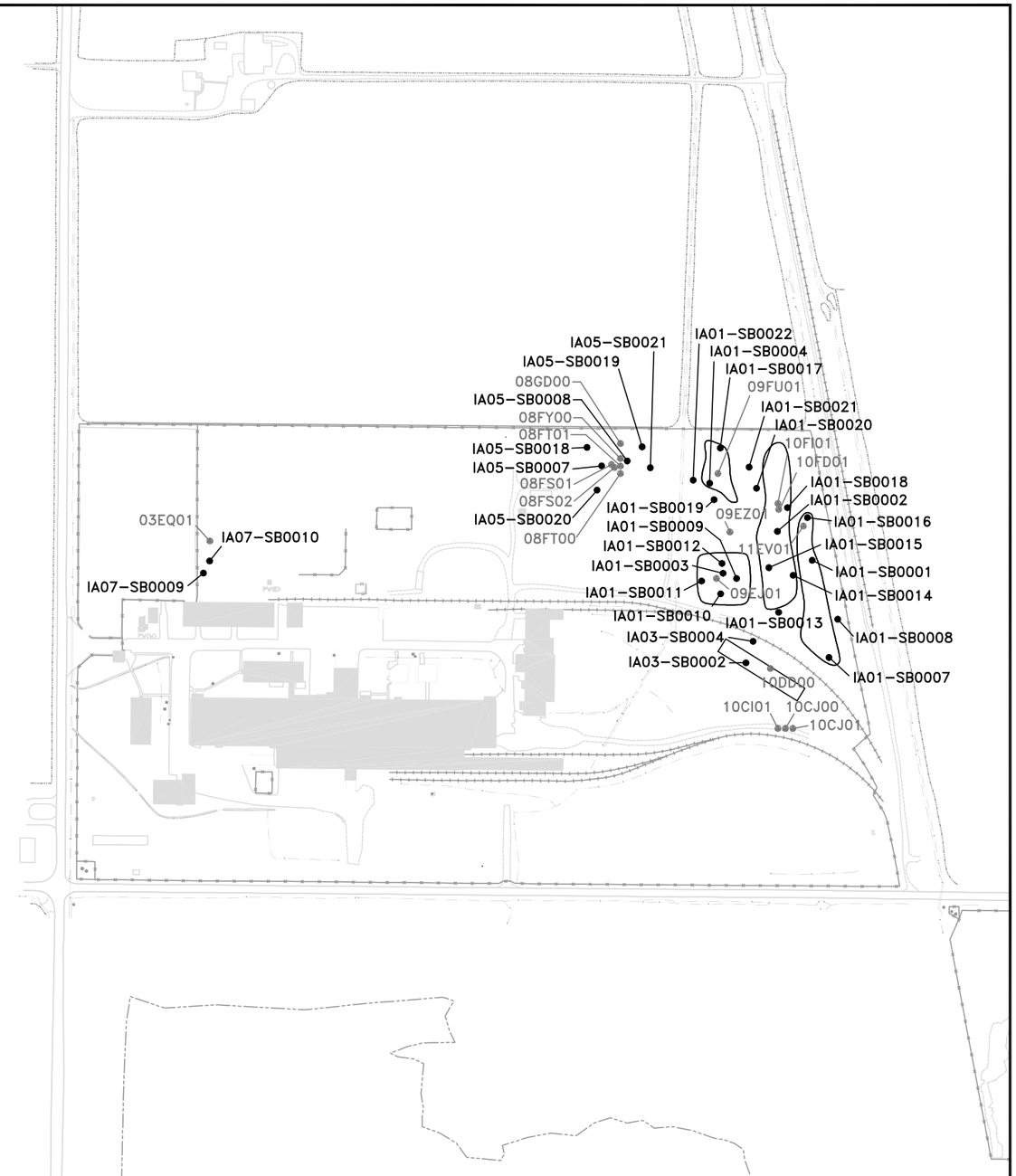
0.0-0.2 FT	Lead	28900 J	MG/KG
0.0-0.2 FT	Fluoride	576	MG/KG

10FI01

2.5-3.5 FT	Lead	52.6	MG/KG
2.5-3.5 FT	Fluoride	213	MG/KG

11EV01

1.5-2.5 FT	Lead	25.8	MG/KG
1.5-2.5 FT	Fluoride	164	MG/KG
1.5-2.5 FT	Fluoride	152	MG/KG



BUILDING

LOW LYING AREAS

FENCE LINE

STREAMS & CREEKS

ABANDONED RAILROAD GRADE

PHASE II SOIL BORING

PHASE IV SOIL BORING

TRENCH/PIT BOUNDARY

6.0-7.0 FT Fluoride 9.67 MG/KG — ANALYTICAL RESULTS

N
True North

150 0 150 300
FEET

46 0 46 92
METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Disposal Trenches and Pits
Distribution of Arsenic, Barium, Fluoride, and Lead in Soil

Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	02-11-00	AS SHOWN	04-1748-801	4.2

NAME: S:\LUCKEY\C041748\801\RIRPT_DISP-TRENCH-PITS-RAD.DWG DATE: APR 19, 2000 TIME: 7:28 PM PCP: S:\PCP\GRAY7,251,252.PCP

IA01-SB0001

1.0-2.0 FT Actinium-227 [AS]	2.06 J	PCI/G
1.0-2.0 FT Radium-226 [GS]	41	PCI/G
1.0-2.0 FT Thorium-230 [AS]	21	PCI/G
1.0-2.0 FT Thorium-234 [GS]	39.8	PCI/G
1.0-2.0 FT Uranium-233/234 [AS]	36.3	PCI/G
1.0-2.0 FT Uranium-235 [AS]	1.94	PCI/G
1.0-2.0 FT Uranium-238 [AS]	37.3	PCI/G
3.0-4.0 FT Radium-226 [GS]	22.4	PCI/G
3.0-4.0 FT Thorium-230 [AS]	8.39	PCI/G
3.0-4.0 FT Thorium-234 [GS]	18.1	PCI/G
3.0-4.0 FT Uranium-233/234 [AS]	13.1	PCI/G
3.0-4.0 FT Uranium-235 [AS]	0.694 J	PCI/G
3.0-4.0 FT Uranium-238 [AS]	12.6	PCI/G

IA01-SB0002

1.0-2.0 FT Radium-226 [GS]	22.9	PCI/G
1.0-2.0 FT Thorium-230 [AS]	12.1	PCI/G
1.0-2.0 FT Thorium-234 [GS]	14.4	PCI/G
1.0-2.0 FT Uranium-235 [GS]	1.36	PCI/G

IA01-SB0003

1.0-2.0 FT Thorium-230 [AS]	6.03	PCI/G
1.0-2.0 FT Uranium-233/234 [AS]	3.59	PCI/G
1.0-2.0 FT Uranium-238 [AS]	3.24	PCI/G
8.5-9.5 FT Thorium-228 [AS]	2.11	PCI/G

IA01-SB0004

1.0-2.0 FT Thorium-230 [AS]	3.84	PCI/G
6.0-7.0 FT Radium-226 [GS]	10.4	PCI/G
6.0-7.0 FT Thorium-230 [AS]	12.6	PCI/G
6.0-7.0 FT Thorium-234 [GS]	10.6	PCI/G
6.0-7.0 FT Uranium-233/234 [AS]	10.4	PCI/G
6.0-7.0 FT Uranium-235 [AS]	0.454 J	PCI/G
6.0-7.0 FT Uranium-238 [AS]	9.37	PCI/G

IA01-SB0007

1.0-2.0 FT Radium-226 [GS]	30	PCI/G
1.0-2.0 FT Thorium-230 [AS]	18.1	PCI/G
1.0-2.0 FT Thorium-234 [GS]	25.3	PCI/G
1.0-2.0 FT Uranium-233/234 [AS]	21.6	PCI/G
1.0-2.0 FT Uranium-235 [AS]	1.08	PCI/G
1.0-2.0 FT Uranium-238 [AS]	20.7	PCI/G
3.0-4.0 FT Actinium-228 [GS]	1.42	PCI/G
3.0-4.0 FT Radium-226 [GS]	13	PCI/G
3.0-4.0 FT Thorium-230 [AS]	8.67	PCI/G
3.0-4.0 FT Thorium-234 [GS]	9.72	PCI/G
3.0-4.0 FT Uranium-233/234 [AS]	9.55	PCI/G
3.0-4.0 FT Uranium-235 [AS]	0.545 J	PCI/G
3.0-4.0 FT Uranium-238 [AS]	9.03	PCI/G
9.0-10.0 FT Potassium-40 [GS]	31.3	PCI/G

IA01-SB0008

5.0-6.0 FT Uranium-235 [GS]	0.3 J	PCI/G

IA01-SB0009

1.0-2.0 FT Radium-226 [GS]	7.28	PCI/G
1.0-2.0 FT Thorium-230 [AS]	21.6	PCI/G
1.0-2.0 FT Thorium-234 [GS]	8.12	PCI/G
1.0-2.0 FT Uranium-233/234 [AS]	8.03	PCI/G
1.0-2.0 FT Uranium-235 [AS]	0.475 J	PCI/G
1.0-2.0 FT Uranium-238 [AS]	8.39	PCI/G

IA01-SB0010

7.0-8.0 FT Uranium-235 [GS]	0.284 J	PCI/G

IA01-SB0012

1.0-2.0 FT Radium-226 [GS]	6.38	PCI/G
1.0-2.0 FT Thorium-228 [AS]	1.69	PCI/G
1.0-2.0 FT Thorium-230 [AS]	21.6	PCI/G
1.0-2.0 FT Thorium-234 [GS]	6.98	PCI/G
1.0-2.0 FT Uranium-233/234 [AS]	11.2	PCI/G
1.0-2.0 FT Uranium-235 [AS]	1.07	PCI/G
1.0-2.0 FT Uranium-238 [AS]	10.9	PCI/G

IA01-SB0014

1.0-2.0 FT Thorium-234 [GS]	4.22 J	PCI/G
1.0-2.0 FT Uranium-233/234 [AS]	2.11	PCI/G

IA01-SB0015

1.0-2.0 FT Radium-226 [GS]	24.6	PCI/G
1.0-2.0 FT Thorium-230 [AS]	17	PCI/G
1.0-2.0 FT Thorium-234 [GS]	18.3	PCI/G
1.0-2.0 FT Uranium-233/234 [AS]	22.8	PCI/G
1.0-2.0 FT Uranium-235 [AS]	0.991 J	PCI/G
1.0-2.0 FT Uranium-238 [AS]	23.6	PCI/G
3.0-4.0 FT Radium-226 [GS]	3.75	PCI/G
3.0-4.0 FT Thorium-230 [AS]	5.02	PCI/G
3.0-4.0 FT Thorium-234 [GS]	3.16 J	PCI/G
3.0-4.0 FT Uranium-233/234 [AS]	4.84	PCI/G
3.0-4.0 FT Uranium-238 [AS]	4.94	PCI/G
5.0-6.0 FT Uranium-233/234 [AS]	2.02	PCI/G

IA01-SB0016

1.0-2.0 FT Radium-226 [GS]	12	PCI/G
1.0-2.0 FT Thorium-230 [AS]	6.26	PCI/G
1.0-2.0 FT Thorium-234 [GS]	10.9	PCI/G
1.0-2.0 FT Uranium-233/234 [AS]	6.83	PCI/G
1.0-2.0 FT Uranium-235 [AS]	0.285 J	PCI/G
1.0-2.0 FT Uranium-238 [AS]	7.15	PCI/G

IA01-SB0017

2.0-3.0 FT Thorium-228 [AS]	1.63	PCI/G
5.0-6.0 FT Potassium-40 [GS]	27.7	PCI/G

IA01-SB0018

1.0-2.0 FT Actinium-227 [AS]	2.03 J	PCI/G
1.0-2.0 FT Radium-226 [GS]	55.4	PCI/G
1.0-2.0 FT Thorium-230 [AS]	26.5	PCI/G
1.0-2.0 FT Thorium-234 [GS]	43.3	PCI/G
1.0-2.0 FT Uranium-233/234 [AS]	43.2	PCI/G
1.0-2.0 FT Uranium-235 [AS]	2.29	PCI/G
1.0-2.0 FT Uranium-238 [AS]	41.5	PCI/G

IA01-SB0019

1.0-2.0 FT Radium-226 [GS]	7.46	PCI/G
1.0-2.0 FT Thorium-230 [AS]	5.88	PCI/G
1.0-2.0 FT Thorium-234 [GS]	6.37	PCI/G
1.0-2.0 FT Uranium-233/234 [AS]	6.5	PCI/G
1.0-2.0 FT Uranium-235 [AS]	0.445 J	PCI/G
1.0-2.0 FT Uranium-238 [AS]	6.7	PCI/G
3.0-4.0 FT Potassium-40 [GS]	28.1	PCI/G

IA01-SB0021

1.0-2.0 FT Thorium-228 [AS]	1.62	PCI/G
6.0-7.0 FT Uranium-235 [GS]	0.278 J	PCI/G

IA03-SB0003

1.0-2.0 FT Uranium-233/234 [AS]	2.8	PCI/G
1.0-2.0 FT Uranium-238 [AS]	2.7	PCI/G

IA03-SB0004

12.0-13.5 FT Uranium-235 [GS]	0.323 J	PCI/G

IA03-SB0005

1.0-2.0 FT Potassium-40 [GS]	28.1	PCI/G

IA03-SB0007

12.0-13.5 FT Thorium-234 [GS]	3.33 J	PCI/G

IA03-SB0009

1.0-2.0 FT Thorium-228 [AS]	1.81	PCI/G
3.0-4.0 FT Potassium-40 [GS]	27.5	PCI/G
3.0-4.0 FT Thorium-228 [AS]	2.1	PCI/G
3.0-4.0 FT Thorium-232 [AS]	1.75	PCI/G

IA03-SB0017

12.0-13.0 FT Uranium-235 [GS]	0.355 J	PCI/G

IA05-SB0007

3.0-4.0 FT Radium-226 [GS]	9.55	PCI/G
3.0-4.0 FT Thorium-230 [AS]	15.7	PCI/G
3.0-4.0 FT Thorium-234 [GS]	6.61	PCI/G
3.0-4.0 FT Uranium-233/234 [AS]	7.98	PCI/G
3.0-4.0 FT Uranium-235 [AS]	0.545 J	PCI/G
3.0-4.0 FT Uranium-238 [AS]	8.11	PCI/G
5.5-6.5 FT Radium-226 [GS]	9.71	PCI/G
5.5-6.5 FT Thorium-230 [AS]	14.5	PCI/G
5.5-6.5 FT Thorium-234 [GS]	5.22	PCI/G
5.5-6.5 FT Uranium-233/234 [AS]	5.47	PCI/G
5.5-6.5 FT Uranium-238 [AS]	4.9	PCI/G
7.5-8.5 FT Radium-226 [GS]	3.02	PCI/G

IA05-SB0008

2.5-4.0 FT Uranium-233/234 [AS]	2.09	PCI/G

IA05-SB0019

9.0-10.0 FT Potassium-40 [GS]	28.4	PCI/G

IA05-SB0020

3.0-4.0 FT Uranium-235 [GS]	0.401 J	PCI/G
4.0-5.0 FT Potassium-40 [GS]	27.6	PCI/G

IA07-SB0009

4.0-5.0 FT Potassium-40 [GS]	29.6	PCI/G
6.5-7.5 FT Thorium-228 [AS]	1.61	PCI/G

IA07-SB0010

5.0-6.0 FT Potassium-40 [GS]	27.5	PCI/G
5.0-6.0 FT Thorium-228 [AS]	1.67	PCI/G

09EH01

0.0-0.5 FT Thorium-230	11.5	PCI/G
0.0-0.5 FT Thorium-230	11.2	PCI/G
0.0-0.5 FT Uranium-234	5.96	PCI/G
0.0-0.5 FT Uranium-234	5.67	PCI/G
0.0-0.5 FT Uranium-238	6.02	PCI/G
0.0-0.5 FT Uranium-238	5.77	PCI/G
0.0-0.5 FT Radium-226	5.59 J	PCI/G
0.0-0.5 FT Radium-226	5.58 J	PCI/G

09EI01

0.0-0.5 FT Thorium-230 [AS]	18.3	PCI/G
0.0-0.5 FT Uranium-234 [AS]	8.07	PCI/G
0.0-0.5 FT Uranium-235 [AS]	0.289	PCI/G
0.0-0.5 FT Uranium-238 [AS]	8.13	PCI/G
0.0-0.5 FT Radium-226 [GS]	9.67 J	PCI/G

09EI02

0.0-0.5 FT Thorium-230	11.8	PCI/G
0.0-0.5 FT Uranium-234	5.46	PCI/G
0.0-0.5 FT Uranium-238	5.25	PCI/G
0.0-0.5 FT Radium-226	9.16 J	PCI/G

09EJ01

0.0-0.5 FT Thorium-230 [AS]	29.4	PCI/G
0.0-0.5 FT Uranium-234 [AS]	16	PCI/G
0.0-0.5 FT Uranium-235 [AS]	0.818	PCI/G
0.0-0.5 FT Uranium-238 [AS]	16.2	PCI/G
0.0-0.5 FT Radium-226 [GS]	16.7 J	PCI/G
0.5-1.5 FT Actinium-227 [AS]	1.98	PCI/G
0.5-1.5 FT Thorium-227 [AS]	1.98	PCI/G
0.5-1.5 FT Thorium-230 [AS]	60.3	PCI/G
0.5-1.5 FT Uranium-234 [AS]	31.1	PCI/G
0.5-1.5 FT Uranium-235 [AS]	1.16	PCI/G
0.5-1.5 FT Uranium-238 [AS]	30.5	PCI/G
0.5-1.5 FT Radium-226 [GS]	34 J	PCI/G

09EJ02

0.0-0.5 FT Thorium-230 [AS]	32.5	PCI/G
0.0-0.5 FT Uranium-234 [AS]	12.6	PCI/G
0.0-0.5 FT Uranium-235 [AS]	0.563	PCI/G
0.0-0.5 FT Uranium-238 [AS]	13.1	PCI/G
0.0-0.5 FT Radium-226 [GS]	9.24 J	PCI/G

09EZ01

0.0-0.2 FT Thorium-230 [AS]	16.4	PCI/G
0.0-0.2 FT Uranium-234 [AS]	12	PCI/G
0.0-0.2 FT Uranium-235 [AS]	0.452	PCI/G
0.0-0.2 FT Uranium-238 [AS]	12	PCI/G
0.0-0.2 FT Radium-226 [GS]	22.6	PCI/G

09FU01

2.5-3.5 FT Thorium-230 [AS]	17.6	PCI/G
2.5-3.5 FT Uranium-234 [AS]	14.5	PCI/G
2.5-3.5 FT Uranium-235 [AS]	0.671	PCI/G
2.5-3.5 FT Uranium-238 [AS]	14	PCI/G
2.5-3.5 FT Radium-226 [GS]	17.4 J	PCI/G

10EF00

0.0-0.5 FT Thorium-230 [AS]	39.8	PCI/G
0.0-0.5 FT Uranium-234 [AS]	13.2	PCI/G
0.0-0.5 FT Uranium-235 [AS]	0.456	PCI/G
0.0-0.5 FT Uranium-238 [AS]	13.1	PCI/G
0.0-0.5 FT Radium-226 [GS]	16.8 J	PCI/G

10EF01

0.0-0.5 FT Thorium-230 [AS]	39	PCI/G
0.0-0.5 FT Uranium-234 [AS]	15.5	PCI/G
0.0-0.5 FT Uranium-235 [AS]	0.544	PCI/G
0.0-0.5 FT Uranium-238 [AS]	14.7	PCI/G
0.0-0.5 FT Radium-226 [GS]	16.6 J	PCI/G

10FD01

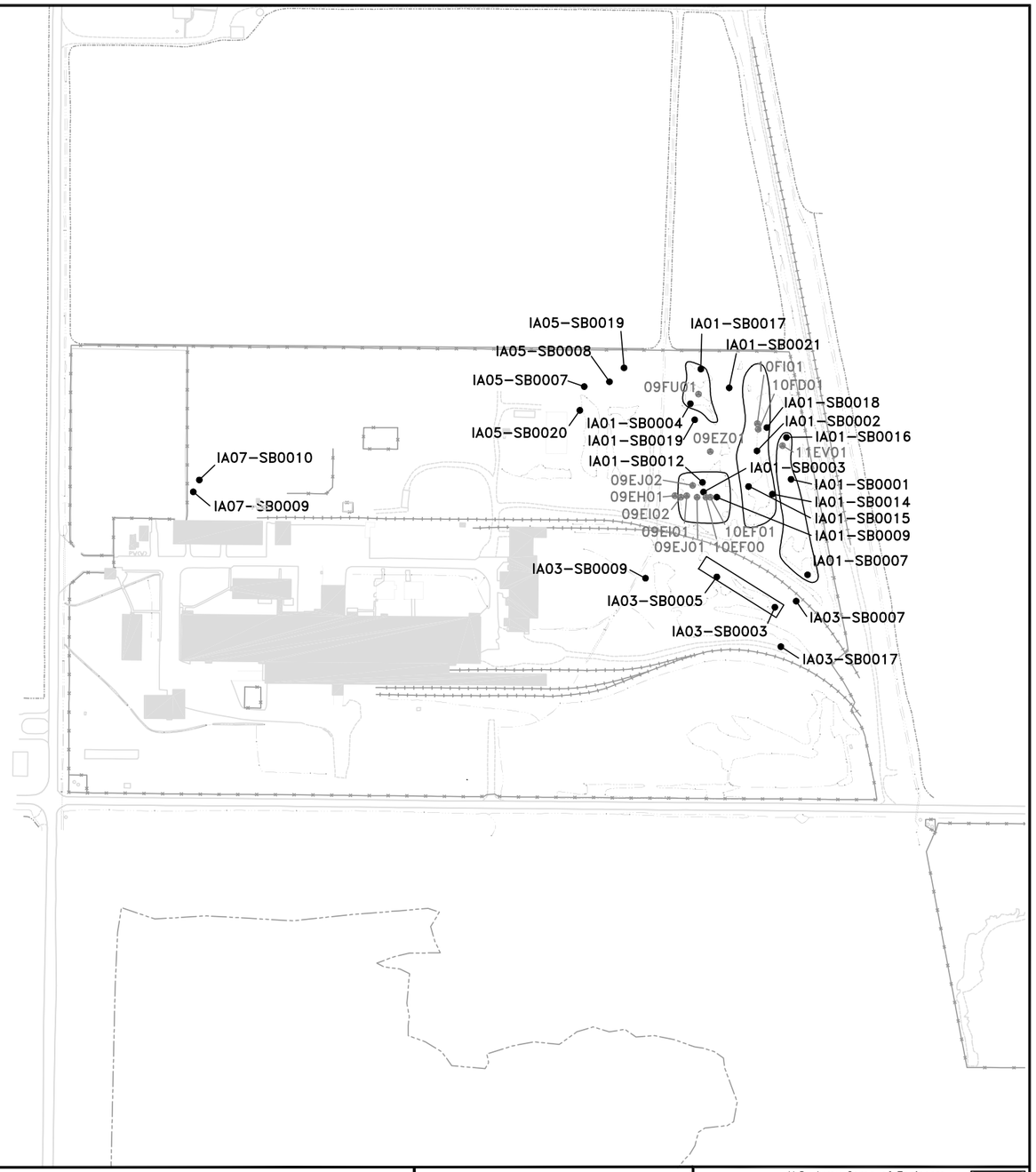
0.0-0.2 FT Thorium-230 [AS]	23.5	PCI/G
0.0-0.2 FT Uranium-234 [AS]	5.5	PCI/G
0.0-0.2 FT Uranium-235 [AS]	0.289	PCI/G
0.0-0.2 FT Uranium-238 [AS]	5.83	PCI/G
0.0-0.2 FT Radium-226 [GS]	9.32	PCI/G

10FI01

2.5-3.5 FT Actinium-227 [AS]	2.08	PCI/G
2.5-3.5 FT Thorium-227 [AS]	2.08	PCI/G
2.5-3.5 FT Thorium-230 [AS]	14	PCI/G
2.5-3.5 FT Uranium-234 [AS]	21.4	PCI/G
2.5-3.5 FT Uranium-235 [AS]	0.782	PCI/G
2.5-3.5 FT Uranium-238 [AS]	21.3	PCI/G
2.5-3.5 FT Radium-226 [GS]	193 J	PCI/G

11EV01

1.5-2.5 FT Uranium-234	3.13	PCI/G
1.5-2.5 FT Uranium-238	2.83	PCI/G
1.5-2.5 FT Radium-226	30.7 J	PCI/G
1.5-2.5 FT Radium-226	30.5 J	PCI/G



BUILDING

LOW LYING AREAS

FENCE LINE

STREAMS & CREEKS

ABANDONED RAILROAD GRADE

PHASE II SOIL BORING

PHASE IV SOIL BORING

TRENCH/PIT BOUNDARY

1.0-2.0 FT Thorium-228 [AS] 1.62 PCI/G — ANALYTICAL RESULTS

N True North

150 0 150 300 FEET

45 0 45 90 METERS

U.S. Army Corps of Engineers
Buffalo District

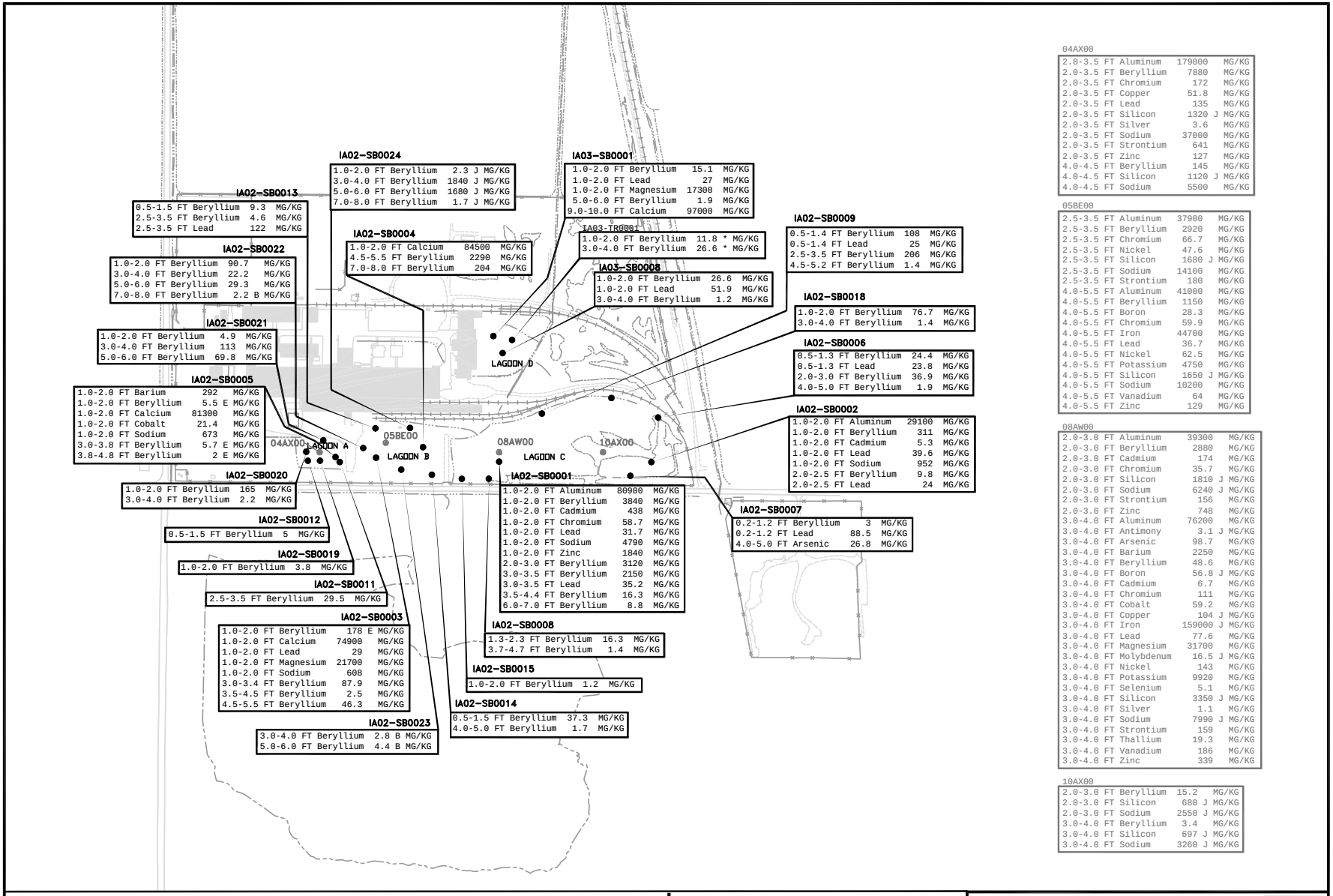
LUCKEY SITE
RI REPORT

Disposal Trenches and Pits
Distribution of Radionuclides in Soil

SAIC Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-25-00	AS SHOWN	04-1748-801	4.3

NAME: S:\LUCKEY\C041748\801\RIRPT_LAGOONS-INORGANICS.DWG DATE: APR 19, 2000 TIME: 6:55 PM PCP: S:\PCP\GRAY7,251,252.PCP



04AX00

2.0-3.5 FT Aluminum	179000	MG/KG
2.0-3.5 FT Beryllium	7880	MG/KG
2.0-3.5 FT Chromium	172	MG/KG
2.0-3.5 FT Copper	51.8	MG/KG
2.0-3.5 FT Lead	135	MG/KG
2.0-3.5 FT Silicon	1320 J	MG/KG
2.0-3.5 FT Silver	3.6	MG/KG
2.0-3.5 FT Sodium	37000	MG/KG
2.0-3.5 FT Strontium	641	MG/KG
2.0-3.5 FT Zinc	127	MG/KG
4.0-4.5 FT Beryllium	145	MG/KG
4.0-4.5 FT Silicon	1120 J	MG/KG
4.0-4.5 FT Sodium	5500	MG/KG

05BE00

2.5-3.5 FT Aluminum	37900	MG/KG
2.5-3.5 FT Beryllium	2920	MG/KG
2.5-3.5 FT Chromium	66.7	MG/KG
2.5-3.5 FT Nickel	47.6	MG/KG
2.5-3.5 FT Silicon	1680 J	MG/KG
2.5-3.5 FT Sodium	14100	MG/KG
2.5-3.5 FT Strontium	180	MG/KG
4.0-5.5 FT Aluminum	41000	MG/KG
4.0-5.5 FT Beryllium	1150	MG/KG
4.0-5.5 FT Boron	28.3	MG/KG
4.0-5.5 FT Chromium	59.9	MG/KG
4.0-5.5 FT Iron	44700	MG/KG
4.0-5.5 FT Lead	36.7	MG/KG
4.0-5.5 FT Nickel	62.5	MG/KG
4.0-5.5 FT Potassium	4750	MG/KG
4.0-5.5 FT Silicon	1650 J	MG/KG
4.0-5.5 FT Sodium	10200	MG/KG
4.0-5.5 FT Vanadium	64	MG/KG
4.0-5.5 FT Zinc	129	MG/KG

08AW00

2.0-3.0 FT Aluminum	39300	MG/KG
2.0-3.0 FT Beryllium	2880	MG/KG
2.0-3.0 FT Cadmium	174	MG/KG
2.0-3.0 FT Chromium	35.7	MG/KG
2.0-3.0 FT Silicon	1810 J	MG/KG
2.0-3.0 FT Sodium	6240 J	MG/KG
2.0-3.0 FT Strontium	156	MG/KG
2.0-3.0 FT Zinc	748	MG/KG
3.0-4.0 FT Aluminum	76200	MG/KG
3.0-4.0 FT Antimony	3.1 J	MG/KG
3.0-4.0 FT Arsenic	98.7	MG/KG
3.0-4.0 FT Barium	2250	MG/KG
3.0-4.0 FT Beryllium	48.6	MG/KG
3.0-4.0 FT Boron	56.8 J	MG/KG
3.0-4.0 FT Cadmium	6.7	MG/KG
3.0-4.0 FT Chromium	111	MG/KG
3.0-4.0 FT Cobalt	59.2	MG/KG
3.0-4.0 FT Copper	104 J	MG/KG
3.0-4.0 FT Iron	159000 J	MG/KG
3.0-4.0 FT Lead	77.6	MG/KG
3.0-4.0 FT Magnesium	31700	MG/KG
3.0-4.0 FT Molybdenum	16.5 J	MG/KG
3.0-4.0 FT Nickel	143	MG/KG
3.0-4.0 FT Potassium	9920	MG/KG
3.0-4.0 FT Selenium	5.1	MG/KG
3.0-4.0 FT Silicon	3350 J	MG/KG
3.0-4.0 FT Silver	1.1	MG/KG
3.0-4.0 FT Sodium	7990 J	MG/KG
3.0-4.0 FT Strontium	159	MG/KG
3.0-4.0 FT Thallium	19.3	MG/KG
3.0-4.0 FT Vanadium	186	MG/KG
3.0-4.0 FT Zinc	339	MG/KG

10AX00

2.0-3.0 FT Beryllium	15.2	MG/KG
2.0-3.0 FT Silicon	680 J	MG/KG
2.0-3.0 FT Sodium	2550 J	MG/KG
3.0-4.0 FT Beryllium	3.4	MG/KG
3.0-4.0 FT Silicon	697 J	MG/KG
3.0-4.0 FT Sodium	3260 J	MG/KG

BUILDING

LOW LYING AREAS

FENCE LINE

STREAMS & CREEKS

ABANDONED RAILROAD GRADE

PHASE II SOIL BORING

PHASE IV SOIL BORING

6.0-7.0 FT Beryllium 2.4 MG/KG ANALYTICAL RESULTS

N True North

250 0 250 500 FEET

89 0 89 178 METERS

U.S. Army Corps of Engineers
Buffalo District

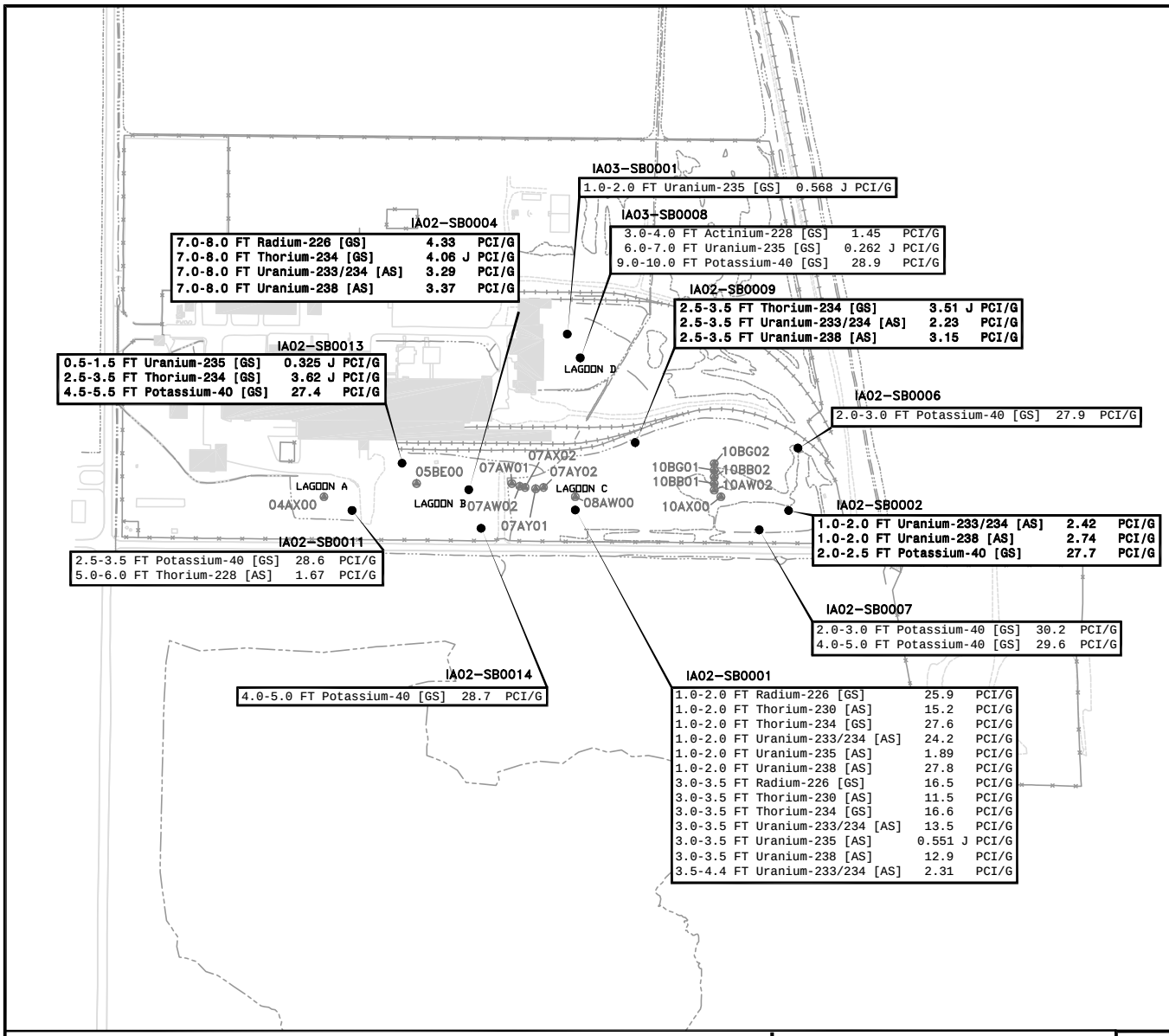
LUCKEY SITE
RI REPORT

Lagoons A, B, C, and D
Distribution of Inorganics in Soil

Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-25-00	AS SHOWN	04-1748-801	4.4

NAME: S:\LUCKEY\C041748\801\RIRPT_LAGOONS-RAD.DWG DATE: APR 19, 2000 TIME: 8:14 PM PCP: S:\PCP\GRAY7,251,252.PCP



04AX00

2.0-3.5 FT Thorium-230 [AS]	25.6 J	PCI/G
2.0-3.5 FT Uranium-234 [AS]	52.3	PCI/G
2.0-3.5 FT Uranium-235 [AS]	0.559 J	PCI/G
2.0-3.5 FT Uranium-238 [AS]	51.1	PCI/G
2.0-3.5 FT Radium-226 [GS]	22.4 J	PCI/G
4.0-4.5 FT Uranium-234 [AS]	4.86	PCI/G
4.0-4.5 FT Uranium-235 [AS]	0.275 J	PCI/G
4.0-4.5 FT Uranium-238 [AS]	4.72	PCI/G

05BE00

2.5-3.5 FT Thorium-230 [AS]	24.6	PCI/G
2.5-3.5 FT Uranium-234 [AS]	13.1	PCI/G
2.5-3.5 FT Uranium-235 [AS]	0.527 J	PCI/G
2.5-3.5 FT Uranium-238 [AS]	14.6	PCI/G
2.5-3.5 FT Radium-226 [GS]	37.4 J	PCI/G
4.0-5.5 FT Uranium-234 [AS]	6.8	PCI/G
4.0-5.5 FT Uranium-235 [AS]	0.268 J	PCI/G
4.0-5.5 FT Uranium-238 [AS]	6.53	PCI/G
4.0-5.5 FT Radium-226 [GS]	6.51 J	PCI/G

07AW01

0.0-0.5 FT Thorium-230	5.62	PCI/G
0.0-0.5 FT Uranium-234	3.24	PCI/G
0.0-0.5 FT Uranium-238	3.18	PCI/G
0.0-0.5 FT Radium-226	6.62 J	PCI/G

07AW02

0.0-0.5 FT Thorium-230	7.47	PCI/G
0.0-0.5 FT Uranium-234	3.11	PCI/G
0.0-0.5 FT Uranium-238	3.34	PCI/G
0.0-0.5 FT Radium-226	6.75 J	PCI/G

07AX02

0.0-0.5 FT Thorium-230	14.3	PCI/G
0.0-0.5 FT Uranium-234	6.38	PCI/G
0.0-0.5 FT Uranium-238	6.66	PCI/G
0.0-0.5 FT Radium-226	12.3 J	PCI/G

07AY01

0.0-0.5 FT Radium-226	3.08 J	PCI/G

07AY02

0.0-0.5 FT Radium-226	3.05 J	PCI/G

08AW00

2.0-3.0 FT Thorium-230 [AS]	6.14	PCI/G
2.0-3.0 FT Uranium-234 [AS]	9.43	PCI/G
2.0-3.0 FT Uranium-235 [AS]	0.416	PCI/G
2.0-3.0 FT Uranium-238 [AS]	9.39	PCI/G
2.0-3.0 FT Radium-226 [GS]	32.1 J	PCI/G
3.0-4.0 FT Potassium-40 [GS]	28 J	PCI/G

10AW02

0.0-0.5 FT Radium-226	4.5 J	PCI/G

10BB01

0.0-0.5 FT Radium-226	5.95 J	PCI/G

10BB02

0.0-0.5 FT Radium-226	5.56 J	PCI/G

10BG01

0.0-0.5 FT Radium-226	10.3 J	PCI/G

10BG02

0.0-0.5 FT Radium-226	3.9 J	PCI/G
0.0-0.5 FT Radium-226	3.92 J	PCI/G

BUILDING

LOW LYING AREAS

FENCE LINE

STREAMS & CREEKS

ABANDONED RAILROAD GRADE

PHASE II SOIL BORING

PHASE IV SOIL BORING

1.0-2.0 FT Radium [AS] 8.15 PCI/G ANALYTICAL RESULTS

N True North

200 0 200 400 FEET

36 0 36 72 METERS

U.S. Army Corps of Engineers
Buffalo District

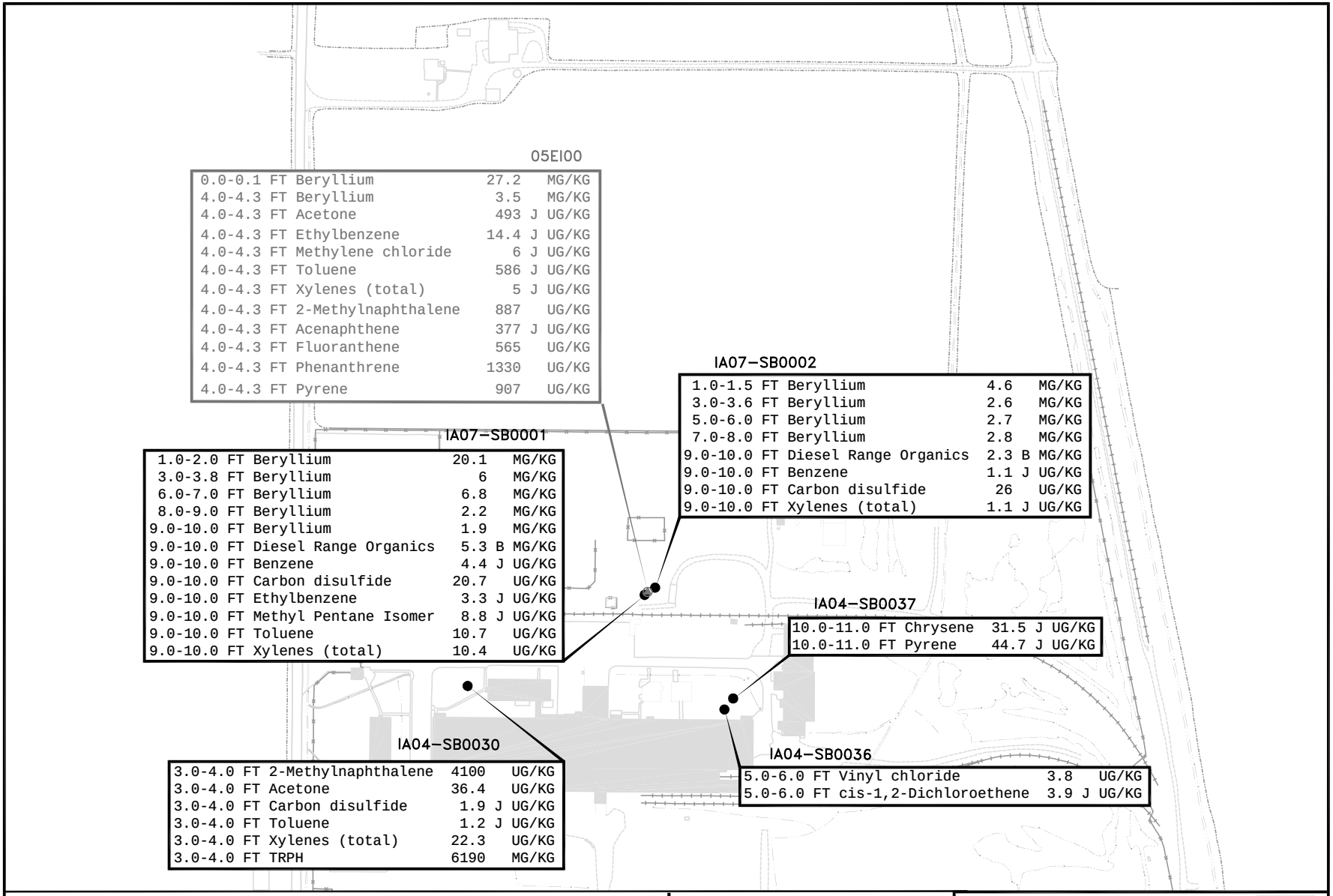
LUCKEY SITE
RI REPORT

Lagoons A, B, C, and D
Distribution of Radionuclides in Soil

SAIC Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-25-00	AS SHOWN	04-1748-801	4.5

NAME: S:\LUCKEY\C041748\801\RIRPT_FORM-PETRO-BLDG-UST-ORG-BE.DWG DATE: APR 19, 2000 TIME: 6:23 PM PCP: S:\PCP\GRAY7,251,252.PCP



BUILDING

LOW LYING AREAS

FENCE LINE

STREAMS & CREEKS

ABANDONED RAILROAD GRADE

PHASE II SOIL BORING

PHASE IV SOIL BORING

6.0-7.0 FT Beryllium 2.4 MG/KG ANALYTICAL RESULTS

N True North

150 0 150 300 FEET

45 0 45 90 METERS

U.S. Army Corps of Engineers
Buffalo District

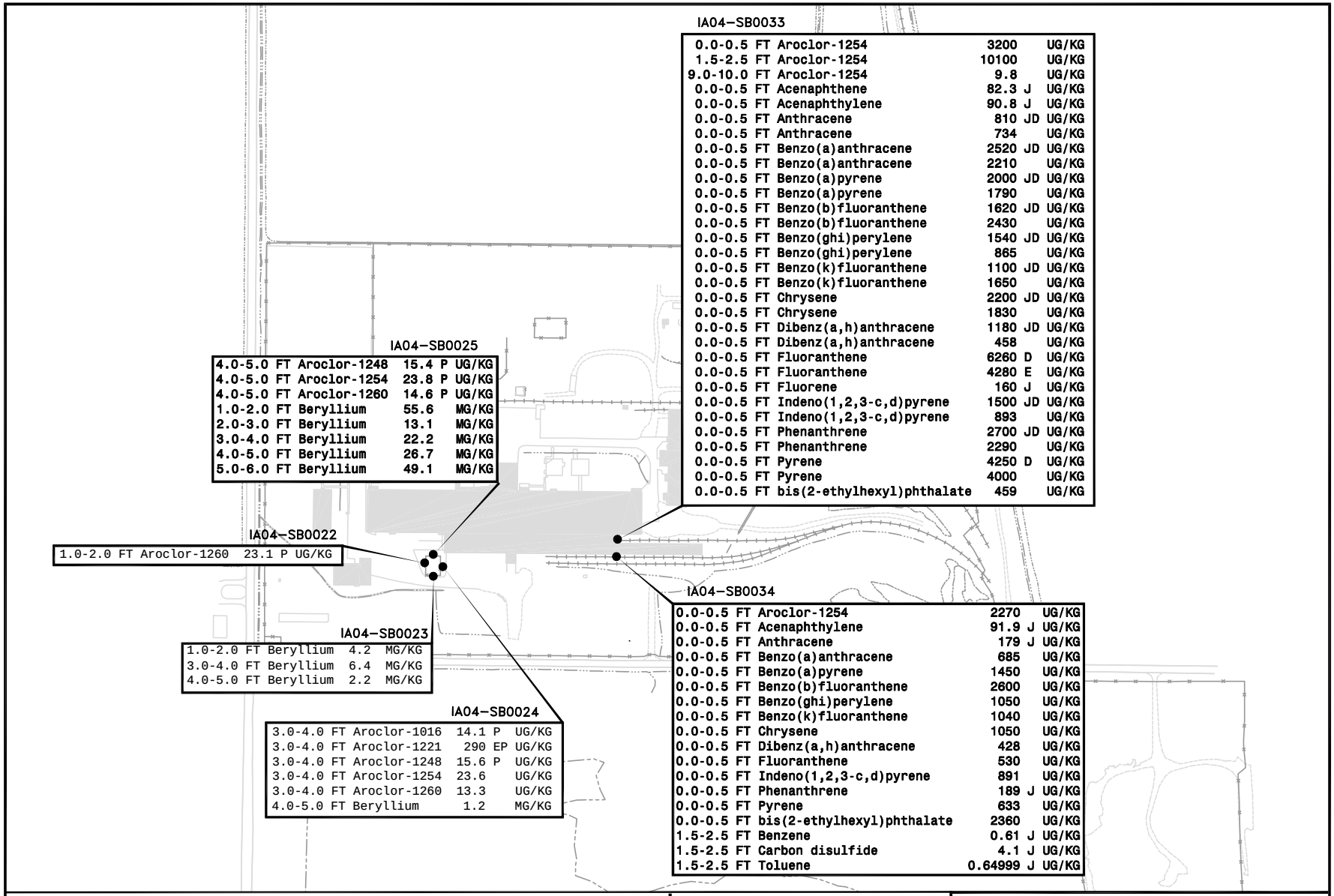
LUCKEY SITE
RI REPORT

Former Petroleum Handling Buildings & UST Area
Distribution of Organics & Beryllium in Soil

SAIC. Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-26-00	AS SHOWN	04-1748-801	4.6

NAME: S:\LUCKEY\C041748\801\RIRPT_ELEC-TRANSFORMER-ORGANIC-BE.DWG DATE: APR 19, 2000 TIME: 5:34 PM PCP: S:\PCP\GREY1.PCP



BUILDING
LOW LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE
PHASE IV SOIL BORING
ANALYTICAL RESULTS

N True North

150 0 150 300 FEET

45 0 45 90 METERS

U.S. Army Corps of Engineers
Buffalo District

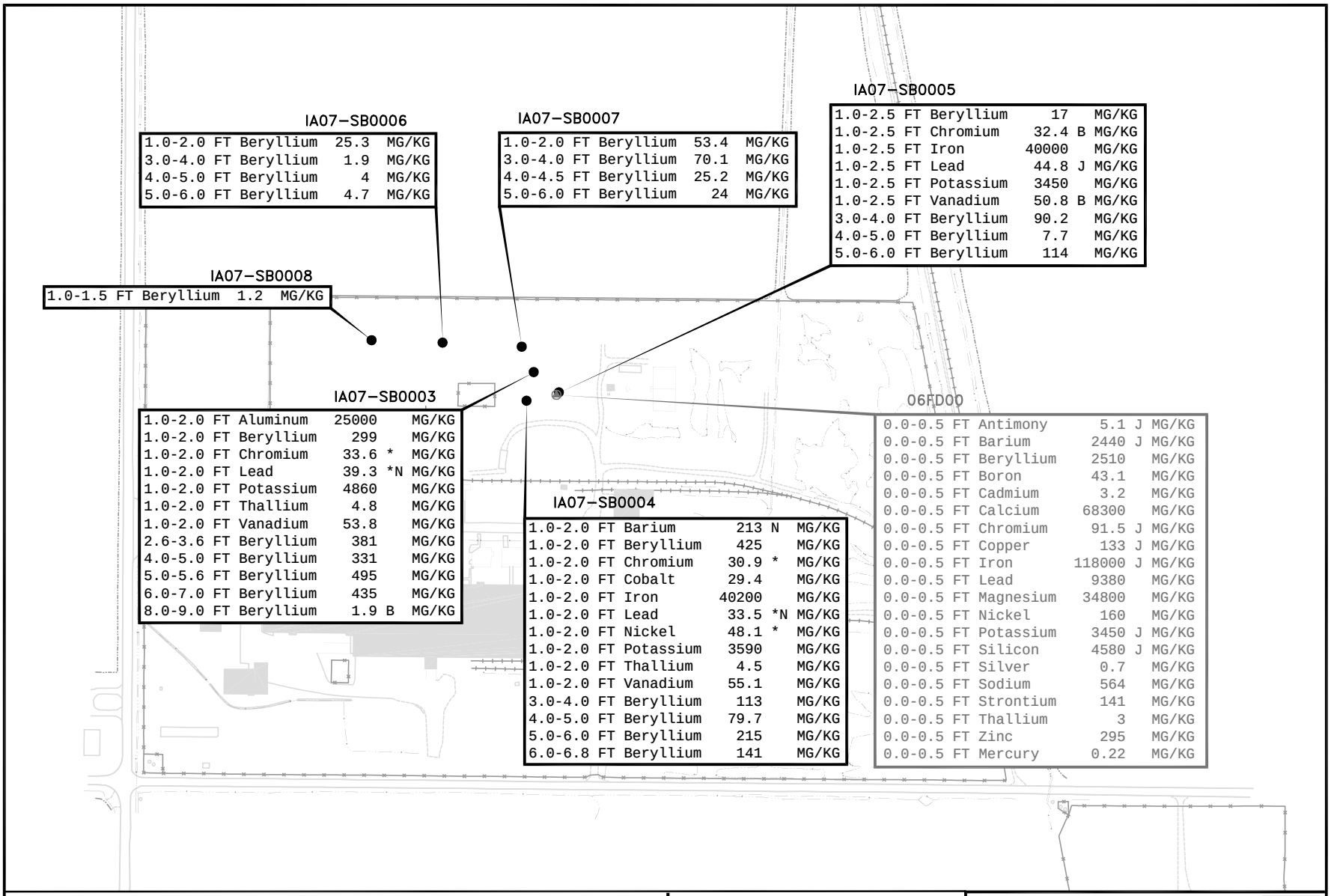
LUCKEY SITE
RI REPORT

Electrical Transformer Areas
Distribution of Organics & Beryllium in Soil

SAIC. Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-26-00	AS SHOWN	04-1748-801	4.7

NAME: S:\LUCKEY\C041748\801\RIRPT_STRESS-VEG-INORGANIC.DWG DATE: APR 19, 2000 TIME: 6:59 PM PCP: S:\PCP\GRAY7,251,252.PCP



BUILDING
LOW LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE

PHASE II SOIL BORING
PHASE IV SOIL BORING

1.0-2.0 FT Nickel 8.15 MG/KG ANALYTICAL RESULTS

N True North

150 0 150 300 FEET

45 0 45 90 METERS

U.S. Army Corps of Engineers
Buffalo District

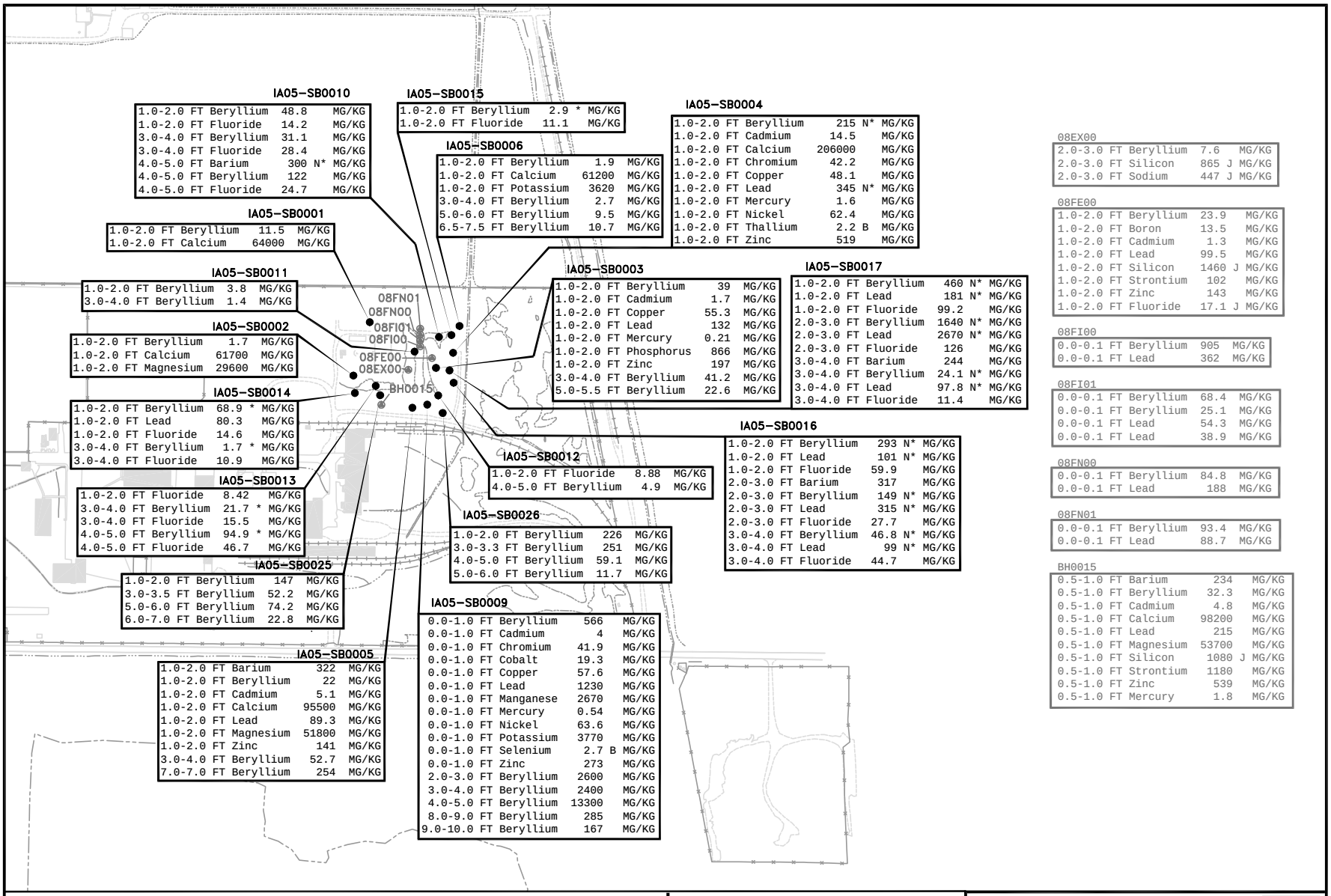
LUCKEY SITE
RI REPORT

Bare Spot and Areas of Stressed Vegetation
Distribution of Inorganics in Soil

SAIC Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-26-00	AS SHOWN	04-1748-801	4.8

NAME: S:\LUCKEY\C041748\801\RIRPT_FILTER-BED-PILES-METS-FL.DWG DATE: APR 19, 2000 TIME: 6:07 PM PCP: S:\PCP\GRAY7,251,252.PCP



IA05-SB0010

1.0-2.0 FT Beryllium	48.8	MG/KG
1.0-2.0 FT Fluoride	14.2	MG/KG
3.0-4.0 FT Beryllium	31.1	MG/KG
3.0-4.0 FT Fluoride	28.4	MG/KG
4.0-5.0 FT Barium	300 N*	MG/KG
4.0-5.0 FT Beryllium	122	MG/KG
4.0-5.0 FT Fluoride	24.7	MG/KG

IA05-SB0015

1.0-2.0 FT Beryllium	2.9 *	MG/KG
1.0-2.0 FT Fluoride	11.1	MG/KG

IA05-SB0006

1.0-2.0 FT Beryllium	1.9	MG/KG
1.0-2.0 FT Calcium	61200	MG/KG
1.0-2.0 FT Potassium	3620	MG/KG
3.0-4.0 FT Beryllium	2.7	MG/KG
5.0-6.0 FT Beryllium	9.5	MG/KG
6.5-7.5 FT Beryllium	10.7	MG/KG

IA05-SB0004

1.0-2.0 FT Beryllium	215 N*	MG/KG
1.0-2.0 FT Cadmium	14.5	MG/KG
1.0-2.0 FT Calcium	206000	MG/KG
1.0-2.0 FT Chromium	42.2	MG/KG
1.0-2.0 FT Copper	48.1	MG/KG
1.0-2.0 FT Lead	345 N*	MG/KG
1.0-2.0 FT Mercury	1.6	MG/KG
1.0-2.0 FT Nickel	62.4	MG/KG
1.0-2.0 FT Thallium	2.2 B	MG/KG
1.0-2.0 FT Zinc	519	MG/KG

IA05-SB0001

1.0-2.0 FT Beryllium	11.5	MG/KG
1.0-2.0 FT Calcium	64000	MG/KG

IA05-SB0011

1.0-2.0 FT Beryllium	3.8	MG/KG
3.0-4.0 FT Beryllium	1.4	MG/KG

IA05-SB0002

1.0-2.0 FT Beryllium	1.7	MG/KG
1.0-2.0 FT Calcium	61700	MG/KG
1.0-2.0 FT Magnesium	29600	MG/KG

IA05-SB0014

1.0-2.0 FT Beryllium	68.9 *	MG/KG
1.0-2.0 FT Lead	80.3	MG/KG
1.0-2.0 FT Fluoride	14.6	MG/KG
3.0-4.0 FT Beryllium	1.7 *	MG/KG
3.0-4.0 FT Fluoride	10.9	MG/KG

IA05-SB0013

1.0-2.0 FT Fluoride	8.42	MG/KG
3.0-4.0 FT Beryllium	21.7 *	MG/KG
3.0-4.0 FT Fluoride	15.5	MG/KG
4.0-5.0 FT Beryllium	94.9 *	MG/KG
4.0-5.0 FT Fluoride	46.7	MG/KG

IA05-SB0025

1.0-2.0 FT Beryllium	147	MG/KG
3.0-3.5 FT Beryllium	52.2	MG/KG
5.0-6.0 FT Beryllium	74.2	MG/KG
6.0-7.0 FT Beryllium	22.8	MG/KG

IA05-SB0005

1.0-2.0 FT Barium	322	MG/KG
1.0-2.0 FT Beryllium	22	MG/KG
1.0-2.0 FT Cadmium	5.1	MG/KG
1.0-2.0 FT Calcium	95500	MG/KG
1.0-2.0 FT Lead	89.3	MG/KG
1.0-2.0 FT Magnesium	51800	MG/KG
1.0-2.0 FT Zinc	141	MG/KG
3.0-4.0 FT Beryllium	52.7	MG/KG
7.0-7.0 FT Beryllium	254	MG/KG

IA05-SB0003

1.0-2.0 FT Beryllium	39	MG/KG
1.0-2.0 FT Cadmium	1.7	MG/KG
1.0-2.0 FT Copper	55.3	MG/KG
1.0-2.0 FT Lead	132	MG/KG
1.0-2.0 FT Mercury	0.21	MG/KG
1.0-2.0 FT Phosphorus	866	MG/KG
1.0-2.0 FT Zinc	197	MG/KG
3.0-4.0 FT Beryllium	41.2	MG/KG
5.0-5.5 FT Beryllium	22.6	MG/KG

IA05-SB0017

1.0-2.0 FT Beryllium	460 N*	MG/KG
1.0-2.0 FT Lead	181 N*	MG/KG
1.0-2.0 FT Fluoride	99.2	MG/KG
2.0-3.0 FT Beryllium	1640 N*	MG/KG
2.0-3.0 FT Lead	2670 N*	MG/KG
2.0-3.0 FT Fluoride	126	MG/KG
3.0-4.0 FT Barium	244	MG/KG
3.0-4.0 FT Beryllium	24.1 N*	MG/KG
3.0-4.0 FT Lead	97.8 N*	MG/KG
3.0-4.0 FT Fluoride	11.4	MG/KG

IA05-SB0016

1.0-2.0 FT Beryllium	293 N*	MG/KG
1.0-2.0 FT Lead	101 N*	MG/KG
1.0-2.0 FT Fluoride	59.9	MG/KG
2.0-3.0 FT Barium	317	MG/KG
2.0-3.0 FT Beryllium	149 N*	MG/KG
2.0-3.0 FT Lead	315 N*	MG/KG
2.0-3.0 FT Fluoride	27.7	MG/KG
3.0-4.0 FT Beryllium	46.8 N*	MG/KG
3.0-4.0 FT Lead	99 N*	MG/KG
3.0-4.0 FT Fluoride	44.7	MG/KG

IA05-SB0012

1.0-2.0 FT Fluoride	8.88	MG/KG
4.0-5.0 FT Beryllium	4.9	MG/KG

IA05-SB0026

1.0-2.0 FT Beryllium	226	MG/KG
3.0-3.3 FT Beryllium	251	MG/KG
4.0-5.0 FT Beryllium	59.1	MG/KG
5.0-6.0 FT Beryllium	11.7	MG/KG

IA05-SB0009

0.0-1.0 FT Beryllium	566	MG/KG
0.0-1.0 FT Cadmium	4	MG/KG
0.0-1.0 FT Chromium	41.9	MG/KG
0.0-1.0 FT Cobalt	19.3	MG/KG
0.0-1.0 FT Copper	57.6	MG/KG
0.0-1.0 FT Lead	1230	MG/KG
0.0-1.0 FT Manganese	2670	MG/KG
0.0-1.0 FT Mercury	0.54	MG/KG
0.0-1.0 FT Nickel	63.6	MG/KG
0.0-1.0 FT Potassium	3770	MG/KG
0.0-1.0 FT Selenium	2.7 B	MG/KG
0.0-1.0 FT Zinc	273	MG/KG
2.0-3.0 FT Beryllium	2600	MG/KG
3.0-4.0 FT Beryllium	2400	MG/KG
4.0-5.0 FT Beryllium	13300	MG/KG
8.0-9.0 FT Beryllium	285	MG/KG
9.0-10.0 FT Beryllium	167	MG/KG

08EX00

2.0-3.0 FT Beryllium	7.6	MG/KG
2.0-3.0 FT Silicon	865 J	MG/KG
2.0-3.0 FT Sodium	447 J	MG/KG

08FE00

1.0-2.0 FT Beryllium	23.9	MG/KG
1.0-2.0 FT Boron	13.5	MG/KG
1.0-2.0 FT Cadmium	1.3	MG/KG
1.0-2.0 FT Lead	99.5	MG/KG
1.0-2.0 FT Silicon	1460 J	MG/KG
1.0-2.0 FT Strontium	102	MG/KG
1.0-2.0 FT Zinc	143	MG/KG
1.0-2.0 FT Fluoride	17.1 J	MG/KG

08FI00

0.0-0.1 FT Beryllium	905	MG/KG
0.0-0.1 FT Lead	362	MG/KG

08FI01

0.0-0.1 FT Beryllium	68.4	MG/KG
0.0-0.1 FT Beryllium	25.1	MG/KG
0.0-0.1 FT Lead	54.3	MG/KG
0.0-0.1 FT Lead	38.9	MG/KG

08FN00

0.0-0.1 FT Beryllium	84.8	MG/KG
0.0-0.1 FT Lead	188	MG/KG

08FN01

0.0-0.1 FT Beryllium	93.4	MG/KG
0.0-0.1 FT Lead	88.7	MG/KG

BH0015

0.5-1.0 FT Barium	234	MG/KG
0.5-1.0 FT Beryllium	32.3	MG/KG
0.5-1.0 FT Cadmium	4.8	MG/KG
0.5-1.0 FT Calcium	98200	MG/KG
0.5-1.0 FT Lead	215	MG/KG
0.5-1.0 FT Magnesium	53700	MG/KG
0.5-1.0 FT Silicon	1080 J	MG/KG
0.5-1.0 FT Strontium	1180	MG/KG
0.5-1.0 FT Zinc	539	MG/KG
0.5-1.0 FT Mercury	1.8	MG/KG

BUILDING
LOW LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE
PHASE II SOIL BORING
PHASE IV SOIL BORING
6.0-7.0 FT Beryllium 2.4 MG/KG
ANALYTICAL RESULTS

N True North

200 0 200 400
FEET

71 0 71 142
METERS

U.S. Army Corps of Engineers
Buffalo District

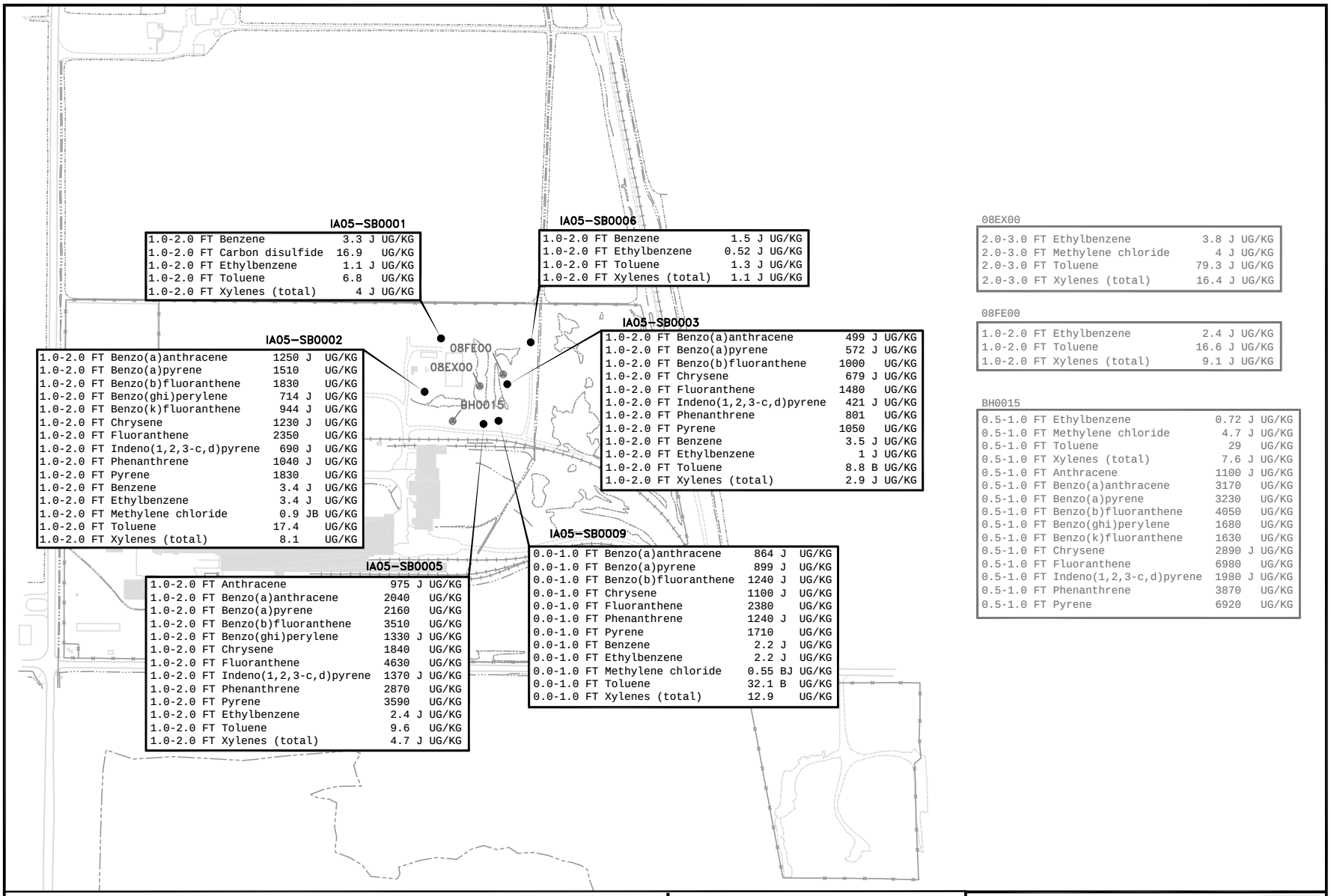
LUCKEY SITE
RI REPORT

Filter Bed Area and Debris Piles
Distribution of Metals and Fluoride in Soil

Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-26-00	AS SHOWN	04-1748-801	4.9

NAME: S:\LUCKEY\C041748\801\RIRPT_FILTER-BED-PILES-ORGANIC.DWG DATE: APR 19, 2000 TIME: 8:01 PM PCP: S:\PCP\GRAY7,251,252.PCP



IA05-SB0001

1.0-2.0 FT Benzene	3.3 J	UG/KG
1.0-2.0 FT Carbon disulfide	16.9	UG/KG
1.0-2.0 FT Ethylbenzene	1.1 J	UG/KG
1.0-2.0 FT Toluene	6.8	UG/KG
1.0-2.0 FT Xylenes (total)	4 J	UG/KG

IA05-SB0006

1.0-2.0 FT Benzene	1.5 J	UG/KG
1.0-2.0 FT Ethylbenzene	0.52 J	UG/KG
1.0-2.0 FT Toluene	1.3 J	UG/KG
1.0-2.0 FT Xylenes (total)	1.1 J	UG/KG

IA05-SB0002

1.0-2.0 FT Benzo(a)anthracene	1250 J	UG/KG
1.0-2.0 FT Benzo(a)pyrene	1510	UG/KG
1.0-2.0 FT Benzo(b)fluoranthene	1830	UG/KG
1.0-2.0 FT Benzo(ghi)perylene	714 J	UG/KG
1.0-2.0 FT Benzo(k)fluoranthene	944 J	UG/KG
1.0-2.0 FT Chrysene	1230 J	UG/KG
1.0-2.0 FT Fluoranthene	2350	UG/KG
1.0-2.0 FT Indeno(1,2,3-c,d)pyrene	690 J	UG/KG
1.0-2.0 FT Phenanthrene	1040 J	UG/KG
1.0-2.0 FT Pyrene	1830	UG/KG
1.0-2.0 FT Benzene	3.4 J	UG/KG
1.0-2.0 FT Ethylbenzene	3.4 J	UG/KG
1.0-2.0 FT Methylene chloride	0.9 JB	UG/KG
1.0-2.0 FT Toluene	17.4	UG/KG
1.0-2.0 FT Xylenes (total)	8.1	UG/KG

IA05-SB0003

1.0-2.0 FT Benzo(a)anthracene	499 J	UG/KG
1.0-2.0 FT Benzo(a)pyrene	572 J	UG/KG
1.0-2.0 FT Benzo(b)fluoranthene	1000	UG/KG
1.0-2.0 FT Chrysene	679 J	UG/KG
1.0-2.0 FT Fluoranthene	1480	UG/KG
1.0-2.0 FT Indeno(1,2,3-c,d)pyrene	421 J	UG/KG
1.0-2.0 FT Phenanthrene	801	UG/KG
1.0-2.0 FT Pyrene	1050	UG/KG
1.0-2.0 FT Benzene	3.5 J	UG/KG
1.0-2.0 FT Ethylbenzene	1 J	UG/KG
1.0-2.0 FT Toluene	8.8 B	UG/KG
1.0-2.0 FT Xylenes (total)	2.9 J	UG/KG

IA05-SB0005

1.0-2.0 FT Anthracene	975 J	UG/KG
1.0-2.0 FT Benzo(a)anthracene	2040	UG/KG
1.0-2.0 FT Benzo(a)pyrene	2160	UG/KG
1.0-2.0 FT Benzo(b)fluoranthene	3510	UG/KG
1.0-2.0 FT Benzo(ghi)perylene	1330 J	UG/KG
1.0-2.0 FT Chrysene	1840	UG/KG
1.0-2.0 FT Fluoranthene	4630	UG/KG
1.0-2.0 FT Indeno(1,2,3-c,d)pyrene	1370 J	UG/KG
1.0-2.0 FT Phenanthrene	2870	UG/KG
1.0-2.0 FT Pyrene	3590	UG/KG
1.0-2.0 FT Ethylbenzene	2.4 J	UG/KG
1.0-2.0 FT Toluene	9.6	UG/KG
1.0-2.0 FT Xylenes (total)	4.7 J	UG/KG

IA05-SB0009

0.0-1.0 FT Benzo(a)anthracene	864 J	UG/KG
0.0-1.0 FT Benzo(a)pyrene	899 J	UG/KG
0.0-1.0 FT Benzo(b)fluoranthene	1240 J	UG/KG
0.0-1.0 FT Chrysene	1100 J	UG/KG
0.0-1.0 FT Fluoranthene	2380	UG/KG
0.0-1.0 FT Phenanthrene	1240 J	UG/KG
0.0-1.0 FT Pyrene	1710	UG/KG
0.0-1.0 FT Benzene	2.2 J	UG/KG
0.0-1.0 FT Ethylbenzene	2.2 J	UG/KG
0.0-1.0 FT Methylene chloride	0.55 BJ	UG/KG
0.0-1.0 FT Toluene	32.1 B	UG/KG
0.0-1.0 FT Xylenes (total)	12.9	UG/KG

08EX00

2.0-3.0 FT Ethylbenzene	3.8 J	UG/KG
2.0-3.0 FT Methylene chloride	4 J	UG/KG
2.0-3.0 FT Toluene	79.3 J	UG/KG
2.0-3.0 FT Xylenes (total)	16.4 J	UG/KG

08FE00

1.0-2.0 FT Ethylbenzene	2.4 J	UG/KG
1.0-2.0 FT Toluene	16.6 J	UG/KG
1.0-2.0 FT Xylenes (total)	9.1 J	UG/KG

BH0015

0.5-1.0 FT Ethylbenzene	0.72 J	UG/KG
0.5-1.0 FT Methylene chloride	4.7 J	UG/KG
0.5-1.0 FT Toluene	29	UG/KG
0.5-1.0 FT Xylenes (total)	7.6 J	UG/KG
0.5-1.0 FT Anthracene	1100 J	UG/KG
0.5-1.0 FT Benzo(a)anthracene	3170	UG/KG
0.5-1.0 FT Benzo(a)pyrene	3230	UG/KG
0.5-1.0 FT Benzo(b)fluoranthene	4050	UG/KG
0.5-1.0 FT Benzo(ghi)perylene	1680	UG/KG
0.5-1.0 FT Benzo(k)fluoranthene	1630	UG/KG
0.5-1.0 FT Chrysene	2890 J	UG/KG
0.5-1.0 FT Fluoranthene	6980	UG/KG
0.5-1.0 FT Indeno(1,2,3-c,d)pyrene	1980 J	UG/KG
0.5-1.0 FT Phenanthrene	3870	UG/KG
0.5-1.0 FT Pyrene	6920	UG/KG

BUILDING
LOW LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE
PHASE II SOIL BORING
PHASE IV SOIL BORING
1.0-2.0 FT Pyrene 3590 UG/KG
ANALYTICAL RESULTS

N
True North

200 0 200 400
FEET

71 0 71 142
METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Filter Bed Area and Debris Piles
Distribution of Organics in Soil

SAIC Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-26-00	AS SHOWN	04-1748-801	4.10

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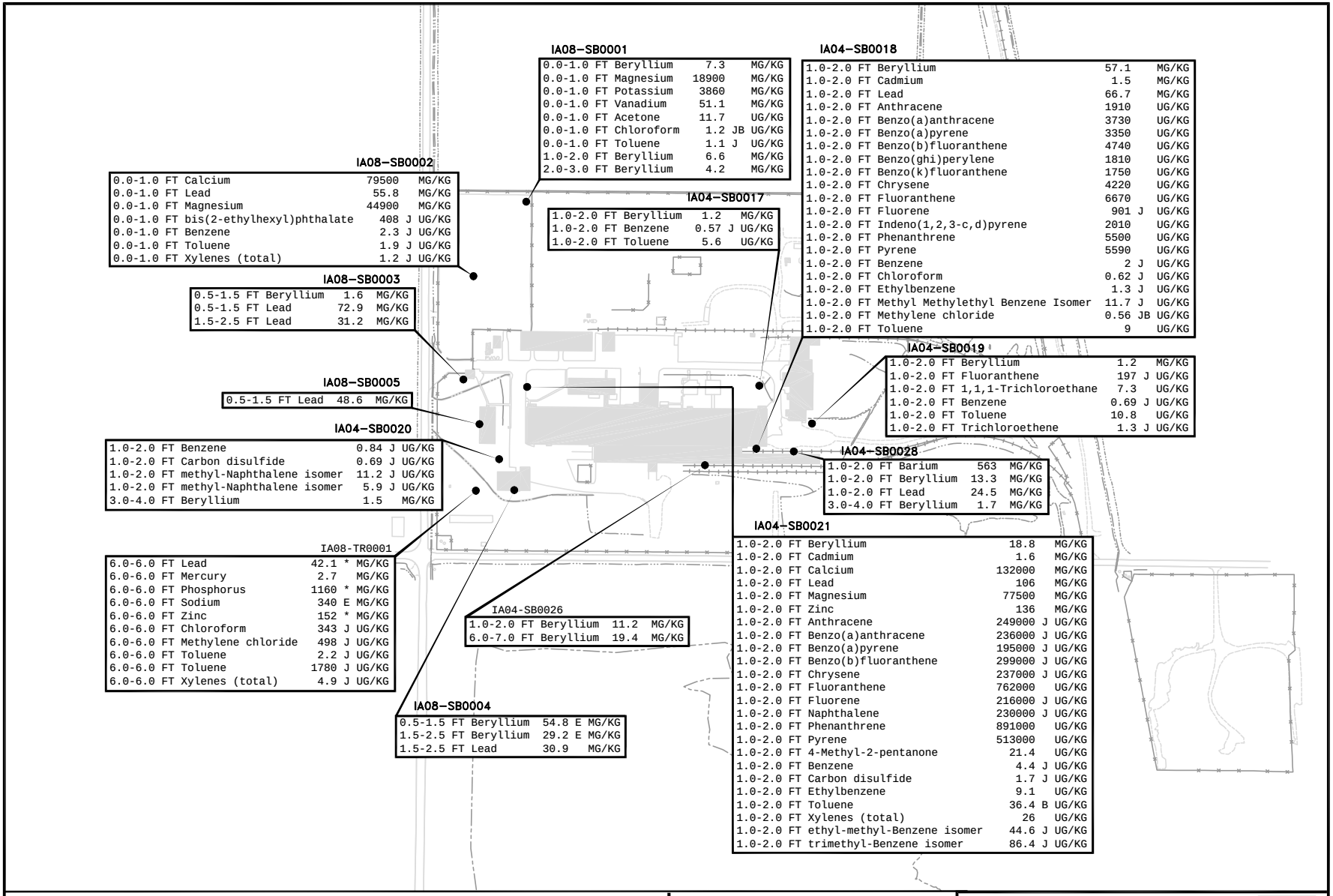

● SOIL BORING LOCATION

1.0-2.0 FT Fluoride 8.15 MG/KG ANALYTICAL RESULTS

N True North

200 0 200 400 FEET

60 0 60 120 METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Existing Buildings and Associated Areas
Distribution of Organics & Inorganics in Soil

SAIC Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-26-00	AS SHOWN	04-1748-801	4.11

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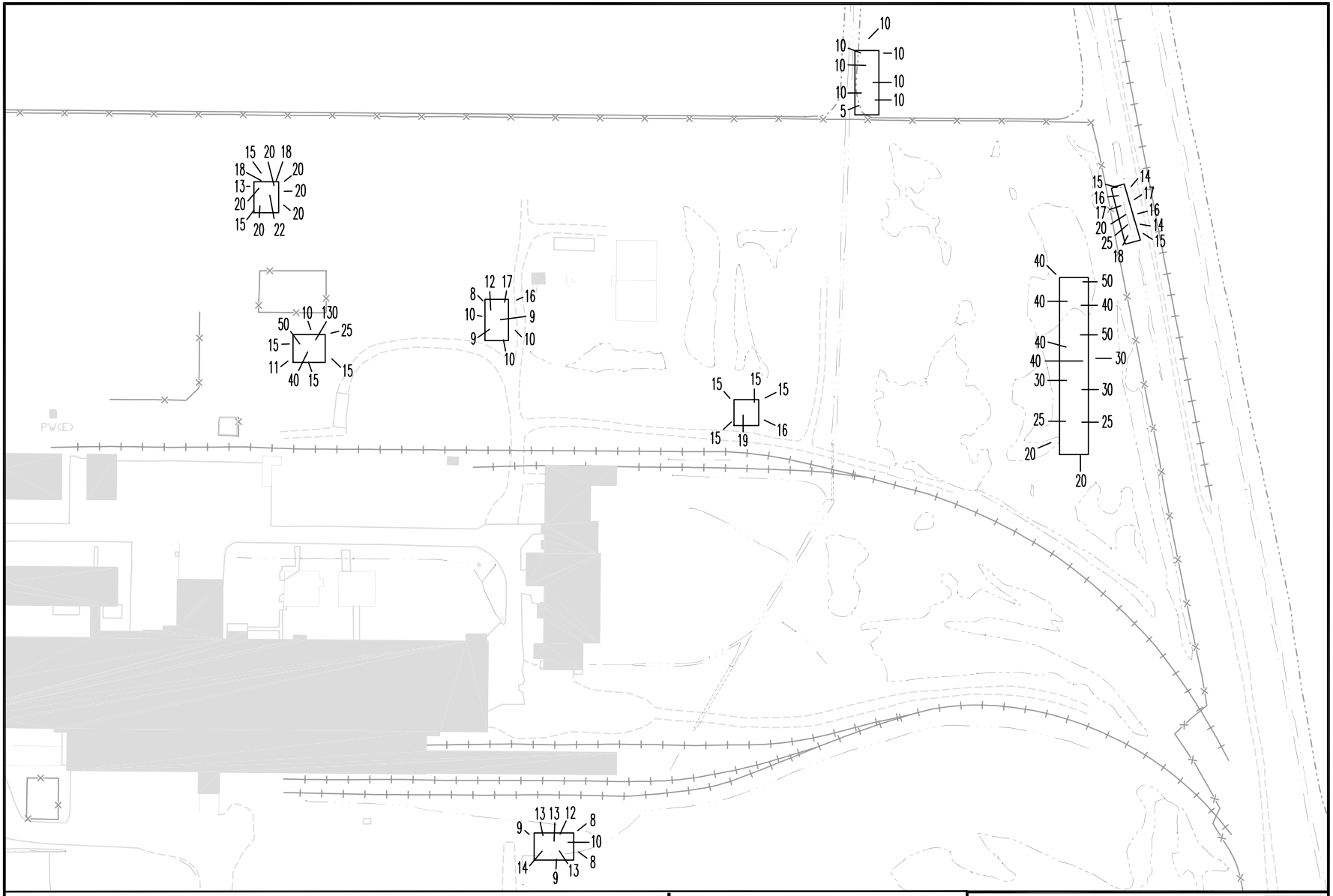


BUILDING

LOW LYING AREAS

FENCE LINE

STREAMS & CREEKS

ABANDONED RAILROAD GRADE

9 14 10 9 MEASUREMENT AREA

RESULT (urem/hr)

N True North

80 0 80 160
FEET

25 0 25 50
METERS

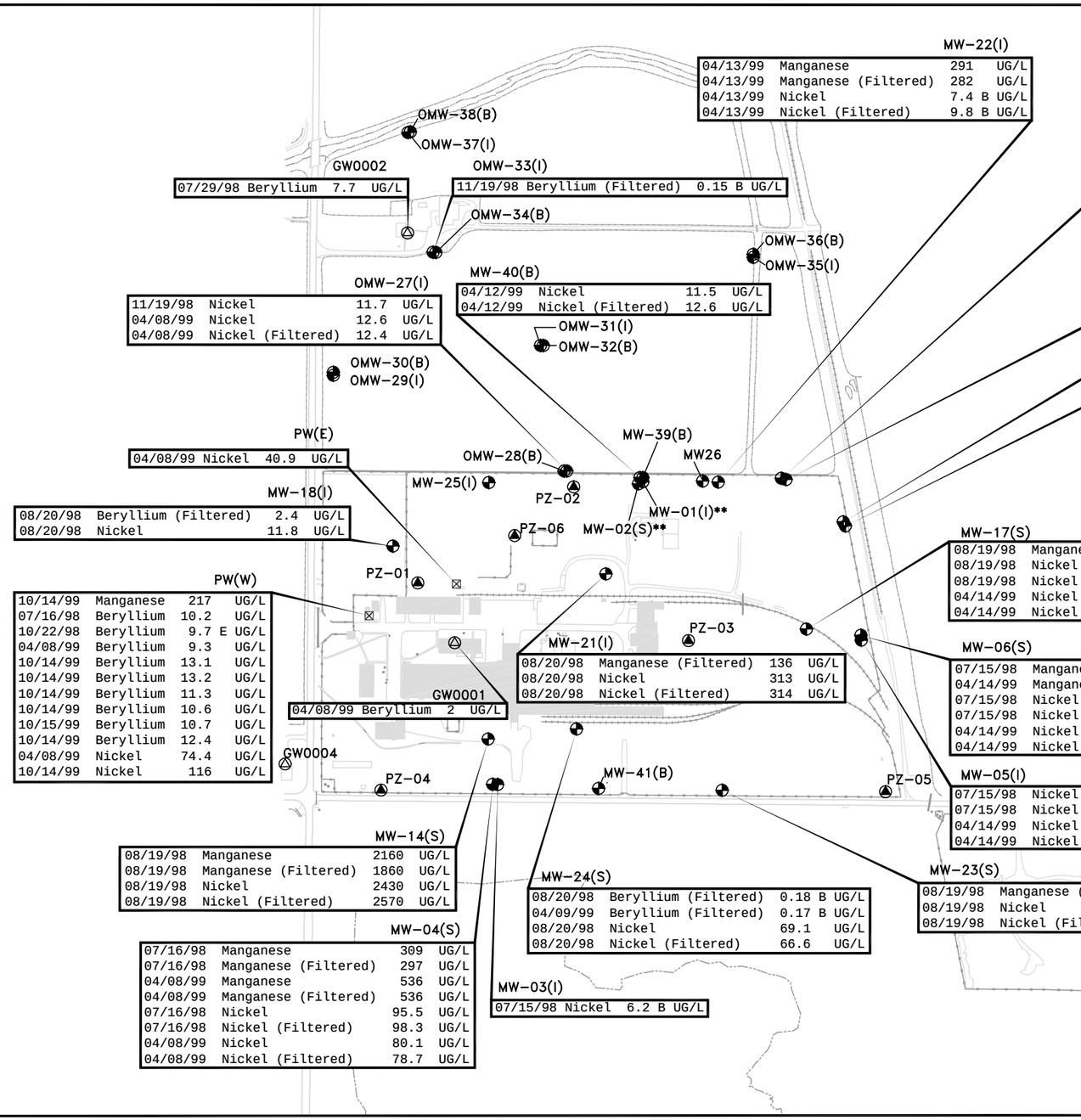
U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Dose Rate Measurement Results in On-Site Soil

SAIC. Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-10-00	AS SHOWN	04-1748-801	4.12



MW-22(I)

04/13/99	Manganese	291	UG/L
04/13/99	Manganese (Filtered)	282	UG/L
04/13/99	Nickel	7.4 B	UG/L
04/13/99	Nickel (Filtered)	9.8 B	UG/L

MW-13(S)

08/19/98	Manganese	848	UG/L
08/19/98	Manganese (Filtered)	351	UG/L
04/14/99	Manganese	897	UG/L
08/19/98	Beryllium	3.3	UG/L
08/19/98	Beryllium (Filtered)	0.2 B	UG/L
04/14/99	Beryllium	0.86 B	UG/L
08/19/98	Nickel	45.9	UG/L
08/19/98	Nickel (Filtered)	15.9	UG/L
04/14/99	Nickel	42	UG/L

GW0002

07/29/98	Beryllium	7.7	UG/L

OMW-33(I)

11/19/98	Beryllium (Filtered)	0.15 B	UG/L

MW-19(I)

08/19/98	Beryllium	2.4	UG/L
08/19/98	Beryllium (Filtered)	2.5	UG/L
04/14/99	Beryllium	4.2	UG/L
04/14/99	Beryllium (Filtered)	3.9	UG/L

OMW-27(I)

11/19/98	Nickel	11.7	UG/L
04/08/99	Nickel	12.6	UG/L
04/08/99	Nickel (Filtered)	12.4	UG/L

MW-40(B)

04/12/99	Nickel	11.5	UG/L
04/12/99	Nickel (Filtered)	12.6	UG/L

MW-07(I)

04/14/99	Beryllium (Filtered)	0.25 B	UG/L

MW-08(S)

07/21/98	Manganese (Filtered)	114	UG/L
04/14/99	Manganese	156	UG/L
04/14/99	Manganese (Filtered)	155	UG/L
07/21/98	Nickel	22.3	UG/L
07/21/98	Nickel (Filtered)	25.2	UG/L
04/14/99	Nickel	28.3	UG/L
04/14/99	Nickel (Filtered)	32.6	UG/L

PW(E)

04/08/99	Nickel	40.9	UG/L

MW-18(I)

08/20/98	Beryllium (Filtered)	2.4	UG/L
08/20/98	Nickel	11.8	UG/L

MW-17(S)

08/19/98	Manganese (Filtered)	127	UG/L
08/19/98	Nickel	14.4	UG/L
08/19/98	Nickel (Filtered)	15.7	UG/L
04/14/99	Nickel	17.3	UG/L
04/14/99	Nickel (Filtered)	19.8	UG/L

PW(W)

10/14/99	Manganese	217	UG/L
07/16/98	Beryllium	10.2	UG/L
10/22/98	Beryllium	9.7 E	UG/L
04/08/99	Beryllium	9.3	UG/L
10/14/99	Beryllium	13.1	UG/L
10/14/99	Beryllium	13.2	UG/L
10/14/99	Beryllium	11.3	UG/L
10/14/99	Beryllium	10.6	UG/L
10/15/99	Beryllium	10.7	UG/L
10/14/99	Beryllium	12.4	UG/L
04/08/99	Nickel	74.4	UG/L
10/14/99	Nickel	116	UG/L

MW-21(I)

08/20/98	Manganese (Filtered)	136	UG/L
08/20/98	Nickel	313	UG/L
08/20/98	Nickel (Filtered)	314	UG/L

MW-06(S)

07/15/98	Manganese (Filtered)	101	UG/L
04/14/99	Manganese (Filtered)	95.5	UG/L
07/15/98	Nickel	63.6	UG/L
07/15/98	Nickel (Filtered)	67.6	UG/L
04/14/99	Nickel	50.4	UG/L
04/14/99	Nickel (Filtered)	53.4	UG/L

MW-01(I)**

07/14/98	Beryllium	30.5 E	UG/L
07/14/98	Beryllium (Filtered)	30.1 E	UG/L
11/19/98	Beryllium	39.5	UG/L
07/23/98	Beryllium	31.5	UG/L
04/07/99	Beryllium	32.8	UG/L
04/07/99	Beryllium (Filtered)	33.5	UG/L
07/14/98	Nickel	23	UG/L
07/14/98	Nickel (Filtered)	25.1	UG/L
04/07/99	Nickel	23.2	UG/L
04/07/99	Nickel (Filtered)	27	UG/L

GW0001

04/08/99	Beryllium	2	UG/L

MW-05(I)

07/15/98	Nickel	46.9	UG/L
07/15/98	Nickel (Filtered)	49.1	UG/L
04/14/99	Nickel	48.4	UG/L
04/14/99	Nickel (Filtered)	48.2	UG/L

MW-02(S)**

07/14/98	Manganese	253	UG/L
07/14/98	Manganese (Filtered)	247	UG/L
04/07/99	Manganese (Filtered)	145	UG/L
07/14/98	Beryllium	14 E	UG/L
07/14/98	Beryllium (Filtered)	14.5 E	UG/L
11/19/98	Beryllium	14	UG/L
07/23/98	Beryllium	13.9	UG/L
04/07/99	Beryllium	15	UG/L
04/07/99	Beryllium (Filtered)	16.4	UG/L
07/14/98	Nickel	26.6	UG/L
07/14/98	Nickel (Filtered)	27.8	UG/L
04/07/99	Nickel	19.6	UG/L
04/07/99	Nickel (Filtered)	24.6	UG/L

MW-14(S)

08/19/98	Manganese	2160	UG/L
08/19/98	Manganese (Filtered)	1860	UG/L
08/19/98	Nickel	2430	UG/L
08/19/98	Nickel (Filtered)	2570	UG/L

MW-24(S)

08/20/98	Beryllium (Filtered)	0.18 B	UG/L
04/09/99	Beryllium (Filtered)	0.17 B	UG/L
08/20/98	Nickel	69.1	UG/L
08/20/98	Nickel (Filtered)	66.6	UG/L

MW-23(S)

08/19/98	Manganese (Filtered)	111	UG/L
08/19/98	Nickel	12.4	UG/L
08/19/98	Nickel (Filtered)	12.3	UG/L

MW-04(S)

07/16/98	Manganese	309	UG/L
07/16/98	Manganese (Filtered)	297	UG/L
04/08/99	Manganese	536	UG/L
04/08/99	Manganese (Filtered)	536	UG/L
07/16/98	Nickel	95.5	UG/L
07/16/98	Nickel (Filtered)	98.3	UG/L
04/08/99	Nickel	80.1	UG/L
04/08/99	Nickel (Filtered)	78.7	UG/L

MW-03(I)

07/15/98	Nickel	6.2 B	UG/L

BUILDINGS
LOW-LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE

MONITORING WELL
PIEZOMETER
RESIDENTIAL WELL/TAP WATER
04/08/99 Nickel 40.9 UG/L — SAMPLING RESULTS

N True North

200 0 200 400 FEET
61 0 61 122 METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Distribution of Beryllium, Manganese, and Nickel in Groundwater

SAIC Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	02-11-00	AS SHOWN	04-1748-801	4.13

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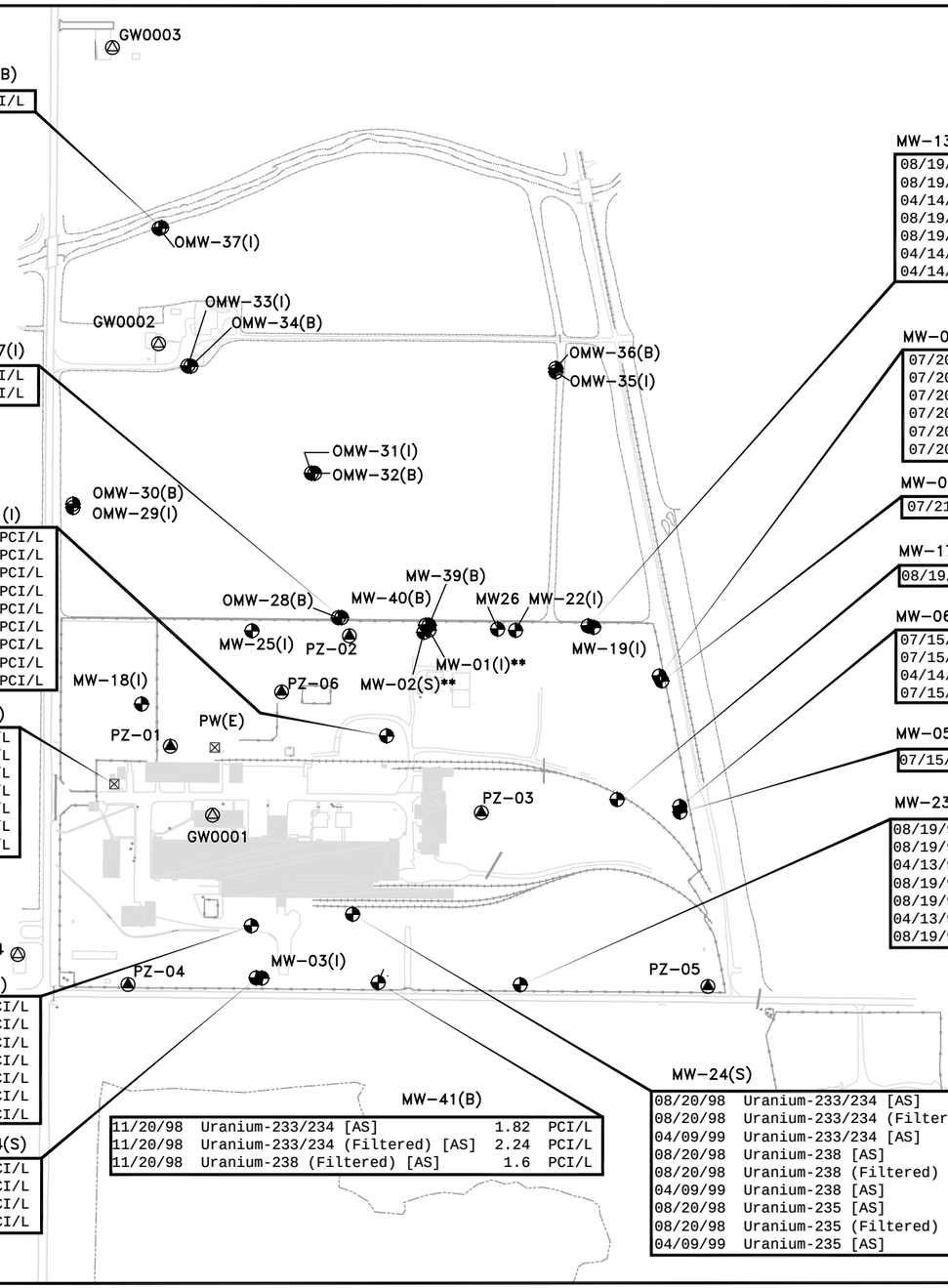

OMW-38(B)

11/18/98	Uranium-233/234 (Filtered) [AS]	1.41	PCI/L

OMW-27(I)

11/19/98	Uranium-233/234 (Filtered) [AS]	1.33	PCI/L
11/19/98	Uranium-238 (Filtered) [AS]	1.1	PCI/L

MW-21(I)

08/20/98	Uranium-233/234 [AS]	8.19	PCI/L
08/20/98	Uranium-233/234 (Filtered) [AS]	7.87	PCI/L
04/09/99	Uranium-233/234 [AS]	6.25	PCI/L
08/20/98	Uranium-238 [AS]	8.63	PCI/L
08/20/98	Uranium-238 (Filtered) [AS]	9.87	PCI/L
04/09/99	Uranium-238 [AS]	6.04	PCI/L
08/20/98	Uranium-235 [AS]	0.287 J	PCI/L
08/20/98	Uranium-235 (Filtered) [AS]	0.3 J	PCI/L
04/09/99	Uranium-235 [AS]	0.18 J	PCI/L

PW(W)

07/16/98	Uranium-233/234 [AS]	.81	PCI/L
10/22/98	Uranium-233/234 [AS]	3.38	PCI/L
04/08/99	Uranium-233/234 [AS]	2.67	PCI/L
07/16/98	Uranium-238 [AS]	3.21	PCI/L
10/22/98	Uranium-238 [AS]	3.47	PCI/L
04/08/99	Uranium-238 [AS]	2.86	PCI/L
07/16/98	Uranium-235 [AS]	0.104 J	PCI/L

MW-14(S)

08/19/98	Uranium-233/234 [AS]	2.56	PCI/L
08/19/98	Uranium-233/234 (Filtered) [AS]	2.62	PCI/L
04/09/99	Uranium-233/234 [AS]	3.36	PCI/L
08/19/98	Uranium-238 [AS]	2.26	PCI/L
08/19/98	Uranium-238 (Filtered) [AS]	1.94	PCI/L
04/09/99	Uranium-238 [AS]	2.94	PCI/L
04/09/99	Uranium-235 [AS]	0.2 J	PCI/L

MW-04(S)

07/16/98	Uranium-233/234 (Filtered) [AS]	1.56	PCI/L
07/16/98	Uranium-238 (Filtered) [AS]	1.31	PCI/L
04/08/99	Uranium-238 [AS]	2.93	PCI/L
07/16/98	Uranium-235 (Filtered) [AS]	0.11 J	PCI/L

MW-41(B)

11/20/98	Uranium-233/234 [AS]	1.82	PCI/L
11/20/98	Uranium-233/234 (Filtered) [AS]	2.24	PCI/L
11/20/98	Uranium-238 (Filtered) [AS]	1.6	PCI/L

MW-13(S)

08/19/98	Uranium-233/234 [AS]	2.16	PCI/L
08/19/98	Uranium-233/234 (Filtered) [AS]	2.66	PCI/L
04/14/99	Uranium-233/234 [AS]	14.9	PCI/L
08/19/98	Uranium-238 [AS]	1.55	PCI/L
08/19/98	Uranium-238 (Filtered) [AS]	1.86	PCI/L
04/14/99	Uranium-238 [AS]	8.58	PCI/L
04/14/99	Uranium-235 [AS]	0.47 J	PCI/L

MW-07(I)

07/20/98	Uranium-233/234 [AS]	3.97	PCI/L
07/20/98	Uranium-233/234 (Filtered) [AS]	4.46	PCI/L
07/20/98	Uranium-238 [AS]	3.27	PCI/L
07/20/98	Uranium-238 (Filtered) [AS]	3.51	PCI/L
07/20/98	Uranium-235 [AS]	0.137 J	PCI/L
07/20/98	Uranium-235 (Filtered) [AS]	0.118 J	PCI/L

MW-08(S)

07/21/98	Uranium-235 (Filtered) [AS]	0.0751 J	PCI/L

MW-17(S)

08/19/98	Uranium-235 (Filtered) [GS]	41.7	PCI/L

MW-06(S)

07/15/98	Uranium-233/234 (Filtered) [AS]	1.46	PCI/L
07/15/98	Uranium-238 (Filtered) [AS]	1.19	PCI/L
04/14/99	Uranium-238 [AS]	1.5	PCI/L
07/15/98	Uranium-235 [AS]	0.0736 J	PCI/L

MW-05(I)

07/15/98	Uranium-233/234 (Filtered) [AS]	1.28	PCI/L

MW-23(S)

08/19/98	Uranium-233/234 [AS]	5.02	PCI/L
08/19/98	Uranium-233/234 (Filtered) [AS]	2.88	PCI/L
04/13/99	Uranium-233/234 [AS]	3.43	PCI/L
08/19/98	Uranium-238 [AS]	4.04	PCI/L
08/19/98	Uranium-238 (Filtered) [AS]	2	PCI/L
04/13/99	Uranium-238 [AS]	2.74	PCI/L
08/19/98	Uranium-235 (Filtered) [AS]	0.364 J	PCI/L

MW-24(S)

08/20/98	Uranium-233/234 [AS]	92.3	PCI/L
08/20/98	Uranium-233/234 (Filtered) [AS]	87.1	PCI/L
04/09/99	Uranium-233/234 [AS]	129	PCI/L
08/20/98	Uranium-238 [AS]	88	PCI/L
08/20/98	Uranium-238 (Filtered) [AS]	81.5	PCI/L
04/09/99	Uranium-238 [AS]	129	PCI/L
08/20/98	Uranium-235 [AS]	4.52	PCI/L
08/20/98	Uranium-235 (Filtered) [AS]	4.37	PCI/L
04/09/99	Uranium-235 [AS]	6.39	PCI/L

MW-01(I)**

07/14/98	Uranium-233/234 (Filtered) [AS]	1.38	PCI/L
04/07/99	Uranium-233/234 [AS]	1.7	PCI/L
07/14/98	Uranium-235 [AS]	0.0729 J	PCI/L

MW-02(S)**

07/14/98	Uranium-233/234 [AS]	2.33	PCI/L
07/14/98	Uranium-233/234 (Filtered) [AS]	2.36	PCI/L
04/07/99	Uranium-233/234 [AS]	2.09	PCI/L
07/14/98	Uranium-238 [AS]	2.02	PCI/L
07/14/98	Uranium-238 (Filtered) [AS]	1.78	PCI/L
04/07/99	Uranium-238 [AS]	1.56	PCI/L
07/14/98	Uranium-235 [AS]	0.0853 J	PCI/L
07/14/98	Uranium-235 (Filtered) [AS]	0.147 J	PCI/L

BUILDINGS
LOW-LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE

MONITORING WELL
PIEZOMETER
RESIDENTIAL WELL/TAP WATER
04/08/99 Uranium-238 2.93 PCI/L — SAMPLING RESULTS

N True North

200 0 200 400 FEET
61 0 61 122 METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Distribution of Uranium-233/234, Uranium-235, and Uranium-238 in Groundwater

Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	02-11-00	AS SHOWN	04-1748-801	4.14

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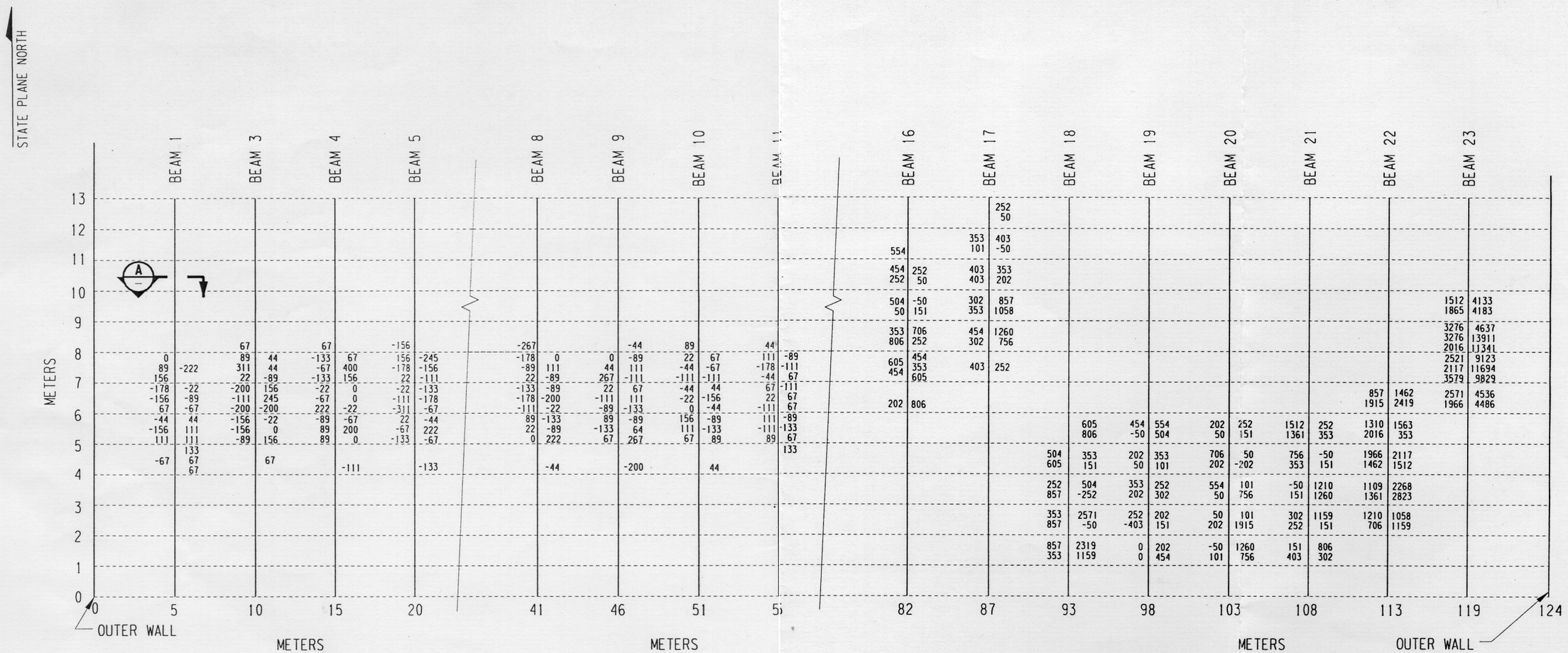
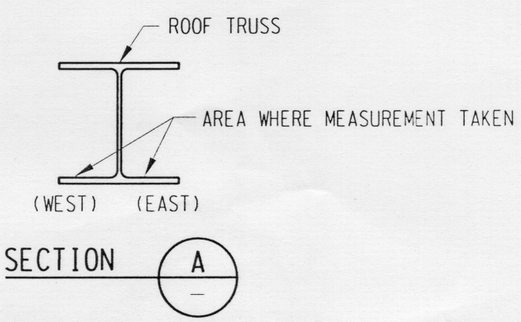


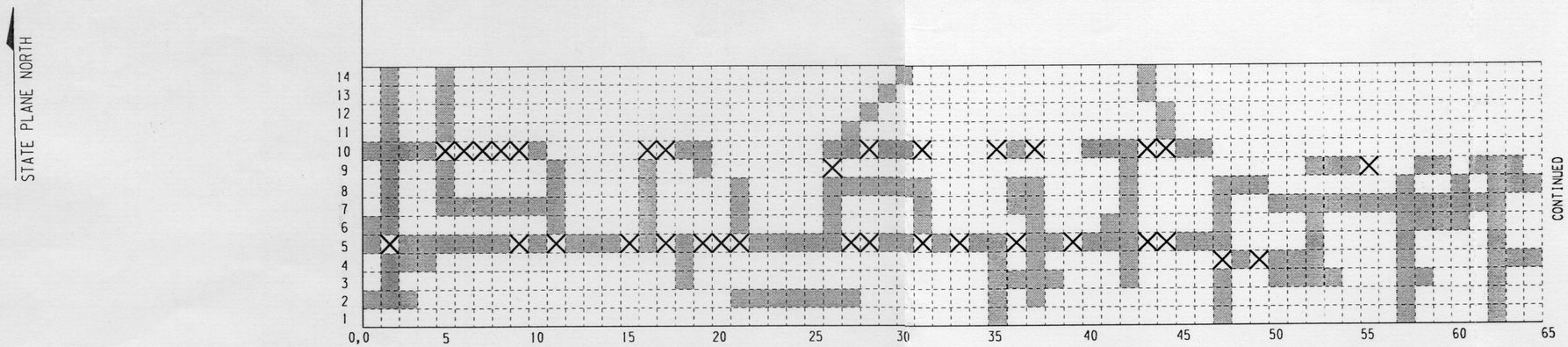


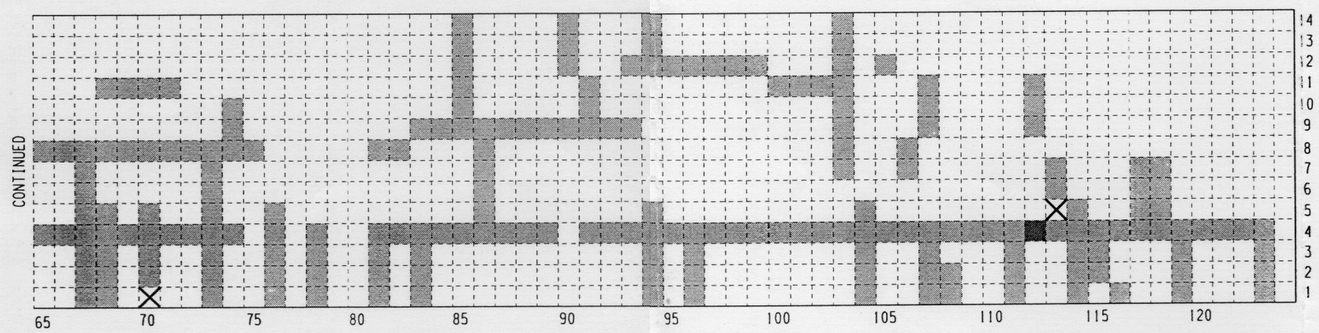
NOTES:

1. DIRECT β/γ dpm/100 cm^2
2. NOT TO SCALE

14501 111 111F022.DGN

Figure 4.15
Luckey Site
Direct Beta/Gamma Radiological
Survey of Roof Trusses in AEC Annex





LEGEND

NO DATA

AREAS <1,000 dpm/100 cm² (DIRECT β/γ)

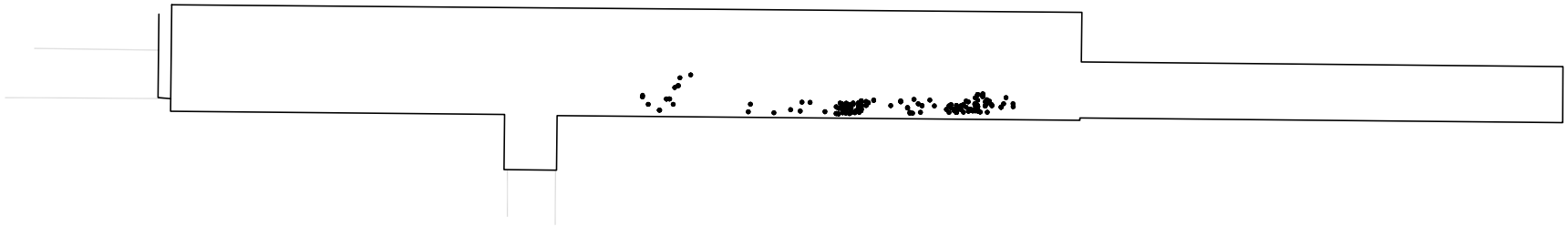
AREAS ≥1,000 dpm/100 cm² AND <5,000 dpm/100 cm² (DIRECT β/γ)

AREAS ≥5,000 dpm/100 cm² AND <15,000 dpm/100 cm² (DIRECT β/γ)

NOT TO SCALE

14501 111 111F023.DGN

Figure 4.16
Luckey Site
Direct Beta/Gamma Radiological
Survey of Floor in AEC Annex



BUILDING OUTLINE

LOCATIONS EXCEEDING GUIDELINES

N
True North

78 0 39 78
FEET

12 0 12 24
METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Alpha Activity Exceeding NRC
Guidelines on Annex Floor

Science Applications International Corporation
Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-30-00	AS SHOWN	04-1748-801	4.17

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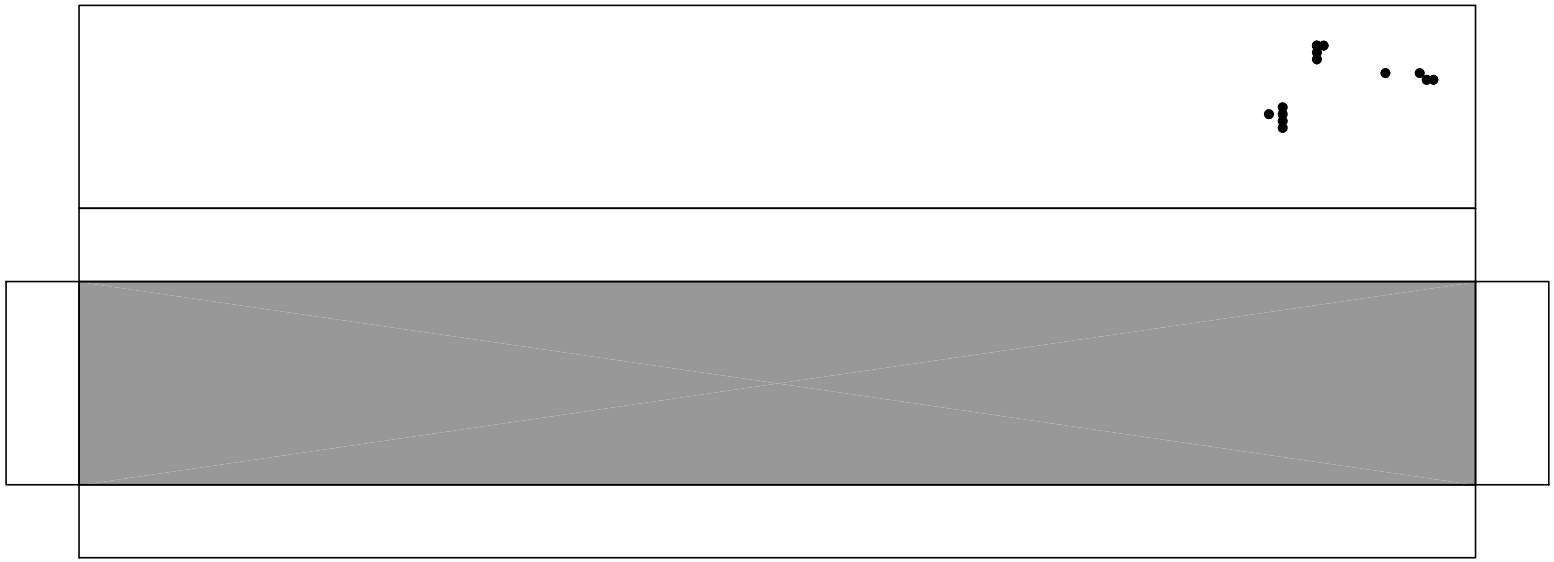


BUILDING OUTLINE

LOCATIONS EXCEEDING GUIDELINES

FLOOR AREA

NOTE: BUILDING OUTLINE IS IN PLAN VIEW WITH THE BUILDING LAID FLAT

N
True North

92 0 46 92
FEET

14 0 14 28
METERS

U.S. Army Corps of Engineers
Buffalo District

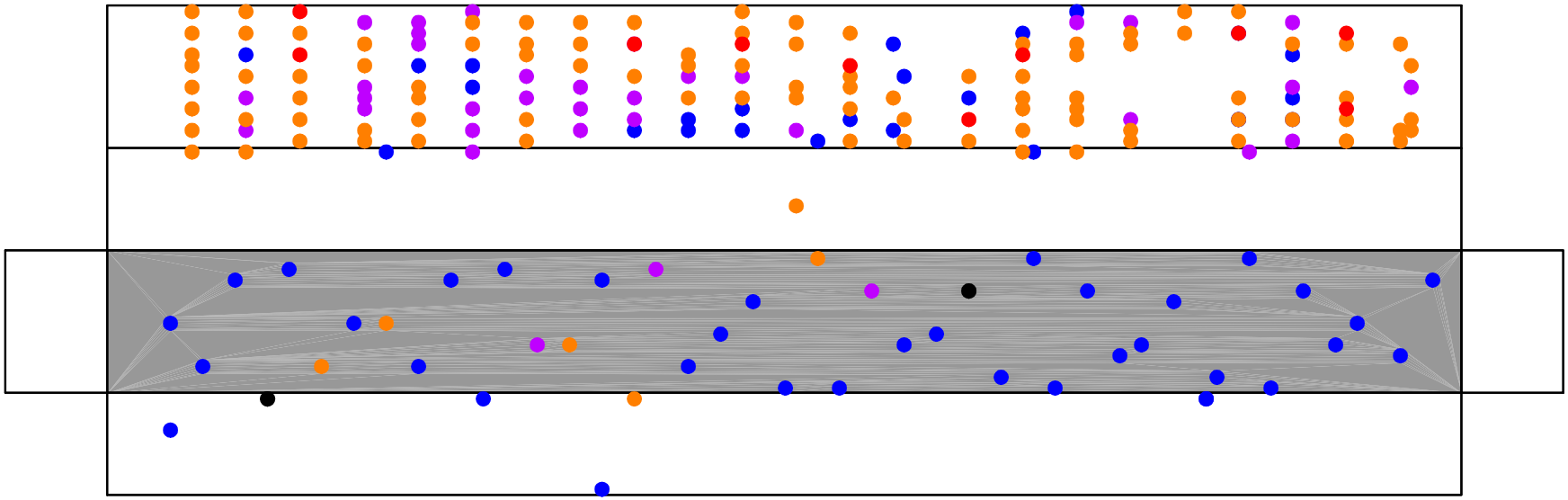
LUCKEY SITE
RI REPORT

Production Building–2nd Floor: Alpha & Beta–Gamma Activity Exceeding NRC Guidelines

Science Applications International Corporation
Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01–31–00	AS SHOWN	04–1748–801	4.18

NAME: S:\LUCKEY\C041748\801\RIRPT_DPM-PROD.DWG DATE: APR 13, 2000 TIME: 9:41 AM PCP: S:\PCP\GREY1.PCP



BUILDING OUTLINE

FLOOR AREA

NON-DETECT

SWIPE RESULT <5 ug/100cm2

SWIPE RESULT 5-10 ug/100cm2

SWIPE RESULT 10-100 ug/100cm2

SWIPE RESULT >100 ug/100cm2

NOTE: BUILDING OUTLINE IS IN PLAN VIEW WITH THE BUILDING LAID FLAT

N
True North

52 0 26 52
FEET

8 0 8 16
METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Annex Building
Beryllium Swipe Results

Science Applications International Corporation
Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	DRAWING NO.
BJW	01-31-00	AS SHOWN	04-1748-801	4.19

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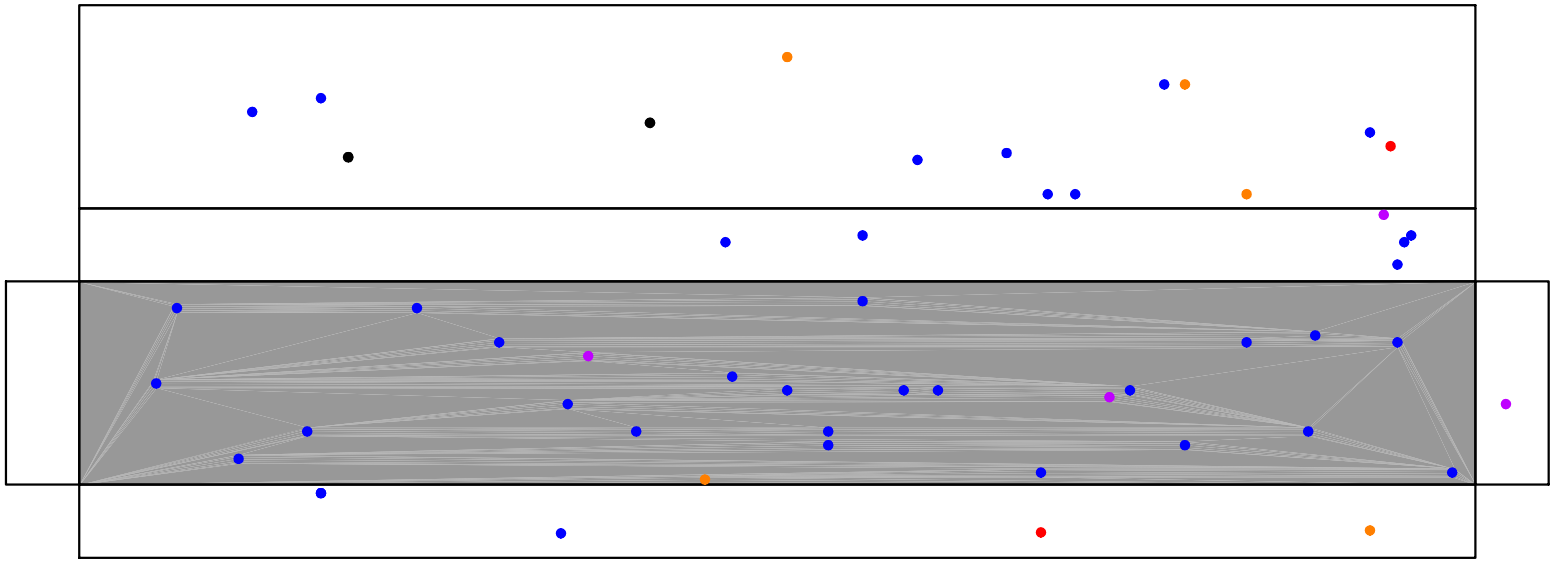

BUILDING OUTLINE

FLOOR AREA

NON-DETECT

SWIPE RESULT <5 ug/100cm2

SWIPE RESULT 5-10 ug/100cm2

SWIPE RESULT 10-100 ug/100cm2

SWIPE RESULT >100 ug/100cm2

NOTE: BUILDING OUTLINE IS IN PLAN VIEW WITH THE BUILDING LAID FLAT

N
True North

92 0 46 92
FEET

14 0 14 28
METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Production Building-First Floor
Beryllium Swipe Results

Science Applications International Corporation
Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
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NAME: S:\LUCKEY\C04174B\801\RIRPT_SWIPE-RANGES-PROD-DWN.DWG DATE: APR 13, 2000 TIME: 12:35 PM PCP: S:\PCP\FULLCOLR.PCP

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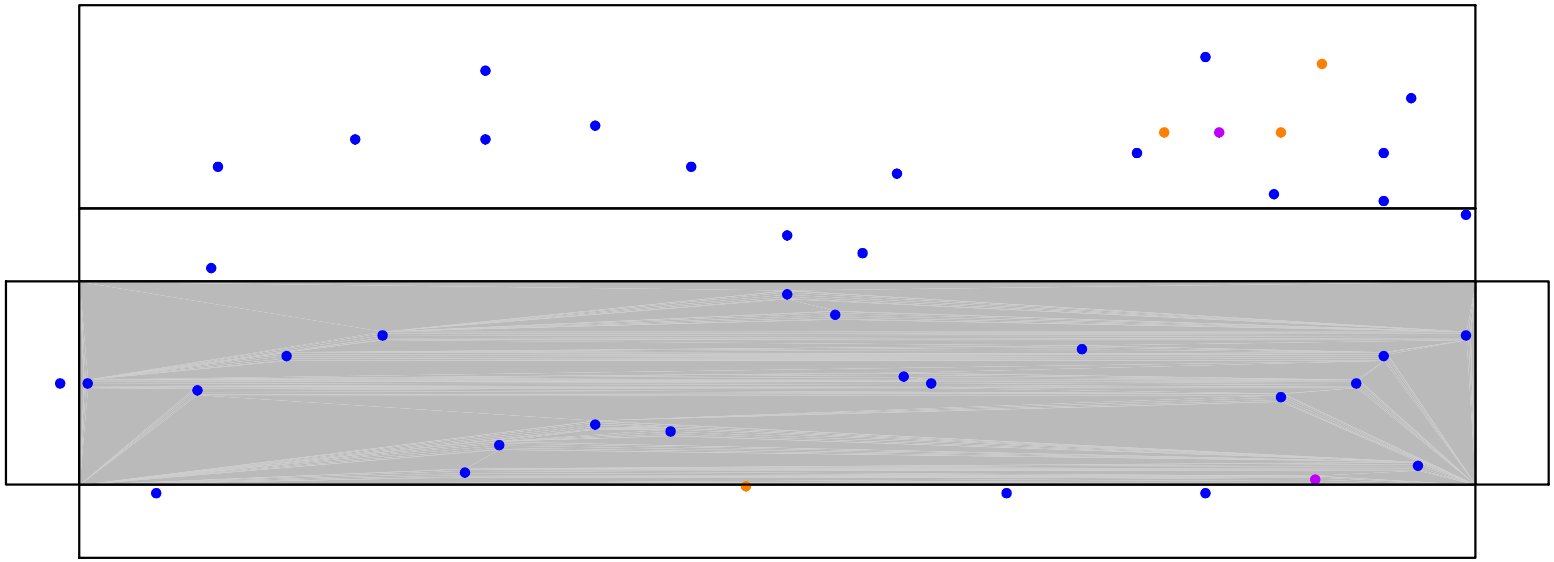

BUILDING OUTLINE

FLOOR AREA

NON-DETECT

SWIPE RESULT <5 ug/100cm2

SWIPE RESULT 5-10 ug/100cm2

SWIPE RESULT 10-100 ug/100cm2

SWIPE RESULT >100 ug/100cm2

NOTE: BUILDING OUTLINE IS IN PLAN VIEW WITH THE BUILDING LAID FLAT

N
True North

92 0 46 92
FEET

14 0 14 28
METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Production Building-Second Floor
Beryllium Swipe Results

Science Applications International Corporation

Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
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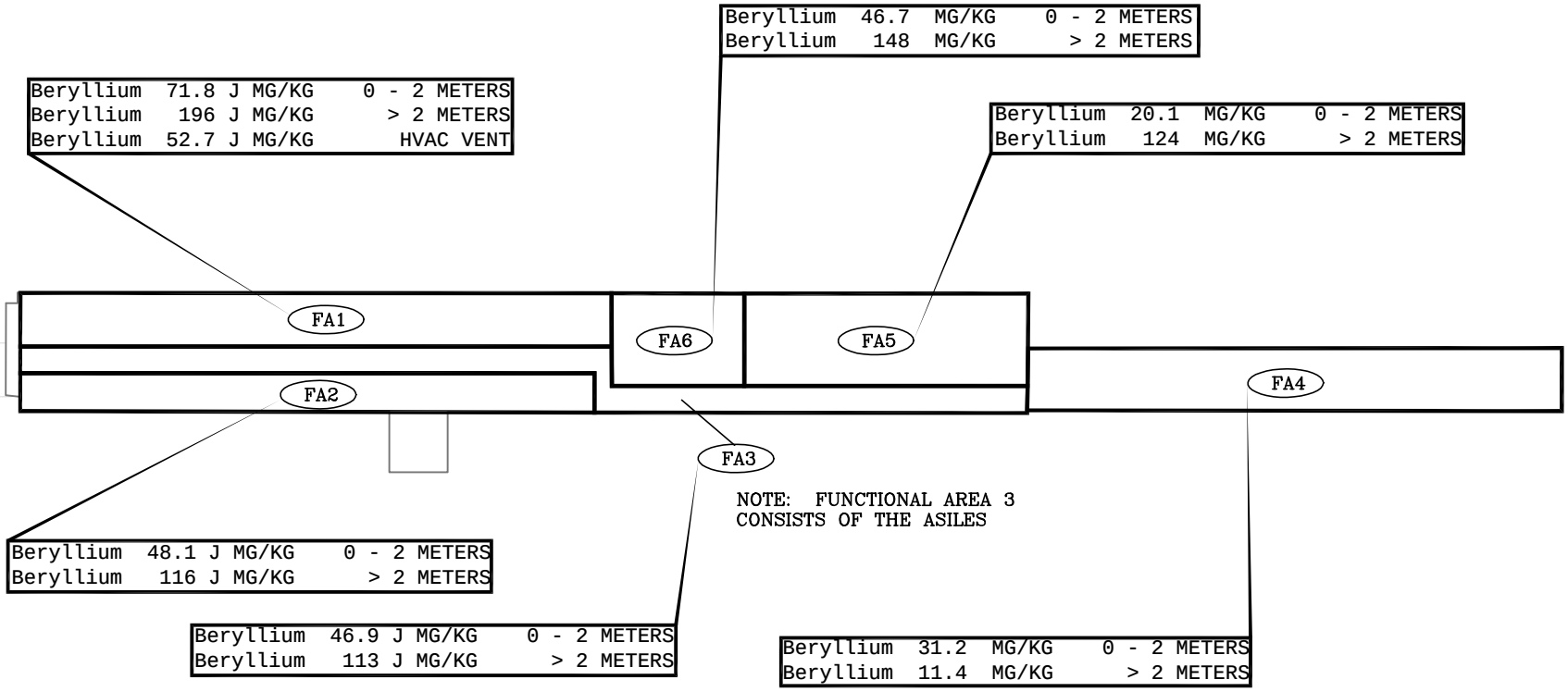

BUILDING OUTLINE

FUNCTIONAL AREA OUTLINE

N
True North

72 0 36 72
FEET

11 0 11 22
METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Annex Building
Dust Sampling Results

SAIC. Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-13-00	AS SHOWN	04-1748-801	4.22

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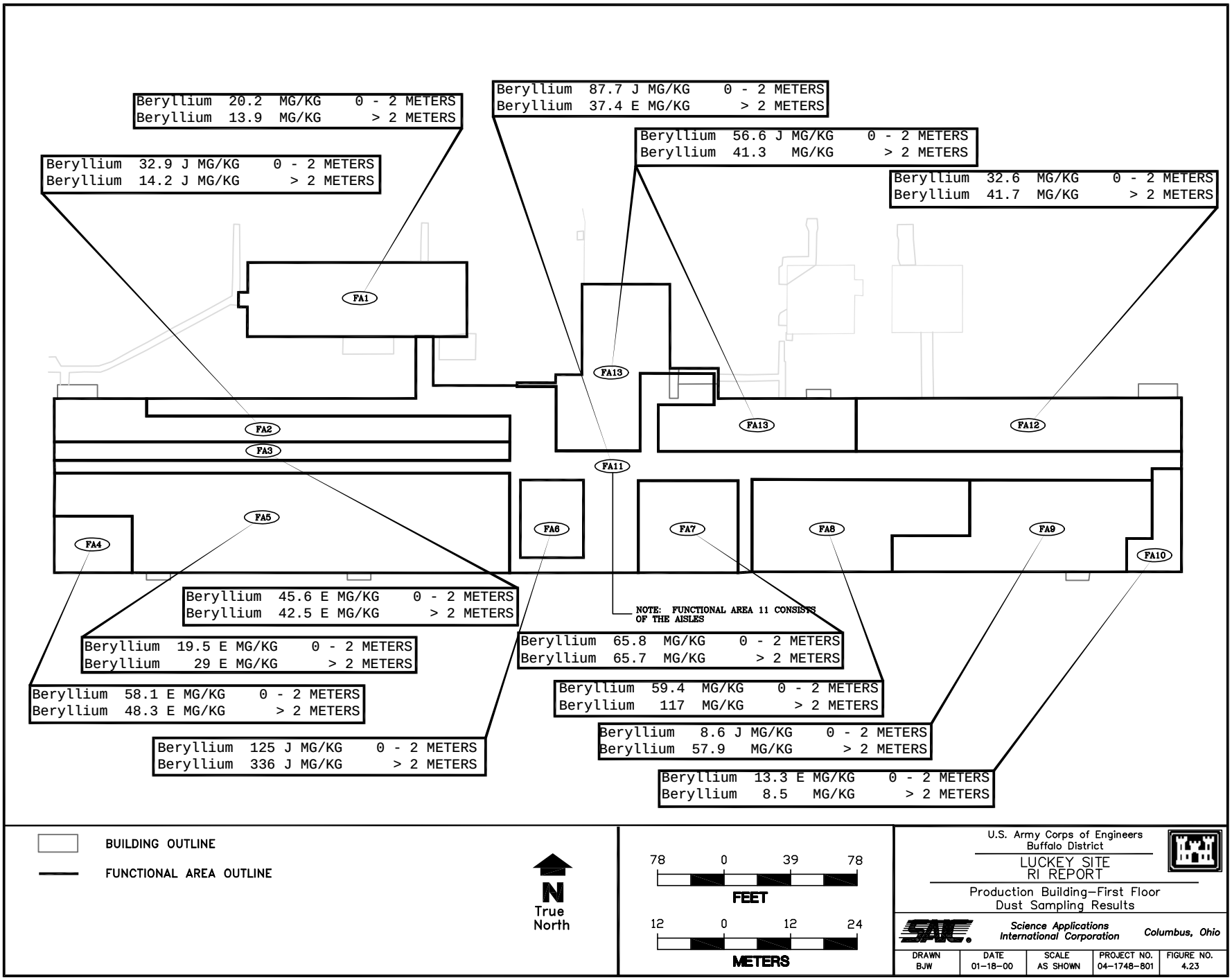


U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

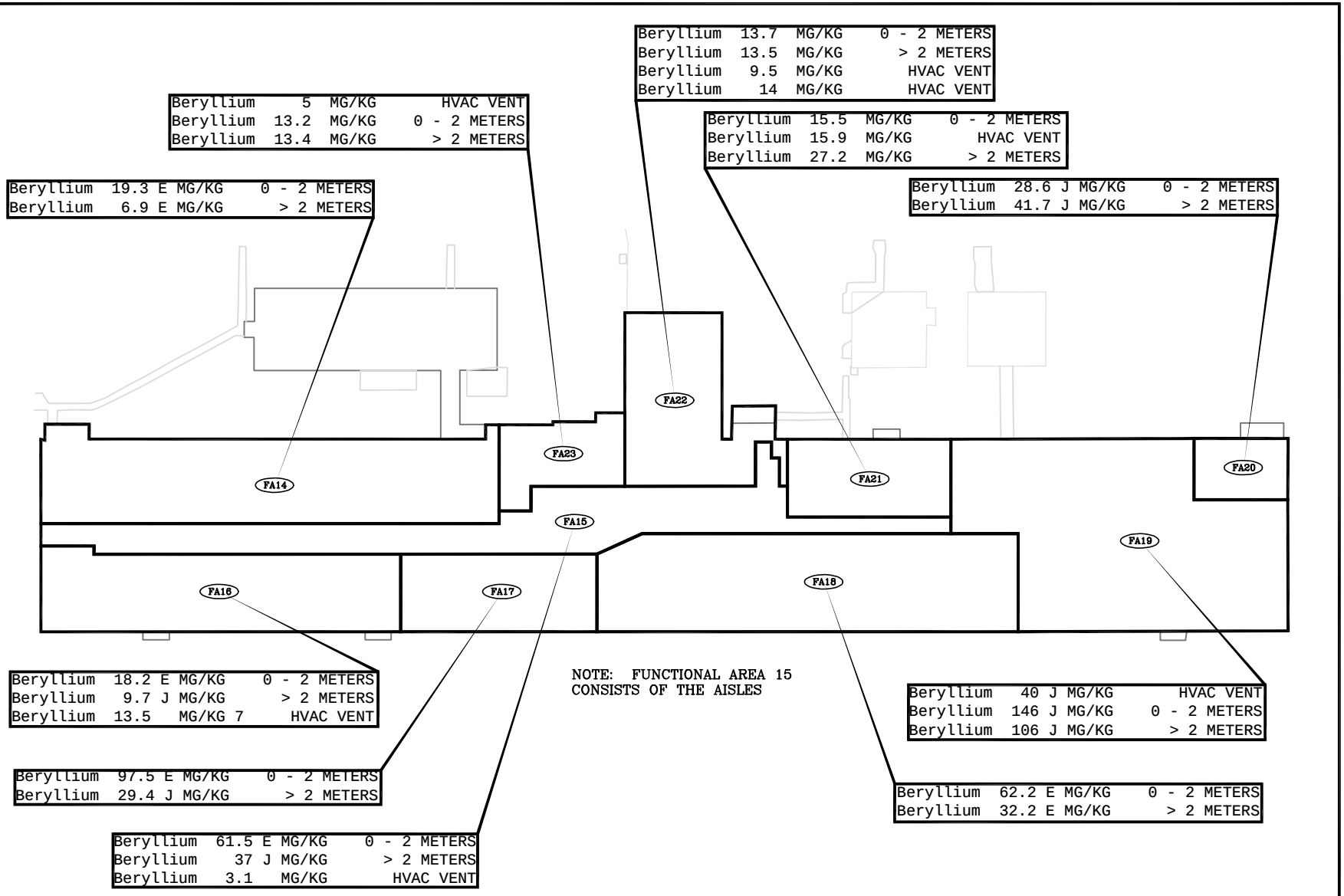
Production Building–First Floor
Dust Sampling Results

SAIC Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-18-00	AS SHOWN	04-1748-801	4.23

NAME: S:\LUCKEY\C041748\801\RIRPT_BUILD-FUNCTPRDD-DWN-MTR-BE.DWG DATE: APR 13, 2000 TIME: 1:31 PM PCP: S:\PCP\FRP2.PCP

NAME: S:\LUCKEY\C041748\801\RIRPT_BUILD-FUNCTPROD-UP-MTR-BE.DWG DATE: APR 17, 2000 TIME: 6:28 PM PCP: S:\PCP\FRP2.PCP



BUILDING OUTLINE

FUNCTIONAL AREA OUTLINE

N
True North

78 0 39 78
FEET

12 0 12 24
METERS

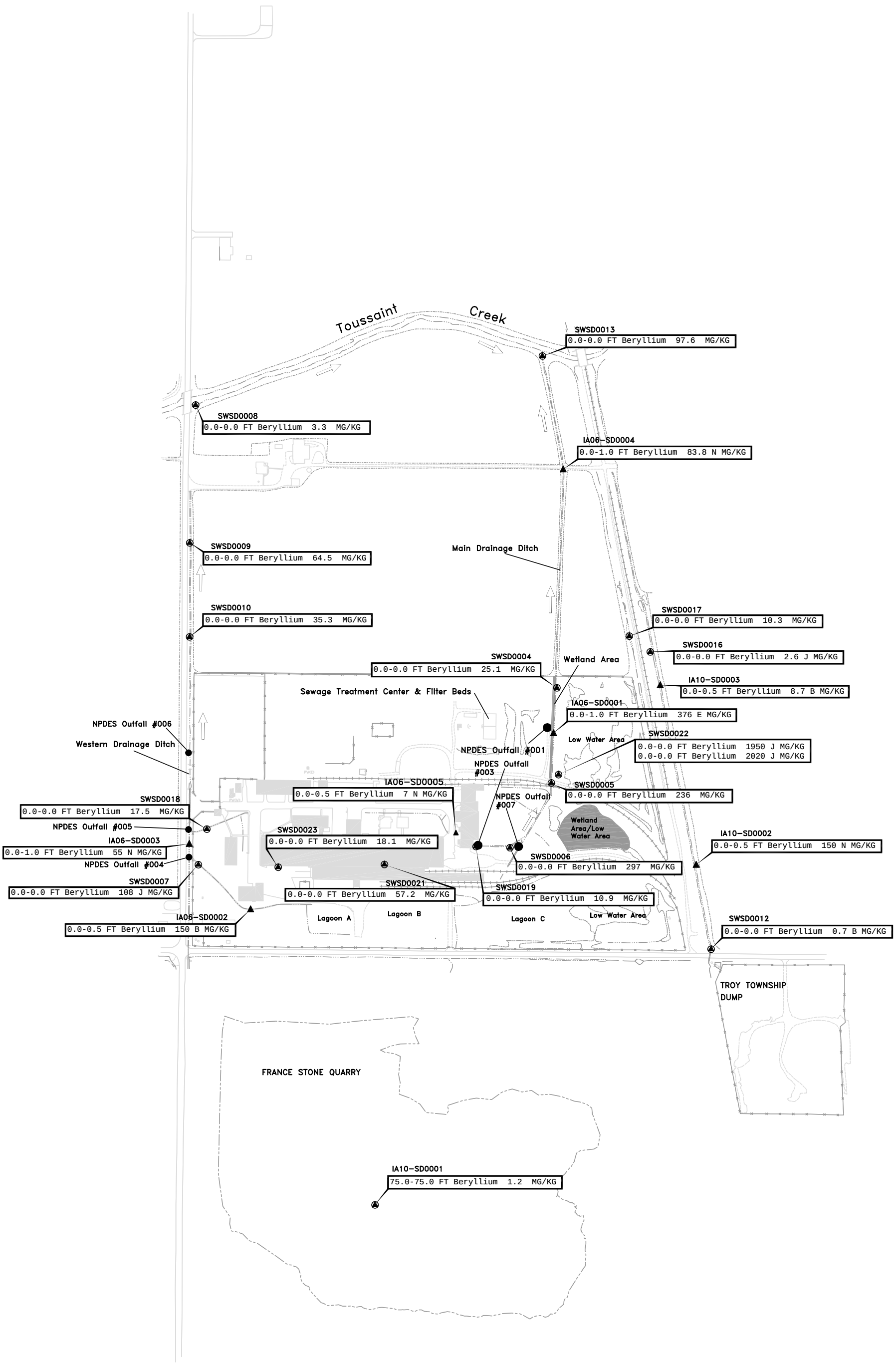
U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Production Building—Second Floor
Dust Sampling Results

SAIC Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-18-00	AS SHOWN	04-1748-801	4.24



BUILDING
LOW LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE
1.0-2.0 FT Beryllium 8.15 MG/KG SAMPLING RESULTS
DIRECTION OF FLOW IN DITCHES & STREAMS
SEDIMENT/SURFACE WATER SAMPLE LOCATION
SEDIMENT SAMPLE LOCATION
NPDES Outfalls
N True North

175 0 175 350 FEET
55 0 55 110 METERS

U.S. Army Corps of Engineers
Buffalo District

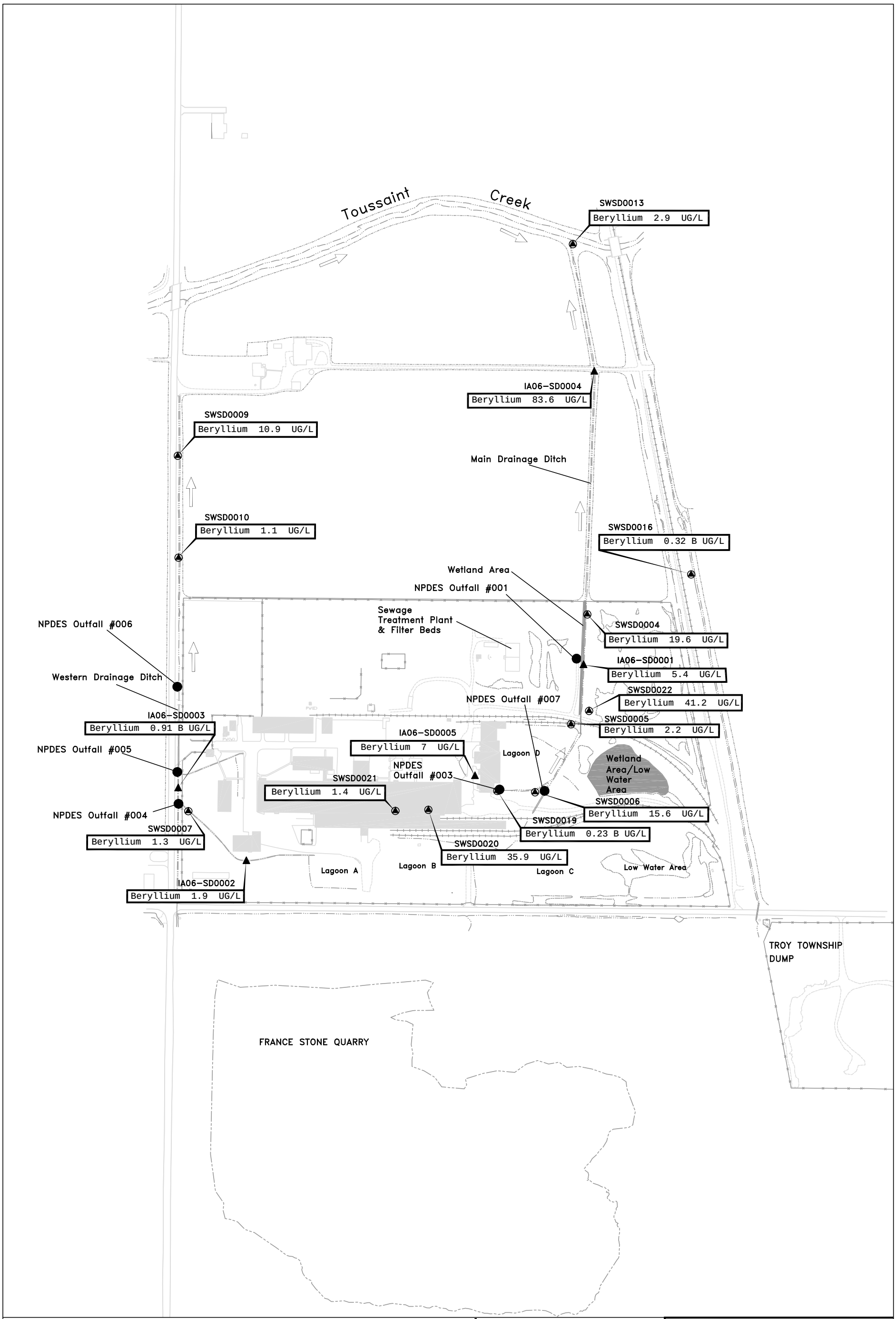
LUCKEY SITE
RI REPORT

Onsite and Adjacent Areas
Distribution of Beryllium in Sediment

Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-30-00	AS SHOWN	04-1748-801	4.25

NAME: S:\LUCKEY\C041748\801\RIRPT_ONSITE-ADJACENT-SED.DWG DATE: APR 17, 2000 TIME: 4:32 PM PCP: S:\PCP\GREY1.PCP



BUILDING
LOW-LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE
1.0-2.0 FT Beryllium 8.15 MG/KG — ANALYTICAL RESULTS

DIRECTION OF FLOW IN DITCHES & STREAMS
SEDIMENT/SURFACE WATER SAMPLE LOCATION
SEDIMENT SAMPLE LOCATION
NPDES Outfalls

N True North

45 0 45 90 FEET
150 0 150 300 METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

On-site and Adjacent Areas
Distribution of Beryllium in Surface Water

Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-31-00	AS SHOWN	04-1748-801	4.26

NAME: LAYOUT1-S:\LUCKEY\C041748\801\RIRPT_ONSITE-ADJACENT-SW.DWG DATE: SEP 12, 2000 TIME: 5:24 PM CTB: S:\CTB PLOTTING\GRAY1.CTB

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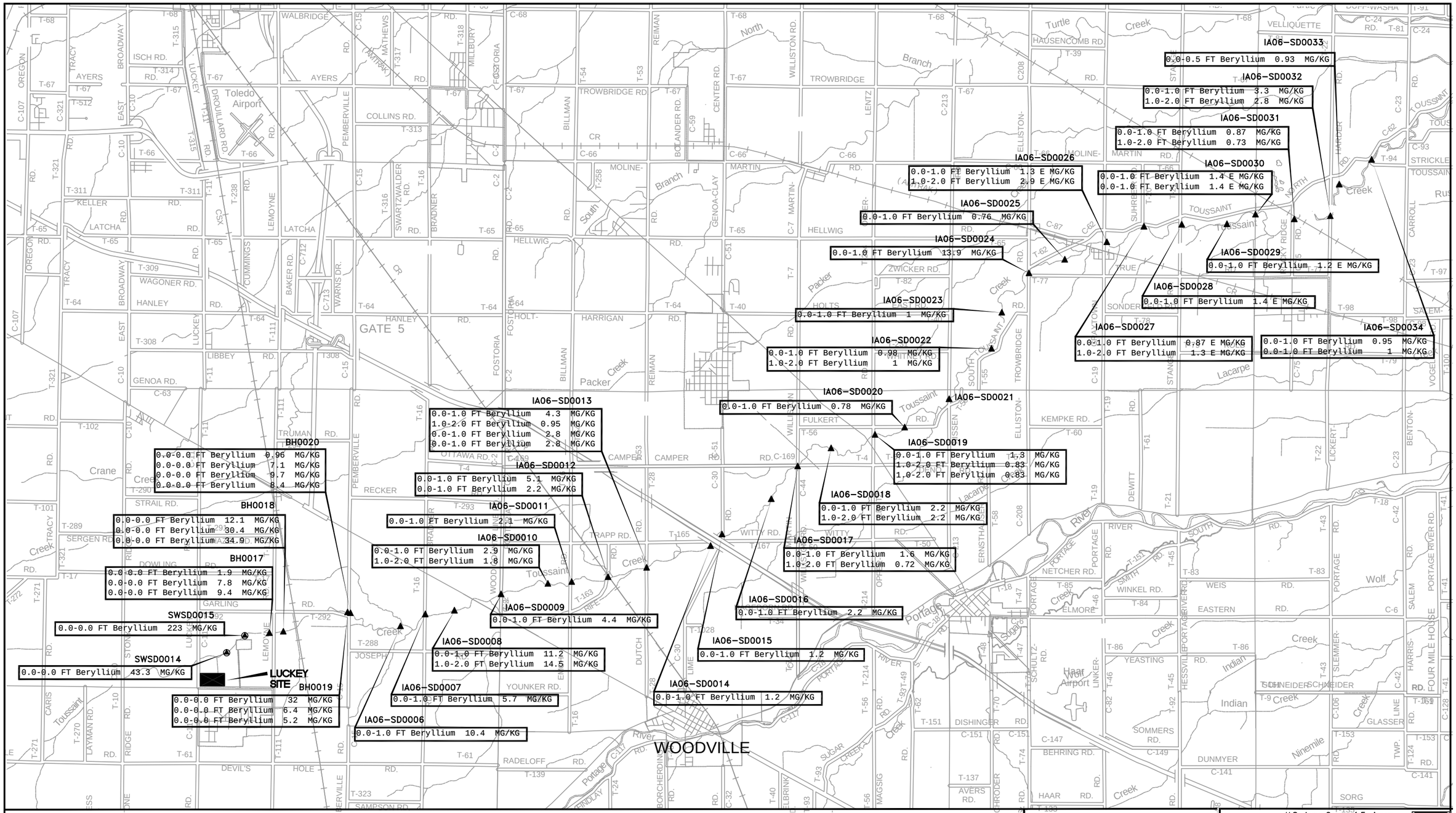


STREAMS & CREEKS

SEDIMENT/SURFACE WATER SAMPLE LOCATION

SEDIMENT SAMPLE LOCATION

N
True North

3280 0 3280 6560
FEET

1000 0 1000 2000
METERS

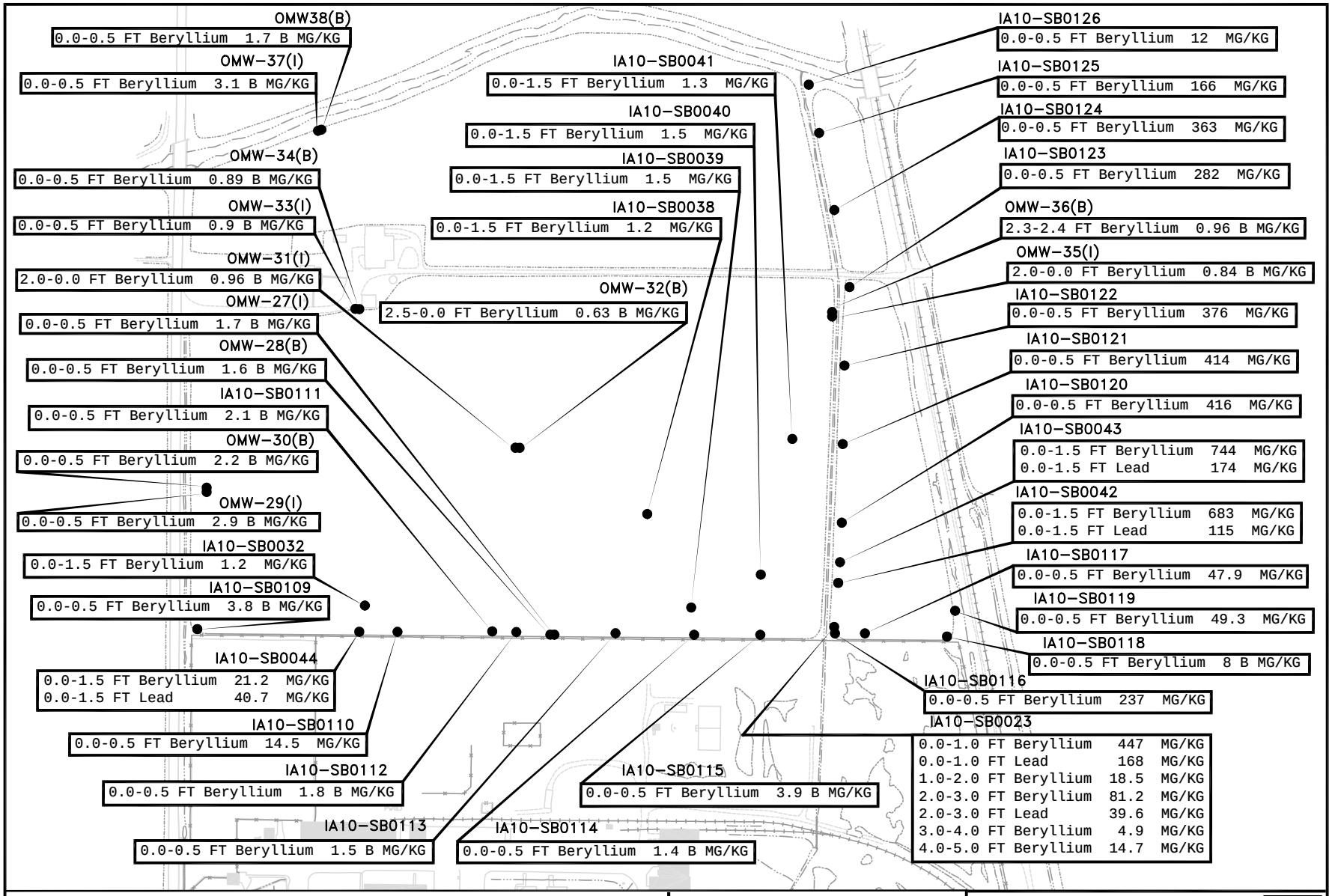
U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Toussaint Creek
Distribution of Beryllium Sediments

Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-31-00	AS SHOWN	04-1748-801	4.27



U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Northern Farm Field
Distribution of Beryllium and Lead in Soil

Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-27-00	AS SHOWN	04-1748-801	4.28

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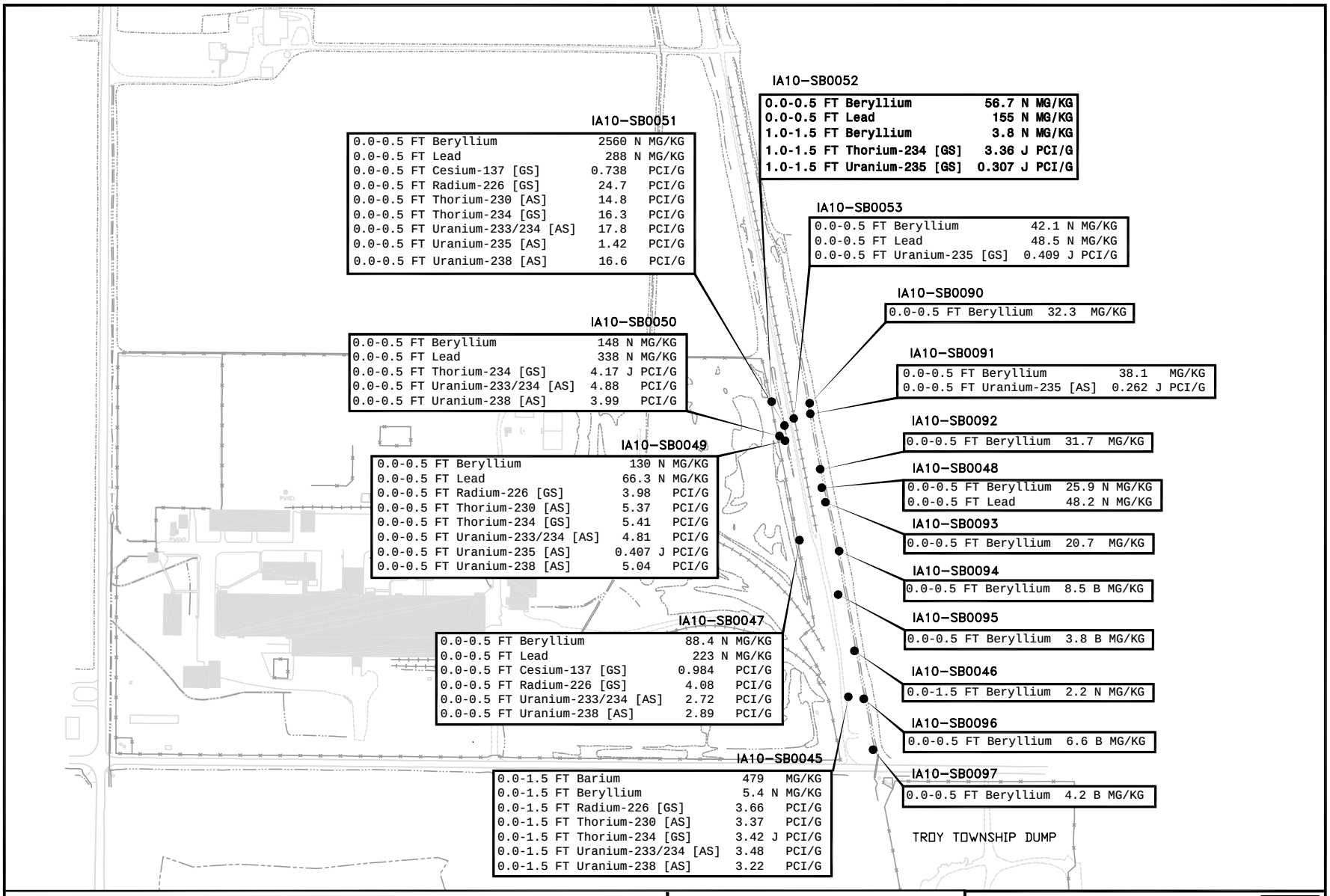


BUILDING

LOW LYING AREAS

FENCE LINE

STREAMS & CREEKS

ABANDONED RAILROAD GRADE

PHASE IV SOIL BORING

1.0-2.0 FT Barium 8.15 MG/KG — ANALYTICAL RESULTS

N True North

175 0 175 350 FEET

55 0 55 110 METERS

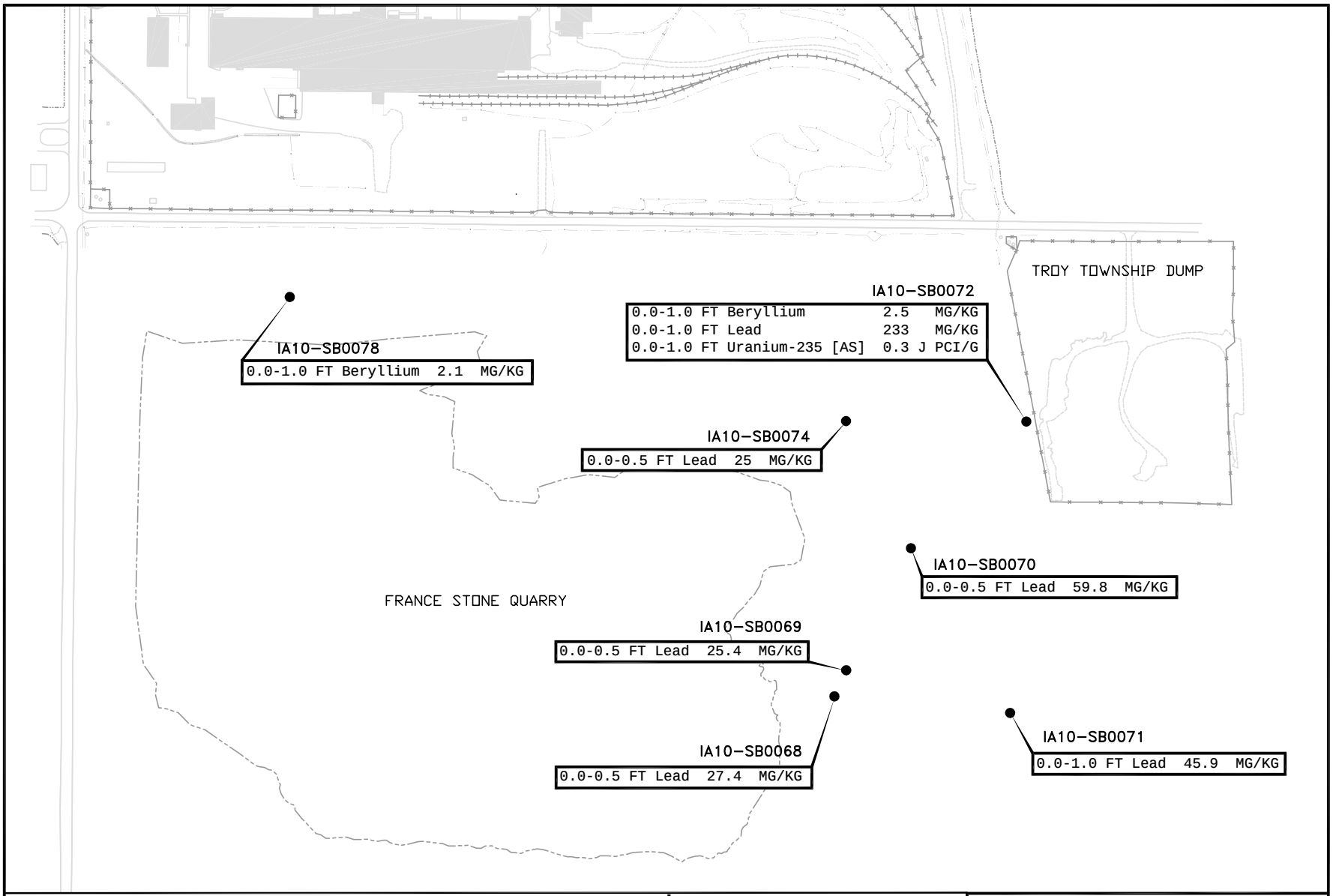
U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Former NYCRR Bed
Distribution of Metals and Radionuclides in Soil

Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-29-00	AS SHOWN	04-1748-801	4.29



BUILDING
LOW LYING AREAS
FENCE LINE
STREAMS & CREEKS
ABANDONED RAILROAD GRADE
PHASE IV SOIL BORING
QUARRY BOUNDARY
6.0-7.0 FT Beryllium 2.4 MG/KG
ANALYTICAL RESULTS

N True North

150 0 150 300
FEET

45 0 45 90
METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

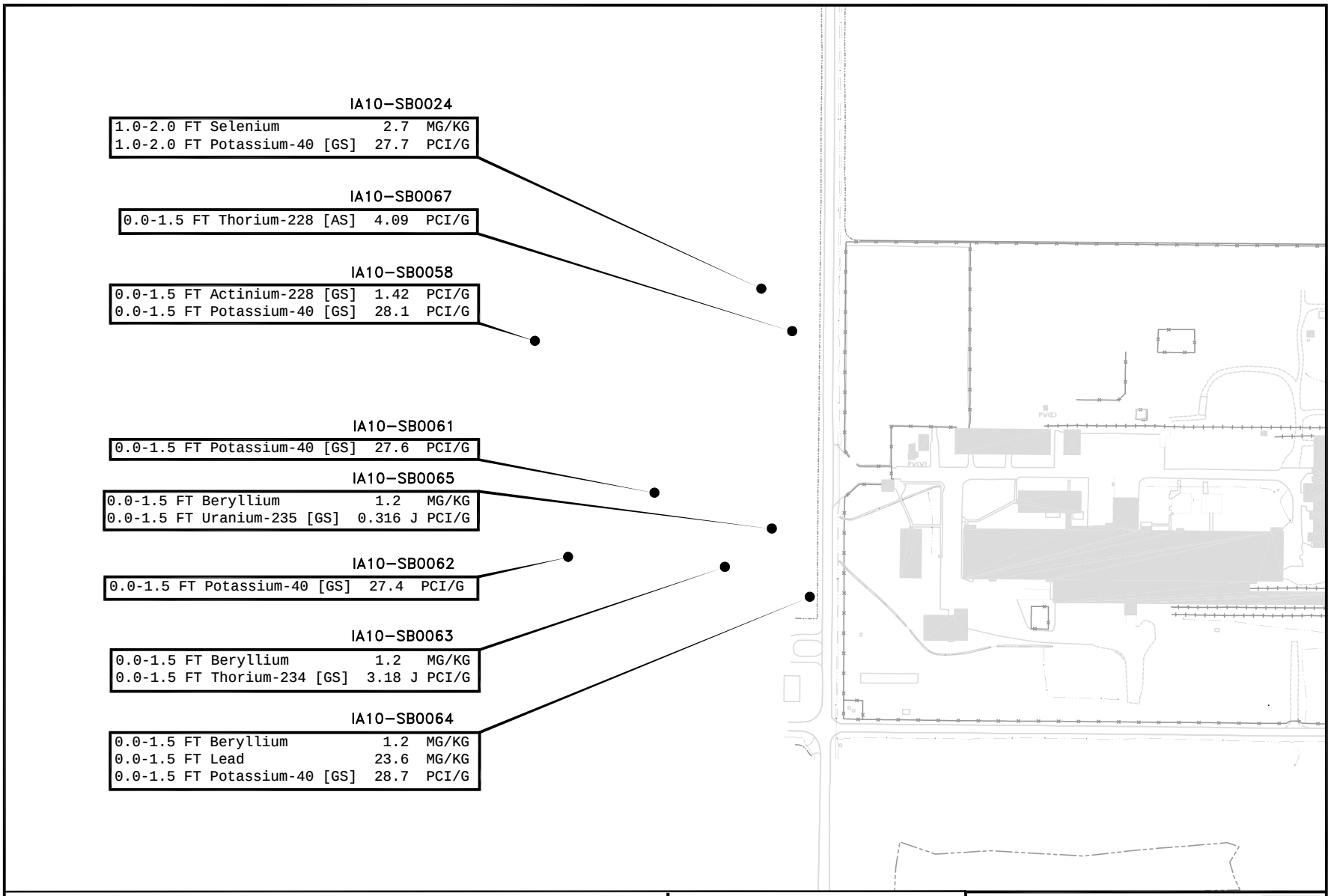
France Stone Quarry
Distribution of Metals and Radionuclides in Soil

SAIC. Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-29-00	AS SHOWN	04-1748-801	4.30

NAME: S:\LUCKEY\C041748\801\RIRPT_QUARRY-MET-RAD.DWG DATE: APR 19, 2000 TIME: 6:26 PM PCP: S:\PCP\GREY1.PCP

NAME: S:\LUCKEY\C041748\801\RIRPT_W-FARM-MET-RAD.DWG DATE: APR 19, 2000 TIME: 2:24 PM PCP: S:\PCP\GREY1.PCP



BUILDING

LOW LYING AREAS

FENCE LINE

STREAMS & CREEKS

ABANDONED RAILROAD GRADE

PHASE IV SOIL BORING

6.0-7.0 FT Beryllium 2.4 MG/KG ANALYTICAL RESULTS

N True North

150 0 150 300 FEET

45 0 45 90 METERS

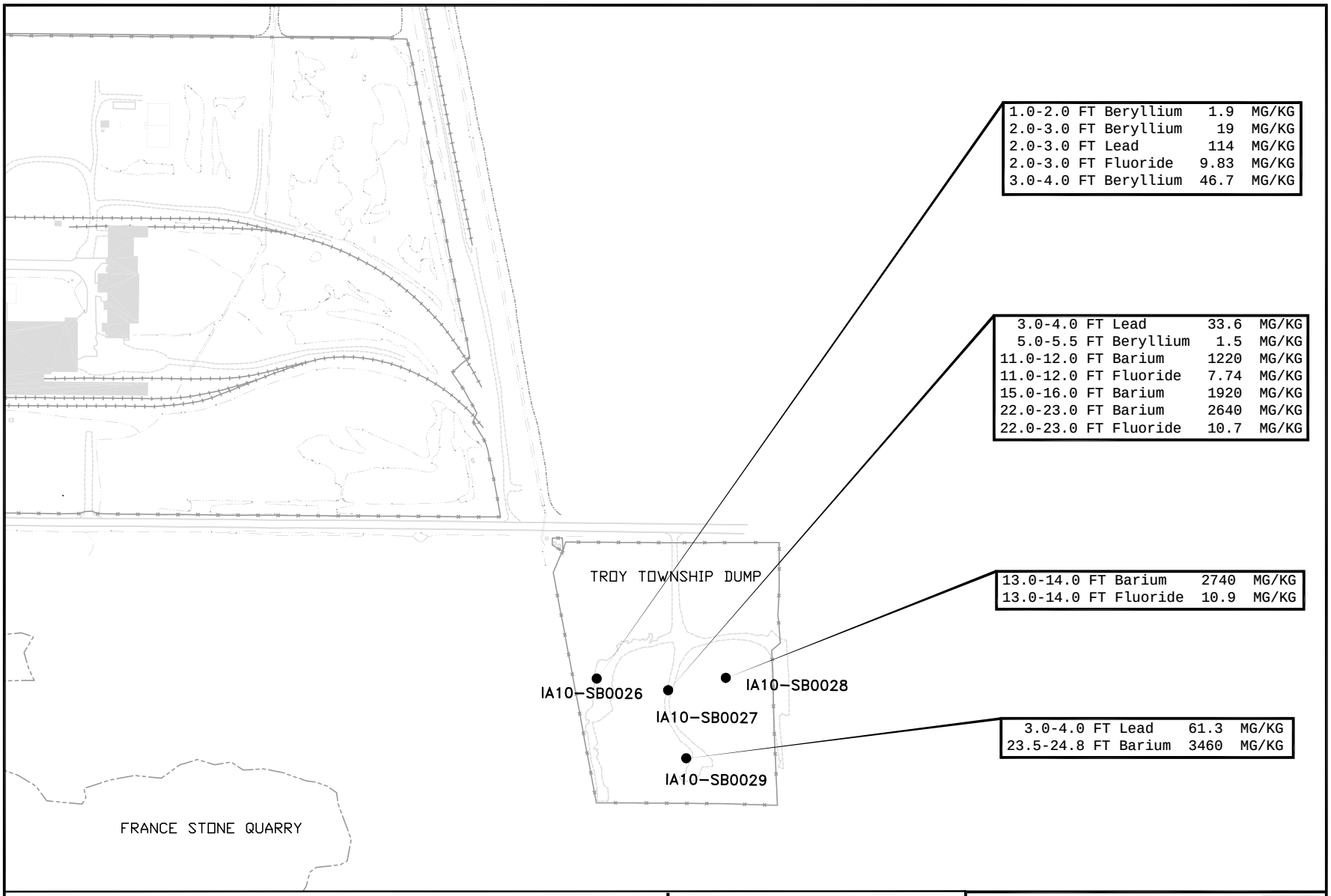
U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Western Farm Field
Distribution of Metals and Radionuclides in Soil

SAIC Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-29-00	AS SHOWN	04-1748-801	4.31



SOIL BORING LOCATION

1.0-2.0 FT Fluoride 8.15 MG/KG — ANALYTICAL RESULTS

N True North

150 0 150 300 FEET

45 0 45 90 METERS

U.S. Army Corps of Engineers
Buffalo District

LUCKEY SITE
RI REPORT

Troy Township Dump
Distribution of Metals and Fluoride in Soil

Science Applications International Corporation — Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	01-29-00	AS SHOWN	04-1748-801	4.32

NAME: S:\LUCKEY\C041748\801\RIRPT_DUMP-MET-FL.DWG DATE: APR 13, 2000 TIME: 2:32 PM PCP: S:\PCP\GREY1.PCP

5.0 FATE AND TRANSPORT 5-1
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5.0 FATE AND TRANSPORT

This section provides a description of the sources of contamination at the site and the mechanisms affecting their migration. A graphical depiction of the fate and transport mechanisms (Figure 5.1) as well as narrative descriptions are included. A tabular presentation of the conceptual model also is presented. The table summarizes source media, release and transport mechanisms, and potential exposure pathways. Exposure pathways and receptors are evaluated in the human health and ecological baseline risk assessments contained in Sections 6 and 7.

A number of constituents have been identified in the soil, groundwater, surface water, and sediment during the RI. A large number were detected above background levels in one or more samples collected during the RI. However, not all of these constituents are cause for concern. This section is not meant to describe the fate and transport of each individual constituent that exceeded background levels in one or more samples. Instead, the discussion is focused on those constituents and classes of compounds that were most frequently detected above background levels or EPA Region 9 PRGS or had a few significant exceedances of these levels. These constituents are summarized in Table 5.1 and include several metals, radionuclides, PAHs, and one PCB.

The fate and transport processes are discussed in a qualitative manner in this section. A quantitative groundwater flow model is being developed to permit a more detailed evaluation of these processes. This modeling will be conducted in future efforts and is not part of this RI.

5.1 PRIMARY SOURCE MEDIA

"Primary source media" is the term used to describe the original sources of contamination at the Luckey site. As such, the primary source media include the raw materials sent to the site for processing and the byproducts generated during the site processes. For the purposes of the fate and transport discussion, the primary source media will include process materials and by-products of beryllium processing operations. Because of the use of a high frequency induction furnace, fuel combustion products are not discussed. Primary source media were brought to the site in a number of forms. Beryl ore from Africa and South America was shipped to the site in bags and barrels. Reagents used to process the ore arrived at the site by train and truck. Due to plans to restart the magnesium production process, 1,000 tons of scrap iron were brought to the site by rail car. The scrap metal was contaminated with radionuclides from the processing of pitchblende ore for uranium and thorium. Scrap beryllium, also contaminated with radionuclides, was sent to the site for re-processing.

The primary source media at the Luckey site are described below and are summarized in Table 5.2. Because beryllium production operations at the Luckey site were discontinued in 1958, some of the source media and release mechanisms described in Table 5.2 no longer occur at the site. Since the risk assessment addresses current and future site risk, the risk assessment considers all constituents that may contribute to a complete exposure pathway now or in the future. Although some primary source media have been removed from the Luckey site, constituents may have migrated to other media (e.g., soil, groundwater, sediment, and surface water) that are still present at the site. This section examines the patterns of historic and current constituent migration at the Luckey site leading to the existing distribution of contaminants.

5.1.1 Beryl Ore

Beryl ore is a naturally occurring alumino-silicate rock formed during late-stage, low-temperature crystallization of granitic rocks (Guilbert and Park 1986). Ore was brought to the site via rail and was processed in several buildings to produce beryllium hydroxide, beryllium oxide, or beryllium metal.

Primary processing activities occurred in the Annex on the south side of the Luckey production building. The material arrived as gravel-sized chunks of rock in bags and barrels and was stored along the rail spurs. Beryllium from the beryl ore may have migrated to soil during storage near the former rail spurs. A detailed description of historical operations at the site is presented in Section 2.1.

5.1.2 Processing By-Products

Waste from the various processing steps was discharged into the lagoons as liquid or as suspended solids (slurry). These wastes may have included solid silica in sulfate liquor, ammonium alum, sodium sulfate and sodium hydroxide, Glauber's salt, alum, calcium sulfate, magnesium sulfate, barium sulfate, iron sulfide, lead oxide and sulfate, magnesium fluoride, and ammonium fluoride along with unreacted reagents and various beryllium compounds. Liquids from Lagoon A were discharged to the Luckey Road ditch. Liquids from Lagoons B and C were discharged to the main ditch.

5.1.3 Radioactively Contaminated Scrap

Two different types of radioactively contaminated scrap metal were sent to the site. Radioactively contaminated scrap metal intended for use in restarting the magnesium production process was shipped from the Lake Ontario Storage Area. Scrap metal was stored on either side of the northern rail spur in locations that are now a parking lot and a grassy area on the north side of the rail spur. The final disposition of this material is uncertain since the magnesium process was never restarted and the material was not usable as structural steel for improvements in the beryllium production line. In addition, radioactively contaminated beryllium metal was brought to the site for re-processing. During re-processing, radionuclides were removed from the metal.

5.1.4 Process Chemicals

Process chemicals arrived at the site in by rail or truck and were stored in and around the buildings. Various chemicals were used in the beryllium production process and discharged as slurry or liquids to the lagoons. These chemicals may have included sulfuric acid, ammonium hydroxide, sodium hydroxide, ammonium bi-fluoride, calcium carbonate, lead oxide, and sodium sulfide. Other chemicals also may have been used either as part of the process or as part of operations.

5.1.5 Air Emissions

As part of the process of forming beryllium oxide, beryllium hydroxide was dissolved with sulfuric acid and then crystallized. The sulfur oxides were then driven off in a furnace. Flue gasses were scrubbed but some were released with smokestack emissions.

5.1.6 Trenches, Pits and Landfills

Scrap metal, lagoon sludges, and other waste materials were deposited in trenches and pits. An area in the northeastern portion of the site known as the landfill contains at least four trenches, pits, and numerous piles of building debris. Two additional trenches were located south of the northern railroad spur and between the northern fence line and the filter beds. It is reported that the trenches were not re-excavated during site closure (Cline 1990).

5.1.7 Lagoons

Process wastes were discharged into lagoons A, B, and C. The lagoons were unlined with clay bottoms and bermed sides. Periodically lagoon sludges were removed and dumped in the northeastern corner of the site. Some sludge remains in the lagoons beneath the soil cover.

5.2 CONSTITUENT RELEASE AND TRANSPORT MECHANISMS

AEC activities at the Luckey site were discontinued approximately 40 years ago. The sources of contamination during AEC activities included smokestack emissions and waste disposal activities in excavated trenches, pits, lagoons, and debris piles. The smokestack emissions resulted in the widespread distribution of contaminants over the site. This airborne release affected mainly surface and near-surface soils through fallout and infiltration with precipitation. Wastes disposed in trenches, pits, and lagoons resulted in the contamination of more deeply seated soils. Based on the results of the RI sampling and analysis program, surface and subsurface soils still contain residual contamination from these past activities. The transport mechanisms affecting the migration of contaminants now present in the soils include volatilization, wind transport, surface runoff erosion, and infiltration/percolation, and leaching from soils to groundwater.

Historically, leaks, spills, and dumping may have occurred during beryllium processing operations. A diagram illustrating the conceptual model of release and transport mechanisms at the Luckey site is shown in Figure 5.1, while a tabular presentation of the sources, release mechanisms, and exposure pathways is shown in Table 5.2.

The release of constituents from areas within the Luckey site may result from particulate release and downwind transport of process by-products or contaminated soil particles. Surface water runoff and erosion of surface soils may result in the transport of process by-products to site ditches discharging to Toussaint Creek. The dissolution of site-related constituents from soil by the infiltration of rain or snowmelt may contribute to the transport of site-related constituents to groundwater. Additional release mechanisms directly related to historical site activities, including the processing of beryl ore, the dumping or spilling of process constituents or by-products, and the runoff of constituents from process material stored outside, no longer occur at the site but may have contributed to constituent releases.

The release mechanisms identified above have acted upon the source media identified in Table 5.2, increasing constituent mobility and enabling constituents to migrate from their original source media to the adjacent media, e.g., from buried sludge to subsurface soils. Transport mechanisms are the environmental processes that facilitate the movement of constituents. The primary transport mechanisms affecting the migration of constituents within and away from the Luckey site include wind transport, surface water runoff, infiltration, and groundwater flow. The fate and transport of site contaminants becomes important when they have the potential to come in contact with ecological or human receptors through the transport pathways, discussed in Sections 6 and 7.

The following discussion provides a general description of the release and transport mechanisms operating at the Luckey site. Also, if applicable, the primary sources that are being acted upon by the particular release mechanism are discussed.

5.2.1 Volatilization

Volatilization is defined as the transfer of matter from a liquid phase to a gaseous phase. A common example of volatilization is the evaporation of water. Constituents within the groundwater or in the soil may volatilize with the vapors moving into the aerated pore spaces in the soil or directly to the

atmosphere. The tendency of a compound to transfer to the gas phase is determined by its vapor pressure. Vapor pressure is defined as the pressure of the vapor of a compound in equilibrium with its liquid phase. Vapor pressure tends to increase as temperature increases. Compounds with higher vapor pressures are more volatile than compounds with low vapor pressures. The constituents associated with this type of release mechanism are VOCs. VOCs are chemicals with high vapor pressures facilitating their rapid transition from a liquid state to a gaseous state at normal ambient temperatures.

5.2.2 Wind Erosion

Contaminants adsorbed to surface soils on the site may be released to the atmosphere as particles transported by near-surface winds in the form of airborne contaminated dust. Soil particles containing contaminants may be eroded from areas containing little vegetative cover and transported to areas downwind of these sites. Such source areas include the bare spot located just east of the propane tanks and the interior of the disposal area in the northeast corner of the property. However, air monitoring for beryllium and radionuclides conducted during the RI field activities indicate that this is currently not a major transport mechanism. A discussion of the air monitoring completed during the RI is presented in Section 3.1.7 with complete results presented in Appendix 3D. In addition, except for the two above-mentioned areas, much of the site is covered with native grasses and other vegetation.

5.2.3 Soil Erosion and Surface Water Runoff

Surface water runoff from precipitation can erode soil from contaminated areas and can carry dissolved and suspended contaminants to local ditches. Three ditches drain the Luckey site and include the main or central ditch and two ditches that flow towards Luckey road and then on towards Toussaint Creek. Vegetative cover at the site reduces surface water runoff to the site drainage ditches. Possible areas where surface water runoff may be important include the areas immediately adjacent to the drainage ditches. In many areas on site, water ponds locally on the surface during periods of high precipitation, because of the poor natural drainage. The ponded water dissipates slowly by infiltration and evaporation. Such ponding has been observed in many areas of the site.

Surface drainage from the Luckey site flows from south to north across the eastern part of the property, running through a farm field north of the site, eventually draining into Toussaint Creek. Periodic flooding of the site drainage ditches or Toussaint Creek may also contribute soil erosion via surface water runoff. Based on analytical results from sediment and surface water sampling in the ditches and Toussaint Creek, the movement of contaminated sediment and surface water to surface drainage ditches appears to remain an active transport mechanism at the Luckey site. Beryllium levels were detected above background in surface water and sediment samples collected from the drainage ditches. Further evidence of surface water runoff has been measured in samples collected of Toussaint Creek sediments, as well as in soil samples collected along the creek's meander bends.

5.2.4 Leaks, Spills, and Dumping

During historical beryllium processing activities leaks, spills, and dumping of process constituents or by-products occurred at the Luckey site. Such practices did follow acceptable procedures at that time. Known dumping or spill areas include the on-site Landfill/Spoils Area, Lagoons A, B, and C, and along the railroad sidings. Although leaks, spills, and dumping associated with beryllium production operations no longer take place at the site, they are considered to be a major factor in the occurrence of contaminants at the site.

5.2.5 Infiltration, Dissolution, and Groundwater Flow

Precipitation falling on the Luckey site may run off, or it may return to the atmosphere through evaporation, or through plant uptake and evapotranspiration. Precipitation also may infiltrate the soil, where it can remain fixed in the (unsaturated) vadose zone soils or percolate to the water table. Water percolating through contaminated soil may result in the dissolution of water-soluble compounds that eventually reach the groundwater. Although the principle contaminants at the Luckey site (e.g. PAHs, radiological constituents, beryllium, cadmium, and manganese) are not highly soluble or readily mobile, it is possible for transport to groundwater to occur. To further evaluate transport within the groundwater, a fate and transport model is being developed. Currently, the groundwater flow model has been calibrated (SAIC, 2000) and will be used to evaluate the potential transport of constituents in groundwater under several different scenarios. Some results of the modeling have been incorporated into this qualitative discussion on the fate and transport of constituents at the site.

Infiltration and percolation provide the major transport mechanisms for contaminants currently found in the surface and vadose soils at the site. Contaminant concentrations generally diminish with depth. However, when contaminants are in a soluble form, they can migrate down to the water table. The contaminants may be re-adsorbed on soils at a greater depth. This mechanism accounts for the distribution of several contaminants throughout the vadose zone.

The mean annual precipitation for Wood County is 32 inches. With runoff measurement of 10 inches per year and an evapotranspiration rate of 22 inches per year, little rainfall is available for groundwater recharge (Harstine 1991). Literature sources indicate the value of recharge from precipitation ranges from near zero inches per year to four inches per year, with higher rates occurring where the overlying glacial tills are thin or absent. In the groundwater flow model, calibrated recharge rates over the Luckey site were estimated at 0.044 inches per year. This rate provided for the best match between simulated and observed water levels at the site and takes into account the thickness and measured hydraulic properties of the till at the Luckey site.

Groundwater discharge or release into a surface water body may occur if the top of the surface water possesses lower elevation than the adjacent water table. This may be a seasonal or periodic phenomenon along Toussaint Creek. Groundwater elevation data collected during the residential well survey and as part of the periodic water level measurements taken at the site indicate that pumping groundwater from production wells at the Luckey site has depressed local groundwater in an area, known as a cone of influence. The cone of influence from the production wells is roughly circular and extends northward beneath Toussaint Creek, causing the creek to lose water to the underlying groundwater. Modeling results also indicate that Toussaint Creek is losing water to groundwater in this area directly north of the site (SAIC 2000).

Constituent migration through the unsaturated zone to the water table generally reduces the soil leachate concentration through processes such as adsorption (adhesion to the surfaces of soil particles) and degradation. Groundwater transport in the saturated zone further reduces concentrations through attenuation (reduction in concentration through sorption, degradation, and dilution). These processes indicate that the concentration of a constituent arriving at an exposure point, such as a domestic drinking water well, is generally lower than the original constituent concentration in soil leachate. The reduction in concentration can be expressed using a dilution attenuation factor (DAF). The DAF is the ratio of original soil leachate concentration to the concentration at an exposure point. A DAF of one means that no dilution or attenuation has occurred between the source of the leachate and the down-gradient exposure point. High DAF values correspond to a high degree of dilution and attenuation.

The complex interactions that drive DAF values are best simulated with the aid of a suitable computer fate and transport model. A calibrated groundwater flow model has been constructed (SAIC 2000) for the site. Results of the flow model are planned for use in simulating the fate and transport of contaminants at the Luckey site after their release into the saturated zone. Site-specific DAFs will be derived (as part of the ongoing fate and transport modeling) for the leaching of contaminants through the vadose zone. Where appropriate, the methods presented in Soil Screening Guidance: Technical Background Document (EPA 1996g) will be used. Calculation of DAFs is not included in this qualitative discussion of the fate and transport of contaminants at the Luckey site.

5.3 PHYSICAL AND CHEMICAL CHARACTERISTICS OF ENVIRONMENTAL MEDIA AND CONSTITUENTS

The physical and chemical characteristics affecting the fate and transport of constituents through and among environmental media are discussed in this section. Emphasis is placed upon those characteristics and processes most likely to influence the movement of the contaminants identified at the Luckey site. The general information on chemical characteristics is summarized from published sources (EPA 1979, Dragun 1988, Knox et al. 1993).

5.3.1 Soil Characteristics

The most important soil properties that affect the transport of contaminants through the soil include infiltration capacity or permeability, cation exchange capacity, and organic carbon content. Permeability is a physical property that controls the rate of movement of a gas or liquid through the soil. CEC and organic carbon content are chemical characteristics that can affect contaminant migration by chemically interacting with dissolved constituents as they percolate through the soil. This section discusses the importance of these properties with respect to the site soils.

5.3.1.1 Infiltration Capacity/Permeability

Infiltration capacity is a measure of the rate at which soil material can absorb precipitation. Soil permeability is a measure of the ability of soil to permit water to pass through. Both properties are based largely upon the texture and structure of the soil material. In general, coarse-grained soils like loose sand will transmit water more readily than fine-grained soils such as clay. Infiltration capacity has not been measured in the on-site soils. Values of soil permeability for the Hoytville Clay were obtained from the Wood County Soil Survey (USDA 1966). The permeability of surface soils (0 to 1 ft) was reported to be 0.2 to 0.8 inches per hour (inches/hr). At depths between 1 and 5 ft the permeability was reported to be 0.05 to 0.2 inches/hr. Comparatively, the permeability of sandy soils around the region was reported to be 5 to 12 inches/hr. Values for soil infiltration (or percolation) rates can be roughly correlated to USDA soil permeabilities (personal communication with Frank Gibbs USDA Natural Resources Conservation Service, April 13, 2000). Soil percolation rates for surface soils are estimated at 1 to 2.5 inches/hr. For soils at depths between 1 and 5 ft, the estimated percolation rates range from <½ inch/hr to 1 inch/hr.

The Hoytville soils also were reported to have a moderate to high shrink-swell potential, which could drastically affect the infiltration and permeability values seasonally. Ordinarily, cracks form in this soil during dry weather because of shrinkage. These cracks measure as great as one inch across and extend into the subsoil, but they disappear when the soil becomes moist and swells. This reported phenomenon was substantiated in the field during the RI activities.

Hydraulic conductivity is also a measure of the ability of soil to transmit water. The hydraulic conductivity of the soil was evaluated during the RI by performing slug tests in several of the shallow monitoring wells. These tests were used to estimate the horizontal hydraulic conductivity within the

saturated zone and to estimate the migration rate of groundwater contaminants. The estimated values of hydraulic conductivity across the site are presented in Section 2.2.2.5.

The values of infiltration capacities and hydraulic conductivities for the soils at the Luckey site are relatively low. This is primarily due to the high clay content and compact nature of the soil. Because of these factors, both the downward and horizontal movement of water through the soil is slow. The rate of contaminant migration in the soil is expected to be correspondingly slow as well.

5.3.1.2 Cation Exchange Capacity

The cation exchange capacity (CEC) of a soil represents its capacity to attract positively charged ions (cations), such as metals and radionuclides, by exchange of those ions onto the surfaces of soil particles. Cation exchange specifically refers to the reaction in which cations adsorbed on the surface of a solid are displaced by cations in the surrounding solution. The CEC of a soil is greatly influenced by the surface area of the soil particles, since ions are exchanged on the exposed mineral surfaces. Clay particles generally consists of a larger surface area, compared to sand grains, and can exchange cations within their layered structures to a greater or lesser degree depending on the clay species present. The CEC of a typical clay-rich soil may be two to 30 times higher than the CEC of a typical sandy soil (Dragun 1988). Therefore, a soil with a high clay content can be expected to attenuate dissolved ions during transport more readily than a clay-free soil through the process of cation exchange.

Soil at the Luckey site was not specifically analyzed for CEC; however, inferences can be made based on soil composition and on values for Hoytville soil reported in the Wood County Soil Survey (USDA 1966). Typically, the surface and subsurface soils at the site contain relatively high clay content, and the CEC values are correspondingly high. Values of CEC for the Hoytville clay as reported in the Wood County Soil Survey (USDA 1966), range from 20.6 to 34.8 milli-equivalents per 100 grams of soil. Due to the high CEC of these soils, they have the potential to attract and chemically adsorb the positively charged ions found in many metal complexes and radionuclides. This process can effectively slow the migration of many inorganic and radioactive contaminants, and some contaminants may be attenuated under certain conditions.

5.3.1.3 Organic Carbon Content

The amount of naturally occurring organic carbon present in a soil affects the adsorption of organic compounds in that soil. The greater the organic carbon content in the soil, the more likely it is that the organic compounds migrating through the soil will become adsorbed by the organic component of the soil. Soils with increased organic matter content generally have a higher CEC. The organic material in the soil may also sorb certain metals by other solutes through complexation reactions and cation exchange.

Typically, organic matter constitutes less than 5% of a particular soil. The organic content of the soils at the Luckey site was not quantitatively determined during the RI. As reported in the Wood County Soil Survey, the organic content for the Hoytville Clay ranges from 4.2 to 6.5% but is commonly greater than 5% (USDA 1966).

5.3.2 Groundwater Characteristics

Solutes dissolved in groundwater can undergo several processes that remove them from the groundwater. These processes include sorption to the aquifer materials, sorption to organic carbon present within the aquifer, biodegradation, oxidation-reduction reactions, and chemical precipitation. Radioactive constituents also decay over time. The sorption processes tend to slow the movement of a

contaminant through the groundwater. The other processes can reduce the concentration of the solute in groundwater but may not slow its movement within the groundwater. The fate and transport of constituents in groundwater is being addressed in a separate modeling task; however, the primary factors influencing groundwater transport are described here.

5.3.2.1 Advection and Dispersion

Groundwater beneath the Luckey site migrates toward the cone of influence created by the on-site production wells. Groundwater moves through secondary porosity features, such as fractures and dissolution along bedding planes and joints within the Lockport Dolomite. The hydraulic conductivity of the dolomite increases near the upper surface of the bedrock, where more weathering and dissolution has taken place. Sand and gravel and weathered bedrock occur immediately above the competent bedrock and represent one preferential pathway for groundwater flow and contaminant migration. Lateral groundwater flow within the overlying clay-rich glacial till at the site is believed to be negligible.

Dissolved solutes within groundwater typically migrate in the direction of groundwater flow through the processes of advection and dispersion. Advection is the process by which dissolved contaminants are transported by the motion of flowing groundwater. Groundwater moves at rates that are both greater and less than the average linear groundwater flow velocity, resulting in mixing along the flow path and dilution of the contaminant at the leading edge of flow. This mixing, referred to as dispersion, is a function of groundwater flow velocity and the distance of groundwater flow.

Average linear groundwater flow velocities have been estimated for hydraulic conditions in August and November 1999 (Table 5.3). Velocities were calculated based on gradients observed at three locations on the site. Two locations were selected along the southern half of the site to provide estimates of velocity beneath the site. One was located directly south of the main production building (roughly 500 feet from the western property boundary) where gradients were the steepest. The second was located roughly 400 feet from the eastern boundary of the site where gradients were less. Because of their proximity to the property boundaries, the locations are referred to here as the east and west ends. The third area where velocities were estimated is in the northeast corner of the site (flow with a potential to migrate away from the site to the northeast). With the exception of flow in the sand and gravel, estimated flow velocities are typically less than a foot per day over the site. Velocities in the Lockport Dolomite may exceed a foot per day in the more permeable (more highly weathered) portions of the unit.

Diffusion is the process whereby solutes migrate from areas of high to low concentrations. It is the primary mechanism for contaminant transport in very low permeability units and may therefore, be an important transport mechanism within the clay-rich tills. Solutes may also diffuse into the dolomite matrix along bedding planes and fractures.

5.3.2.2 Oxidation-Reduction Potential

The mobility of a constituent in groundwater is determined by properties of the constituent, as well as by the chemistry of groundwater. The pH and oxidation/reduction (redox) potential of groundwater are important factors in the fate and transport of constituents because they control the ability of groundwater to dissolve and mobilize metals and other constituents. These chemical characteristics can be measured directly, or indirectly estimated, using field instruments. Water quality parameters measured during well development and groundwater sampling activities are provided in Appendix 3B.

The behavior of ionizable constituents in groundwater, such as metals, is greatly influenced by pH, which is a measure of the relative acidity of the groundwater. The groundwater pH beneath the site is primarily neutral to slightly basic, which will act to reduce the mobility of metals in the groundwater.

The Eh is a numerical index of the intensity of oxidizing or reducing conditions in groundwater. The redox potential is useful in predicting which chemical reactions involving electron transfer are likely to occur in groundwater. Both oxidizing and reducing conditions are apparent in the Eh measurements recorded during groundwater sampling events. Where data are available from the same well for several sampling events, there is a trend from oxidizing conditions during the summer and fall of 1998 toward reducing conditions in April 1999 [except at MW-07(I) and MW-08(S)]. Both MW-07(I) and MW-08(S) are located along the eastern boundary of the site, adjacent to each other. Their proximity to one another suggests a localized anomaly to the general trend. The cause of this anomaly has not been determined.

5.3.2.3 Distribution Coefficient

The amount of a solute that will sorb to a particular sediment or rock type can be determined experimentally. Partitioning is used to describe the process by which a solute becomes distributed between the solid phase (sorbed to soil) and the liquid phase (groundwater). If there is a linear relation between the amount of solute sorbed and the concentration of the solute in groundwater, the distribution coefficient, (K_d), can be used to represent the partitioning process. Values for K_d have been compiled for many of the common contaminants encountered within groundwater under a variety hydrogeologic settings. Representative K_d values are tabulated in Table 5.4. As K_d increases, more mass is sorbed to the solid phase and removed from solution. The values in Table 5.4 indicate that the contaminants will be sorbed more by the silty clay (till) than the sand and gravel at the site. Site-specific values of K_d were not determined as part of this RI.

K_d can be combined with bulk density and effective porosity of aquifer materials to calculate retardation factors for inorganic COPCs at the site. Physical properties, including bulk density and grain-size distribution of the soils and overlying till, were measured during the RI (see Table 2.3). Estimates of porosity and bulk densities of the geologic materials at Luckey are summarized in Table 5.4 and can be used to estimate the retardation factors for inorganic constituents to be applied in the fate and transport modeling. For organic constituents, the respective organic carbon partition coefficients (K_{oc}) can be combined with the fraction organic carbon (foc) to estimate retardation factors to be applied in the fate and transport modeling. Estimated retardation factors for the organic COPCs are also presented in Table 5.4.

5.3.3 Physical and Chemical Characteristics of Contaminants

The chemical and physical processes associated with contaminants include solubility, sorption and partitioning, volatilization, and degradation. These chemical characteristics are described below.

5.3.3.1 Solubility

Solubility is one of the most important properties affecting the fate and transport of chemical compounds released to the environment. The tendency of a chemical to be transported by groundwater is directly related to its solubility and inversely related to its tendency to adsorb to soils and volatilize from water. The solubility of a compound is described as the amount of a compound that dissolves in pure water at a specific temperature. The solubility of most common organic compounds range from 1 to 100,000 ppm at ambient temperatures. Metals and radionuclides are typically more soluble under acidic conditions. Table 5.5 presents the solubility values for several constituents detected at the site.

5.3.3.2 Sorption and Partitioning

The fate and transport of contaminants in soil are influenced by two processes that tend to bind the contaminant to the soil: adsorption and fixation. Adsorption is the process whereby dissolved ions are

removed from the liquid phase and become chemically attached to the surfaces of soil particles. Positively charged metals (cations) are adsorbed to balance the negative surface charges on soil and organic matter particles. The cation exchange capacity of the soil, the presence and relative quantity of other cations, and various other factors affect adsorption rates. Fixation refers to the geochemical reactions that immobilize an element within the structure of a mineral or at the mineral surface.

Sorption processes are less complicated for organic contaminants. The affinity of a chemical for sorption on natural organic matter is expressed by its sorption partition coefficient (K_{oc}). A high K_{oc} indicates the compound is more likely to become fixed to organic matter within the soil matrix.

The octanol-water partition coefficient can be used to estimate the tendency for a chemical to separate between the two or more environmental media (e.g., soil and groundwater). Compounds with log K_{ow} values less than 1 are highly attracted to the water phase, or hydrophilic, while those with log K_{ow} values greater than 4 will partition to the soil. Measured log K_{ow} values for organic compounds range from –3 to 7.

K_{ow} values for organic compounds are used to evaluate fate in the environment. The parameter can be related to solubility in water and bioconcentration effects, but it is mainly used to relate to soil/sediment adsorption. When combined with the organic content of the soil, K_{ow} values can be used to predict the amount of material adsorbed in the soil and the retardation factor for the movement with groundwater through the aquifer. Table 5.5 presents K_{ow} values for selected organic compounds.

5.3.3.3 Volatilization

Volatilization refers to the transfer of a compound to a gas state. Two properties of organic compounds can be used to estimate the degree to which the compound occurs in the gas state: vapor pressure and Henry's Law Constant (see Table 5.5 for selected constituents). Vapor pressure is a measure of the pressure at which a compound is in equilibrium with its vapor. The value can be used to estimate the extent to which a chemical will travel in air, as well as the rate of volatilization from soils and solution. Generally, a vapor pressure lower than 10^{-7} mm mercury means the compound will not be present in air or soil pore spaces. Compounds with vapor pressures higher than 10^{-2} mm mercury will exist primarily in air.

Henry's Law constant expresses the amount of chemical partitioning that can occur between air and water at equilibrium. Generally, the greater the Henry's Law constant, the more volatile a compound, and the more easily it can be removed from solution. Some generalizations between volatilization rates from aqueous solutions and Henry's constants (K_H) are presented below:

- At $K_H < 10^{-7}$ atm-m^3/mol-the substance is less volatile than water, and it is essentially non-volatile.
- Where $10^{-7} < K_H < 10^{-5}$ atm-m^3/mol -the substance slowly volatilizes, and the rate is controlled by slow molecular movement (diffusion) through the air.
- Where $10^{-5} < K_H < 10^{-3}$ atm-m^3/mol -volatilization begins to become a significant transfer mechanism; this range includes some PAHs and halogenated aromatic compounds.
- At $K_H > 10^{-3}$ atm-m^3/mol -substances may be released in significant quantities; resistance from the water film (i.e., solubility and diffusion rate in water) is the rate controlling process.

5.3.3.4 Degradation

Contaminant degradation or attenuation is a function of physical, chemical, and biological processes that affect the contaminant as it moves through air, soil, and water. These processes include

hydrolysis, photolysis, bioaccumulation, biotransformation or biodegradation, and radioactive decay. Inorganic contaminants may undergo chemical species transformation that affects the mobility of the contaminants in the environment. For example, the reduction of chromium from the +6 to the +3 charge (valence) state greatly reduces its mobility in the environment. With the exception of redox reactions and cation exchange, inorganic contaminants are much more stable in the environment. Hydrolysis, photolysis, and biodegradation are the processes and reactions of greatest importance in regard to degrading organic contaminants.

For both metals and radionuclides, the natural attenuation processes are dilution and sorption. Dilution may occur by dispersion of dissolved contaminants in water percolating through the soil column or in groundwater. Sorption generally includes the processes of adsorption, coprecipitation, precipitation, and diffusion into the soil matrix. These are processes by which solutes become associated with the immobile, solid phase. Sorption may be either reversible or slowly reversible. Slowly reversible sorption of contaminants from solid phases exposed to uncontaminated groundwater may also contribute to dilution of the contaminant. The extent of dilution will be determined by the rate of contaminant release into solution relative to the velocity of water flow.

Most organic contaminants interact with the soil and do not move at the same rate that water does through the soil matrix. This phenomenon is referred to as retardation. Retardation is the dynamic process of adsorption to and desorption from soil materials and is specific to individual chemical compounds. In general, if a compound is strongly adsorbed, it is highly retarded. Biochemical reactions (in addition to retardation) have a major effect on the fate and transport of organic compounds. Biological degradation appears to be the main attenuation process for organic contaminants present in the site soils.

Hydrolysis occurs when a water molecule (or hydroxide ion) substitutes for another atom or group of atoms present in organic compounds. Because water is plentiful in most soils hydrolysis is an important reaction. In this reaction, a functional group, from the organic molecule is exchanged with a hydroxyl functional group from the water. One example of this reaction is the hydrolysis of chlorinated compounds, which often yields an alcohol or an alkene. This reaction is significant because typically chlorinated compounds are not readily biodegraded.

Photolysis is the degradation of dissolved compounds by sunlight. Light is absorbed by the compound, resulting in a chemical reaction involving molecular rearrangement, dissociation, or oxidation of the energized molecules. Indirect photolysis occurs when an organic compound reacts with other previously energized molecules, rather than directly with solar radiation. Generally, compounds in the subsurface are not significantly affected by photolysis until released into the atmosphere.

Biodegradation is the breakdown of organic compounds through biological processes. An example of biodegradation is the reduction of chlorinated organic compounds, which may be consumed by aerobic and anaerobic bacteria as food sources. Biodegradation may occur aerobically and/or anaerobically, depending upon the molecular structure of the chemical and the environmental conditions. Chemicals that may be completely, but slowly, degradable can be persistent in the environment over long periods of time.

A chemical's biodegradation potential can be categorized as degradable, persistent, and recalcitrant. Readily degradable refers to compounds that have exhibited biodegradability in a variety of aerobic environments. Degradable also refers to compounds that are normally degraded in tests but not necessarily in the environment. Persistent refers to chemicals that remain in the environment for long periods of time. These compounds are not necessarily non-degradable, but degradation requires long

periods of acclimation or modification of the environment to induce degradation. Recalcitrant refers to compounds that are non-degradable.

An additional process contributing to the fate or attenuation of radionuclides is radioactive decay. The decay is a first-order reaction in which the amount of radioactive element decaying over a unit period of time is proportional to the amount present. A half-life is the period of time during which half of a given number of atoms of a specific radionuclide decay. After one half-life, half of the original amount of the radionuclide will remain. The half-lives for many of the radionuclides detected in the soils at the site are measured in tens of years to millions of years.

5.4 FATE OF INORGANIC AND ORGANIC CONTAMINANTS AT THE SITE

As shown in Table 5.1, the contaminants at the Luckey site consist of metals, radionuclides, PAHs, and one PCB. Typically, inorganic contaminants will be transported in the dissolved phase through the soil column. Slightly lower pHs (and Ehs) increases the mobility of some inorganic species. At the Luckey site, the metals and radionuclides are believed to be principally bound to soil particles. In general, the migration rate of metals in the vadose zone soil is not expected to be significant. This is based on the relatively high CEC and organic matter content of the soils, their high K_d values, and the observed distribution of contaminants detected in the soils.

Contaminants released to the atmosphere through volatilization could have been an important consideration at the site in the past when the contaminants may have been more concentrated. Currently, the release of contaminants by volatilization is limited. Although the few VOCs now present in the soils are moderately volatile, they were detected at very low or estimated concentrations. Several SVOCs, including PAHs, were detected at higher concentrations, but these compounds have relatively low volatility. Under current conditions, the amount of volatile compounds present at the site is limited, and volatilization is not considered to be a major transport mechanism for contaminants at the site.

The fate and transport of several inorganic and organic contaminants detected in the soils at the Luckey site are discussed in this section. The contaminants have been grouped together according to similar physical and chemical properties because the fate and transport mechanisms would be expected to be similar as well.

5.4.1 Inorganic Contaminants

The metals and radionuclides at the Luckey site are cations and generally have limited mobility in soil and groundwater because of cation exchange or sorption onto the surface of mineral grains. The inorganic constituents discussed below include beryllium, cadmium, manganese, chromium, copper, lead, and zinc. The radionuclides include Ra-226, Th-230, U-238.

Cationic metals tend to form stable and immobile oxides, hydroxides, carbonates, or phosphates under neutral to alkaline pH conditions such as are present in the soils and groundwater at the Luckey site. Most transitional and heavy metals are present in cationic forms under natural environmental conditions. They are generally not mobile and tend to remain relatively close to the point of their initial deposition (EPA 1992). A brief discussion of each of the constituents is provided below.

Beryllium is a naturally occurring element in the Earth's crust and forms stable compounds with anions. Beryllium oxides and hydroxides have low solubilities in the pH range of most natural waters. The fate of beryllium in the environment is most likely the adsorption to mineral surfaces or complexing into insoluble compounds. In aqueous solutions, beryllium occurs only in the +2 oxidation state (Bodek 1988). Soluble beryllium salts are hydrolyzed to form insoluble beryllium hydroxides (EPA 1980).

Under typical environmental conditions, the dominant dissolved species are expected to be the hydroxo-complex BeOH+ and Be2+. Beryllium hydroxide is expected to precipitate from water given its low solubility at the pH range of most natural systems (Bodek 1998). In aquatic systems with fluoride, BeF+ and BeF2 would also be significant dissolved species (Bodek 1988). Beryllium may adsorb to suspended mineral solids and sediments in water based upon soil studies. Bioconcentration may be important in sediment-originated food chains. If released to the soil, beryllium is expected to be essentially immobile.

Beryllium was commonly detected above background in soils, surface water, and sediments, and infrequently detected above background in the groundwater. Highest concentrations in the soil occurred in the samples from the disposal pits and trenches, filter bed areas, and the lagoons. The highest concentrations in groundwater occurred along the northern boundary of the site, just downgradient from the filter bed area. The relatively low levels of beryllium in the groundwater indicate that leaching from the overlying soils is a minor transport mechanism.

Cadmium carbonate has a very low solubility, which could limit its concentration and mobility. Clay minerals, carbonates, or hydrous oxides of iron and manganese may adsorb cadmium. As with all cationic metals, the chemistry of cadmium in the environment is controlled to a great extent by pH. Under acidic conditions, cadmium solubility increases and very little adsorption of cadmium takes place. At pH values greater than 6 (typical of the Luckey site), cadmium is adsorbed by the soil or is precipitated, and cadmium concentrations in soil water or groundwater water are greatly reduced. The highest levels of cadmium were detected in the soil samples collected from the Lagoons, specifically, Lagoon C, and to a lesser extent, in soil samples collected from the filter bed area. Cadmium exceeded background levels in groundwater in only 3 of 58 samples.

Manganese is a naturally occurring element in the Earth's crust and forms stable compounds with anions. The solubility of manganese carbonates and oxides is low and acts to reduce its concentration in the aqueous phase. Under acidic conditions, manganese becomes more mobile in the environment. At Luckey, manganese is not expected to be mobile in the environment. Manganese was detected above background in 9 of 58 groundwater samples. It was not detected above background levels in the soil, surface water, or sediment samples.

Chromium is a naturally occurring metal in soil and is considered an essential trace nutrient. It occurs in two states. One is relatively insoluble and occurs naturally. The other is highly reactive and is usually the result of industrial activity. All forms are toxic if the concentration is high enough but the reactive form is toxic at lower concentrations. Chromium was detected above background levels in soil samples collected from the Lagoons, the trenches and pits, and the filter bed area. Only one groundwater sample exceeded background levels.

Copper is a reddish naturally occurring metal that is present in small quantities in soil. It is soluble in acid conditions. Some copper compounds can be soluble although copper sulfide is relatively insoluble. The highest concentration of copper above background levels was detected in soil samples from the trenches and pits. Copper also exceeded background levels in the filter bed area. Only 4 of 43 groundwater samples exceeded background levels.

Nickel is a metal used commonly in industry. It is naturally present in soil at fairly low levels. It adsorbs readily to clays iron and manganese oxides and organic matter. Formation of complexes with inorganic and organic anions will increase mobility of nickel. Nickel was only detected above background levels in a few soil samples from the lagoons, disposal trenches and pits and the filter bed area. It was detected above background levels in 29 of 58 groundwater samples.

Lead is naturally present in soil. Under most conditions lead reacts with clays, phosphates, sulfates, carbonates hydroxides and organic matter to reduce its solubility. The formation of organic complexes may significantly increase the solubility of lead in soil. Above a pH of 6 most lead is bound in lead carbonate or adsorbed on clay surfaces. (EPA 1992). Lead was detected above background in soil sample collected from nearly all of the on-site features investigated. The most significant exceedances occurred in the disposal trenches and pits and the filter bed areas. Lead was also detected slightly above background in 10 of 71 groundwater samples. Lead was also detected above background levels in surface water and sediment samples collected from on-site drainage ditches and Toussaint Creek.

Zinc is a naturally occurring metal that is present in normal soils at low concentrations and is considered an essential trace nutrient. Clay minerals, carbonates or hydrous oxides readily adsorb it. Zinc is relatively soluble although its adsorption increases with pH. Zinc oxide is a commonly used sunscreen applied directly to the skin. Zinc was detected at elevated levels above background in soils from the Lagoons, disposal trenches and pits, and the filter bed area. Zinc was not detected above background levels in unfiltered groundwater samples.

Ra-226 is a naturally occurring isotope with a half-life of 1599 years. It occurs as a daughter product in the decay series of U-238 to lead-206. The aqueous chemistry of radium is similar to barium, strontium, and calcium (Fetter 1993). It is more soluble than uranium or thorium and can be bioconcentrated by plants. Radium can be strongly exchanged through cation exchange. Ra-226 was detected at elevated levels above background in soils from the Lagoons, disposal trenches and pits, and the filter bed area. It was also detected slightly above background levels in 17 of 86 unfiltered groundwater sample.

Thorium is a naturally occurring element, with Th-232 being the principal isotope. It has a half-life of 1.39×10^{10} years (Fetter 1993). Thorium typically has a very low solubility. The mobility of thorium increases through complexation with organic compounds. Adsorption of dissolved thorium increases with increasing pH. The sorption of thorium onto clays, oxides and soil organic matter is nearly total at a pH of 6.5 or higher (Fetter 1993). Therefore, thorium at the Luckey site should be nearly immobile. Thorium was detected at elevated levels above background in soils from the Lagoons, disposal trenches and pits, and the filter bed area. Thorium was not detected above background levels in any of the groundwater samples. Thorium levels slightly exceeded background levels in several sediment samples from the on-site ditches and Toussaint Creek.

Uranium occurs primarily as U-238, and has a half-life of 4.5×10^{9} years. The chemistry of dissolved uranium is complex. Uranium occurs in three valence states and undergoes oxidation-reduction reactions. It forms soluble complexes with a wide variety of anions, including fluoride, phosphate, carbonate, hydroxide and sulfate. Under reducing conditions, uraninite, a solid uranium oxide compound, may form, which would remove uranium from solution (Fetter 1993). Uranium was detected at elevated levels above background in soils from the Lagoons, disposal trenches and pits, and the filter bed area. Uranium isotopes U-233/234 and U-238 were detected above background levels in 18 groundwater samples. Uranium levels slightly exceeded background levels in several surface water and sediment samples from the on-site ditches and Toussaint Creek.

5.4.2 Organic Contaminants

PAHs such as benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, and ideno(1,2,3-c,d)pyrene are formed during incomplete combustion of hydrocarbon fuels and can also be present at elevated concentrations in coal tar, creosote, waste engine oil, and no. 6 fuel oil. PAHs were detected above background levels primarily in the surface soil samples collected near the existing buildings and associated areas. Aroclor-1254 was detected at the electrical

transformer area. PAHs slightly above background levels were also detected at the electrical transformer area, the disposal trenches and pits, filter bed area, and sediments from the on-site ditches and Toussaint Creek. The lone PCB, aroclor-1254, behaves similarly in the environment to the PAH compounds. The behavior of aroclor-1254 can, therefore, be inferred from the discussion of PAHs presented below.

The environmental fate and transport of these compounds are largely inferred from data on benzo(a)pyrene and PAH mixtures. The relatively high octanol/water partition coefficients of PAHs indicate that they should be strongly adsorbed onto soils and suspended particulate matter, especially those high in organic content. Available information suggests that these compounds can accumulate in the sediment and biotic portions of the aquatic environment, and adsorption is probably the dominant aquatic transport process. Atmospheric transport of PAHs is also possible. This generally occurs by adsorption onto airborne particulate matter. They can also reach groundwater by leaching from contaminated soils.

In soil, PAHs can volatilize, biodegrade, or percolate to groundwater. PAHs are relatively insoluble in water, but the dissolved portion may undergo rapid direct photolysis. Oxidation by chlorine and ozone may be an important fate process when those oxidants are available in sufficient quantities. Because of their low aqueous solubility, they can persist in the environment and inhibit rates of hydrolysis, photolysis, and oxidation. Henry's Law Constants and vapor pressures for the PAHs at Luckey indicate that they are nonvolatile to slightly volatile. As a result, volatilization is not considered to be a significant transport process for the PAHs at the Luckey site.

Although PAHs are rapidly bioaccumulated, they are also quickly metabolized and eliminated from most organisms (shellfish are a known exception). Bioaccumulation, especially in vertebrate organisms, is usually short term, so it is not considered an important fate process in multi-cellular organisms. Biodegradation and biotransformation are probably the ultimate fate processes for PAHs. The available data suggest that the PAHs with high molecular weights are degraded slowly by microbes and are readily metabolized by multi-cellular organisms. Microbes appear to degrade PAHs more completely than mammals. Biodegradation probably occurs more slowly in aquatic systems than in soil, and it may be more important in systems that are chronically affected by PAH contamination.

5.5 SUMMARY

The original sources of contamination at the Luckey site include the raw materials sent to the site for processing and the byproducts generated during the beryllium processing operations. Beryl ore and reagents used to process the ore arrived at the site by train and truck. Scrap iron (1,000 tons) and beryllium, both contaminated with radionuclides, were also brought to the site by rail car. Several metals, radionuclides, PAHs, and one PCB were commonly detected or significantly exceeded background. A qualitative discussion of the fate and transport processes affecting the migration of these compounds has been developed. All constituents detected are further evaluated in the human health and ecological risk assessments presented Sections 6 and 7, respectively.

Historical releases of contaminants to the environment occurred during the beryllium processing. As part of the process of forming beryllium oxide, beryllium hydroxide was dissolved with sulfuric acid and then crystallized. The sulfur oxides were then driven off in a furnace. Flue gasses containing sulfur oxides were released with smokestack emissions. Wastes were discharged into the lagoons as liquid or as suspended solids (slurry). Liquids from Lagoon A were discharged to the Luckey Road ditch. Liquids from Lagoons B and C were discharged to the main ditch. Scrap metal, lagoon sludge, and other waste materials were deposited in trenches and pits. At least four trenches, pits, and numerous piles of building debris occur in the northeastern portion of the site. Two additional trenches were located south of the

northern railroad spur and between the northern fence line and the filter beds. In addition, leaks, spills, and dumping may have occurred during beryllium processing operations.

The transport mechanisms affecting the migration of contaminants now present at the Luckey site include volatilization, wind transport, surface runoff and erosion, leaching from soils to groundwater and transport within the groundwater. Based upon the results of the RI, volatilization and wind transport of contaminants are not significant transport mechanisms for contaminants at the site. Very few VOCs were detected on site and only at low levels, so volatilization is not an important transport mechanism based upon current conditions. Similarly, air-monitoring results during the RI indicate that wind-blown transport of dust and particulates containing sorbed contaminants were essentially at background levels and therefore is not a significant transport mechanism.

The presence of contaminants (beryllium, arsenic, and lead) in the surface water and sediments in the drainage ditches and Toussaint Creek indicate that transport via surface runoff and erosion remains an active transport mechanism. The detection of contaminants in the groundwater indicates that leaching of contaminants from the overlying soils also represents an active transport mechanism at the site. However, the low levels of contaminants detected in the groundwater and their spotty distribution suggest that the contaminants are sorbed tightly to the soils and are only slowly released through leaching.

The groundwater transport mechanism represents a potential pathway for the off-site migration of contaminants. Several metals and radionuclides have been identified above background levels in the shallow groundwater in the unconsolidated overburden and in the shallow bedrock wells (completed 10 ft into bedrock). Currently, the cone of influence from the Uretech production wells appears to be preventing off-site migration from all areas with the exception of groundwater in the unconsolidated glacial sediments in the northeast corner of the site. In this area, there is the potential for groundwater to flow north and east away from the site and towards Toussaint Creek, but the RI data do not show contaminants moving off site in the groundwater from this area. The lack of contaminant plumes in the groundwater and the spotty nature of groundwater contamination indicate that transport via the groundwater pathway is not a major transport mechanism under current conditions. However, this mechanism could become more important in the future if conditions change such as shutting down the Uretech production wells.

Metals and radionuclides were detected in soil, in groundwater, and in surface water and sediments samples collected during the RI. While low levels of metals and inorganics have been detected in shallow groundwater, the conditions at the Luckey site tend to limit the vertical infiltration of metals and inorganics through the soils to the groundwater. The infiltration rate is low (estimated at 0.044 inches/year). The glacial tills are high in clay and organic matter and have pH that is generally neutral to slightly alkaline, all of which tends to favor the sorption of metals or the precipitation of metal compounds from solution. De-sorption of metals from soils and sediments may contribute low levels of these constituents to surface water and groundwater over time

The PAHs and aroclor-1254 appear to be very immobile at the Luckey site. Elevated detections were typically limited to surface soils, and they were not detected in the groundwater. The detection of PAHs in ditch sediments and along Toussaint Creek indicates at least limited transport of via sediments in surface water. The properties of these compounds support their immobility. They tend to partition to the sediment rather than to the water or air. They have low solubilities in water and a strong tendency to sorb onto soil and organic matter within the soil. They also have low vapor pressures and therefore have little tendency to volatilize.

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Table 5.1. List of Contaminants by Media Type at the Luckey Site

Media	Metals	Semivolatile Organic Compounds (SVOCs)	Polychlorinated Biphenyls (PCBs)	Radionuclides
Soil	Beryllium Cadmium Copper Nickel Lead Zinc Fluoride	Benz(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenz(a,h)anthracene Indeno(1,2,3-c,d)pyrene	Aroclor-1254	Radium-226 Thorium-230 Uranium-238
Groundwater	Manganese	--	--	--
Sediment	Beryllium Cadmium Copper Nickel Lead Zinc	Benz(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene	--	--
Surface Water	Beryllium Cadmium Copper Lead Manganese Fluroide	Bis(2-ethylhexyl)phthalate	--	--

Table 5.2. Tabular Presentation of the Site Conceptual Model

Primary Source	Primary Release Mechanism	Secondary Source	Secondary Release Mechanism	Potential Exposure Pathways
Historic processing of beryl ore. Scrap metal handling	1. Air emissions from beryllium processing operations 2. Leaks from process piping and drains 3. Infiltration 4. Spills, leaks, and dumping 5. Shipment and storage of process materials 6. Past deposition in ventilation system 7. Surface water runoff	1. Surface soil 2. Subsurface soil 3. Groundwater 4. Surface water 5. Ditch and creek sediment 6. Floodplain soils	1. Volatilization and wind erosion 2. Resuspension by off-site plowing 3. Dissolution in water 4. Surface water runoff/soil erosion	1. Dust and vapor inhalation 2. Dermal contact and incidental ingestion of surface water 3. Dermal contact and incidental ingestion of sediments and floodplain soils 4. Dermal contact and incidental ingestion of surface soil 5. Groundwater consumption
Processing by-products 1. Material disposed in trenches, pits, and landfill 2. Lagoon sludges	1. Volatilization and wind erosion 2. Spills, leaks, and dumping 3. Release to air and subsurface soils during excavation activities 4. Infiltration to subsurface soil 5. Dissolution in water 6. Groundwater transport	1. Surface soil 2. Subsurface soil 3. Groundwater 4. Surface water 5. Creek sediment 6. Floodplain soils	1. Volatilization and wind erosion 2. Resuspension by off-site plowing 3. Dissolution in water 4. Surface water runoff/soil erosion	1. Dust and vapor inhalation 2. Dermal contact and incidental ingestion of surface water 3. Dermal contact and incidental ingestion of sediments and floodplain soils 4. Dermal contact and incidental ingestion of surface soil 5. Groundwater consumption

Table 5.3. Hydraulic Gradients and Average Groundwater Flow Velocities

Water Bearing Unit	Effective Porosity[a]	Hydraulic Gradient[b]	Hydraulic Conductivity (ft/day)			Avg. Water Flow Velocity (ft/day)		
			Minimum	Modeled	Maximum	Minimum	Average	Maximum
Till (Silty Clay)								
West End	0.06	0.068	0.028	0.05	0.057	0.032	0.057	0.065
East End	0.06	0.01	0.028	0.05	0.057	0.005	0.0083	0.010
Northeast Area	0.06	0.007	0.028	0.05	0.057	0.003	0.0058	0.007
Sand and Gravel								
West End	0.25	0.068	4.27	20	126.3	1.161	5.44	34.354
East End	0.25	0.01	4.27	20	126.3	0.171	0.8	5.052
Northeast Area	0.25	0.007	4.27	20	126.3	0.120	0.56	3.536
Lockport Dolomite								
West End	0.14	0.03	0.0269	1	18.16	0.006	0.21	3.891
East End	0.14	0.012	0.0269	1	18.16	0.002	0.086	1.557

[a]Effective Porosity Estimated from Kruseman and de Ridder (1992) and Domenico and Swartz (1990)
[b]Hydraulic Gradients From Measurements Collected on August 18, 1999

Water Bearing Unit	Effective Porosity[a]	Hydraulic Gradient[b]	Hydraulic Conductivity (ft/day)			Avg. Water Flow Velocity (ft/day)		
			Minimum	Modeled	Maximum	Minimum	Average	Maximum
Till (Silty Clay)								
West End	0.06	0.062	0.028	0.05	0.057	0.029	0.052	0.059
East End	0.06	0.01	0.028	0.05	0.057	0.005	0.0083	0.010
Northeast Area	0.06	0.002	0.028	0.05	0.057	0.001	0.0017	0.002
Sand and Gravel								
West End	0.25	0.062	4.27	20	126.3	1.059	4.96	31.322
East End	0.25	0.01	4.27	20	126.3	0.171	0.8	5.052
Northeast Area	0.25	0.002	4.27	20	126.3	0.034	0.16	1.010
Lockport Dolomite								
West End	0.14	0.025	0.0269	1	18.16	0.005	0.18	3.243
East End	0.14	0.01	0.0269	1	18.16	0.002	0.071	1.297

[a]Effective Porosity Estimated from Kruseman and de Ridder (1992) and Domenico and Swartz (1990)
[b]Hydraulic Gradients From Measurements Collected on November 18, 1999

Table 5.4. K_d Values and Calculated Retardation Factors for Selected Contaminants at the Luckey Site

Water Bearing Unit	Calculated Koc (ft3/lb)[1]	Minimum Kd (ft3/lb)[2]	Maximum Kd (ft3/lb)[2]	Calculated Retardation Factor (rf)[3]	
				Minimum	Maximum
Till (Silty Clay)					
Arsenic	-	4.6E-01	5.0E-01	8.5E+02	1.0E+03
Beryllium	-	1.3E+01	1.6E+03	2.3E+04	3.3E+06
Cadmium	-	1.2E+00	6.9E+01	2.2E+03	1.4E+05
Lead	-	1.1E+01	3.7E+02	2.1E+04	7.6E+05
Manganese	-	-	-	-	-
Nickel	-	1.0E+00	3.0E+01	1.9E+03	6.2E+04
Zinc	-	9.9E-01	8.5E+00	1.8E+03	1.7E+04
Thorium	-	2.6E+03	-	4.7E+06	5.2E+06
Uranium	-	7.0E+01	-	1.3E+05	1.4E+05
Benzo(a)anthracene	6.37E+03	3.2E+02	-	5.9E+05	6.5E+05
Benzo(a)pyrene	1.63E+04	8.2E+02	-	1.5E+06	1.7E+06
Bezo(b)fluoranthene	1.97E+04	9.9E+02	-	1.8E+06	2.0E+06
Dibenz(a,h)anthracene	6.09E+04	3.0E+03	-	5.6E+06	6.2E+06
Indeno(1,2,3-cd)pyrene	5.56E+04	2.8E+03	-	5.1E+06	5.7E+06
Sand and Gravel					
Arsenic	-	4.6E-01	5.0E-01	2.3E+02	2.7E+02
Beryllium	-	1.3E+01	1.6E+03	6.3E+03	8.7E+05
Cadmium	-	1.2E+00	6.9E+01	6.0E+02	3.8E+04
Lead	-	1.1E+01	3.7E+02	5.6E+03	2.0E+05
Manganese	-	-	-	-	-
Nickel	-	1.0E+00	3.0E+01	5.2E+02	1.7E+04
Zinc	-	9.9E-01	8.5E+00	4.9E+02	4.6E+03
Thorium	-	2.6E+03	-	1.3E+06	1.4E+06
Uranium	-	7.0E+01	-	3.5E+04	3.8E+04
Benzo(a)anthracene	6.37E+03	3.2E+02	-	1.6E+05	1.7E+05
Benzo(a)pyrene	1.63E+04	8.2E+02	-	4.1E+05	4.5E+05
Bezo(b)fluoranthene	1.97E+04	9.9E+02	-	4.9E+05	5.4E+05
Dibenz(a,h)anthracene	6.09E+04	3.0E+03	-	1.5E+06	1.7E+06
Indeno(1,2,3-cd)pyrene	5.56E+04	2.8E+03	-	1.4E+06	1.5E+06

Fraction of Organic Carbon (foc)	Bulk Density (lb/ft^3)				Effective Porosity
	Till		Sand and Gravel		Till = 0.06
0.05	Minimum	Maximum	Minimum	Maximum	Sand and Gravel = 0.25
	110.2	122.5	124.1	136.5	

1: EPA (May, 1996). Soil Screening Guidance: Technical Background Document.
2: Kd for the organic compounds was calculated using the relation Kd=Koc*foc; Kd's for thorium and uranium were obtained from the RESRAD Manual and RESRAD Data Collection Handbook; Lead's Kd value was obtained from:
EPA (August, 1999). Understanding Variation in Partition Coefficient, Kd, Values. Document: EPA 402-R-99-004A&B;
all other Kds were obtained from: EPA (May, 1996). Soil Screening Guidance: Technical Background Document.
3: Retardation Factors were calculated using the equation: rf = 1 + (Bulk Density/Effective Porosity)*Kd; for the minimum value, the minimum bulk density and minimum Kd were used; for the maximum rf, the max bulk density and max Kd were used where available, otherwise the minimum Kd was used with the maximum bulk density.

Table 5.5. Chemical Properties of Organic Constituents of Concern

CONSTITUENT	Log K_{ow} (unitless)	Henry's Law Constant (atm-m3/mol)	Log K_{oc} (unitless)	Solubility (mg/L)	Vapor Pressure (mmHg)
Benz(a)anthracene	5.76(a)	8.02E-06(a)	5.55(b)	9.40E-03(a)	3.05E-08(a)
Benzo(a)pyrene	5.97(a)	2.45E-06(a)	6.74(b)	1.63E-03(a)	5.49E-09(a)
Benzo(b)fluoranthene	5.78(a)	1.20E-05(b)	5.74(b)	1.50E-03(a)	5.00E-07(a)
Dibenz(a,h)anthracene	6.70(b)	2.61E-09(c)	6.52(b)	5.00E-04(b)	1.00E-10(b)
Indeno(1,2,3-c,d)pyrene	6.70(a)	2.86E-07(d)	6.20(e)	2.20E-05(a)	1.00E-10(a)
Bis(2-ethylhexyl)phthalate	7.60(a)	1.47E-05(a)	4.94(f)	3.40E-01(a)	9.75E-06(a)

Solubility Data for Inorganic Constituents(g)

Beryllium Compounds	Lead Compounds	Arsenic Compounds
$BeSO_4$ = 425g/L @ 25°C BeO = 20 ug/L @ 30°C $BeCl_2$ = Very soluble BeF_2 = Soluble in all proportions $Be(OH)_2$ = Very slightly soluble	PbO = 0.017g/L @ 20 °C $PbCO_3$ = 1.1 mg/L @20°C $PbSO_4$ = 32 mg/L @ 15°C PbS = 0.86 mg/L @13°C $H_3O4P_{3/2}Pb$ = 14 mg/L @ 20°C PbF_2 = 570 mg/L @ 0°C	As_2O_3 = $1x10^4$ mg/L @ 16 °C Arsenic trioxide = 5.9 x 105 mg/L Calcium arsenate = 130 mg/L @ 25 °C Arsenic pentoxide = 150g/100ml @ 16°C $AsCl_3$ = 1 mole in 9 mole water AsS_3 = 0.5 mg/L @ 18 °C

Cadmium Compounds	Manganese Compounds	Nickel Compounds
$CdCl_2$ = 140g/100ml @ 20°C CdAcetate = Very soluble CdO = Insoluble $CdSO_4$ = 75.5 g/100ml @ 0°C CdS = 1.3 mg/L in cold water $CdCO_3$ = Insoluble	$MnCl_2$ = 72.3 g/100ml @25°C MnO = Insoluble $MnSO_4$ = 52 g/100ml @ 5°C $MnCO_3$ = Insoluble Potassium permanganate = 6.38 g/100ml @20 °C Zinc permanganate = 1 in 3 water Sodium permanganate = Very soluble	$NiCl_2$ = 64.2 g/100ml @ 20°C $NiSO_4$ = 29.3 g/100ml @ 0°C $NiCO_3$ = 93 mg/L @ 25°C NiO = 0.11 mg/100ml @ 20°C NiF_2 = 4 g/100ml @25 °C

atm – atmospheres
Koc – sorption partition coefficient
Kow – octanol/water partition coefficient
mmHg – millimeters of mercury
mol - mole

(a) CRC. 1997. Handbook of Physical Properties of Organic Chemicals. P.H. Howard, and W. Meylan, Eds. Lewis Publishers, Boca Raton, LA.
(b) Mackay, D., W.Y. Shiu, and K.C. Ma. 1992. Illustrated handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals, Vol. 2: Volatile Organic Chemicals. Lewis Publishers, Chelsea, Michigan.
(c) Calculated from solubility and vapor pressure.
(d) Texas Natural Resources Conservation Commission (TNRCC). 1998. 30 TAC 350.53(e)—COC Chemical/Physical Parameter Values. Obtained from http:\\www.tnrcc.state.tx.us\.
(e) Mabey, W., J. Smith, R. Podoll, H. Johnson, T. Mill, T. Chou, J. Gates, I. Patridge, H. Jaber, D. Vandenberg. 1982. Aquatic Fate Process Data for Organic Priority Pollutants, prepared by SRI for Monitoring and Data Support Division, OWRS, Washington, D.C.
(f) Mackay, D., W.Y. Shiu, and K.C. Ma. 1992. Illustrated handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals, Vol. 4: Oxygen, Nitrogen, and Sulfur Containing Compounds. Lewis Publishers, Chelsea, Michigan.
(g) TOXNET Data retrieved from http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB (September 2000).

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Figure 5.1. Conceptual Site Model of Release and Transport Mechanisms

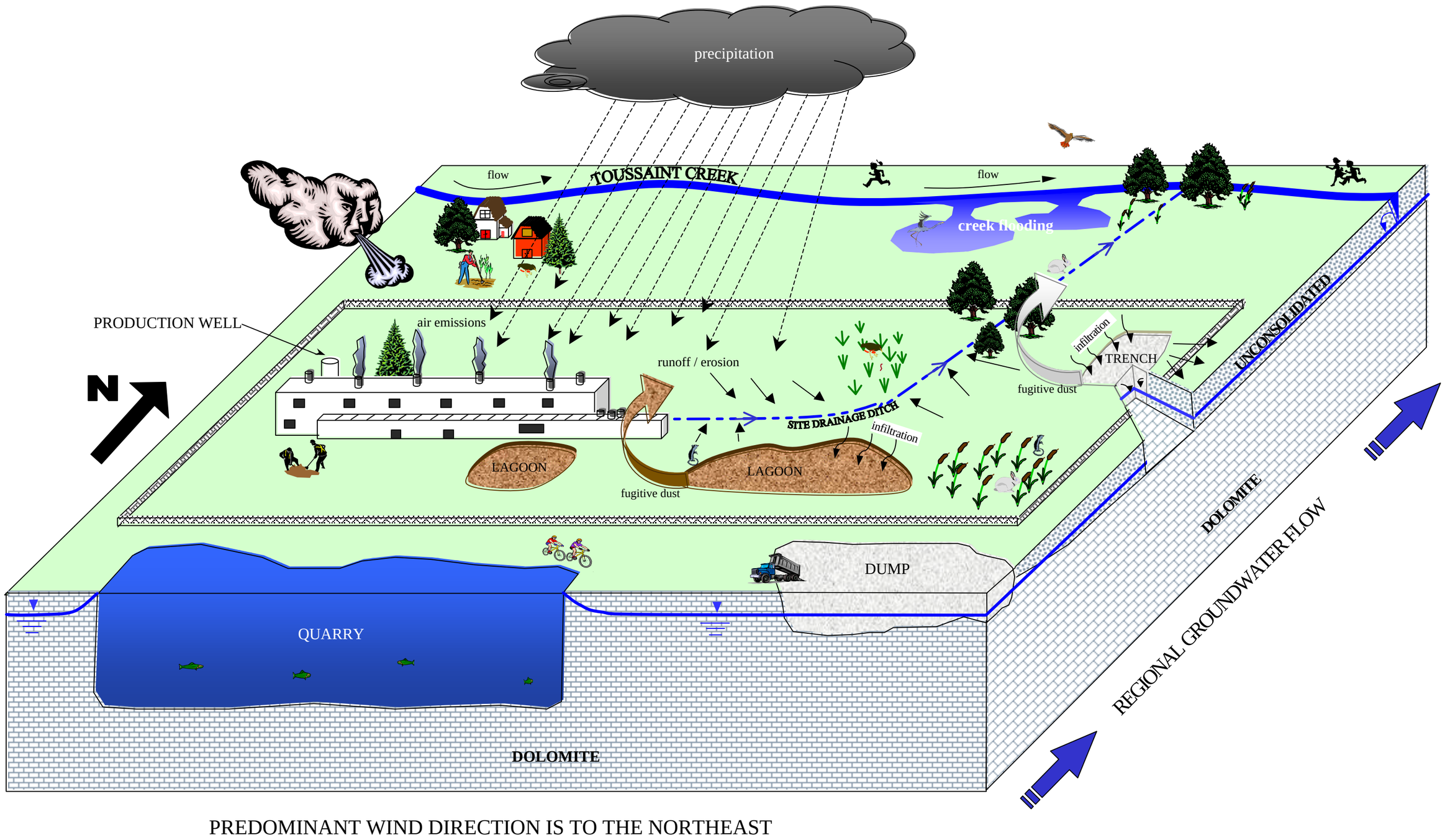

Figure 5.1. Conceptual Site Model of Release and Transport Mechanisms

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6.0 BASELINE HUMAN HEALTH RISK ASSESSMENT

The objective of this baseline risk assessment (BRA) is to provide an analysis of baseline human health risks associated with the Luckey site. Screening for ecological risks at the site are presented in Section 7. The human health and ecological risks will be used in conjunction with ARARs and other regulations that are necessary "to be considered" (TBC) in order to determine the need for remedial action at the Luckey site. Standard baseline risk assessment methodology does not exist for building interiors, and worker safety is believed more appropriately addressed from an industrial hygiene perspective. In addition, the discharge of a hazardous substance, pollutant, or contaminant that remains entirely contained within a building is not considered a release under CERCLA (EPA 1993d). Therefore, risks associated with beryllium contamination within site buildings were not quantitatively evaluated in the human health risk assessment (HHRA).

The risk assessment, along with ARARs and TBCs, will provide a basis for determining the concentrations of radiological and non-radiological constituents that can remain on site and still be adequately protective of human health and the environment. The HHRA and the ecological risk assessment were conducted according to the methodology presented by the EPA in the *Risk Assessment Guidance for Superfund* (RAGS) and other guidance documents. The BRA evaluates both radiological and non-radiological constituents. The evaluation of radiological and non-radiological constituents was conducted separately, however, excess cancer risk estimates from radiological and non-radiological constituents were summed to provide an estimate of the combined risk present by all carcinogenic constituents. The HHRA for radiological constituents presented in Section 6.7 was conducted using the residual radiation (RESRAD) computer code Version 5.82.

This section has been organized as follows:

- Section 6.1 presents methods used for the baseline risk assessment
- Section 6.2 presents identification procedures for constituents of potential concern
- Section 6.3 presents exposure assessment methodology
- Section 6.4 presents toxicity assessment
- Section 6.5 presents risk characterization
- Section 6.6 presents uncertainty assessment

6.1 METHODS USED FOR THE BASELINE RISK ASSESSMENT

The methods used in this BRA were initially proposed in the Technical Memorandum (TM) for the BRA (SAIC 1999). The purpose of preparing the TM was to allow for review of the proposed risk assessment methodology by site stakeholders, including the USACE, the Ohio EPA, the EPA, the Ohio DOH, Uretech International, Inc., Goodyear, Hayes Lemmerz International, Inc., and the Town of Luckey. Concurrence with the risk assessment methods presented in the TM was sought from all stakeholders before the BRA was prepared.

The TM presented methodologies for conducting the human health and ecological risk assessments for both radiological and non-radiological constituents. The methodologies have been developed to ensure that the objectives of the BRA will be met. The specific objectives of the BRA are to:

- estimate potential human health risks and environmental impacts associated with the Luckey site if no remedial action occurs;
- identify areas that do not pose unacceptable risks to human health or the environment, and thus require no further action;

- develop a list of COCs for each exposure unit, which contribute to unacceptable risks to human health or the environment;
- provide baseline risks for the no action alternative in the Feasibility Study (FS) that will be used to evaluate risk reduction for each proposed alternative; and
- develop risk-based concentrations (RBCs) and radionuclide action levels for the identified COCs to provide the basis of preliminary cleanup goals for use in decision making during the FS, in order to focus future remedy selection for COCs that are the significant contributors to human and ecological health risks.

The human health risk assessment (HHRA) includes separate evaluations for radiological and non-radiological constituent risk. A detailed site history and description are provided in Section 2.0 of this report. Some of the information provided in Section 2.0 is summarized in Section 6.1.1 to provide background information on current exposure conditions.

For clarity, some of the risk assessment methods described in the TM have been repeated in the BRA. For example, the BRA describes how site-sampling data was evaluated and organized for inclusion in the assessment of human health and ecological baseline risks. The method used for comparing background concentrations to site data also will be presented, along with the criteria for selecting COPCs. The BRA presents a detailed conceptual exposure model. It also describes the methods used for each step in the risk assessment process, including data collection and evaluation, exposure assessment, toxicity assessment, risk characterization, and an uncertainty assessment. Where methods have been revised in response to comments received on the TM, changes from TM methods have been noted.

6.1.1 Site Description

The Luckey site covers approximately 40 acres. The area surrounding the site to the west, north, and east is primarily residential farmland. The France Stone Quarry and the Troy Township Dump bound the site to the south. The site consists of a large production building and warehouse, two abandoned railroad spurs, and several smaller process and ancillary buildings. Historical disposal areas on the Luckey site include three former lagoons in the southeastern portion of the site and a landfill in the northeastern portion of the site. The former lagoons and landfill have been capped.

Surface water features on the site include the Luckey Road ditch and the main drainage ditch, which drain to Toussaint Creek, north of the site. The France Stone Quarry, located south of the site, receives up-gradient groundwater. No surface runoff from the Luckey site reaches the quarry. Surface drainage in the interior of the facility includes NPDES outfalls. There are drainage ditches adjacent to roads and the railroad bed along the eastern boundary of the site. Historically, Lagoons B and C discharged first to the main drainage ditch then to Toussaint Creek.

A description of site soils, geology, hydrogeology, groundwater, surface water, and ecology is presented in Section 2.2 of this report. For the BRA the Luckey site and adjacent areas were divided into six Exposure Units (EUs). The EUs for the Luckey site were defined based on data collected on site and off site, on observed or assumed patterns of receptor behavior, and on conformity for use in the human health risk assessment and ecological risk assessment. EUs are areas over which a receptor is likely to average his or her exposure. Groundwater was assessed across the site and incorporated into the risk assessment for the EUs where exposure to groundwater is likely to occur. The EUs for the Luckey site are presented in Figure 6.1.1. A detailed discussion of the site exposure units and potential receptors is presented in Section 6.3. Section 6.3.2 identifies the exposure pathways evaluated in the human health risk assessment.

6.1.2 Data Collection and Evaluation

In accordance with the Luckey RI Work Plan (USACE 1998a) and two SAPs (SAIC 1997, 1998) samples were collected from the following media: soil, sediment, surface water, groundwater, building materials, and surface wipe samples. Samples were analyzed for inorganic compounds (metals, anions, radionuclides), SVOCs, VOCs, PCBs, and pesticides, depending on investigative area and media. Results of this sampling formed the analytical data set evaluated in the BRA.

SAIC conducted independent data validation on at least 10% of the data received from the subcontracting laboratory, in accordance with the approved Luckey RI QAPP (USACE 1998c). Results flagged "J" (estimated) during the validation have been used as reported. Results flagged "U" (not detected) have been included in the database for statistical summaries at one-half the reported sample quantitation limit (SQL). Results flagged "R" (rejected) during data validation were excluded from the risk assessment summaries. Analytes detected in blank samples were flagged as non-detects in the associated site samples if the concentrations in the site samples were less than five times the concentration in the blanks. When blank samples contained detectable levels of common laboratory contaminants (e.g. acetone, 2-butanone, methylene chloride, toluene, or phthalate esters), sample results were considered positive only if the sample concentration exceeds 10 times the maximum amount detected in the associated blanks. Data qualifiers are defined in Tables 3.15 and 3.16.

Detection limits achieved during sample analysis were reviewed to ensure that required detection limits were met. Typically, detection limit requirements are established to ensure that characterization has occurred to levels that are low enough to determine if constituents are present at hazardous levels. These levels are constituent-specific and related to each constituent's toxicity. Required detection limits were presented in the QAPP (USACE 1998c).

In some cases, a laboratory cannot achieve recommended detection limits, such as when matrix or constituent interference requires that a sample be diluted. This may cause some samples to have unusually high detection limits. Including these results in the data set could cause the calculated exposure concentration to exceed the health-based standard. Therefore, analytes detected with unusually high quantitation limits that would cause the calculated exposure concentration to exceed the maximum detected concentration were further evaluated. If an analyte was detected with unusually high quantitation limits, the sample location and results for other sample analytes were reviewed to determine whether there was reason to believe that a hot spot may be present or that the chemical may be present at a concentration below the SQL. If sufficient evidence was found to retain the chemical, either one-half the SQL or the entire SQL was used, depending on the nature of the evidence used to retain the chemical. If insufficient evidence was found to retain the chemical, the analyte was excluded from the risk assessment data set (EPA 1989a).

Once data for each constituent were determined to be usable, the data were tabulated for evaluation as a potential COPC. COPCs were screened for each EU by media, with the exception of site-wide groundwater. Groundwater was assessed on a site-wide basis. The COPC screening tables are included in Section 6.2 of the BRA. The COPC screening tables include the (1) frequency of detection, (2) range of detected values, (3) range of detection limits, (4) mean concentration, (5) data set distributions, (6) 95% upper confidence limit (UCL) of site data set, (7) 95% UTL of background data, (8) mean background concentrations, and (9) risk-based screening concentrations.

In order to quantify the potential for kidney damage caused by exposure to uranyl salts, the concentration of U-238 detected in soil and sediment was converted from pCi/g to mg/kg (using the conversion factor 0.335 pCi per μg of U-238). The concentration of U-238 detected in surface water was converted from pCi/L to μg/L.

6.1.3 HHRA for Non-Radiological Constituents

The HHRA for non-radiological constituents was conducted in accordance with methods presented in the *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, (Part A)* (RAGS) (EPA 1989a). Additional methodology was taken from:

- *Dermal Exposure Assessment: Principals and Applications* (EPA 1992b, EPA 1992c),
- *Human Health Evaluation Manual, Supplemental Guidance Standard Default Exposure Factors* (EPA 1991a),
- *Exposure Factors Handbook* (EPA 1997a),
- *EPA Integrated Risk Information System (IRIS)* (EPA 1998a), and
- *Health Effects Assessment Summary Tables (HEAST)* (EPA 1995b).

The methodology for developing the risk-based concentrations for the Luckey site is presented in Section 6.5 of the BRA.

6.2 IDENTIFICATION OF HUMAN HEALTH CONSTITUENTS OF POTENTIAL CONCERN (COPCS)

Data collected, verified, and validated according to the QAPP (USACE 1998c) were used to determine human health and ecological risks at the Luckey site. Data were reviewed and screened to identify site-related constituents. The following sections summarize the process used to select the COPCs that were carried through the BRA. COPCs were screened for each EU by media, with the exception of site-wide groundwater.

The COPC selection criteria discussed below are applied to the detected constituents by EU and by media in Tables 6.1 through 6.6. Groundwater was not broken out by exposure unit but was addressed on a site-wide basis. The COPCs identified for groundwater are presented in Table 6.7. The COPC tables provide information on the magnitude of chemical detection at the site and present the rationale for selection of the COPCs. The same COPCs were utilized for current and future exposures. Essential human nutrients are not presented in the screening tables.

A similar process was used to identify ecological COPCs; however, essential human nutrients were retained, and the detected constituents were not screened against the Region 9 PRGs. Details on the selection of ecological COPCs are presented in Section 7.

6.2.1 Initial Data Reduction

The data set used in the risk assessment consists of sample results verified and validated using methodology described in the QAPP (USACE 1998c). During the data validation process, if a blank contained detectable levels of common laboratory contaminants (e.g. acetone, 2-butanone, methylene chloride, toluene, or phthalate esters), sample results were considered positive only if the sample concentration exceeded 10 times the maximum amount detected in the associated blanks. If a constituent that is not a common laboratory contaminant was detected at concentrations greater than or equal to five times the concentration detected in the associated blanks, it was considered to be a positive result and was retained as a COPC. Constituents detected at low concentrations, in less than 5% of the samples from a given medium, were dropped from further consideration. However, they were retained if process knowledge suggested that the data might represent a hot spot.

Ubiquitous elements that were present at low concentrations and are essential human nutrients were eliminated as COPCs for the BRA. Essential human nutrients include iron, magnesium, calcium,

potassium, and sodium. These constituents are toxic only at very high doses and are considered to be human nutrients essential to a well-balanced diet. For these reasons they typically are not considered hazardous to humans.

Radiological and non-radiological constituents that were detected infrequently (e.g. less then 5%) may be artifacts in the data due to sampling, analytical, or other problems and may not be related to site activities or disposal practices (EPA 1989b). These constituents were not included in the risk assessment.

The Luckey data set does include tentatively identified compounds (TICs), however, they do not appear to dominate the data set in any location or media. When only a few TICs are present compared to TAL and target compound list (TCL) constituents, and no other site information indicates that a particular TIC may be present at the site, the CERCLA process allows for the TICs be addressed qualitatively in the risk assessment. The laboratory may attempt to identity TICs using computerized searches of a library containing mass spectra; however, in most cases the assigned identity is highly uncertain. Given the high cost of assigning identities to TICs and the uncertainty associated with this process, TICs were addressed in the BRA database on a qualitative basis. A discussion of the uncertainty associated with this practice has been included in the uncertainty assessment (Section 6.6).

6.2.2 Background Characterization and Comparison

A major step in assessing site data is to distinguish between constituents that are likely related to past material or waste handling and/or disposal practices at the site and those that may be present at naturally occurring or background levels. As part of the RI field investigation, samples of various environmental media were collected at background or up-gradient locations. The methods used for sample collection and the rationale for sample locations and analyte selection are discussed in Section 3 of this report.

The chemical-specific upper 95% tolerance limit, with 95% coverage (hereafter referred to as the 95% UTL) was used to identify which constituents detected at the site are present above naturally occurring background levels. This method is recommended in *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities* (EPA 1989b) and in other EPA guidance (EPA 1989c and EPA 1992a). A UTL is the value that the specified portion (i.e., 95%) of the data population will fall below, with a specified level of confidence. The background concentration was calculated as the upper 95% tolerance limit, with 95% coverage. Background was characterized for each appropriate inorganic analyte (e.g., metal and for each radioisotope). The equations used to calculate the 95% UTL for analytes with normal and log normal distributions are presented in Section 3.5.3.

6.2.3 Weight-of-Evidence Screening

Because of problems inherent in applying a single statistical tool to data sets that have different characteristics, an additional screening step was applied to the data after they were screened against background concentrations. This screening step is referred to as a weight-of-evidence screening; that is, multiple types of evidence are considered to determine whether a constituent is site-related or naturally occurring. This screening was applied to constituents that were not screened out during the background screen. The following weight-of-evidence screening technique was used to further evaluate the data.

Constituents infrequently detected were eliminated as COPCs if they were detected in less than 5% of the samples from a given medium, unless their presence is expected based on historical site information or is likely to identify the existence of a hot spot.

Because the UTL represents the 95th percentile of the data (not the full range), it is possible to observe occasional hits above the UTL that are still within the range of background. This review of the analytes with a low frequency of detection above the background criteria was performed. If a single detection was greater than the UTL or the constituent was detected at levels only slightly above the background screening value, the constituent was evaluated as being significantly above background or within the expected range of variation of the data set. Weight-of-evidence screening was not used to reduce the number of chemical COPCs for the Luckey HHRA.

6.2.4 Risk-Based Screening

Constituents detected above background concentrations were screened using EPA Region 9 PRGs. EPA Region 9 PRGs are risk-based values calculated for defined exposure pathways using standard risk assessment methods, models, and assumptions. Multiple COPCs were detected in each of the EUs. Consequently, risk-based screening was conducted using $1/10^{th}$ of the EPA Region 9 PRG values for non-carcinogenic COPCs and using the whole PRG for carcinogenic constituents. Screening non-carcinogenic COPCs using $1/10^{th}$ the Region 9 PRG value accounts for the possibility of multiple non-carcinogenic COPCs. Since the target risk level for EPA Region 9 non-carcinogenic PRGs is one, if more than one non-carcinogenic COPC is present, screening constituents present at the PRG may allow for cumulative risk levels that exceed the target level of one. Since the Region 9 PRGs are calculated for a carcinogenic risk of $1x10^{-6}$ and the National Contingency Plan (NCP) provides a range of $1x10^{-4}$ to $1x10^{-6}$ for carcinogenic risk, screening COPCs by the whole PRG value is protective.

6.2.5 Selection of Radiological COPCs

Potential radiological constituents at the Luckey site are members of the naturally occurring uranium, thorium, and actinium decay series. Because cancer slope factors (CSFs) are limited to radionuclides with half-lives of six months or longer, the primary list of potential radiological constituents includes only the long-lived radionuclides in these series. Short-lived decay products are included in slope factors for long-lived radionuclides so that they need not be included separately. The list of long-lived radionuclides includes U-238, U-234, Th-230, Ra-226 and Pb-210 from the uranium series; Th-232, Ra-228 and Th-228 from the thorium series; and U-235, Pa-231 and Ac-227 from the actinium series.

Risk-based screening levels for the radionuclides at the Luckey site are not currently available from EPA, and background concentrations of these radionuclides typically produce risks on the order of 10^{-4}. Therefore, radionuclides underwent a background screen but not a risk screen to identify COPCs. Details on the screening of radiological COPCs can be found in Section 6.7.1.

6.3 EXPOSURE ASSESSMENT

The exposure assessment for the Luckey site evaluates potential risk for all receptor populations reasonably anticipated to be exposed to COPCs. The exposure assessment was performed in two steps. Potentially complete exposure pathways between constituent sources and potential receptors were identified first. This was accomplished by the following:

1) identifying current and potential future on-site and off-site receptors;
2) identifying media through which constituents may come in contact with the receptors, including soils, groundwater, sediment and surface water, and air; and
3) identifying the routes of exposure or pathways through which the receptors may be exposed (i.e. ingestion, dermal contact, and inhalation).

A detailed discussion of the site exposure units and potential receptors is presented in Section 6.3.1. Section 6.3.2 presents the exposure pathways evaluated in the human health risk assessment.

In the second step of the exposure assessment, exposure point concentrations for each receptor resulting from contact with contaminated media were assessed. In order to quantify exposure for each receptor, an exposure point concentration (EPC), or a high-end estimate of the constituent concentration a receptor may come in contact with over the duration of exposure, was estimated as the 95% UCL. If the 95% UCL was found to be greater than the maximum detected concentration for a particular COPC, the maximum concentration was used as the EPC rather than the 95% UCL. Potential risks for all COPCs at their respective EPCs were quantified for all identified receptors using high-end or reasonable maximum exposure (RME) scenario exposure assumptions. Receptors whose potential risks exceeded a hazard index (HI) of greater than 0.1 or a cancer risk of greater than $1x10^{-6}$ were evaluated using median or central tendency (CT) exposure assumptions. The general equations used to quantify exposure to contaminated media at the Luckey site are presented in Section 6.3.3.

6.3.1 Characterization of Potentially Exposed Populations

The exposure assessment evaluated potential risk to all receptor populations reasonably anticipated to be exposed to COPCs at the Luckey site. The site was divided into separate EUs, or areas over which a receptor is likely to average his or her exposure, for the BRA. The EUs for the Luckey site were defined based on data collected on site and off site, on observed or assumed patterns of behavior, and on conformity for use in the HHRA and ERA. The EUs for the Luckey site are presented in Figure 6.1. They include:

1) Exposure Unit 1 – on-site undisturbed soil area within the current fenced boundaries of the site,
2) Exposure Unit 2 – on-site disturbed soil area within the current fenced boundaries of the site,
3) Exposure Unit 3 – off-site land surrounding the facility currently used for residential/ agricultural purposes,
4) Exposure Unit 4 – Toussaint Creek down-gradient from the Luckey site,
5) Exposure Unit 5 – France Stone Quarry south of the site,
6) Exposure Unit 6 – landfill (Troy Township Dump) south of the site.

Offsite EUs were selected according to location, physical characteristics, and current land use. The two on-site EUs present different types of exposures for both human and ecological receptors. The on-site undisturbed soil area (EU 1) encompasses the paved roads and parking areas. This unit includes all the areas where daily activities by industrial workers are occurring, and all of the areas where tanks and pumps for petroleum products are known to have been or are currently located. With the exception of Lagoon A, this unit also includes all the mowed lawn.

The on-site disturbed soil area (EU 2) consists of the northeastern and southeastern portions of the site. The eastern unit consists of all the areas on site that were highly disturbed during disposal or operational activities while AEC was directing operations at the site. It also includes most of the on-site areas with more or less natural vegetation including most of the large trees and most of the wetlands. Most of the significant contamination as defined by the Phase II report and preliminary assessment of the Phase IV data is included in this unit. In addition, with a few exceptions, workers do not visit most of this area on a regular basis.

The conceptual site model, in Section 5.0 of this report, presents a pictorial of the site and potential constituent migration pathways for all media. Figures 6.2 through 6.6 are graphical exposure models showing source media, and potential migration and exposure pathways for receptors at each EU. The exposure assessment evaluated the risk to all receptor populations reasonably anticipated to be

exposed to COPCs on and off the site. Under the current land use scenario, on-site receptors include adult industrial workers who may contact surface soils while working outside. Current off-site receptors include resident farmers (adult/children) and adolescent trespassers near Toussaint Creek. A 6-ft chain-linked fence with a locked gate currently restricts access to the Troy Township Dump; therefore, current receptors will be limited to adolescent trespassers. No physical barriers currently exist for the France Stone Quarry; however, a local ordinance does restrict access to the site. Despite the local ordinance, trespassers have been observed fishing in the quarry and riding motorcycles around it. An adolescent trespasser will be evaluated for this property since this is the age group (7- to 17-year-olds) most likely to frequent the site on a regular basis.

Two separate receptor scenarios were evaluated for on-site exposures under a future land use scenario. On-site exposures were evaluated for an industrial worker receptor, assuming that the property is maintained as an industrial property. Based on surrounding land use, a future resident farmer (adult/children) receptor also was evaluated for both the on-site and off-site EUs. Receptors evaluated under a future scenario remain the same as the current scenario for Toussaint Creek, the Troy Township Dump, and the France Stone Quarry.

6.3.2 Identification of Exposure Pathways

The elements necessary to construct a complete exposure pathway and to develop the conceptual site model include the following:

- sources (i.e., contaminated environmental media),
- constituent release mechanisms,
- constituent transport routes,
- receptors, and
- exposure pathways.

Receptors may be exposed to constituents through direct contact with site media, or as the result of chemical migration away from the source into other media. Direct contact pathways represent exposure via direct contact with the source media. The source media for the Luckey site include surface and subsurface soils. It is probable that initial constituent releases were restricted to surface soils, with various transport mechanisms leading to subsequent contamination of other environmental media such as groundwater, subsurface soils, surface water, and sediments.

Exposure pathways that incorporate constituent migration from a source to a secondary media (groundwater, surface water, sediments, air, and biota) or to an off-site receptor will be referred to as indirect contact pathways. Constituent release mechanisms and transport pathways evaluated in the BRA include the following:

- release of volatiles or dust with organic substances or metals into the air,
- leaching of constituents from soil to groundwater, and
- release of contaminated soil particulates to storm water runoff (sediments) and surface water.

The exposure point concentration for COPCs in secondary media were determined using data collected from the impacted media, whenever possible. Mathematical models that take into consideration constituent-specific and media-specific properties were used to estimate the constituent concentration in secondary exposure media (i.e., air) when needed to accurately predict potential exposures.

All of the exposure pathways, receptors, media, and scenarios evaluated in the HHRA are presented in Figures 6.2 through 6.6. Exposures were estimated using standard exposure equations and

standard parameter values identified for various exposure conditions (EPA 1997a, EPA 1989d, EPA 1992a, and EPA 1992b). No site-specific exposure parameter values have been identified for the Luckey site. For this CERCLA exposure assessment, intake variables for given pathways were selected to estimate the reasonable maximum exposure (RME) conditions. The RME is the maximum exposure that is reasonably expected to occur at the site and represents a conservative estimate of exposure. Exposure parameters used in the intake equations were presented in the TM and summarized in Tables 6.8 and 6.9 for current and future parameters, respectively. Additionally, the central tendency (CT, mean or 50th percentile) exposure that is expected to occur at the site was assessed if the RME exposure parameters showed risk that exceeds target risk criteria. The CT assumptions are presented in Tables 6.10 and 6.11 for current and future parameters, respectively.

The HHRA assumed 350 days per year exposure to soil zero to 2 ft below land surface (bls) and soil zero to 10 ft bls for the resident farmer scenarios. Two soil intervals were assessed for the resident farm scenario to account for the heterogeneous distribution of contaminants within site soils. The zero to 2 ft interval includes constituents that appear to be concentrated in the first two feet of soil. The zero to 10 ft interval includes constituents that are now located at depth but which may be brought to the surface during home construction allowing for daily exposure. Both of these scenarios are conservative because they assume that daily exposure to soil could occur and they do not account for days when surface soil will be frozen or covered by snow.

Surface water and sediment samples were collected from a number of locations on site (EUs 1 and 2), in drainage ditches leading from the site to Toussaint Creek (EU 3), and within Toussaint Creek, both upstream and downstream from the site outfalls (EU 4). On site, sediment and surface water samples were collected from ditches as well as from building sumps and shallow concrete drains. Routine worker exposure to sediment and surface water in building sumps and shallow concrete drains is very unlikely; therefore, this risk was not evaluated quantitatively. Instead, due to the close proximity and connectivity of the on-site ditch sampling locations and the sampling locations in ditches leading from the site to Toussaint Creek, on-site sediment and surface water samples collected from ditches, were aggregated and evaluated with ditch samples collected in EU 3. Receptors evaluated for this exposure unit included current/future adult and child resident farmers. For this evaluation, only samples collected from areas where routine exposures likely would occur (i.e., ditches) were evaluated. For future site use it was assumed that building sumps and concrete drains would be removed. Perimeter fencing prevents current exposure.

All downstream sampling locations in Toussaint Creek were included in EU 4 where the current/future adolescent trespasser receptor was evaluated. Upstream samples were used as background locations for both EUs 3 and 4.

6.3.3 Quantification of Exposure Concentration and Pathway Specific Intakes

In order to quantify exposure to each receptor, an EPC, or the estimate of the constituent concentration a receptor is likely to come in contact with over the duration of exposure, was calculated. For both the CT and the RME scenarios, the 95 % UCL of the arithmetic mean was calculated according to the guidance provided in the Supplemental Guidance to RAGS: Calculating the Concentration Term (EPA, 1992a) and used as the EPC. However, when the 95% UCL for a COPC was greater than the maximum detected value for that COPC the maximum detected value was used as the EPC not the 95% UCL. Additionally, if the data set of a constituent has a distribution that is neither normal nor log normal, the maximum detected value was used as the EPC. The distribution of each data set was tested for normality using the Shapiro-Wilk normality test. The equations used to calculate the UCL for normal and log normal data sets are presented below.

The UCL of the arithmetic mean for a normal distribution was calculated as follows:

$$UCL = \bar{x} + t\,(s/n^{1/2})$$

where:

UCL	=	upper confidence limit
t	=	Student t statistic (Gilbert 1987)
s	=	standard deviation
n	=	number of data
$\bar{x}$	=	mean of data results

The UCL of the arithmetic mean for a log normal distribution was calculated using the following equation:

$$UCL = e^{\bar{x} + 0.5s^2 + sH/((n-1)^{1/2})}$$

where:

UCL	=	upper confidence limit
H	=	H statistic (Gilbert 1987)
s	=	standard deviation
n	=	number of data
e	=	exponential constant
$\bar{x}$	=	mean of data results

The exposure concentrations defined above were used to estimate the intake of each COPC to individual receptors via all pathways and medium proposed in the conceptual model. Intake is a measure of exposure expressed as the concentration of a constituent that has come in contact (e.g. ingestion, inhalation, dermal, etc.) with a receptor per unit body weight per unit of time [milligram per kilogram day (mg/kg-d)].

The following subsections present the equations used to quantify exposure for receptors identified at the Luckey site and the intake resulting from the exposure. The equations presented below were taken from RAGS (EPA 1992c) except where noted otherwise.

<u>Soils and Sediments Exposure Pathways</u>

Incidental ingestion of soils and sediments was estimated using the following equation:

$$\textit{Constituent Intake (mg / kg - d)} = \frac{C_s \times IR_s \times CF \times EF \times ED}{BW \times AT}$$

where:

C_s	=	constituent concentration in soils or sediments (mg/kg)
IR_s	=	ingestion rate (mg soil /day)
CF	=	conversion factor (10^{-6} kg/mg)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days)

The dermal absorbed dose (DAD) from constituents in soils and sediments was calculated as follows:

$$\textit{Constituent DAD (mg / kg – d)} = \frac{C_s \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$$

where:

DAD	=	dermal absorbed dose (mg/kg-d)
C_s	=	constituent concentration in soils or sediments (mg/kg)
CF	=	conversion factor (10^{-6} kg/mg)
SA	=	skin surface area exposed to soil (cm^2/event)
AF	=	soil to skin adherence factor (mg/cm^2)
ABS	=	constituent-specific absorption factor (unitless)
EF	=	exposure frequency (days/yr)
ED	=	exposure duration (years)
BW	=	body weight (kg), and
AT	=	averaging time (days)

Please note that some of the soil-to-skin adherence factors differ from those reported in the TM. These changes reflect clarifying guidance on quantifying dermal risk provided by EPA Region 5 Toxicologist, Mark Johnson, in February 2000. Since this guidance has yet to be released to the public, a copy of this guidance has been provided in Appendix 6C. Inhalation of constituents in soils or dry sediments was calculated as follows:

$$\textit{Constituent Intake (mg / kg – d)} = \frac{C_s \times IR_a \times ET \times EF \times ED \times (VF^{-1} + PEF^{-1})}{BW \times AT}$$

where:

C_s	=	constituent concentration in soils or sediments (mg/kg)
IR_a	=	inhalation rate (m^3/day)
ET	=	exposure time (hours/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
VF	=	volatilization factor (constituent-specific m^3/kg)
PEF	=	particulate emission factor (4.63×10^9 m^3/kg)
BW	=	body weight (kg)
AT	=	averaging time (days)

<u>Groundwater and Surface Water Exposure Pathways</u>

Drinking water ingestion was estimated for constituents by the following equation:

$$\textit{Constituent Intake (mg / kg – d)} = \frac{C_w \times IR_w \times EF \times ED}{BW \times AT}$$

where:

C_w	=	constituent concentration in water (mg/L)
IR_w	=	ingestion rate (L/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)

AT = averaging time (days)

The dermal absorbed dose from dermal contact with constituents in surface water or groundwater will be calculated as follows:

$$\text{Constituent DAD (mg / kg – d)} = \frac{DA_{event} \times SA \times ET \times EF \times ED}{BW \times AT}$$

where:

DAD	=	dermal absorbed dose (mg/kg-day)
DA_{event}	=	absorbed dose per event in water (mg/cm^2-event)
SA	=	surface area of skin exposed (cm^2)
ET	=	exposure time (hours/event)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time

For inorganics, DA_{event} (mg/cm^2-event) was calculated as follows:

$$DA_{event} = K_p \times C_w \times t_{event}$$

where:

DA_{event}	=	absorbed dose per event in water (mg/cm^2-event)
K_p	=	permeability coefficient from water (constituent-specific, cm/hr)
C_w	=	concentration of chemical in water (mg/cm^3 = 10^{-3} X mg/L)
t_{event}	=	duration of event (hr/event)

For organics, DA_{event} (mg/cm2-event) was calculated as follows:

$$\text{If } t_{event} < t^* \text{ then: } DA_{event} = 2 K_p C_w (6 \tau t_{event}/\pi)^{1/2}$$

$$\text{If } t_{event} > t^* \text{ then: } DA_{event} = K_p C_w [\{(t_{event}/(1+B)\} + 2 \tau \{(1+3B)/(1 + B)\}]$$

where:

DA_{event}	=	absorbed dose per event in water (mg/cm^2-event)
K_p	=	permeability coefficient from water (constituent-specific, cm/hr)
C_w	=	concentration of chemical in water (mg/cm^3 = 10^{-3} X mg/L)
t_{event}	=	duration of event (hr/event)
t_{event}	=	duration of event (hr/event)
B	=	Chemical-specific constant reflecting the partitioning properties
t*	=	Chemical-specific time to reach steady-state (hour)
τ	=	lag time (hour)
π	=	constant (3.14159)

Values and equations for K_p, t*, τ, and B can be found in Chapter 5 of *Dermal Exposure Assessment: Principles and Applications* (EPA 1992b). If a K_p was not found, it was calculated using the following formula:

$$\log (PC) = -2.72 + 0.71 \log (K_{ow}) - 0.0061\, MW$$

where:

K_{ow}	=	octanol/water coefficient (constituent-specific)
MW	=	molecular weight (g/mole)

The daily intake from the inhalation of VOCs while showering was evaluated using the following equation (Murphy, 1987):

$$I_s = [(1000 \times N_s \times T_s \times IR \times C_{gw} \times F) / (A \times V)] \times [1 + (1/(A \times T_s)) \times (e^{-A \times T_s} - 1)] \times [1 - e^{-1/(0.93 \times 1.48 \times 10^{-3}/H)}]$$

where:

I_s	=	estimated inhalation exposure during showering (mg/day)
N_s	=	number of showers per day (shower/day)
T_s	=	duration of shower (hours/shower)
IR	=	inhalation rate (m^3/hour)
C_{gw}	=	concentration in groundwater (constituent-specific; mg/l)
F	=	shower water flow rate (L/hour)
A	=	air exchange rate between shower and rest of home (12 $hour^{-1}$)
V	=	volume of shower or bathroom (12 m^3)
H	=	Henry's law constant (constituent-specific; atm-m^3/mole)

The daily intake of constituents from the inhalation of VOCs from non-showering household use was evaluated using the following equation:

$$I_{ns} = \frac{[T_h \times IR \times C_{gw} \times Q_w \times M] \times [1 - e^{1.26 + (2 \times 10^{-3})/H}]}{Q_a}$$

where:

I_{ns}	=	estimated intake due to other household water use (mg/day)
T_h	=	time spent in home (hours/day)
IR	=	inhalation rate (m^3/hour)
C_{gw}	=	concentration in groundwater (constituent-specific; mg/L)
Q_w	=	quantity of household water used (L/day)
M	=	mixing factor (0.5 unitless)
H	=	Henry's Law Constant (constituent-specific; atm-m^3/day)
Q_a	=	volume air exchange rate for home (m^3/day)

The total daily intake from household groundwater use is the sum of the intake from showering and other household water use:

$$I = I_s + I_{ns}$$

where:

I	=	total daily intake (mg/day)
I_s	=	daily intake from showering (mg/day)
I_{ns}	=	daily intake from non-showering activities (mg/day)

The dose a receptor receives from the inhalation of VOCs was calculated using the Murphy (1987) equation:

$$Dose\ (mg / kg\text{-}day) = \frac{I \times EF \times ED}{BW \times AT}$$

where:

I	=	total daily intake (mg/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time

Risk-Based Concentration Calculations

An equation of the following general form was used to derive the risk-based concentration (RBC) for carcinogens:

$$C_i = \frac{TR}{(Intake_{Ing} \times CSF_{Oral}) + (Intake_{Inh} \times CSF_{Inh}) + (Intake_{Derm} \times CSF_{Derm})}$$

where:

C_I	=	Cancer-RBC (medium- and pathway-specific) for constituent i
TR	=	target risk level (1×10^{-6})
$Intake_{Ing}$	=	media-specific intake for ingestion pathway, excluding the EPC
CSF_{Oral}	=	oral cancer slope factor for constituent i
$Intake_{Inh}$	=	media-specific intake for inhalation pathway, excluding the EPC
CSF_{Inh}	=	oral cancer slope factor for constituent i
$Intake_{Derm}$	=	media-specific intake for dermal pathway, excluding the EPC
CSF_{Derm}	=	dermal cancer slope factor for constituent i

Intake factors for the different exposure routes (i.e., ingestion, inhalation, and dermal contact) were derived using equations and parameters provided in other sections of the TM.

An equation of the following general form was used to derive the RBC for non-carcinogens:

$$N\ C_i = THI\ /[(Intake_{Ing} / RFD_{oral}) + (Intake_{Inh} / RFD_{Inh}) + (Intake_{Derm} / RFD_{Derm})]$$

where:

NC_i	=	Non-Cancer RBC (medium- and pathway-specific) for constituent i
THI	=	target hazard index (1)
$Intake_{Ing}$	=	media-specific intake for ingestion pathway, excluding the EPC
RFD_{Oral}	=	oral chronic reference dose for constituent i
$Intake_{Inh}$	=	media-specific intake for inhalation pathway, excluding the EPC
RFD_{Inh}	=	inhalation chronic reference dose factor for constituent i
$Intake_{Derm}$	=	media-specific intake for dermal pathway, excluding the EPC
RFD_{Derm}	=	dermal chronic reference dose factor for constituent i

Intake factors for the different exposure routes (i.e., ingestion rate, inhalation rate, and dermal contact) were presented in the TM and are repeated in Tables 6.8 through 6.11.

6.4 TOXICITY ASSESSMENT

The toxicity criteria used in the HHRA were obtained from the most current update of the EPA Integrated Risk Information System (IRIS) or, if the information was not available in IRIS, the EPA Health Effects Assessment Summary Tables (HEAST). IRIS is an electronic database containing the most current descriptive and quantitative EPA regulatory toxicity information for non-radiological and radiological constituents. Files maintained in IRIS contain information related to non-carcinogenic and carcinogenic health effects of constituents. HEAST is a published reference, updated quarterly by EPA. It contains toxicity information and values for constituents from health effects documents and profiles. Other sources for toxicity information include the National Center for Environmental Assessment (NCEA) Provisional Values, Agency for Toxic Substances and Disease Registry (ATSDR) Toxicology Profiles, or EPA Criteria Documents. Table 6.12 presents a summary of toxicological criteria, and the chemical-specific characteristics used to estimate dermal absorbed dose and the concentrations present in vapors or dust.

Route-to-route extrapolation can be used where no toxicity values are available for a given route of exposure. For example, cancer slope factors and reference doses derived for oral exposures may be adjusted or used as is, to assess exposure via inhalation or dermal contact. The soon to be released EPA guidance was followed for assessment of the dermal route of exposure (Appendix 6C). For many chemicals, a scientifically defensible database does not exist for adjusting oral slope factors and reference doses to estimate a dermal toxicity value. Information on the fraction of a compound that is actually absorbed through the skin also is lacking. For the HHRA quantitative assessment of risk due to dermal exposure to contaminated soil was completed only for chemicals with EPA recommended gastrointestinal absorption efficiencies and dermal absorption factors. EPA recommended gastrointestinal absorption efficiencies and dermal absorption factors are presented in Table 6.12. When the EPA recommended gastrointestinal absorption efficiency was greater than 50 percent, oral cancer slope factors and reference doses were used without adjustment to assess potential dermal risks. Soil-to-skin adherence factors were updated from those presented in the TM. The updated soil adherence factors were taken from *Exposure Factors Handbook* (EPA 1997a) and are presented in Tables 6.8 through 6.11.

There are two identified COPCs, 2-hexanone and phosphorus (inorganic), for which no human health toxicity values exist in IRIS, HEAST, or NCEA guidance and for which little definitive information is available. Therefore, a quantitative risk estimate cannot be calculated for these compounds. These constituents are qualitatively discussed in Section 6.6.3.

Lead also was identified as a COPC. Lead does not have toxicological reference values because risks from exposure to lead are better evaluated by predicting the associated blood lead level. Blood lead levels have been accepted as the best measure of external dose of lead. Sensitive populations include preschool-age children and fetuses. In fetuses and children, a blood lead level of between 10 and 15 micrograms per deciliter (µg/dL) has been associated with a level at which no adverse effects would be expected [Centers for Disease Control and Prevention (CDC), 1985]. The approach used here relates intake of lead from soil to blood lead concentrations in residential children and to women of child bearing age who may be exposed to lead in soil while working at the site. Protection of a hypothetical fetus of an occupationally exposed mother ensures that other workers at the site will be adequately protected.

A risk-based remediation goal of 400 ppm lead in soil was established by EPA based on the "Interim Guidance on Establishing Soil Lead Cleanup Levels at RCRA Facilities" (EPA 1994a). The allowable concentration of 400 ppm lead in soil is supported by EPA's Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) (EPA 1994b). The IEUBK predicts that 400 ppm of lead in soil could cause a 6-year-old resident child (averaged across the preceding 84 months) to have a probability of no greater than 5% of having a blood lead level of 10 micrograms/deciliter (µg/dL). For

current and future off-site resident farmer scenarios, the concentration of lead in soil was compared to the acceptable level of 400 ppm lead.

Recommendations of EPA's Technical Review Workgroup (TRW) for lead were used to assess risks associated with adult worker exposures to lead in soil (EPA 1996f). The TRW approach for assessing non-residential adult risks utilizes some basic algorithms to relate soil lead intake to blood lead concentrations in women of child bearing age. The basis for the calculation is the relationship between the concentration of lead in soil and the blood lead concentration in a developing fetus of adult women that have occupational site exposures. The TRW model uses the same threshold for elevated blood lead concentrations as the IEUBK. The highest acceptable fetal blood lead level was set at the 95th percentile of 10 μg/dL, which is the concentration recommended by EPA and the CDC (1985).

The TRW model assumes that the increase in blood lead from exposure to lead in soil is linear. A linear biokinetic slope factor was developed for the model based on available data relating fetal blood lead levels to maternal blood lead levels and soil exposure. Using the TRW risk estimation algorithm which assumes a typical adult blood lead level of 2.0 μg/dL and an inter-individual variability in blood lead of 1.9 (recommended for non-Hispanic white populations such as the one found near the site), the acceptable concentration of lead in soil was calculated as 958 ppm. The algorithm and assumptions used to calculate this value are presented in Figure 6.7. The concentrations of lead in soil at the on-site exposure units (EUs 1 and 2) where occupational exposures may occur were compared to the risk-based remediation goal of 958 ppm.

The toxicity of tetrachloroethene (PCE) and several PAHs are currently under review by the EPA. In lieu of EPA-determined values, the oral and inhalation slope factors and the inhalation reference dose for PCE were taken from NCEA guidance (EPA 1998d). The slope factors for various PAHs were estimated based on the slope factors for benzo(a)pyrene. The oral and inhalation slope factors for benzo(a)pyrene were adjusted for other PAHs using relative potency factors drawn from "*Provisional Guidance for the Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons*" (EPA 1993a).

6.4.1 Toxicity Criteria Definitions

The cancer slope factor (CSF) defines the plausible upper-bound estimate of the probability of developing cancer per unit intake of a constituent over a lifetime (EPA 1989d). Slope factors are specific for each constituent and route of exposure. The potential for non-carcinogenic health effects resulting from exposure to COPCs was assessed by comparing an exposure estimate (intake or dose) to the reference dose (RfD). The chronic RfD is defined as an estimate of the daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime (EPA 1989a). A RfD also is specific for a constituent and route of exposure.

Oral and inhalation CSF and RfDs are currently available in IRIS and HEAST. Inhalation CSFs and RfDs take into consideration the fractional amount of a constituent absorbed into the blood. The oral CSF and RfD values take into consideration the fractional amount of a constituent absorbed across the gastrointestinal (GI) tract into the bloodstream. When EPA-derived RfDs and CSFs were not available for a route of exposure being evaluated but were available for a different route, route-to-route extrapolation was considered. Dermal CSFs and RfDs were estimated from the oral toxicity values using constituent-specific gut absorption factors to calculate the total administered dose by the following equations (EPA 1992a):

$$CSF_{dermal} = CSF_{oral} \ / \ ABS_{gi} \ ,$$

$$RfD_{dermal} = RfD_{oral} \times ABS_{gi} ,$$

where:

CSF	=	constituent-specific cancer slope factors $(mg/kg\text{-}day)^{-1}$
RfD	=	constituent-specific reference doses (mg/kg-day)
ABS_{gi}	=	constituent-specific gut absorption factor (unitless)

Few chemical-specific skin absorption factors are currently available from EPA. However, guidance on this matter was obtained via personal communication with EPA Region 5 toxicologist, Mark Johnson. Guidance from Dr. Johnson was utilized for the selection of soil-to-skin adherence factors, dermal absorption fractions and gastrointestinal absorption efficiencies. Since this guidance has yet to be released to the public, a copy of this guidance has been provided in Appendix 6C. The guidance recommends a default dermal absorption factor of 0.1 for the majority of SVOCs, 0.13 for PAHs, 0.14 for PCBs, and 0.001 for cadmium (Table 6.12). Gut absorption factors provided in the EPA Region 9 PRG tables and EPA recommended procedures (EPA 1998d) were used to estimate dermal toxicity values.

CSFs and RfDs may not be available for some detected constituents at the Luckey site because the carcinogenic and/or non-carcinogenic effects of the constituents have not yet been determined. Although these constituents may contribute to carcinogenic and non-carcinogenic effects from exposure to the contaminated media, their effects cannot be quantified at the present time. A qualitative evaluation of the toxicity information for the COPCs without toxicity criteria and a discussion of the implications of the absence of the COPCs from the risk assessment are presented in the uncertainty assessment (Sections 6.6 through 6.6.5).

6.5 RISK CHARACTERIZATION

Risk characterization integrates the findings of the exposure assessment and toxicity assessment to estimate the likelihood that a receptor may experience an adverse effect as the result of exposure to COPCs (EPA 1989a). Risks were calculated using toxicity information and intakes calculated as part of the exposure assessment. Total site risk refers to the risk associated with all COPCs at the site. Site-related risks refer to the risk associated with the COPCs present as a result of site-related activity; constituents present at or below background concentrations were not included in these evaluations. Background risk refers to risk associated with COPCs that are present due to natural or anthropogenic causes other than site-related activity.

6.5.1 Carcinogenic Risk Characterization

Cancer slope factors were used to quantify potential future risks. A CSF for a radionuclide is defined differently than a CSF for a non-radiological constituent. EPA outlines these differences in *Radiation Exposure and Risk Assessment Manual* (EPA 1996a). Major differences include the following:

- the endpoint for radiological constituents is fatal cancer – the endpoint for non-radiological constituents is the incidence of tumorigenic cancer;
- radiological risk estimates are based primarily on human data – chemical risk estimates are based primarily on animal studies; and
- radiological risk estimates are based on the central estimate of the mean – chemical risk estimates are based on 95% UCL of the mean.

Additional considerations include the fact that exposure point concentrations for radionuclides and non-radionuclides are specific to distinct models incorporating different assumptions; RAGS cautions

against combining radiological and non-radiological risks. Despite these differences, risks from chemicals and radionuclides are presented separately and then summed. Excess cancer risk estimates from radiological and non-radiological carcinogens were summed to provide an estimate of the combined risk presented by all carcinogenic contaminants.

For carcinogenic COPCs, incremental lifetime cancer risk (ILCRs), or the increased lifetime probability of cancer, was calculated for each EU using RME exposure assumptions. The resulting ILCRs were compared to the range specified in the NCP (EPA 1990). The NCP specifies a target risk range of 10^{-6} to 10^{-4}, or the probability that one additional person in a population of 1 million to one additional person in a population of 10,000 persons may develop cancer as the result of exposure to contaminants at the Luckey site. ILCRs below 10^{-6}, were considered acceptable risks. ILCRs above 10^{-4}, are considered unacceptable risks. Risks between 10^{-6} and 10^{-4} fall into the NCP "area of concern." To further evaluate these risk exposure scenarios with an ILCR of greater than 10^{-6} were evaluated using CT exposure assumptions. This approach provides some measure of the uncertainty inherent to the baseline risk calculations. Both the RME and CT risk should be considered prior to making any decisions to address risks between 10^{-6} and 10^{-4}. The incremental lifetime risk of developing cancer was determined as follows (EPA 1989a):

$$ILCR = I \times CSF$$

where:

ILCR	=	incremental lifetime cancer risk (unitless probability)
I	=	chronic daily intake or DAD from exposure assessment (mg/kg-day)
CSF	=	cancer slope factor $(mg/kg\text{-}day)^{-1}$

Use of the ILCR assumes that the constituent carcinogenesis does not exhibit a threshold and that the dose-response relationship is linear in the low dose range. Because ILCR could generate cancer risks that fall in the nonlinear, high dose response range, the resulting ILCR was considered to be inaccurate at cancer risks greater than $1x10^{-2}$. When the predicted theoretic cancer risk is greater than $1x10^{-2}$, cancer risk will be estimated by the one-hit model (EPA, 1989a) as follows:

$$ILCR = 1 - e^{(-I)(CSF)}$$

where:

ILCR	=	incremental lifetime cancer risk (unitless), adjusted for background,
$e^{[(-I)(CSF)]}$	=	the exponential of the negative of the risk calculated by ILCR =(I)(CSF)
I	=	chronic daily intake or DAD from exposure assessment (mg/kg-day)
CSF	=	cancer slope factor $(mg/kg\text{-}day)^{-1}$

6.5.2 Non-carcinogenic Risk Characterization

For a given pathway, with simultaneous exposure of a receptor to several carcinogens, the total risk to a receptor is the sum of the ILCRs for each carcinogen encountered in all sources by each identified exposure pathway. The equation used to calculate the total ILCR is:

$$ILCR_{total} = \sum ILCR_i$$

where:

$ILCR_{total}$	=	total incremental lifetime cancer risk (unitless probability)
$ILCR_i$	=	ILCR for the ith constituent

In addition to calculating the probability of developing cancer due to exposure to COPCs, the BRA evaluated the likelihood that an individual may experience non-carcinogenic toxic effects due to exposures to COPCs. The term "toxic effects" describes a wide variety of systemic effects, ranging from minor ailments, such as skin irritation and headaches, to more substantial effects, such as kidney or liver disease and neurological damage. The risks associated with exposure to toxic constituents were evaluated by comparing an exposure level or intake calculated using RME intake assumptions to a reference dose (RfD). The RfD is the threshold, below which no toxic effects are expected to occur in a normal population, including sensitive subpopulations. The ratio of intake or single-constituent exposure level over a specified time period to the RfD for that constituent derived from a similar exposure period is termed the Hazard Quotient (HQ) (EPA 1989a) and is defined as:

$$HQ = \frac{I}{RfD}$$

where:

HQ	=	hazard quotient (unitless ratio)
I	=	chronic daily intake or DAD (dermal absorbed dose) (mg/kg-day)
RfD	=	reference dose (mg/kg-day)

The HQs of each COPC identified for the EUs were summed to obtain a HI. A HI greater than 1 was defined as the level of concern for potential adverse non-carcinogenic health effects (EPA 1989a). To further evaluate non-carcinogenic risks, RME exposure scenarios with a HI greater than 0.1 were run using CT intake assumptions. Just as with the carcinogenic risk calculations, this approach provides some measure of the uncertainty inherent to the baseline risk calculations. Both the RME and CT HI should be considered prior to making any decisions to address risks further, either through continued study or engineered control measures. This approach is different from the probabilistic approach used to evaluate carcinogens. A HQ of 0.01 does not imply a one in 100 chance of an adverse effect; it indicates only that the estimated intake is 100 times less than the threshold level at which adverse health effects may occur. For simultaneous exposure of a receptor to several constituents, HIs were calculated as the sum of the individual HQs for all non-carcinogenic COPCs encountered for each pathway as follows:

$$HI = \sum HQ_i$$

where:

HI	=	hazard index
HQ_i	=	hazard quotient for the ith constituent

The $ILCR_{total}$ and the total HI associated with each media, for each receptor, were derived by summing pathway-specific values. Where the HI exceeded one, the HQs were segregated based on their target organ. If the segregated HIs still exceeded 1, it was concluded that the target risk level had been exceeded.

As recommended in EPA guidance (EPA, 1992a), a description of individual risk that includes the high end (RME) and median (CT) risk distribution has been provided in the HHRA. Therefore, if either cancer or non-cancer risk exceed acceptable limits (cancer risk > 10E-6, or HI > 1), the risk calculations were recomputed using CT values for as many intake model variables as possible.

6.5.3 Risk Characterization Results

The following subsections present the risk characterization results in a narrative form for each of the Luckey site EUs by receptors. Tables 6.13 through 6.22 present this information as summaries of the quantitative results of the risk assessments for all scenarios and pathways for RME and CT exposures,

respectively. In the summary tables, risk estimates that are at or above the non-cancer HI of 1 and the cancer target risk level of 1 x 10^{-6} (1.0E-06) are **bolded**. Risk estimates of zero indicate that toxicity criteria are not available for any contaminant evaluated in the pathway. Risk estimates for individual COPCs for all scenarios and pathways are presented in Appendix 6A. In Appendix 6A, Tables 6A.1 through 6A.37 present risk estimates based on RME exposure parameters, and Tables 6A.38 through 6A.69 present risk estimates based on CT exposure parameters. Based on the results of the risk characterization for each EU, the constituents of concern (COCs) are those with a cancer risk greater than 1 x 10^{-6} or a non-cancer risk greater than 1. Tables 6.23 and 6.24 summarize the resulting COCs from the risk characterization for each EU media by receptors for both the RME and CT scenarios, respectively.

Exposure Unit 1

For each of the scenarios for EU 1, Table 6.13 presents the summary of risk to RME exposures, and Table 6.19 summarizes the CT exposure risks.

Current and Future Industrial Worker Scenario

The current and future industrial worker scenario evaluated exposure to soil zero to 2 ft bls. For the current and future RME scenario, the total non-cancer risk goal was not exceeded for the industrial worker receptor. The current and future total HI for the industrial worker in EU 1 was 0.34.

The total incremental lifetime cancer risk (ILCR) for the RME current and future industrial worker scenario was 6.6 x 10^{-5} with a majority of the risk coming from incidental soil ingestion and dermal contact with soil. The soil dermal pathway contributed 74% and the soil ingestion pathway contributed 26% of the total ILCR. Compounds that exceed the target ILCR goal of 1 x 10^{-6} for the dermal and ingestion pathways include benzo(a)pyrene, benzo(b)fluoranthene, benzo(a)anthracene, and aroclor-1254, listed in descending order of total risk contribution. Benzo(a)pyrene, benzo(b)fluoranthene, benzo(a)anthracene, and aroclor-1254 represent 76%, 12%, 9%, and 5%, respectively, of the total ILCR of 6.6 x 10^{-5}. The soil inhalation pathway did not contribute significantly to risk for this receptor.

Since the RME cancer risk values exceed the target ILCR goal of 1 x 10^{-6}, the CT risk values were calculated for the industrial worker. The ILCR for soil pathways for the CT current and future scenario was 4.4 x 10^{-6}. Dermal contact with soil accounted for 19% and soil ingestion accounted for 82% of the total ILCR. Only one compound exceeds the target ILCR goal of 1 x 10^{-6}, and that was benzo(a)pyrene for the ingestion pathway. Benzo(a)pyrene risk represents 76% of the total ILCR of 4.4 x 10^{-6}. The inhalation pathway did not significantly contribute to risk for this receptor.

The COCs for soils in EU 1 for the industrial worker receptor are benzo(a)pyrene, benzo(b)fluoranthene, benzo(a)anthracene, and aroclor-1254. The majority of the elevated levels of PAHs detected at the Luckey site occur within the top two feet of soil. The concentrations of PAHs detected at the Luckey site are commonly found in soils near roads and at industrial sites where PAHs are a normal part of the environment (DOE 1997a). EPA Region 4 has concluded: " As a matter of definition of a release under CERCLA 101(22), to which CERCLA 104 gives authority to respond, as well as a common sense issue, that an exemption to PAHs adjacent to roads exist in the CERCLA program" (USAF 2000). The fact that PAHs occur predominantly in surface soils suggests that they may be related to ongoing industrial processes rather than AEC activities that occurred over 50 years ago.

The maximum concentration of PAHs detected at Luckey (3,828,000 ug/kg) was found adjacent to a road/parking area where heavy trucks pass frequently and park or idle their engines. Diesel truck exhaust is known to contain high levels of PAHs and these activities have quite likely contributed to PAH contamination in this area. For comparison, road dust has been reported to have total PAH concentrations

of up to 336,000 ug/kg (Eisler 1987), while soil adjacent to a utility pole was found to contain total PAH concentrations in excess of 3,000,000 ug/kg (Wan 1994). These results suggest that the level of PAHs observed at the Luckey site could be the result of current industrial operations rather than an AEC source.

Future Resident Farmer Adult Scenario

The future resident farmer adult scenario was assessed for exposure to soil zero to 2 ft bls and for soil zero to 10 ft bls. The same COCs were identified for both soil intervals. For both soil intervals, the future non-cancer RME risk for the resident adult farmer was 0.6 which does not exceed the target HI of 1. When exposure to groundwater (HI=1.3) is added, the total HI is 1.9 which does exceed the target HI. The soil pathway contributed 31%, and groundwater contributed 69% of the non-cancer risk to the total HI of 1.9. The total groundwater HI was 1.3, and the ingestion pathway accounted for 85% of this risk. No individual groundwater COPCs exceeded the target value of 1.

The evaluation of non-cancer risk for the CT scenario with both soil intervals produced a total HI of 0.9 for both the soil and groundwater pathways, and does not exceed the target HI of 1.

The RME ILCR for the future adult farmer scenario in EU 1 with exposure to soil zero to 2 ft bls was 8.5×10^{-4}. The RME ILCR for the future adult farmer scenario with exposure to zero to 10 ft bls was 3.4×10^{-4}, and all of the cancer risk was due to soil exposure pathways. The dermal pathway contributed 74% and the ingestion pathway contributed 26% of the total ILCR. Compounds that exceed the target ILCR goal of 1×10^{-6} for the dermal pathway include benzo(a)pyrene, benzo(b)fluoranthene, benzo(a)anthracene, aroclor-1254, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene, listed in descending order of total risk contribution. For the ingestion pathway, compounds that exceed the target ILCR goal of 1×10^{-6} include benzo(a)pyrene, benzo(b)fluoranthene, benzo(a)anthracene, aroclor-1254, and dibenz(a,h)anthracene, listed in descending order of total soil risk contribution. Benzo(a)pyrene, benzo(b)fluoranthene, and benzo(a)anthracene represent 72%, 11%, and 9%, respectively, of the total soil ILCR of 3.4×10^{-4}. The inhalation pathway did not contribute significantly to risk for this receptor.

Since the RME cancer risk values exceeding the target ILCR goal of 1×10^{-6}, the CT cancer risk values were calculated for the resident adult farmer receptor with exposure to soil zero to 2 ft bls and with exposure to soil zero to 10 ft bls. The CT ILCR for all pathways with exposure to soil zero to 2 ft bls was 4.3×10^{-5}. The CT ILCR for all pathways with exposure to soil zero to 10 ft bls was 1.7×10^{-5}, and 100% of the cancer risk was from soil pathways. Dermal contact with soil and incidental soil ingestion presented risk greater than the target ILCR goal of 1×10^{-6}. Compounds that exceed the target ILCR goal of 1×10^{-6} for the dermal pathway include benzo(a)pyrene and benzo(b)fluoranthene listed in descending order of total risk contribution. For the ingestion pathway, the only compound that exceeds the target ILCR goal is benzo(a)pyrene. For the zero to 2 ft soil interval, benzo(a)pyrene, benzo(b)fluoranthene, and benzo(a)anthracene are the COPCs that contribute 76%, 12% and 9% of the total ILCR of 4.3×10^{-5}, respectively. For the zero to 10 ft soil interval benzo(a)pyrene, benzo(b)fluoranthene, and benzo(a)anthracene are the COPCs that represent 72%, 11%, and 9% of the total soil ILCR of 1.7×10^{-5}, respectively. The inhalation pathway did not contribute significantly to risk for the resident farmer adult receptor.

The COCs for soils in EU 1 for the resident farmer adult receptor are aroclor-1254, benzo(a)pyrene, benzo(b)fluoranthene, benzo(a)anthracene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene. Ninety five percent of the potential cancer risk for the resident farmer adult receptor is due to PAHs that could be due to on-going industrial operations rather than AEC activities that took place approximately 50 years ago.

Future Resident Farmer Child Scenario

The future resident farmer child scenario was assessed for exposure to soil zero to 2 ft bls and for soil zero to 10 ft bls. The future total non-cancer RME HI for the resident child farmer exposed to both soil and groundwater was 5.9 for the zero to 2 ft soil interval and 5.7 for the zero to 10 ft soil interval. For both soil intervals, the HIs exceed the target HI of 1. Approximately half of the non-carcinogenic risk comes from exposure to groundwater. For the zero to 2 ft soil interval, soil pathways contributed 46% (HI=2.7), and groundwater contributed 54% (HI=3.2) of the non-cancer risk for a total HI of 5.9. For the zero to 10 ft soil interval, soil pathways contributed 44% (HI=2.5), and groundwater contributed 56% (HI=3.2) of the non-cancer risk for a total HI of 5.7. Nearly all the non-cancer risk due to exposures to soil was from the soil ingestion pathway. For the RME scenario, aroclor-1254 was the only COPC that exceeded the target HI criteria with a HI of 2.2 which represents 88% and 76% of the total soil HI for the zero to 10 and zero to 2 ft soil intervals, respectively.

Groundwater presented non-cancer risk at levels above the target HI goal of 1. The RME total groundwater HI was 3.2, and 91% of this was from the ingestion pathway. Manganese, nickel, and total uranium are the major contributing COPCs to the groundwater ingestion HI of 3.2, but only manganese exceeds the target goal HI with a risk of 1.4 (44% of total groundwater).

Since the RME scenario produced non-cancer risk exceeding the target HI, non-cancer risk was evaluated for the CT resident farmer child exposed to soil zero to 2 ft bls and zero to 10 ft bls. The CT non-cancer risk HIs for a resident farm child exposed to soil zero to 2 ft bls and soil zero to 10 ft bls were 0.81 and 0.17, respectively. These values do not exceed the target HI of 1. The non-cancer HI for this same receptor due to exposure to groundwater was 1.6 which does exceed the target level. For the CT child receptor exposed to soil zero to 2 ft bls the soil pathways contributed 34% of the total HI and groundwater pathways contributed 66% of the total HI. For the CT child receptor exposed to soil zero to 10 ft bls soil pathways contributed 10% of non-cancer risk and groundwater pathways contributed 90% of the total HI of 1.7. For both soil intervals aroclor-1254 was the principal COPC presenting 76% and 88% of the total soil HI risk for the zero to 2 and zero to 10 ft soil intervals, respectively. The CT total groundwater HI was 1.6, and 94% of this value was due to the groundwater ingestion pathway. Manganese, nickel, and total uranium were the principle contributors to the ingestion HI of 1.5, but none individually exceeded the HI of 1. Manganese contributed 44% of the total groundwater HI with a groundwater non-cancer risk of 0.7.

The RME ILCR for all pathways for the resident farmer child receptor was 5.2×10^{-4} with exposure to soil zero to 2 ft bls and 2.1×10^{-4} with exposure to soil zero to 10 ft bls. All of the cancer risk resulted from exposures to soil. The same COCs were identified for both soil intervals. For the zero to 2 ft soil interval the soil ingestion and dermal contact with soil contributed 79% and 21% of the total soil ILCR at EU 1, respectively. For the zero to 10 ft soil interval the soil ingestion and dermal contact with soil contributed 78% and 22% of the total soil ILCR at EU 1, respectively. The inhalation pathway did not contribute significantly to risk for this receptor.

Since the RME cancer risk values exceeded the target ILCR goal of 1×10^{-6}, the CT cancer risk values were calculated for the resident farm child receptor. The total CT ILCR for all pathways with exposure to soil zero to 2 ft bls was 1.4×10^{-4} while the total CT ILCR for all pathways with exposure to soil zero to 10 ft bls was 4.3×10^{-5}. All the cancer risk was due to exposures to soil. Soil ingestion and dermal pathways presented risk greater than the target ILCR goal of 1×10^{-6}. For the zero to 2 ft soil interval benzo(a)pyrene, benzo(b)fluoranthene, and benzo(a)anthracene are the COPCs that represent 76%, 12%, and 9% of the total soil ILCR of 1.4×10^{-4}, respectively. For the zero to 10 ft soil interval benzo(a)pyrene, benzo(b)fluoranthene, and benzo(a)anthracene are COPCs that represent 72%, 11%, and

9%of the total soil ILCR of 4.3 x 10^{-5} , respectively. The inhalation pathway did not contribute significantly to risk for the resident farmer child receptor.

The COCs for soils in EU 1 for the resident farmer child receptor are aroclor-1254, benzo(a)pyrene, benzo(b)fluoranthene, benzo(a)anthracene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene. Manganese is the only COC in groundwater for EU 1. Ninety five percent of the potential cancer risk for the resident farmer child receptor is due to PAHs in soil. The PAHs in soil could be due to on-going industrial operations rather than AEC activities that took place approximately 50 years ago.

Summary of EU 1 COCs

The following is a summary of all COCs for EU 1 receptors based on RME exposure assumptions.

Summary of EU 1 Non-Radiological COCs

Receptor/Media	COC
Current/Future Industrial Worker/ Surface Soils	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Aroclor-1254
Future Resident Farmer- Adult/ Soil 0-2 ft bls	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenz(a,h)anthracene Indeno(1,2,3-cd)pyrene Aroclor-1254
Future Resident Farmer- Adult/ Soil 0-10 ft bls	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenz(a,h)anthracene Indeno(1,2,3-cd)pyrene Aroclor-1254
Future Resident Farmer- Child/ Soil 0-2 ft bls	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenz(a,h)anthracene Indeno(1,2,3-cd)pyrene Aroclor-1254
Future Resident Farmer- Child/ Soil 0-10 ft bls	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenz(a,h)anthracene Indeno(1,2,3-cd)pyrene Aroclor-1254
Future Resident Farmer- Child/ Groundwater	Manganese

<u>Exposure Unit 2</u>

For each of the scenarios for EU 2, Table 6.14 presents the summary of risk to RME exposures and Table 6.20 summarizes the CT exposure risks for EU 2. The following is a narrative of the results presented in the tables.

Current and Future Industrial Worker Scenario

The current and future industrial worker was evaluated for exposure to soil zero to 2 ft bls. For the current and future RME scenario, the total non-cancer risk goal was not exceeded for the industrial worker receptor. Therefore, no non-cancer COCs in soil and groundwater were identified at EU 2 for this receptor.

The total RME ILCR for the RME current and future industrial scenario was 1.6×10^{-6}. The soil pathways presented 100% of the total cancer risk and the soil dermal pathway contributed the majority of the total ILCR. No single compound exceeded the target ILCR goal of 1×10^{-6} for any individual pathway. Benzo(a)pyrene is the only COPC that presents cancer risk from the combined dermal and ingestion pathways above the target level with a value of 1.2×10^{-6}. This represents 77% of the total ILCR from soil exposure.

Since the RME cancer risk values exceeded the target ILCR of 1×10^{-6}, CT ILCRs were calculated for the industrial worker in EU 2. The CT ILCR for all pathways for the industrial worker in EU 2 was 1.0×10^{-7}, which is below the target ILCR goal of 1×10^{-6}.

For the industrial receptor, lead was evaluated by comparing the EPC to the value obtained using the TRW lead model. The lead EPC of 1,380 mg/kg in the EU 2 surface soils exceeded the TRW lead target value of 958 mg/kg. Therefore lead is a COC for the industrial receptor at EU 2.

The COCs for soils in EU 2 for the industrial worker receptor are benzo(a)pyrene and lead. There are no COCs for groundwater for this receptor. All of the potential cancer risk for the industrial worker in EU 2 is due to PAHs in soil. A majority of the elevated levels of PAHs detected at the Luckey site occur within the top two feet of soil. The concentrations of PAHs detected at the Luckey site are commonly found in soils near roads and at industrial sites where PAHs are a normal part of the environment (DOE 1997a). EPA Region 4 has concluded: "As a matter of definition of a release under CERCLA 101(22), to which CERCLA 104 gives authority to respond, as well as a common sense issue, that an exemption to PAHs adjacent to roads exist in the CERCLA program" (USAF 2000). The fact that PAHs occur predominantly in surface soils suggests that they may be related to ongoing industrial processes rather than due to AEC activities that occurred over 50 years ago.

Future Resident Farmer Adult Scenario

The future resident farmer adult scenario was assessed for exposure to soil zero to 2 ft bls and for soil zero to 10 ft bls. For the future RME scenario with exposure to soil zero to 2 ft bls, the total soil HI was 0.9. For the future RME scenario with exposure to soil zero to 10 ft bls, the total soil HI was 0.54. Neither of these values exceeds the target HI of 1. The total groundwater HI for the resident farmer adult receptor was 1.3, which does exceed the target HI of 1. For the zero to 2 ft soil interval, exposure to groundwater and soil accounted for 59% and 41% of the total HI, respectively. For the zero to 10 ft soil interval, exposure to groundwater and soil accounted for 70% and 30% of the total HI, respectively. For both soil intervals groundwater ingestion was the pathway that contributed most to the total non-cancer HI. No individual COPC in groundwater presented non-cancer risk greater than 1. Manganese has the largest HI (0.56) and represents 43% of the total HI, predominately by the route of ingestion. For the CT scenario the total non-cancer risk goal was not exceeded.

When considering total non-carcinogenic risk for EU 2 it is important to note that beryllium, cadmium, uranium, and manganese are the principal constituents contributing to this risk and that each of these metals affects different target organs. Beryllium causes small intestinal lesions. Cadmium affects the kidney and also displaces calcium in the bone leading to itai-itai disease. Manganese is a neurotoxin

affecting the central nervous system. Since each of the principal COPCs affect different target organs, the sum of the HQs for the metals results in an over-estimation of the non-cancer risk.

For EU 2 the RME ILCR for all pathways future resident adult farmer with exposure to soil zero to 2 ft bls was 2.0×10^{-5}. For the same receptor exposed to soil zero to 10 ft bls the RME ILCR for all pathways was 1.9×10^{-5}. The soil pathways contributed 100% of the total ILCR. Compounds that exceed the target ILCR goal of 1×10^{-6} for the combined dermal and ingestion pathways for the zero to 2 ft soil interval include benzo(a)pyrene, and benzo(b)fluoranthene, listed in descending order of total risk contribution. For the zero to 10 ft soil interval compounds that exceed the target ILCR goal of 1×10^{-6} for the combined dermal and ingestion pathways include benzo(a)pyrene, benzo(b)fluoranthene, benzo(a)anthracene, and indeno(1,2,3-cd)pyrene, listed in descending order of total risk contribution. No COPCs exceeded the target ILCR goal of 1×10^{-6} via the inhalation pathway.

Since the RME cancer risk values exceed the target ILCR goal of 1×10^{-6}, the CT risk values were calculated for the adult resident farmer exposed to soil zero to 2 and zero to 10 ft bls. The total CT ILCR for the adult resident farmer including soil zero to 2 ft bls was 1.0×10^{-6}, which does not exceed the target ILCR goal. The total CT ILCR for the adult resident farmer including soil zero to 10 ft bls was 9.7×10^{-7}, which also does not exceed the target ILCR goal.

For the resident farmer-adult receptor, lead was evaluated by comparing the EPC to the value obtained using the IEUBK model. The lead EPC of 1380 mg/kg in soil zero to 2 ft bls and 561 mg/kg in soil zero to 10 ft bls exceeded the IEUBK lead target value of 400 mg/kg; therefore, lead is a COC for this receptor at EU 2.

The COCs for soils in EU 2 for the resident farmer adult receptor are benzo(a)pyrene, benzo(b)fluoranthene, benzo(a)anthracene, indeno(1,2,3-cd)pyrene, and lead. There are no COCs for groundwater for this receptor. All of the potential cancer risk for the resident farmer adult receptor are due to PAHs in soil that could be due to on-going industrial operations rather than AEC activities that took place approximately 50 years ago.

Future Resident Farmer Child Scenario

The future resident farm child in EU 2 was assessed for exposure to soil zero to 2 and zero to 10 ft bls. For the future RME scenario, the total non-cancer risk goal was exceeded for the resident farm child exposed to both soil intervals. The total HI for the resident farm child exposed to soil zero to 2 ft bls was 11. Exposure to soil accounted for 70% and groundwater exposure accounted for 30% of the total HI. The total HI for the resident farm child exposed to soil zero to 10 ft bls was 8.0. Exposure to soil accounted for 60% and groundwater exposure accounted for 40% of the total HI. The soil ingestion pathway accounted for nearly all of the total soil HI. For the zero to 2 ft soil interval beryllium (HI=4.9) and cadmium (HI=2.2) present 65% and 29% of the total soil non-cancer risk primarily through the ingestion pathway. For the zero to 10 ft soil interval beryllium (HI=3.3) and cadmium (HI=0.7) present 69% and 16% of the total soil non-cancer risk primarily through the ingestion pathway, respectively. The RME HI for groundwater was 3.2. Manganese (HI=1.4) accounted for 44% of the groundwater HI primarily through the ingestion pathway. Nickel and uranium each had HIs less than 1 and represented 25% and 22% of the remaining groundwater non-cancer risk, respectively.

The CT total HI for the resident farm child also exceeded the target risk goal of 1. The total CT HI for the resident farm child exposed to soil zero to 2 ft bls was 3.9. Exposure to soil accounted for 59% of the total HI. The total CT HI for the resident farm child exposed to soil zero to 10 ft bls was 3.0. Exposure to soil accounted for 47% of the total HI The soil ingestion pathway accounted for nearly all of the total soil HI. Ingestion of soil containing beryllium accounts for 65-69% of the total non-cancer risk

from exposure to soil. The HI for CT to groundwater was 1.6. Manganese again accounted for 44% of the groundwater HI, primarily through the ingestion pathway.

When considering total non-carcinogenic risk it is important to note that beryllium, cadmium and manganese are the principal constituents contributing to this risk and that each of these metals affects different target organs. Beryllium causes small intestinal lesions. Cadmium affects the kidney and also displaces calcium in the bone leading to itai-itai disease. Manganese is a neurotoxin affecting the central nervous system. Since each of the principal COPCs affect different target organs, the sum of the HQs for the metals results in an over-estimation of the non-cancer risk.

The total RME ILCR for the current and future scenario for a resident farm child including exposure to soil zero to 2 and zero to 10 ft bls at EU 2 was 1.2×10^{-5}. All of the cancer risk was from exposure to soils. The soil ingestion pathway contributed 78% of the total ILCR. The total cancer risk for all pathways in soil for benzo(a)pyrene and benzo(b)fluoranthene exceed the target ILCR goal. For both soil intervals benzo(a)pyrene and benzo(b)fluoranthene represent 77%, and 9% of the RME ILCR from soil exposure. No COPCs exceeded the target ILCR goal of 1×10^{-6} via the inhalation pathway.

Since the RME cancer risk values exceeding the target ILCR goal of 1×10^{-6}, the CT ILCR was calculated for the child resident. The total CT ILCR for the resident farm child in EU 2 was 3.3×10^{-6} with exposure to soil zero to 2 ft bls and 3.2×10^{-6} with exposure to soil zero to 10 ft bls. Both values exceed the target ILCR goal of 1×10^{-6}. Only benzo(a)pyrene exceeded the target risk by the oral pathway. Benzo(a)pyrene presented approximately 77% of the total ICLR.

For the resident farm child receptor, lead was evaluated by comparing the EPC to the value obtained using the IEUBK model. The lead EPCs of 1380 mg/kg in soil zero to 2 ft bls and 561 mg/kg in soil zero to 10 ft bls exceed the IEUBK lead target value of 400 mg/kg; therefore, lead is a COC for this receptor at EU 2.

The COCs for soils in EU 2 for the resident farm child receptor are benzo(a)pyrene, benzo(b)fluoranthene, cadmium, lead, and beryllium. Manganese is the only COC for groundwater for this receptor All of the potential cancer risk for the resident farm child receptor is due to PAHs in soil which could be due to on-going industrial operations rather than AEC activities which took place approximately 50 years ago.

Summary of EU 2 COCs

The following is a summary of all COCs for EU 2 receptors.

Summary of EU 2 Non-Radiological COCs

Receptor/Media	COC
Current/Future Industrial Worker/ Surface Soils	Benzo(a)pyrene Lead
Future Resident Farmer- Adult/ Soil 0-2 ft bls	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Indeno(1,2,3-cd)pyrene Lead
Future Resident Farmer- Adult/ Soil 0-10 ft bls	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Indeno(1,2,3-cd)pyrene Lead

Summary of EU 2 Non-Radiological COCs

Receptor/Media	COC
Future Resident Farmer- Child/ Soil 0-2 ft bls	Benzo(a)pyrene Benzo(b)fluoranthene Beryllium Cadmium Lead
Future Resident Farmer- Child Soil 0-10 ft bls	Benzo(a)pyrene Benzo(b)fluoranthene Beryllium Lead
Future Resident Farmer- Child/ Groundwater	Manganese

Exposure Unit 3

Table 6.15 presents the summary of risk to RME exposures, and Table 6.21 summarizes the CT exposure risks for EU 3.

Future Resident Farmer Adult Scenario

The current and future resident farm adult scenario in EU 3 was assessed for exposure to soil zero to 2 ft bls and for soil zero to 10 ft bls. The RME HIs for the future resident adult farmer exposed to soil zero to 2 and zero to 10 ft bls did not exceed the total non-cancer risk goal of an HI of 1. However, the total HI for soil, groundwater, surface water, and sediment pathways was 1.4. Only the groundwater pathway exceeded the target HI of 1. The groundwater pathways contributed approximately 90% of the total HI with the ingestion pathway (HI=1.1) contributing 85% of risk to the total groundwater HI. Manganese, nickel, and total uranium presented 43%, 25%, and 21% to the total groundwater HI, respectively. The soil, sediment, and surface water exposure pathways did not significantly contribute to the total non-cancer risk. When considering total non-carcinogenic risk it is important to note that each of these metals produces affects in different target organs. For this scenario manganese, presents non-cancer risk at levels that could potentially have an impact as a neurotoxin affecting the central nervous system.

Since the RME HI for both soil intervals exceeded the non-cancer target risk level, an evaluation of non-cancer risk using CT exposure parameters was conducted for the resident farmer adult receptor. The total soil CT HI for the future resident adult farmer exposed to soil zero to 2 ft bls was 0.8. The total soil CT HI for the future resident adult farmer exposed to soil zero to 10 ft bls was 0.78. Neither of the CT HIs for soil exceeded the total non-cancer risk goal.

The total RME ILCR for the current and future resident adult farmer in EU 3 was 2.5×10^{-6} for both of the soil intervals that were evaluated. The sediment pathways contribute 83% of the total ILCR, yet only one compound in sediment exceeds the target ILCR goal of 1×10^{-6} and that was benzo(a)pyrene via dermal exposure. Benzo(a)pyrene represents 78% of the total sediment ILCR for the resident adult farmer in EU 3. The ingestion and inhalation pathways did not contribute significantly to risk for this receptor. The PAHs detected in sediments may have come from upstream sources or could be due to on-going industrial operations rather than AEC activities that took place approximately 50 years ago.

Since the RME ILCRs for the resident adult farmer in EU 3 exceeded the target ILCR of 1×10^{-6}, CT ILCRs were calculated for the resident farmer adult receptor for both of the soil intervals that were evaluated. The total CT ILCR for the resident adult farmer in EU 3 does not exceed the target cancer risk level.

The COCs for sediments in EU 3 for the resident farmer adult receptor are benzo(a)pyrene. There are no COCs found in soil, surface water, or groundwater for this receptor.

Future Resident Farmer Child Scenario

The current and future resident farmer child scenario was assessed for exposure to soil zero to 2 ft bls and for soil zero to 10 ft bls. The total RME HIs for the resident farm child was 4.4 for both soil intervals evaluated. The groundwater pathways exceeded the target HI of 1 and contributed 73% of the total HI value. Soil pathways contributed 23% and 21% of the non-cancer risk with HIs of 1 and 0.9 for the zero to 2 and zero to 10 ft soil intervals, respectively. In surface soil beryllium has an HI of 1and is the only COPC in soils. The sediment and surface water pathways presented little non-cancer risk. The groundwater ingestion pathway (HI=2.9) contributed 91% of the total groundwater HI. Manganese (HI=1.4) was the only COPC that exceeds the target HI of 1 and presented 44% of the total groundwater non-cancer risk.

Since the RME HI for the resident farmer child receptor exceeded the non-cancer target risk level, an evaluation of non-cancer risk using CT exposure parameters was conducted. The total CT HI for the resident farm child in EU 3 was 2, which exceeds the target non-cancer risk goal. The groundwater pathways (HI=1.6) contributed 79% of the total non-cancer risk for all pathways and media. Groundwater ingestion (HI=1.5) contributed 94% of risk to the total groundwater HI. No individual COPC exceeds the target HI of 1, but manganese, nickel, and uranium presented 44%, 25%, and 23%, respectively, of the total groundwater non-cancer risk. The soil, sediment, and surface water pathways did not significantly contribute to the total CT HI for the resident farmer child receptor.

The total RME ILCR for the current and future resident farm child in EU 3 was 1.1×10^{-6} for both soil intervals evaluated. No media presented cancer risks that exceed or approximate the target ILCR level. The largest cancer risk was posed by the sediment pathways with an ILCR of 7.7×10^{-7}. Sediment contributed 70% of the total ILCR for all media. No compounds in sediment exceeded or approximate the target ILCR goal of 1×10^{-6}.

Since the RME cancer risk values exceeded the target ILCR goal of 1×10^{-6}, CT cancer risk values were calculated for the resident farmer child receptor. The total CT ILCRs for the two soil intervals evaluated did not exceed the target cancer risk level of 1.0×10^{-6}.

Manganese is the only COC for groundwater for this receptor. Beryllium is a COC in surface soil and there are no COCs in sediment or surface water.

Summary of EU 3 COCs

The following is a summary of all COCs for EU 3 receptors.

Summary of EU 3 Non-Radiological COCs

Receptor/Media	COC
Future Resident Farmer- Adult/ Sediment	Benzo(a)pyrene
Future Resident Farmer- Child/ Groundwater	Manganese
Surface Soil	Beryllium

Exposure Unit 4

Table 6.16 presents the summary of risk to RME exposures, and Table 6.22 summarizes the CT exposure risks for EU 4.

Current and Future Adolescent Trespasser

The current and future adolescent trespasser was evaluated for exposure to soil zero to 2 ft bls. For the current and future RME scenario, the total non-cancer risk goal was not exceeded for the adolescent receptor. The total non-cancer HI for exposure to surface soil, surface water and sediment was 0.072, which does not exceed the target risk threshold of one.

The total RME ILCR for the current and future adolescent trespasser scenario was 1.4×10^{-6}. The sediment dermal pathway contributed 91% of the total ILCR. Benzo(a)pyrene was the only compound to exceed the target ILCR goal of 1×10^{-6} and represented 79% of the total ILCR from sediment exposure. No COPCs exceeded the target ILCR goal of 1×10^{-6} via the sediment ingestion pathway. Cancer risk did not exceed 1×10^{-6} for either surface soil or surface water exposure pathways. Most of the potential cancer risk for an adolescent trespasser receptor is due to PAHs in sediment which could have come from an upstream source such as roadways or bridges or be due to on-going industrial operations rather than AEC activities which took place approximately 50 years ago.

Since the RME ILCR exceeded the target ILCR goal of 1×10^{-6}, CT ILCRs were calculated for the adolescent trespasser. The ILCR for all pathways for the CT scenario was 1.7×10^{-7}, which does not exceed the target ILCR goal of 1×10^{-6}.

The COC for EU 4 are found in sediments and include benzo(a)pyrene. No soil or surface water COCs were identified for the adolescent trespasser. All non-radiological human health COCs that have been identified are presented in Table 6.23 for the RME scenarios and in Table 6.24 and for the CT scenarios.

Summary of EU 4 COCs

The following is a summary of all COCs for EU 4.

Summary of EU 4 Non-Radiological COCs

Receptor/Media	COC
Current/Future adolescent Trespasser/ Sediment	Benzo(a)pyrene

Exposure Unit 5

Table 6.17 presents the summary of risk to RME exposures for EU 5. Since no carcinogenic COPCs were identified in EU 5 cumulative carcinogenic risk was not calculated.

Current and Future Adolescent Trespasser

The current and future adolescent trespasser was evaluated for exposure to soil zero to 2 ft bls. For the current and future adolescent trespasser scenario, the target total RME HI of 1 and the target total RME ILCR of 1×10^{-6} was not exceeded in any media. The total RME HI for the adolescent trespasser in EU 5 was 0.00016. Since none of the COPCs identified for EU 5 have cancer slope factors, the ILCR for

this receptor was zero. No soil or surface water COCs were identified for the adolescent trespasser at EU 5.

Exposure Unit 6

Table 6.18 presents the summary of risk to RME exposures for EU 6.

Current and Future Adolescent Trespasser

The current and future adolescent trespasser was evaluated for exposure to soil zero to 2 ft bls. No COPCs were identified in soils in EU 6,; therefore, no risk calculations were conducted for the adolescent trespasser and no COCs were identified.

6.6 UNCERTAINTY ASSESSMENT

Risk values calculated in a HHRA are not fully probabilistic estimates of risk, but are conditional estimates given a considerable number of conservative assumptions about exposure and toxicity. Therefore, there are many uncertainties inherent in the risk assessment evaluations. Uncertainty will always surround estimates of environmental concentrations at waste sites. The objective is to understand, minimize, and quantify this uncertainty in the risk assessment. There are uncertainties with the exposure assessment, the toxicity information used in the risk assessment, and the risk characterization.

6.6.1 Uncertainty Related to Environmental Data

Uncertainty is associated with the process of data collection, analysis, and evaluation. The characterization of data from waste sites presents considerable uncertainty due to variation in wastes, environmental media, and time. Characterization of surface water and sediment is especially difficult due to impacts from other discharges in the area and the variability of flow in the drainage ditches.

The sampling program at the Luckey site was designed to minimize the potential to underestimate exposure point concentrations. Background levels were established using data collected from locations on or near the site. Background was established to distinguish between naturally occurring or ubiquitous anthropogenic chemicals found near the site from chemicals associated with past waste activities at the areas under investigation. Up-gradient and down-gradient surface water and sediment samples were collected in order to characterize chemicals associated with the units.

The Luckey data set does include TICs, however, they do not appear to dominate the data set in any location or media.

Uncertainty is minimized in the analysis of the data by adhering to strict QA/QC standards both in the field and in the laboratory. The uncertainty associated with the statistical analysis of environmental data is low, with little introduction of bias.

6.6.2 Uncertainty in Exposure Assessment

Exposure assessment may introduce considerable uncertainty in the risk assessment process. Uncertainty in all elements of the exposure assessment are brought together and compounded in the estimate of intake or dose. The professional judgment of the risk assessor becomes particularly important. The risk assessor must examine and interpret diverse information, including the nature, extent, and magnitude of contamination; transport of chemicals in the environment; identification of exposure

routes; identification of receptor groups currently at risk and potentially at risk in the future; and activity patterns of receptors and receptor groups.

The following types of uncertainty have been identified in the exposure assessment:

- Scenario Uncertainty--missing or incomplete information needed to define the exposure scenario or pathway;
- Model Uncertainty--inability to quantify all assumptions in model variables; and
- Parameter Uncertainty--inadequate information to quantify an exposure variable or parameter.

Receptors for the EUs at the Luckey site were defined based on information provided by the facility and on-site observations. Site-specific information for the EUs was used to develop exposure assumptions and intake parameters, if available. However, many assumptions were based on EPA standard default parameters. Many of the RME exposure parameters represent 90th to 95th percentile values. When several upper bound values are combined in estimating exposure for any one pathway, resulting risk estimates may well be in excess of the 99th percentile exposure and thereby be outside the range of exposures that might reasonably be expected to occur at a site. Therefore, resulting risks calculations are conservative and most likely overestimate the actual exposures that may be associated with the site. The CT scenario was provided to account for this overestimation. CT parameters represent 50th percentile values and more closely represents typical or average exposures.

The risk assessment treats each exposure parameter as a single point estimate. None of these parameters, however, is truly a single value. Instead, a range of values or distribution would more accurately represent these parameters. Defining a range of values for any given parameter is actually a measure of variability in the risk assessment. Quantitative uncertainty analysis allows one to measure this variability, but poses difficulties because of the quantity and quality of data available.

For quantification of potential risk presented through dermal exposure to soil two exposure factors contribute significantly to uncertainty; the soil-to-skin adherence factor and the dermal absorption efficiency. Soil-to-skin adherence factors impact the estimated intake from dermal exposure to contaminated soil, however, there are limited studies that address this issue. Soil-to-skin adherence factors are influenced by soil properties (e.g. particle size, moisture contact), the part of the body exposed and activities the person is engaged in. The adherence factors used in the HHRA are based on EPA guidance (EPA 1997a) and have been updated from those presented in the TM. The RME dermal adherence factors are 95th percentile values while the CT dermal adherence factors are 50th percentile values. These factors are presented in Tables 6.8 through 6.11.

Another area of uncertainty concerning quantification of potential risk presented through dermal exposure to soil is the fraction of a constituent in soil that is actually absorbed through the skin or the dermal absorption factor. Here again limited compound specific information is available. Compound specific dermal absorption factors were taken from the soon to be release guidance from EPA (Appendix 6C). Of the COPCs identified for the Luckey site, compound-specific dermal absorption factors are available for cadmium, benzo(a)pyrene and other PAHs, aroclor-1254, and SVOCs. Quantification of potential risk presented through dermal exposure to soil for compounds lacking dermal absorption factors was not possible

6.6.3 Uncertainties Related to Toxicity Information

Although EPA provides toxicity values that are point estimates, a significant amount of uncertainty may surround these point estimates. Identification of the sources of this uncertainty enables the risk assessor to establish the degree of confidence associated with the toxicity measures.

Uncertainty is inherent within the toxicity assessment and is primarily due to differences in study design, species, sex, routes of exposure, or dose-response relationships. A major source of uncertainty involves using toxicity values based on experimental studies that substantially differ from typical human exposure scenarios. The derivation of the toxicity values must consider differences such as (1) using dose-response information from animal studies to predict effects in humans, (2) using dose-response information from high-dose studies to predict adverse health effects at low doses, (3) using data from short-term studies to predict chronic effects, and (4) extrapolating from specific homogeneous populations to general heterogeneous populations.

The CSFs in particular are based on studies that may differ greatly from realistic situations. Experimental cancer bioassays typically expose animals to very high levels of chemicals (i.e., the maximum tolerated dose) for their entire lifetime. After the appropriate studies have been identified, the slope factor is calculated as the upper 95th percent confidence limit of the slope of the dose-response curve. This introduces conservatism into the risk assessment. The derivation of reference doses generally involves the use of animal studies. Uncertainty factors ranging from 1 to 10,000 are incorporated into the reference dose to provide an extra level of public health protection. The factors used depend on the type of study from which the value has been derived (e.g., animal or human, chronic or acute). The scientific basis for this practice is somewhat uncertain. In general, high uncertainty factors are meant to bias the results conservatively so that exposures at the reference dose level will not result in adverse health effects.

Route-to-route extrapolation can be used to estimate toxicity values for pathways that lack toxicity values. For example, a chemical-specific gastrointestinal absorption factor may be used to convert an oral administered dose to a dermal adsorbed dose. However, for many chemicals scientifically defensible data does not exist for making adjustment of an oral slope factor/RfD to estimate a dermal toxicity value. For quantification of potential risk due to dermal exposure to contaminants in soil oral slope factors/RfDs were adjusted using gastrointestinal absorption efficiencies drawn from the soon to be released EPA guidance (Appendix 6C). When compound-specific gastrointestinal absorption factors where greater than 50 percent, oral slope factors and RfDs were not adjusted. Of the COPCs identified for soil at the Luckey site, compound-specific gastrointestinal absorption efficiencies are available for various metals (beryllium, cadmium, chromium, manganese, mercury, nickel, thallium, and zinc, see Table 6.12), aroclor-1254, benzo(a)pyrene and other PAHs, and other organic compounds. Quantification of the dermal pathway was only performed for constituents with EPA recommended gastrointestinal absorption efficiencies and dermal absorption factors. The uncertainty associated with using the absorbed dose toxicity values for the dermal pathway is moderate and the bias unknown.

The use of estimated or calculated dermal CSFs poses great uncertainty in the Luckey HHRA. Cadmium and beryllium were found to pose risk to humans by the dermal pathway. The most likely and expected pathways for cadmium and beryllium toxicity are first by inhalation and second by ingestion. Neither of these pathways posed any risk to human receptors. The calculation of dermal CSFs from oral CSFs and the use of default GI absorption factors greatly contribute to the uncertainty in the conservative dermal results for these two constituents.

There are many chemicals for which no toxicity values exist and for which little information is available. Therefore, a quantitative risk estimate cannot be calculated for these chemicals. For example, many chemicals are not evaluated for the inhalation pathway because of limited inhalation-based toxicological information. The lack of toxicity information for some chemicals contributes to the underestimation of risks.

Two COPCs at the Luckey site, 2-hexanone and phosphorus, have no approved toxicity criteria for any pathway; therefore no quantitative risk estimates were calculated. Phosphorus is an essential element in many chemicals necessary for human life (e.g., it is a component of DNA). At the

concentrations detected in Luckey Site EUs, phosphorus is not expected to pose any risk to human health. The VOC 2-hexanone was only detected once (9.9 ug/kg in surface soil at the France Stone Quarry). The low concentration and apparent limited distribution of 2-hexanone indicates that the compound poses little risk to human health.

Cancer and non-cancer risks are summed in the risk characterization process (separately for carcinogens and non-carcinogens) to estimate potential risks associated with the simultaneous exposure to multiple chemicals. For carcinogens, this results in giving class B or class C carcinogens the same weight as class A carcinogens. It also equally weights slope factors derived from animal data with those derived from human data. Uncertainties in the combined risks also are compounded because RfDs and CSFs do not have equal accuracy or levels of confidence and are not based on the same severity of effect.

6.6.4 Uncertainties in Risk Characterization

Uncertainties in any phase of the risk analysis are reflected in the risk estimates. Some uncertainty is associated with the summation of risks and HQs for multiple chemical contaminants. As stated in RAGS (EPA 1989b), "The assumption of dose additivity ignores possible synergisms or antagonisms among chemicals, and assumes similarity in mechanisms of action and metabolism." However, summing cancer risks and HQs for multiple substances in the risk assessment provides a conservative estimate.

6.6.5 Non-Radiological Human Health Risk Assessment Summary and Identification of Constituents of Concern

The results of the risk characterization for non-radiological constituents for the Luckey site indicate there is risk to human receptors for the COCs as identified in Table 6.23 for the RME scenario. COCs have been identified as those COPCs that exceed an acceptable cancer risk criteria of 1×10^{-6} or non-cancer risk criteria (HI) of 1 for each receptor and pathway. COCs are specific to EUs, media and receptors, and include the following; aroclor-1254, PAHs, beryllium, and manganese. Lead also was identified as a COC by comparing EPC to using the IEUBK and the TRW Waste Group models for receptors at EU 2. Of these constituents, beryllium is the only COC that can be attributed solely to AEC operations at the site. PAHs are ubiquitous in industrial settings and near roadways. EPA Region 4 has concluded: " As a matter of definition of a release under CERCLA 101(22), to which CERCLA 104 gives authority to respond, as well as a common sense issue, that an exemption to PAHs adjacent to roads exist in the CERCLA program" (USAF 2000). Additionally, it is difficult to determine the contribution of PAH contamination from AEC processes or practices after AEC operations. These constituents represent the main non-radiological contributors to human health risks at the site that will need to be addressed during remedial action. The following is a list of COCs for each exposure unit and the associated media for the RME scenario.

List of Non-Radiological COCs at Luckey Site

Exposure Unit/Media	COC
EU 1/Soils	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenz(a,h)anthracene Indeno(1,2,3-cd)pyrene Aroclor-1254
EU 2/Soils	Benzo(a)anthracene Benzo(a)pyrene

List of Non-Radiological COCs at Luckey Site

Exposure Unit/Media	COC
	Benzo(b)fluoranthene Indeno(1,2,3-cd)pyrene Beryllium Cadmium (surface soil only) Lead
EU 3/Soil (surface)	Beryllium
EU 3/Sediments	Benzo(a)pyrene
EU 3/Surface Water	None
EUs 1, 2, and 3/Groundwater	Manganese
EU 4/Sediment	Benzo(a)pyrene

6.6.6 Revised Risk-Based Concentrations

Site-specific RBCs have been developed for COCs based on the exposure assumptions and pathways of concern identified in the HHRA. The RBCs for the COCs have been developed based on the guidance set forth in RAGS, Volume I, Human Health Evaluation Manual -Part B (EPA. 1991b). RBCs for non-radiological COCs are presented in the summary tables for the RME scenario in Table 6.23 and for the CT scenario in Table 6.24.

6.7 HHRA FOR RADIOLOGICAL CONTAMINATION

Risk calculation methods for both radiological and non-radiological constituents follow guidance provided by RAGS, but some adjustments are required for radionuclides. EPA Region 9 risk-based screening levels for radiological constituents are not available, and background concentrations of site-related radiological constituents typically produce risks on the order of 10^{-4} (RAGS Part B). Therefore, radionuclides underwent a background subtraction screen and a weight-of-evidence screen, but not a risk screen, to identify COPCs for the Luckey BRA. Because cleanup of radiological contamination is often driven by an ARAR rather than carcinogenic risk, action levels for all relevant media are provided for risk-based, radiological dose-based, and concentration-based endpoints.

The HHRA for radiological contaminants in soil and sediment was conducted by utilizing the RESRAD computer code Version 5.82 as discussed in the TM. While estimating radiological risks with RESRAD uses methods consistent with those presented in the RAGS, the code presents several advantages over standard RAGS methods, including the following:

- RESRAD models future conditions, taking into account source removal by radiological decay, leaching, erosion, etc., and radiological in-growth;
- RESRAD considers site-specific variables, such as rainfall, soil density, etc., that may impact results;
- RESRAD considers source geometry, taking into account the thickness and surface area of soil contamination;
- RESRAD is an integrated code that accounts for all potential exposure pathways with a single calculation or “run”; and
- RESRAD provides both carcinogenic risk and radiological dose estimates for comparison to appropriate regulatory limits.

Except for these differences, the RESRAD calculations parallel the HHRA for non-radiological constituents. The same exposure parameters are utilized (units may vary), similar exposure pathways are

considered (external gamma exposure replaces dermal contact), and the same exposure scenarios are evaluated.

For groundwater and surface water, equations similar to those presented in RAGS were used to estimate risk from ingestion. RESRAD does contain a model that estimates the risks from radionuclides leaching into groundwater from soil; however, the model was not used as it is considered overly conservative, generic, and highly uncertain.

The methodology for evaluating risk from radiological constituents in all media presented in this HHRA is organized as follows:

- Section 6.7.1 provides the criteria that were used to evaluate and screen the Luckey site data and determine the radiological COPCs that were evaluated in the HHRA;
- Section 6.7.2 defines land use assumptions and receptors that were evaluated in the HHRA;
- Section 6.7.3 presents the methodology and guidance that were used to perform the radiological toxicity assessment;
- Section 6.7.4 presents the methodology that was used to conduct the risk characterization for radiological constituents;
- Section 6.7.5 outlines the criteria and guidance that were used to evaluate the uncertainties associated with the radiological HHRA;
- Section 6.7.6 identifies COCs; and
- Section 6.7.7 develops action levels for the Luckey site.

Background screens and risk calculations for each pathway, medium, and EU are presented in Appendix 6B.

Note that while the HHRA focuses on risk-based criteria, it is conceivable that radiological dose-based limits may be selected for the site. The two primary differences in risk and dose estimates include the following:

1) Risks are presented as lifetime estimates while doses are yearly estimates; and
2) Cancer slope factors (CSFs) convert an exposure to risk (e.g., risk per pCi uptake), while dose factors convert an exposure to radiological dose (e.g., mrem/yr per pCi uptake).

Otherwise, risk and dose calculations are identical. The RESRAD code simultaneously calculates risk and dose for comparison against appropriate limits.

All radionuclides are identified as carcinogens. Some radionuclides like uranium, however, are also known to have non-carcinogenic hazardous properties when ingested or inhaled (e.g., uranium is a kidney toxin independent of radiological characteristics). The focus of Section 6.7 is to assess baseline risk and present action levels for radionuclides based on their carcinogenic properties only. The assessment of non-carcinogenic properties is found in the previous sections of the HHRA for non-radiological constituents.

The characterization of site buildings has identified elevated levels of radioactivity on various surfaces. RAGS does not provide guidance to address this type of contamination. So as not to overlook potential exposure to building contamination, the RESRAD-BUILD computer code Version 2.36 was used as an approach to identify COCs, if any. The RESRAD-BUILD code estimates radiological dose only. COCs will be identified as those radionuclides that exceed specified radiological dose criteria (based on potential ARARs).

6.7.1 Identification of Human Health Radiological Constituents of Potential Concern (COPCs)

Data that were collected, verified, and validated according to the QAPP were used to determine human health risks at the Luckey site. Data were reviewed and screened to identify site-related radionuclides. The following subsections summarize the process through which the data were reviewed and subjected to background and weight-of-evidence screens.

6.7.1.1 Initial Data Reduction

Potential radiological constituents at the Luckey site are members of the naturally occurring uranium, thorium, and actinium decay series, as shown in Figures 6.8, 6.9, and 6.10. Because CSFs are limited to radionuclides with half-lives of six months or longer, the primary list of potential radiological constituents includes only the long-lived radionuclides in these series (short-lived decay products are included in slope factors for long-lived radionuclides so that they need not be included separately.) The list of long-lived radionuclides includes U-238, U-234, Th-230, Ra-226 and Pb-210 from the uranium series; Th-232, Ra-228 and Th-228 from the thorium series; and U-235, Pa-231 and Ac-227 from the actinium series. (Because no results were available for soil and sediment, Pb-210 was assumed to be in equilibrium with Ra-226, its closest long-lived parent.)

The site database includes results obtained through different analytical methods, sometimes producing multiple entries for a single sample and radionuclide (e.g., four methods are reported for Phase II Ra-226 results). Because of the multiple analytical methods and the established relationships between radionuclides in decay series, all data should not be used at face value in risk calculations. Instead, a series of tests was performed to refine the data set used in the risk calculations so that each sample contained a single result for each radionuclide. Site data were refined using the criteria presented in Table 6.25 and as described below:

- Many samples were analyzed by both alpha spectrometry and gamma spectrometry. Because the detection limits and analytical errors are lower for alpha spectrometry, this method was used preferentially to estimate the source term.
- In-situ gamma spectrometry results are not used because very high detection limits are reported as non-detects that would bias the source term high.
- Results for parent radionuclides are sometimes reported in addition to results for short-lived decay products. Often the parent/decay product results are presented separately although the values are identical, or the wrong method was listed for a decay product. To eliminate this duplication and/or mislabeling, the parent radionuclide result was always used and equilibrium conditions were assumed.
- Results with no listed method were not included in calculations.

Bolded-italicized text in Table 6.25 shows the methods used to produce data summaries for screens and risk calculations. This approach simplified the source term calculation process by eliminating extraneous information and improved the overall quality of the data set used in risk calculations.

Site data were refined using the criteria presented in Table 6.25. In general, alpha spectrometry is preferred over gamma spectrometry, in-situ gamma results are not used (because they produce very high non-detects and biased results), and short-lived decay products are assumed to be in equilibrium with their closest long-lived parent. Bolded-italicized text in Table 6.25 shows the methods used to produce data summaries for screens and risk calculations.

6.7.1.2 Background Screening

Risk-based screening levels for Luckey radionuclides are not available for EPA Region 9, and background concentrations of these radionuclides typically produce risks on the order of 10^{-4}. Therefore, radionuclides underwent a background subtraction screen but not a risk screen to identify COPCs. This background screen consisted of comparing the maximum detected radionuclide against background criteria. If the maximum detected concentration was below background criteria, the radionuclide was not considered a COPC. However, if the radionuclide was present at concentrations above background criteria, that radionuclide was retained as a COPC, depending on the results of the weight-of-evidence screen. For this assessment, the background criterion was the 95% UTL on background concentrations. Table 6.26 lists by medium the radionuclides identified above the background UTL. Note that background data were not available for some radionuclides.

Although elevated scan results were identified in site buildings, little radionuclide-specific data are available. Only five samples were submitted for laboratory analysis. The results from these samples are provided in Table 6.27. These results show elevated levels of Ra-226, Th-230, and uranium isotopes consistent with findings in soil. Given there are no background data for building material, Ra-226, Th-230, uranium isotopes may be selected as qualitative COPCs for building media.

6.7.1.3 Weight-of-Evidence Screening

The weight-of-evidence screening for radionuclides was similar to the weight-of-evidence screening for non-radionuclides as described in Section 6.2.3. A review of the site database reveals that of the 17 radionuclides identified, only the 11 long-lived members of the uranium, thorium, and actinium series may be tied to site activities. Specifically, results for Am-241, Co-60, Cs-137, K-40, U-233, and U-236 are identified with no link to site activities. Of the laboratory results, Am-241 and Co-60 were never found above detection limits and were eliminated from the list of COPCs. Of the 171 Cs-137 results reported above detection limits, only 5 results exceed the UTL of 0.72 pCi/g, with a maximum result of 1.34 pCi/g. Because less than five percent of the results are above the UTL, Cs-137 was eliminated from the list of COPCs. Of the approximately 700 results for K-40, less than 5% are above the UTL of 27.2 pCi/g with a maximum concentration of 31.3 pCi/g. Additionally, K-40 was eliminated from the list of COPCs given that no sample deviates significantly from the background distribution. Some uranium isotopes were reported together: U-233/U-234 and U-235/U-236. Fissile materials/wastes are not part of the site's history, and radionuclides characteristic of the fission reaction have not been found at the site. Therefore, all U-233/U-234 data are interpreted as U-234 only, and U-235/U-236 data are interpreted as U-235 only. If a background screening value was not available, the radionuclide was retained as a CPOC depending on the result of the weight-of-evidence screening.

Table 6.26 shows that no background or PRG screening values is available for thorium series radionuclides in surface water and groundwater. These radionuclides were eliminated as surface water and groundwater COPCs for the following reasons:

- thorium series radionuclides were eliminated in the soil and sediment background screens;
- thorium series radionuclides are minor constituents in site waste;
- thorium leaches at a very slow rate; and
- thorium series radionuclides were rarely detected in water media.

U-235 is retained as a surface water COPC even though no background UTL is available, as U-235 is a COPC for sediment. Protactinium-231 is conservatively retained as a soil and sediment COPC even though background UTL values are not available.

Having eliminated some of the extraneous radionuclides, the list of COPCs for the Luckey site is presented in Table 6.28. This list includes only members of the uranium, thorium, and actinium decay series as expected based on site process history. UTL screening values for COPCs are presented in Tables 6B.1 through 6B.6 in Appendix 6B.

6.7.2 Exposure Assessment

The exposure assessment for radionuclides was performed in two steps. The first step was to identify any potential complete pathways between the constituent source and potential receptors. This is accomplished by identifying the following:

- potential current and future on-site and off-site receptors;
- media through which contamination may come in contact with the receptors, including building surfaces, soils, groundwater, sediment, surface water; and air; and
- routes of exposure or pathways through which the receptors may be exposed (i.e., ingestion, external gamma, and inhalation).

A detailed discussion of the exposure units and potential receptors appears in Section 6.3. The same exposure units were used for radiological and non-radiological constituents. Section 6.7.2.2 presents the exposure pathways to be evaluated in the radiological HHRA.

The second step was to quantify the exposure concentration for each COPC in each contaminated medium. Both the RME and the CT exposures were evaluated in the HHRA. In order to quantify exposure for each receptor, an exposure point concentration was estimated (i.e., a high-end estimate of the radionuclide concentration a receptor is likely to come in contact with over the duration of exposure). Exposure point concentrations were estimated by subtracting the radionuclide-specific background UTLs from the radionuclide-specific 95% UCL estimates from each exposure unit. Appendix 6B Tables 6B.1 through 6B.6 present EPC calculations for all exposure units and media.

Once the EPCs were developed, the risk from exposure to contaminated media was quantified. Section 6.3 presents the general equations that were used to quantify exposure to contaminated media at the Luckey site. RESRAD and RESRAD-BUILD codes were used to perform calculations for radionuclides in soil, sediment, and building materials. Equations similar to those found in RAGS were used to estimate the risk from ingestion of surface water and groundwater, as described in Section 6.3.3. A general discussion on site data may be found in Section 4.

6.7.2.1 Characterization of Potentially Exposed Populations

Section 6.3 provides a detailed discussion of the EUs and potential receptors at the Luckey site. Because that discussion applies to both radiological and non-radiological constituents, it is not repeated here. The following sections focus on the radiological exposure pathways for the receptors that were not identified in Section 6.3.

6.7.2.2 Identification of Exposure Pathways

The process for identifying exposure pathways is similar for radionuclides and non-radionuclides, as described in Section 6.3. There are, however, four significant differences. First, radon is a radioactive noble gas that tends to accumulate in enclosed structures. The radiological HHRA qualitatively addresses the potential for exposure to indoor radon. Radon limits are based on concentration and not risk or dose. This difference is due partly to the fact that background radon concentrations are highly variable, typically producing risk estimates well above the CERCLA target risk range. In fact, EPA has stated in

Model Standards and Techniques for Control in New Residential Buildings that "indoor radon levels for any given building cannot be (accurately) predicted due to different site and environmental conditions, building design, construction practices, and variations in the operation of buildings." USACE does not attempt to calculate indoor radon levels that may grossly overestimate or underestimate current or future conditions, but rather presumes that radon will be controlled per the selected ARAR(s) and remedial alternative by controlling the concentration of Ra-226 in soil. Second, dermal slope factors are not available for the radiological constituents at the Luckey site. Thus, the dermal contact pathway is not evaluated. Third, external exposure to radionuclides that emit gamma radiation or x-rays must be considered. This external exposure pathway accounts for radionuclides that may produce a risk without direct physical contact with the contaminant. Finally, radionuclides have been identified in site buildings. Radio-analytical data were evaluated using the RESRAD-BUILD model for comparison to potential dose-based limits (driven by ARARs). The pathways are the same for the building occupants as the industrial worker's exposure to soil (the building occupant is assumed to be an industrial worker). However, the approach for estimating exposure is significantly different.

6.7.2.3 Quantification of Exposure Concentration and Pathway-Specific Intakes

The method for calculating the exposure point concentration is similar for radiological and non-radiological constituents. This method is described in Section 6.3, and is not repeated here.

Pathway-specific intakes and exposure to soil and sediment are estimated by the RESRAD code as outlined by Argonne National Laboratories [(ANL) 1993 and ANL 1998]. In general, the RESRAD code uses the same equations listed in Section 6.3. Exceptions include units for constituent concentration (e.g., pCi/g instead of mg/kg), the addition of the external radiation pathway, and the exclusion of the dermal contact pathway. The radon pathway also may be modeled by the RESRAD code. However, risk from exposure to radon was not estimated given the large uncertainty of the model and the fact that guidelines for exposure to radon are not based on risk or dose. Pathway-specific intakes and exposures to sources on building surfaces are estimated using the RESRAD-BUILD code outlined in ANL 1994.

Specific parameter values are presented in Table 6.29. The RESRAD and RESRAD-BUILD codes also require inputs that describe the physical characteristics of the contaminated media. Certain site-specific data such as evapotranspiration coefficients and air exchange rates are limited. Site-specific parameter values were used when available. The preference was to use site-specific data first, use values recommended or otherwise employed by EPA second, and use RESRAD or RESRAD-BUILD defaults last.

For surface water and groundwater, intakes were estimated using equations similar to those found in RAGS and using the parameter values listed in Table 6.29. Intake (in pCi of radionuclide) was calculated as follows:

Surface Water Intake

Intake (pCi of radionuclide "i") = $C_i \times IR \times ET \times EF \times ED$

where:

C_i = net concentration of radionuclide "i" in surface water (pCi/L);
IR = ingestion rate (L/hour);
ET = exposure time (hours/day);
EF = exposure frequency (days/year); and
ED = exposure duration (years).

Groundwater Intake

Intake (pCi of radionuclide "i") = $C_i \times IR \times EF \times ED$

where:

C_i = net concentration of radionuclide "i" in groundwater (pCi/L);
IR = ingestion rate (L/day);
EF = exposure frequency (days/year); and
ED = exposure duration (years).

Net concentrations are estimated by taking the 95% UCL value minus average background. Radionuclide intake results are presented in Appendix 6B Table 6B.5 for surface water and Appendix 6B Table 6B.6 for groundwater.

6.7.3 Toxicity Assessment

With the exception of uranium, the toxicity criteria for radionuclides are limited to carcinogenic risk. That is, only uranium is considered as both a carcinogenic and non-carcinogenic hazard. To estimate radiological risk, the RESRAD code utilizes HEAST CSF values. These slope factors are presented in units of risk per pCi (internal pathways) or risk per year per pCi/g (external pathway).

A CSF for a radionuclide is defined differently than a CSF for a non-radiological constituent. EPA outlines these differences in *Radiation Exposure and Risk Assessment Manual* (EPA 1996a). Major differences include the following:

- the radiological endpoint is fatal cancer – the constituent endpoint is tumorigenic cancer;
- radiological risk estimates are based primarily on human data – constituent risk estimates are based primarily on animal studies; and
- radiological risk estimates are based on the central estimate of the mean – constituent risk estimates are based on 95% UCL of the mean.

Additional considerations include the fact that exposure point concentrations for radionuclides and non-radionuclides are specific to distinct models incorporating different assumptions; RAGS cautions against combining radiological and non-radiological risks. Given these differences, risk from non-radionuclides and radionuclides were assessed and presented separately. In addition, natural background radiation is ubiquitous at levels exceeding typical EPA risk targets, and natural variability may preclude the ability to quantify small incremental risks due to contamination (EPA 1996a). Consideration will, therefore, be given to risk-based and dose-based cleanup goals, as performed by EPA for sites with similar radiological constituents.

RESRAD codes utilize conversion factors from EPA Federal Guidance Reports 11 and 12 (EPA 1993b) to estimate radiological dose. These factors are presented in units of mrem per pCi (internal pathways) or mrem per year per pCi/g (external pathway).

6.7.4 Risk Characterization

Risk characterization integrates the findings of the exposure assessment and toxicity assessment to estimate the likelihood that a receptor will experience cancer as a result of exposure to radiological COPCs. Risks were calculated from toxicity information and the results of the exposure assessment. Total risk refers to risk associated with all radiological COPCs in an exposure unit. Site-related risk refers to the risk associated with the COPCs as a result of site-related activity. Contributions from

background are not included in these evaluations. Specifically, when the gross EPC was larger than the background UTL, average background was subtracted producing a net EPC. Otherwise the net EPC was assumed to be zero. The ILCR was calculated and compared to the range specified in the NCP (EPA 1990) of 10^{-6} to 10^{-4}, or one in 1 million to a few in 10,000 persons developing a fatal cancer. The RESRAD code provides estimates of ILCR by radionuclide and pathway. Radiological dose estimates in mrem/yr also are provided for building media for comparison against dose-based goals. Otherwise, the risk characterization follows the approach outlined in Section 6.5.

For soil and sediment, risk was estimated using the parameter values listed in Table 6.29 and the RESAD code Version 5.82. Because there is a mixture of radionuclides in the site data, risk estimates were calculated covering a 1,000-year period. The maximum risk over this period was then selected for comparison to risk criteria. Appendix 6B Tables 6B.1 through 6B.6 present the risk calculation for each receptor and pathway. Table 6.30 summarizes total radionuclide risk results for exposure to soil and sediment. Table 6.30 also lists total risk results for surface water and groundwater. Risks from ingestion of surface water and groundwater were estimated by multiplying the intake estimates by the appropriate ingestion slope factors. Risk calculations are presented in Appendix 6B Table 6B.5 for surface water and 6B.6 for groundwater.

The total radiological risk results indicate that the resident farmer adult and child could receive a risk greater than 10^{-4} in EUs 1, 2 and 3 but only for exposure to soils. Risks from exposure to soils from zero to 2 ft and from zero to 10 ft would exceed 10^{-4} under both RME and CT conditions only in EUs 1 and 2. CT risks from exposure to soils are less than 10^{-4} in EU 3 using either depth interval. Review of risk calculations in Appendix 6B shows that the external gamma pathway drives risks from exposure to soil. Therefore, the adjustment of soil ingestion rates from RME to CT conditions has little impact on total risk. The only relevant adjustment is the reduction of the adult exposure duration from 30 years to 9 years, effectively lowering the CT risk estimate to 30 percent of the RME value. No adjustment is made between RME and CT exposure duration values for the child; therefore, the RME and CT risks are the same value within a few significant digits (only two digits are shown).

For radionuclides in buildings, a dose characterization was performed using the RESRAD-BUILD model, the parameter values listed in Table 6.29**,** and the sample results from LUBM0068 in Table 6.27. Sample LUBM0068 was selected as the sample containing the highest radionuclide concentrations to produce a conservative dose estimate. Results indicate that the total dose is approximately 1.5 mrem/yr (not including radon) with approximately 100% coming from Ra-226 and the external gamma pathway. These relatively low results are likely due to the fact that only small (less than 1 m^2) and sparsely distributed areas of elevated activity were identified in site buildings.

6.7.5 Uncertainty Assessment

The same uncertainties that apply to non-radiological constituents (as discussed in Section 6.6) also apply to radiological constituents. However, there are uncertainties that are unique to radionuclides including the following:

- Data for some radioactive decay products within a decay series may not be available. For example, Pb-210 data is not available, although other radionuclides in the uranium decay series have been identified. The assessment assumes Pb-210 is in equilibrium with the nearest long-lived parent, Ra-226. Otherwise risk would be underestimated.

- Most building data are not radionuclide-specific. If a surface measurement is reported in cpms of alpha radiation, the assessor has made assumptions about the source of the radiation. Only five radio-analytical results were available for dose calculations.

- The risk from gamma radiation is dependent on the source surface area and thickness. Slope factors for external gamma radiation assume that the source is a semi-infinite slab. This geometry may over represent actual conditions resulting in an overestimate of risk.

These examples address some of the uncertainties associated with a HHRA for radionuclides. While care was taken to assure that risk assessment results are conservative (i.e., tend to overestimate actual conditions), the methods used to address uncertainties may significantly impact results.

6.7.6 Identification of Radiological Constituents of Concern

COCs are conservatively identified as those individual radionuclides that contribute a single-pathway risk greater than 10^{-6}, even if the total radiological risk for a particular receptor and medium is less than 10^{-4}. Six radionuclides (Pa-231, Ra-226, Th-230, U-234, U-235, and U-238) are identified as radiological COCs for the Luckey site. Only residential farmer scenarios produced risk estimates in excess of 10^{-4}, although Ra-226 and U-238 produce an estimated industrial worker radiological risk in excess of 10^{-6}. COCs are identified for soil, sediment, and groundwater only, as no radionuclide from the surface water pathway produced an estimated risk in excess of 10^{-6}. Due to the uncertainty associated with the minimal building data, no radiological COCs have been identified for buildings, although Ra-226, Th-230, and uranium isotopes have been identified at significantly elevated concentrations. Radiological COCs for the Luckey site are listed by medium in Table 6.31.

6.7.7 Action Level Update

Action levels were derived for soil, sediment, and groundwater considering risk-based, dose-based, and concentration-based endpoints. The concentration corresponding to the risk endpoint of $1x10^{-6}$ (the point of departure) using site-specific parameters is presented to replace the generic PRG derived using RAGS defaults. These site-specific radiological "threshold" concentrations are listed in Table 6.32 and may be selected as action levels for the Luckey site.

Action levels also may be selected as dose-based or concentration-based as required by ARARs. The following three potential ARARs were considered in this assessment:

1) 40 CFR Part 192: *Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings* (Subparts A, B, and C may be relevant and appropriate);
2) 10 CFR Part 20, *Standards for Protection Against Radiation* (Subpart E may be relevant and appropriate); and
3) 10 CFR Part 40: *Criteria Relating to the Operation of Uranium Mills and the Deposition of Tailings or Waste Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content* [Appendix A, Criterion 6(6) may be relevant and appropriate].

Although these three standards are not applicable for the Luckey site, each may be relevant and appropriate and are considered in order to identify potential radiological action levels. The official set of ARARs will be identified in the FS at a later date.

Both 40 CFR Part 192 and 10 CFR Part 40 Appendix A Criterion 6(6) [hereafter Criterion 6(6)] require the cleanup of Ra-226 to 5 pCi/g above background in the top 6-inches of soil and 15 pCi/g above background in any subsequent 6-inch layer. However, Criterion 6(6) also requires the cleanup of non-radium contaminants such as thorium and uranium. The benchmark dose, or the dose that would be produced by 5 pCi/g of Ra-226 defines the cleanup goal. For example, 5 pCi/g of radium produces 32.5 mrem/yr to the adult resident farmer using the parameters listed in Table 6.29. Therefore, all radiological

COCs including Ra-226 must be reduced so that the total dose does not exceed the 32.5 mrem/yr benchmark. Radionuclide-specific limits were estimated for the adult resident farmer by setting the dose criterion to 32.5 and then letting RESRAD calculate the limiting values (RESRAD calculates how much of an individual radionuclide is required to produce the dose criterion). The same approach was used to produce limits for the child resident farmer, with a benchmark of 33.6 mrem/yr, and the industrial worker, with a benchmark dose of 10.1 mrem/yr. Action levels based on 40 CFR Part 192 and Criterion 6(6) are listed in Table 6.32.

10 CFR Part 20 Subpart E also may be used to calculate action levels. Subpart E limits the dose to 25 mrem/yr for a site to be released for unrestricted use. Action levels are calculated for each radiological COC for comparison to the 25 mrem/yr limit with the same approach used to estimate benchmark values. Action levels based on 10 CFR Part 20 are listed in Table 6.32.

Table 6.32 lists potential action levels by medium, receptor, and radionuclide. If either 10 CFR part 20 or Criterion 6(6) is selected as an ARAR, the dose limit is a total from exposure from all complete pathways. Thus the combined dose from exposure to soil, sediment, and groundwater may not exceed the benchmarks or 25 mrem/yr limits, as appropriate. The application of a total dose criterion will depend on the remedial alternatives defined in the FS, and will be addressed in more detail there.

6.8 SUMMATION OF CHEMICAL AND RADIOLOGICAL RISK

Uranium, in soluble form, is a kidney toxin at concentrations slightly above background levels, and is the only radionuclide for which the chemical toxicity has been identified to be comparable to or greater than the radiotoxicity. Only uranium is considered as both a carcinogenic and non-carcinogenic hazard. For this reason, the radiological risk of uranium were estimated using the RESRAD code which utilizes HEAST CSF values while chemical toxicity was estimated using the RfD.

A CSF for a radionuclide is defined differently than a CSF for a non-radiological constituent. EPA outlines these differences in *Radiation Exposure and Risk Assessment Manual* (EPA 1996a). Major differences include the following:

- the radiological endpoint is fatal cancer – the constituent endpoint is tumorigenic cancer;
- radiological risk estimates are based primarily on human data – constituent risk estimates are based primarily on animal studies; and
- radiological risk estimates are based on the central estimate of the mean – constituent risk estimates are based on 95% UCL of the mean.

Additional considerations include the fact that exposure point concentrations for radionuclides and non-radionuclides are specific to distinct models incorporating different assumptions; RAGS cautions against combining radiological and non-radiological risks. Given these differences, risk from non-radionuclides and radionuclides were assessed and presented separately in the Sections 6.5.3 and 6.7.4. Despite these differences, excess cancer risk from both radionuclides and chemical carcinogens have been summed in Table 6.33 to provide an estimate of the combined risk presented by all carcinogenic contaminants.

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TABLE 6.1 IDENTIFICATION OF NON-RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR HUMAN HEALTH
EXPOSURE UNIT 1 - ON SITE UNDISTURBED SOIL AREA

MEDIUM	CAS NUMBER	PARAMETER	MINIMUM DETECTION		MAXIMUM DETECTION		UNITS	LOCATION OF MAXIMUM	DETECTION FREQUENCY	UCL95	VALUE FOR COMPARISON	BKGD. VALUE	PRG[a]	COPC
Soil (0-10 ft)	7429-90-5	Aluminum	1030		22100		mg/kg	IA08-SB0001	52/ 52	13600	13600	23700	7.6E+03	NO:1
Soil (0-10 ft)	7440-36-0	Antimony	0.3	J	0.71		mg/kg	IA08-SB0002	5/ 21	0.26	0.26	0.9	3.1E+00	NO:1,2
Soil (0-10 ft)	7440-38-2	Arsenic	1		30.3		mg/kg	04EY00	89/ 91	8.32	8.32	24.1	3.9E-01	NO:1
Soil (0-10 ft)	7440-39-3	Barium	1.6		563		mg/kg	IA04-SB0028	60/ 60	120	120	209	5.4E+02	NO:1,2
Soil (0-10 ft)	7440-41-7	Beryllium	0.26		619		mg/kg	09DI00	161/161	36.4	36.4	1.13	1.5E+01	YES
Soil (0-10 ft)	7440-42-8	Boron	11.4	B	15.9		mg/kg	03EQ01	5/ 6	15	15	13.4	5.5E+02	NO:2
Soil (0-10 ft)	7440-43-9	Cadmium	0.24		12.6		mg/kg	09DI00	18/ 20	2.47	2.47	0.98	3.7E+00	NO:2
Soil (0-10 ft)	7440-47-3	Chromium	5.2		27		mg/kg	IA08-SB0001	21/ 21	21.1	21.1	29.6	2.1E+02	NO:1,2
Soil (0-10 ft)	7440-48-4	Cobalt	1.2		16.5		mg/kg	09DI00	21/ 21	10.3	10.3	19.1	4.7E+02	NO:1,2
Soil (0-10 ft)	7440-50-8	Copper	3.7		41.4		mg/kg	IA04-SB0019	21/ 21	26.3	26.3	42	2.9E+02	NO:1,2
Soil (0-10 ft)	7439-92-1	Lead	2.2		797	J	mg/kg	05EE00	91/ 91	106	106	23.2	4.0E+01	YES
Soil (0-10 ft)	7439-96-5	Manganese	96.1	N	913		mg/kg	09DI00	21/ 21	492	492	2340	1.8E+02	NO:1
Soil (0-10 ft)	7439-94-7	Mercury	0.02		2.7		mg/kg	IA08-TR0001	15/ 21	0.39	0.39	0.19	2.3E+00	NO:2
Soil (0-10 ft)	7439-98-7	Molybdenum	2.8	B	5		mg/kg	09DI00	6/ 6	4.58	4.58	11.3	3.9E+01	NO:1,2
Soil (0-10 ft)	7440-02-0	Nickel	4.3		39.4		mg/kg	09DI00	21/ 21	28.6	28.6	46.1	1.6E+02	NO:1,2
Soil (0-10 ft)	7440-00-0	Phosphorus	221		1160		mg/kg	IA08-TR0001	15/ 15	567	567	808	--	NO:1
Soil (0-10 ft)	7782-49-2	Selenium	0.97		2.1		mg/kg	IA04-SB0019	10/ 21	0.99	0.99	2.33	3.9E+01	NO:1,2
Soil (0-10 ft)	7440-22-4	Silver	0.11	B	0.5		mg/kg	IA04-SB0021	11/ 21	0.23	0.23	0.51	3.9E+01	NO:1,2
Soil (0-10 ft)	7440-24-6	Strontium	35		2980		mg/kg	03EQ01	6/ 6	1870	1870	75.6	4.7E+03	NO:2
Soil (0-10 ft)	7440-28-0	Thallium	0.49	B	2	B	mg/kg	09DI00	9/ 21	0.82	0.82	2.1	6.3E-01	NO:1
Soil (0-10 ft)	24678-82-8	Uranium-238*	0.0977	J	50.9		pCi/g	09DA02	70/ 70	4.69	4.69	2.63	--	YES
Soil (0-10 ft)	7440-62-2	Vanadium	6.3		51.1		mg/kg	IA08-SB0001	21/ 21	30.6	30.6	42.8	5.5E+01	NO:1,2
Soil (0-10 ft)	7440-66-6	Zinc	12.7		152		mg/kg	IA08-TR0001	21/ 21	87.8	87.8	110	2.3E+03	NO:1,2
Soil (0-10 ft)	7782-50-5	Chloride	4.39		43.3		mg/kg	03EQ01	3/ 3	50	43.3	--	--	YES
Soil (0-10 ft)	16984-48-8	Fluoride	0.75		40.4		mg/kg	IA07-SB0007	42/ 42	8.01	8.01	6.94	3.7E+02	NO:2
Soil (0-10 ft)	7664-41-7	Nitrogen, Ammonia	0.92	J	40.4		mg/kg	IA08-SB0005	37/ 39	13.1	13.1	--	--	YES
Soil (0-10 ft)	SO_4	Sulfate	149		348		mg/kg	03EQ01	3/ 3	340	340	--	--	YES
Soil (0-10 ft)	91-57-6	2-Methylnaphthalene	887		4100		ug/kg	IA04-SB0030	2/ 37	14500	4100	--	2.3E+02	NO:2
Soil (0-10 ft)	83-32-9	Acenaphthene	82.3	J	377	J	ug/kg	05EI00	2/ 37	14300	377	--	3.7E+02	NO:2
Soil (0-10 ft)	208-96-8	Acenaphthylene	90.8	J	91.9	J	ug/kg	IA04-SB0034	2/ 37	14300	91.9	--	2.3E+02	NO:2
Soil (0-10 ft)	120-12-7	Anthracene	179	J	249000	J	ug/kg	IA04-SB0021	4/ 37	18500	18500	--	2.2E+03	NO:2
Soil (0-10 ft)	56-55-3	Benzo(a)anthracene	685		236000	J	ug/kg	IA04-SB0021	4/ 37	17700	17700	--	6.2E-01	YES
Soil (0-10 ft)	50-32-8	Benzo(a)pyrene	1450		195000	J	ug/kg	IA04-SB0021	4/ 37	14700	14700	--	6.2E-02	YES
Soil (0-10 ft)	205-99-2	Benzo(b)fluoranthene	2430		299000	J	ug/kg	IA04-SB0021	4/ 37	22300	22300	--	6.2E-01	YES
Soil (0-10 ft)	191-24-2	Benzo(ghi)perylene	865		1810		ug/kg	IA04-SB0018	3/ 37	14400	1810	--	2.3E+02	NO:2
Soil (0-10 ft)	207-08-9	Benzo(k)fluoranthene	1040		1750		ug/kg	IA04-SB0018	3/ 37	14400	1750	--	6.2E+00	NO:2
Soil (0-10 ft)	218-01-9	Chrysene	1050		237000	J	ug/kg	IA04-SB0021	4/ 37	17800	17800	--	6.2E+01	NO:2
Soil (0-10 ft)	53-70-3	Dibenz(a,h)anthracene	428		458		ug/kg	IA04-SB0033	2/ 37	14400	458	--	6.2E-02	YES
Soil (0-10 ft)	206-44-0	Fluoranthene	197	J	762000		ug/kg	IA04-SB0021	6/ 37	56100	56100	--	2.3E+02	NO:2
Soil (0-10 ft)	86-73-7	Fluorene	160	J	216000	J	ug/kg	IA04-SB0021	3/ 37	16100	16100	--	2.6E+02	NO:2
Soil (0-10 ft)	193-39-5	Indeno(1,2,3-c,d)pyrene	891		2010		ug/kg	IA04-SB0018	3/ 37	14400	2010	--	6.2E-01	YES
Soil (0-10 ft)	85-01-8	Phenanthrene	189	J	891000		ug/kg	IA04-SB0021	5/ 37	65300	65300	--	2.3E+02	NO:2
Soil (0-10 ft)	129-00-0	Pyrene	633		513000		ug/kg	IA04-SB0021	5/ 37	37900	37900	--	2.3E+02	NO:2

TABLE 6.1 IDENTIFICATION OF NON-RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR HUMAN HEALTH EXPOSURE UNIT 1 - ON SITE UNDISTURBED SOIL AREA (Continued)

MEDIUM	CAS NUMBER	PARAMETER	MINIMUM DETECTION		MAXIMUM DETECTION		UNITS	LOCATION OF MAXIMUM	DETECTION FREQUENCY	UCL95	VALUE FOR COMPARISON	BKGD. VALUE	PRG[a]	COPC
Soil (0-10 ft)	117-81-7	bis(2-ethylhexyl)phthalate	408	J	2360		ug/kg	IA04-SB0034	3/ 37	14400	2360	--	3.5E+01	NO:2
Soil (0-10 ft)	75-15-0	Carbon disulfide	0.69	J	61.5		ug/kg	IA07-SB0008	9/ 24	22.8	22.8	--	3.6E+01	NO:2
Soil (0-10 ft)	67-66-3	Chloroform	0.62	J	2.7	J	ug/kg	03EQ01	3/ 24	12.7	2.7	--	2.4E-01	NO:2
Soil (0-10 ft)	74-87-3	Chloromethane	60.6	J	211		ug/kg	09DI00	2/ 6	98.7	98.7	--	1.2E+00	NO:2
Soil (0-10 ft)	100-41-4	Ethylbenzene	1.3	J	14.4	J	ug/kg	05EI00	5/ 24	13.5	13.5	--	2.3E+01	NO:2
Soil (0-10 ft)	75-09-2	Methylene chloride	0.56	JB	6	J	ug/kg	05EI00	4/ 24	9.58	6	--	8.9E+00	NO:2
Soil (0-10 ft)	108-88-3	Toluene	0.64999	J	586	J	ug/kg	05EI00	18/ 24	113	113	--	5.2E+01	NO:2
Soil (0-10 ft)	79-01-6	Trichloroethene	1.3	J	1.3	J	ug/kg	IA04-SB0019	1/ 24	14.2	1.3	--	2.8E+00	NO:0
Soil (0-10 ft)	75-01-4	Vinyl chloride	3.8		3.8		ug/kg	IA04-SB0036	1/ 24	25.8	3.8	--	2.2E-02	NO:0
Soil (0-10 ft)	1330-20-7	Xylenes (total)	0.83	J	26		ug/kg	IA04-SB0021	9/ 24	14.9	14.9	--	2.1E+01	NO:2
Soil (0-10 ft)	12674-11-2	Aroclor-1016	14.1	P	14.1	P	ug/kg	IA04-SB0024	1/ 10	157	14.1	--	3.9E-01	NO:2
Soil (0-10 ft)	11104-28-2	Aroclor-1221	290	EP	290	EP	ug/kg	IA04-SB0024	1/ 10	192	192	--	2.2E-01	NO:2
Soil (0-10 ft)	12672-29-6	Aroclor-1248	15.4	P	15.6	P	ug/kg	IA04-SB0024	2/ 10	158	15.6	--	2.2E-01	NO:2
Soil (0-10 ft)	11097-69-1	Aroclor-1254	9.8		10100		ug/kg	IA04-SB0033	6/ 10	3430	3430	--	2.2E-01	YES
Soil (0-10 ft)	11096-82-5	Aroclor-1260	13.3		23.1	P	ug/kg	IA04-SB0022	3/ 10	159	23.1	--	2.2E-01	NO:2
Soil (0-10 ft)	TPH	Total Petro. Hydrocarbons	11.5	J	6190		mg/kg	IA04-SB0030	9/ 16	1110	1110	--	--	YES
Soil (0-2 ft)	7429-90-5	Aluminum	1030		22100		mg/kg	IA08-SB0001	43/ 43	14200	14200	23700	7.6E+03	NO:1
Soil (0-2 ft)	7440-36-0	Antimony	0.3	J	0.71		mg/kg	IA08-SB0002	4/ 12	0.33	0.33	0.9	3.1E+00	NO:1,2
Soil (0-2 ft)	7440-38-2	Arsenic	1.6		30.3		mg/kg	04EY00	52/ 53	8.89	8.89	24.1	3.9E-01	NO:1
Soil (0-2 ft)	7440-39-3	Barium	1.6		563		mg/kg	IA04-SB0028	22/ 22	170	170	209	5.4E+02	NO:1,2
Soil (0-2 ft)	7440-41-7	Beryllium	0.36		619		mg/kg	09DI00	66/ 66	68.3	68.3	1.13	1.5E+01	YES
Soil (0-2 ft)	7440-42-8	Boron	11.9		11.9		mg/kg	09DI00	1/ 1	--	11.9	13.4	5.5E+02	NO:1,2
Soil (0-2 ft)	7440-43-9	Cadmium	0.24		5.4		mg/kg	09DI00	10/ 11	3.89	3.89	0.98	3.7E+00	YES
Soil (0-2 ft)	7440-47-3	Chromium	14.7		27		mg/kg	IA08-SB0001	12/ 12	23	23	29.6	2.1E+02	NO:1,2
Soil (0-2 ft)	7440-48-4	Cobalt	4.5		12.9		mg/kg	IA07-SB0008	12/ 12	10.4	10.4	19.1	4.7E+02	NO:1,2
Soil (0-2 ft)	7440-50-8	Copper	9.6		41.4		mg/kg	IA04-SB0019	12/ 12	27.6	27.6	42	2.9E+02	NO:1,2
Soil (0-2 ft)	7439-92-1	Lead	6.5		797	J	mg/kg	05EE00	53/ 53	218	218	23.2	4.0E+01	YES
Soil (0-2 ft)	7439-96-5	Manganese	127		677	J	mg/kg	IA07-SB0008	12/ 12	476	476	2340	1.8E+02	NO:1
Soil (0-2 ft)	7439-94-7	Mercury	0.02		0.2		mg/kg	09DI00	9/ 12	0.09	0.09	0.19	2.3E+00	NO:1,2
Soil (0-2 ft)	7439-98-7	Molybdenum	3.7	B	3.7	B	mg/kg	09DI00	1/ 1	--	3.7	11.3	3.9E+01	NO:1,2
Soil (0-2 ft)	7440-02-0	Nickel	15.8		34.9		mg/kg	IA07-SB0008	12/ 12	29.3	29.3	46.1	1.6E+02	NO:1,2
Soil (0-2 ft)	7440-00-0	Phosphorus	290		723		mg/kg	IA08-SB0002	11/ 11	543	543	808	--	NO:1
Soil (0-2 ft)	7782-49-2	Selenium	0.97		2.1		mg/kg	IA04-SB0019	8/ 12	1.31	1.31	2.33	3.9E+01	NO:1,2
Soil (0-2 ft)	7440-22-4	Silver	0.11	B	0.5		mg/kg	IA04-SB0021	5/ 12	0.27	0.27	0.51	3.9E+01	NO:1,2
Soil (0-2 ft)	7440-24-6	Strontium	65.5		65.5		mg/kg	09DI00	1/ 1	--	65.5	75.6	4.7E+03	NO:1,2
Soil (0-2 ft)	7440-28-0	Thallium	0.58	B	1.7		mg/kg	IA04-SB0018	5/ 12	0.88	0.88	2.1	6.3E-01	NO:1
Soil (0-2 ft)	24678-82-8	Uranium-238*	0.208	J	50.9		pCi/g	09DA02	32/ 32	8.95	8.95	2.63	--	YES
Soil (0-2 ft)	7440-62-2	Vanadium	18.9		51.1		mg/kg	IA08-SB0001	12/ 12	35.7	35.7	42.8	5.5E+01	NO:1,2
Soil (0-2 ft)	7440-66-6	Zinc	63.3		136		mg/kg	IA04-SB0021	12/ 12	95.4	95.4	110	2.3E+03	NO:1,2
Soil (0-2 ft)	16984-48-8	Fluoride	1.62		20.1		mg/kg	IA03-SB0008	10/ 10	11.6	11.6	6.94	3.7E+02	NO:2
Soil (0-2 ft)	7664-41-7	Nitrogen, Ammonia	1.17	J	31.5		mg/kg	IA08-SB0004	9/ 10	20.3	20.3	--	--	YES
Soil (0-2 ft)	83-32-9	Acenaphthene	82.3	J	82.3	J	ug/kg	IA04-SB0033	1/ 14	38200	82.3	--	3.7E+02	NO:2
Soil (0-2 ft)	208-96-8	Acenaphthylene	90.8	J	91.9	J	ug/kg	IA04-SB0034	2/ 14	38200	91.9	--	2.3E+02	NO:2
Soil (0-2 ft)	120-12-7	Anthracene	179	J	249000	J	ug/kg	IA04-SB0021	4/ 14	49600	49600	--	2.2E+03	NO:2

TABLE 6.1 IDENTIFICATION OF NON-RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR HUMAN HEALTH
EXPOSURE UNIT 1 - ON SITE UNDISTURBED SOIL AREA (Continued)

MEDIUM	CAS NUMBER	PARAMETER	MINIMUM DETECTION		MAXIMUM DETECTION		UNITS	LOCATION OF MAXIMUM	DETECTION FREQUENCY	UCL95	VALUE FOR COMPARISON	BKGD. VALUE	PRG[a]	COPC
Soil (0-2 ft)	56-55-3	Benzo(a)anthracene	685		236000	J	ug/kg	IA04-SB0021	4/ 14	47200	47200	--	6.2E-01	YES
Soil (0-2 ft)	50-32-8	Benzo(a)pyrene	1450		195000	J	ug/kg	IA04-SB0021	4/ 14	39100	39100	--	6.2E-02	YES
Soil (0-2 ft)	205-99-2	Benzo(b)fluoranthene	2430		299000	J	ug/kg	IA04-SB0021	4/ 14	59900	59900	--	6.2E-01	YES
Soil (0-2 ft)	191-24-2	Benzo(ghi)perylene	865		1810		ug/kg	IA04-SB0018	3/ 14	38400	1810	--	2.3E+02	NO:2
Soil (0-2 ft)	207-08-9	Benzo(k)fluoranthene	1040		1750		ug/kg	IA04-SB0018	3/ 14	38400	1750	--	6.2E+00	NO:2
Soil (0-2 ft)	218-01-9	Chrysene	1050		237000	J	ug/kg	IA04-SB0021	4/ 14	47500	47500	--	6.2E+01	NO:2
Soil (0-2 ft)	53-70-3	Dibenz(a,h)anthracene	428		458		ug/kg	IA04-SB0033	2/ 14	38200	458	--	6.2E-02	YES
Soil (0-2 ft)	206-44-0	Fluoranthene	197	J	762000		ug/kg	IA04-SB0021	5/ 14	152000	152000	--	2.3E+02	NO:2
Soil (0-2 ft)	86-73-7	Fluorene	160	J	216000	J	ug/kg	IA04-SB0021	3/ 14	43000	43000	--	2.6E+02	NO:2
Soil (0-2 ft)	193-39-5	Indeno(1,2,3-c,d)pyrene	891		2010		ug/kg	IA04-SB0018	3/ 14	38400	2010	--	6.2E-01	YES
Soil (0-2 ft)	85-01-8	Phenanthrene	189	J	891000		ug/kg	IA04-SB0021	4/ 14	177000	177000	--	2.3E+02	NO:2
Soil (0-2 ft)	129-00-0	Pyrene	633		513000		ug/kg	IA04-SB0021	4/ 14	102000	102000	--	2.3E+02	NO:2
Soil (0-2 ft)	117-81-7	bis(2-ethylhexyl)phthalate	408	J	2360		ug/kg	IA04-SB0034	3/ 14	38400	2360	--	3.5E+01	NO:2
Soil (0-2 ft)	71-55-6	1,1,1-Trichloroethane	7.3		7.3		ug/kg	IA04-SB0019	1/ 12	9.4	7.3	--	7.7E+01	NO:2
Soil (0-2 ft)	108-10-1	4-Methyl-2-pentanone	21.4		21.4		ug/kg	IA04-SB0021	1/ 12	19.5	19.5	--	7.9E+01	NO:2
Soil (0-2 ft)	67-64-1	Acetone	11.7		11.7		ug/kg	IA08-SB0001	1/ 12	27	11.7	--	1.6E+02	NO:2
Soil (0-2 ft)	71-43-2	Benzene	0.57	J	4.4	J	ug/kg	IA04-SB0021	10/ 12	8.23	4.4	--	6.7E-01	NO:2
Soil (0-2 ft)	75-15-0	Carbon disulfide	0.69	J	61.5		ug/kg	IA07-SB0008	5/ 12	26.3	26.3	--	3.6E+01	NO:2
Soil (0-2 ft)	67-66-3	Chloroform	0.62	J	1.2	JB	ug/kg	IA08-SB0001	2/ 12	8.81	1.2	--	2.4E-01	NO:2
Soil (0-2 ft)	74-87-3	Chloromethane	211		211		ug/kg	09DI00	1/ 1	--	211	--	1.2E+00	NO:2
Soil (0-2 ft)	100-41-4	Ethylbenzene	1.3	J	9.1		ug/kg	IA04-SB0021	3/ 12	9.41	9.1	--	2.3E+01	NO:2
Soil (0-2 ft)	75-09-2	Methylene chloride	0.56	JB	0.56	JB	ug/kg	IA04-SB0018	1/ 12	8.73	0.56	--	8.9E+00	NO:2
Soil (0-2 ft)	108-88-3	Toluene	1.1	J	182		ug/kg	09DI00	8/ 12	306	182	--	5.2E+01	NO:2
Soil (0-2 ft)	79-01-6	Trichloroethene	1.3	J	1.3	J	ug/kg	IA04-SB0019	1/ 12	8.93	1.3	--	2.8E+00	NO:2
Soil (0-2 ft)	1330-20-7	Xylenes (total)	1.2	J	26		ug/kg	IA04-SB0021	3/ 12	11.7	11.7	--	2.1E+01	NO:2
Soil (0-2 ft)	11097-69-1	Aroclor-1254	2270		3200		ug/kg	IA04-SB0033	2/ 3	4600	3200	--	2.2E-01	YES
Soil (0-2 ft)	11096-82-5	Aroclor-1260	23.1	P	23.1	P	ug/kg	IA04-SB0022	1/ 3	225	23.1	--	2.2E-01	NO:2
Soil (0-2 ft)	TPH	Total Petro. Hydrocarbons	141		418		mg/kg	IA04-SB0033	2/ 2	1150	418	--	--	YES

a = USEPA Region 9 Residential PRGs. Lower of 1E-6 Cancer PRG or 1/10 Noncancer PRG. Note that All soil PRGs reported as mg/kg and all tap water PRGs reported as ug/L
NO:0 = Frequency of Detection Less than 5%
NO:1 = Comparison value less than background value
NO:2 = Comparison value less than PRG
YES = Chemical is a COPC
*Only the alpha-spectrum data was used to calculate the 95% UCL. The concentration of uranium-238 in soil was converted from pCi/g to mg/kg for evaluation of risk.

TABLE 6.2 IDENTIFICATION OF NON-RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR HUMAN HEALTH
EXPOSURE UNIT 2 - ON SITE DISTURBED SOIL AREA

MEDIUM	CAS NUMBER	PARAMETER	MINIMUM DETECTION		MAXIMUM DETECTION		UNITS	LOCATION OF MAXIMUM	DETECTION FREQUENCY	UCL95	VALUE FOR COMPARISON	BKGD. VALUE	PRG[a]	COPC
Soil (0-10 ft)	7429-90-5	Aluminum	4940		179000		mg/kg	04AX00	75/ 75	26100	26100	23700	7.6E+03	YES
Soil (0-10 ft)	7440-36-0	Antimony	0.26	J	9.1		mg/kg	IA05-SB0007	17/ 50	1.14	1.14	0.9	3.1E+00	NO:2
Soil (0-10 ft)	7440-38-2	Arsenic	1.5		98.7		mg/kg	08AW00	230/235	9.84	9.84	24.1	3.9E-01	NO:1
Soil (0-10 ft)	7440-39-3	Barium	12.4		2440	J	mg/kg	06FD00	209/209	146	146	209	5.4E+02	NO:1,2
Soil (0-10 ft)	7440-41-7	Beryllium	0.07		13300		mg/kg	IA05-SB0009	462/462	514	514	1.13	1.5E+01	YES
Soil (0-10 ft)	7440-42-8	Boron	3.2	J	56.8	J	mg/kg	08AW00	19/ 25	28	28	13.4	5.5E+02	NO:2
Soil (0-10 ft)	7440-43-9	Cadmium	0.2	B	438		mg/kg	IA02-SB0001	37/ 54	28.3	28.3	0.98	3.7E+00	YES
Soil (0-10 ft)	7440-47-3	Chromium	8		172		mg/kg	04AX00	54/ 54	46.8	46.8	29.6	2.1E+02	NO:2
Soil (0-10 ft)	7440-48-4	Cobalt	0.92		59.2		mg/kg	08AW00	54/ 54	15.2	15.2	19.1	4.7E+02	NO:1,2
Soil (0-10 ft)	7440-50-8	Copper	6.1	J	1970		mg/kg	IA03-SB0002	54/ 54	151	151	42	2.9E+02	NO:2
Soil (0-10 ft)	7439-92-1	Lead	4.9		28900	J	mg/kg	10FD01	232/232	561	561	23.2	4.0E+01	YES
Soil (0-10 ft)	7439-96-5	Manganese	31.5		2720		mg/kg	BH0016	54/ 54	718	718	2340	1.8E+02	NO:1
Soil (0-10 ft)	7439-94-7	Mercury	0.02		1.8		mg/kg	BH0015	45/ 54	0.34	0.34	0.19	2.3E+00	NO:2
Soil (0-10 ft)	7439-98-7	Molybdenum	0.14	B	16.5	J	mg/kg	08AW00	21/ 25	10.4	10.4	11.3	3.9E+01	NO:1,2
Soil (0-10 ft)	7440-02-0	Nickel	8.6	B	194		mg/kg	10DD00	54/ 54	52.9	52.9	46.1	1.6E+02	NO:2
Soil (0-10 ft)	7440-00-0	Phosphorus	0.391	J	866		mg/kg	IA05-SB0003	30/ 39	342	342	808	--	NO:1
Soil (0-10 ft)	7782-49-2	Selenium	0.34		5.1	B	mg/kg	08AW00	38/ 54	1.34	1.34	2.33	3.9E+01	NO:1,2
Soil (0-10 ft)	7440-22-4	Silver	0.08	B	3.6	B	mg/kg	04AX00	16/ 54	0.43	0.43	0.51	3.9E+01	NO:1,2
Soil (0-10 ft)	7440-24-6	Strontium	0.125	J	1180		mg/kg	BH0015	25/ 25	312	312	75.6	4.7E+03	NO:2
Soil (0-10 ft)	7440-28-0	Thallium	0.44		19.3	B	mg/kg	08AW00	27/ 54	2.18	2.18	2.1	6.3E-01	YES
Soil (0-10 ft)	24678-82-8	Uranium-238*	0.256		51.1		pCi/g	04AX00	246/246	4.40	4.40	2.63	--	YES
Soil (0-10 ft)	7440-62-2	Vanadium	1.5		186		mg/kg	08AW00	54/ 54	36.6	36.6	42.8	5.5E+01	NO:1,2
Soil (0-10 ft)	7440-66-6	Zinc	6.5		1840		mg/kg	IA02-SB0001	54/ 54	351	351	110	2.3E+03	NO:2
Soil (0-10 ft)	7782-50-5	Chloride	3.92	J	320		mg/kg	09EZ01	10/ 15	1660	320	--	--	YES
Soil (0-10 ft)	16984-48-8	Fluoride	0.19	J	576		mg/kg	10FD01	170/170	65.6	65.6	6.94	3.7E+02	NO:2
Soil (0-10 ft)	7664-41-7	Nitrogen, Ammonia	0.65	J	765		mg/kg	IA07-SB0003	153/155	37.7	37.7	--	--	YES
Soil (0-10 ft)	SO_4	Sulfate	36.8		24800		mg/kg	09EZ01	14/ 15	41100	24800	--	--	YES
Soil (0-10 ft)	91-57-6	2-Methylnaphthalene	246	J	246	J	ug/kg	IA03-SB0002	1/ 52	421	246	--	2.3E+02	NO:0
Soil (0-10 ft)	120-12-7	Anthracene	75.3	J	7220	J	ug/kg	07FR00	4/ 53	698	698	--	2.2E+03	NO:2
Soil (0-10 ft)	56-55-3	Benzo(a)anthracene	73.3	J	10200	J	ug/kg	07FR00	10/ 53	919	919	--	6.2E-01	YES
Soil (0-10 ft)	50-32-8	Benzo(a)pyrene	187	J	9190	J	ug/kg	07FR00	10/ 53	888	888	--	6.2E-02	YES
Soil (0-10 ft)	205-99-2	Benzo(b)fluoranthene	275	J	10000	J	ug/kg	07FR00	10/ 53	1010	1010	--	6.2E-01	YES
Soil (0-10 ft)	191-24-2	Benzo(ghi)perylene	176	J	4470	J	ug/kg	07FR00	5/ 53	599	599	--	2.3E+02	NO:2
Soil (0-10 ft)	207-08-9	Benzo(k)fluoranthene	94.1	J	5530	J	ug/kg	07FR00	4/ 53	634	634	--	6.2E+00	NO:2
Soil (0-10 ft)	86-74-8	Carbazole	4440	J	4440	J	ug/kg	07FR00	1/ 53	563	563	--	2.4E+01	NO:0
Soil (0-10 ft)	218-01-9	Chrysene	66.7	J	9590	J	ug/kg	07FR00	11/ 53	893	893	--	6.2E+01	NO:2
Soil (0-10 ft)	53-70-3	Dibenz(a,h)anthracene	51.6	J	51.6	J	ug/kg	IA05-SB0007	1/ 52	418	51.6	--	6.2E-02	NO:0
Soil (0-10 ft)	206-44-0	Fluoranthene	181	J	23400	J	ug/kg	07FR00	13/ 53	1790	1790	--	2.3E+02	NO:2
Soil (0-10 ft)	86-73-7	Fluorene	3160	J	3160	J	ug/kg	07FR00	1/ 53	509	509	--	2.6E+02	NO:0
Soil (0-10 ft)	193-39-5	Indeno(1,2,3-c,d)pyrene	183	J	5510	J	ug/kg	07FR00	6/ 53	653	653	--	6.2E-01	YES
Soil (0-10 ft)	85-01-8	Phenanthrene	129	J	21400	J	ug/kg	07FR00	10/ 53	1500	1500	--	2.3E+02	NO:2
Soil (0-10 ft)	129-00-0	Pyrene	147	J	19400	J	ug/kg	07FR00	11/ 53	1630	1630	--	2.3E+02	NO:2
Soil (0-10 ft)	117-81-7	bis(2-ethylhexyl)phthalate	219	J	246	J	ug/kg	09EZ01	3/ 52	421	246	--	3.5E+01	NO:2
Soil (0-10 ft)	78-93-3	2-Butanone	3.8	J	3.8	J	ug/kg	IA01-SB0002	1/ 49	15.1	3.8	--	7.3E+02	NO:0
Soil (0-10 ft)	591-78-6	2-Hexanone	1.1	J	1.1	J	ug/kg	IA01-SB0003	1/ 49	15.7	1.1	--	--	NO:0

TABLE 6.2 IDENTIFICATION OF NON-RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR HUMAN HEALTH
EXPOSURE UNIT 2 - ON SITE DISTURBED SOIL AREA (Continued)

MEDIUM	CAS NUMBER	PARAMETER	MINIMUM DETECTION		MAXIMUM DETECTION		UNITS	LOCATION OF MAXIMUM	DETECTION FREQUENCY	UCL95	VALUE FOR COMPARISON	BKGD. VALUE	PRG[a]	COPC
Soil (0-10 ft)	67-64-1	Acetone	9	J	9	J	ug/kg	IA07-SB0005	1/ 45	19.8	9	--	1.6E+02	NO:0
Soil (0-10 ft)	74-87-3	Chloromethane	115	J	115	J	ug/kg	10DD00	1/ 20	30.7	30.7	--	1.2E+00	NO:2
Soil (0-10 ft)	100-41-4	Ethylbenzene	0.28	J	49.7		ug/kg	IA01-SB0002	27/ 49	9.89	9.89	--	2.3E+01	NO:2
Soil (0-10 ft)	74-83-9	Methyl Bromide	6.7	J	6.7	J	ug/kg	IA05-SB0008	1/ 29	7.74	6.7	--	3.9E-01	NO:0
Soil (0-10 ft)	74-87-3	Methyl Chloride	5.9	J	5.9	J	ug/kg	IA05-SB0008	1/ 29	7.71	5.9	--	1.2E+00	NO:0
Soil (0-10 ft)	75-09-2	Methylene chloride	0.55	BJ	37.1	B	ug/kg	08AW00	18/ 49	10.5	10.5	--	8.9E+00	NO:2
Soil (0-10 ft)	108-88-3	Toluene	0.44	J	422	J	ug/kg	10DD00	46/ 49	56.2	56.2	--	5.2E+01	NO:2
Soil (0-10 ft)	1330-20-7	Xylenes (total)	0.71	J	35.8		ug/kg	IA03-SB0002	23/ 49	20.4	20.4	--	2.1E+01	NO:2
Soil (0-2 ft)	7429-90-5	Aluminum	4940		80900		mg/kg	IA02-SB0001	50/ 50	21700	21700	23700	7.6E+03	NO:1
Soil (0-2 ft)	7440-36-0	Antimony	0.27	J	5.1	J	mg/kg	06FD00	10/ 26	0.99	0.99	0.9	3.1E+00	NO:2
Soil (0-2 ft)	7440-38-2	Arsenic	1.5		39.4		mg/kg	10DD00	86/ 88	9.64	9.64	24.1	3.9E-01	NO:1
Soil (0-2 ft)	7440-39-3	Barium	17.8		2440	J	mg/kg	06FD00	67/ 67	204	204	209	5.4E+02	NO:1,2
Soil (0-2 ft)	7440-41-7	Beryllium	0.54		8760		mg/kg	IA01-SB0035	129/129	765	765	1.13	1.5E+01	YES
Soil (0-2 ft)	7440-42-8	Boron	11.2	B	43.1		mg/kg	06FD00	7/ 9	30.8	30.8	13.4	5.5E+02	NO:2
Soil (0-2 ft)	7440-43-9	Cadmium	0.2		438		mg/kg	IA02-SB0001	20/ 29	83.5	83.5	0.98	3.7E+00	YES
Soil (0-2 ft)	7440-47-3	Chromium	8		153	J	mg/kg	10DD00	29/ 29	50.8	50.8	29.6	2.1E+02	NO:2
Soil (0-2 ft)	7440-48-4	Cobalt	3		35.3		mg/kg	10DD00	29/ 29	14.3	14.3	19.1	4.7E+02	NO:1,2
Soil (0-2 ft)	7440-50-8	Copper	6.1	J	420	J	mg/kg	10DD00	29/ 29	85.5	85.5	42	2.9E+02	NO:2
Soil (0-2 ft)	7439-92-1	Lead	9.8		28900	J	mg/kg	10FD01	88/ 88	1380	1380	23.2	4.0E+01	YES
Soil (0-2 ft)	7439-96-5	Manganese	166		2720		mg/kg	BH0016	29/ 29	884	884	2340	1.8E+02	NO:1
Soil (0-2 ft)	7439-94-7	Mercury	0.02		1.8		mg/kg	BH0015	24/ 29	0.54	0.54	0.19	2.3E+00	NO:2
Soil (0-2 ft)	7439-98-7	Molybdenum	0.14	B	15.8		mg/kg	10DD00	9/ 9	11.2	11.2	11.3	3.9E+01	NO:1,2
Soil (0-2 ft)	7440-02-0	Nickel	8.9		194		mg/kg	10DD00	29/ 29	63.5	63.5	46.1	1.6E+02	NO:2
Soil (0-2 ft)	7440-00-0	Phosphorus	0.391	J	866		mg/kg	IA05-SB0003	19/ 23	415	415	808	--	NO:1
Soil (0-2 ft)	7782-49-2	Selenium	0.54		3.7	J	mg/kg	BH0016	21/ 29	1.23	1.23	2.33	3.9E+01	NO:1,2
Soil (0-2 ft)	7440-22-4	Silver	0.2	B	1.2	B	mg/kg	10DD00	8/ 29	0.35	0.35	0.51	3.9E+01	NO:1,2
Soil (0-2 ft)	7440-24-6	Strontium	0.125	J	1180		mg/kg	BH0015	9/ 9	574	574	75.6	4.7E+03	NO:2
Soil (0-2 ft)	7440-28-0	Thallium	0.44		12	B	mg/kg	BH0016	18/ 29	2.4	2.4	2.1	6.3E-01	YES
Soil (0-2 ft)	24678-82-8	Uranium-238*	0.256		41.5		pCi/g	IA01-SB0018	104/104	6.67	6.67	2.63	--	YES
Soil (0-2 ft)	7440-62-2	Vanadium	5.8		71		mg/kg	10DD00	29/ 29	35.1	35.1	42.8	5.5E+01	NO:1,2
Soil (0-2 ft)	7440-66-6	Zinc	20.4	J	1840		mg/kg	IA02-SB0001	29/ 29	509	509	110	2.3E+03	NO:2
Soil (0-2 ft)	7782-50-5	Chloride	7.76	J	320		mg/kg	09EZ01	3/ 5	178	178	--	--	YES
Soil (0-2 ft)	16984-48-8	Fluoride	0.93		576		mg/kg	10FD01	43/ 43	144	144	6.94	3.7E+02	NO:2
Soil (0-2 ft)	7664-41-7	Nitrogen, Ammonia	5.26		116		mg/kg	IA01-SB0012	38/ 38	30.7	30.7	--	--	YES
Soil (0-2 ft)	SO_4	Sulfate	124		24800		mg/kg	09EZ01	4/ 5	286000000	24800	--	--	YES
Soil (0-2 ft)	120-12-7	Anthracene	975	J	1100	J	ug/kg	BH0015	2/ 27	639	639	--	2.2E+03	NO:2
Soil (0-2 ft)	56-55-3	Benzo(a)anthracene	73.3	J	3170		ug/kg	BH0015	8/ 27	887	887	--	6.2E-01	YES
Soil (0-2 ft)	50-32-8	Benzo(a)pyrene	187	J	3230		ug/kg	BH0015	8/ 27	921	921	--	6.2E-02	YES
Soil (0-2 ft)	205-99-2	Benzo(b)fluoranthene	275	J	4050		ug/kg	BH0015	8/ 27	1140	1140	--	6.2E-01	YES
Soil (0-2 ft)	191-24-2	Benzo(ghi)perylene	714	J	1680		ug/kg	BH0015	3/ 27	696	696	--	2.3E+02	NO:2
Soil (0-2 ft)	207-08-9	Benzo(k)fluoranthene	94.1	J	1630		ug/kg	BH0015	3/ 27	669	669	--	6.2E+00	NO:2
Soil (0-2 ft)	218-01-9	Chrysene	66.7	J	2890	J	ug/kg	BH0015	9/ 27	876	876	--	6.2E+01	NO:2
Soil (0-2 ft)	206-44-0	Fluoranthene	181	J	6980		ug/kg	BH0015	10/ 27	1640	1640	--	2.3E+02	NO:2
Soil (0-2 ft)	193-39-5	Indeno(1,2,3-c,d)pyrene	421	J	1980	J	ug/kg	BH0015	4/ 27	721	721	--	6.2E-01	YES
Soil (0-2 ft)	85-01-8	Phenanthrene	129	J	3870		ug/kg	BH0015	7/ 27	1060	1060	--	2.3E+02	NO:2
Soil (0-2 ft)	129-00-0	Pyrene	147	J	6920		ug/kg	BH0015	8/ 27	1430	1430	--	2.3E+02	NO:2

TABLE 6.2 IDENTIFICATION OF NON-RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR HUMAN HEALTH
EXPOSURE UNIT 2 - ON SITE DISTURBED SOIL AREA (Continued)

MEDIUM	CAS NUMBER	PARAMETER	MINIMUM DETECTION		MAXIMUM DETECTION		UNITS	LOCATION OF MAXIMUM	DETECTION FREQUENCY	UCL95	VALUE FOR COMPARISON	BKGD. VALUE	PRG[a]	COPC
Soil (0-2 ft)	117-81-7	bis(2-ethylhexyl)phthalate	242	J	246	J	ug/kg	09EZ01	2/ 27	608	246	--	3.5E+01	NO:2
Soil (0-2 ft)	71-43-2	Benzene	0.92	J	5.7	J	ug/kg	IA05-SB0007	18/ 24	9.97	5.7	--	6.7E-01	NO:2
Soil (0-2 ft)	75-15-0	Carbon disulfide	3.2	J	43.2		ug/kg	IA02-SB0003	7/ 24	16	16	--	3.6E+01	NO:2
Soil (0-2 ft)	67-66-3	Chloroform	1.9	J	1.9	J	ug/kg	IA02-SB0001	1/ 24	10.1	1.9	--	2.4E-01	NO:0
Soil (0-2 ft)	74-87-3	Chloromethane	115	J	115	J	ug/kg	10DD00	1/ 4	116	115	--	1.2E+00	NO:2
Soil (0-2 ft)	100-41-4	Ethylbenzene	0.52	J	3.4	J	ug/kg	IA05-SB0002	15/ 24	8.22	3.4	--	2.3E+01	NO:2
Soil (0-2 ft)	75-09-2	Methylene chloride	0.55	BJ	4.7	J	ug/kg	BH0015	5/ 24	9.69	4.7	--	8.9E+00	NO:2
Soil (0-2 ft)	108-88-3	Toluene	1.3	J	422	J	ug/kg	10DD00	23/ 24	64.3	64.3	--	5.2E+01	NO:2
Soil (0-2 ft)	1330-20-7	Xylenes (total)	0.91	J	26.9		ug/kg	IA01-SB0003	14/ 24	15	15	--	2.1E+01	NO:2

a = USEPA Region 9 Residential PRGs. Lower of 1E-6 Cancer PRG or 1/10 Noncancer PRG. Note that All soil PRGs reported as mg/kg and all tap water PRGs reported as ug/L
NO:0 = Frequency of Detection Less than 5%
NO:1 = Comparison value less than background value
NO:2 = Comparison value less than PRG
YES = Chemical is a COPC

*Only the alpha-spectrum data was used to calculate the 95% UCL. The concentration of uranium-238 in soil was converted from pCi/g to mg/kg for evaluation of risk.

TABLE 6.3 IDENTIFICATION OF NON-RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR HUMAN HEALTH
EXPOSURE UNIT 3 - OFF SITE RESIDENTIAL/AGRICULTURAL LANDS

MEDIUM	CAS NUMBER	PARAMETER	MINIMUM DETECTION		MAXIMUM DETECTION		UNITS	LOCATION OF MAXIMUM	DETECTION FREQUENCY	UCL95	VALUE FOR COMPARISON	BKGD. VALUE	PRG[a]	COPC
Soil (0-10 ft)	7429-90-5	Aluminum	19900		19900		mg/kg	IA10-SB0024	1/ 1	--	19900	23700	7.6E+03	NO:1
Soil (0-10 ft)	7440-38-2	Arsenic	2.4	N	15.6	N	mg/kg	IA10-SB0045	43/ 43	8.22	8.22	24.1	3.9E-01	NO:1
Soil (0-10 ft)	7440-39-3	Barium	25.4		479		mg/kg	IA10-SB0045	43/ 43	127	127	209	5.4E+02	NO:1,2
Soil (0-10 ft)	7440-41-7	Beryllium	0.63		2560	N	mg/kg	IA10-SB0051	86/ 86	144	144	1.13	1.5E+01	YES
Soil (0-10 ft)	7440-47-3	Chromium	28.8		28.8		mg/kg	IA10-SB0024	1/ 1	--	28.8	29.6	2.1E+02	NO:1,2
Soil (0-10 ft)	7440-48-4	Cobalt	12.9		12.9		mg/kg	IA10-SB0024	1/ 1	--	12.9	19.1	4.7E+02	NO:1,2
Soil (0-10 ft)	7440-50-8	Copper	25.4		25.4		mg/kg	IA10-SB0024	1/ 1	--	25.4	42	2.9E+02	NO:1,2
Soil (0-10 ft)	7439-92-1	Lead	8.9	N	338	N	mg/kg	IA10-SB0050	43/ 43	71.9	71.9	23.2	4.0E+01	YES
Soil (0-10 ft)	7439-96-5	Manganese	371		371		mg/kg	IA10-SB0024	1/ 1	--	371	2340	1.8E+02	NO:1
Soil (0-10 ft)	7439-94-7	Mercury	0.03		0.03		mg/kg	IA10-SB0024	1/ 1	--	0.03	0.19	2.3E+00	NO:1,2
Soil (0-10 ft)	7440-02-0	Nickel	34.6		34.6		mg/kg	IA10-SB0024	1/ 1	--	34.6	46.1	1.6E+02	NO:1,2
Soil (0-10 ft)	7440-00-0	Phosphorus	514		514		mg/kg	IA10-SB0024	1/ 1	--	514	808	--	NO:1
Soil (0-10 ft)	7782-49-2	Selenium	2.7		2.7		mg/kg	IA10-SB0024	1/ 1	--	2.7	2.33	3.9E+01	NO:2
Soil (0-10 ft)	7440-28-0	Thallium	0.84		0.84		mg/kg	IA10-SB0024	1/ 1	--	0.84	2.1	6.3E-01	NO:1
Soil (0-10 ft)	24678-82-8	Uranium-238*	0.908	J	16.6		pCi/g	IA10-SB0051	52/ 52	2.49	2.49	2.63	--	NO:1
Soil (0-10 ft)	7440-62-2	Vanadium	41.2		41.2		mg/kg	IA10-SB0024	1/ 1	--	41.2	42.8	5.5E+01	NO:1,2
Soil (0-10 ft)	7440-66-6	Zinc	91.2		91.2		mg/kg	IA10-SB0024	1/ 1	--	91.2	110	2.3E+03	NO:1,2
Soil (0-10 ft)	67-64-1	Acetone	19.3	B	19.3	B	ug/kg	IA10-SB0024	1/ 1	--	19.3	--	1.6E+02	NO:2
Soil (0-10 ft)	67-66-3	Chloroform	0.58	JB	0.58	JB	ug/kg	IA10-SB0024	1/ 1	--	0.58	--	2.4E-01	NO:2
Soil (0-10 ft)	108-88-3	Toluene	0.9	J	0.9	J	ug/kg	IA10-SB0024	1/ 1	--	0.9	--	5.2E+01	NO:2
Sediment	7429-90-5	Aluminum	3600		18400		mg/kg	SWSD0022	15/ 15	12200	12200	12000	--	YES
Sediment	7440-36-0	Antimony	0.36	J	0.7	J	mg/kg	SWSD0016	5/ 15	0.39	0.39	0.88	--	NO:1
Sediment	7440-38-2	Arsenic	2.8	J	21.6		mg/kg	SWSD0022	18/ 18	6.71	6.71	12.1	--	NO:1
Sediment	7440-39-3	Barium	49.4	J	232	J	mg/kg	SWSD0019	18/ 18	153	153	94.3	--	YES
Sediment	7440-41-7	Beryllium	0.7	B	2020	J	mg/kg	SWSD0022	18/ 18	146000	2020	0.69	--	YES
Sediment	7440-42-8	Boron	9.3	J	47.2	J	mg/kg	SWSD0022	8/ 15	37	37	15.5	--	YES
Sediment	7440-43-9	Cadmium	0.11	B	56.8		mg/kg	SWSD0005	11/ 15	113	56.8	0.51	--	YES
Sediment	7440-47-3	Chromium	9.8		36.3	J	mg/kg	SWSD0022	15/ 15	23.2	23.2	17.6	--	YES
Sediment	7440-48-4	Cobalt	2.9		28.5		mg/kg	SWSD0022	15/ 15	8.17	8.17	10	--	NO:1
Sediment	7440-50-8	Copper	7.3	J	228	J	mg/kg	SWSD0016	15/ 15	208	208	23	--	YES
Sediment	7439-92-1	Lead	13.1	J	453	J	mg/kg	SWSD0022	18/ 18	339	339	14.3	--	YES
Sediment	7439-96-5	Manganese	137	J	2300		mg/kg	SWSD0022	15/ 15	280	280	563	--	NO:1
Sediment	7439-94-7	Mercury	0.06	J	0.72		mg/kg	SWSD0022	15/ 15	0.25	0.25	--	--	YES
Sediment	7439-98-7	Molybdenum	1.4	B	5.8	J	mg/kg	SWSD0016	11/ 15	3.46	3.46	2.6	--	YES
Sediment	7440-02-0	Nickel	10.2		60.1	J	mg/kg	SWSD0022	15/ 15	42.1	42.1	25.3	--	YES
Sediment	7440-00-0	Phosphorus	1.14	J	2.64	J	mg/kg	SWSD0004	3/ 3	3.32	2.64	680	--	NO:1
Sediment	7782-49-2	Selenium	0.5	B	3.3	B	mg/kg	SWSD0022	8/ 15	1.39	1.39	1.8	--	NO:1
Sediment	7440-22-4	Silver	9.8		9.8		mg/kg	SWSD0019	1/ 15	2.83	2.83	--	--	YES
Sediment	7440-24-6	Strontium	5.5		545		mg/kg	SWSD0005	15/ 15	335	335	98.3	--	YES
Sediment	7440-28-0	Thallium	0.95	B	9.6	B	mg/kg	SWSD0022	9/ 15	1.54	1.54	3.4	--	NO:1
Sediment	24678-82-8	Uranium-238*	0.327		5.11		pCi/g	SWSD0022	15/ 15	2.38	2.38	2.08	--	YES
Sediment	7440-62-2	Vanadium	8.3		36.7		mg/kg	SWSD0022	15/ 15	24.2	24.2	24.8	--	NO:1
Sediment	7440-66-6	Zinc	25.5		712	J	mg/kg	SWSD0016	15/ 15	549	549	108	--	YES

TABLE 6.3 IDENTIFICATION OF NON-RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR HUMAN HEALTH
EXPOSURE UNIT 3 - OFF SITE RESIDENTIAL/AGRICULTURAL LANDS (Continued)

MEDIUM	CAS NUMBER	PARAMETER	MINIMUM DETECTION		MAXIMUM DETECTION		UNITS	LOCATION OF MAXIMUM	DETECTION FREQUENCY	UCL95	VALUE FOR COMPARISON	BKGD. VALUE	PRG[a]	COPC
Sediment	7782-50-5	Chloride	14.6		779	J	mg/kg	SWSD0016	6/ 6	10600	779	--	--	YES
Sediment	16984-48-8	Fluoride	2.14		163		mg/kg	IA06-SD0001	9/ 9	678	163	5.35	--	YES
Sediment	205-99-2	Benzo(b)fluoranthene	1400	J	2250	J	ug/kg	SWSD0016	3/ 14	4380	2250	--	--	YES
Sediment	191-24-2	Benzo(ghi)perylene	448	J	448	J	ug/kg	IA06-SD0005	1/ 14	4030	448	--	--	YES
Sediment	207-08-9	Benzo(k)fluoranthene	1130	J	1130	J	ug/kg	SWSD0009	1/ 14	4340	1130	--	--	YES
Sediment	218-01-9	Chrysene	1090	J	2050		ug/kg	SWSD0009	2/ 14	4350	2050	--	--	YES
Sediment		Di-n-octylphthalate	479	J	479	J	ug/kg	IA06-SD0005	1/ 14	4260	479	--	--	YES
Sediment	206-44-0	Fluoranthene	886	J	5430		ug/kg	SWSD0009	4/ 14	4830	4830	--	--	YES
Sediment	193-39-5	Indeno(1,2,3-c,d)pyrene	452	J	452	J	ug/kg	IA06-SD0005	1/ 14	4030	452	--	--	YES
Sediment	85-01-8	Phenanthrene	2510	J	3630		ug/kg	SWSD0009	3/ 14	4550	3630	--	--	YES
Sediment	129-00-0	Pyrene	1750	J	3640		ug/kg	SWSD0009	2/ 14	5070	3640	--	--	YES
Sediment	117-81-7	bis(2-ethylhexyl)phthalate	1030	J	11000		ug/kg	IA06-SD0005	4/ 14	5190	5190	--	--	YES
Sediment	78-93-3	2-Butanone	4.3	J	14.9		ug/kg	IA06-SD0005	4/ 9	7.37	7.37	--	--	YES
Sediment	67-64-1	Acetone	21.5	J	365		ug/kg	IA06-SD0004	7/ 9	221	221	--	--	YES
Sediment	71-43-2	Benzene	0.83	J	5.2	J	ug/kg	IA06-SD0004	3/ 9	3.13	3.13	--	--	YES
Sediment	75-15-0	Carbon disulfide	3.6	J	41.2		ug/kg	IA06-SD0005	3/ 9	14.8	14.8	--	--	YES
Sediment	75-00-3	Chloroethane	32.4		32.4		ug/kg	IA06-SD0001	1/ 9	10.3	10.3	--	--	YES
Sediment	100-41-4	Ethylbenzene	0.67	J	3.2	J	ug/kg	IA06-SD0004	3/ 9	13.5	3.2	--	--	YES
Sediment	75-09-2	Methylene chloride	0.58	BJ	0.86	BJ	ug/kg	IA06-SD0004	2/ 9	13.4	0.86	--	--	YES
Sediment	108-88-3	Toluene	0.76	J	54.6		ug/kg	SWSD0009	8/ 9	296	54.6	--	--	YES
Sediment	1330-20-7	Xylenes (total)	0.77	J	9.9		ug/kg	IA06-SD0004	3/ 9	40.5	9.9	--	--	YES
Soil (0-2 ft)	7429-90-5	Aluminum	19900		19900		mg/kg	IA10-SB0024	1/ 1	--	19900	23700	7.6E+03	NO:1
Soil (0-2 ft)	7440-38-2	Arsenic	2.4	N	15.6	N	mg/kg	IA10-SB0045	41/ 41	7.79	7.79	24.1	3.9E-01	NO:1
Soil (0-2 ft)	7440-39-3	Barium	25.4		479		mg/kg	IA10-SB0045	41/ 41	128	128	209	5.4E+02	NO:1,2
Soil (0-2 ft)	7440-41-7	Beryllium	0.63		2560	N	mg/kg	IA10-SB0051	79/ 79	155	155	1.13	1.5E+01	YES
Soil (0-2 ft)	7440-47-3	Chromium	28.8		28.8		mg/kg	IA10-SB0024	1/ 1	--	28.8	29.6	2.1E+02	NO:1,2
Soil (0-2 ft)	7440-48-4	Cobalt	12.9		12.9		mg/kg	IA10-SB0024	1/ 1	--	12.9	19.1	4.7E+02	NO:1,2
Soil (0-2 ft)	7440-50-8	Copper	25.4		25.4		mg/kg	IA10-SB0024	1/ 1	--	25.4	42	2.9E+02	NO:1,2
Soil (0-2 ft)	7439-92-1	Lead	8.9	N	338	N	mg/kg	IA10-SB0050	41/ 41	74	74	23.2	4.0E+01	YES
Soil (0-2 ft)	7439-96-5	Manganese	371		371		mg/kg	IA10-SB0024	1/ 1	--	371	2340	1.8E+02	NO:1
Soil (0-2 ft)	7439-94-7	Mercury	0.03		0.03		mg/kg	IA10-SB0024	1/ 1	--	0.03	0.19	2.3E+00	NO:1,2
Soil (0-2 ft)	7440-02-0	Nickel	34.6		34.6		mg/kg	IA10-SB0024	1/ 1	--	34.6	46.1	1.6E+02	NO:1,2
Soil (0-2 ft)	7440-00-0	Phosphorus	514		514		mg/kg	IA10-SB0024	1/ 1	--	514	808	--	NO:1
Soil (0-2 ft)	7782-49-2	Selenium	2.7		2.7		mg/kg	IA10-SB0024	1/ 1	--	2.7	2.33	3.9E+01	NO:2
Soil (0-2 ft)	7440-28-0	Thallium	0.84		0.84		mg/kg	IA10-SB0024	1/ 1	--	0.84	2.1	6.3E-01	NO:1
Soil (0-2 ft)	24678-82-8	Uranium-238*	0.908	J	16.6		pCi/g	IA10-SB0051	50/ 50	2.51	2.51	2.63	--	NO:1
Soil (0-2 ft)	7440-62-2	Vanadium	41.2		41.2		mg/kg	IA10-SB0024	1/ 1	--	41.2	42.8	5.5E+01	NO:1,2
Soil (0-2 ft)	7440-66-6	Zinc	91.2		91.2		mg/kg	IA10-SB0024	1/ 1	--	91.2	110	2.3E+03	NO:1,2

TABLE 6.3 IDENTIFICATION OF NON-RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR HUMAN HEALTH
EXPOSURE UNIT 3 - OFF SITE RESIDENTIAL/AGRICULTURAL LANDS (Continued)

MEDIUM	CAS NUMBER	PARAMETER	MINIMUM DETECTION		MAXIMUM DETECTION		UNITS	LOCATION OF MAXIMUM	DETECTION FREQUENCY	UCL95	VALUE FOR COMPARISON	BKGD. VALUE	PRG[a]	COPC
Soil (0-2 ft)	67-64-1	Acetone	19.3	B	19.3	B	ug/kg	IA10-SB0024	1/ 1	--	19.3	--	1.6E+02	NO:2
Soil (0-2 ft)	67-66-3	Chloroform	0.58	JB	0.58	JB	ug/kg	IA10-SB0024	1/ 1	--	0.58	--	2.4E-01	NO:2
Soil (0-2 ft)	108-88-3	Toluene	0.9	J	0.9	J	ug/kg	IA10-SB0024	1/ 1	--	0.9	--	5.2E+01	NO:2
Surf. Water	7429-90-5	Aluminum	132		3340		ug/l	SWSD0009	7/ 11	1090	1090	733	--	YES
Surf. Water	7440-38-2	Arsenic	2.6	B	125		ug/l	SWSD0022	3/ 14	3.08	3.08	--	--	YES
Surf. Water	7440-39-3	Barium	13.4		219		ug/l	IA06-SD0005	14/ 14	188	188	38.8	--	YES
Surf. Water	7440-41-7	Beryllium	0.23	B	83.6		ug/l	IA06-SD0004	13/ 14	283	83.6	--	--	YES
Surf. Water	7440-42-8	Boron	53.8		475		ug/l	SWSD0016	10/ 11	235	235	--	--	YES
Surf. Water	7440-43-9	Cadmium	0.47	B	42.2		ug/l	SWSD0022	5/ 11	1.06	1.06	--	--	YES
Surf. Water	7440-47-3	Chromium	0.78	B	125		ug/l	SWSD0022	6/ 11	2.27	2.27	1.2	--	YES
Surf. Water	7440-48-4	Cobalt	0.95	B	126		ug/l	SWSD0022	5/ 11	1.21	1.21	--	--	YES
Surf. Water	7440-50-8	Copper	4.3	B	127		ug/l	SWSD0022	10/ 11	23.3	23.3	4.6	--	YES
Surf. Water	7439-92-1	Lead	1.8		181		ug/l	IA06-SD0005	7/ 14	45.8	45.8	1.2	--	YES
Surf. Water	7439-96-5	Manganese	2.6	B	248		ug/l	SWSD0006	11/ 11	1540	248	19.7	--	YES
Surf. Water	7439-94-7	Mercury	0.13	B	0.27		ug/l	SWSD0012	3/ 11	0.13	0.13	--	--	YES
Surf. Water	7439-98-7	Molybdenum	48.8		49		ug/l	SWSD0022	2/ 11	22.6	22.6	11.1	--	YES
Surf. Water	7440-02-0	Nickel	3.9	B	131		ug/l	SWSD0022	10/ 11	42.7	42.7	--	--	YES
Surf. Water	7440-00-0	Phosphorus	0.039	J	5.96		ug/l	SWSD0016	5/ 6	3.57	3.57	--	--	YES
Surf. Water	7782-49-2	Selenium	124		124		ug/l	SWSD0022	1/ 11	1.32	1.32	--	--	YES
Surf. Water	7440-22-4	Silver	43.2		43.2		ug/l	SWSD0022	1/ 11	0.88	0.88	--	--	YES
Surf. Water	7440-24-6	Strontium	409		16800		ug/l	SWSD0009	10/ 11	10400	10400	1450	--	YES
Surf. Water	7440-28-0	Thallium	251		251		ug/l	SWSD0022	1/ 11	1.98	1.98	--	--	YES
Surf. Water	24678-82-8	Uranium-238*	0.31		4.5		pCi/L	SWSD0022	8/ 14	1.21	1.21	1.02	--	YES
Surf. Water	7440-62-2	Vanadium	0.47	B	124		ug/l	SWSD0022	6/ 11	3.25	3.25	2.2	--	YES
Surf. Water	7440-66-6	Zinc	12.2		129		ug/l	SWSD0022	11/ 11	46.3	46.3	--	--	YES
Surf. Water	ALK	Alkalinity	69		522		mg/l	SWSD0016	10/ 10	369	369	--	--	YES
Surf. Water	NH_4	Ammonia	0.08		26.8		mg/l	SWSD0012	10/ 10	10.8	10.8	--	--	YES
Surf. Water	7782-50-5	Chloride	12.8		961		mg/l	SWSD0010	6/ 6	49800	961	--	--	YES
Surf. Water	16984-48-8	Fluoride	0.58		9.11		mg/l	SWSD0022	8/ 9	72.3	9.11	0.18	--	YES
Surf. Water	SO_4	Sulfate	50.2		378		mg/l	SWSD0022	6/ 6	383	378	--	--	YES
Surf. Water		Di-n-octylphthalate	10.8		10.8		ug/l	SWSD0016	1/ 13	10.2	10.2	--	--	YES
Surf. Water	84-66-2	Diethyl phthalate	5.1	J	5.1	J	ug/l	SWSD0012	1/ 13	9.88	5.1	--	--	YES
Surf. Water	108-95-2	Phenol	6.4	J	6.4	J	ug/l	SWSD0012	1/ 11	11.6	6.4	--	--	YES
Surf. Water	117-81-7	bis(2-ethylhexyl)phthalate	25.4		25.4		ug/l	SWSD0004	1/ 13	22.6	22.6	--	--	YES
Surf. Water	106-44-5	m,p-cresol	17.3		17.3		ug/l	SWSD0012	1/ 8	11.1	11.1	--	--	YES
Surf. Water	78-93-3	2-Butanone	9.1	J	9.1	J	ug/l	IA06-SD0004	1/ 13	5.75	5.75	--	--	YES
Surf. Water	67-64-1	Acetone	4.4	J	59	J	ug/l	SWSD0012	2/ 9	18.8	18.8	--	--	YES

TABLE 6.3 IDENTIFICATION OF NON-RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR HUMAN HEALTH
EXPOSURE UNIT 3 - OFF SITE RESIDENTIAL/AGRICULTURAL LANDS (Continued)

MEDIUM	CAS NUMBER	PARAMETER	MINIMUM DETECTION		MAXIMUM DETECTION		UNITS	LOCATION OF MAXIMUM	DETECTION FREQUENCY	UCL95	VALUE FOR COMPARISON	BKGD. VALUE	PRG[a]	COPC
Surf. Water	75-27-4	Bromodichloromethane	0.33	J	0.6	J	ug/l	SWSD0019	2/ 10	9.34	0.6	--	--	YES
Surf. Water	67-66-3	Chloroform	0.44	J	0.76	J	ug/l	SWSD0005	2/ 13	8.16	0.76	--	--	YES
Surf. Water	124-48-1	Dibromochloromethane	0.22	J	3.4	J	ug/l	SWSD0019	2/ 10	9.25	3.4	--	--	YES
Surf. Water	127-18-4	Tetrachloroethene	1.3	J	1.3	J	ug/l	IA06-SD0001	1/ 13	8.41	1.3	--	--	YES
Surf. Water		Tribromomethane	6	J	6	J	ug/l	SWSD0019	1/ 10	8.75	6	--	--	YES

a = USEPA Region 9 Residential PRGs. Lower of 1E-6 Cancer PRG or 1/10 Noncancer PRG. Note that All soil PRGs reported as mg/kg and all tap water PRGs reported as ug/L
NO:0 = Frequency of Detection Less than 5%
NO:1 = Comparison value less than background value
NO:2 = Comparison value less than PRG
YES = Chemical is a COPC
*Only the alpha-spectrum data was used to calculate the 95% UCL. The concentration of uranium-238 in soil was converted from pCi/g to mg/kg and in water from pCi/L to mg/L for evaluation of risk.

TABLE 6.4 IDENTIFICATION OF NON-RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR HUMAN HEALTH
EXPOSURE UNIT 4 - TOUSSAINT CREEK DOWNSTREAM OF LUCKEY

MEDIUM	CAS NUMBER	PARAMETER	MINIMUM DETECTION		MAXIMUM DETECTION		UNITS	LOCATION OF MAXIMUM	DETECTION FREQUENCY	UCL95	VALUE FOR COMPARISON	BKGD. VALUE	PRG[a]	COPC
Soil (0-10 ft)	7429-90-5	Aluminum	8210		15500		mg/kg	IA10-SB0015	3/ 3	20000	15500	23700	7.6E+03	NO:1
Soil (0-10 ft)	7440-36-0	Antimony	1.5	BN	1.5	BN	mg/kg	IA10-SB0015	1/ 3	1.9	1.5	0.9	3.1E+00	NO:2
Soil (0-10 ft)	7440-38-2	Arsenic	5.1		12		mg/kg	IA10-SB0008	30/ 30	7.81	7.81	24.1	3.9E-01	NO:1
Soil (0-10 ft)	7440-39-3	Barium	58.9	N	92.9		mg/kg	IA10-SB0019	30/ 30	82.9	82.9	209	5.4E+02	NO:1,2
Soil (0-10 ft)	7440-41-7	Beryllium	0.29		89.7		mg/kg	IA10-SB0011	47/ 47	20.7	20.7	1.13	1.5E+01	YES
Soil (0-10 ft)	7440-43-9	Cadmium	0.19		2.1		mg/kg	IA10-SB0015	3/ 3	2.97	2.1	0.98	3.7E+00	NO:2
Soil (0-10 ft)	7440-47-3	Chromium	13.4		22		mg/kg	IA10-SB0015	3/ 3	26.9	22	29.6	2.1E+02	NO:1,2
Soil (0-10 ft)	7440-48-4	Cobalt	9.7		10.2		mg/kg	IA10-SB0008	3/ 3	10.4	10.2	19.1	4.7E+02	NO:1,2
Soil (0-10 ft)	7440-50-8	Copper	23.3		25.4		mg/kg	IA10-SB0020	3/ 3	26.2	25.4	42	2.9E+02	NO:1,2
Soil (0-10 ft)	7439-92-1	Lead	10.4		34.7		mg/kg	IA10-SB0010	30/ 30	25.3	25.3	23.2	4.0E+01	NO:2
Soil (0-10 ft)	7439-96-5	Manganese	480		550		mg/kg	IA10-SB0015	3/ 3	574	550	2340	1.8E+02	NO:1
Soil (0-10 ft)	7439-94-7	Mercury	0.04	B	0.08	B	mg/kg	IA10-SB0015	3/ 3	0.09	0.08	0.19	2.3E+00	NO:1,2
Soil (0-10 ft)	7440-02-0	Nickel	26.6		28.1		mg/kg	IA10-SB0008	3/ 3	28.6	28.1	46.1	1.6E+02	NO:1,2
Soil (0-10 ft)	7440-00-0	Phosphorus	430		703		mg/kg	IA10-SB0020	3/ 3	826	703	808	--	NO:1
Soil (0-10 ft)	7782-49-2	Selenium	1.4		1.8		mg/kg	IA10-SB0008	3/ 3	1.92	1.8	2.33	3.9E+01	NO:1,2
Soil (0-10 ft)	7440-28-0	Thallium	2.3		2.3		mg/kg	IA10-SB0015	1/ 3	2.91	2.3	2.1	6.3E-01	YES
Soil (0-10 ft)	24678-82-8	Uranium-238*	0.594	J	1.5		pCi/g	IA10-SB0015	30/ 30	1.16	1.16	2.63	--	NO:1
Soil (0-10 ft)	7440-62-2	Vanadium	17.5		32.2		mg/kg	IA10-SB0020	3/ 3	41.4	32.2	42.8	5.5E+01	NO:1,2
Soil (0-10 ft)	7440-66-6	Zinc	72.3		98.7		mg/kg	IA10-SB0020	3/ 3	114	98.7	110	2.3E+03	NO:1,2
Soil (0-10 ft)	100-41-4	Ethylbenzene	0.76	J	1	J	ug/kg	IA10-SB0015	2/ 3	2.82	1	--	2.3E+01	NO:2
Soil (0-10 ft)	108-88-3	Toluene	0.86	J	2.6		ug/kg	IA10-SB0020	3/ 3	3.19	2.6	--	5.2E+01	NO:2
Soil (0-10 ft)	1330-20-7	Xylenes (total)	0.52	J	2.7	J	ug/kg	IA10-SB0015	3/ 3	3.39	2.7	--	2.1E+01	NO:2
Sediment	7429-90-5	Aluminum	4210		10700		mg/kg	BH0018	17/ 17	7870	7870	12000	--	NO:1
Sediment	7440-38-2	Arsenic	2.8	J	31.3		mg/kg	IA06-SD0012	62/ 62	7.52	7.52	12.1	--	NO:1
Sediment	7440-39-3	Barium	15.3		145		mg/kg	IA06-SD0019	49/ 49	53.9	53.9	94.3	--	NO:1
Sediment	7440-41-7	Beryllium	0.43		223		mg/kg	SWSD0015	62/ 62	17.6	17.6	0.69	--	YES
Sediment	7440-42-8	Boron	7.3	B	10.1	J	mg/kg	SWSD0014	4/ 4	10.5	10.1	15.5	--	NO:1
Sediment	7440-43-9	Cadmium	0.56	B	32.3		mg/kg	SWSD0013	4/ 4	27.5	27.5	0.51	--	YES
Sediment	7440-47-3	Chromium	10.9		13.1		mg/kg	SWSD0013	4/ 4	12.8	12.8	17.6	--	NO:1
Sediment	7440-48-4	Cobalt	6.8		9.6		mg/kg	SWSD0015	4/ 4	9.27	9.27	10	--	NO:1
Sediment	7440-50-8	Copper	14.6	J	23.1		mg/kg	SWSD0015	4/ 4	23.8	23.1	23	--	YES
Sediment	7439-92-1	Lead	6.2	J	2170		mg/kg	BH0018	62/ 62	107	107	14.3	--	YES
Sediment	7439-96-5	Manganese	271		351	J	mg/kg	SWSD0008	4/ 4	350	350	563	--	NO:1
Sediment	7439-94-7	Mercury	0.03	B	0.07		mg/kg	SWSD0015	4/ 4	0.07	0.07	--	--	YES
Sediment	7439-98-7	Molybdenum	2.3	B	5	B	mg/kg	SWSD0015	4/ 4	4.66	4.66	2.6	--	YES
Sediment	7440-02-0	Nickel	15.8		19.2		mg/kg	SWSD0015	4/ 4	19	19	25.3	--	NO:1
Sediment	7440-00-0	Phosphorus	2.68	J	2.68	J	mg/kg	SWSD0013	1/ 1	2.68	2.68	680	--	NO:1
Sediment	7782-49-2	Selenium	0.42	B	0.5	B	mg/kg	SWSD0008	2/ 4	0.52	0.5	1.8	--	NO:1
Sediment	7440-22-4	Silver	0.27	B	0.76	B	mg/kg	SWSD0015	3/ 4	0.68	0.68	--	--	YES
Sediment	7440-24-6	Strontium	115		192	J	mg/kg	SWSD0013	4/ 4	185	185	98.3	--	YES
Sediment	7440-28-0	Thallium	1.1	B	1.1	B	mg/kg	SWSD0008	1/ 4	1.03	1.03	3.4	--	NO:1
Sediment	24678-82-8	Uranium-238*	0.327	J	13		pCi/g	IA06-SD0029	62/ 62	1.36	1.36	2.08	--	NO:1
Sediment	7440-62-2	Vanadium	15.3		18.1		mg/kg	SWSD0015	4/ 4	18.7	18.1	24.8	--	NO:1

TABLE 6.4 IDENTIFICATION OF NON-RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR HUMAN HEALTH
EXPOSURE UNIT 4 - TOUSSAINT CREEK DOWNSTREAM OF LUCKEY (Continued)

MEDIUM	CAS NUMBER	PARAMETER	MINIMUM DETECTION		MAXIMUM DETECTION		UNITS	LOCATION OF MAXIMUM	DETECTION FREQUENCY	UCL95	VALUE FOR COMPARISON	BKGD. VALUE	PRG[a]	COPC
Sediment	7440-66-6	Zinc	52		79.4		mg/kg	SWSD0013	4/ 4	76.9	76.9	108	--	NO:1
Sediment	7782-50-5	Chloride	16.5		16.5		mg/kg	SWSD0013	1/ 1	22.7	16.5	--	--	YES
Sediment	120-12-7	Anthracene	116	J	116	J	ug/kg	SWSD0015	1/ 4	535	116	--	--	YES
Sediment	56-55-3	Benzo(a)anthracene	74.5	J	74.5	J	ug/kg	SWSD0014	1/ 4	534	74.5	--	--	YES
Sediment	50-32-8	Benzo(a)pyrene	34	J	199	J	ug/kg	SWSD0015	3/ 4	531	199	--	--	YES
Sediment	205-99-2	Benzo(b)fluoranthene	52.5	J	271	J	ug/kg	SWSD0015	3/ 4	538	271	--	--	YES
Sediment	191-24-2	Benzo(ghi)perylene	44.6	J	88	J	ug/kg	SWSD0015	2/ 4	534	88	--	--	YES
Sediment	207-08-9	Benzo(k)fluoranthene	48.6	J	109	J	ug/kg	SWSD0015	2/ 4	534	109	--	--	YES
Sediment	86-74-8	Carbazole	164	J	164	J	ug/kg	SWSD0015	1/ 4	533	164	--	--	YES
Sediment	218-01-9	Chrysene	45.3	J	253	J	ug/kg	SWSD0015	3/ 4	536	253	--	--	YES
Sediment	53-70-3	Dibenz(a,h)anthracene	9.2	J	9.2	J	ug/kg	SWSD0015	1/ 4	541	9.2	--	--	YES
Sediment	132-64-9	Dibenzofuran	18.9	J	18.9	J	ug/kg	SWSD0015	1/ 4	541	18.9	--	--	YES
Sediment	84-66-2	Diethyl phthalate	25.5	J	48.2	J	ug/kg	SWSD0014	3/ 4	523	48.2	--	--	YES
Sediment	206-44-0	Fluoranthene	59.6	J	534		ug/kg	SWSD0015	3/ 4	586	534	--	--	YES
Sediment	86-73-7	Fluorene	64	J	64	J	ug/kg	SWSD0015	1/ 4	538	64	--	--	YES
Sediment	193-39-5	Indeno(1,2,3-c,d)pyrene	14	J	86.2	J	ug/kg	SWSD0015	2/ 4	535	86.2	--	--	YES
Sediment	85-01-8	Phenanthrene	81	J	402		ug/kg	SWSD0015	2/ 4	556	402	--	--	YES
Sediment	129-00-0	Pyrene	62.7	J	420		ug/kg	SWSD0015	3/ 4	557	420	--	--	YES
Sediment	117-81-7	bis(2-ethylhexyl)phthalate	56.8	J	84.7	J	ug/kg	SWSD0014	2/ 4	528	84.7	--	--	YES
Sediment	78-93-3	2-Butanone	4.7	J	4.7	J	ug/kg	SWSD0008	1/ 1	--	4.7	--	--	YES
Sediment	67-64-1	Acetone	58.4	J	58.4	J	ug/kg	SWSD0008	1/ 1	--	58.4	--	--	YES
Sediment	108-88-3	Toluene	24		24		ug/kg	SWSD0008	1/ 1	--	24	--	--	YES
Soil (0-2 ft)	7429-90-5	Aluminum	15300		15500		mg/kg	IA10-SB0015	2/ 2	16000	15500	23700	7.6E+03	NO:1
Soil (0-2 ft)	7440-36-0	Antimony	1.5	BN	1.5	BN	mg/kg	IA10-SB0015	1/ 2	4.48	1.5	0.9	3.1E+00	NO:2
Soil (0-2 ft)	7440-38-2	Arsenic	5.1		11.7		mg/kg	IA10-SB0010	29/ 29	7.6	7.6	24.1	3.9E-01	NO:1
Soil (0-2 ft)	7440-39-3	Barium	58.9	N	92.9		mg/kg	IA10-SB0019	29/ 29	83.3	83.3	209	5.4E+02	NO:1,2
Soil (0-2 ft)	7440-41-7	Beryllium	0.95		89.7		mg/kg	IA10-SB0011	30/ 30	28.9	28.9	1.13	1.5E+01	YES
Soil (0-2 ft)	7440-43-9	Cadmium	1.6		2.1		mg/kg	IA10-SB0015	2/ 2	3.43	2.1	0.98	3.7E+00	NO:2
Soil (0-2 ft)	7440-47-3	Chromium	21.2		22		mg/kg	IA10-SB0015	2/ 2	24.1	22	29.6	2.1E+02	NO:1,2
Soil (0-2 ft)	7440-48-4	Cobalt	9.7		10.1		mg/kg	IA10-SB0015	2/ 2	11.2	10.1	19.1	4.7E+02	NO:1,2
Soil (0-2 ft)	7440-50-8	Copper	23.3		25.4		mg/kg	IA10-SB0020	2/ 2	31	25.4	42	2.9E+02	NO:1,2
Soil (0-2 ft)	7439-92-1	Lead	10.4		34.7		mg/kg	IA10-SB0010	29/ 29	25.6	25.6	23.2	4.0E+01	NO:2
Soil (0-2 ft)	7439-96-5	Manganese	514		550		mg/kg	IA10-SB0015	2/ 2	646	550	2340	1.8E+02	NO:1
Soil (0-2 ft)	7439-94-7	Mercury	0.06	B	0.08	B	mg/kg	IA10-SB0015	2/ 2	0.13	0.08	0.19	2.3E+00	NO:1,2
Soil (0-2 ft)	7440-02-0	Nickel	26.6		26.6		mg/kg	IA10-SB0020	2/ 2	26.6	26.6	46.1	1.6E+02	NO:1,2
Soil (0-2 ft)	7440-00-0	Phosphorus	630		703		mg/kg	IA10-SB0020	2/ 2	897	703	808	--	NO:1
Soil (0-2 ft)	7782-49-2	Selenium	1.4		1.5		mg/kg	IA10-SB0015	2/ 2	1.77	1.5	2.33	3.9E+01	NO:1,2
Soil (0-2 ft)	7440-28-0	Thallium	2.3		2.3		mg/kg	IA10-SB0015	1/ 2	6.82	2.3	2.1	6.3E-01	YES
Soil (0-2 ft)	24678-82-8	Uranium-238*	0.594	J	1.5		pCi/g	IA10-SB0015	29/ 29	1.15	1.15	2.63	--	NO:1
Soil (0-2 ft)	7440-62-2	Vanadium	31.9		32.2		mg/kg	IA10-SB0020	2/ 2	33	32.2	42.8	5.5E+01	NO:1,2
Soil (0-2 ft)	7440-66-6	Zinc	96.2		98.7		mg/kg	IA10-SB0020	2/ 2	105	98.7	110	2.3E+03	NO:1,2
Soil (0-2 ft)	100-41-4	Ethylbenzene	0.76	J	1	J	ug/kg	IA10-SB0015	2/ 2	1.64	1	--	2.3E+01	NO:2
Soil (0-2 ft)	108-88-3	Toluene	1.7	J	2.6		ug/kg	IA10-SB0020	2/ 2	4.99	2.6	--	5.2E+01	NO:2
Soil (0-2 ft)	1330-20-7	Xylenes (total)	1.4	J	2.7	J	ug/kg	IA10-SB0015	2/ 2	6.15	2.7	--	2.1E+01	NO:2
Surf. Water	7429-90-5	Aluminum	194		1700		ug/l	IA06-SW0002	5/ 6	981	981	733	--	YES
Surf. Water	7440-38-2	Arsenic	2.7	B	8.7		ug/l	IA06-SW0002	5/ 14	3.91	3.91	--	--	YES

TABLE 6.4 IDENTIFICATION OF NON-RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR HUMAN HEALTH
EXPOSURE UNIT 4 - TOUSSAINT CREEK DOWNSTREAM OF LUCKEY (Continued)

MEDIUM	CAS NUMBER	PARAMETER	MINIMUM DETECTION		MAXIMUM DETECTION		UNITS	LOCATION OF MAXIMUM	DETECTION FREQUENCY	UCL95	VALUE FOR COMPARISON	BKGD. VALUE	PRG[a]	COPC
Surf. Water	7440-39-3	Barium	41.4		109		ug/l	IA06-SW0002	14/ 14	69.3	69.3	38.8	--	YES
Surf. Water	7440-41-7	Beryllium	0.39		5.1		ug/l	IA06-SW0002	11/ 14	2.55	2.55	--	--	YES
Surf. Water	7440-42-8	Boron	76.4	J	160	J	ug/l	SWSD0014	5/ 5	151	151	--	--	YES
Surf. Water	7440-43-9	Cadmium	0.43	B	1	B	ug/l	SWSD0013	3/ 6	0.81	0.81	--	--	YES
Surf. Water	7440-47-3	Chromium	0.86	B	0.89	B	ug/l	SWSD0008	2/ 6	1.34	0.89	1.2	--	NO:1
Surf. Water	7440-48-4	Cobalt	0.7	B	1.6		ug/l	IA06-SW0002	5/ 6	1.47	1.47	--	--	YES
Surf. Water	7440-50-8	Copper	8.4		8.4		ug/l	IA06-SW0002	1/ 6	5.64	5.64	4.6	--	YES
Surf. Water	7439-92-1	Lead	2		10.3	B	ug/l	SWSD0015	6/ 14	3.56	3.56	1.2	--	YES
Surf. Water	7439-96-5	Manganese	28.4		720		ug/l	SWSD0008	6/ 6	662	662	19.7	--	YES
Surf. Water	7439-98-7	Molybdenum	6.4	B	16.4	B	ug/l	SWSD0008	3/ 5	14.3	14.3	11.1	--	YES
Surf. Water	7440-02-0	Nickel	4.8		36.4		ug/l	SWSD0013	6/ 6	26.8	26.8	--	--	YES
Surf. Water	7440-00-0	Phosphorus	0.134	J	287		ug/l	IA06-SW0002	2/ 2	0.38	0.38	--	--	YES
Surf. Water	7440-24-6	Strontium	3110		7820		ug/l	SWSD0013	5/ 5	6610	6610	1450	--	YES
Surf. Water	7440-28-0	Thallium	5.3		5.3		ug/l	IA06-SW0002	1/ 6	4.75	4.75	--	--	YES
Surf. Water	24678-82-8	Uranium-238*	0.144	J	3.19		pCi/l	IA06-SW0002	12/ 14	1.11	1.11	1.02	--	YES
Surf. Water	7440-62-2	Vanadium	1.2	B	5.5		ug/l	IA06-SW0002	4/ 6	3.31	3.31	2.2	--	YES
Surf. Water	7440-66-6	Zinc	11.8		14.4		ug/l	IA06-SW0002	2/ 6	12.9	12.9	--	--	YES
Surf. Water	ALK	Alkalinity	187		298	J	mg/l	SWSD0014	5/ 5	301	298	--	--	YES
Surf. Water	NH_4	Ammonia	0.04	J	5.55		mg/l	SWSD0014	4/ 5	4.15	4.15	--	--	YES
Surf. Water	7782-50-5	Chloride	63.3		63.3		mg/l	SWSD0013	1/ 1	--	63.3	--	--	YES
Surf. Water	16984-48-8	Fluoride	0.18		0.979		mg/l	SWSD0013	10/ 10	0.56	0.56	0.18	--	YES
Surf. Water	SO_4	Sulfate	355		355		mg/l	SWSD0013	1/ 1	--	355	--	--	YES
Surf. Water	117-81-7	bis(2-ethylhexyl)phthalate	35.9		35.9		ug/l	SWSD0008	1/ 5	16.9	16.9	--	--	YES
Surf. Water	67-64-1	Acetone	4.4	J	4.4	J	ug/l	SWSD0008	1/ 5	15.6	4.4	--	--	YES
Surf. Water	67-66-3	Chloroform	0.16	J	0.16	J	ug/l	SWSD0008	1/ 5	13.9	0.16	--	--	YES
Surf. Water	108-88-3	Toluene	1	J	1	J	ug/l	SWSD0015	1/ 5	13	1	--	--	YES

a = USEPA Region 9 Residential PRGs. Lower of 1E-6 Cancer PRG or 1/10 Noncancer PRG. Note that All soil PRGs reported as mg/kg and all tap water PRGs reported as ug/L
NO:0 = Frequency of Detection Less than 5%
NO:1 = Comparison value less than background value
NO:2 = Comparison value less than PRG
YES = Chemical is a COPC
*Only the alpha-spectrum data was used to calculate the 95% UCL. The concentration of uranium-238 in soil was converted from pCi/g to mg/kg and in water from pCi/l to mg/l for evaluation of risk.

TABLE 6.5 IDENTIFICATION OF NON-RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR HUMAN HEALTH
EXPOSURE UNIT 5 - FRANCE STONE QUARRY

MEDIUM	CAS NUMBER	PARAMETER	MINIMUM DETECTION		MAXIMUM DETECTION		UNITS	LOCATION OF MAXIMUM	DETECTION FREQUENCY	UCL95	VALUE FOR COMPARISON	BKGD. VALUE	PRG[a]	COPC
Soil (0-10 ft)	7440-38-2	Arsenic	1.4		12.5		mg/kg	IA10-SB0072	16/ 16	9.58	9.58	24.1	3.9E-01	NO:1
Soil (0-10 ft)	7440-39-3	Barium	8.4		160		mg/kg	IA10-SB0072	16/ 16	94.8	94.8	209	5.4E+02	NO:1,2
Soil (0-10 ft)	7440-41-7	Beryllium	0.11		2.5		mg/kg	IA10-SB0072	16/ 16	1.28	1.28	1.13	1.5E+01	NO:2
Soil (0-10 ft)	7439-92-1	Lead	9.2		233		mg/kg	IA10-SB0072	16/ 16	58.6	58.6	23.2	4.0E+01	YES
Soil (0-10 ft)	16984-48-8	Fluoride	0.5	J	5.47		mg/kg	IA10-SB0076	15/ 16	2.67	2.67	6.94	3.7E+02	NO:1,2
Soil (0-10 ft)	24678-82-8	Uranium-238*	0.199	J	1.76		pCi/g	IA10-SB0072	14/ 16	1.89	1.76	2.63	--	NO:1
Soil (0-10 ft)	591-78-6	2-Hexanone	9.9	J	9.9	J	ug/kg	IA10-SB0025	1/ 1	--	9.9	--	--	YES
Soil (0-10 ft)	71-43-2	Benzene	1.4	J	1.4	J	ug/kg	IA10-SB0025	1/ 1	--	1.4	--	6.7E-01	NO:2
Soil (0-10 ft)	100-41-4	Ethylbenzene	1	J	1	J	ug/kg	IA10-SB0025	1/ 1	--	1	--	2.3E+01	NO:2
Soil (0-10 ft)	108-88-3	Toluene	3	J	3	J	ug/kg	IA10-SB0025	1/ 1	--	3	--	5.2E+01	NO:2
Soil (0-10 ft)	1330-20-7	Xylenes (total)	2.8	J	2.8	J	ug/kg	IA10-SB0025	1/ 1	--	2.8	--	2.1E+01	NO:2
Soil (0-2 ft)	7440-38-2	Arsenic	1.4		12.5		mg/kg	IA10-SB0072	15/ 15	9.57	9.57	24.1	3.9E-01	NO:1
Soil (0-2 ft)	7440-39-3	Barium	8.4		160		mg/kg	IA10-SB0072	15/ 15	102	102	209	5.4E+02	NO:1,2
Soil (0-2 ft)	7440-41-7	Beryllium	0.11		2.5		mg/kg	IA10-SB0072	15/ 15	1.39	1.39	1.13	1.5E+01	NO:2
Soil (0-2 ft)	7439-92-1	Lead	9.2		233		mg/kg	IA10-SB0072	15/ 15	61.9	61.9	23.2	4.0E+01	YES
Soil (0-2 ft)	16984-48-8	Fluoride	0.5	J	5.47		mg/kg	IA10-SB0076	14/ 15	2.61	2.61	6.94	3.7E+02	NO:1,2
Soil (0-2 ft)	24678-82-8	Uranium-238*	0.199	J	1.76		pCi/g	IA10-SB0072	13/ 15	1.98	1.76	2.63	--	NO:1
Soil (0-2 ft)	591-78-6	2-Hexanone	9.9	J	9.9	J	ug/kg	IA10-SB0025	1/ 1	--	9.9	--	--	YES
Soil (0-2 ft)	71-43-2	Benzene	1.4	J	1.4	J	ug/kg	IA10-SB0025	1/ 1	--	1.4	--	6.7E-01	NO:2
Soil (0-2 ft)	100-41-4	Ethylbenzene	1	J	1	J	ug/kg	IA10-SB0025	1/ 1	--	1	--	2.3E+01	NO:2
Soil (0-2 ft)	108-88-3	Toluene	3	J	3	J	ug/kg	IA10-SB0025	1/ 1	--	3	--	5.2E+01	NO:2
Soil (0-2 ft)	1330-20-7	Xylenes (total)	2.8	J	2.8	J	ug/kg	IA10-SB0025	1/ 1	--	2.8	--	2.1E+01	NO:2
Surf. Water	7429-90-5	Aluminum	36.3		53.2		ug/l	IA10-SW0003	2/ 2	98.1	53.2	733	--	NO:1
Surf. Water	7440-39-3	Barium	35.3		36.6		ug/l	IA10-SW0003	2/ 2	40.1	36.6	38.8	--	NO:1
Surf. Water	7440-50-8	Copper	2		2.1		ug/l	IA10-SW0004	2/ 2	2.37	2.1	4.6	--	NO:1
Surf. Water	7439-96-5	Manganese	1.7		2		ug/l	IA10-SW0004	2/ 2	2.8	2	19.7	--	NO:1
Surf. Water	7440-02-0	Nickel	1.3		1.3		ug/l	IA10-SW0003	1/ 2	3.29	1.3	--	--	YES
Surf. Water	7440-00-0	Phosphorus	46.1		59.5		ug/l	IA10-SW0004	2/ 2	95.1	59.5	--	--	YES
Surf. Water	7782-49-2	Selenium	2.5		2.5		ug/l	IA10-SW0003	1/ 2	5.95	2.5	--	--	YES
Surf. Water	24678-82-8	Uranium-238*	1.22		1.41		pCi/l	IA10-SW0004	2/ 2	1.91	1.41	1.02	--	YES
Surf. Water	7440-62-2	Vanadium	0.71		1		ug/l	IA10-SW0003	2/ 2	1.77	1	2.2	--	NO:1
Surf. Water	7440-66-6	Zinc	3.8		5.3		ug/l	IA10-SW0003	2/ 2	9.29	5.3	--	--	YES
Surf. Water	16984-48-8	Fluoride	0.16		0.17		mg/l	IA10-SW0003	2/ 2	0.2	0.17	0.18	--	NO:1

a = USEPA Region 9 Residential PRGs. Lower of 1E-6 Cancer PRG or 1/10 Noncancer PRG. Note that All soil PRGs reported as mg/kg and all tap water PRGs reported as ug/L
NO:0 = Frequency of Detection Less than 5%
NO:1 = Comparison value less than background value
NO:2 = Comparison value less than PRG
YES = Chemical is a COPC
*Only the alpha-spectrum data was used to calculate the 95% UCL for the risk assessment. The concentration of uranium-238 in soil was converted from pCi/g to mg/kg and in water from pCi/l to mg/l for evaluation of risk.

TABLE 6.6 IDENTIFICATION OF NON-RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR HUMAN HEALTH
EXPOSURE UNIT 6 - TROY TOWNSHIP DUMP

MEDIUM	CAS NUMBER	PARAMETER	MINIMUM DETECTION	MAXIMUM DETECTION	UNITS	LOCATION OF MAXIMUM	DETECTION FREQUENCY	UCL95	VALUE FOR COMPARISON	BKGD. VALUE	PRG[a]	COPC
Soil (0-10 ft)	7440-38-2	Arsenic	5	18.3	mg/kg	IA10-SB0088	9/ 9	13.9	13.9	24.1	3.9E-01	NO:1
Soil (0-10 ft)	7440-39-3	Barium	30.4	127 N	mg/kg	IA10-SB0088	9/ 9	105	105	209	5.4E+02	NO:1,2
Soil (0-10 ft)	7440-41-7	Beryllium	0.17	46.7	mg/kg	IA10-SB0026	15/ 15	10.6	10.6	1.13	1.5E+01	NO:2
Soil (0-10 ft)	7439-92-1	Lead	8.7	114	mg/kg	IA10-SB0026	9/ 9	90.1	90.1	23.2	4.0E+01	YES
Soil (0-10 ft)	16984-48-8	Fluoride	0.7	9.83	mg/kg	IA10-SB0026	9/ 9	6.3	6.3	6.94	3.7E+02	NO:1,2
Soil (0-10 ft)	7664-41-7	Nitrogen, Ammonia	2.5	33	mg/kg	IA10-SB0088	9/ 9	28.6	28.6	--	--	YES
Soil (0-10 ft)	24678-82-8	Uranium-238*	0.267 J	1.75	pCi/g	IA10-SB0088	9/ 9	1.36	1.36	2.63	--	NO:1
Soil (0-2 ft)	7440-41-7	Beryllium	0.33	1.9	mg/kg	IA10-SB0026	2/ 2	6.07	1.9	1.13	1.5E+01	NO:2

a = USEPA Region 9 Residential PRGs. Lower of 1E-6 Cancer PRG or 1/10 Noncancer PRG. Note that All soil PRGs reported as mg/kg and all tap water PRGs reported as ug/L
NO:0 = Frequency of Detection Less than 5%
NO:1 = Comparison value less than background value
NO:2 = Comparison value less than PRG
YES = Chemical is a COPC

TABLE 6.7 IDENTIFICATION OF NON-RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR HUMAN HEALTH
EXPOSURE UNIT 7 - SITE-WIDE GROUNDWATER

MEDIUM	CAS NUMBER	PARAMETER	MINIMUM DETECTION	MAXIMUM DETECTION	UNITS	LOCATION OF MAXIMUM	DETECTION FREQUENCY	UCL95	VALUE FOR COMPARISON	BKGD. VALUE	PRG[a]	COPC
Groundwater	7429-90-5	Aluminum	12.1	10800 J	ug/l	MW-13(S)	25/ 32	1510	1510	2960	3.6E+03	NO:1,2
Groundwater	7440-36-0	Antimony	2.1	3.9	ug/l	MW-13(S)	5/ 32	1.76	1.76	2.9	6	NO:1,2
Groundwater	7440-38-2	Arsenic	2.9	16.8	ug/l	MW-14(S)	19/ 63	3.49	3.49	4.7	50	NO:1,2
Groundwater	7440-39-3	Barium	13.2	562	ug/l	OMW-34(B)	63/ 63	104	104	105	2000	NO:1,2
Groundwater	7440-41-7	Beryllium	0.15	39.5	ug/l	MW-01(I)	21/ 67	4.84	4.84	0.79	4	YES
Groundwater	7440-43-9	Cadmium	0.35	3.1	ug/l	MW-13(S)	5/ 32	0.7	0.7	1	5	NO:1,2
Groundwater	7440-47-3	Chromium	0.47	18.3	ug/l	MW-13(S)	22/ 32	3.26	3.26	21.3	100	NO:1,2
Groundwater	7440-48-4	Cobalt	0.54	41.8	ug/l	MW-14(S)	12/ 32	5.39	5.39	1.2	2.2E+02	NO:2
Groundwater	7440-50-8	Copper	0.84	35	ug/l	MW-13(S)	21/ 32	5.33	5.33	5.6	1.4E+02	NO:1,2
Groundwater	7439-92-1	Lead	1.4	47	ug/l	MW-21(I)	45/ 63	6.39	6.39	7.2	--	NO:1
Groundwater	7439-96-5	Manganese	9.7	2160	ug/l	MW-14(S)	32/ 32	373	373	144	8.8E+01	YES
Groundwater	7439-94-7	Mercury	0.19	0.19	ug/l	MW-41(B)	1/ 30	0.07	0.07	0.1	1.1E+00	NO:0
Groundwater	7440-02-0	Nickel	1.2	2430	ug/l	MW-14(S)	32/ 32	176	176	5.5	100	YES
Groundwater	7440-00-0	Phosphorus	9.1	4570	ug/l	MW-13(S)	18/ 26	453	453	177	--	YES
Groundwater	7782-49-2	Selenium	1.9	3.7	ug/l	MW-13(S)	5/ 32	1.49	1.49	--	50	NO:2
Groundwater	7440-28-0	Thallium	6.2	9	ug/l	MW-14(S)	5/ 32	3.87	3.87	6.7	2	NO:1
Groundwater	24678-82-8	Uranium-238*	0.181 J	129	pCi/l	MW-24(S)	49/ 63	8.59	8.59	1.4	--	YES
Groundwater	7440-62-2	Vanadium	0.9	18.9	ug/l	MW-13(S)	7/ 32	3.1	3.1	6.3	2.6E+01	NO:1,2
Groundwater	7440-66-6	Zinc	0.73	95.4 J	ug/l	MW-13(S)	25/ 31	23.2	23.2	122	4700	NO:1,2
Groundwater	ALK	Alkalinity	95.6	771	mg/l	MW-14(S)	30/ 30	350	350	--	--	YES
Groundwater	7782-50-5	Chloride	5.17	255	mg/l	MW-14(S)	30/ 30	75.1	75.1	--	3.6E+02	YES
Groundwater	16984-48-8	Fluoride	0.13	2.49	mg/l	MW-24(S)	63/ 63	0.68	0.68	1.24	4000	NO:1,2
Groundwater	7664-41-7	Nitrogen, Ammonia	0.03 J	22.1	mg/l	MW-06(S)	50/ 60	2.4	2.4	0.21	--	YES
Groundwater	SO_4	Sulfate	44.8	2170	mg/l	MW-14(S)	30/ 30	599	599	--	--	YES
Groundwater	TPH	Total Petro. Hydrocarbons	0.82 J	0.82 J	mg/l	MW-21(I)	1/ 1	--	0.82	--	--	YES
Groundwater	156-59-2	1,2-Dichloroethylene	4.5 J	4.5 J	ug/l	MW-41(B)	1/ 30	2.68	2.68	--	70	NO:0
Groundwater	75-15-0	Carbon disulfide	0.81 J	1.2 J	ug/l	MW-07(I)	3/ 30	2.49	1.2	--	1.0E+02	NO:2
Groundwater	74-83-9	Methyl Bromide	0.82 J	0.82 J	ug/l	MW-21(I)	1/ 30	5.1	0.82	--	8.7E-01	NO:0
Groundwater	79-01-6	Trichloroethene	2.6 J	2.6 J	ug/l	MW-41(B)	1/ 30	2.51	2.51	--	5	NO:0

a = USEPA Region 9 Residential PRGs. Lower of 1E-6 Cancer PRG or 1/10 Noncancer PRG. Note that All soil PRGs reported as mg/kg and all tap water PRGs reported as ug/L
NO:0 = Frequency of Detection Less than 5%
NO:1 = Comparison value less than background value
NO:2 = Comparison value less than PRG
YES = Chemical is a COPC
*Only the alpha-spectrum data was used to calculate the 95% UCL. The concentration of uranium-238 in water was converted from pCi/l to mg/l for evaluation of non-cancer risk.

Table 6.8 Reasonable Maximum Exposure Parameters for Chemical Exposures by Medium and Receptor, Current Land Use Receptors

Parameter	Units	On site	Off site		Toussaint Creek	Quarry	Landfill	Reference
		Industrial Worker	Resident Farmer - Adult	Resident Farmer - Child	Adolescent Trespasser	Adolescent Trespasser	Adolescent Trespasser	
Medium/pathway								
Surface soil (0 - 2 ft)								
Incidental ingestion								
Soil ingestion rate	mg/day	50	100	200	100	100	100	a
Exposure frequency	days/year	250	350	350	52	52	52	b
Exposure duration	years	6.6	30	6	10	10	10	c
Body weight	kg	70	70	15	42	42	42	d
Carcinogen averaging time	days	25550	25550	25550	25550	25550	25550	e
Non carcinogen averaging time	days	2409	10950	2190	3650	3650	3650	e
Conversion factor	kg/mg	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	
Dermal contact								
Skin surface area available for contact	cm^2	5463	5463	2115	4041	4041	4041	f
Adherence factor	mg/cm^2	0.2	0.4	0.2	0.2	0.2	0.2	g
Exposure frequency	events/year	250	350	350	52	52	52	b
Exposure duration	years	6.6	30	6	10	10	10	c
Body weight	kg	70	70	15	42	42	42	d
Carcinogen averaging time	days	25550	25550	25550	25550	25550	25550	e
Non carcinogen averaging time	days	2409	10950	2190	3650	3650	3650	e
Conversion factor	kg/mg	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	
Inhalation of VOCs and dust								
Inhalation rate	m^3/day	13	13	8.7	12	12	12	h
Exposure time	hours/day	8	16.4	16.4	1	1	1	i
Exposure frequency	days/year	250	350	350	52	52	52	b
Exposure duration	years	6.6	30	6	10	10	10	c
Body weight	kg	70	70	15	42	42	42	d
Carcinogen averaging time	days	25550	25550	25550	25550	25550	25550	e
Non carcinogen averaging time	days	2409	10950	2190	3650	3650	3650	e
Conversion factor	days/hour	0.042	0.042	0.042	0.042	0.042	0.042	
Air Exchange rate	air changes/hour	N/A	0.45	0.45	N/A	N/A	N/A	m

Table 6.8 Reasonable Maximum Exposure Parameters for Chemical Exposures by Medium and Receptor, Current Land Use Receptors

Parameter	Units	On site	Off site		Toussaint Creek	Quarry	Landfill	Reference
		Industrial Worker	Resident Farmer - Adult	Resident Farmer - Child	Adolescent Trespasser	Adolescent Trespasser	Adolescent Trespasser	
Surface/Subsurface soil (0 - 10 ft)								
Incidental ingestion								
Soil ingestion rate	mg/day	NA	100	200	NA	NA	NA	a
Exposure frequency	days/year	NA	350	350	NA	NA	NA	b
Exposure duration	years	NA	30	6	NA	NA	NA	c
Body weight	kg	NA	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	10950	2190	NA	NA	NA	e
Conversion factor	kg/mg	NA	1.00E-06	1.00E-06	NA	NA	NA	
Dermal contact								
Skin surface area available for contact	cm^2	NA	5463	2115	NA	NA	NA	f
Adherence factor	mg/cm^2	NA	0.4	0.2	NA	NA	NA	g
Exposure frequency	events/year	NA	350	350	NA	NA	NA	b
Exposure duration	years	NA	30	6	NA	NA	NA	c
Body weight	kg	NA	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	10950	2190	NA	NA	NA	e
Conversion factor	kg/mg	NA	1.00E-06	1.00E-06	NA	NA	NA	
Inhalation of VOCs and dust								
Inhalation rate	m^3/day	NA	13	8.7	NA	NA	NA	h
Exposure time	hours/day	NA	16.4	16.4	NA	NA	NA	i
Exposure frequency	days/year	NA	350	350	NA	NA	NA	b
Exposure duration	years	NA	30	6	NA	NA	NA	c
Body weight	kg	NA	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	10950	2190	NA	NA	NA	e
Conversion factor	days/hour	NA	0.042	0.042	NA	NA	NA	

Table 6.8 Reasonable Maximum Exposure Parameters for Chemical Exposures by Medium and Receptor, Current Land Use Receptors

Parameter	Units	On site	Off site		Toussaint Creek	Quarry	Landfill	Reference
		Industrial Worker	Resident Farmer - Adult	Resident Farmer - Child	Adolescent Trespasser	Adolescent Trespasser	Adolescent Trespasser	
Sediment								
Incidental ingestion								
Sediment ingestion rate	mg/day	NA	1	2	2	NA	NA	j
Exposure frequency	days/year	NA	26	52	52	NA	NA	b
Exposure duration	years	NA	30	6	10	NA	NA	c
Body weight	kg	NA	70	15	42	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	NA	NA	e
Non carcinogen averaging time	days	NA	10950	2190	3650	NA	NA	e
Conversion factor	kg/mg	NA	1.00E-06	1.00E-06	1.00E-06	NA	NA	
Dermal contact								
Skin surface area available for contact	cm^2/event	NA	5463	2115	4041	NA	NA	f
Adherence factor	mg/cm^2	NA	0.4	0.2	2.7	NA	NA	g
Exposure frequency	events/year	NA	26	52	52	NA	NA	b
Exposure duration	years	NA	30	6	10	NA	NA	c
Body weight	kg	NA	70	15	42	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	NA	NA	e
Non carcinogen averaging time	days	NA	10950	2190	3650	NA	NA	e
Conversion factor	kg/mg	NA	1.00E-06	1.00E-06	1.00E-06	NA	NA	
Surface Water								
Incidental ingestion while wading								
Incidental water ingestion rate	L/hour	NA	0.023	0.013	0.023	0.023	NA	k
Exposure time	hours/day	NA	1	1	1	1	NA	i
Exposure frequency	days/year	NA	26	52	52	6	NA	b
Exposure duration	years	NA	30	6	10	10	NA	c
Body weight	kg	NA	70	15	42	42	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	NA	e
Non carcinogen averaging time	days	NA	10950	2190	3650	3650	NA	e
Dermal contact while wading								
Skin surface area available for contact	cm^2	NA	5463	2115	4041	16165	NA	f
Exposure frequency	events/year	NA	26	52	52	6	NA	b
Exposure duration	years	NA	30	6	10	10	NA	c
Body weight	kg	NA	70	15	42	42	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	NA	e
Non carcinogen averaging time	days	NA	10950	2190	3650	3650	NA	e
Conversion factor	L/cm^3	NA	1.00E-03	1.00E-03	1.00E-03	1.00E-03	NA	

Table 6.8 Reasonable Maximum Exposure Parameters for Chemical Exposures by Medium and Receptor, Current Land Use Receptors

Parameter	Units	On site	Off site		Toussaint Creek	Quarry	Landfill	Reference
		Industrial Worker	Resident Farmer - Adult	Resident Farmer - Child	Adolescent Trespasser	Adolescent Trespasser	Adolescent Trespasser	
Groundwater								
Drinking water ingestion								
Drinking water ingestion rate	L/day	1.2	2.3	1.3	NA	NA	NA	l
Exposure frequency	days/year	250	350	350	NA	NA	NA	b
Exposure duration	years	6.6	30	6	NA	NA	NA	c
Body weight	kg	70	70	15	NA	NA	NA	d
Carcinogen averaging time	days	25550	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	2410	10950	2190	NA	NA	NA	e
Dermal contact while showering								
Skin surface area available for contact	cm^2	NA	21850	8461	NA	NA	NA	f
Exposure time	hr/day	NA	0.58	0.58	NA	NA	NA	i
Exposure frequency	days/year	NA	350	350	NA	NA	NA	b
Exposure duration	years	NA	30	6	NA	NA	NA	c
Body weight	kg	NA	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	10950	2190	NA	NA	NA	e
Conversion factor	L/cm^3	NA	1.00E-03	1.00E-03	NA	NA	NA	
Inhalation of VOCs during household water use								
Inhalation rate	m^3/day	NA	13	8.7	NA	NA	NA	h
Exposure time	hr/day	NA	0.58	0.58	NA	NA	NA	i
Exposure frequency	days/year	NA	350	350	NA	NA	NA	b
Exposure duration	years	NA	30	6	NA	NA	NA	c
Body weight	kg	NA	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	10950	2190	NA	NA	NA	e

Table 6.9 Reasonable Maximum Exposure Parameters for Chemical Exposures by Medium and Receptor, Future Land Use Receptors

		On site			Off site		Toussaint Creek	Quarry	Landfill	Reference
Parameter	**Units**	**Industrial Worker**	**Resident Farmer - Adult**	**Resident Farmer - Child**	**Resident Farmer - Adult**	**Resident Farmer - Child**	**Adolescent Trespasser**	**Adolescent Trespasser**	**Adolescent Trespasser**	
Medium/pathway										
Surface soil (0 - 2 ft)										
Incidental ingestion										
Soil ingestion rate	mg/day	50	100	200	100	200	100	100	100	a
Exposure frequency	days/year	250	350	350	350	350	52	52	52	b
Exposure duration	years	6.6	30	6	30	6	10	10	10	c
Body weight	kg	70	70	15	70	15	42	42	42	d
Carcinogen averaging time	days	25550	25550	25550	25550	25550	25550	25550	25550	e
Non carcinogen averaging time	days	2409	10950	2190	10950	2190	3650	3650	3650	e
Conversion factor	kg/mg	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	
Dermal contact										
Skin surface area available for contact	cm^2	5463	5463	2115	5463	2115	4041	4041	4041	f
Adherence factor	mg/cm^2	0.2	0.4	0.2	0.4	0.2	0.2	0.2	0.2	g
Exposure frequency	events/year	250	350	350	350	350	52	52	52	b
Exposure duration	years	6.6	30	6	30	6	10	10	10	c
Body weight	kg	70	70	15	70	15	42	42	42	d
Carcinogen averaging time	days	25550	25550	25550	25550	25550	25550	25550	25550	e
Non carcinogen averaging time	days	2409	10950	2190	10950	2190	3650	3650	3650	e
Conversion factor	kg/mg	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	
Inhalation of VOCs and dust										
Inhalation rate	m^3/day	13	13	8.7	13	8.7	12	12	12	h
Exposure time	hours/day	8	16.4	16.4	16.4	16.4	1	1	1	i
Exposure frequency	days/year	250	350	350	350	350	52	52	52	b
Exposure duration	years	6.6	30	6	30	6	10	10	10	c
Body weight	kg	70	70	15	70	15	42	42	42	d
Carcinogen averaging time	days	25550	25550	25550	25550	25550	25550	25550	25550	e
Non carcinogen averaging time	days	2409	10950	2190	10950	2190	3650	3650	3650	e
Conversion factor	days/hour	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	
Air Exchange Rate	air changes/hour	N/A	0.45	0.45	0.45	0.45	N/A	N/A	N/A	m

Table 6.9 Reasonable Maximum Exposure Parameters for Chemical Exposures by Medium and Receptor, Future Land Use Receptors

		On site			Off site		Toussaint Creek	Quarry	Landfill	Reference
Parameter	**Units**	**Industrial Worker**	**Resident Farmer - Adult**	**Resident Farmer - Child**	**Resident Farmer - Adult**	**Resident Farmer - Child**	**Adolescent Trespasser**	**Adolescent Trespasser**	**Adolescent Trespasser**	
Surface/Subsurface soil (0 - 10 ft)										
Incidental ingestion										
Soil ingestion rate	mg/day	NA	100	200	100	200	NA	NA	NA	a
Exposure frequency	days/year	NA	350	350	350	350	NA	NA	NA	b
Exposure duration	years	NA	30	6	30	6	NA	NA	NA	c
Body weight	kg	NA	70	15	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	10950	2190	10950	2190	NA	NA	NA	e
Conversion factor	kg/mg	NA	1.00E-06	1.00E-06	1.00E-06	1.00E-06	NA	NA	NA	
Dermal contact										
Skin surface area available for contact	cm^2	NA	5463	2115	5463	2115	NA	NA	NA	f
Adherence factor	mg/cm^2	NA	0.4	0.2	0.4	0.2	NA	NA	NA	g
Exposure frequency	events/year	NA	350	350	350	350	NA	NA	NA	b
Exposure duration	years	NA	30	6	30	6	NA	NA	NA	c
Body weight	kg	NA	70	15	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	10950	2190	10950	2190	NA	NA	NA	e
Conversion factor	kg/mg	NA	1.00E-06	1.00E-06	1.00E-06	1.00E-06	NA	NA	NA	
Inhalation of VOCs and dust										
Inhalation rate	m^3/day	NA	13	8.7	13	8.7	NA	NA	NA	h
Exposure frequency	days/year	NA	350	350	350	350	NA	NA	NA	b
Exposure time	hours/day	NA	16.4	16.4	16.4	16.4	1	1	1	i
Exposure duration	years	NA	30	6	30	6	NA	NA	NA	c
Body weight	kg	NA	70	15	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	10950	2190	10950	2190	NA	NA	NA	e
Conversion factor	days/hour	NA	0.042	0.042	0.042	0.042	NA	NA	NA	

Table 6.9 Reasonable Maximum Exposure Parameters for Chemical Exposures by Medium and Receptor, Future Land Use Receptors

		On site			Off site		Toussaint Creek	Quarry	Landfill	Reference
Parameter	**Units**	**Industrial Worker**	**Resident Farmer - Adult**	**Resident Farmer - Child**	**Resident Farmer - Adult**	**Resident Farmer - Child**	**Adolescent Trespasser**	**Adolescent Trespasser**	**Adolescent Trespasser**	
Sediment										
Incidental ingestion										
Sediment ingestion rate	mg/day	NA	1	2	1	2	1	NA	NA	j
Exposure frequency	days/year	NA	26	52	26	52	52	NA	NA	b
Exposure duration	years	NA	30	6	30	6	10	NA	NA	c
Body weight	kg	NA	70	15	70	15	42	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	25550	NA	NA	e
Non carcinogen averaging time	days	NA	10950	2190	10950	2190	3650	NA	NA	e
Conversion factor	kg/mg	NA	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	NA	NA	
Dermal contact										
Skin surface area available for contact	cm^2/event	NA	5463	2115	5463	2115	4041	NA	NA	f
Adherence factor	mg/cm^2	NA	0.4	0.2	0.4	0.2	2.7	NA	NA	g
Exposure frequency	events/year	NA	26	52	26	52	52	NA	NA	b
Exposure duration	years	NA	30	6	30	6	10	NA	NA	c
Body weight	kg	NA	70	15	70	15	42	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	25550	NA	NA	e
Non carcinogen averaging time	days	NA	10950	2190	10950	2190	3650	NA	NA	e
Conversion factor	kg/mg	NA	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	NA	NA	
Surface Water										
Incidental ingestion while wading										
Incidental water ingestion rate	L/hour	NA	0.023	0.013	0.023	0.013	0.023	0.023	NA	k
Exposure time	hours/day	NA	1	1	1	1	1	1	NA	i
Exposure frequency	days/year	NA	26	52	26	52	52	6	NA	b
Exposure duration	years	NA	30	6	30	6	10	10	NA	c
Body weight	kg	NA	70	15	70	15	42	42	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	25550	25550	NA	e
Non carcinogen averaging time	days	NA	10950	2190	10950	2190	3650	3650	NA	e
Dermal contact while wading										
Skin surface area available for contact	cm^2	NA	5463	2115	5463	2115	4041	16165	NA	f
Event frequency	events/year	NA	26	52	26	52	52	6	NA	b
Exposure duration	years	NA	30	6	30	6	10	10	NA	c
Body weight	kg	NA	70	15	70	15	42	42	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	25550	25550	NA	e
Noncarcinogen averaging time	days	NA	10950	2190	10950	2190	3650	3650	NA	e
Conversion Factor	L/cm^3	NA	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	NA	

Table 6.9 Reasonable Maximum Exposure Parameters for Chemical Exposures by Medium and Receptor, Future Land Use Receptors

		On site			Off site		Toussaint Creek	Quarry	Landfill	Reference
Parameter	**Units**	**Industrial Worker**	**Resident Farmer - Adult**	**Resident Farmer - Child**	**Resident Farmer - Adult**	**Resident Farmer - Child**	**Adolescent Trespasser**	**Adolescent Trespasser**	**Adolescent Trespasser**	
Groundwater										
Drinking water ingestion										
Drinking water ingestion rate	L/day	1.2	2.3	1.3	2.3	1.3	NA	NA	NA	l
Exposure frequency	days/year	250	350	350	350	350	NA	NA	NA	b
Exposure time	years	6.6	30	6	30	6	NA	NA	NA	c
Body weight	kg	70	70	15	70	15	NA	NA	NA	d
Carcinogen averaging time	days	25550	25550	25550	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	2410	10950	2190	10950	2190	NA	NA	NA	e
Dermal contact while showering										
Skin surface area available for contact	cm^2	NA	21850	8461	21850	8461	NA	NA	NA	f
Exposure time	hr/day	NA	0.58	0.58	0.58	0.58	NA	NA	NA	i
Exposure frequency	days/year	NA	350	350	350	350	NA	NA	NA	b
Exposure duration	years	NA	30	6	30	6	NA	NA	NA	c
Body weight	kg	NA	70	15	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	10950	2190	10950	2190	NA	NA	NA	e
Conversion factor	L/cm^3	NA	1.00E-03	1.00E-03	1.00E-03	1.00E-03	NA	NA	NA	
Inhalation of VOCs during household water use										
Inhalation rate	m^3/day	NA	13	8.7	13	8.7	NA	NA	NA	h
Exposure time	hr/day	NA	0.58	0.58	0.58	0.58	NA	NA	NA	i
Exposure frequency	days/year	NA	350	350	350	350	NA	NA	NA	b
Exposure duration	years	NA	30	6	30	6	NA	NA	NA	c
Body weight	kg	NA	70	15	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	10950	2190	10950	2190	NA	NA	NA	e

References
Tables 6.8 and 6.9 RME – Current and Future Land Use

a	Soil ingestion rate	EFH Volume I, Table 4-23. 200 mg/day is used as a conservative estimate of the mean value for soil ingestion for children. 100 mg/day is used as a conservative estimate of the mean value for adolescent trespassers.
b	Exposure frequency	Industrial workers work indoors and are not routinely exposed to soil. The RME has industrial workers exposed to surface soil every work day or 250 days/year (EPA 1989a). Exposure frequency for the farm scenario (adult & child) is based on contact with outside soils every day of the year (350 days/year) except for 15 days/year spent away from home (EPA 1989a). Exposure to subsurface soils is assumed to occur at the same frequency as surface soils because subsurface soils are assumed to have been brought to the surface during home foundation excavation. EFH Volume I, Table 1-2. Exposure frequencies for contact with surface soil, surface water and sediment is based on 1hr/event assuming that an adult goes in the creek for fishing or wading day/week during April through October, while a resident child or adolescent trespasser goes in the creek 2 days/week during April through October. Exposure frequencies for the quarry pond are based on one swimming event per month during April through October (6 events/year) EFH Volume I, Table 1-2. Drinking water ingestion and showering is daily, excluding 15 days/year spent away from home. Adolescent trespassers are exposed to surface soils 2 days/week during summer months (April through October) or 52 days/year.
c	Exposure duration	EFH Volume I, Table 1-2. Exposure duration for the industrial worker is based on occupation tenure. Exposure duration for the resident farmer is based on the 95th percentile for population mobility, 30 years. The exposure duration for adolescent trespassers is 10 years (ages 7-16) based on Region 4, Supplemental guidance to RAGS (EPA 1995).
d	Body weight	EFH Volume I, Chapter 7. 70 kg body weight is used for derivation of cancer slope factors presented in IRIS. Children and adolescent weights are 50th percentile values for the appropriate age range which was assumed to be ages 0-6 for the resident child and ages 7-16 for the adolescent trespasser.
e	Averaging time	Carcinogenic averaging time = 70 yrs * 365 days/year. Non-carcinogenic averaging time = exposure duration (yrs) * 365 days/year.
f	Skin surface available for contact	EFH, Volume I, recommended value for outdoor activities based on 25 percent of 95th percentile of total body surface. Skin surface a available for contact with surface water in the quarry and groundwater while bathing is the 95th percentile of the total body surface for males and females in the appropriate age ranges.

g	Adherence factor	Weighted adherence factors were based on EFH Volume I, Table 6-12.
h	Inhalation rate	EFH Volume I, Table 1-2.
i	Exposure time	Industrial workers exposure time is based on an 8-hour work day. Resident farmer exposure time indoors is 16.4 hours assuming that 8 hours per day are spent sleeping (EFH Volume III, page 15-17). Exposure time for trespassers and incidental exposure to surface water is based on best professional judgment.
j	Sediment ingestion	There are no data currently available for incidental ingestion of rate sediment during fishing/wading activities, therefore, value assumes sediment would be 1/100th of incidental soil ingestion. Quarry lake is too deep to allow for exposure to sediments. Since sediments are typically wet, inhalation of VOCs and dust from sediments is unlikely.
k	Incidental ingestion of	There are no data currently available for incidental ingestion of surface water surface water during fishing/wading activities, therefore, value assumes incidental ingestion would be 1/100th of drinking water ingestion rate.
l	Groundwater ingestion	EFH, Volume I, Table 1-2. Value for adults is 90th percentile value (2.3 L/day). Value for children is 90th percentile for children 1-10 years old (1.3 L/day). It was assumed that industrial workers consume half of their daily intake while at work.
m	Air exchange rate	Volume of residential homes, EFH, Volume III, Table 17-3. 50th percentile air exchange rate of 0.45 air changes per hour, EFH, Volume III, Table 17-10.

Table 6.10 Central Tendency Parameters for Chemical Exposures by Medium and Receptor, Current Land Use Receptors

Parameter	Units	On site	Off site		Toussaint Creek	Quarry	Landfill	Reference
		Industrial Worker	Resident Farmer - Adult	Resident Farmer - Child	Adolescent Trespasser	Adolescent Trespasser	Adolescent Trespasser	
Medium/pathway								
Surface soil (0 - 2 ft)								
Incidental ingestion								
Soil ingestion rate	mg/day	50	50	100	50	50	50	a
Exposure frequency	days/year	52	210	210	52	52	52	b
Exposure duration	years	6.6	9	6	10	10	10	c
Body weight	kg	70	70	15	42	42	42	d
Carcinogen averaging time	days	25550	25550	25550	25550	25550	25550	e
Noncarcinogen averaging time	days	2409	3285	2190	3650	3650	3650	e
Conversion Factor	kg/mg	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	
Dermal contact								
Skin surface area available for contact	cm^2/event	4538	4538	1803	3293	3293	3293	f
Adherence factor	mg/cm^2	0.02	0.1	0.06	0.04	0.04	0.04	g
Exposure frequency	events/year	52	210	210	52	52	52	b
Exposure duration	years	6.6	9	6	10	10	10	c
Body weight	kg	70	70	15	42	42	42	d
Carcinogen averaging time	days	25550	25550	25550	25550	25550	25550	e
Noncarcinogen averaging time	days	2409	3285	2190	3650	3650	3650	e
Conversion Factor	kg/mg	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	
Inhalation of VOCs and dust								
Inhalation rate	m^3/day	13	13	8.7	12	12	12	h
Exposure time	hours/day	8	16.4	16.4	1	1	1	i
Exposure frequency	days/year	52	210	210	52	52	52	b
Exposure duration	years	6.6	9	6	10	10	10	c
Body weight	kg	70	70	15	42	42	42	d
Carcinogen averaging time	days	25550	25550	25550	25550	25550	25550	e
Non carcinogen averaging time	days	2409	3285	2190	3650	3650	3650	e
Conversion factor	days/hour	0.042	0.042	0.042	0.042	0.042	0.042	
Air exchange rate	air changes/hour	NA	0.45	0.45	NA	NA	NA	j

Table 6.10 Central Tendency Parameters for Chemical Exposures by Medium and Receptor, Current Land Use Receptors

Parameter	Units	On site	Off site		Toussaint Creek	Quarry	Landfill	Reference
		Industrial Worker	Resident Farmer - Adult	Resident Farmer - Child	Adolescent Trespasser	Adolescent Trespasser	Adolescent Trespasser	
Surface/Subsurface soil (0 - 10 ft)								
Incidental ingestion								
Soil ingestion rate	mg/day	NA	50	100	NA	NA	NA	a
Exposure frequency	days/year	NA	210	210	NA	NA	NA	b
Exposure duration	years	NA	9	6	NA	NA	NA	c
Body weight	kg	NA	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	3285	2190	NA	NA	NA	e
Conversion factor	kg/mg	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	
Dermal contact								
Skin surface area available for contact	cm^2/event	NA	4538	1803	NA	NA	NA	f
Adherence factor	mg/cm^2	NA	0.1	0.06	NA	NA	NA	g
Exposure frequency	events/year	NA	210	210	NA	NA	NA	b
Exposure duration	years	NA	9	6	NA	NA	NA	c
Body weight	kg	NA	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	3285	2190	NA	NA	NA	e
Conversion factor	kg/mg	NA	1.00E-06	1.00E-06	NA	NA	NA	
Inhalation of VOCs and dust								
Inhalation rate	m^3/day	NA	13	8.7	NA	NA	NA	h
Exposure time	hours/day	NA	16	16	NA	NA	NA	i
Exposure frequency	days/year	NA	210	210	NA	NA	NA	b
Exposure duration	years	NA	9	6	NA	NA	NA	c
Body weight	kg	NA	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	3285	2190	NA	NA	NA	e
Conversion factor	days/hour	NA	0.042	0.042	NA	NA	NA	

Table 6.10 Central Tendency Parameters for Chemical Exposures by Medium and Receptor, Current Land Use Receptors

Parameter	Units	On site	Off site		Toussaint Creek	Quarry	Landfill	Reference
		Industrial Worker	Resident Farmer - Adult	Resident Farmer - Child	Adolescent Trespasser	Adolescent Trespasser	Adolescent Trespasser	
Sediment								
Incidental ingestion								
Sediment ingestion rate	mg/day	NA	0.5	1.0	0.5	NA	NA	k
Exposure frequency	days/year	NA	26	52	52	NA	NA	b
Exposure duration	years	NA	9	6	10	NA	NA	c
Body weight	kg	NA	70	15	42	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	NA	NA	e
Non carcinogen averaging time	days	NA	3285	2190	3650	NA	NA	e
Dermal contact								
Skin surface area available for contact	cm^2/event	NA	4538	1803	3293	NA	NA	f
Adherence factor	mg/cm^2	NA	0.1	0.06	0.2	NA	NA	g
Exposure frequency	events/year	NA	26	52	52	NA	NA	b
Exposure duration	years	NA	9	6	10	NA	NA	c
Body weight	kg	NA	70	15	42	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	NA	NA	e
Non carcinogen averaging time	days	NA	3285	2190	3650	NA	NA	e
Conversion factor	kg/mg	NA	1.00E-06	1.00E-06	1.00E-06	NA	NA	

Table 6.10 Central Tendency Parameters for Chemical Exposures by Medium and Receptor, Current Land Use Receptors

Parameter	Units	On site	Off site		Toussaint Creek	Quarry	Landfill	Reference
		Industrial Worker	Resident Farmer - Adult	Resident Farmer - Child	Adolescent Trespasser	Adolescent Trespasser	Adolescent Trespasser	
Surface Water								
Incidental ingestion while wading								
Incidental ingestion of surface water	L/hour	NA	0.014	0.0066	0.014	0.014	NA	l
Exposure time	hours/day	NA	1	1	1	1	NA	i
Exposure frequency	days/year	NA	26	52	52	6	NA	b
Exposure duration	years	NA	9	6	10	10	NA	c
Body weight	kg	NA	70	15	42	42	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	NA	e
Non carcinogen averaging time	days	NA	3285	2190	3650	3650	NA	e
Dermal contact while wading								
Skin surface area available for contact	cm^2/event	NA	4538	1803	3293	15314	NA	f
Exposure frequency	events/year	NA	26	52	52	6	NA	b
Exposure duration	years	NA	9	6	10	10	NA	c
Body weight	kg	NA	70	15	42	42	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	NA	e
Non carcinogen averaging time	days	NA	3285	2190	3650	3650	NA	e
Conversion factor	L/cm^3	NA	1.00E-03	1.00E-03	1.00E-03	1.00E-03	NA	

Table 6.10 Central Tendency Parameters for Chemical Exposures by Medium and Receptor, Current Land Use Receptors

Parameter	Units	On site	Off site		Toussaint Creek	Quarry	Landfill	Reference
		Industrial Worker	Resident Farmer - Adult	Resident Farmer - Child	Adolescent Trespasser	Adolescent Trespasser	Adolescent Trespasser	
Groundwater								
Drinking water ingestion								
Drinking water ingestion rate	L/day	0.7	1.4	0.66	NA	NA	NA	m
Exposure frequency	days/year	250	350	350	NA	NA	NA	b
Exposure duration	years	6.6	9	6	NA	NA	NA	c
Body weight	kg	70	70	15	NA	NA	NA	d
Carcinogen averaging time	days	25550	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	2409	3285	2190	NA	NA	NA	e
Dermal contact while showering/bathing								
Skin surface area available for contact	cm^2	NA	18150	7213	NA	NA	NA	f
Exposure time	hr/event	NA	0.25	0.25	NA	NA	NA	i
Exposure frequency	events/year	NA	350	350	NA	NA	NA	b
Exposure duration	years	NA	9	6	NA	NA	NA	c
Body weight	kg	NA	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	3285	2190	NA	NA	NA	e
Conversion Factor	L/cm^3	NA	0.001	0.001	NA	NA	NA	
Inhalation of VOCs during household water use								
Inhalation rate	m^3/day	NA	13	8.7	NA	NA	NA	h
Exposure time	hr/event	NA	0.16	0.16	NA	NA	NA	c
Exposure frequency	events/year	NA	350	350	NA	NA	NA	b
Exposure duration	years	NA	9	9	NA	NA	NA	c
Body weight	kg	NA	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	3285	3285	NA	NA	NA	e
Conversion factor	days/hour	NA	0.042	0.042	NA	NA	NA	

Table 6.11 Central Tendency Parameters for Chemical Exposures by Medium and Receptor,

Future Land Use Receptors

Parameter	Units	On site			Off site		Toussaint Creek	Quarry	Landfill	Reference
		Industrial Worker	Resident Farmer - Adult	Resident Farmer - Child	Resident Farmer - Adult	Resident Farmer - Child	Adolescent Trespasser	Adolescent Trespasser	Adolescent Trespasser	
Medium/pathway										
Surface Soil (0 - 2 ft)										
Incidental ingestion										
Soil ingestion rate	mg/day	50	50	100	50	100	50	50	50	a
Exposure frequency	days/year	52	210	210	210	210	52	52	52	b
Exposure duration	years	6.6	9	6	9	6	10	10	10	c
Body weight	kg	70	70	15	70	15	42	42	42	d
Carcinogen averaging time	days	25550	25550	25550	25550	25550	25550	25550	25550	e
Non carcinogen averaging time	days	2409	3285	2190	3285	2190	3650	3650	3650	e
Conversion factor	kg/mg	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	
Dermal contact										
Skin surface area available for contact	cm^2	4538	4538	1803	4538	1803	3293	3293	3293	f
Adherence factor	mg/cm^2	0.02	0.1	0.06	0.1	0.06	0.2	0.2	0.2	g
Exposure frequency	events/year	52	210	210	210	210	52	52	52	b
Exposure duration	years	6.6	9	6	9	6	10	10	10	c
Body weight	kg	70	70	15	70	15	42	42	42	d
Carcinogen averaging time	days	25550	25550	25550	25550	25550	25550	25550	25550	e
Non carcinogen averaging time	days	2409	3285	2190	3285	2190	3650	3650	3650	e
Conversion factor	kg/mg	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	
Inhalation of VOCs and dust										
Inhalation rate	m^3/day	13	13	8.7	13	8.7	12	12	12	h
Exposure time	hours/day	8	16.4	16.4	16.4	16.4	1	1	1	i
Exposure frequency	days/year	52	210	210	210	210	52	52	52	b
Exposure duration	years	6.6	9	6	9	6	10	10	10	c
Body weight	kg	70	70	15	70	15	42	42	42	d
Carcinogen averaging time	days	25550	25550	25550	25550	25550	25550	25550	25550	e
Non carcinogen averaging time	days	2409	3285	2190	3285	2190	3650	3650	3650	e
Conversion factor	days/hour	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	
Air exchange rate	air changes/hour	NA	0.45	0.45	0.45	0.45	NA	NA	NA	j

Table 6.11 Central Tendency Parameters for Chemical Exposures by Medium and Receptor,

Future Land Use Receptors

Parameter	Units	On site			Off site		Toussaint Creek	Quarry	Landfill	Reference
		Industrial Worker	Resident Farmer - Adult	Resident Farmer - Child	Resident Farmer - Adult	Resident Farmer - Child	Adolescent Trespasser	Adolescent Trespasser	Adolescent Trespasser	
Surface/Subsurface Soil (0 - 10 ft)										
Incidental ingestion										
Soil ingestion rate	mg/day	NA	50	100	50	100	NA	NA	NA	a
Exposure frequency	days/year	NA	210	210	210	210	NA	NA	NA	b
Exposure duration	years	NA	9	6	9	6	NA	NA	NA	c
Body weight	kg	NA	70	15	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	3285	2190	3285	2190	NA	NA	NA	e
Conversion factor	kg/mg	NA	1.00E-06	1.00E-06	1.00E-06	1.00E-06	NA	NA	NA	
Dermal contact										
Skin surface available for contact	cm^2	NA	4538	1803	4538	1803	NA	NA	NA	f
Adherence factor	mg/cm^2	NA	0.1	0.06	0.1	0.06	NA	NA	NA	g
Exposure frequency	events/year	NA	210	210	210	210	NA	NA	NA	b
Exposure duration	years	NA	9	6	9	6	NA	NA	NA	c
Body weight	kg	NA	70	15	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	3285	2190	3285	2190	NA	NA	NA	e
Conversion factor	kg/mg	NA	1.00E-06	1.00E-06	1.00E-06	1.00E-06	NA	NA	NA	
Inhalation of VOCs and dust										
Inhalation rate	m^3/day	NA	13	8.7	13	8.7	NA	NA	NA	h
Exposure time	hours/day	NA	16.4	16.4	16.4	16.4	NA	NA	NA	i
Exposure frequency	days/year	NA	210	210	210	210	NA	NA	NA	b
Exposure duration	years	NA	9	6	9	6	NA	NA	NA	c
Body weight	kg	NA	70	15	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	3285	2190	3285	2190	NA	NA	NA	e
Conversion factor	days/hour	NA	0.042	0.042	0.042	0.042	NA	NA	NA	

Table 6.11 Central Tendency Parameters for Chemical Exposures by Medium and Receptor,

Future Land Use Receptors

Parameter	Units	On site			Off site		Toussaint Creek	Quarry	Landfill	Reference
		Industrial Worker	Resident Farmer - Adult	Resident Farmer - Child	Resident Farmer - Adult	Resident Farmer - Child	Adolescent Trespasser	Adolescent Trespasser	Adolescent Trespasser	
Sediment										
Incidental ingestion										
Sediment ingestion rate	kg/day	NA	0.5	1.0	0.5	1.0	0.5	NA	NA	k
Exposure time	hours/day	NA	1	1	1	1	1	NA	NA	i
Exposure frequency	days/year	NA	26	52	26	52	52	NA	NA	b
Exposure duration	years	NA	9	6	9	6	10	NA	NA	c
Body weight	kg	NA	70	15	70	15	42	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	25550	NA	NA	e
Non carcinogen averaging time	days	NA	3285	2190	3285	2190	3650	NA	NA	e
Dermal contact										
Skin surface available for contact	cm^2/event	NA	4538	1803	4538	1803	3293	NA	NA	f
Adherence factor	mg/cm^2	NA	0.1	0.06	0.1	0.06	0.2	NA	NA	g
Exposure frequency	events/year	NA	26	52	26	52	52	NA	NA	b
Exposure duration	years	NA	9	6	9	6	10	NA	NA	c
Body weight	kg	NA	70	15	70	15	42	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	25550	NA	NA	e
Non carcinogen averaging time	days	NA	3285	2190	3285	2190	3650	NA	NA	e
Conversion factor	kg/mg	NA	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	NA	NA	

Table 6.11 Central Tendency Parameters for Chemical Exposures by Medium and Receptor,

Future Land Use Receptors

Parameter	Units	On site			Off site		Toussaint Creek	Quarry	Landfill	Reference
		Industrial Worker	Resident Farmer - Adult	Resident Farmer - Child	Resident Farmer - Adult	Resident Farmer - Child	Adolescent Trespasser	Adolescent Trespasser	Adolescent Trespasser	
Surface Water										
Incidental ingestion while wading										
Incidental ingestion of surface water	L/hour	NA	0.014	0.0066	0.014	0.0066	0.014	0.014	NA	l
Exposure time	hours/day	NA	1	1	1	1	1	1	NA	i
Exposure frequency	days/year	NA	26	52	26	52	52	6	NA	b
Exposure duration	years	NA	9	6	9	6	10	10	NA	c
Body weight	kg	NA	70	15	70	15	42	42	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	25550	25550	NA	e
Non carcinogen averaging time	days	NA	3285	2190	3285	2190	3650	3650	NA	e
Dermal contact while wading										
Skin surface available for contact	cm^2	NA	4538	1803	4538	1803	3293	15314	NA	f
Exposure frequency	events/year	NA	26	52	26	52	52	6	NA	b
Exposure duration	years	NA	9	6	9	6	10	10	NA	c
Body weight	kg	NA	70	15	70	15	42	42	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	25550	25550	NA	e
Non carcinogen averaging time	days	NA	3285	2190	3285	2190	3650	3650	NA	e
Conversion factor	L/cm^3	NA	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-06	NA	

Table 6.11 Central Tendency Parameters for Chemical Exposures by Medium and Receptor,

Future Land Use Receptors

Parameter	Units	On site			Off site		Toussaint Creek	Quarry	Landfill	Reference
		Industrial Worker	Resident Farmer - Adult	Resident Farmer - Child	Resident Farmer - Adult	Resident Farmer - Child	Adolescent Trespasser	Adolescent Trespasser	Adolescent Trespasser	
Groundwater										
Drinking water ingestion										
Drinking water ingestion rate	L/day	0.7	1.4	0.66	1.4	0.66	NA	NA	NA	m
Exposure frequency	days/year	250	350	350	350	350	NA	NA	NA	b
Exposure duration	years	6.6	9	6	9	6	NA	NA	NA	c
Body weight	kg	70	70	15	70	15	NA	NA	NA	d
Carcinogen averaging time	days	25550	25550	25550	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	2409	3285	2190	3285	2190	NA	NA	NA	e
Dermal contact while showering/bathing										
Skin surface available for contact	cm^2	NA	18150	7213	18150	7213	NA	NA	NA	f
Exposure time	hr/day	NA	0.16	0.16	0.16	0.16	NA	NA	NA	i
Exposure frequency	days/year	NA	350	350	350	350	NA	NA	NA	b
Exposure duration	years	NA	9	6	9	6	NA	NA	NA	c
Body weight	kg	NA	70	15	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	127750	127750	127750	127750	NA	NA	NA	e
Conversion factor	L/cm^3	NA	0.001	0.001	0.001	NA	NA			
Inhalation of VOCs during household water use										
Inhalation rate	m^3/day	NA	13	8.7	13	8.7	NA	NA	NA	h
Exposure time	hr/day	NA	0.25	0.25	0.25	0.25	NA	NA	NA	c
Exposure frequency	days/year	NA	350	350	350	350	NA	NA	NA	b
Exposure duration	years	NA	9	6	9	6	NA	NA	NA	c
Body weight	kg	NA	70	15	70	15	NA	NA	NA	d
Carcinogen averaging time	days	NA	25550	25550	25550	25550	NA	NA	NA	e
Non carcinogen averaging time	days	NA	3285	2190	3285	2190	NA	NA	NA	e
Conversion factor	days/hour	NA	0.042	0.042	NA	NA	NA			

References
Tables 6.10 and 6.11 CT – Current and Future Land Use

a	Soil ingestion rate	EFH Volume I, Table 1-2.
b.	Exposure frequency	Industrial workers work indoors, but are assumed to be exposed to soil 1day/week (52 days/year). Exposure frequency for farm scenario (adult & child) is based on contact with outside soils 7 days/week during April through October (210 days/years). Exposure to subsurface soils is assumed to occur at the same frequency as surface soils because subsurface soils are assumed to have been brought to the surface during home foundation excavation. Adolescent trespassers are exposed to sediment and surface water in Toussaint Creek 2 days/week during the summer months (6 months /year) or 52 days/years. Exposure frequencies for the quarry pond are based on one swimming event per month during April through October (6 events/year). EFH Volume I, Table 1-2. Exposure frequencies for contact with surface water is based on 1hr/event assuming that an adult goes in the creek for fishing or wading 1 day/week during April through October, while a resident child or adolescent trespasser goes in the creek 2 days/week during April through October. Exposure frequencies for the quarry pond are based on one swimming event per month during April through October EFH Table 1-2. Drinking water ingestion and showering is daily, excluding 15 days/year spent away from home. Industrial workers are exposed 250 days/year.
c.	Exposure duration	EFH Volume I, Table 1-2. Exposure duration for the industrial worker is based on occupation tenure. Exposure duration for the resident farmer is based on 50th percentile for residence time of 9 years. The exposure duration for adolescent trespassers is 10 years (ages 7-16) based on Region 4, Supplemental guidance to RAGS (EPA 1995).
d.	Body weight	EFH Volume I, Chapter 7. 70 kg body weight is used for derivation of cancer slope factors presented in IRIS. Children and adolescent weights are 50th percentile values for the appropriate age range which was assumed to be ages 0-6 for the resident child and ages 7-16 for the adolescent trespasser.
e.	Averaging time	Carcinogenic averaging time = 70 yrs * 365 days/year. Noncarcinogenic averaging time = exposure duration (yrs) * 365 days/year.
f	Skin surface available for contact	EFH, Volume I, recommended value for outdoor activities based on 25 percent of 50th percentile of total body surface. Skin surface available for contact with surface water in the quarry and groundwater while bathing is the 50th percentile of the total body surface for males and females in the appropriate age ranges.

		For swimming in the quarry pond the skin surface available for contact was assumed to be the entire skin surface of the adolescent trespasser.
g.	Adherence factor	Weighted adherence factors were based on EFH Volume I, Table 6-12.
h.	Inhalation rate	EFH Volume I, Table 1-2.
i.	Exposure time	Industrial workers exposure time is based on an 8-hour workday. Resident farmer exposure time is 16.4 hours/day which is the 50th percentile value for time spent indoors based on EFH Volume III, page 15-17. Exposure time for trespassers and incidental exposure to surface water is based on best professional judgment. Based on EFH Volume III, Table 15-21 the recommended 50th percentile value for shower duration is 15 minutes (CT value). The 95th percentile value for shower duration is 35 minutes (RME value).
j.	Air exchange rate	Volume of residential homes, EFH, Volume III, Table 17-3. 50th percentile air exchange rate of 0.45 air changes per hour, EFH, Volume III, Table 17-10.
k.	Sediment ingestion	There are no data currently available for incidental ingestion of rate sediment during fishing/wading activities, therefore, value assumes sediment would be 1/100th of incidental soil ingestion. Quarry lake is too deep to allow for exposure to sediments. Since sediments are typically wet, inhalation of VOCs and dust from sediments is unlikely.
l.	Incidental ingestion of surface water	There are no data currently available for incidental ingestion of surface water during fishing/wading activities, therefore, value assumes incidental ingestion would be 1/100th of drinking water ingestion rate.
m.	Drinking water ingestion rate	EFH, Volume I, Table 1-2. Value for adults is average intake value (1.4 L/day.) Value for children is 50th percentile for children 1-10 years old (0.66 L/day). It was assumed that industrial worker consumes half of daily intake while at work.

Table 6.12 Toxicity Values[1] and Chemical-Specific Parameters for Non-Radiological Chemicals

	Non-Cancer			Cancer			Dermal Exposure Parameters[2]					
									Water			
Chemical	Oral RFD[o] (mg/kg/day)	Dermal Adjusted RFD[a] (mg/kg/day)	Inhalation RFD[i] (mg/kg/day)	Oral CSF[o] $(mg/kg/day)^{-1}$	Dermal Adjusted CSF[a] $(mg/kg/day)^{-1}$	Inhalation CSF[i] $(mg/kg/day)^{-1}$	General GI Factor (% Absorbed)	Soil Dermal ABS (Unitless)	Kp (cm/hr)	tau (hour)	t* (hour)	B (Unitless)
INORGANICS												
Aluminum	1.00E+00	NA	1.40E-03	NA	NA	NA	NA	NA	1.00E-03			
Arsenic	3.00E-04	2.85E-04	NA	1.50E+00	1.58E+00	1.50E+01	95%	0.03	1.00E-03			
Barium	7.00E-02	4.90E-03	1.40E-04	NA	NA	NA	7%	NA	1.00E-03			
Beryllium	2.00E-03	1.40E-05	5.70E-06	NA	NA	8.40E+00	0.7%	NA	1.00E-03			
Boron	9.00E-02	NA	5.71E-03	NA	NA	NA	NA	NA	1.00E-03			
Cadmium	5.00E-04	2.50E-05	NA	NA	NA	6.30E+00	5%	0.001	1.00E-03			
Chromium III	1.50E+00	1.95E-02	NA	NA	NA	NA	1.3%	NA	1.00E-03			
Cobalt	6.00E-02	NA	NA	NA	NA	NA	NA	NA	1.00E-03			
Copper	3.70E-02	NA	NA	NA	NA	NA	NA	NA	1.00E-03			
Lead	NA	NA	NA	NA	NA	NA	NA	NA	1.00E-03			
Manganese	2.40E-02	9.60E-04	1.40E-05	NA	NA	NA	4%	NA	1.00E-03			
Mercury	3.00E-04	2.85E-04	8.60E-05	NA	NA	NA	95%	NA	1.00E-03			
Molybdenum	5.00E-03	NA	NA	NA	NA	NA	NA	NA	1.00E-03			
Nickel	2.00E-02	8.00E-04	NA	NA	NA	NA	4%	NA	1.00E-03			
Selenium	5.00E-03	4.00E-03	NA	NA	NA	NA	80%	NA	1.00E-03			
Silver	5.00E-03	2.00E-04	NA	NA	NA	NA	4%	NA	1.00E-03			
Strontium	6.00E-01	NA	NA	NA	NA	NA	NA	NA	1.00E-03			
Thallium	8.00E-05	8.00E-05	NA	NA	NA	NA	100%	NA	1.00E-03			
Uranium	3.00E-03	NA	NA	NA	NA	NA	NA	NA	1.00E-03			
Vanadium	7.00E-03	1.82E-04	NA	NA	NA	NA	2.6%	NA	1.00E-03			
Zinc	3.00E-01	3.00E-01	NA	NA	NA	NA	100%	NA	1.00E-03			
SVOCs												
Acenaphthene	6.00E-02	6.00E-02	6.00E-02	NA	NA	NA	100%	0.1				
Anthracene	3.00E-01	3.00E-01	3.00E-01	NA	NA	NA	100%	0.1				
Benzo(a)anthracene	NA	NA	NA	7.30E-01	7.30E-01	3.10E-01	100%	0.13	8.10E-01	2.20E+00	1.00E+01	4.60E+01
Benzo(a)pyrene	NA	NA	NA	7.30E+00	7.30E+00	3.10E+00	100%	0.13	1.20E+00	2.90E+00	1.40E+01	1.30E+02
Benzo(b)fluoranthene	NA	NA	NA	7.30E-01	7.30E-01	3.10E-01	100%	0.13	1.20E+00	3.00E+00	1.40E+01	1.30E+02
Benzo(ghi)perylene	3.00E-02	3.00E-02	3.00E-02	NA	NA	NA	100%	0.1				
Benzo(k)fluoranthene	NA	NA	NA	7.30E-02	7.30E-02	3.10E-02	100%	0.13				
bis(2-ethylhexyl)phthalate	2.00E-02	2.00E-02	2.20E-02	1.40E-02	1.40E-02	1.40E-02	100%	0.1	3.30E-02	7.51E+00	3.61E+01	1.26E+01
Carbazole	NA	NA	NA	2.00E-02	2.00E-02	2.00E-02	100%	0.1				
Chrysene	NA	NA	NA	7.30E-03	7.30E-03	3.10E-03	100%	0.13	8.10E-01	2.20E+00	1.00E+01	4.60E+01
m,p-cresol	5.00E-03	5.00E-03	5.00E-03	NA	NA	NA	100%	0.1	1.65E-02	4.00E-01	9.60E-01	8.90E-03
3,3'-Dichlorobenzidine	NA	NA	NA	4.50E-01	4.50E-01	4.50E-01	100%	0.1	1.70E-02	3.10E+00	1.70E+01	3.20E-01
Dibenz(a,h)anthracene	NA	NA	NA	7.30E+00	7.30E+00	3.10E+00	100%	0.13	2.70E+00	4.40E+00	2.10E+01	6.90E+02
Dibenzofuran	4.00E-03	4.00E-03	4.00E-03	NA	NA	NA	100%	0.1				
Di-n-octyl phthalate	2.00E-02	2.00E-02	2.00E-02	NA	NA	NA	100%	0.1	1.91E-03	7.51E+00	3.54E+01	1.60E+05
Diethyl phthalate	8.00E-01	8.00E-01	8.00E-01	NA	NA	NA	100%	0.1	4.80E-03	2.00E+00	4.70E+00	3.00E-02
Fluoranthene	4.00E-02	4.00E-02	4.00E-02	NA	NA	NA	100%	0.13	3.60E-01	1.50E+00	7.30E+00	8.90E+00

Table 6.12 Toxicity Values[1] and Chemical-Specific Parameters for Non-Radiological Chemicals

	Non-Cancer			Cancer			Dermal Exposure Parameters[2]					
									Water			
Chemical	Oral RFD[o] (mg/kg/day)	Dermal Adjusted RFD[a] (mg/kg/day)	Inhalation RFD[i] (mg/kg/day)	Oral CSF[o] $(mg/kg/day)^{-1}$	Dermal Adjusted CSF[a] $(mg/kg/day)^{-1}$	Inhalation CSF[i] $(mg/kg/day)^{-1}$	General GI Factor (% Absorbed)	Soil Dermal ABS (Unitless)	Kp (cm/hr)	tau (hour)	t* (hour)	B (Unitless)
Fluorene	4.00E-02	4.00E-02	4.00E-02	NA	NA	NA	100%	0.1				
Indeno(1,2,3-c,d)pyrene	NA	NA	NA	7.30E-01	7.30E-01	3.10E-01	100%	0.13	1.90E+00	4.20E+00	2.00E+01	3.80E+02
Phenanthrene	3.00E-02	3.00E-02	3.00E-02	NA	NA		100%	0.1	2.30E-01	1.10E+00	5.60E+00	2.90E+00
Phenol	6.00E-01	6.00E-01	6.00E-01	NA	NA	NA	100%	0.1	8.20E-03	3.30E-01	7.90E-01	2.90E-03
Pyrene	3.00E-02	3.00E-02	3.00E-02	NA	NA	NA	100%	0.1				
PCBs												
Aroclor-1254	2.00E-05	1.92E-05	2.00E-05	2.00E+00	2.08E+00	2.00E+00	96%	0.14				
VOCs												
2-Butanone (aka MEK)	6.00E-01	6.00E-01	2.90E-01	NA	NA	NA	100%	NA	5.00E-03	2.40E-01	5.80E-01	1.90E-04
2-Hexanone	NA	NA	NA	NA	NA	NA	100%	NA				
Acetone	1.00E-01	1.00E-01	1.00E-01	NA	NA	NA	100%	NA	1.91E-03	7.06E-02	1.69E-01	5.75E-05
Benzene	3.00E-03	3.00E-03	1.70E-03	2.90E-02	2.90E-02	2.70E-02	100%	NA	1.10E-01	2.60E-01	6.30E-01	1.30E-02
Bromodichloromethane	2.00E-02	2.00E-02	2.00E-02	6.20E-02	6.20E-02	6.20E-02	100%	NA	5.80E-03	8.70E-01	2.10E+00	1.20E-02
Carbon Disulfide	1.00E-01	1.00E-01	2.00E-01	NA	NA	NA	100%	NA	5.00E-01	2.70E-01	6.50E-01	1.70E-02
Chloroethane	4.00E-01	4.00E-01	2.90E+00	2.90E-03	2.90E-03	2.90E-03	100%	NA	8.00E-03	2.20E-01	5.20E-01	2.70E-03
Chloroform	1.00E-02	1.00E-02	8.60E-05	6.10E-03	6.10E-03	8.10E-02	100%	NA	1.30E-01	4.70E-01	1.10E+00	9.30E-03
Dibromochloromethane	2.00E-02	2.00E-02	2.00E-02	8.40E-02	8.40E-02	8.40E-02	100%	NA	3.90E-03	5.81E-01	1.39E+00	1.20E-02
Ethylbenzene	1.00E-01	1.00E-01	2.90E-01	NA	NA	NA	100%	NA	1.00E+00	3.90E-01	1.30E+00	1.40E-01
Methylene Chloride	6.00E-02	6.00E-02	8.60E-01	7.50E-03	7.50E-03	1.60E-03	100%	NA	4.50E-03	2.90E-01	6.90E-01	1.80E-03
Tetrachloroethene	1.00E-02	1.00E-02	1.10E-01	5.20E-02	5.20E-02	2.00E-03	100%	NA	3.70E-01	9.00E-01	4.30E+00	2.50E-01
Toluene	2.00E-01	2.00E-01	1.10E-01	NA	NA	NA	100%	NA	1.00E+00	3.20E-01	7.70E-01	5.40E-02
Tribromomethane	2.00E-02	2.00E-02	2.00E-02	7.90E-03	7.90E-03	3.90E-03	100%	NA	2.60E-03	3.00E+00	7.30E+00	2.30E-02
Xylenes (total)	2.00E+00	2.00E+00	2.00E-01	NA	NA	NA	100%	NA	8.00E-02	3.90E-01	1.40E+00	1.60E-01

1 Reference IRIS or HEAST, other sources noted in Section 6.4

2. Recommended gastrointestinal absorption effeciencies and dermal absorption fractions for specific compounds were based on soon to be released guidance obtained from USEPA's Dr. Mark Johnson (Johnson, 2000). When gastrontestinal absorption was greater than 50% absorbed oral toxicity factors were nor adjusted.

NA = Not Available
RfD = Reference Dose
CSF = Cancer Slope Factor
GI = Gastrointestinal
ABS = Dermal Absorption Factor

Kp = Permeability Coefficient
tau = Lag Time
t* = Diffusion time
B = Dimensionless constant reflecting the partitioning properties of a compound

SVOCs = Semi-volatile Organic Compounds
PCBs = Polychlorinated biphenyls
VOCs = Volatile Organic Compounds

Table 6.13. Exposure Unit 1 RME Summary Table (Non-Radiologicals)

Scenario and Receptor	Media	Pathway	Non-carcinogenic Risk HI	Percent of Total HI	Carcinogenic Risk ILCR	Percent of Total ILCR
Current/Future Scenario Industrial Worker	Soil (0-2 ft bls)	Ingestion	2.5E-02	7%	**1.7E-05**	26%
		Dermal	1.7E-03	1%	**4.9E-05**	74%
		Inhalation of Dust	1.1E-04	0%	6.6E-10	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	2.7E-02	8%	**6.6E-05**	100%
	Groundwater	Ingestion	3.1E-01	92%	0.0E+00	0%
		TOTAL	3.4E-01		**6.6E-05**	
Future Scenario Resident Farmer - Adult	Soil (0-2 ft bls)	Ingestion	2.9E-01	16%	**2.2E-04**	26%
		Dermal	2.9E-01	16%	**6.3E-04**	74%
		Inhalation of Dust	3.2E-04	0%	8.6E-09	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	5.8E-01	31%	**8.5E-04**	100%
	Groundwater	Ingestion	1.1E+00	59%	0.0E+00	0%
		Dermal	1.7E-01	9%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	**1.3E+00**	69%	0.0E+00	0%
		TOTAL (0-2 ft bls)	**1.9E+00**		**8.5E-04**	
Future Scenario Resident Farmer - Adult	Soil (0-10 ft bls)	Ingestion	2.7E-01	15%	**8.7E-05**	26%
		Dermal	3.1E-01	17%	**2.5E-04**	74%
		Inhalation of Dust	1.7E-04	0%	4.2E-09	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	5.8E-01	31%	**3.4E-04**	100%
	Groundwater	Ingestion	1.1E+00	59%	0.0E+00	0%
		Dermal	1.7E-01	9%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	**1.3E+00**	69%	0.0E+00	0%
		TOTAL (0-10 ft bls)	**1.9E+00**		**3.4E-04**	
Future Scenario Resident Farmer - Child	Soil (0-2 ft bls)	Ingestion	**2.7E+00**	46%	**4.1E-04**	79%
		Dermal	5.2E-02	1%	**1.1E-04**	21%
		Inhalation of Dust	1.0E-03	0%	5.4E-09	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	**2.7E+00**	46%	**5.2E-04**	100%
	Groundwater	Ingestion	**2.9E+00**	49%	0.0E+00	0%
		Dermal	3.0E-01	5%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	**3.2E+00**	54%	0.0E+00	0%
		TOTAL (0-2 ft bls)	**5.9E+00**		**5.2E-04**	

Table 6.13. Exposure Unit 1 RME Summary Table (continued)
(Non-Radiologicals)

Scenario and Receptor	Media	Pathway	Non-carcinogenic Risk HI	Percent of Total HI	Carcinogenic Risk ILCR	Percent of Total ILCR
Future Scenario Resident Farmer - Child	Soil (0-10 ft bls)	Ingestion	**2.5E+00**	44%	**1.6E-04**	78%
		Dermal	5.6E-02	1%	**4.5E-05**	22%
		Inhalation of Dust	5.4E-04	0%	2.6E-09	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	**2.5E+00**	44%	**2.1E-04**	100%
	Groundwater	Ingestion	**2.9E+00**	51%	0.0E+00	0%
		Dermal	3.0E-01	5%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	**3.2E+00**	56%	0.0E+00	0%
		TOTAL (0-10 ft bls)	**5.7E+00**		**2.1E-04**	

Table 6.14. Exposure Unit 2 RME Summary Table (Non-Radiologicals)

Scenario and Receptor	Media	Pathway	Non-carcinogen Risk HI	Percent of Total HI	Carcinogenic Risk ILCR	Percent of Total ILCR
Current/Future Scenario Industrial Worker	Soil (0-2 ft bls)	Ingestion	2.9E-01	39%	4.0E-07	25%
		Dermal	3.6E-02	5%	**1.1E-06**	69%
		Inhalation of Dust	1.2E-03	0%	6.0E-09	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	3.3E-01	44%	**1.6E-06**	100%
	Groundwater	Ingestion	4.2E-01	56%	0.0E+00	0%
		TOTAL (0-2 ft bls)	7.5E-01		**1.6E-06**	
Future Scenario Resident Farmer - Adult	Soil (0-2 ft bls)	Ingestion	7.9E-01	36%	**5.1E-06**	25%
		Dermal	1.0E-01	5%	**1.5E-05**	74%
		Inhalation of Dust	3.6E-03	0%	7.9E-08	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	9.0E-01	41%	**2.0E-05**	100%
	Groundwater	Ingestion	**1.1E+00**	51%	0.0E+00	0%
		Dermal	1.7E-01	8%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	**1.3E+00**	59%	0.0E+00	0%
		TOTAL (0-2 ft bls)	**2.2E+00**		**2.0E-05**	
Future Scenario Resident Farmer - Adult	Soil (0-10 ft bls)	Ingestion	5.0E-01	28%	**4.9E-06**	26%
		Dermal	3.4E-02	2%	**1.4E-05**	74%
		Inhalation of Dust	2.9E-03	0%	5.1E-08	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	5.4E-01	30%	**1.9E-05**	100%
	Groundwater	Ingestion	**1.1E+00**	61%	0.0E+00	0%
		Dermal	1.7E-01	9%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	**1.3E+00**	70%	0.0E+00	0%
		TOTAL (0-10 ft bls)	**1.8E+00**		**1.9E-05**	
Future Scenario Resident Child Farmer	Soil (0-2 ft bls)	Ingestion	**7.5E+00**	69%	**9.6E-06**	78%
		Dermal	9.0E-02	1%	**2.6E-06**	21%
		Inhalation of Dust	1.1E-02	0%	4.9E-08	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	**7.6E+00**	70%	**1.2E-05**	100%
	Groundwater	Ingestion	**2.9E+00**	27%	0.0E+00	0%
		Dermal	3.0E-01	3%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	**3.2E+00**	30%	0.0E+00	0%
		TOTAL (0-2 ft bls)	**1.1E+01**		**1.2E-05**	

Table 6.14. Exposure Unit 2 RME Summary Table (Non-Radiologicals)

Scenario and Receptor	Media	Pathway	Non-carcinogen Risk HI	Percent of Total HI	Carcinogenic Risk ILCR	Percent of Total ILCR
Future Scenario Resident Child Farmer	Soil (0-10 ft bls)	Ingestion	**4.7E+00**	59%	**9.2E-06**	78%
		Dermal	3.1E-02	0%	**2.5E-06**	21%
		Inhalation of Dust	9.0E-03	0%	3.2E-08	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	**4.7E+00**	59%	**1.2E-05**	100%
	Groundwater	Ingestion	**2.9E+00**	36%	0.0E+00	0%
		Dermal	3.0E-01	4%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	**3.2E+00**	40%	0.0E+00	0%
		TOTAL (0-10 ft bls)	**8.0E+00**		**1.2E-05**	

Table 6.15. Exposure Unit 3 RME Summary Table (Non-Radiologicals)

Scenario and Receptor	Media	Pathway	Non-carcinogen Risk HI	Percent of Total HI	Carcinogenic Risk ILCR	Percent of Total ILCR
Future Scenario Resident Farmer - Adult	Soil (0-2 ft bls)	Ingestion	1.1E-01	8%	0.0E+00	0%
		Dermal	0.0E+00	0%	0.0E+00	0%
		Inhalation of Dust	7.2E-04	0%	1.5E-08	1%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	1.1E-01	8%	1.5E-08	1%
	Groundwater	Ingestion	**1.1E+00**	77%	0.0E+00	0%
		Dermal	1.7E-01	12%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	**1.3E+00**	89%	0.0E+00	0%
	Surface Water	Ingestion	4.0E-03	0%	5.4E-08	2%
		Dermal	3.9E-02	3%	3.7E-07	15%
		Total Surface Water	4.3E-02	3%	4.2E-07	17%
	Sediment	Ingestion	1.2E-03	0%	7.3E-09	0%
		Dermal	5.2E-03	0%	**2.1E-06**	82%
		Total Sediment	6.4E-03	0%	**2.1E-06**	83%
		TOTAL (0-2 ft bls)	**1.4E+00**		**2.5E-06**	
Future Scenario Resident Farmer - Adult	Soil (0-10 ft bls)	Ingestion	9.9E-02	7%	0.0E+00	0%
		Dermal	0.0E+00	0%	0.0E+00	0%
		Inhalation of Dust	6.7E-04	0%	1.4E-08	1%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	9.9E-02	7%	1.4E-08	1%
	Groundwater	Ingestion	**1.1E+00**	78%	0.0E+00	0%
		Dermal	1.7E-01	12%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	**1.3E+00**	90%	0.0E+00	0%
	Surface Water	Ingestion	4.0E-03	0%	5.4E-08	2%
		Dermal	3.9E-02	3%	3.7E-07	15%
		Total Surface Water	4.3E-02	3%	4.2E-07	17%
	Sediment	Ingestion	1.2E-03	0%	7.3E-09	0%
		Dermal	5.2E-03	0%	**2.1E-06**	83%
		Total Sediment	6.4E-03	0%	**2.1E-06**	83%
		TOTAL (0-10 ft bls)	**1.4E+00**		**2.5E-06**	

Table 6.15. Exposure Unit 3 RME Summary Table (continued)
(Non-Radiologicals)

Scenario and Receptor	Media	Pathway	Non-carcinogen Risk HI	Percent of Total HI	Carcinogenic Risk ILCR	Percent of Total ILCR
Future Scenario Resident Child Farmer	Soil (0-2 ft bls)	Ingestion	9.9E-01	23%	0.0E+00	0%
		Dermal	0.0E+00	0%	0.0E+00	0%
		Inhalation of Dust	2.2E-03	0%	9.2E-09	1%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	9.9E-01	23%	9.2E-09	1%
	Groundwater	Ingestion	**2.9E+00**	66%	0.0E+00	0%
		Dermal	3.0E-01	7%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	**3.2E+00**	73%	0.0E+00	0%
	Surface Water	Ingestion	1.6E-02	0%	5.7E-08	5%
		Dermal	1.4E-01	3%	2.7E-07	25%
		Total Surface Water	1.5E-01	3%	3.2E-07	29%
	Sediment	Ingestion	2.2E-02	1%	2.7E-08	2%
		Dermal	9.4E-03	0%	7.4E-07	68%
		Total Sediment	3.1E-02	1%	7.7E-07	70%
		TOTAL (0-2 ft bls)	**4.4E+00**		**1.1E-06**	
Future Scenario Resident Child Farmer	Soil (0-10 ft bls)	Ingestion	9.2E-01	21%	0.0E+00	0%
		Dermal	0.0E+00	0%	0.0E+00	0%
		Inhalation of Dust	2.1E-03	0%	8.6E-09	1%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	9.2E-01	21%	8.6E-09	1%
	Groundwater	Ingestion	**2.9E+00**	66%	0.0E+00	0%
		Dermal	3.0E-01	7%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	**3.2E+00**	73%	0.0E+00	0%
	Surface Water	Ingestion	1.6E-02	0%	5.7E-08	5%
		Dermal	1.4E-01	3%	2.7E-07	25%
		Total Surface Water	1.5E-01	3%	3.2E-07	29%
	Sediment	Ingestion	2.2E-02	1%	2.7E-08	2%
		Dermal	9.4E-03	0%	7.4E-07	68%
		Total Sediment	3.1E-02	1%	7.7E-07	70%
		TOTAL (0-10 ft bls)	**4.4E+00**		**1.1E-06**	

Table 6.16. Exposure Unit 4 RME Summary Table (Non-Radiologicals)

Scenario and Receptor	Media	Pathway	Non-carcinogen Risk HI	Percent of Total HI	Carcinogenic Risk ILCR	Percent of Total ILCR
Current/Future Scenario Adolescent Trespasser	Soil (0-2 ft bls)	Ingestion	1.5E-02	21%	0.0E+00	0%
		Dermal	0.0E+00	0%	0.0E+00	0%
		Inhalation of Dust	1.9E-06	0%	1.3E-11	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	1.5E-02	21%	1.3E-11	0%
	Surface Water	Ingestion	3.2E-03	4%	2.6E-09	0%
		Dermal	1.3E-02	18%	1.2E-07	8%
		Total Surface Water	1.6E-02	23%	1.2E-07	9%
	Sediment	Ingestion	4.3E-04	1%	1.8E-09	0%
		Dermal	4.1E-02	57%	**1.3E-06**	91%
		Total Sediment	4.1E-02	58%	**1.3E-06**	91%
		TOTAL	7.2E-02		**1.4E-06**	

Table 6.17. Exposure Unit 5 RME Summary Table (Non-Radiologicals)

Scenario and Receptor	Media	Pathway	Noncarcinogen Risk HI	Percent of Total HI	Carcinogenic Risk ILCR	Percent of Total ILCR
Current/Future Scenario Adolescent Trespasser	Soil (0-2 ft bls)	Ingestion	0.0E+00	--	0.0E+00	--
		Dermal	0.0E+00	--	0.0E+00	--
		Inhalation of Dust	0.0E+00	--	0.0E+00	--
		Inhalation of VOCs	0.0E+00	--	0.0E+00	--
		Total Soil	0.0E+00	--	0.0E+00	--
	Surface Water	Ingestion	1.6E-04	100%	0.0E+00	--
		Dermal	0.0E+00	--	0.0E+00	--
		Total Surface Water	1.6E-04	100%	0.0E+00	--
		TOTAL	1.6E-04		0.0E+00	

Table 6.18. Exposure Unit 6 RME Summary Table (Non-Radiologicals)

Scenario and Receptor	Media	Pathway	Non-carcinogen Risk HI	Carcinogenic Risk ILCR
Current/Future Scenario Adolescent Trespasser	Soil (0-2 ft bls)	Ingestion	0.0E+00	0.0E+00
		Dermal	0.0E+00	0.0E+00
		Inhalation of Dust	0.0E+00	0.0E+00
		Inhalation of VOCs	0.0E+00	0.0E+00
		TOTAL	0.0E+00	0.0E+00

Table 6.19. Exposure Unit 1 CT Summary Table (Non-Radiologicals)

Scenario and Receptor	Media	Pathway	Non-carcinogen Risk HI	Percent of Total HI	Carcinogenic Risk ILCR	Percent of Total ILCR
Current/Future Scenario Industrial Worker	Soil (0-2 ft bls)	Ingestion	2.1E-02	10%	**3.6E-06**	82%
		Dermal	4.2E-03	2%	8.5E-07	19%
		Inhalation of Dust	2.3E-05	0%	1.4E-10	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	2.6E-02	13%	**4.4E-06**	100%
	Groundwater	Ingestion	1.8E-01	87%	0.0E+00	0%
		TOTAL	2.1E-01		**4.4E-06**	
Future Scenario Resident Farmer - Adult	Soil (0-2 ft bls)	Ingestion	8.7E-02	10%	**2.0E-05**	47%
		Dermal	8.4E-02	9%	**2.3E-05**	53%
		Inhalation of Dust	1.9E-04	0%	1.6E-09	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	1.7E-01	19%	**4.3E-05**	100%
	Groundwater	Ingestion	6.8E-01	76%	0.0E+00	0%
		Dermal	3.8E-02	4%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	7.2E-01	81%	0.0E+00	0%
		TOTAL (0-2 ft bls)	8.9E-01		**4.3E-05**	
Future Scenario Resident Farmer - Adult	Soil (0-10 ft bls)	Ingestion	8.0E-02	9%	**7.8E-06**	46%
		Dermal	9.0E-02	10%	**9.3E-06**	55%
		Inhalation of Dust	1.0E-04	0%	7.6E-10	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	1.7E-01	19%	**1.7E-05**	100%
	Groundwater	Ingestion	6.8E-01	77%	0.0E+00	0%
		Dermal	3.8E-02	4%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	7.2E-01	81%	0.0E+00	0%
		TOTAL (0-10 ft bls)	8.9E-01		**1.7E-05**	
Future Scenario Resident Farmer-Child	Soil (0-2 ft bls)	Ingestion	8.1E-01	34%	**1.2E-04**	88%
		Dermal	0.0E+00	0%	**1.7E-05**	12%
		Inhalation of Dust	6.0E-04	0%	3.2E-09	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	8.1E-01	34%	**1.4E-04**	100%
	Groundwater	Ingestion	**1.5E+00**	63%	0.0E+00	0%
		Dermal	7.0E-02	3%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	**1.6E+00**	66%	0.0E+00	0%
		TOTAL (0-2 ft bls)	**2.4E+00**		**1.4E-04**	

Table 6.19. Exposure Unit 1 CT Summary Table (Non-Radiologicals)

Scenario and Receptor	Media	Pathway	Non-carcinogen Risk HI	Percent of Total HI	Carcinogenic Risk ILCR	Percent of Total ILCR
Future Scenario Resident Farmer-Child	Soil (0-10 ft bls)	Ingestion	8.7E-02	5%	**2.0E-05**	47%
		Dermal	8.4E-02	5%	**2.3E-05**	53%
		Inhalation of Dust	1.9E-04	0%	1.6E-09	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	1.7E-01	10%	**4.3E-05**	100%
	Groundwater	Ingestion	**1.5E+00**	86%	0.0E+00	0%
		Dermal	7.0E-02	4%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	**1.6E+00**	90%	0.0E+00	0%
		TOTAL (0-10 ft bls)	**1.7E+00**		**4.3E-05**	

Table 6.20. Exposure Unit 2 CT Summary Table (Non-Radiologicals)

Scenario and Receptor	Media	Pathway	Non-carcinogen Risk HI	Percent of Total HI	Carcinogenic Risk ILCR	Percent of Total ILCR
Current/Future Scenario Industrial Worker	Soil (0-2 ft bls)	Ingestion	6.0E-02	24%	8.4E-08	84%
		Dermal	6.2E-04	0%	2.0E-08	20%
		Inhalation of Dust	2.6E-04	0%	1.2E-09	1%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	6.1E-02	24%	1.0E-07	100%
	Groundwater	Ingestion	1.9E-01	76%	0.0E+00	0%
		TOTAL	2.5E-01		1.0E-07	
Future Scenario Resident Farmer - Adult	Soil (0-2 ft bls)	Ingestion	2.4E-01	25%	4.6E-07	45%
		Dermal	1.2E-02	1%	5.4E-07	53%
		Inhalation of Dust	2.1E-03	0%	1.4E-08	1%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	2.5E-01	26%	1.0E-06	100%
	Groundwater	Ingestion	6.8E-01	70%	0.0E+00	0%
		Dermal	3.8E-02	4%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	7.2E-01	74%	0.0E+00	0%
		TOTAL (0-2 ft bls)	9.7E-01		**1.0E-06**	
Future Scenario Resident Farmer - Adult	Soil (0-10 ft bls)	Ingestion	1.5E-01	17%	4.4E-07	45%
		Dermal	4.2E-03	0%	5.2E-07	54%
		Inhalation of Dust	1.7E-03	0%	9.2E-09	1%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	1.6E-01	18%	9.7E-07	100%
	Groundwater	Ingestion	6.8E-01	78%	0.0E+00	0%
		Dermal	3.8E-02	4%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	7.2E-01	82%	0.0E+00	0%
		TOTAL (0-10 ft bls)	8.7E-01		9.7E-07	
Future Scenario Resident Child Farmer	Soil (0-2 ft bls)	Ingestion	**2.2E+00**	57%	**2.9E-06**	88%
		Dermal	1.4E-02	0%	4.0E-07	12%
		Inhalation of Dust	6.7E-03	0%	3.0E-08	1%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	**2.3E+00**	59%	**3.3E-06**	100%
	Groundwater	Ingestion	**1.5E+00**	39%	0.0E+00	0%
		Dermal	7.0E-02	2%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	**1.6E+00**	41%	0.0E+00	0%
		TOTAL (0-2 ft bls)	**3.9E+00**		**3.3E-06**	

Table 6.20. Exposure Unit 2 CT Summary Table (continued)
(Non-Radiologicals)

Scenario and Receptor	Media	Pathway	Non-carcinogen Risk HI	Percent of Total HI	Carcinogenic Risk ILCR	Percent of Total ILCR
Future Scenario Resident Child Farmer	Soil (0-10 ft bls)	Ingestion	**1.4E+00**	47%	**2.8E-06**	88%
		Dermal	4.7E-03	0%	3.9E-07	12%
		Inhalation of Dust	5.4E-03	0%	1.9E-08	1%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	**1.4E+00**	47%	**3.2E-06**	100%
	Groundwater	Ingestion	**1.5E+00**	50%	0.0E+00	0%
		Dermal	7.0E-02	2%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	**1.6E+00**	53%	0.0E+00	0%
		TOTAL (0-10 ft bls)	**3.0E+00**		**3.2E-06**	

Table 6.21. Exposure Unit 3 CT Summary Table (Non-Radiologicals)

Scenario and Receptor	Media	Pathway	Non-carcinogen Risk HI	Percent of Total HI	Carcinogenic Risk ILCR	Percent of Total ILCR
Current/Future Scenario Resident Farmer - Adult	Soil (0-2 ft bls)	Ingestion	3.2E-02	4%	0.0E+00	0%
		Dermal	0.0E+00	0%	0.0E+00	0%
		Inhalation of Dust	4.3E-04	0%	2.7E-09	1%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	3.2E-02	4%	2.7E-09	1%
	Groundwater	Ingestion	6.8E-01	85%	0.0E+00	0%
		Dermal	3.8E-02	5%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	7.2E-01	90%	0.0E+00	0%
	Surface Water	Ingestion	1.8E-03	0%	9.9E-09	4%
		Dermal	3.2E-02	4%	9.1E-08	40%
		Total Surface Water	3.4E-02	4%	1.0E-07	43%
	Sediment	Ingestion	5.9E-04	0%	1.1E-09	0%
		Dermal	1.1E-03	0%	1.3E-07	57%
		Total Sediment	1.7E-03	0%	1.3E-07	57%
		TOTAL	8.0E-01		2.3E-07	
Current/Future Scenario Resident Farmer - Adult	Soil (0-10 ft bls)	Ingestion	3.0E-02	4%	0.0E+00	0%
		Dermal	0.0E+00	0%	0.0E+00	0%
		Inhalation of Dust	4.0E-04	0%	2.5E-09	1%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	3.0E-02	4%	2.5E-09	1%
	Groundwater	Ingestion	6.8E-01	85%	0.0E+00	0%
		Dermal	3.8E-02	5%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	7.2E-01	90%	0.0E+00	0%
	Surface Water	Ingestion	1.8E-03	0%	9.9E-09	4%
		Dermal	3.2E-02	4%	9.1E-08	40%
		Total Surface Water	3.4E-02	4%	1.0E-07	43%
	Sediment	Ingestion	5.9E-04	0%	1.1E-09	0%
		Dermal	1.1E-03	0%	1.3E-07	57%
		Total Sediment	1.7E-03	0%	1.3E-07	57%
		TOTAL	7.8E-01		2.3E-07	

Table 6.21. Exposure Unit 3 CT Summary Table (Non-Radiologicals)

Scenario and Receptor	Media	Pathway	Non-carcinogen Risk HI	Percent of Total HI	Carcinogenic Risk ILCR	Percent of Total ILCR
Current/Future Scenario Resident Farmer - Child	Soil (0-2 ft bls)	Ingestion	3.0E-01	15%	0.0E+00	0%
		Dermal	0.0E+00	0%	0.0E+00	0%
		Inhalation of Dust	1.3E-03	0%	5.5E-09	1%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	3.0E-01	15%	5.5E-09	1%
	Groundwater	Ingestion	**1.5E+00**	75%	0.0E+00	0%
		Dermal	7.0E-02	4%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	**1.6E+00**	79%	0.0E+00	0%
	Surface Water	Ingestion	8.0E-03	0%	2.9E-08	6%
		Dermal	1.2E-01	6%	2.3E-07	50%
		Total Surface Water	1.3E-01	7%	2.5E-07	54%
	Sediment	Ingestion	1.1E-02	1%	1.4E-08	3%
		Dermal	2.4E-03	0%	1.9E-07	41%
		Total Sediment	1.3E-02	1%	2.0E-07	44%
		TOTAL	**2.0E+00**		4.6E-07	
Current/Future Scenario Resident Farmer - Child	Soil (0-10 ft bls)	Ingestion	2.8E-01	14%	0.0E+00	0%
		Dermal	0.0E+00	0%	0.0E+00	0%
		Inhalation of Dust	1.3E-03	0%	5.1E-09	1%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	2.8E-01	14%	5.1E-09	1%
	Groundwater	Ingestion	**1.5E+00**	75%	0.0E+00	0%
		Dermal	7.0E-02	4%	0.0E+00	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Groundwater	**1.6E+00**	79%	0.0E+00	0%
	Surface Water	Ingestion	8.0E-03	0%	2.9E-08	6%
		Dermal	1.2E-01	6%	2.3E-07	50%
		Total Surface Water	1.3E-01	7%	2.5E-07	54%
	Sediment	Ingestion	1.1E-02	1%	1.4E-08	3%
		Dermal	2.4E-03	0%	1.9E-07	41%
		Total Sediment	1.3E-02	1%	2.0E-07	44%
		TOTAL	**2.0E+00**		4.6E-07	

Table 6.22. Exposure Unit 4 CT Summary Table (Non-Radiologicals)

Scenario and Receptor	Media	Pathway	Non-carcinogen Risk HI	Percent of Total HI	Carcinogenic Risk ILCR	Percent of Total ILCR
Current/Future Scenario Adolescent Trespasser	Soil (0-2 ft bls)	Ingestion	7.3E-03	33%	0.0E+00	0%
		Dermal	0.0E+00	0%	0.0E+00	0%
		Inhalation of Dust	1.9E-06	0%	1.3E-11	0%
		Inhalation of VOCs	0.0E+00	0%	0.0E+00	0%
		Total Soil	7.3E-03	33%	1.3E-11	0%
	Surface Water	Ingestion	1.9E-03	9%	1.6E-09	1%
		Dermal	1.0E-02	45%	9.5E-08	55%
		Total Surface Water	1.2E-02	54%	9.6E-08	55%
	Sediment	Ingestion	1.1E-04	1%	4.5E-10	0%
		Dermal	2.5E-03	11%	7.7E-08	44%
		Total Sediment	2.6E-03	12%	7.7E-08	45%
		TOTAL	2.2E-02		1.7E-07	

Table 6.23. Risk-Based Concentrations for COCs,
RME Scenarios

Receptor	COC	EPC (mg/kg)	RME ILCR	RME HI	RBC - Cancer 1×10^{-6}	RBC - Non-cancer HI = 1
EXPOSURE UNIT 1 SURFACE SOIL (0 - 2 FT)						
Current/Future Industrial Worker	Benzo(a)anthracene	47.20	6.10E-06	0.00E+00	7.74E+00	--
	Benzo(a)pyrene	39.10	5.10E-05	0.00E+00	7.67E-01	--
	Benzo(b)fluoranthene	59.90	7.70E-06	0.00E+00	7.78E+00	--
	Aroclor-1254	3.20	1.20E-06	1.50E-06	2.67E+00	2.13E+06
Future Resident Farmer - Adult	Benzo(a)anthracene	47.20	7.77E-05	0.00E+00	6.08E-01	--
	Benzo(a)pyrene	39.10	6.44E-04	0.00E+00	6.08E-02	--
	Benzo(b)fluoranthene	59.90	9.86E-05	0.00E+00	6.08E-01	--
	Dibenz(a,h)anthracene	0.46	7.54E-06	0.00E+00	6.08E-02	--
	Indeno(1,2,3-c,d)pyrene	2.01	3.31E-06	0.00E+00	6.08E-01	--
	Aroclor-1254	3.20	1.5E-05	5.07E-01	2.10E-01	6.32E+00
Future Resident Farmer - Child	Benzo(a)anthracene	47.20	4.81E-05	0.00E+00	9.80E-01	--
	Benzo(a)pyrene	39.10	3.99E-04	0.00E+00	9.80E-02	--
	Benzo(b)fluoranthene	59.90	6.11E-05	0.00E+00	9.80E-01	--
	Dibenz(a,h)anthracene	0.46	4.67E-06	0.00E+00	9.80E-02	--
	Indeno(1,2,3-c,d)pyrene	2.01	2.05E-06	0.00E+00	9.80E-01	--
	Aroclor-1254	3.20	9.09E-06	2.10E+00	3.52E-01	1.53E+00
EXPOSURE UNIT 1 TOTAL SOIL (0 - 10 FT)						
Receptor	**COC**	**EPC (mg/kg)**	**RME ILCR**	**RME HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Future Resident Farmer - Adult	Benzo(a)anthracene	17.70	2.90E-05	0.00E+00	6.10E-01	--
	Benzo(a)pyrene	14.70	2.40E-04	0.00E+00	6.13E-02	--
	Benzo(b)fluoranthene	22.30	3.70E-05	0.00E+00	6.03E-01	--
	Dibenz(a,h)anthracene	0.46	7.50E-06	0.00E+00	6.11E-02	--
	Indeno(1,2,3-c,d)pyrene	2.01	3.30E-06	0.00E+00	6.09E-01	--
	Aroclor-1254	3.43	1.60E-05	5.40E-01	2.14E-01	6.35E+00
Future Resident Farmer - Child	Benzo(a)anthracene	17.70	1.80E-05	0.00E+00	9.83E-01	--
	Benzo(a)pyrene	14.70	1.50E-04	0.00E+00	9.80E-02	--
	Benzo(b)fluoranthene	22.30	2.30E-05	0.00E+00	9.70E-01	--
	Dibenz(a,h)anthracene	0.46	4.70E-06	0.00E+00	9.74E-02	--
	Indeno(1,2,3-c,d)pyrene	2.01	2.10E-06	0.00E+00	9.57E-01	--
	Aroclor-1254	3.43	9.70E-06	2.20E+00	3.54E-01	1.56E+00
EXPOSURE UNIT 2 SURFACE SOIL (0 - 2 FT)						
Receptor	**COC**	**EPC (mg/kg)**	**RME ILCR**	**RME HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Current/Future Industrial Worker	Benzo(a)pyrene	0.92	1.20E-06	0.00E+00	7.68E-01	--
	Lead	1380.00	--	--	--	9.58E+02
Future Resident Farmer - Adult	Benzo(a)anthracene	0.89	1.46E-06	0.00E+00	6.08E-01	--
	Benzo(a)pyrene	0.92	1.52E-05	0.00E+00	6.08E-02	--
	Benzo(b)fluoranthene	1.14	1.88E-06	0.00E+00	6.08E-01	--
	Indeno(1,2,3-cd)pyrene	0.72	1.19E-06	0.00E+00	6.08E-01	--
	Lead	1380.00	--	--	--	4.00E+02
Future Resident Farmer - Child	Benzo(a)pyrene	0.92	9.39E-06	0.00E+00	9.80E-02	--
	Benzo(b)fluoranthene	1.14	1.16E-06	0.00E+00	9.80E-01	--
	Beryllium	765.00	4.56E-08	4.90E+00	1.68E+04	1.56E+02
	Cadmium	83.50	3.73E-09	2.23E+00	2.24E+04	3.75E+01
	Lead	1380.00	--	--	--	4.00E+02

Table 6.23. Risk-Based Concentrations for COCs, RME Scenarios

Receptor	COC	EPC (mg/kg)	RME ILCR	RME HI	RBC - Cancer 1×10^{-6}	RBC - Non-cancer HI = 1
EXPOSURE UNIT 2 TOTAL SOIL (0 - 10 FT)						
Future Resident Farmer - Adult	Benzo(a)anthracene	0.92	1.50E-06	0.00E+00	6.13E-01	--
	Benzo(a)pyrene	0.89	1.50E-05	0.00E+00	5.92E-02	--
	Benzo(b)fluoranthene	1.01	1.70E-06	0.00E+00	5.94E-01	--
	Indeno(1,2,3-cd)pyrene	0.65	1.10E-06	0.00E+00	5.94E-01	--
	Lead	561.00	--	--	--	4.00E+02
Future Resident Farmer - Child	Benzo(a)pyrene	0.89	9.10E-06	0.00E+00	9.76E-02	--
	Benzo(b)fluoranthene	1.01	1.00E-06	0.00E+00	1.01E+00	--
	Beryllium	514.00	3.10E-08	3.30E+00	1.66E+04	1.56E+02
	Lead	561.00	--	--	--	4.00E+02
EXPOSURE UNIT 3 SURFACE SOIL (0 - 2 FT)						
Receptor	**COC**	**EPC (mg/kg)**	**RME ILCR**	**RME HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Current/Future Resident Farmer - Adult	None					
Current/Future Resident Farmer - Child	Beryllium	155.00	9.23E-09	9.93E-01	1.68E+04	1.56E+02
EXPOSURE UNIT 3 TOTAL SOIL (0 - 10 FT)						
Receptor	**COC**	**EPC (mg/kg)**	**RME ILCR**	**RME HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Current/Future Resident Farmer - Adult	None					
Current/Future Resident Farmer - Child	None					
EXPOSURE UNIT 3 SURFACE WATER						
Receptor	**COC**	**EPC (mg/L)**	**RME ILCR**	**RME HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Current/Future Resident Farmer - Adult	None					
Current/Future Resident Farmer - Child	None					
EXPOSURE UNIT 3 SEDIMENT						
Receptor	**COC**	**EPC (mg/kg)**	**RME ILCR**	**RME HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Current/Future Resident Farmer - Adult	Benzo(a)pyrene	1.78	1.60E-06	0.00E+00	1.11E+00	--
Current/Future Resident Farmer - Child	None					

Table 6.23. Risk-Based Concentrations for COCs, RME Scenarios

Receptor	COC	EPC (mg/L)	RME ILCR	RME HI	RBC - Cancer 1×10^{-6}	RBC - Non-cancer HI = 1
EXPOSURE UNITS 1, 2, AND 3 SITE-WIDE GROUNDWATER						
Current/Future Industrial Worker	None					
Current/Future Resident Farmer - Adult	None					
Current/Future Resident Farmer - Child	Manganese	0.37	0.00E+00	1.40E+00	--	2.66E-01
EXPOSURE UNIT 4 SURFACE SOIL (0 - 2 FT)						
Receptor	**COC**	**EPC (mg/kg)**	**RME ILCR**	**RME HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Current/Future Adolescent Trespasser	None					
EXPOSURE UNIT 4 SURFACE WATER						
Receptor	**COC**	**EPC (mg/L)**	**RME ILCR**	**RME HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Current/Future Adolescent Trespasser	None					
EXPOSURE UNIT 4 SEDIMENT						
Receptor	**COC**	**EPC (mg/kg)**	**RME ILCR**	**RME HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Current/Future Adolescent Trespasser	Benzo(a)pyrene	0.20	1.00E-06	0.00E+00	1.99E-01	--
EXPOSURE UNIT 5 SURFACE SOIL (0 - 2 FT)						
Receptor	**COC**	**EPC (mg/kg)**	**RME ILCR**	**RME HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Current/Future Adolescent Trespasser	None					
EXPOSURE UNIT 5 SURFACE WATER						
Receptor	**COC**	**EPC (mg/L)**	**RME ILCR**	**RME HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Current/Future Adolescent Trespasser	None					
EXPOSURE UNIT 6 SURFACE SOIL (0 - 2 FT)						
Receptor	**COC**	**EPC (mg/kg)**	**RME ILCR**	**RME HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Current/Future Adolescent Trespasser	None					

COC = Constituent of Concern
RME = Reasonable Maximum Exposures
EPC = Exposure Point Concentration
HI = Hazard Index (Non Cancer Risk)
ILCR = Incremental Lifetime Cancer Risk
RBC = Risk Based Concentration

Table 6.24. Risk-Based Concentrations for COCs, CT Scenarios

Receptor	COC	EPC (mg/kg)	CT ILCR	CT HI	RBC - Cancer 1×10^{-6}	RBC - Non-cancer HI = 1
EXPOSURE UNIT 1 SURFACE SOIL (0 - 2 FT)						
Current/Future Industrial Worker	Benzo(a)pyrene	39.10	3.40E-06	0.00E+00	1.15E+01	--
Future Resident Farmer - Adult	Benzo(a)anthracene	47.20	3.97E-06	0.0E+00	1.19E+01	--
	Benzo(a)pyrene	39.10	3.29E-05	0.0E+00	1.19E+00	--
	Benzo(b)fluoranthene	59.90	5.04E-06	0.0E+00	1.19E+01	--
Future Resident Farmer - Child	Benzo(a)anthracene	47.20	1.29E-05	0.0E+00	3.65E+00	--
	Benzo(a)pyrene	39.10	1.07E-04	0.0E+00	3.65E-01	--
	Benzo(b)fluoranthene	59.90	1.64E-05	0.0E+00	3.65E+00	--
	Dibenz(a,h)anthracene	0.46	1.25E-06	0.0E+00	3.65E-01	--
	Aroclor-1254	3.20	2.42E-06	6.14E-01	1.32E+00	5.21E+00
EXPOSURE UNIT 1 TOTAL SOIL (0 - 10 FT)						
Receptor	**COC**	**EPC (mg/kg)**	**CT ILCR**	**CT HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Future Resident Farmer - Adult	Benzo(a)anthracene	17.70	1.50E-06	0.00E+00	1.18E+01	--
	Benzo(a)pyrene	14.70	1.20E-05	0.00E+00	1.23E+00	--
	Benzo(b)fluoranthene	22.30	1.90E-06	0.00E+00	1.17E+01	--
Future Resident Farmer - Child	Benzo(a)anthracene	17.70	4.80E-06	0.00E+00	3.69E+00	--
	Benzo(a)pyrene	14.70	4.00E-05	0.00E+00	3.68E-01	--
	Benzo(b)fluoranthene	22.30	6.10E-06	0.00E+00	3.66E+00	--
	Dibenz(a,h)anthracene	0.46	1.30E-06	0.00E+00	3.52E-01	--
	Aroclor-1254	3.43	2.60E-06	6.60E-01	1.32E+00	5.20E+00
EXPOSURE UNIT 2 TOTAL SOIL (0 - 10 FT)						
Receptor	**COC**	**EPC (mg/kg)**	**CT ILCR**	**CT HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Current/Future Industrial Worker	Lead	1380.00	--	--	--	9.58E+02
Future Resident Farmer - Adult	Lead	1380.00	--	--	--	4.00E+02
Future Resident Farmer - Child	Benzo(a)pyrene	0.92	2.52E-06	0.00E+00	3.65E-01	--
	Beryllium	765.00	2.73E-08	1.47E+00	2.80E+04	5.19E+02
	Lead	1380.00	--	--	--	4.00E+02
EXPOSURE UNIT 2 TOTAL SOIL (0 - 10 FT)						
Receptor	**COC**	**EPC (mg/kg)**	**CT ILCR**	**CT HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Future Resident Farmer - Adult	Lead	561.00	--	--	--	4.00E+02
Future Resident Farmer - Child	Benzo(a)pyrene	0.89	2.40E-06	0.00E+00	3.70E-01	--
	Beryllium	514.00	1.80E-08	9.90E-01	2.86E+04	5.19E+02
	Lead	561.00	--	--	--	4.00E+02

Table 6.24. Risk-Based Concentrations for COCs,
CT Scenarios

Receptor	COC	EPC (mg/kg)	CT ILCR	CT HI	RBC - Cancer 1×10^{-6}	RBC - Non-cancer HI = 1
EXPOSURE UNIT 3 SURFACE SOIL (0 - 2 FT)						
Current/Future Resident Farmer - Adult	None					
Current/Future Resident Farmer - Child	None					
EXPOSURE UNIT 3 TOTAL SOIL (0 - 10 FT)						
Current/Future Resident Farmer - Adult	None					
Current/Future Resident Farmer - Child	None					
EXPOSURE UNIT 3 SEDIMENT						
Current/Future Resident Farmer - Adult	None					
Current/Future Resident Farmer - Child	None					
EXPOSURE UNIT 3 SURFACE WATER						
Current/Future Resident Farmer - Adult	None					
Current/Future Resident Farmer - Child	None					
EXPOSURE UNITS 1, 2, AND 3 SITE-WIDE GROUNDWATER						
Current/Future Industrial Worker	None					
Current/Future Resident Farmer - Adult	None					
Current/Future Resident Farmer - Child	None					

Table 6.24. Risk-Based Concentrations for COCs,
CT Scenarios

Receptor	COC	EPC (mg/kg)	CT ILCR	CT HI	RBC - Cancer 1×10^{-6}	RBC - Non-cancer HI = 1
EXPOSURE UNIT 4 SURFACE SOIL (0 - 2 FT)						
Current/Future Adolescent Trespasser	None					
EXPOSURE UNIT 4 SURFACE WATER						
Receptor	**COC**	**EPC (mg/L)**	**CT ILCR**	**CT HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Current/Future Adolescent Trespasser	None					
EXPOSURE UNIT 4 SEDIMENT						
Receptor	**COC**	**EPC (mg/kg)**	**CT ILCR**	**CT HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Current/Future Adolescent Trespasser	None					
EXPOSURE UNIT 5 SURFACE SOIL (0 - 2 FT)						
Receptor	**COC**	**EPC (mg/kg)**	**CT ILCR**	**CT HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Current/Future Adolescent Trespasser	None					
EXPOSURE UNIT 5 SURFACE WATER						
Receptor	**COC**	**EPC (mg/L)**	**CT ILCR**	**CT HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Current/Future Adolescent Trespasser	None					
EXPOSURE UNIT 6 SURFACE SOIL (0 - 2 FT)						
Receptor	**COC**	**EPC (mg/kg)**	**CT ILCR**	**CT HI**	**RBC - Cancer 1×10^{-6}**	**RBC - Non-cancer HI = 1**
Current/Future Adolescent Trespasser	None					

COC = Constituent of Concern
CT = Central Tendancy
EPC = Exposure Point Concentration
HI = Hazard Index (Non-cancer Risk)
ILCR = Incremental Lifetime Cancer Risk
RBC = Risk Based Concentration

Table 6.25. Radionuclides Populating the Site Database and Preferred Methods

Radionuclide	Phase II Analytical Method [1]	Phase IV Analytical Method [1]	Note
Actinium-227	GAMMASPEC ***ALPHASPEC***	***Alpha Spec.*** ***EPI A-012*** EPI A-013	Alpha Spec. = EPI A-012
Actinium-228	none	EPI A-013	Don't need. Same as Ra-228
Americium-241	***GAMMASPEC*** ISGS	None	
Cesium-137	***GAMMASPEC*** ISGS	***EPI A-013***	
Cobalt-60	none	***EPI A-013***	
Potassium-40	***GAMMASPEC*** ISGS	***EPI A-013***	
Protactinium-231	***GAMMASPEC***	***EPI A-013***	
Radium-226	No entry GAMMASPEC ***ALPHASPEC*** ISGS	***EPI A-013***	"No entry" does not produce conflicts
Radium-228	***GAMMASPEC*** ALPHASPEC ISGS	***EPI A-013***	ALPHASPEC representative of Th-228 conc., not Ra-228
Thorium-227	ALPHASPEC	None	Don't need. Same as Ac-227
Thorium-228	GAMMASPEC ***ALPHASPEC*** ISGS	***Alpha Spec.*** ***EPI A-012***	Alpha Spec. = EPI A-012
Thorium-230	GAMMASPEC ***ALPHASPEC*** ISGS	***Alpha Spec.*** ***EPI A-012***	Alpha Spec. = EPI A-012
Thorium-232	No entry GAMMASPEC ***ALPHASPEC*** ISGS	***Alpha Spec.*** ***EPI A-012***	Alpha Spec. = EPI A-012 "No entry" does not produce conflicts
Thorium-234	none	EPI A-013	Don't need. Same as U-238
Uranium-233/234	none	***Alpha Spec.*** ***EPI A-011***	Alpha Spec. = EPI A-011 Likely only U-234
Uranium-234	***ALPHASPEC***	***EPI A-011*** EPI A-013	
Uranium-235	GAMMASPEC ***ALPHASPEC*** ISGS	None	
Uranium-235/236	none	***Alpha Spec.***	Likely only U-235
Uranium-238	No entry GAMMASPEC ***ALPHASPEC*** ISGS	***Alpha Spec.*** ***EPI A-011***	Alpha Spec. = EPI A-011 "No entry" does not produce conflicts.

[1] Results from bolded methods used to produce data summaries for screens and risk calculations. Methods presented as listed in the site database:

EPI A-011 = isotopic uranium analysis by alpha spectrometry
EPI A-012 = isotopic thorium analysis by alpha spectrometry
EPI A-013 = gamma spectrometry
ISGS = insitu gamma spectrometry
No entry = method not listed
none = not analyzed during phase

Table 6.26. Radionuclides Identified above UTL Screening Values**

	Medium			
Radionuclide	Soil	Sediment	Surface Water	GroundWater
Actinium-227		Yes		
Americium-241	Yes			
Cobalt-60				
Cesium-137		Yes		
Potassium-40			Yes	
Protactinium-231	No UTL	No UTL		
Radium-226*	Yes	Yes	Yes	
Radium-228			No UTL	
Thorium-228			No UTL	
Thorium-230	Yes	Yes		
Thorium-232			No UTL	No UTL
Uranium-234	Yes	Yes	Yes	Yes
Uranium-235		Yes	No UTL	
Uranium-238	Yes	Yes	Yes	Yes

* Includes lead-210 for soil and sediment.
** Radionuclides with no upper tolerance limit (UTL) were retained as COPCs depending on the result of the weight-of-evidence screening.

Table 6.27. Building Material Analytical Results

PARAMETER	LUBM0043 (pCi/g)	LUBM0068 (pCi/g)	LUBM0093 (pCi/g)	LUBM0098 (pCi/g)	LUBM0099 (pCi/g)
Actinium-227	0.314 U ± 0.34	0.832 J ± 0.4	0.245 J ± 0.21	0.0866 U ± 0.14	-0.0279 U ± 0.028
Actinium-228	0.582 J ± 0.18	0.292 U ± 0.3	0.0965 U ± 0.16	0.198 U ± 0.16	0.0 U ± 0.14
Cesium-137	0.0346 U ± 0.031	0.0099 U ± 0.066	-0.0009 U ± 0.039	0.0 U ± 0.027	0.0144 U ± 0.022
Cobalt-60	0.0198 U ± 0.026	-0.0261 U ± 0.082	0.0106 U ± 0.033	0.0084 U ± 0.021	-0.0187 U ± 0.021
Potassium-40	3.47 ± 0.86	1.76 ± 1.4	0.652 U ± 0.44	9.03 ± 1.1	7.34 ± 1.2
Protactinium-231	0.324 U ± 1.1	-0.0813 U ± 3.1	-0.774 U ± 1.5	-0.0385 U ± 0.75	-0.29 U ± 0.82
Radium-226	2.69 ± 0.35	21.5 ± 2.4	4.4000 ± 0.52	0.752 J ± 0.15	0.444 J ± 0.095
Radium-228	0.582 J ± 0.18	0.292 U ± 0.3	0.0965 U ± 0.16	0.198 J ± 0.16	0.316 J ± 0.14
Thorium-228	0.742 J ± 0.4	0.0846 U ± 0.088	0.255 J ± 0.16	0.308 J ± 0.17	0.273 J ± 0.16
Thorium-230	7.3 ± 1.9	19.1 ± 4.4	7.28 ± 1.9	0.519 J ± 0.23	0.533 J ± 0.23
Thorium-232	0.592 J ± 0.34	0.145 J ± 0.11	0.123 J ± 0.11	0.137 J ± 0.11	0.14 J ± 0.11
Thorium-234	1.43 U ± 1.5	19.5 ± 5	1.85 U ± 2.3	7.06 ± 1.5	13.6 ± 3.3
Uranium-233/234	2.39 J ± 0.99	22.2 ± 3	5.48 ± 0.93	3.42 ± 0.69	11.3 ± 1.6
Uranium-235	0.152 U ± 0.25	1.35 ± 0.35	0.26 J ± 0.14	0.358 J ± 0.19	0.567 J ± 0.22
Uranium-235	0.191 U ± 0.17	1.84 ± 0.73	0.443 J ± 0.34	0.457 J ± 0.21	0.707 J ± 0.24
Uranium-238	1.77 J ± 0.84	21.6 ± 3	4.92 ± 0.86	4.1 ± 0.78	10.9 ± 1.6

Table 6.28. Radiological COPCs for the Luckey Site

	Medium				
Radionuclide	Soil	Sediment	Surface Water	GroundWater	Buildings
Actinium-227		COPC			
Protactinium-231	COPC	COPC			
Radium-226*	COPC	COPC			COPC
Thorium-230	COPC	COPC			COPC
Uranium-234	COPC	COPC	COPC	COPC	COPC
Uranium-235		COPC	COPC		COPC
Uranium-238	COPC	COPC	COPC	COPC	COPC

* Includes lead-210.

Table 6.29. Reasonable Maximum and Central Tendency Exposure Parameters for Radionuclide Exposures by Medium and Receptor – Current and Future Land Use

Parameter	Units	On site	On site & Off site		Toussaint Creek	Quarry	Landfill	Reference
		Industrial Worker	Resident Farmer – Adult	Resident Farmer - Child	Adolescent Trespasser	Adolescent Trespasser	Adolescent Trespasser	
Surface & Subsurface Soil								
Parameters independent of pathway								
Exposure time indoors	hours/day	7	16.4	16.4	0	0	0	a
Exposure time outdoors	hours/day	1	1.75	1.75	1	1	1	a
Exposure frequency	days/year	250	350	350	52	52	52	b
Exposure duration	years	6.6	30 (9) *	6	10	10	10	c
Fraction indoors	unit-less	0.20	0.655	0.655	0.0	0.0	0.0	**
Fraction outdoors	unit-less	0.0285	0.070	0.070	0.005936	0.005936	0.005936	**
Gamma shielding factor	unit-less	0.2	0.2	0.2	N/A	N/A	N/A	b
Incidental ingestion								
Soil ingestion rate (daily)	mg/day	50	100 (50)	200 (100)	100 (50)	100 (50)	100 (50)	d
Soil ingestion rate (yearly)	g/yr	18.25	36.5 (18.25)	73 (36.5)	36.5 (18.25)	36.5 (18.25)	36.5 (18.25)	**
Dermal contact								
Not applicable for radionuclides								
Inhalation of dust								
Inhalation rate (daily)	m^3/day	13	13	8.7	12	12	12	e
Inhalation rate (yearly)	m^3/year	4745	4745	3176	4380	4380	4380	**
Sediment								
Parameters independent of pathway								
Exposure time indoors	hours/day	N/A	0	0	0	N/A	N/A	
Exposure time outdoors	hours/day	N/A	1	1	1	N/A	N/A	b
Exposure frequency	days/year	N/A	26	52	52	N/A	N/A	b
Exposure duration	years	N/A	30 (9)	6	10	N/A	N/A	c
Fraction indoors	unit-less	N/A	0.0	0.0	0.0	N/A	N/A	**
Fraction outdoors	unit-less	N/A	0.002968	0.005936	0.005936	N/A	N/A	**
Shielding factor	unit-less	N/A	N/A	N/A	N/A	N/A	N/A	-
Incidental ingestion								
Soil ingestion rate (daily)	mg/day	N/A	1.0 (0.5)	2 (1.0)	1.0 (0.5)	N/A	N/A	e
Soil ingestion rate (yearly)	g/yr	N/A	0.365 (0.1825)	0.73 (0.365)	0.365 (0.1825)	N/A	N/A	**
Dermal contact								
Not applicable for radionuclides								
Inhalation of VOCs								
Not applicable for radionuclides								
Surface Water								
Incidental ingestion rate	L/hour	N/A	0.023	0.013	0.023	0.023	N/A	
Exposure time	hours/day	N/A	1	1	1	1	N/A	
Exposure frequency	days/year	N/A	26	52	52	6	N/A	
Exposure duration	years	N/A	30	6	10	10	N/A	

Table 6.29 Reasonable Maximum and Central Tendency Exposure Parameters for Radionuclide Exposures by Medium and Receptor – Current and Future Land Use (cont'd)

Parameter	Units	Onsite	Onsite & Offsite		Toussaint Creek	Quarry	Landfill	Reference
		Industrial Worker	Resident Farmer - Adult	Resident Farmer - Child	Adolescent Trespasser	Adolescent Trespasser	Adolescent Trespasser	
Groundwater								
Drinking water intake								
Drinking water intake rate (daily)	L/day	1.2 (0.7)	2.3 (1.4)	1.3 (0.66)	N/A	N/A	N/A	e
Drinking water intake rate (yearly)	L/year	365 (511)	839.5 (511)	474.5 (241)	N/A	N/A	N/A	**
Exposure frequency	days/year	250	350	350	N/A	N/A	N/A	b
Exposure duration	years	6.6	30 (9)	6	N/A	N/A	N/A	c
Dermal contact while showering								
Not applicable for radionuclides								
Inhalation of VOCs during household use								
Not applicable for radionuclides								
Building Material								
Indoor fraction	hours/24hours	7/24 = 0.29	N/A	N/A	N/A	N/A	N/A	**
Exposure frequency	days/year	250	N/A	N/A	N/A	N/A	N/A	b
Inhalation rate	m^3/day	13	N/A	N/A	N/A	N/A	N/A	e
Impacted surface area	m^2	1	N/A	N/A	N/A	N/A	N/A	f

a – RAGS Part A for industrial worker exposure time is based on an 8-hour work day. One hour per work day outside based on professional judgement. EFH Volume III for resident farmer exposure time of 16.4 hours indoors at home and 2 hours outdoors at home. Exposure time for trespasser is based on professional judgement.
b – RAGS Part A (EPA 1989) for industrial worker and resident exposure to soils; assumes that adolescent trespassers are exposed to surface soils 2 days/week during summer months (April through October); EFH Volume I, Table 1-2 for exposure to sediment.
c – EFH Volume I, Table 1-2 for industrial worker and resident; Region IV Supplemental Guidance to RAGS (EPA 1995) for adolescent trespasser.
d – EFH Volume I, Table 4-23
e – EFH Volume I, Table 1-2
f – Based on a review of site building data

∗ – Central tendency parameter values given in parentheses, where applicable.
** – Input (units) required by the RESRAD codes

Table 6.30. Radiological Total Risk Summary for the Luckey Site

Receptor	Surface Soil (0 to 2 ft)	Total Soil (0 to 10 ft)	Sediment	Surface Water	Ground Water
Exposure Unit 1					
Industrial Worker	7.6E-05	-	-	-	-
Resident Farmer - Adult	**1.1E-03**	**4.6E-04**	-	-	-
Resident Farmer - Child	**2.2E-04**	9.6E-05	-	-	-
Exposure Unit 2					
Industrial Worker	5.2E-05	-	-	-	-
Resident Farmer - Adult	**7.3E-04**	**5.8E-04**	-	-	-
Resident Farmer - Child	**1.5E-04**	**1.2E-04**	-	-	-
Exposure Unit 3					
Resident Farmer - Adult	**1.7E-04**	**1.7E-04**	2.4E-06	1.2E-08	-
Resident Farmer - Child	3.6E-05	3.5E-05	1.0E-06	2.8E-09	-
Exposure Units 4 through 6					
Adolescent Trespasser (Unit 4)	3.8E-09	-	8.0E-10	1.3E-09	-
Adolescent Trespasser (Unit 5)	2.0E-09	-	-	6.0E-11	-
Adolescent Trespasser (Unit 6)	-	-	-	-	-
Exposure Unit 7					
Industrial Worker	-	-	-	-	2.1E-06
Resident Farmer - Adult	-	-	-	-	2.6E-05
Resident Farmer - Child	-	-	-	-	2.9E-06
Unit 1 CT Risk Estimates for RME > 10^{-4}					
Resident Farmer - Adult	**3.2E-04**	**1.4E-04**	-	-	-
Resident Farmer - Child	**2.2E-04**	-	-	-	-
Unit 2 CT Risk Estimates for RME > 10^{-4}					
Resident Farmer - Adult	**2.2E-04**	**1.7E-04**	-	-	-
Resident Farmer - Child	**1.5E-04**	-	-	-	-
Unit 3 CT Risk Estimates for RME > 10^{-4}					
Resident Farmer - Adult	5.2E-05	5.0E-05	-	-	-

Risks > 10^{-4} bolded for emphasis
"-" pathway not evaluated for this receptor

Table 6.31. Radiological COCs by Medium and Receptor *

Receptor	Medium				
	Soil	Sediment	Surface Water	Groundwater	Buildings **
Adolescent Trespasser	None	None	None	None	None
Industrial Worker	Ra-226 Th-230	None	None	U-238	None
Resident Farmer – Adult	Pa-231 Ra-226 Th-230 U-235 U-238	Ra-226	None	U-234 U-235 U-238	None
Resident Farmer – Child	Ra-226 Th-230 U-238	Ra-226	None	U-234 U-238	None

* Any radionuclide producing an estimated single-pathway radiological risk of 1.0×10^{-6} or larger.
** COCs for buildings may be identified at a later date, but doses (1.5 mrem/yr) do not justify inclusion at this time.

Table 6.32. Action Levels for the Luckey Site

Receptor	Medium (units)	Radionuclide	Action Level and Basis			
			10^{-6} Risk	40 CFR 192 [a]	Criterion 6(6) [b]	10 CFR 20 [c]
RFA	Soil (pCi/g)	Pa-231	0.17	-	77	59
		Ra-226	0.0092	5.0	5.0	3.8
		Th-230 [d]	0.061	-	34	26
		U-235	0.23	-	74	57
		U-238 [e]	0.90	-	370	290
	Sediment (pCi/g)	Ra-226	1.9	5.0	5.0	800
	Groundwater (pCi/L)	U-234	0.94	-	140	110
		U-235	0.88	-	150	120
		U-238 [e]	0.67	-	150	120
RFC	Soil (pCi/g)	Ra-226	0.044	5.0	5.0	3.7
		Th-230 [d]	0.30	-	34	25
		U-238 [e]	4.2	-	360	270
	Sediment (pCi/g)	Ra-226	4.5	5.0	5.0	400
	Groundwater (pCi/L)	U-234	8.3	-	260	190
		U-238 [e]	5.9	-	270	200
IW	Soil (pCi/g)	Ra-226	0.13	5.0	5.0	12
		Th-230 [d]	0.88	-	34	84
	Groundwater (pCi/L)	U-238 [e]	8.1	-	130	310

All values rounded to two significant digits.

[a] Concentration for surface soils - subsurface limit is 15 pCi/g
[b] Concentration corresponding to benchmark dose
32.5 mrem/yr = resident farmer – adult (RFA) benchmark
33.6 mrem/yr = resident farmer – child (RFC) benchmark
10.1 mrem/yr = industrial worker (IW) benchmark
[c] Concentration corresponding to 25 mrem/yr
[d] Value conservatively represents Th-230 limit for year 1,000 allowing ingrowth of Ra-226
[e] Concentration may be reduced if U-238 is used as a surrogate for other uranium isotopes

Table 6.33. Summation of Chemical and Radiological Carcinogenic Risk for the Luckey Site

Receptor	Surface Soil (0-2 ft bls)	Total Soil (0-10 ft bls)	Sediment	Surface Water	Groundwater
Exposure Unit 1 RME Risk Estmates					
Industrial Worker	**1.4E-04**	-	-	-	**2.1E-06**
Resident Farmer - Adult	**2.0E-03**	**8.0E-04**	-	-	**2.6E-05**
Resident Farmer - Child	**7.4E-04**	**3.1E-04**	-	-	**2.9E-06**
Exposure Unit 2 RME Risk Estimates					
Industrial Worker	**5.4E-05**	-	-	-	**2.1E-06**
Resident Farmer - Adult	**7.5E-04**	**6.0E-04**	-	-	**2.6E-05**
Resident Farmer - Child	**1.6E-04**	**1.3E-04**	-	-	**2.9E-06**
Exposure Unit 3 RME Risk Estimates					
Resident Farmer - Adult	**1.7E-04**	**1.7E-04**	**4.5E-06**	4.4E-07	**2.6E-05**
Resident Farmer - Child	**3.6E-05**	**3.5E-05**	**1.8E-06**	3.2E-07	**2.9E-06**
Exposure Unit 4 RME Risk Estimates					
Adolescent Trespasser	3.8E-09	-	**1.3E-06**	1.2E-07	-
Exposure Unit 5 RME Risk Estimates					
Adolescent Trespasser	2.0E-09	-	-	6.00E-11	-
Exposure Unit 6 RME Risk Estimates					
Adolescent Trespasser	-	-	-	-	-

"-" inciates media was not evaluated

Bold indicates cancer risk greater than 10^{-6}

a - Cancer risks for chemicals and radiological constituents were summed

SECTION 6: LIST OF FIGURES

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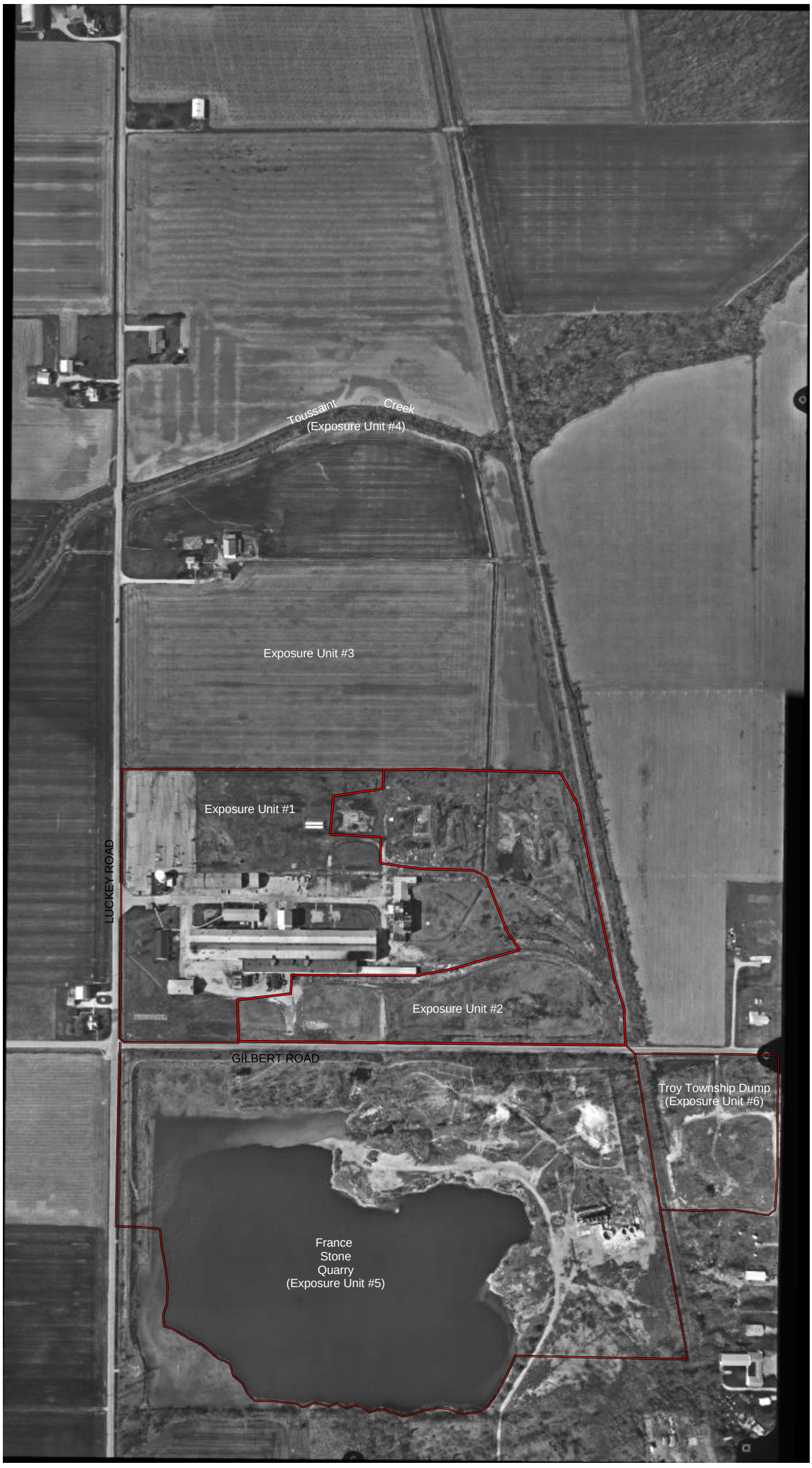
Figure 6.9	Decay Series for Uranium-235
Figure 6.10	Decay Series for Thorium-232



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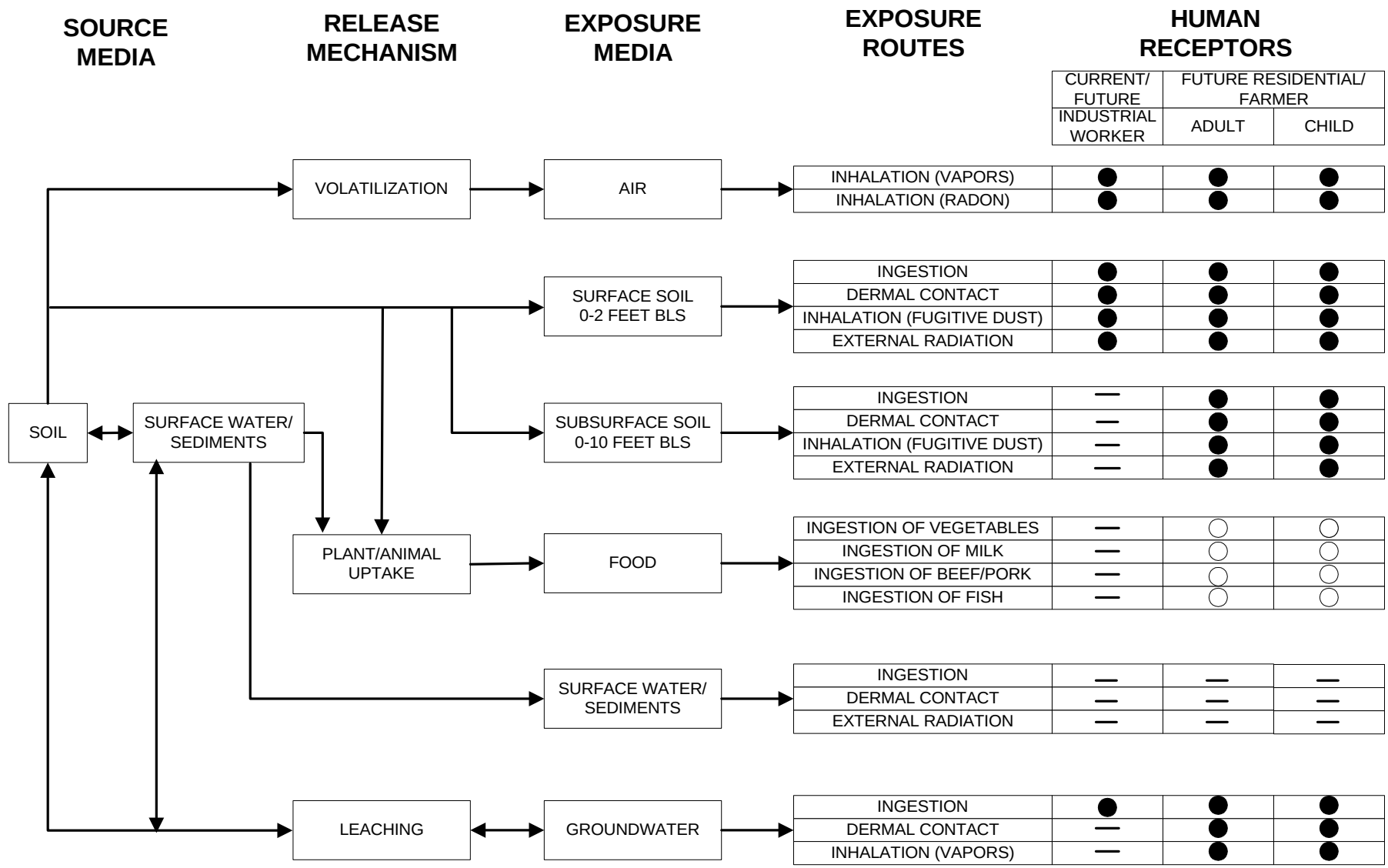
U.S. ARMY CORPS OF ENGINEERS
BUFFALO DISTRICT
LUCKEY SITE

Exposure Units at Luckey Site

Science Applications International Corporation
An Employee-Owned Company
Columbus, Ohio

DRAWN BY	DATE	SCALE	PROJECT NO.	FIGURE NO.
LMA	02/09/00	AS SHOWN	04-1748-801	6.1



● COMPLETE PATHWAY EVALUATED QUANTITATIVELY

○ COMPLETE PATHWAY EVALUATED QUALITATIVELY

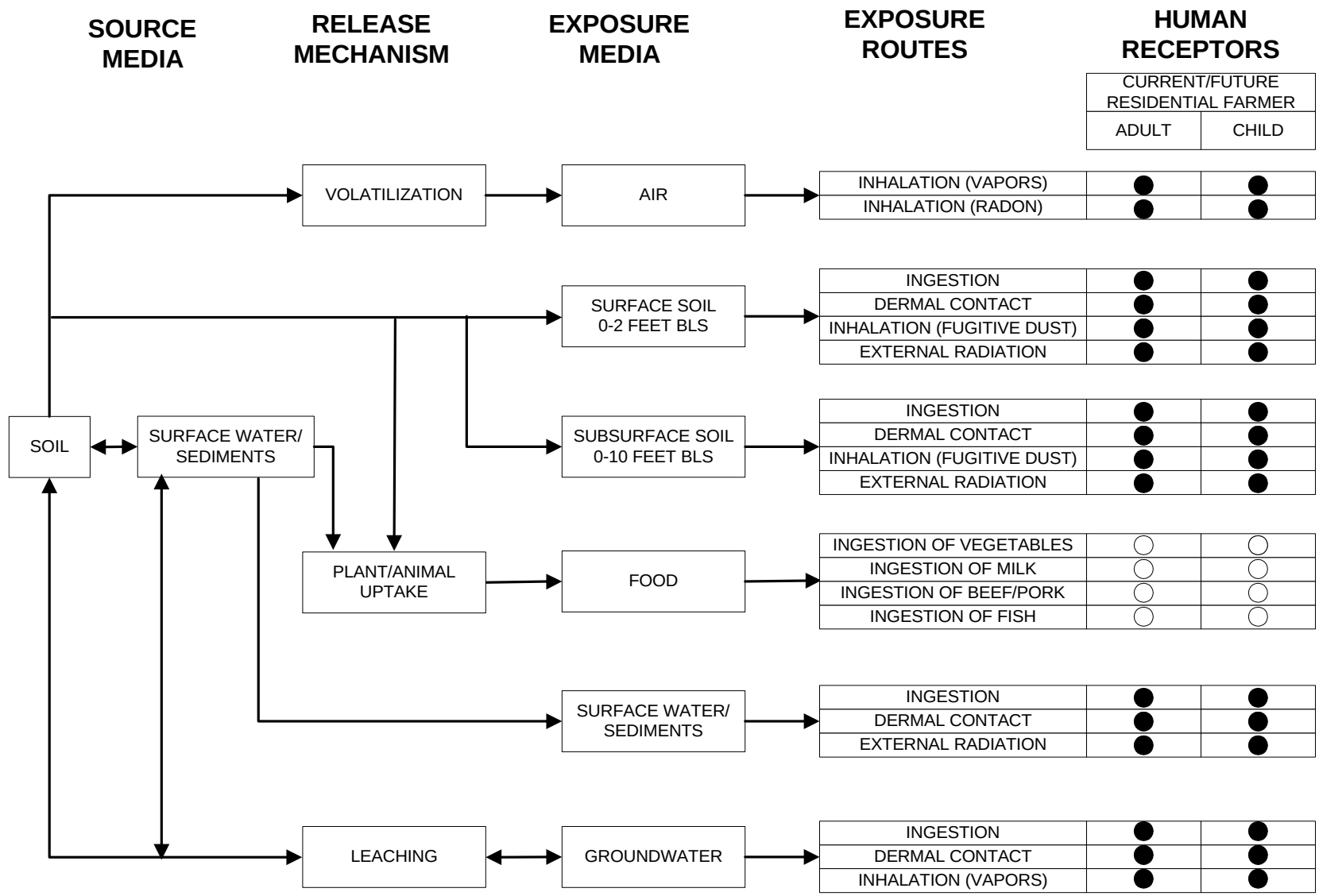
— INCOMPLETE PATHWAY, NOT EVALUATED

BLS BELOW LAND SURFACE

Figure 6.2

Exposure Pathways for Human Receptors at Exposure Units 1 and 2 (Luckey Site Property)

S:/LUCKEY/CO41748/702_exp1_FIG6.2.VSDThursday, February 10,2000



● COMPLETE PATHWAY EVALUATED QUANTITATIVELY

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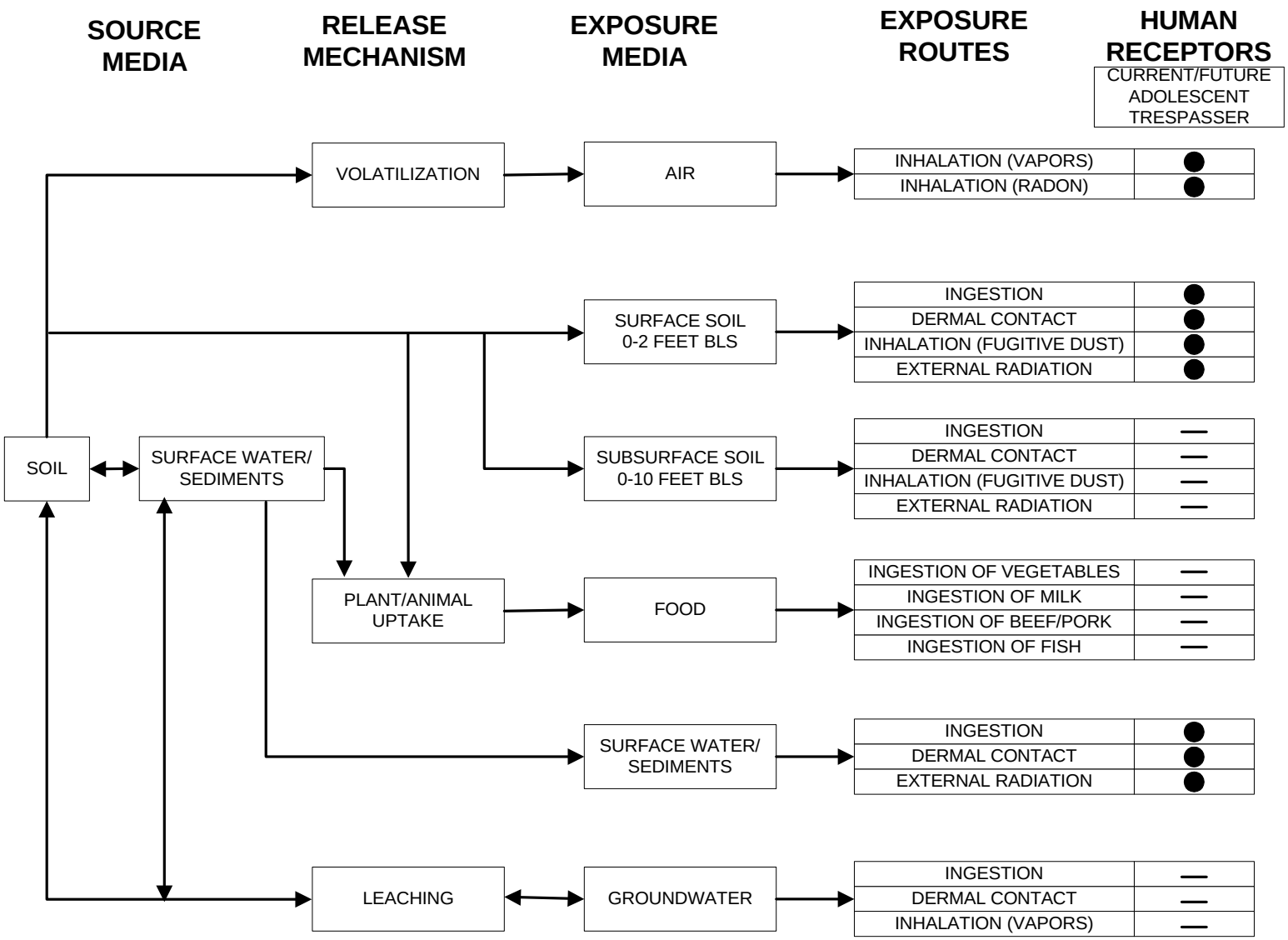
— INCOMPLETE PATHWAY, NOT EVALUATED

BLS BELOW LAND SURFACE

Figure 6.3

Exposure Pathways for Human Receptors at Exposure Unit 3 (Off-site Agricultural Property)

S:/LUCKEY/CO41748/702EXP3_FIG6.3.vsdEXP3_FIG6.3February 10, 2000



● COMPLETE PATHWAY EVALUATED QUANTITATIVELY

○ COMPLETE PATHWAY EVALUATED QUALITATIVELY

— INCOMPLETE PATHWAY, NOT EVALUATED

BLS BELOW LAND SURFACE

Figure 6.4

Exposure Pathways for Human Receptors at Exposure Unit 4 (Toussaint Creek)

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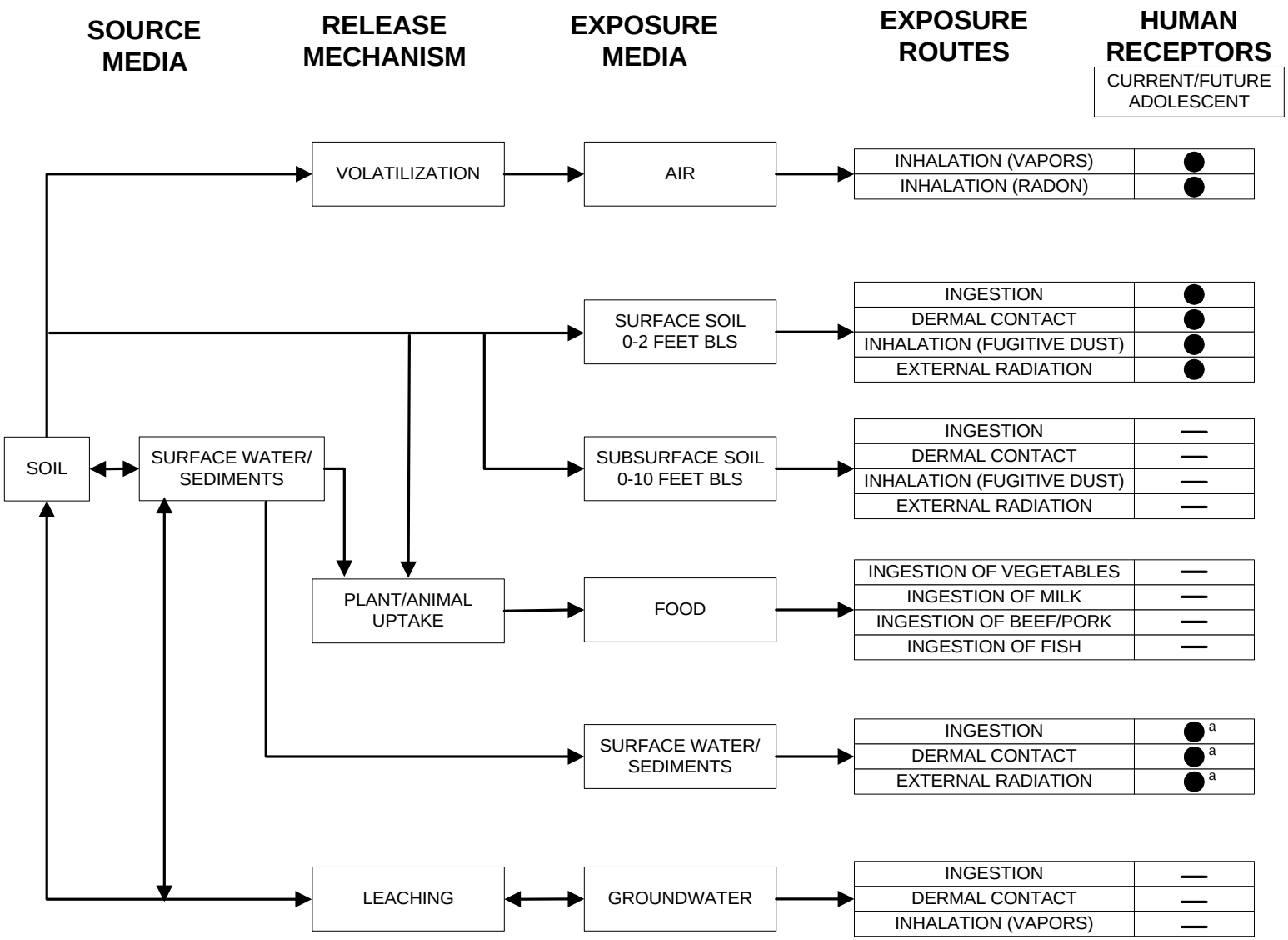

● COMPLETE PATHWAY EVALUATED QUANTITATIVELY

○ COMPLETE PATHWAY EVALUATED QUALITATIVELY

— INCOMPLETE PATHWAY, NOT EVALUATED

BLS BELOW LAND SURFACE

a = Surface water contact only; quarry is over 70 ft deep so no contact with sediment expected.

Figure 6.5

Exposure Pathways for Human Receptors at Exposure Unit 5 (France Stone Quarry)

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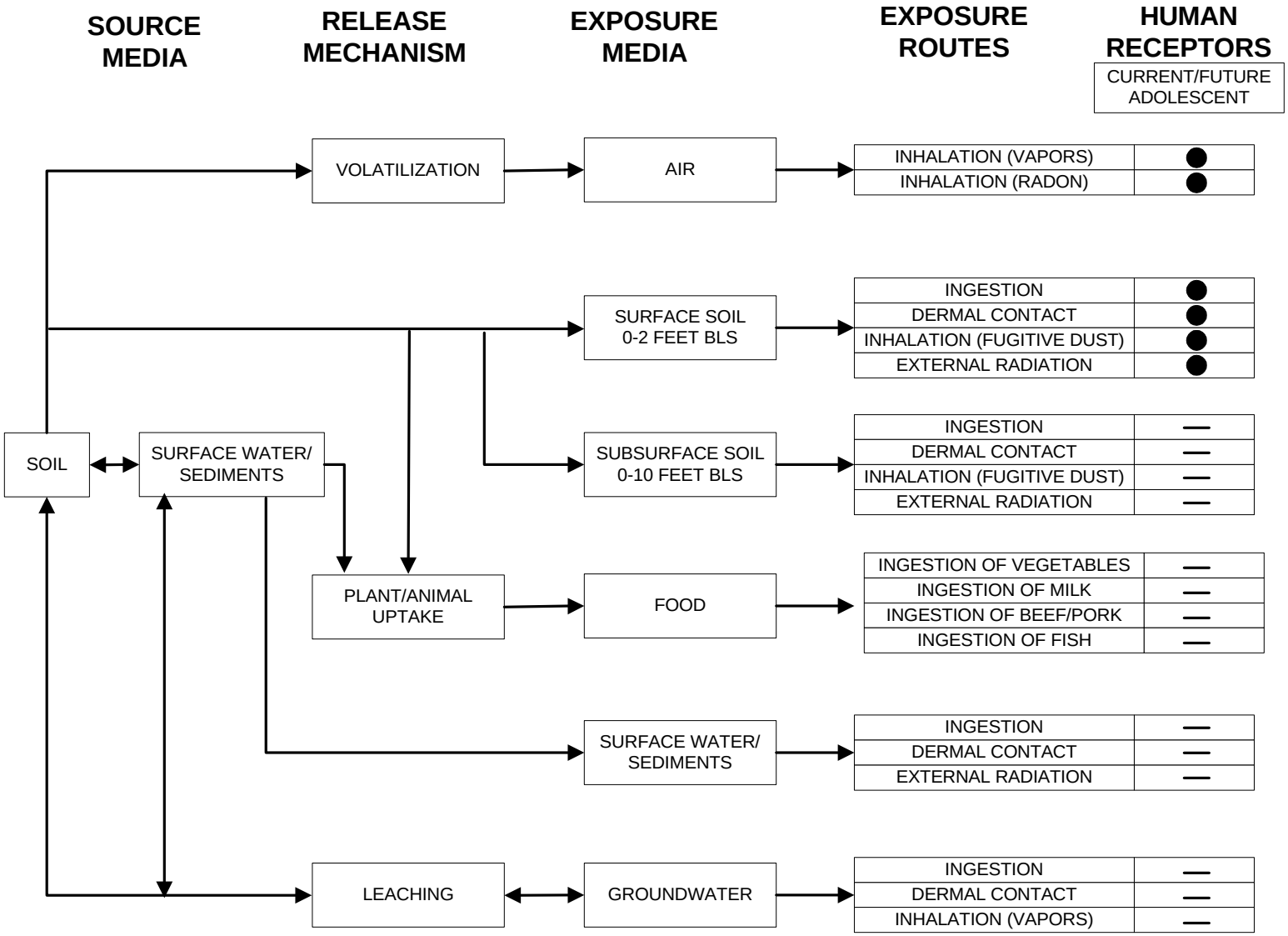

● COMPLETE PATHWAY EVALUATED QUANTITATIVELY

○ COMPLETE PATHWAY EVALUATED QUALITATIVELY

— INCOMPLETE PATHWAY, NOT EVALUATED

BLS BELOW LAND SURFACE

Figure 6.6

Exposure Pathways for Human Receptors at Exposure Unit 6 (Troy Township Dump)

S:/LUCKEY/C041748/702exp6_FIG6.6.vsdexp6_FIG6.6February 10,2000

Figure 6.7 Calculation of Risk-Based Remediation Goal for Adult Exposures to Lead in Soil Using Recommendations of the Technical Review Workgroup for Lead.

$$RGO_{lead} = \left[\frac{\left(PbB_{adult,\,central,goal} - PbB_{adult,0}\right) \times AT}{BSF \times EF_S} \right] \left(I_S \times AF_S\right)^{-1}$$

where:

$$PbB_{adult,central,goal} = \frac{PbB_{fetal,0.95,goal}}{GSD_{i,adult}^{1.645} \times R_{fetal/maternal}}$$

where:

AF_S	Absolute gastrointestinal absorption factor for soil (0.12).
AT	Averaging time (365 days/year).
BSF	Biokinetic slope factor (0.4 µg/dL per µg/day).
EF_s	Exposure frequency (219 days/year).
$GSD_{i.adult}$	Geometric standard deviation (2.1).
I_s	Ingestion rate for soil (0.050 g/day).
$PbB_{adult.0}$	Typical blood lead concentration in adults in the absence of site exposures (1.9 µg/dL).
$PbB_{adult,central,goal}$	Goal for central blood lead concentrations that have site exposures (µg/dL).
$PbB_{fetal,0.95,goal}$	Goal for the 95th percentile blood lead concentrations among fetuses born to woman having exposures to site soils (10 µg/dL).
$R_{fetal/maternal}$	Constant of proportionality between fetal blood lead concentration at birth and maternal blood lead concentration (0.9).
RGO_{lead}	Risk-based remedial goal option for lead in soil (mg/kg).

Sample calculation:

$$PbB_{adult,central,goal} = \frac{10\ \mu g/dL}{2.1^{1.645} \times 0.9}$$

$$= 3.28\ \mu g\ /dL$$

$$RGO_{lead} = \left[\frac{\left(3.28\ \mu g\ /\ dL - 1.9\ \mu g\ /\ dL\right) \times 365\ days/year}{0.4\ \frac{\mu g\ /\ dL}{\mu g\ /\ day} \times 219\ days\ /\ year} \right] \times \left[\left(0.05\ g\ /\ day\right)\left(0.12\right)\right]^{-1}$$

$$= 958\ mg\ /\ kg$$

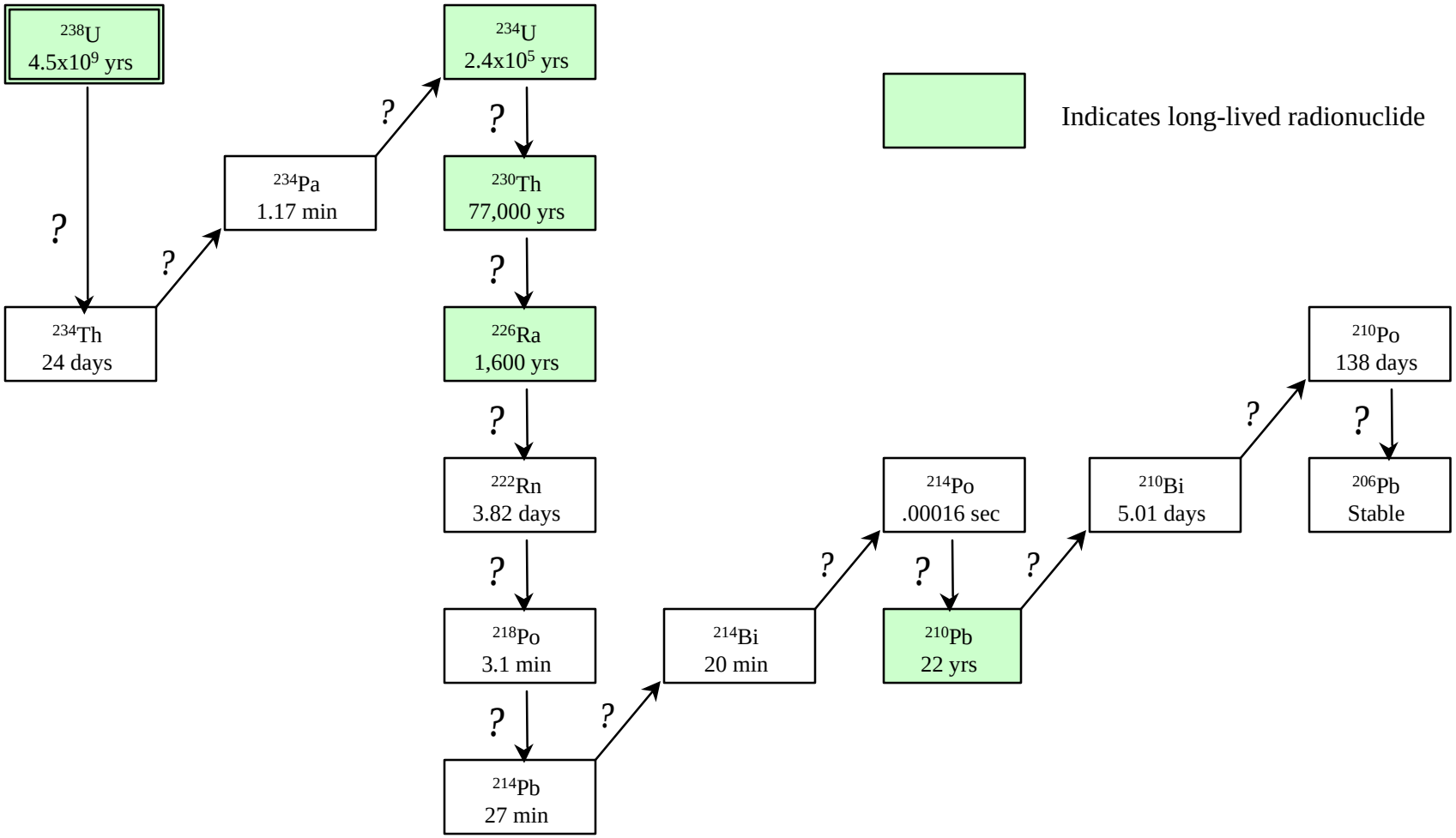

Figure 6.8 Decay Series for Uranium-238

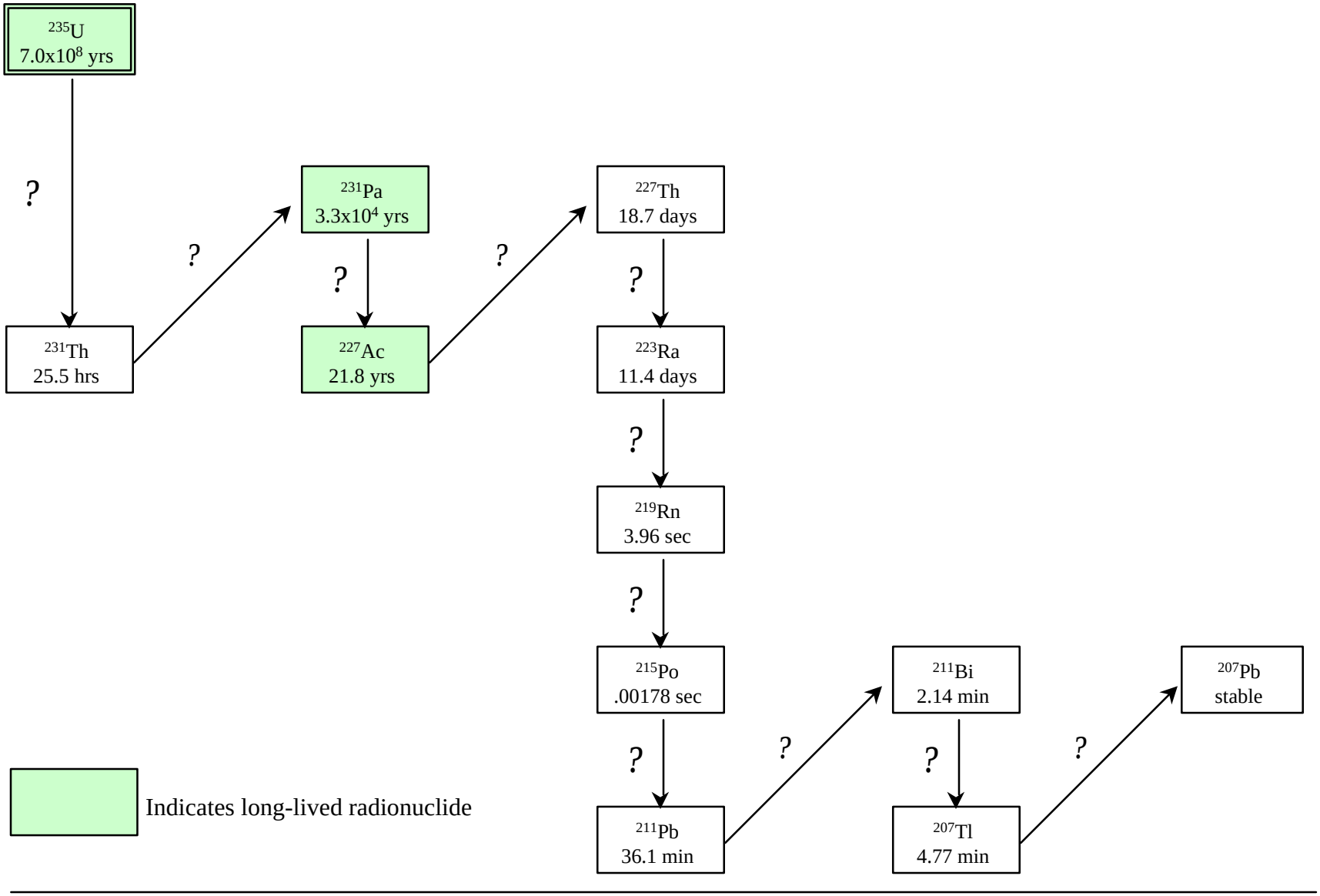

Figure 6.9 Decay Series for Uranium-235

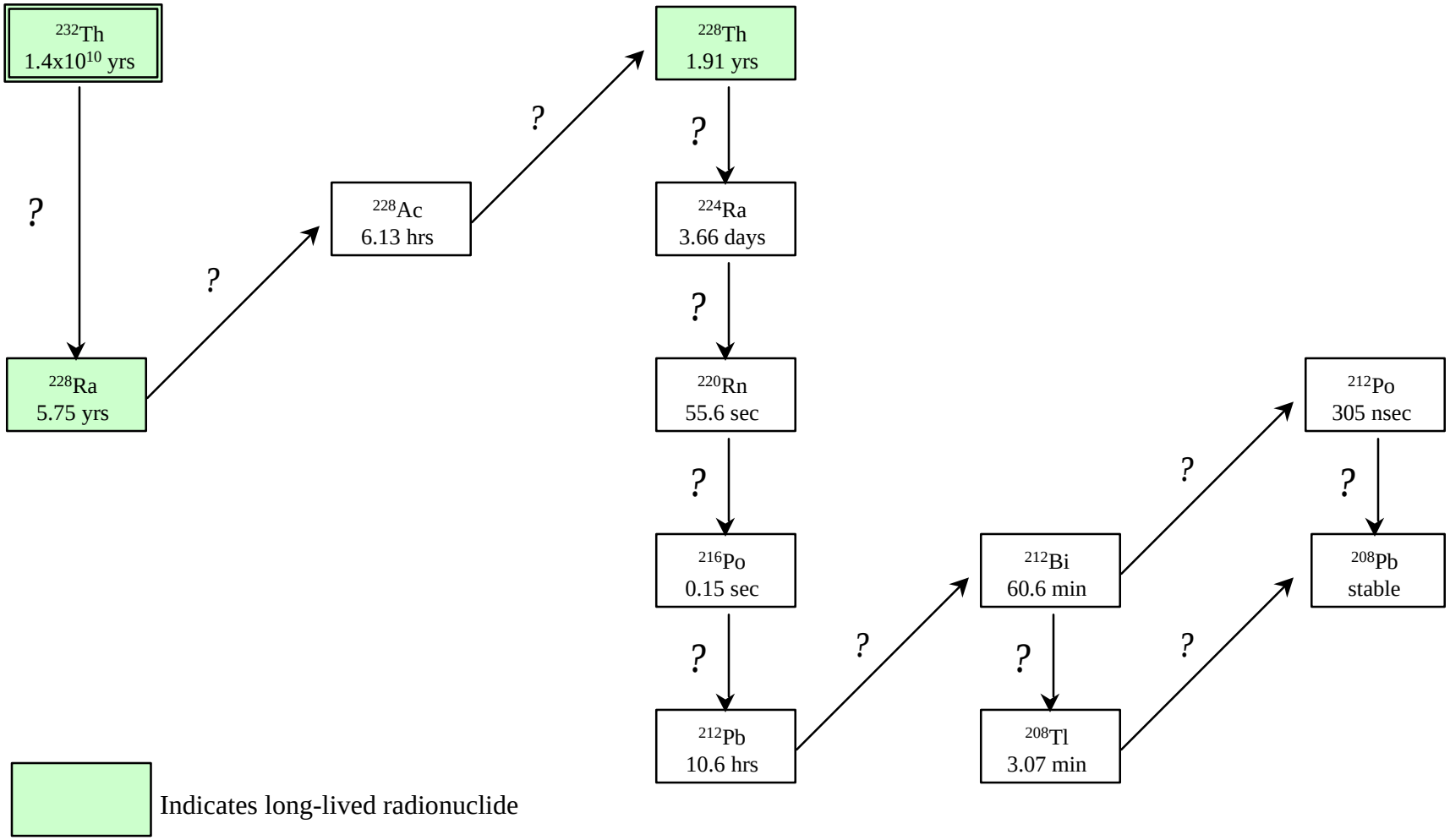

Figure 6.10 Decay Series for Thorium-232

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7.0 SCREENING ECOLOGICAL RISK ASSESSMENT

An ERA defines the likelihood of harmful effects on plants and animals as a result of exposure to non-radiological and radiological constituents. There are two types of ERAs screening and baseline. A screening ERA uses site-specific data about the chemical concentrations, and particularly, maximum values or 95th percentiles of the site data set. A baseline ERA requires even more site-specific exposure and effects information, including such measurements as body burden measurements and bioassays, and it often uses less conservative assumptions. A screening ERA was conducted to evaluate the possible risk to plants and wild animals from current and future exposure to contamination at the Luckey site and its nearby aquatic environments at Toussaint Creek and the France Stone Quarry. The need for a baseline ERA will be assessed following completion of the screening ERA.

The initial regulatory guidance for the ERA is contained in EPA's *RAGS, Volume II, Environmental Evaluation Manual* (EPA 1989d) and subsequent documents (EPA 1991c, 1992d). Further discussion on the scientific basis for assessing ecological effects and risk is presented in *Ecological Assessments of Hazardous Waste Sites: A Field and Laboratory Reference Document* (EPA 1989e). Other early 1990s guidance is provided in the *Framework for Ecological Risk Assessment* (EPA 1992e). A second generation of guidance consists of the *Procedural Guidance for Ecological Risk Assessments at U.S. Army Exposure Units* (Wentsel et al. 1994), and its replacement, the *Tri-Service Procedural Guidelines for Ecological Risk Assessments* (Wentsel et al. 1996), and the Army's EM 200-1-4 (USACE 1995). In addition, the newly published *Ecological Risk Assessment Guidance* (EPA 1997b, EPA 1998c) supersedes *RAGS, Volume II* (EPA 1989d). This latter guidance makes the distinction between the inter-related roles of screening and baseline ERAs. Briefly, screening ERAs utilize conservative assumptions for exposures and effects, while a baseline ERA means increasingly unit-specific, more realistic (and generally less conservative) exposures and effects. Newly published EPA guidance (EPA 1997b) will be used because it provides the clearest information on preliminary or screening ERAs.

These documents discuss an overall approach to considering ecological effects and identifying sources of information necessary to perform ERAs. However, they do not provide all the details. Thus, professional knowledge and experience are important in ERAs to compensate for this lack of specific guidance and established methods. This professional experience comes from a team of risk scientists. Team members are representatives from the USACE, Ohio EPA, and the Army's contractors Montgomery Watson and SAIC.

The following sections present the scope and objectives (Sect. 7.1); the procedural framework (Sect. 7.2); the four steps to complete the screening, hereafter referred to as the ERA: problem formulation (Sect. 7.3); exposure assessment (Sect. 7.4); effects assessment (Sect. 7.5); and risk characterization (Sect. 7.6).

7.1 SCOPE AND OBJECTIVES

The scope of the ERA is to characterize, in a preliminary way, the risk to plant and animal populations at the Luckey site and nearby aquatic environments. This is done for both current and future conditions. The ERA assesses the risk to ecological receptors, especially terrestrial and aquatic animals. Unlike the HHRA, which focuses on individuals, the ERA focuses on populations or groups of interbreeding individuals. In the ERA process, individuals are addressed only if they are protected under the Endangered Species Act (ESA). Radiological and non-radiological constituents are called constituents of potential ecological concern (CPECs). When it has been demonstrated that CPECs cause risk, they are called ecological constituents of concern (ecological COCs). The ecological COCs are usually associated with the more definitive or baseline ERAs.

To assess the potential for an analyte to pose a risk at the Luckey site, the analytes were subjected to a screening step that consisted of comparing the measured concentration at any location on the Luckey site to a background concentration (95% UTL; see Section 6.1). Analytes whose concentrations exceeded the background screening levels were designated CPECs and were further subjected to more quantitative estimates of exposure. First, chemical properties of the CPECs that are considered to be indicators of bioaccumulation were compared to screening values. For CPECs whose indicators exceeded screening criteria, a Luckey site-wide comparison of concentrations was made against toxicity screening criteria, followed by an assessment on an exposure unit-by-exposure unit basis to various ecological receptors. This was done for the most important pathways involving soil, sediment, and surface water. Deep groundwater is not a medium of concern for ecological receptors. However, shallow groundwater is expected to flow into Toussaint Creek and is treated as surface water once it surfaces and mixes with existing surface water. The surface water column of the France Stone quarry is up-gradient from and 3 ft higher than on-site groundwater. Therefore, there is no reason to expect flow from the site to the quarry at this time. Historically, the quarry was pumped down, which may have caused shallow groundwater flow from the facility toward the quarry and discharge to surface water. The shallow groundwater may have been contaminated at that time. In addition, windblown dust may have transported site contaminants to the quarry. These potential migration pathways prompted the investigation of surface water and sediment in the quarry.

As explained above, it is assumed that when groundwater surfaces, it mixes with existing surface water at on-site ditches and Toussaint Creek. Once it surfaces and mixes, it becomes, by definition, surface water. Surface water screening values and toxicity reference values were compared to the measured concentrations in the surface water.

The next step was to further analyze the CPECs. Technically defensible values or benchmark concentrations of analytes obtained from published literature serve as toxicity reference values or thresholds (concentrations below which there are no unacceptable adverse effects). The ratio of the exposure concentration to the toxicity reference value (TRV) results in an environmental effects quotient (EEQ). An EEQ was calculated for each CPEC at each exposure unit and for each present medium and each receptor. Each EEQ was compared to an assessment endpoint, which is a pre-established ecological resource expressed as a ratio, to determine whether the EEQ exceeds or does not exceed the assessment endpoint.

When there is no toxicity value, the ratio of exposure point concentration and TRV cannot be determined. Usually, there are a number of such situations where no EEQ is possible because there is no TRV. Collectively, they are handled in the uncertainty section. One way to obtain a “proxy” TRV is to use surrogate values. USACE, Ohio EPA, or other agencies have not issued surrogate values. Inspection of the screening value tables and TRV tables in Appendix 7B shows which constituents require surrogate values. For example, TRVs for aluminum, barium, and vanadium are needed for sediments.

If the EEQ exceeds the assessment endpoint, a baseline or Phase II ERA and/or site remediation may be required to further investigate the potential risk in order to protect the ecological receptors. Uncertainties in the measured, estimated, and calculated concentrations on the final characterization of ecological risk at the Luckey site are discussed qualitatively.

7.2 PROCEDURAL FRAMEWORK

According to the *Framework for Ecological Risk Assessment* (EPA 1992e), the ERA process consists of three interrelated phases: problem formulation, analysis (composed of exposure assessment and ecological effects assessment), and risk characterization. In conducting the ERA for the Luckey site, these three phases were completed by performing four interrelated steps. As explained above, definitive

or more recent guidance (EPA 1997b) indicates two levels of rigor, screening and more definitive or baseline. Each contains the following elements:

- **Problem formulation -** Problem formulation establishes the goals, breadth, and focus of the ERA and provides a characterization (screening step) of chemical stressors (chemicals that restrict growth and reproduction or otherwise disturb the balance of ecological populations and systems) present in the various habitats at the site. The problem formulation step also considers a preliminary characterization of the components, especially the receptor species, in the ecosystem likely to be at risk. In addition, it includes the selection of assessment and measurement endpoints as a basis for developing a conceptual model of stressors, components, and effects (Section 7.3).

- **Exposure assessment -** Exposure assessment defines and evaluates the concentrations of the chemical stressors. It also describes the ecological receptors and defines the route, magnitude, frequency, duration, trend, and spatial pattern of the exposure of each receptor population to a chemical or physical stressor (Section 7.4).

- **Effects assessment -** Effects assessment evaluates the ecological response to chemical and physical stressors in terms of the selected assessment and measurement endpoints. The effects assessment results in a profile of the ecological response of populations of plants and animals to the chemical concentrations or doses and to other types and units of stress to which they are exposed. Data from both field observations and controlled laboratory studies are used to assess ecological effects (Section 7.5).

- **Risk characterization -** Risk characterization integrates exposure and effects or the response to chemical stressors on receptor populations using EEQs (ratios of exposure to effect). The results are used to define the risk from contamination at the Luckey site, in contrast to background (naturally occurring) risk, and to assess the potential for population and ecosystem recovery (Section 7.6).

The ERA is organized by the four interrelated steps of the EPA framework. Sections 7.3 through 7.6 detail the technical issues and data evaluation procedures associated with each step. Section 7.7 evaluates the degree of reliability or uncertainty of these methodological steps and the data used. Finally, Section 7.8 deals with the transition from a screening ERA to a baseline ERA.

7.3 PROBLEM FORMULATION

The first step of EPA's approach to the ERA process, problem formulation (data collection and evaluation), includes the following:

- determination of the scope of the assessment (as discussed in Section 7.1);
- formulation of a conceptual site model of the Luckey site based on existing information and reasonable assumptions, including habitats and populations, and any threatened and endangered (T&E) species (Section 7.3.1);
- identification of CPECs (Section 7.3.2);
- selection of EU and ecological receptors (Sections 7.3.3 and 7.3.4);
- selection of assessment and measurement endpoints for the ERA (Section 7.3.5); and
- summary of CPECs (Section 7.3.6).

7.3.1 Conceptual Site Model

The conceptual site model of the Luckey site has been developed for the ERA using available site-specific information and professional judgment. The constituent source, exposure media, receptors, and the routes by which they are exposed to constituents are described below. Figure 7.1 shows the ecological conceptual site model.

Constituent Source and Source Media. Constituent sources at the Luckey site are defined in Section 5 of the RI report. Non-radiological and radiological constituents from these sources are now present in surface soil, sediment, and surface water. Groundwater is shown in the conceptual model for the sake of completeness.

Release Mechanisms. These mechanisms include plant/animal uptake, and to a lesser extent volatilization. Leaching to surface water and to groundwater may be an additional release mechanism.

Exposure Media. Sufficient time, more than 10 years, has elapsed for the soil and sediment constituents in original sources to have migrated to potential exposure media, resulting in possible exposure of plants and animals that come into contact with these media.

Sediment and surface water are also present in drainage ditches, in Toussaint Creek, and in the nearby France Stone Quarry. Deep groundwater is not considered an exposure medium because ecological receptors are unlikely to contact groundwater at its depth of greater than 5 ft bgs. Shallow groundwater, once it surfaces, is assumed to be the same as surface water. Air is not considered an exposure medium because potential VOCs are believed to have dissipated. The assertion that VOCs have dissipated is based on observations and physical/chemical properties. Only minimal levels of VOCs were detected in samples collected onsite, and there were no exceedences of VOC-monitoring equipment during drilling activities. In addition, AEC activities ceased in 1962, and it is the nature of this type of chemical to volatilize and reach lower and lower concentrations below method detection limits within a relatively short time period. Thus, surface soil, sediment, and surface water (for direct exposure), and biota (e.g., indirect exposure via the food chain) were retained as the exposure media for this ERA.

Exposure Routes. A principal exposure route is contact of biota with soils at the Luckey site. Animals also are exposed indirectly through ingestion of contaminated vegetation and prey species. Plants are exposed directly by root uptake from soil at the Luckey site and serve as the path of contaminant transport to animals. Terrestrial animals may potentially come into contact with soil by means of incidental ingestion, dermal contact, and inhalation of dust. Aquatic organisms are exposed directly from the sediment and water.

Ingestion of soil and biota by animals are the two principal exposure routes evaluated quantitatively for terrestrial animals. The exposure of animals to constituents in soil by dermal contact and inhalation are likely to be a small fraction of these two routes. Furthermore, the available toxicity data are almost exclusively for the ingestion pathway (e.g., Sample et al. 1996). By contrast, direct exposure to constituents in sediment and surface water are principal pathways for sediment-dwelling organisms and fish. The exposure pathways were evaluated quantitatively using site measurements and published exposure parameters.

Ecological Receptors. Terrestrial and aquatic animal receptors are recognized in the ecological conceptual site model (Figure 7.1) and are presented and discussed in Section 7.4.1. A "_" on the figure means that the pathway was not direct and that no ecological receptor could be exposed.

7.3.2 Identification of Constituents of Potential Ecological Concern (CPECs)

There are two parts to the identification of CPECs. The first part is a site-wide screening using variables such as blank contamination, frequency of detection, background, persistence, and toxicity screening values. Essential nutrients, e.g., calcium and potassium, were not used to remove analytes, rather they were retained and only eliminated in the absence of a TRV. The second part involves determining concentrations on an exposure unit-by-exposure unit basis and TRVs on a receptor-by-receptor basis.

7.3.2.1 <u>Initial or Site-Wide Screening</u>

The results of analysis of environmental media samples were organized and evaluated. Constituents that were not detected (i.e., were less than analytical blank concentrations and/or method detection limits) were dropped. More specifically, a CPEC must have been detected in fewer than 5% of the samples and represent a maximum or 95% UCL concentration, which is less than the mean computed from the background concentrations, to be eliminated from further evaluation as a CPEC. Regarding blanks, the maximum sample concentration must be more than 10 times the highest blank concentration for all common laboratory contaminants (e.g., acetone, 2-butanone, methylene chloride, toluene, and the phthalates) or 5 times the highest blank concentration for other radiological or non-radiological constituents. Inorganic constituents that are considered essential nutrients were retained for further assessment. Appendix 7A Table 7A.1 presents the list of constituents detected in surface soil, sediment, and surface water at the Luckey site, along with an indication as to whether they were retained for further evaluation.

The handling of trace elements and essential nutrients conforms to USACE EM 200-1-4 guidance. The following constituents were evaluated with regard to essential trace element or nutrient status: calcium, copper, chromium (trivalent), magnesium, manganese, iron, potassium, selenium, sodium, and zinc. However, elements that occur as a result of known site activities were not eliminated based on nutrient status. For example, calcium, magnesium, and sodium were used in beryllium processing at the Luckey site. These and other site-related constituents were not eliminated.

The potential for bioaccumulation and bioconcentration is another important screening criterion. Bioaccumulation refers to a non-radiological or radiological constituent's ability to increase in an organism relative to the concentration in the organism's exposure medium. For soil, the $\log_{10}$ of the organic carbon partition coefficient (log K_{oc}) or the $\log_{10}$ of the octanol water partition coefficient (log K_{ow}) must be greater than 3.5, the half-life must be greater than 14 days, and/or the bioaccumulation factor must be greater than 0.01. For sediment, soil parameters will be used. It is technically reasonable to use log K_{oc} for both soil and sediment. The K_{oc} is defined as the K_d/foc where K_d means the soil (sediment)-water partitioning coefficient and Foc means the fraction of organic carbon in the soil or sediment. In fact, the measurement is made in a slurry from which the soil or sediment is suspended in water and, then, settled. Thus, the K_{oc} will be the same value for soil or a sediment application. For surface water, the half-life must be greater than 14 days, and the bioaccumulation factor must be greater than two. Available values appear in Appendix 7A Tables 7A.2 through 7A.7 for non-radioactive constituents and Appendix 7A Tables 7A.8 through 7A.11 for radionuclides.

Indicators of bioaccumulation of constituents were compared to the criteria stated in the previous paragraph. Appendix 7A Tables 7A.12 through 7A.14 present the results of site-wide screening of non-radioactive analytes in soil, sediment, and surface water, respectively, for potential bioaccumulation and bioconcentration. Appendix 7A Tables 7A.15 through 7A.17 provide the results of site-wide screening of radionuclides in soil, sediment, and surface water, respectively, for potential bioaccumulation and bioconcentration.

Regarding site-wide toxicity screens, screening values for soil have been identified. Ohio EPA recommends toxicity screening values cited in Will and Suter's (1995) soil invertebrate and microorganism and Efroymson et al.'s (1997) plant compilations of soil screening values, followed by the Ecological Data Quality Level (EDQL) values from EPA Region 5 (EPA 1998d). These values are given in Appendix 7A Table 7A.18.

Regarding sediment, the toxicity screening values, in order of preference, from EPA Region 5's (EPA 1996e), EDQLs, Ontario Ministry of the Environment Low (Persaud et al. 1993), Screening Quick Reference Table (Buchman 1998), Effect Range Lows (Jones et al. 1997 from sources including Long and Morgan 1991), and other values have been provided in Appendix 7A Table 7A.19.

Regarding surface water screening values, the ecotox thresholds from the EDQLs by EPA Region 5 (1996e), Chapters 3745-1 and 3745-2 of the Ohio Administrative Code for the Lake Erie Basin (Ohio EPA 1999b), and a compilation (Suter and Tsao 1996) have been provided in Appendix 7A Table 7A.20.

Tables 7A.21 and 7A.22 list screening values for radionuclides in surface water and sediment (Bechtel Jacobs 1998). No radiological screening values for soil were recommended by Ohio EPA or USEPA or were found in the literature.

The site-wide maximum exposure point concentrations were compared to the screening values, and constituents that exceeded screening values were retained for further analysis. The results of site-wide screening against toxicity screening values are presented in Appendix 7A Tables 7A.23 through 7A.27. Constituents that were retained for further evaluation after the site-wide screens, along with the locations at which they occur, are summarized in Table 7.1.

The analysis of exposure units, assessment endpoints, and various ecological receptors is discussed in the following sections.

7.3.2.2 Exposure Unit by Exposure Unit Screening

The input data (detected concentrations), including background, are presented in Appendix 7A Table 7A.1 and are organized by each EU medium (e.g., soil, sediment, and surface water). The values shown as the value for comparison are the maximum detected concentration or the 95% UCL (see Section 3.1.2.3), depending on the sample size for each constituent within the corresponding medium on an exposure unit-by-exposure unit basis, (e.g., drainage ditches, Toussaint Creek, and France Stone Quarry). Analytical results for surface soil and sediment are presented as mg/kg of medium; those for surface water are presented as μg/L of water.

7.3.3 Ecological Surveys and Description of Habitats and Populations

This section provides a description of the ecological resources at the Luckey site. The following discussion is based on a site walkover conducted in June 1998, a wetland survey report from June 1998 (USACE 1998b), site visits during Phase IV sampling and information obtained from the U.S. Fish and Wildlife Service (USFWS 1997) and Ohio Department of Natural Resources (ODNR) (ODNR 1997). Habitats and plants are discussed in Section 7.3.3.1; animals are discussed in Section 7.3.3.2; aquatic habitats are discussed in Section 7.3.3.3; and protected species are discussed in Section 7.3.3.4.

7.3.3.1 Habitats and Plant Communities

The land use surrounding the Luckey site is primarily agricultural. On site the land use includes developed industrial areas, old fields (unused areas), and waste areas. Terrestrial habitats present in the area include very limited to no habitat in developed areas (e.g., buildings, paved areas, gravel lots, and lawns), monoculture croplands (e.g., corn and soybeans) located just off site, early successional old fields, and tree lines. Aquatic habitats include Toussaint Creek located to the north of the site, a small wetland and wet areas in the eastern portion of the site, and the France Stone Quarry located to the south. A small jurisdictional ditch (water of the U.S.) begins in the central portion of the site and flows north through an agricultural field, eventually discharging to Toussaint Creek. A narrow riparian corridor borders Toussaint Creek and is wider and more mature downstream of the site. This patchy landscape is depicted in the aerial photograph in Figure 7.2. Each of the habitats is described briefly below.

Developed Areas

The Luckey site is located immediately northeast of the intersection of Gilbert and Luckey Roads. The industrial area within the Luckey site consists of small lawn areas, buildings, paved lots, and roadways. These developed areas are located in the western and central portions of the site. Small ornamental trees and shrubs are present around buildings. Small patches of weeds appear in some locations. Two concrete-lined ditches exit the industrial property to the west and discharge to a ditch that flows north along Luckey Road, eventually discharging to Toussaint Creek. Another ditch lies southeast of the warehouse and flows east toward former Lagoon C. The lawn areas south of the warehouse cover former Lagoons A and B. Two railroad spurs entering the industrial area from the east are now overgrown by vines (*Vitis* spp.) and weedy species.

The industrial area offers very little habitat for ecological receptors. The small drainage ditches are exceptions to this condition, as two contain some wetland vegetation (narrow-leaf cattail - *Typha angustifolia*, broad-leaf cattail - *Typha latifolia*, flat-stem spikerush - *Elocharis compressa*, Olney's bulrush - *Scirpus americanus*, and common reed - *Phragmites australis*) but were determined not to be jurisdictional wetlands (USACE 1998b). Both of these ditches are small and do not constitute sufficient habitat to be separate exposure units. Furthermore, water is in the ditches for only a few weeks per year, thus fish and other aquatic life are not present.

Agricultural Areas

Large agricultural fields are located to the west, north, and east of the site. Farming practices in the fields are typical of northwestern Ohio, consisting of soybeans, winter wheat, and corn in rotation. These fields are disturbed seasonally by tilling, fertilizing, pesticide applications, and harvesting. Marginal habitat is available to terrestrial invertebrates (insects, spiders, etc.), birds, mammals, and reptiles during the growing season.

Old Fields

Old fields are early successional communities that develop in disturbed, open areas. They are characterized by a predominance of herbaceous and invasive species. Some young woody plants are present. Old field communities are present on much of the northern and eastern portions of the Luckey site. In addition, the Troy Township Dump and part of the area adjacent to the France Stone Quarry contain old field communities. Old fields in the northern part of the site and at the Troy Township Dump are fairly young and do not contain woody species. Old fields in the eastern portion of the site and at the France Stone Quarry are more mature and do contain some woody shrubs and invasive tree species.

Old field herbaceous vegetation consists of forbs and grasses. Common species include tall goldenrod (*Solidago altissima*), lanced-leaved goldenrod (*S. graminofolia*), yarrow (*Achillea millefolium*), dogbane (*Apocynum* sp.), Canada thistle (*Cirsium arvense*), dock (*Rumex obtusifolius*), teasel (*Dipsacus fullonum*), New England aster (*Aster novae-angliae*), small white aster (*A. vimineus*), milkweeds (*Asclepias* spp.), common brome grass (*Bromus commutatus*), chicory *(Cichorium intybus*), Queen Anne's lace (*Daucus carota*), wild strawberry (*Euonymus americanus*), barnyard grass (*Echinochloa crusgalli*), and tall ironweed (*Vernonia gigantea*).

Old field woody vegetation includes eastern cottonwood (*Populus deltoides*), eastern red cedar (*Juniperus virginiana*), willows (*Salix* spp.), gray dogwood (*Cornus racemosa*), choke cherry (*Prunus virginiana*), grape vines (*Vitis* spp.), and multiflora rose (*Rosa multiflora*).

Void of Vegetation Areas

There are several areas void of vegetation. One area in IA07 is located east of the propane tanks and occupies about 10,000 ft^2. Other areas occur in IA01. This lack of vegetation is believed to be due to a combination of physical and chemical causes (see Section 7.8).

Riparian Corridor and Tree Lines

Near the Luckey site, Toussaint Creek is lined primarily with herbaceous vegetation; however, downstream of the abandoned NYC Railroad (NYCRR) bed, a narrow band of trees adjacent to the creek forms a riparian corridor. The width of this corridor varies along the creek. In some places it is fairly extensive where woodlots are connected, and at other locations it is quite narrow where fields and residences encroach on the creek. Tree species include mainly cottonwood, boxelder (*Acer negundo*), sycamore (*Platanus occidentalis*), pin oak (*Quercus palustris*), honey locust (*Gleditsia triacanthos*), swamp white oak (*Quercus bicolor*), and green ash (*Fraxinus pennsylvanica*).

A tree line along the NYCRR bed separates the site from the agricultural field to the east. Another tree line is located south of Gilbert Road between the road and the France Stone Quarry and Troy Township Dump. This tree line, which is fairly wide near the France Stone Quarry, contains many young trees. These tree lines are limited to a few dominant species such as cottonwood, boxelder, white mulberry (*Morus alba*), green ash, and smooth sumac (*Rhus glabra*).

Wetlands

The USACE reported the presence of one on-site jurisdictional wetland east of Lagoon D and north of Lagoon C (USACE 1998b). It is an irregularly shaped shallow emergent wetland occupying approximately 1.59 acres. Dominant plants include narrow-leaf cattail (*T. angustifolia*), flat-stem spikerush (*E. compressa*), slender rush (*Juncus tenuis*), and cottonwood (*P. deltoides*) trees. In addition, the USACE reported the presence of a jurisdictional ditch originating on site and extending north off site to Toussaint Creek (USACE 1998b). The ditch meets the definition of a shallow emergent wetland. It is approximately 10 ft wide and 395 ft long (within the site boundary) and occupies approximately 0.09 acres. Approximately 18 inches of water was present in the ditch during the survey. Dominant plants included water plantain (*Alisma plantago-aquatica*), narrow-leaf cattail, lesser duckweed (*Lemna minor*), and silky dogwood (*Cornus amomum*). Several other small wet areas were noted in the northeast and southeast corners of the site, in addition to the drainage ditches around the industrial area discussed above, but none met all jurisdictional criteria for wetlands.

Sensitive Habitats

ODNR and the USFWS did not identify any sensitive habitats on or near the Luckey site during their natural heritage data searches.

7.3.3.2 Animal Populations

No census has been conducted for terrestrial animal populations at the site; however, the old fields, wetlands, and tree lines would provide habitat for animals tolerant of disturbed environments. These animals could include some the following common mammals: opossum (*Didelphis virginiana*), short-tailed shrew (*Blarina brevicauda*), eastern cottontail (*Sylvilagus floridanus*), eastern chipmunk (*Tamias striatus*), groundhog (*Marmota monax*), eastern gray squirrel (*Sciurus carolinensis*), prairie deer mouse (*Peromyscus maniculatus*), white-footed mouse (*Peromyscus leucopus*), meadow vole (*Microtus pennsylvanicus*), house mouse (*Mus musculus*), meadow jumping mouse (*Zapus hudsonius*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), red fox (*Vulpes vulpes*), white-tailed deer (*Odocoileus virginianus*), and muskrat (*Ondatra zibethicus*). White-tailed deer, cottontail, and raccoon tracks were seen during the site walkover.

Resident amphibians and reptiles likely would include some of the following common species: American toad (*Bufo americanus*), bullfrog (*Rana catesbeiana*), wood frog (*Rana sylvatica*), snapping turtle (*Chelydra serpentina*), eastern box turtle (*Terrapene carolina*), painted turtle (*Chrysemys picta*), blue racer (*Columber constrictor*), rat snake (*Elaphe obsoleta*), northern water snake (*Nerodia sipedon*), queen snake (*Regina septemvittata*), brown snake (*Storeria dekayi*), and garter snake (*Thamnophis sirtalis*).

A large number of bird species could use the available habitats as nesting and foraging areas. Potential bird species are too numerous to list; however, species sighted during walkover included: American crow (*Corvus brachyrhynchos*), killdeer (*Charadrius vociferus*), American goldfinch (*Carduelis tristis*), rock dove (*Columba livia*), northern cardinal (*Cardinalis cardinalis*), American robin (*Turdus migratorius*), house sparrow (*Passer domesticus*), house finch (*Carpodacus mexicanus*), European starling (*Turnus vulgaris*), barn swallow (*Hirundo rustica*), mourning dove (*Zenaida macroura)*, and red-winged blackbird (*Agelainus phoeniceus*). Canada goose (*Branta canadensis*), mallard duck (*Anas platyrhynchos*), and great blue heron (*Ardea herodias*) were observed flying over.

Numerous arthropod species (insects, spiders, etc.) are present. For example, butterflies and moths (lepidoptera), beetles (coleoptera), bees, wasps, and ants (hymenoptera), and flies (diptera) all were seen during the site walkover.

The wetland areas, drainage ditches, and Toussaint Creek would provide habitat for aquatic insects and other arthropods (e.g., crayfish), amphibians, and reptiles.

7.3.3.3 Aquatic Habitats

Toussaint Creek is a low-order, northeastern-flowing stream that drains the area. The creek originates to the west-southwest of the Luckey site and becomes larger downstream of the site, where it receives additional runoff from other agricultural areas. Toussaint Creek eventually discharges to Lake Erie approximately 25 miles to the northeast.

Toussaint Creek, downstream of the site, and the France Stone Quarry are sufficiently large to provide adequate habitat for small and large fish. Trespassers are known to fish in the France Stone Quarry, and carp have been observed in Toussaint Creek.

The France Stone Quarry covers an area of approximately 26 acres and is at least 70 ft deep. The quarry receives water inputs from direct precipitation, surface runoff from adjacent land, and groundwater infiltration. An overflow drainpipe directs excess water to a drainage ditch south of Gilbert Road.

A Rapid Bioassesement Protocol II (RBP II) (Plafkin et al. 1989) benthic macroinvertebrate biosurvey was performed at five stations in Toussaint Creek in July 1998. An RBP II biosurvey is an EPA method that consists of the following components: identification of benthic macroinvertebrates to family taxonomic level, calculation of eight metric scores for various community, population, and functional parameters that each indicate the biological integrity of the benthic macroinvertebrate community; and an aquatic habitat assessment. A summary report describing the RBP II is presented in Appendix 7B Report; thus the results are only briefly discussed here.

The Luckey site benthic invertebrate biosurvey station identifications in Toussaint Creek were as follows: IA06SW0003 (upstream reference site), IA06SW0004 (just downstream from confluence of the Luckey site drainage ditch into Toussaint Creek), IA06SW0006, IA06SW0007, and IA06SW0008 (three sites progressively farther downstream from the Luckey site boundary). The stations corresponded to surface water sampling locations for the RI. Station IA06SW0003 was upstream of the Luckey site border and was intended to be the reference location because of its placement upstream from any potential source inputs from the Luckey site. Although the site selected for the reference was not ideal, it was the available choice, and had conditions most similar to those at and downstream of the Luckey site and was the least impacted by adjacent agricultural activities. A discussion comparing ecological effects downstream to effects at the reference site is presented in Section 7.8.2.

Evidence of local watershed erosion was heavy at four of the six sites and moderate at the two others. Stream widths increased from 6 to 12 ft at the most upstream site to 20 to 30 ft at the most downstream site. Flow rates ranged from nearly still to 3cm/sec. All sites were turbid, except IA06SW0007, which was slightly turbid. Three sites had anaerobic odors in the sediment. All sites had abundant sand and silt deposits. Appendix 7B Report Table 3.3 summarizes substrate composition at the sites. Only two sites had substrate composition containing fractions larger than gravel (IA06SW0004 and IA06SW0008).

Habitat assessment scores for the Luckey RBP II sites are summarized in Appendix 7B Report Table 3.4. All sites except the most downstream location (IA06SW0008) were scored as “poor”. The numerical total score values ranged from 20 to 30 for all the poor scores, and was 48 (fair) at the most downstream station (IA06SW0008). Embeddedness, as well as bottom scouring and deposition, were scored poor at all stations. Flow and channel alteration scored poor at all stations except the most downstream, which was fair. Bank stability and bank vegetative stability were generally poor at most stations, except the most upstream, which scored good.

7.3.3.4 Threatened and Endangered Species

The USFWS and ODNR were contacted in 1997 regarding the presence of federally- and state-listed T&E species (USFWS 1997 and ODNR 1997). The USFWS noted that the Luckey site is located with the range of one federally listed endangered species, the Indiana bat (*Myotis sodalis*). USFWS noted that no impact to this species is expected from activities at the facility. ODNR did not identify any rare species in the area near the site.

The USFWS and ODNR were contacted again in 2000 regarding the presence of federally- and state-listed T&E species (USFWS 2000 and ODNR 2000). These agencies were requested to provide records for T&E species in all USGS quadrangles within five miles of the Luckey Site and in Toussaint

Creek downstream of the Luckey Site to Lake Erie. These quadrangles included Rossford, Walbridge, Dunbridge, Pemberville, Elmore, Genoa, Oak Harbor, and Lacarne. The USFWS again noted that the Luckey site is located with the range of one federally listed endangered species, the Indiana bat. USFWS also noted that the Luckey site lies within the range of the one federally listed threatened species, the bald eagle (*Haliaeetus leucocephalus*). The Luckey site does not provide adequate habitat for the bald eagle and Toussaint Creek does not provide adequate foraging habitat until far downstream near Lake Erie.

ODNR identified state T&E and rare species records in Dunbridge, Pemberville, Oak Harbor, and Lacarne quadrangles. The Luckey site is very unlikely to have any impact to T&E species identified in the Dunbridge and Pemberville quadrangles due to the distance to these recorded locations and the absence of any surface water connection. The state T&E species identified in the Oak Harbor and Lacarne quadrangles are located at the far downstream end of Toussaint Creek near Lake Erie. These species are summarized below. The Luckey site has the potential to impact these receptors due to the surface water connection with Toussaint Creek; however, this potential is considered rather small due the distance (over 20 miles) between these species locations and the Luckey site.

Oak Harbor Quadrangle

Haliaeetus leucocephalus – Bald eagle, state endangered
Emydoidea blandingii – Blanding's turtle, state special interest
Elaphe vulpina gloydi – Eastern fox snake, state special interest

Lacarne Quadrangle

Euphorbia polygonifolia – Seaside spurge, state potentially threatened
Sporobolus cryptandrus – Sand dropseed, state potentially threatened
Cakile edentula – Inlands's sea-rocket, state potentially threatened

7.3.4 Selection of Exposure Units and Receptor Species

From the ecological assessment viewpoint, an EU is the investigation area and some of the surrounding area where ecological receptors are likely to gather food, seek shelter, reproduce, and move around, and, as a result of these activities, be potentially exposed to site constituents. Thus, the EU is defined on the basis of the existing habitat and land use, observed and assumed patterns of behavior of the receptors, and the spatial area of site and Luckey site habitats relative to the home range and foraging areas of the receptors. The spatial boundaries of the ecological EUs are the same as the spatial boundaries of unit defined for the HHRA.

These proposed EUs are as follows:

- Exposure Unit 1 – on-site undisturbed soil area within the current fenced boundaries of the site (excluding the buildings);
- Exposure Unit 2 – on-site disturbed soil area within the current fenced boundaries of the site (excluding the buildings);
- Exposure Unit 3 – off-site, land surrounding the facility currently used for residential/agricultural purposes;
- Exposure Unit 4 – Toussaint Creek (see below for explanation of stretches);
- Exposure Unit 5 – France Stone Quarry, south of the site; and
- Exposure Unit 6 – Landfill (Troy Township Dump), south of the site.

There is a distinction between EU1 and EU2. EU1 contains areas of relatively undisturbed soil with vegetation that is maintained or was maintained until recently (i.e., mostly grassy fields and ornamental shrubs). EU2 contains the more disturbed and more contaminated soils on site including areas

void of vegetation. In addition, EU2 contains more natural vegetation (wetlands, old fields, tree lines). Therefore, the distinction between EU1 and EU2 is two-fold. One is based on available habitat and exposure potential, the other is based on known contamination. The second distinction has been made to facilitate the presentation of a risk characterization that will meet the needs of future FS. Also, note that the plant buildings and roads are not considered part of EU1 and EU2 and will be evaluated separately.

Regarding EU 4, the majority of the contamination exists within the ditch leading into Toussaint Creek. In sediment, concentrations of beryllium, a site-related chemical, range from 2020 ppm to 1 ppm in the ditch. Within the first mile, concentrations range from 220 ppm to 3 ppm. From mile 1 to mile 3 downstream, concentrations range between 90 ppm and 0.3 ppm. Downstream from mile 3, beryllium concentrations generally are less than 3 ppm, except near mile 9 another elevated detection 14 ppm occurred. To accommodate a range of sediment conditions, Toussaint Creek was organized into stretches or reaches. These stretches are:

- downstream: zero to 1 mile,
- downstream: 1 to 3 miles, and
- downstream: 3 to 15 (or end) miles.

These stretches represent the various known gradients and conditions. Note that other measurements such as TOC and grain size have been sampled upstream and within the first mile downstream. Stream macroinvertebrate sampling occurred upstream, immediately downstream, approximately one mile downstream, at the elevated detection nine miles downstream, and approximately 10 miles downstream. These data will help interpret the risk assessment findings and to extrapolate downstream conditions (see Sect. 7.8).

The exposed ecological receptors for the ERA were selected from animal species found in terrestrial/aquatic habitats. Three criteria, listed below, were used to select the ecological receptors.

- Ecological relevance means that the receptor has or represents a role in energy flow (e.g., plants), nutrient cycling (e.g., earthworms), or population regulation (e.g., hawks).
- Susceptibility means that the receptor is known to be present, sensitive to constituents (e.g., rabbits), and exposed through ingestion or direct contact because food of preference is highly available (e.g., robins and shrews).
- Management goals include the sustaining of ecosystems and ecological processes while maintaining the central mission of the Luckey site, which is to manufacture various goods.

Based on these criteria, the ecological receptors for the Luckey site include terrestrial plants, earthworms, short-tailed shrew, American robin, cottontail rabbit, white-tailed deer, red-tailed hawk, red fox, sediment-dwelling organisms, aquatic organisms, and great blue heron (Table 7.2). Risks were quantitatively estimated for each receptor. Figure 7.3 shows the terrestrial food chain for the terrestrial receptors. Figure 7.4 shows the aquatic food chain for the aquatic receptors.

7.3.5 Ecological Assessment and Measurement Endpoints

The protection of ecological resources, such as the species of plants and animals and habitats described in Section 7.3.3, is mandated by a variety of legislation and government agency policies [e.g., CERCLA, RCRA, and the National Environmental Policy Act (NEPA)]. Through these laws, protection goals are established by legislation or agency policy. To determine whether a protection goal has been met, assessment and measurement endpoints were formulated.

An assessment endpoint is defined by EPA (1992e) as "an explicit expression of the environmental value that is to be protected." A measurement endpoint is defined by EPA (1993c) as a measurable ecological characteristic that is related to the valued characteristic chosen as the assessment endpoint. Assessment endpoints are ecological resources that are expressed as ratios, which, if they exceed 1 or unity, suggest the need for further examination. The ratios compare an exposure concentration (estimated from a measured concentration in a medium) and an effects concentration (e.g., the toxicity threshold below which there are no adverse effects). A measurement endpoint refers to the measurement or concentrations (of a constituent and a toxicity threshold) that are used to define and develop the ratio in the assessment endpoint.

Three policy goals were defined for the Luckey ERA. Assessment and measurement end points are provided with each policy goal (Table 7.3). Policy goals are the following:

- Policy Goal 1: The preservation and conservation of any threatened, endangered, and rare species and their environmentally sensitive or critical habitats;
- Policy Goal 2: The maintenance and protection of terrestrial populations and ecosystems; and
- Policy Goal 3: The maintenance and protection of aquatic populations and ecosystems.

The decision rules associated with assessment endpoints for the ERA are stated quantitatively in terms of EEQs (Barnthouse et al. 1986). An EEQ is the ratio of the measured or predicted concentration of an analyte to which receptors are exposed in an environmental medium, and the measured concentration of an analyte that adversely affects an organism (benchmark or TRV). If the measured concentration exactly equals or is less than the concentration producing an adverse effect (i.e., the ratio of the two, or the EEQ, is less than or equal to 1), the risk is considered acceptable (protective of the ecological receptor). Any EEQ greater than 1 indicates that the CPEC qualifies for further investigation of the actual likelihood of harm, i.e., a BRA may be needed. The final ecological COCs are selected only after additional evaluation of the conservatism of exposure assumptions, toxicity thresholds, and uncertainties (e.g., background risk).

Further thresholds may be needed to make decisions. Accordingly, EEQs in the range of 1 to 100 will be designated as low ecological risk, in the range of 100 to 1000 as intermediate ecological risk, and in excess of 1000 as high ecological risk. The basis for these categories is professional judgment founded on experience gained by completing numerous ERAs. The use of such a simple method to organize EEQs is designed to help manage risk, not to supplant this responsibility that is related but different from risk assessment. However, full acknowledgement is given any constituent with an EEQ of 1 or higher based on the screening ERA.

The next possible step for a baseline ERA would be to use less conservative exposure values (e.g., arithmetic mean) and less conservative effects [e.g., lowest observed adverse effects levels (LOAELs)], compared to screening ERAs [e.g., 95% UCL and no observed adverse effect levels (NOAELs)]. The less conservative baseline ERA would serve to drop the large EEQs to smaller ones. However, one cannot often break the EEQ > 1 threshold and more and more work is devoted to better exposures and effects and computations. A second part of the baseline ERA consists of biological measurements. Here, the emphasis is on field-observed effects or ground-truthing of the mathematical predictions of ecological risk from the screening ERA.

In summary, the EEQs >1 will help to focus on which media, places, constituents, and receptors show ecological risk. The proposed direction is not to perform more computations, rather go to the field and look for manifested risk. While the field-metrics need to be refined, two of the likely ones will be lower density of stream macroinvertebrates in Toussaint Creek and lack of vegetation in soil patches at the site (see Section 7.8).

Endpoints stated in terms of specific ecological receptor or exposure classes (groups of species exposed by similar pathways) often require data on the processes that increase or decrease the exposure concentration above or below the measured environmental concentration. Thus, some EEQs in the assessment endpoints incorporate exposure factors (e.g., dietary soil fractions and bioaccumulation factors). Exposure factors for ecological receptors are discussed in Section 7.4.2.

EEQs for assessment endpoints one through six (Table 7.3) were calculated for CPECs in soils. Assessment endpoints seven, eight and nine deal with sediment and surface water assessment endpoints, respectively, and the EEQs were calculated for CPECs. Assessment endpoint six deals with exposure to a raptor and another carnivore species, and assessment endpoint one considers any threatened species.

7.3.6 Summary of Constituents of Potential Ecological Concern

Initially, CPECs are those substances detected in surface soil (zero to 2 ft bgs), sediment, and surface water at the Luckey site that have the potential to pose a hazard or risk to plants and animals. All constituents detected above background levels automatically become CPECs. Maximum concentrations or 95% UCL (if data are sufficient) of soil, sediment, and surface water analytes have been compared to screening values to identify CPECs. These CPECs, or analytes that remain after the screenings, are further evaluated below.

7.4 EXPOSURE ASSESSMENT

Step 2 of EPA's four-step ERA process, as it applies to the ERA for the Luckey site, is discussed in this section. The exposure assessment describes the receptors, constituent sources, and exposure media. It also examines the route, magnitude, frequency, duration, and spatial pattern of exposure of each receptor population and habitat to a chemical or physical stressor.

7.4.1 Ecological Receptors and Their Exposure

The risk assessment evaluates the potential exposures of ecological receptors to constituents in surface soil, surface water, sediments, and plants and animals ingested by other receptors. The primary receptor categories are subcategorized by exposure classes. Exposure classes group together species with similar feeding habits and physiologies. Each exposure class for sites at the Luckey site contains one or more species of ecological receptor because of the preliminary nature of the work.

The terrestrial exposure classes and their ecological receptors for the Luckey site investigation are as follows:

- vegetation (variety of grasses, forbs, and trees);
- soil-dwelling invertebrates (earthworms);
- mammalian herbivores (cottontail rabbits, white-tailed deer);
- worm-eating and/or insectivorous mammals and birds (short-tailed shrews, American robins); and
- terrestrial top predators (red-tailed hawks, red foxes).

These receptors or their ecological equivalents are present or likely to be present at the Luckey site and were selected in accordance with the EPA Framework (EPA 1992e and EPA 1996c), as explained previously. Information on body weights, diets, and ingestion rates of the receptor has been by USEPA (EPA 1993c).

Exposure pathways were chosen to provide a range of potential exposures, including high exposures, to receptors under a variety of conditions. For example, earthworms and shrews constitute a

pathway where exposure of small mammals from soil constituents would be maximized. Hawks represent the top of the food web where exposures from bioaccumulated materials can be maximal. By contrast, herbivores and plants constitute a pathway of lesser chemical and radionuclide exposure. There are insufficient differences between and among the various terrestrial exposure units to have different sets of receptors for each EU. Therefore, for the ERA, the same five terrestrial exposure classes and eight terrestrial receptors were used at each of the soil-related EUs, such as EU1, EU2 and adjacent property. This assures comparability of results for risk characterization.

***Vegetation*—**Vegetation is composed of grasses, forbs, bushes, and trees of the type growing at the Luckey site. Vegetation converts sunlight to biomass in the form of roots, stems, leaves, and floral parts. In turn, the plant parts are eaten by herbivores. There is no parameter table because exposure is direct.

***Soil-dwelling Invertebrates*—**Earthworms and other soil-dwelling invertebrates (lumbricids) are exposed to soil constituents in surface soil by ingestion and direct contact. It is assumed that earthworms ingest only soil and are exposed to the full-measured concentrations. Earthworms have ecological value because of their role in the decomposition of detritus, soil aeration, and soil fertility. Also, worm-eating mammals and birds ingest earthworms; thus, any decrease of earthworm populations would reduce the amount of food going to their predators, which could affect such predators. In addition, contaminated earthworms – both contaminated soil in their guts and contaminated tissue – can contaminate and affect their mammal and bird predators. There is no exposure table because most exposure is direct.

***Worm-eating and/or Insectivorous Mammals and Birds*—**Worm-eating and/or insectivorous mammals [(e.g., short-tailed shrew, *Blarina brevicauda* (Appendix 7A Table 7A.28), American robin, *Turdus migratorius* (Appendix 7A Table 7A.29)] are primarily exposed by ingestion of potentially contaminated prey (e.g., earthworms, insect larvae, slugs), as well as ingestion of soil. Worm-eating and/or insectivorous mammals and birds may also be exposed to soil constituents by direct contact and inhalation of VOCs and SVOCs and particulates. Dermal exposure is expected to be negligible, and skin-associated soil that is ingested is included in the estimated daily soil ingestion rate. For the Luckey site, the exposure for this class of receptors is the sum of materials absorbed from the soil and from ingested plants and animals. The soil fraction of their diet includes soil from the intestinal tracts of their prey. Exposure by direct contact and inhalation will not be evaluated. There are few data on inhalation toxicity or toxicity by direct contact with contaminated soil (or the parameters required to model constituent absorption). Instead, conservative values for soil ingestion and dietary composition will be used for shrews and robins.

***Mammalian Herbivores*—**Mid-sized and large-sized herbivores [e.g., eastern cottontails, *Sylvilagus floridanus* (Appendix 7A Table 7A.30)], and white-tailed deer, *Odcocoileus virginianus* (Appendix 7A Table 7A.31) are exposed primarily to soil constituents that are in plant material. Exposure by direct contact with soil is assumed to be limited for cottontails and deer. The exposure for cottontails and deer is the sum of absorption from the ingested soil and ingestion from plants. The estimated exposure for this class does not include exposure by direct contact or inhalation. Few data are available for inhalation toxicity or toxicity by direct contact with contaminated soil (or the parameters required to model constituent absorption). Instead, conservative intake or exposure values for soil ingestion and dietary composition are used for these herbivores.

***Terrestrial Top Predators*—**Top predators are exposed primarily to CPECs that have accumulated in their prey. Terrestrial top predators [e.g., red-tailed hawk, *Buteo jamaicensis* (Appendix 7A Table 7A.32) and red fox, *Vulpes vulpes* (Appendix 7A Table 7A.33)] feed primarily on terrestrial prey. Some terrestrial predators also may incidentally consume soil; hawks do not. Although hawks and other predators are assumed to forage over an area that is larger than the area of the Luckey site EU, and

certainly for the area of any EU, there is no adjustment made for the fact that they have home ranges in excess of these locations for the screening ERA.

In short, each receptor listed is directly linked to one of the assessment endpoints and provides an explicit expression of the environmental value to be protected. For example, soil-dwelling invertebrates are listed because the soil invertebrate community is ecologically important, is susceptible to constituents in soil, and is exposed at the site. The soil invertebrate community is essential for decomposition of detritus and for energy and nutrient cycling. Earthworms are probably the most important of the soil invertebrates in promoting soil fertility. They are highly exposed to soil, and toxicity information is available. Therefore, earthworms were chosen as the surrogate species to evaluate risks to the soil invertebrate community. Similarly, worm-eating and/or insectivorous mammals are ecologically important because they help control the size of the terrestrial invertebrate population that might otherwise damage populations of primary producers, especially plants. They also are susceptible to soil constituents and are exposed at the site. Short-tailed shrews were chosen as surrogate species because they are highly exposed to constituents by their consumption of large quantities of terrestrial invertebrates that are present in the habitats at the Luckey site. They also ingest soil during feeding, including soil within the bodies of earthworms and other prey. Herbivores, such as cottontail rabbits and deer, feed directly on plants. Of course, plants are the basis for the food webs. Hawks and foxes complete the food chain and represent predators that eat small mammals and birds and that may bioaccumulate constituents.

Aquatic Exposure Classes and Receptors. The aquatic exposure classes and their ecological receptors in the small ditches and Toussaint Creek and France Stone Quarry near the Luckey site including the following:

- sediment-dwelling organisms, which include worms, clams, and crayfish depending on the water body;
- fish and aquatic animals, which include such organisms as omnivores (caddisflies and may flies, minnows), predators (crayfish), mussels, and sediment-ingesting fish; and
- terrestrial top predators of aquatic organisms (great blue heron).

***Sediment-Dwelling Invertebrates*—**Sediment-dwelling invertebrates (e.g., crayfish) are assumed to be exposed to sediment and sediment pore water by multiple routes. The toxicity threshold concentrations for CPECs in sediment for the Luckey site ERA are based on all exposure routes from sediment to sediment-dwelling invertebrates. Thus, the measured CPEC concentrations in sediment are used as the estimated exposure concentrations for sediment-dwelling invertebrates.

***Fish and Aquatic Animals*—**Fish and aquatic animals are exposed primarily to constituents in surface water and in the food they ingest. The exposure concentration for these animals is assumed to be equal to the measured environmental concentration because the aquatic toxicity thresholds used are expected to protect aquatic life from all exposure pathways, including ingestion of contaminated plants and animals. It is assumed that all aquatic animals (omnivores, predators, and sediment-ingesting fish) are exposed to the full concentration in surface water by direct contact and all other pathways. Although sediment-ingesting fish are exposed to constituents in both sediment and surface water, there are no known dietary toxicity data for such fish. Therefore, the exposure of sediment-ingesting fish is considered together with the other aquatic animals, and no exposure specific to sediment ingestion is calculated for these receptors.

***Top Terrestrial Predators of Aquatic Organisms*—**The great blue heron, *Ardea herodias* (Appendix 7A Table 7A.34), represents the various fish-eating birds and mammals or piscivores. Great blue herons feed on fish and other aquatic prey.

The exposures of these receptor classes to analytes are estimated from the measured concentrations in the soil, sediment, or water and are adjusted by exposure factors, as described below.

7.4.2 Quantification of Exposure

The exposure of an endpoint receptor to a constituent in surface soil at the Luckey site was quantified as the average daily dose (ADD) using measured concentrations in the environment and exposure parameters that account for both the transfer of constituents from soil into food and the quantity of food and soil ingested daily. The concentration of a constituent to be used in the exposure calculation is termed the EPC. EPCs are provided in Appendix 7A Table 7A.1 for surface soil, sediment, and surface water, where they are designated "Value for Comparison". When the sample size for soil and sediment was large enough, the EPC was calculated (i.e., 95% UCL). Where the sample size consists of singular datum or small sample size, the maximum detected concentration was used as the EPC.

Exposure parameters used to derive the ADD for each endpoint receptor for the site are provided in Appendix 7A Tables 7A.28 through 7A.34. The quantity of food ingested that is plant matter (I_P), animal matter (I_A), and soil (I_S) is calculated from the total daily rate of food ingestion (IR_F) and the fractions of the diet that contain plant matter (PF), animal matter (AF), and soil (SF). Shrews, robins, cottontails, deer, and foxes are assumed to ingest plant matter, but hawks and great blue herons are assumed to have no plant matter in their diets. Robins and foxes are assumed to ingest fruits and berries; whereas shrews, cottontails, and deer ingest mainly vegetative parts of plants. The animal matter component of the diets of shrews and robins is assumed to consist of earthworms because earthworms are more directly exposed to soil constituents than most other animals and because soil-to-earthworm uptake factors are available. A fraction of the mass ingested while eating earthworms is soil inside the worm intestine; this amount is included in the amount of soil ingested daily (I_S). Cottontails and deer are assumed to ingest no animal matter, and the hawks' and herons' diets consist entirely of animal prey. Constituent-specific transfer factors are provided in Appendix 7A Tables 7A.2 through 7A.4 of this ERA.

Ecological receptors obtain a fraction of their diet from the Luckey site EU. Assuming that individuals are distributed randomly and/or forage randomly over their home or foraging ranges, they obtain only a fraction of their diet from an EU that is smaller than their range. The area use factor (AUF) is the ratio of the size of the home or foraging ranges to the size of the EU. AUFs are based on reported foraging or home ranges (Appendix 7A Tables 7A.28 through 7A.34). As implied above, AUFs would vary from organism to organism, but AUFs were set at one because of the screening, i.e., conservative nature of the work. (Note that less conservative AUF's are possible when Ohio EPA agrees to them. For example, hawks have large home ranges relative to the area of an EU.)

Exposure equations are presented below. The general equation is:

$$\text{Exposure} = \text{Total average daily dose} = ADD_P + ADD_A + ADD_S$$

where:

ADD_P = Average daily dose by ingestion of plant matter (mg/kg body wt/d),
ADD_A = Average daily dose by ingestion of animal matter (mg/kg body wt/d), and
ADD_S = Average daily dose by ingestion of soil (mg/kg body wt/d).

For robins and foxes,

$$ADD_P = EPC \times SP_r \times I_P \times AUF,$$

where:

EPC = Exposure point concentration in soil (mg/kg soil),
SP_r = Soil-to-plant (fruiting parts) uptake factor (kg soil/kg plant),
AUF = Area use factor (unitless), and
I_P = Ingestion rate of plant matter (kg/kg body wt/d)
I_p = IRF x PF x TUF,
where:

IR_F = Ingestion rate of food (kg/kg body wt/d),
PF = Fraction of plant matter in diet (unitless), and
TUF = Temporal use factor (unitless).

ADD_P for shrews, cottontails, and deer is the same, except that the SP uptake factor used is that for transfer from soil to vegetative parts, SP_v. The form of SP is not relevant for hawks and herons because the quantity of plant matter ingested is assumed to be zero.

Ingestion of constituents in animal matter by shrews and robins is given by the following equation:

$$ADD_A = EPC \times BAF_i \times I_A \times AUF$$

where:

EPC = Exposure point concentration in soil (mg/kg soil),
BAF_i = Soil-to-soil-dwelling invertebrates uptake factor (kg soil/kg tissue),
I_A = Ingestion rate of animal matter (kg/kg body wt/d)
I_A = IR_F x AF x TUF,
where:

IR_F = Ingestion rate of food (kg/kg body wt/d),
AF = Fraction of animal matter in diet (unitless), and
AUF = Area use factor (unitless).
TUF = Temporal use factor (unitless).

Ingestion of constituents in prey by hawks (proxy for other terrestrial predators) is a special case because uptake by prey from their diets must be accounted for. It is assumed that the diet of hawks is entirely shrews because shrews are highly exposed to soil constituents. For hawks,

$$ADD_A = (\text{Concentration in prey, Cs}) \times I_{A(hawk)} \times AUF_{(hawk)}$$

Cs = Prey ADD_{total} x BAF_v / IR_f
Prey ADD_{total} = Prey ADD_P + Prey ADD_A + Prey ADD_S
Prey ADD_P = EPC x SP_v x $I_{P\text{-}s}$ x $AUF_{\text{-}s}$
Prey ADD_A = EPC x BAF_i x $I_{A\text{-}s}$ x $AUF_{\text{-}s}$
Prey ADD_S = EPC x $I_{S\text{-}s}$ x $AUF_{\text{-}s}$

where:

$I_{A(hawk)}$ = Ingestion rate of animal matter for hawk,
$AUF_{(hawk)}$ = Area use factor for hawk (unitless),
BAF_v = Food-to-tissue uptake factor in shrews (kg shrew's food/kg tissue),
IR_f = Shrew food ingestion rate (kg/kg body wt/d),
EPC = Exposure point concentration (mg/kg),
SP_v = Soil-to-plant (vegetative parts) uptake factor (kg soil/kg plant),
$I_{P\text{-}s}$ = Ingestion rate of plants by shrews (kg/kg body wt/d),

AUF_{-s} = Shrew area use factor (unitless),
BAF_i = Soil-to-animal bioaccumulation factor for invertebrates,
I_{A-s} = Ingestion rate of animal matter for shrews (kg/kg body wt/d), and
I_{S-s} = Ingestion rate of soil for shrews (kg/kg body wt/d).

The animal ingestion equation for foxes is similar.

The ingestion equation for great blue heron is similar, except that Cs is given by:

Cs = EPC x BCF

where:

EPC = Exposure point concentration in water (mg/L), and
BCF = Bioconcentration factor from water into prey (L/kg).

Ingestion of constituents in soil by all receptors is given by:

$ADD_S = EPC \times I_S \times AUF$

where:
EPC = Exposure point concentration in soil (mg/kg soil),
I_S = Ingestion rate of soil (kg/kg body wt/d)
I_S = $IR_F \times SF \times TUF$,
where:
IR_F = Ingestion rate of food (kg/kg body wt/d),
SF = Fraction of soil in diet (unitless),
TUF = Temporal use factor (unitless), and
AUF = Area use factor (unitless).
Similarly, ingestion of surface water by herons is given by:

$ADD_w = EPC \times I_w \times AUF$

where:

EPC = Exposure point concentration in water (mg/L surface water),
I_w = Ingestion rate of water (L/kg body wt/d), and
AUF = Area use factor (unitless).

The fraction of the constituent in ingested soil and tissue that is absorbed is assumed to be 100%. Continuous year-round exposure or a temporal use factor (TUF) of one is assumed for all receptors. (Note that less conservative TUFs are possible. For example, herons may spend only part of the year in residence.)

Exposure for sediment-dwelling organisms and aquatic organisms is expressed as the EPC (mg/kg for sediment and mg/L for water).

The constituent-specific values for bioaccumulation for soil-to-plant uptake (SP_v and SP_r), soil-to-invertebrate uptake (BAF_i), and animal tissue-to-mammal tissue uptake (BAF_v) are detailed in Appendix 7A Tables 7A.28 through 7A.34. The bioaccumulation factors (BAFs) for soil-dwelling invertebrate prey ingested by shrews are those reported in Risk Assessment Methodology for Loring Air Force Base

(HAZWRAP 1994). The BAFs for prey ingested by hawks are those for small mammals (HAZWRAP 1994). Default BAFs for CPECs without published BAF values are one for metals and one for organics, based on the range of values reported for these two types of constituents (HAZWRAP 1994). Soil-to-plant bioaccumulation factors (SPs) are presented in Appendix 7A Table 7A.5. Soil-to-biota bioaccumulation factors BAFs appear in Appendix 7A Table 7A.6. Sediment-to-biota and water-to-biota bioconcentration factors (BCFs) are presented in Appendix 7A Table 7A.7. Default BCFs for CPECs without published BCF values are 500 for metals and 100,000 for organics.

The exposure of endpoint receptors to CPECs in surface soil in each EU at the Luckey site was estimated by multiplying exposure factors by the EPC concentration, a conservative estimate of the CPEC concentration. The EPC concentration is the calculated upper 95th percentile if the sample size permits. For smaller sample groups, the maximum detect was used as the EPC. See Section 6.2 for further explanation. The EPC is a conservative estimate of the central tendency of the distribution of constituent concentrations in samples, especially in those cases where the maximum detected concentration is smaller than the 95% UCL. Individual organisms are potentially exposed to the maximum concentrations at an EU, which may be the maximum detected concentration. Constituent concentrations are those measured in soil at depths from zero to 2 ft. Soil background concentrations also are given in Appendix 7A Table 7A.1.

The ingestion factors are summarized in Table 7.4. The calculated exposure concentrations are provided in Appendix 7A Table 7A.1. The TRVs are provided in Appendix 7A (Appendix 7A Tables 7A.36 through 7A.39).

It was assumed that there is no dilution of CPECs for sediment-dwelling and aquatic receptors exposed directly to sediment and surface water. Therefore, exposure factors for these receptors are equal to 1.0. Concentrations are provided in Appendix 7A Table 7A.2 for sediment and for water, with background concentrations in the same appendix table.

7.4.3 Radionuclide Exposure Evaluation

Exposure evaluation includes the exposure concentrations in soil and the external and internal exposures of receptors to radionuclides in those soils.

7.4.3.1 Exposure Concentrations

Soil sampling and analyses of samples are described in the SAP (SAIC 1997, SAIC 1998). EPC concentrations of each radionuclide are the smaller of the maximum value in the data set and the 95th percentile confidence limit of the mean. EPC concentrations of radionuclides in soil, water, and sediment at each site are presented in Appendix 7A Table 7A.1.

7.4.3.2 Radionuclide Exposures of Biota

Radionuclides were detected above background in soil at EU 1, EU 2, and EU 3. There were no screening values for radionuclides in soil. No radionuclide was detected above screening values in surface water or sediment (Tables 7.1).

The representative terrestrial biota other than plants that are selected as endpoints for the radiological assessment are the same as those for the non-radionuclide constituent data assessment - terrestrial invertebrates, short-tailed shrew, Eastern cottontail, American robin, red fox, white-tailed deer, and red-tailed hawk. Life history parameters used in the radiological assessment are identical to those used for the non-radionuclide constituent data assessment. In addition, it was necessary to use species-

specific values for fraction of time spent above and below ground. Because plants grow both above ground and below ground, it was assumed that they are both above ground and below ground 100% of the time. Earthworms were assumed to be exposed below ground 100% of the time. The short-tailed shrew, Eastern cottontail, and red fox are all assumed to spend 75% of their time above ground and 25% below ground in dens or burrows. Robins are assumed to spend no more than 50% of their time on the soil surface and no time underground. White-tailed deer spend 100% of their time above ground. The red-tailed hawk also spends 100% of its time above ground, but much of this is flying or perched high in trees; thus, it is assumed that hawks are exposed to external radiation only 10% of the time.

External exposures include both underground exposure, where the receptor is surrounded by contaminants, and surface exposure, where the receptor is to some degree above the source of radioactivity. Underground external exposure was calculated by the following equation (DOE 1997b):

$$D = C_{soil} \times F_{below} \times 1.05 \times (E_{\beta} n_{\beta} \times \Phi_{\beta} + E_{\gamma} n_{\gamma} \times \Phi_{\gamma}) \times CF$$

where:

D	=	dose (rad/d) (includes daughters),
C_{soil}	=	RME radionuclide concentration in soil (pCi/g),
F_{below}	=	fraction of time the receptor spends below ground,
1.05	=	conversion factor to account for immersion in soil vs. water [estimated value; Keith Eckerman, Health Sciences Research Division, Oak Ridge National Laboratory, presented in Bear Creek Vally RI (DOE 1997b)],
E_{β}	=	beta energy of the radionuclide (MeV),
n_{β}	=	proportion of disintegrations producing a β-particle,
Φ_{β}	=	absorbed fraction of energy E_{β} (dimensionless),
E_{γ}	=	photon energy emitted during transition from a higher to a lower energy state (MeV),
n_{γ}	=	proportion of disintegrations producing a γ-ray,
Φ_{γ}	=	absorbed fraction of energy E_{γ} (dimensionless), and
CF	=	conversion factor to go from MeV to g rad/pCi d (5.12×10^{-5}).

Radiation absorption parameter values have been published by Eckerman and Ryman (1993) and Blaylock, Frank, and O'Neal (1993).

The external dose from surface exposure to each receptor was calculated by multiplying the EPC of each radionuclide by the appropriate external dose conversion factor (DCF) using the following equation (NRC 1992):

$$D = C_{soil} \times F_{above} \times F_{ruf} \times DCF \times CFa \times CFd \times 2$$

where:

D	=	dose (rad/d) (includes daughters),
C_{soil}	=	RME radionuclide concentration in soil (pCi/g),
F_{above}	=	fraction of time the receptor spends on the ground surface,
F_{ruf}	=	factor to account for roughness of ground surface (0.7),

DCF = dose conversion factor (Sievert/d per Bq/m^3) (includes daughters, NRC 1992 or converted from Eckerman and Ryman 1993),

CFa = conversion factor for activity (5.92E+04 Bq/m^3 = 1 pCi/g),

CFd = conversion factor for dose (100 rad/Sv), and

2 = arbitrary factor to account for closer proximity of ecological receptors to the radiation source than receptors for which DCF was derived (DOE 1997b). A value of 1 was used for white-tailed deer.

Subsurface and surface external doses to each receptor were summed for each radionuclide. Internal doses of radionuclides were calculated using the estimated tissue concentration of each radionuclide ingested by the receptors in food and soil. Accumulated doses were calculated by using the following equation (DOE 1997b):

$$D = CF \times C \times [(20 \times E_\alpha n_\alpha) + (E_\beta n_\beta \times \Phi_\beta) + (E_\gamma n_\gamma \times \Phi_\gamma)]$$

where:

D = dose (rad/d) (includes daughters),

CF = conversion factor (1E-12 Ci/pCi x 3.7E+10 dis/sec per Ci x 1/62.4E+06 g rad per MeV/dis x 3600 sec/hr x 24 hr/d),

C = radionuclide concentration in receptor (pCi/g body weight),

20 = quality factor to account for higher biological effectiveness of alpha radiation,

E_α = alpha energy of the radionuclide (MeV),

n_α = proportion of disintegrations producing an α-particle,

E_β = beta energy of the radionuclide (MeV),

n_β = proportion of disintegrations producing a β-particle,

Φ_β = absorbed fraction of energy E_β (dimensionless),

E_γ = photon energy emitted during transition from a higher to a lower energy state (MeV),

n_γ = proportion of disintegrations producing a γ-ray, and

Φ_γ = absorbed fraction of energy E_γ (dimensionless).

Radiation absorption parameter values have been published by Eckerman and Ryman (1993) and Blaylock, Frank, and O'Neal (1993). Absorption parameters for radionuclide CPECs in soil at the Luckey site are presented in Appendix 7A Table 7A.35. The tissue concentration, C, was calculated by the equations already described for the ecological receptors. External and internal doses were summed to calculate the total daily dose to each receptor.

Note that the radionuclides screening accounts for biomagnification. In Section 7.4.3.2, in the last equation regarding internal doses. Parameter C is the radionuclide concentration in the receptor or predator. It includes biomagnification from the soil and/or plant to the prey. The BAFs for radionuclides are the same as for non-radioactive isotopes of the same elements and are provided in Appendix 7A Tables 7A.7 through 7A.9.

7.4.4 Summary of Exposure Assessment

The EPCs of CPECs in media at exposure units at the Luckey site were multiplied by exposure factors to estimate exposure concentrations for each endpoint receptor. Exposure concentrations are the concentrations of CPECs in soil and the prey to which the endpoint receptors are exposed. These average daily doses are an estimate of the exposure of receptors to CPECs on a per-unit-constituent-concentration basis. These EPCs were compared to published toxicity threshold concentrations (Section 7.5) in order to characterize the risks to endpoint receptors from direct and indirect exposure to CPECs in soil (and water for herons) at the Luckey site (Section 7.6).

7.5 EFFECTS ASSESSMENT

The purpose of the effects assessment is to determine and evaluate the response to chemical and physical stressors at the Luckey site in terms of the selected assessment and measurement endpoints for the ecological receptors. Depending on the parameters of exposure, this effects assessment results in a profile of the response or TRV of receptor populations to stressors at concentrations or doses (or other units of stress) to which they are exposed.

7.5.1 Chemical Toxicity

Chemicals in the ecosystem may be directly toxic to plants and animals or indirectly harmful by reducing an organism's ability to survive and reproduce. These disparate effects are characterized by different dose response relationships and may result from different exposure pathways. The toxicity thresholds used for animals in the Luckey site are based on toxic effects observed in laboratory studies.

Chronic (long-term) toxicity resulting from non-radiological constituents is the primary concern at the Luckey site. VOCs are unlikely to remain at high concentrations because they have volatilized and/or have been transported off site. Most organisms do not ingest large amounts of soil and sediment, and assuming that the soil is not acutely toxic, these organisms are subject to chronic toxicity only.

Plants accumulate higher-than-background levels of some metals, resulting in chronic toxicity. Bioaccumulation is generally most significant in the roots of plants; however, several metals can be translocated to parts above the ground. Some metals (e.g., cadmium or mercury) accumulate in animal tissues and can have subtle deleterious effects on animals over long exposure times. Many organic constituents (e.g., PCBs and pesticides) are extremely lipophilic (i.e., lipid or fat-seeking) and can bioaccumulate in organisms. No investigation into chronic effects on local plants and animals as a result of exposure to soils and surface water has been conducted at the Luckey site. However, potential chronic effects to benthic macroinvertebrates can be evaluated by comparing the RBPII biosurvey data against measured concentrations of CPECs in co-located sediments.

The toxicity of constituents varies depending on the receptor species and the attending physical and chemical factors, the presence of complexing agents, or interaction with other constituents at the site. Plants can be adversely affected by constituents in numerous ways, including seed production, seed germination, growth rate, and plant biomass. Animals can be adversely effected in terms of behavioral and physiological changes, including reproductive impairment.

7.5.2 Toxicity Reference Values

Site-specific toxicological studies using the Luckey site animal populations have not been conducted to determine whether the concentrations of CPECs at the site are toxic. Therefore, the effects assessment considered toxicity data obtained from compiled databases [e.g., Will and Suter (1996) and

Sample et al. (1996), which utilize USFWS and other toxicity studies]. Information on test concentrations, modes of exposure, and effects on similar species from published toxicity studies was used to establish TRVs or thresholds for risk calculations. Examples of the kinds of toxicological data that are used to assess effects of site constituents on ecological receptors are:

- NOAEL – the highest concentration of a constituent in a study that causes no observable adverse effect on a test species, and
- LOAEL – the lowest concentration of a constituent in a study that causes an observable adverse effect on a test species.

NOAEL-based dietary limits are the preferred toxicity threshold for the Luckey site ERA and were used in this screening ERA when available.

Ecological effects data are available for many CPECs at the Luckey site. These data encompass effects arising from exposure to ingested matter, including soil and food for animals, and root uptake from soil by plants. Data are available for ecological receptors in all exposure classes for the EU. These data are used to identify inorganic and organic CPECs in the soil. Risks are calculated using the toxicity thresholds for CPECs from the soil.

Body weight, an integral part of the exposure equations is expressed as ADD (mg/kg/d). Because chronic toxicity is related to metabolic rate, which depends on body weight, toxicity benchmarks can be adjusted to the body weight of the receptor by applying a scaling factor. Body-weight conversions add more conservatism to the TRV when the field receptor is larger than the laboratory test organism (i.e., cottontail in the field vs. mouse in the laboratory). Conversely, body-weight conversions provide less conservative but more realistic TRVs for animals smaller than the test animals. Body weight scaling was used in the TRV screening at the Luckey site.

TRV thresholds are provided in Appendix 7A Tables 7A.36 (vegetation), 7A.37 (earthworms), 7A.38a (mammals) 7A.38b (body weight-scaled values for mammals), 7A.39a (birds), 7A.39b (body weight-scaled values for birds), 7A.40 (sediment-dwelling biota), and 7A.41 (aquatic biota). Two or more thresholds are presented for sediment and water situations. Usually, the lower or lowest value is selected as the final threshold; the footnotes to these tables provide additional details.

7.5.3 Effects Evaluation for Radionuclides

Because most ecological receptors neither live long enough to receive the high cumulative lifetime exposures experienced by humans nor are protected as stringently from cancer as humans, cancer risks were not evaluated in the screening ERA. Instead, risks of population effects (e.g., reduction in fertility or life span) from radiological effects of chronic exposure were evaluated.

The International Atomic Energy Agency (IAEA 1992) reported that irradiation at chronic dose rates of 1 milliGray per day (mGy/d) (0.1 rad/d) or less do not appear likely to cause observable changes in terrestrial vertebrate animal populations. Therefore, the effects benchmark for terrestrial animals is set at a total internal and external dose of 0.1 rad/d. Because aquatic biota, including invertebrates, appear to remain unharmed by chronic doses of 10 mGy/d (1.0 rad/d) or less (IAEA, 1992), a benchmark of 1 rad/d was used for aquatic invertebrates.

The U.S. Department of Energy reviewed radiation sensitivity data and also concluded that acute doses of 10 rad/d are unlikely to produce long-term effects in terrestrial mammal populations (Barnthouse 1995). Although the sensitivities of different species varies widely, it was concluded that chronic doses of 0.1 rad/d are unlikely to harm even the most radiosensitive populations of terrestrial mammals and

birds (Barnthouse 1995). Similarly, it was concluded that chronic doses of 1 rad/d or less are unlikely to cause harm to the most sensitive terrestrial flora and aquatic fauna (Barnthouse 1995). Radiation effects on invertebrates may result more from damage to plant communities on which the invertebrates depend than on direct effects to the invertebrates themselves (Barnthouse 1995). Russian field studies of ecosystems contaminated by an explosion at Kyshtym, in the Urals, were also evaluated (Barnthouse 1995). Nesting success by birds appeared to be reduced at dose rates above 20 rad/d. Pine trees, the most sensitive plants tested, were killed by chronic doses of 5-10 rad/d, but lower doses caused sublethal damage only. These and other observations were interpreted as confirmation that the IAEA benchmarks of 0.1 rad/d for mammals and birds and 1 rad/d for plants are protective of natural populations.

7.6 RISK CHARACTERIZATION FOR ECOLOGICAL RECEPTORS

Risk characterization integrates exposure and stressor response on receptor organisms used in the assessment, summarizes risk or the likelihood of harm to animals, and interprets the ecological significance of these findings.

The ecological assessment endpoints depend on this comparison by using EEQs for CPECs. The EEQs form the quantitative basis of this risk characterization (EPA 1989a). EEQs compare the ADDs to TRVs. ADDs are derived from measured environmental concentrations expressed as EPCs, e.g., the smaller of the 95% UCL and maximum, by multiplying the measured concentration by exposure factors. The distribution of the data, log-normal or normal, was determined before computation of the summary statistics. The effects information is expressed as the TRV or the constituent concentration that approximates the area of no response to a small response. This relationship is shown as:

$$EEQ = \frac{\text{Environmental Exposure Expressed as Total Average Daily Dose}}{\text{Toxicity Reference Value}}$$

Where an EEQ can not be calculated because insufficient data are available to establish a toxicity threshold, CPECs will be carried through the risk characterization as CPECs of uncertain risk to ecological receptors.

An EEQ greater than unity (1.0) will indicate that there is a potential for harmful ecological effects and that the CPEC qualifies for further investigation (possibly Phase II or the more definitive BRA) into its potential to pose a hazard. Moreover, the risk of potential hazardous effects is assumed to increase with the magnitude of the ratio. An EEQ threshold of 1.0 assumes that the toxicity threshold and exposure concentrations are accurate. In reality, the range of values around 1.0 within which EEQs may or may not indicate the existence of risk increases with the uncertainty of the estimated exposure and toxicity threshold concentrations.

As explained above, an EEQ of one or greater will focus on which chemicals, which receptors, and which exposure units are likely associated with ecological risk. Then, in the next stage, e.g., Baseline ERA, the focus is for actual evidence of manifested risk, e.g., field-observed effects using field-metrics. One of these field-metrics will likely be the result of the RBP on stream macroinvertebrates in Toussaint Creek.

7.6.1 Current Preliminary Risk to Ecological Receptors

Risks to ecological receptors under current conditions were estimated by calculating EEQs for all terrestrial and aquatic exposure classes, as represented by their ecological receptors. The EEQs from all radionuclide CPECs were summed to show a HI; this is an appropriate measure of ecological risk for CPECs with the same mechanism of toxicity, and any HI greater than one is an additional indication of

likely ecological risk. For non-radioactive constituents, EEQs are summarized on a constituent-by-constituent basis in Tables 7.5 through 7.7. The EEQs are reported on a receptor-by-receptor basis as follows:

Soil at Exposure Unit 1 (Appendix 7A Tables 7A.42 through 7A.49). EEQs for three inorganics, one anion, and two organics exceeded 1.0, and some EEQs were above 100. These findings indicate that these CPECs pose a potential risk of unacceptable toxicity to terrestrial receptors at EU1. For plants at EU1, EEQs were between one and 10 for beryllium and lead; no soil EEQ was above 10. For earthworms, no soil EEQ was above one. For shrews, EEQs were between one and 10 for beryllium and benzo(a)pyrene, between 10 and 100 for cadmium and lead, and above 100 for Aroclor 1254. For robins, EEQs were between 1 and 10 for fluoride, between 10 and 100 for cadmium and Aroclor 1254, and above 100 for lead. For rabbits, EEQs were between one and 10 for beryllium and benzo(a)pyrene and between 10 and 100 for Aroclor 1254. No EEQ for rabbits was above 100. For deer, EEQs were between one and 10 for Aroclor 1254. No EEQ for deer was above 10. For hawks, EEQs were between 10 and 100 for Aroclor 1254. No EEQ for hawks was above 100. For foxes, EEQs were between one and 10 for benzo(a)pyrene and above 100 for Aroclor 1254.

Soil at Exposure Unit 2 (Appendix 7A Tables 7A.50 through 7A.57). EEQs for 10 inorganics and one anion exceeded 1.0. These findings indicate that these CPECs pose a potential risk of unacceptable toxicity to terrestrial receptors at EU2. For plants, soil EEQs were between one and 10 for mercury, nickel, and thallium; and between 10 and 100 for beryllium, boron, cadmium, chromium, lead, and zinc. No EEQ for plants was above 100. For earthworms, soil EEQs were between one and 10 for cadmium, copper, lead, mercury, and zinc; and above 100 for chromium. For shrews, soil EEQs were between one and 10 for zinc and fluoride; between 10 and 100 for beryllium, lead, and thallium; and above 100 for cadmium. For robins, EEQs were between one and 10 for chromium, between 10 and 100 for zinc and fluoride, and above 100 for cadmium and lead. For rabbits, soil EEQs were between one and 10 for cadmium, lead, thallium, and fluoride; between 10 and 100 for beryllium. No soil EEQ was above 100 for rabbits. For deer, soil EEQs were between one and 10 for beryllium and cadmium. No soil EEQ was above10 for deer. For hawks, soil EEQs were between one and 10 for cadmium, lead, mercury, and fluoride; between 10 and 100 for zinc. No soil EEQ was above 100 for hawks. For foxes, soil EEQs were between one and 10 for beryllium, cadmium, lead and zinc; and between 10 and 100 for thallium. No soil EEQ was above 100 for foxes.

Soil at Exposure Unit 3 (Appendix 7A Tables 7A.58 through 7A.65). EEQs for three inorganics exceeded 1.0. These findings indicate that these CPECs pose a potential risk of unacceptable toxicity to terrestrial receptors at EU3. No soil EEQ at EU3 was above one for earthworms, deer, and hawks. For plants, soil EEQs were between one and 10 for lead and selenium and between 10 and 100 for beryllium. No soil EEQ was above 100. For shrews, soil EEQs were between one and 10 for lead and selenium and between 10 and 100 for beryllium. For robins, soil EEQs were between one and 10 for selenium and between 10 and 100 for lead. For rabbits, soil EEQs were between one and 10 for beryllium. No soil EEQ was above 10 for rabbits. For foxes, soil EEQs were between one and 10 for beryllium and selenium. No soil EEQ was above 10 for foxes at EU3.

Soil at Exposure Unit 4 (Appendix 7A Tables 7A.66 through 7A.73). EEQs for five inorganics exceeded 1.0. These findings indicate that these CPECs pose a potential risk of unacceptable toxicity to terrestrial receptors at EU4. No soil EEQ was above one for earthworms, deer, and hawks. For plants, soil EEQs were between one and 10 for beryllium and thallium. For shrews, soil EEQs were between one and 10 for antimony, beryllium, cadmium, and lead, and between 10 and 100 for thallium. For robins, soil EEQs were between one and 10 for cadmium, and between 10 and 100 for lead. For rabbits, soil EEQs were between one and 10 for thallium. For foxes, EEQs were between 10 and 100 for thallium. No soil EEQ was above 100 at EU4.

Soil at Exposure Unit 5 (Appendix 7A Tables 7A.74 through 7A.81). EEQs for one inorganic exceeded 1.0. These findings indicate that lead poses a potential risk of unacceptable toxicity to terrestrial receptors at EU5. The soil EEQs were 1.2 for plants, 3.8 for shrews, and 78.6 for robins. No lead EEQ was above 1.0 for the other receptors.

Soil at Exposure Unit 6 (Appendix 7A Tables 7A.82 through 7A.89). At EU6, only beryllium remained after site-wide screening of soil. It had no soil EEQ above one. Therefore it is unlikely that there is any potential risk of toxicity to terrestrial receptors at EU6.

Sediment at Exposure Unit 3 (Appendix 7A Table 7A.90). EEQs for eight inorganics exceeded 1.0. These findings indicate that these CPECs pose a potential risk of unacceptable toxicity to sediment-dwelling biota at EU3. EEQs for sediment-dwelling biota were between one and 10 for mercury, nickel, silver, and zinc; and between 10 and 100 for cadmium, copper, and lead; and above 100 for iron.

Sediment at Exposure Unit 4, zero to 1 mile (Appendix 7A Table 7A.91). EEQs for four inorganics exceeded 1.0. These findings indicate that these CPECs pose a potential risk of unacceptable toxicity to sediment-dwelling receptors in the 0-to-1 mile stretch at EU4. EEQs for sediment-dwelling biota were between one and 10 for copper and silver; and between 10 and 100 for cadmium and lead.

Sediment at Exposure Unit 4, 1 to 3 miles (Appendix 7A Table 7A.92). No EEQ for sediment exceeded 1.0. However, there were three constituents (beryllium, fluoride, and ammonia) for which there were no TRVs. Therefore, there may or may not be risk of toxicity to sediment-dwelling biota at EU 4, 1 to 3 miles.

Sediment at Exposure Unit 4, 3 to 15 miles (Appendix 7A Table 7A.93). No EEQ for sediment exceeded 1.0. However, there was one constituent (beryllium) for which there was no TRV. Therefore, there may or may not be risk of toxicity to sediment-dwelling biota at EU 4, 3 to 15 miles.

Surface water at Exposure Unit 3 (Appendix 7A Tables 7A.94 and 7A.95). EEQs for 12 inorganics, one anion, and one organic exceeded 1.0. These findings indicate that these CPECs pose a potential risk of unacceptable toxicity to surface water receptors at EU3. EEQs for aquatic biota were between one and 10 for cadmium, copper, iron, manganese, silver, and strontium; between 10 and 100 for aluminum, barium, beryllium, and lead; and above 100 for boron. EEQs for herons were between one and 10 for lead, mercury, and bis(2-ethylhexyl)phthalate and above 100 for fluoride.

Surface water at Exposure Unit 4, zero to 1 mile (Appendix 7A Tables 7A.96 and 7A.97). EEQs for seven inorganics, one anion, and one organic exceeded 1.0. These findings indicate that these CPECs pose a potential risk of unacceptable toxicity to surface water receptors at EU4. EEQs for aquatic biota were between one and 10 for iron, lead, manganese, and strontium; and between 10 and 100 for aluminum, barium, and boron. EEQs for herons were between one and 10 for bis(2-ethylhexyl)phthalate and between 10 and 100 for fluoride.

Surface water at Exposure Unit 5 (Appendix 7A Tables 7A.98 and 7A.99). No surface water EEQs exceeded 1.0 at EU 5. These findings indicate that there is no potential risk of unacceptable toxicity to surface water receptors at EU5.

7.6.2 Future Preliminary Risk to Ecological Receptors

The EEQs for the animals at the Luckey site are considered to be the same or similar in the future. Vegetation would be expected to continue to colonize all terrestrial EU areas if the natural invasional/successional process is allowed to proceed. The lack of toxicity thresholds for a few of the organic CPECs will contribute to the uncertainty of any assessment of the risk to future animals at the exposure units. Some organic CPECs would be expected to decrease in concentration through natural degradation processes, although their number and concentration of breakdown products could increase. Regardless, risks in the future are assumed to be the same as risks in the current condition at the Luckey site.

In the aquatic habitats, the ecological environment is expected to change from year to year. Water currents and sedimentation may vary from year to year, but the overall environment, including the various concentrations of CPECs in Toussaint Creek are expected to characterize future conditions.

7.6.3 Current Preliminary Risk Characterization for Radionuclides

Risk characterization for radionuclides was performed using a single line of evidence, the calculated chronic external and internal exposure of receptors to radionuclides in soils. The EEQ was calculated by dividing the daily EPC doses for each radionuclide at each location by the radiological benchmark values (Appendix 7A Tables 7A.100 through 7A.123). The HI was then calculated for each location by adding the EEQ values. It is assumed that if HI values are less than one, no unacceptable risk from exposure to radionuclides exists at the site. Table 7.8 presents a summary of HI values at each site and for each receptor. This table shows that all HI values were below 0.03. Therefore, there is no credible risk of harm to ecological receptors from radionuclides in soil at the Luckey site. Prior screening also demonstrated that there was no credible risk of harm from radionuclides in surface water and sediment.

7.6.4 Future Preliminary Risk Characterization for Radionuclides

There is no known current source for release of radionuclides to the Luckey site, and concentrations of radionuclides will decrease in the future as radioactive decay continues. Because there is currently no credible risk to ecological receptors from radionuclides in soil, sediment, and surface water, and radionuclide concentrations should not increase, it is expected that future risk from radionuclides will remain negligible.

7.6.5 Use of Characterization Results

An EEQ of one or greater is the basis for determining the need for further investigation; however, field verification of these results is provided through sediment weight-of-evidence analysis and soil weight-of-evidence analysis. Regarding sediment, it is to combine and assess the results of the RBP with sediment chemical concentration, grain size, and total organic carbon. Regarding soil, it is to combine and assess the results of aerial and ground-truthing reconnaissance of patches barren of vegetation with soil chemical concentration and soil type. This is further explained in Section 7.8.

7.7 UNCERTAINTIES

Uncertainties in the Luckey site ERA are discussed in this section by the following four interrelated steps of the EPA approach to ERA: problem formulation, exposure assessment, effects assessment, and risk characterization. The uncertainty section also contains specific evaluations of the likely COCs.

7.7.1 Problem Formulation

Environmental concentrations of constituents in the soil, sediment, and surface water on and near the Luckey site were based on a limited number of samples. A degree of uncertainty exists about the actual spatial distribution of constituents. Exposure concentrations could be overestimated or underestimated, depending on how the actual data distribution differs from the measured data distribution. Because the estimated 95% UCL of the mean concentrations or maximum detected concentration were used as the EPC concentration to calculate EEQs, the estimates of risk from CPECs are conservative (i.e., protective). Using 95% UCL or maximum concentrations decreases the likelihood of underestimating the risk posed by each CPEC and increases the likelihood of overestimating the risk.

The distribution and abundance of organisms composing the ecological receptors at the Luckey site has not been quantified by field studies. The lack of quantitative data introduces uncertainties concerning whether, and to what extent, the risk characterization based on the selected receptor species underestimates or overestimates the risk to organisms that were not used in the risk computations but that occur on the Luckey site. On-site reconnaissance has established the nature and quality of habitat and has confirmed the presence of vegetation types and active, visible animal species. Observations made during this reconnaissance justify assumptions about the presence of unobserved organisms that are essential to normal ecosystem functioning, such as soil-dwelling worms and arthropods, and herbivorous insects. This area falls within the acceptable range of each species.

It is possible that one (or more) unobserved species at the Luckey site is more sensitive than the ecological receptors for which toxicity data are available to use in the ERA. It does not necessarily follow that these unevaluated species are at significantly greater risk of harmful ecological effects than that estimated in this ERA because exposure concentrations for ecological receptors could be greater than those for more sensitive receptors, and they could be generally overestimated.

7.7.2 Exposure Assessment

The actual movement of constituents from the Luckey site constituent source media to ecological receptors has not been measured for this ERA. This introduces uncertainties about the actual modes and pathways of exposure and the actual exposure concentrations of these constituents to the ecological receptors. Exposure concentrations can differ from the measured environmental concentrations as a result of physical and chemical processes during transport from source to receptor and as a result of biomagnification through the food web. These processes have not been evaluated quantitatively in this ERA. Although bioaccumulation was estimated for those receptors ingesting food for which toxicity thresholds are available, it is possible that exposure to top predators was underestimated because biomagnification of certain constituents in prey was overlooked.

The modes and pathways used to characterize the exposure to ecological receptors are the most important ones for the relatively large and active species in terrestrial habitats. Soil-dwelling terrestrial animals may be exposed to constituents in soil by way of inhalation following volatilization, but gaseous concentrations in soil interstices, cavities, and burrows will not be available for the Luckey site. Therefore, the exposure to burrowing organisms at the site from contaminated soil and soil interstitial water may be underestimated if gas concentrations are larger than soil concentrations, which is unlikely. The estimate of risk also will be underestimated if toxicity thresholds are lower for inhalation than they are for ingestion. Conservative exposure estimates were used for absorption of CPECs from soil (1.0) and absorption from tissue (1.0). Overestimating exposure by using conservative exposure concentrations is thought to counter-balance the underestimation of exposure that results from neglecting certain exposure modes and pathways of lesser importance, such as inhalation. Additional uncertainties are inherent in ingestion rates and dietary fractions of plants and animals.

It is assumed that uptake of radionuclides by receptors from soil is the same as uptake from plant and animal food. Radionuclides bound to soil may be less available than those in food. Therefore, assuming equal uptake from all ingested sources is likely to overestimate exposures.

Uptake factors from soil to earthworms (BAF_i) are not available for many elements, including beryllium, thallium, radium, and thorium, and for several organics. Instead, the higher of soil-to-plant (B_v) and food-to-tissue (BAF_t) uptake factors were used. It is not known whether this substitution overestimates or underestimates exposure, but in many cases known BAF_i values are less than either the B_v or the BAF_t value for the same element (DOE 1997b). Therefore, it is likely that exposures will not be underestimated.

Literature-derived factors to describe dietary intake and bioaccumulation of elements may not reflect actual diets and bioaccumulation of radionuclides at the site. However, the literature values are assumed to be sufficiently similar to site-specific values that exposures will be neither under- nor over-estimated.

Exposure concentrations are likely to be overestimated because of conservative exposure factors. Exposure factors include using published bioaccumulation factors, irrespective of species and environmental conditions. In particular, it should be noted that, while the largest bioaccumulation factors may overestimate bioaccumulation at the Luckey site by at least one order of magnitude for some CPECs, very high bioaccumulation as well as biomagnification are well-documented for other constituents, although not necessarily all those likely detected.

Conservative AUFs and TUFs represent another uncertainty. Conservative AUFs and TUFs of one are rather routine for the screening ERA, but for wide-ranging or migratory species, an overestimate of site-specific exposure results.

Finally, the exposure of plants and animals to constituents below detection limits was not considered in the ERA. In addition, the exposure of ecological receptors to TICs is not considered, possibly resulting in an underestimation of exposure.

7.7.3 Effects Assessment

Toxicity thresholds were based on concentrations reported to have no or little effect on the test organism or were estimated conservatively from published toxicity data as provided in the Appendix. Dietary limits used as threshold levels for soils were derived from NOAELs or LOAELs using multiplier factors of one or 10 (Opresko et al. 1994), with 10 being the most conventional one. These thresholds would underestimate the risks only to organisms on sites at the Luckey site that are considerably more sensitive than the study organisms. They are more likely to overestimate the risk to organisms that are equally or less sensitive than the study organisms. The possibility remains that some thresholds were set at levels at or above which some harm would occur to organisms at the Luckey site.

The calculated risks to the ecological receptors at the Luckey site present the risks of individual constituents. The risks from exposure to multiple constituents depend on constituent interactions; effects could be greater or lesser than those from a single chemical. This ERA provides findings for CPEC-specific risk estimates. An evaluation of risk from constituent mixtures cannot be conducted without additional data and evaluation of alternative models of constituent interaction.

There are no available TRVs for some compounds, especially organics, for all ecological receptors considered. This, of course, contributes to uncertainty associated with likely underestimates of

risk. This lack of data makes a constituent a CPEC until it undergoes the EEQ analysis. Then, it could be dropped.

The lack of an aquatic TRV for beryllium presents additional uncertainty and technical challenges. Beryllium is a compound commonly found above background in portions of Touissant Creek. It is likely that beryllium-associated risk is underestimated. However, this likely risk is confounded by the dominant physical and pesticides aspects from completely different stressors. This uncertainty will be handled in the risk management part of the FS process.

Dose coefficients for radionuclides used for the ERA (Eckerman and Ryman 1993) were derived for exposure of humans to external radiation. The dose coefficients will be adjusted by a factor of two to allow for the closer proximity of the receptors to soil, but the actual dose coefficients may be higher or lower than the estimated values. Because external doses are typically a small part of the calculated radiation exposure of terrestrial receptors, it is unlikely that any over- or under-estimates of external dose would affect the outcome of the ERA. Thus, most sources of uncertainty tend to overestimate the exposure of ecological receptors to radionuclides.

There are many uncertainties in the derivation of radiation TRVs. In field tests, it is difficult to measure doses to receptors, effects to individuals, and effects to populations. However, IAEA chose the most sensitive receptors and conservative methods to estimate exposures, and independent field data indicate that the IAEA benchmarks are conservative. That is, it is likely that the true benchmarks for radiation damage to populations are higher than the TRVs used in this risk assessment. In addition, the HIs for radiation exposure of biota are well below 1.0, making it very unlikely that exposure to radiation at Luckey is harmful to ecological populations.

Additional uncertainty exists as to the pertinence of individual organism toxicity for characterizing the risk to populations and ecosystems. It is possible that populations may compensate for the loss of large numbers of juveniles or adults with increased survival or birth rates, and habitats or ecosystems may possess functionally redundant species that are less sensitive to constituents. Although the Luckey site habitats surely possess these buffering mechanisms, a conservative approach is still justified to risk assessment based on organismal toxicity thresholds (i.e., NOAELs).

7.7.4 Risk Characterization

The uncertainties described above ultimately produce uncertainty in the quantification of current and future risks to terrestrial and aquatic animals at the Luckey site. The following four additional areas of uncertainty in the risk characterization exist: off-site risk, cumulative risk, future risk, and background risk.

Off-site Risk. The risks to off-site receptors could be characterized with the benefit of clearly identified body burden data from on-site receptors, pathways (especially any surface water pathways), as well as any constituent tracer studies and off-site plant and animal and habitat surveys. Off-site receptors can be exposed to constituents via physical and organismal transport processes, but evaluating the magnitude of this exposure would require additional studies. It is unlikely that off-site receptors would have lower toxicity thresholds for constituents than the thresholds used for on-site receptors. In addition, there is little reason to expect that constituents migrating off site would be concentrated above measured concentrations at the Luckey site unless a constituent bioconcentrates in organisms that migrate on and off the site. In general, the risk to most off-site receptors is likely to be overestimated rather than underestimated by the risk estimate for on-site receptors.

Cumulative Risk. The ERA estimates the risk to populations of ecological receptors from individual constituents. Yet, in nature, receptors are exposed simultaneously to mixtures of constituents. Generally, the methods used are sufficiently conservative resulting in overestimated individual risk. Nevertheless, cumulative risk is possible when several living plants and animals are affected simultaneously. Harmful effects in ecosystems (including effects on individual organisms) may cascade throughout the system and have indirect effects on the ability of a population to persist in the area, even though individual organisms are not sensitive to the given constituents in isolation. Therefore, the ecological risk characterization for the Luckey site may underestimate actual risks to plants and animals from cumulative risks.

Future Risk. A third area of uncertainty in the ecological risk characterization is the future risk to the plants and animals from contamination at the Luckey site. The ERA characterizes the current risk based on chronic exposure to measured concentrations of toxicants with the potential to persist in the environment for extended periods of time. EEQs for animals estimate the risk to animal species that would be natural parts of future successional stages at these areas. Nevertheless, possible mechanisms exist that could significantly increase (e.g., erosion, leaching to surface water or groundwater) or decrease (e.g., enhanced microbial degradation) the risk to future plants and animals at the sites.

Background Risk. Another source of uncertainty is ecological risk relative to background conditions. Although only inorganics with concentrations above background were examined in the CPEC screening, some CPECs are above background only by statistically small amounts. The conservative approach to comparing site concentrations to background likely overestimates the risk from CPECs compared to background.

7.7.5 Summary

The most important uncertainties in the Luckey ERA are those surrounding the estimates of the constituent concentrations to which ecological receptors are actually exposed (exposure concentrations) and the concentrations that present an acceptable level of risk of harmful effects (TRVs or thresholds). These uncertainties arise from multiple sources, especially from the lack of site-specific data on constituent transport and transformation processes, organismal toxicity, animal behavior and diet, population dynamics, and the response of plant and animal populations to stressors in their environments. Despite these uncertainties, the available site-concentration data and published exposure and effects information should allow CPECs (EEQs >1 and HIs > 1) to be identified as risks characterized for each EU or location.

7.8 WEIGHT-OF-EVIDENCE ANALYSIS

Weight-of-evidence analysis refers to the assembly and evaluation of various types and qualities of technical information. The usual types of information are EEQs, field-observed effects, and any site-specific bioassays. Information quality varies from lack of TRVs, through superior laboratory data used in TRVs, to obvious and convincing field data. These are also termed lines of evidence. In this analysis one is guided also by such following principles:

- temporal association of the contamination and the receptors and their predicted response;
- spatial association of the contamination and the receptors and their predicted response;
- strength of dose response association of the exposure and the effects data; and
- biological plausibility of the risk being predicted at its EEQ levels.

There are three exposure units in which weight-of-evidence analysis will be applied. First, the soils in EU2 and also EU1 will be briefly discussed in light of areas void of vegetation, areas with some

vegetation, and areas with much vegetation. Second, Toussaint Creek measurements include chemical concentrations, ecological reconnaissance, and a RBP that gathered site-specific information about the stream habitat and the stream macroinvertebrates.

7.8.1 Weight-of-Evidence Analysis for Soils and Vegetation for EU1 and EU2

Many inorganics/metals (beryllium, boron, cadmium, chromium, copper, fluoride, lead, mercury, nickel, thallium, zinc), PCBs, and benzo(a)pyrene are ecological COCs for soils in EU 1 and 2. The ecological COCs indicate chemicals whose concentrations are associated with ecological risk to vegetation, earthworms, and other animals. However, an EEQ of one or greater does not indicate the presence of real ecological risk or harm. It takes a weight-of-evidence analysis to clarify this, as briefly sketched below.

The physical presence or absence of vegetation is one line of evidence indicating impaired soil conditions. This evidence can be evaluated by comparing EU, as well as examining conditions within an EU. For example, EU1 contains no unpaved areas void of vegetation, while EU2 contains several areas void of vegetation and many areas with dense vegetation. Within EU2, one large void area is located in IA07 east of the propane tanks. This area occupies about 10,000 ft^2 and contains a dense covering of cobbles, as well as fine-grained surface material. IA01 also contains many areas void of vegetation. These areas contain primarily fine-grained surface material. The lack of vegetation in these areas likely is due to a combination of physical and chemical causes. EU2 also contains areas of dense vegetation, such as IA03 where trees and thick herbaceous vegetation are present. The chemical and physical differences between these areas will be discussed in order to identify potential causes for vegetation stress.

Chemical causes may be linked to the concentrations of two surface soil COCs, beryllium and lead. The highest detections of beryllium (8760 mg/kg) and lead (28,900 J mg/kg) occurred in EU2. These detections greatly exceeded background concentrations of 1.7 mg/kg for beryllium and 23.2 mg/kg for lead. In EU1, the highest detections of beryllium and lead were 619 mg/kg and 797 mg/kg, respectively. Furthermore, the mean concentrations of these two COCs differed greatly between the two units. Mean beryllium concentration was 39 mg/kg in EU1 and 596 mg/kg in EU2. Mean lead concentration was 131 mg/kg in EU1 and 750 mg/kg in EU2. Therefore, the chemical concentrations of these two COCs are clearly higher in EU2, which contains areas void of vegetation, compared to EU1, which contains no void areas. The higher EEQs for plants in EU2 compared to EU1 supports this conclusion.

Examining beryllium and lead concentrations within EU2 further refines this evaluation.

- These highest detections occurred in the IA01 area with absent vegetation. In addition, this area contained numerous detections of beryllium in the hundreds to low-thousands of ppm, and a number of lead detections exceeding background.
- In the barren area of IA07, beryllium exceeded background in almost every surface soil sample. The maximum was 489 mg/kg, and several other detections were in the hundreds of ppm. Several lead detections also exceeded background, with the maximum detection at 44.8 mg/kg.
- In the vegetated area of IA03, most beryllium detections were below 5 mg/kg and only one was significantly elevated (489 mg/kg). In addition, lead was not detected above background.

The presence of high concentrations of beryllium and lead appear to be linked with the impairment of plant germination. In addition, the physical barriers of the cobbles in IA07 and the fine-grained material in IA01 likely contribute to vegetation stress.

7.8.2 Weight-of-Evidence Analysis for Toussaint Creek

Four metals (cadmium, copper, lead, and silver) were identified as ecological COCs for sediments in EU4. By definition, these ecological COCs indicate chemical constituents whose concentrations are great enough to indicate risk to sediment-dwelling biota. However, the impact to sediment-dwelling biota from these ecological COCs could potentially be lower or greater than those based solely on the measured COC concentrations. Thus, an examination of the site-specific chemical and biological measurements should help show which direction is correct.

The results of the RBP II analysis for five stations in Toussaint Creek during July 1998 (Appendix 7B) provide an additional line of evidence, which can be used to help corroborate, or refute, the ecological COC implications for risk to sediment-dwelling biota. The RBP results can provide on-site, empirical evidence of impact to the benthic macroinvertebrate communities. The corresponding aquatic habitat evaluation data can be used to interpret whether the impacts are most likely due to habitat conditions or to other factors, which could include the presence of contaminants.

For this weight-of-evidence analysis, two lines of evidence will be examined for each of four stream segments in Toussaint Creek. The two lines of evidence include predicted risk from ecological COCs based on EEQs greater than one, and the RBP results with its aquatic habitat evaluations. The four stream segments in Toussaint Creek include: upstream of the Luckey site, which contains the RBP reference station IA06SW0003; EU 4, zero to 1 mile downstream from the site, which contains RBP station IA06SW0004; EU4, 1 to 3 miles downstream from the site, which contains RBP stations IA06SW006 and IA06SW0007; and EU4, 3 to 15 miles downstream from the site, which contains RBP station IA06SW0008.

Upstream of the Luckey site, there are no sediment analytical data near the RBP reference sampling station IA06SW003. However, the RBP results for this station indicate that the benthic macroinvertebrate community is impacted. For example, taxa richness (seven families) was lowest at this station and the next downstream station among all those sampled in Toussaint Creek. The family biotic index (FBI) was highest at this station (7.8), indicating that it had the highest proportion of pollution-tolerant taxa among all stations. The EPT/chironomid ratio was less than one, indicating potential environmental stress to the benthic community. The percent contribution of the dominant family was nearly 90%, indicating environmental stress. Lastly, the EPT index was very low, with only two EPT taxa. The impacts to the benthic community at this station are likely attributable to the poor habitat in Toussaint Creek. This station was scored as poor for overall habitat, with six of the nine habitat parameters (including substrate composition, flow, and channelization) being scored as poor. The surrounding predominant land use is agricultural, and the creek is extremely channelized, which is typical of streams in the Huron/Erie Lake Plain (HELP) ecoregion (Ohio EPA 1987). As explained in section 6.8.3.3.3, this upstream location was judged to be the best available in Toussaint Creek, in spite of its limitations.

In EU4, zero to 1 mile, four inorganics (cadmium, copper, lead, and silver) in sediment were identified as predicting risk to benthic macroinvertebrates. Also, seven inorganics (iron, lead, manganese, strontium, aluminum, boron, barium), fluoride, and bis(2-ethylhexyl)phthalate had EEQs that exceeded one for surface water and thus indicate risk to aquatic biota. Although beryllium does not have a TRV for sediment, the highest concentration of beryllium in sediment (232 mg/kg) was observed in this segment of Toussaint Creek. The RBP results for station IA06SW0004 in this segment of Toussaint Creek indicate that the benthic community is impacted. For example, the taxa richness is low (seven), which is the lowest value observed among the stations. The percent contribution of the dominant family was nearly 90%, which also was the highest value observed at the stations. EPT index was low, at three taxa. All of these metrics indicate an impacted benthic community. In spite of these impacts, two of the RBP metrics show

a slight improvement at this station relative to upstream or downstream through the lower FBI score of 4.05 and the absence of Chironomidae taxa. The lower FBI score indicates the presence of additional taxa that are less tolerant to pollutants, and the absence of chironimids potentially suggests higher quality habitat. However, the overall aquatic habitat scores for this station were poor and tied for the lowest value (20) among all stations. Thus, it is likely that the impacts to the benthic community at this station are at least partially attributed to the poor aquatic habitat, as well as some impact from the ecological COCs and potential impact from the high beryllium sediment concentrations.

In EU4, 1 to 3 miles, there are no EEQs that exceed one for sediment, although beryllium, fluoride, and ammonia are present. The maximum concentration of beryllium in sediment in this segment of Toussaint Creek was 32 mg/kg, which was lower than the maximum concentration in EU4, zero to 1 mile. Because there were no TRVs for these constituents for benthic invertebrates, quantitative risks could not be calculated for that community. However, because these constituents are known to be toxic to other taxa, including aquatic biota, it is reasonable to conclude that these constituents might be toxic to sediment-dwelling biota. The RBP results for stations IA06SW0006 and IA06SW007 indicate that the benthic macroinvertebrate communities are still impacted, but with slight improvement in some of the metrics relative to the upstream stations. For example, taxa richness slightly increased to nine at both stations, compared to seven taxa upstream. The percent contribution of the dominant family decreased substantially to 30% at IA06SW0006 and 50% at IA06SW0007, from 90% at the upstream stations. EPT index was very low at IA06SW006 (2), while station IA06SW0007 had no EPT taxa. The aquatic habitat overall scores were still low at both locations (22 and 21), with both stations being scored as poor. Nearly all of the aquatic habitat parameters were scored as poor for both locations, including substrate composition, flow, and channelization. The slight improvement in taxa richness and percent contribution of the dominant family could be due to the absence of ecological COCs, but the high FBI values (6.2 and 6.7) and presence of beryllium suggest there are still some contaminants present, albeit at diminishing concentrations.

In EU4, 3 to 15 miles, there were no sediment EEQs that exceeded one, but beryllium was present in the sediment at 14.4 mg/kg at RBP station IA06SW0008. As previously mentioned, there is no TRV for this metal for sediment. The RBP results for station IA06SW0008 in this segment of Toussaint Creek indicate that the benthic macroinvertebrate community at this station is the least impacted among the benthic communities evaluated in Toussaint Creek for this SERA. For example, the taxa richness was highest at this station (10 taxa). The second lowest FBI value (4.5) was obtained here. The highest EPT/chironomid ratio (13.3) was observed at this station, and the percent contribution of the dominant family was 38% (second lowest value). Only the EPT index was still low, at three. In addition, the overall aquatic habitat score for this station was the highest one measured for the study (48), and the only one that was scored as fair. Much better substrate composition (good), higher flow rates (fair), and less channelization (fair) predominantly contributed to the higher aquatic habitat score. Thus, the improvement in the benthic community downstream from the Luckey site at this station is likely attributable to the combination of much improved habitat, absence of ecological COCs, and lower sediment concentration of beryllium.

In summary, the SERA calculations indicate that the benthic macroinvertebrate community is at risk of harmful impacts from several ecological COCs in sediment and surface water at three segments in Toussaint Creek (zero to 1 mile, 1 to 3 miles, and 3 to 15 miles) downstream from the Luckey site. Furthermore, a few constituents, including beryllium, are present in the sediments, but they have no TRVs with which to calculate EEQs. RBP results for stations upstream of the Luckey site, and in each of the three segments downstream, clearly indicate that the benthic communities at all sampling stations in Toussaint Creek are impacted but that they improve downstream from the site. The impacts to the benthic communities are likely due to a combination of very poor aquatic habitat (from the surrounding agricultural land use and stream channelization), as well as presence of ecological COCs in the sediments

and surface water. Improvement in the aquatic habitat and decrease in ecological COCs downstream from the Luckey site support this conclusion.

7.9 SUMMARY OF THE SCREENING OR PRELIMINARY ECOLOGICAL RISK ASSESSMENT

A screening ERA was performed in accordance with written guidance from the USACE and Ohio EPA. This guidance recognizes step-by-step procedures. The present ERA adheres to an ERA process including problem formulation, followed by exposure assessment and effects assessment, and culminating in risk characterization with attention to uncertainties and summarization. The ERA is of the screening type.

The Luckey site covers about 40 acres, with additional acreage for the Troy Township Dump and the France Stone Quarry. Agricultural land occupies additional acreage of mostly man-made habitats, including agricultural fields. Patches of forests and old fields of varying ages occupy the total area. The appearance of the abundant vegetation and various animal life suggest no immediate threat from acute nor chronic exposures to many places. However, there are patches of soil containing no growing vegetation (see Figure 7.2), and this lack of growth may be associated with soil contamination. Regardless, appearances are insufficient to identify field-observed effects and ecological risk. Thus, an ERA was needed.

A screening step compared indicators of bioaccumulation to screening criteria, and a second screening step compared maximum EPCs in soil, sediment, and surface water to toxicity screening values. Analytes whose indicators of bioaccumulation exceeded the criteria and whose maximum EPCs exceeded toxicity values were called CPECs or analytes that remained after screening.

The current and future risks to ecological receptors from CPECs at the Luckey site and nearby aquatic EUs were characterized by evaluating effects quotients according to ecological assessment endpoints. EEQs were calculated for several different receptors of every CPEC for which a toxicity reference value is available from published information. Each EEQ compared two concentrations: the estimated CPEC concentration (EPC) in soil or other media or dietary dose from soil or other media to which a given receptor is exposed, and the TRV for the CPEC and receptor. The TRV is the dietary limit or other threshold concentration expected to cause no harm to the receptor, minimal harm with no ecological significance, or minimal harm to a community of organisms (i.e., assemblage of species) exposed to the CPEC in that medium. Thus, the TRV is meant to be a safe or protective concentration.

Of the many observed plant and animal taxa, five terrestrial classes (vegetation, soil-dwelling invertebrates, worm-eating and/or insectivorous mammals, mammalian herbivores, and terrestrial top predators) were selected for terrestrial receptors. For aquatic classes, sediment-dwelling organisms, aquatic organisms, and great blue herons were selected.

EEQs were calculated for CPECs at the surface soil and sediment/surface water exposure locations.

From the regulatory viewpoint, an EEQ > 1 has negative connotations for ecological receptors in the environment. From a technical viewpoint, a range of EEQs strongly implies a range of risk. For example, an EEQ > 1000 means more ecological risk than an EEQ > 1 or > 10 or > 100. The regulatory exit strategy is the BRA for screening risk assessments that show EEQ > 1. There are two parts to the baseline ERA – (A) mathematical treatments using less and less conservative exposure/effects values and more and more Luckey-specific knowledge, and (B) a site-specific biological measurement, e.g., ground-truthing as previously mentioned in the text. Usually, A precedes B. We recommend that B precede A,

as explained in Section 7.8. Ground-truthing by skilled biologists would emphasize field-observed effects and manifest risk rather than mathematical manipulations to reach recommendations about protection of the environment.

In summary, where ecological risk (EEQ >1) from the screening ERA was present in surface soil, it was noted. Further thresholds may be needed to make decisions. Accordingly and as explained elsewhere in this ERA, EEQs in the range of one to 100 were designated as low ecological risk, in the range of 100 to 1000 as intermediate ecological risk, and in excess of 1000 as high ecological risk. The rationale for these categories is professional judgment based on numerous ecological risk assessments. The use of such a simple method to organize EEQs is designed to help risk management, not supplant this responsibility that is related but different from risk assessment. However, full acknowledgement was given any constituent with an EEQ of one or higher based on the screening ERA. There may be a need to better define this risk in the next phase or the baseline ERA. If so, the emphasis should be on field-observed effects to confirm predicted risk. Regardless, for this screening ERA, an ecological COC is defined as any constituent for which EEQ >1.

7.9.1 Soil ecological COCs (EEQs >1)

Ecological COCs in soil were:

- Exposure Unit 1
  - beryllium
  - cadmium
  - lead
  - fluoride
  - benzo(a)pyrene
  - Aroclor-1254
- Exposure Unit 2
  - beryllium
  - boron
  - cadmium
  - chromium
  - copper
  - lead
  - mercury
  - nickel
  - thallium
  - zinc
  - fluoride
- Exposure Unit 3
  - beryllium
  - lead
  - selenium
- Exposure Unit 4
  - antimony
  - beryllium
  - cadmium
  - lead
  - thallium
- Exposure Unit 5
  - lead
- Exposure Unit 6
  - no ecological COC

7.9.2 Sediment ecological COCs (EEQs >1)

Ecological COCs in sediment were:

- Exposure Unit 3
  - cadmium
  - copper
  - iron
  - lead
  - mercury
  - nickel
  - silver
  - zinc

- Exposure Unit 4
  - cadmium
  - copper
  - lead
  - silver

7.9.3 Surface water COCs (EEQs >1)

Ecological COCs in surface water were:

- Exposure Unit 3
  - aluminum
  - barium
  - beryllium
  - boron
  - cadmium
  - copper
  - iron
  - lead
  - manganese
  - mercury
  - silver
  - strontium
  - fluoride
  - bis(2-ethylhexyl)phthalate

- Exposure Unit 4
  - aluminum
  - barium
  - boron
  - iron
  - lead
  - manganese
  - strontium
  - fluoride
  - bis(2-ethylhexyl)phthalate

- Exposure Unit 5
  - no ecological COCs

In summary, there are ecological COCs (EEQ >1) at various places in various media. The majority of ecological COCs are in the soil at EU1 and EU2. For radionuclides, no EEQs or HIs exceeded unity for any receptor. The HI for radionuclides at EU 1 actually decreased by a factor of 10 in organisms up the trophic food chain, indicating no biomagnification of radionuclides and a progressive decrease in risk up the food chain.

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Table 7.1. Analytes above Background Remaining after Abiotic and Biotic Site-wide Screening (Page 1 of 3)

Analytes remaining after the site-wide screens	Surface Soil						Sediment[a]				Surface Water[b]		
								Exposure Unit 4					
	Exposure Unit 1	Exposure Unit 2	Exposure Unit 3	Exposure Unit 4	Exposure Unit 5	Exposure Unit 6	Exposure Unit 3	(0 to 1 mile)	(1 to 3 miles)	(3 to 15 miles)	Exposure Unit 3	Exposure Unit 4 (0 to 1 mile)	Exposure Unit 5
Inorganics													
Aluminum	-	-	-	-	-	-	+	-	-	-	+	+	-
Antimony	-	+	-	+	-	-	-	-	-	-	-	-	-
Barium	-	-	-	-	-	-	+	-	-	-	+	+	-
Beryllium	+	+	+	+	+	+	+	+	+	+	+	+	-
Boron	-	+	-	-	-	-	+	-	-	-	+	+	-
Cadmium	+	+	-	+	-	-	+	+	-	-	+	+	-
Calcium	+	+	-	-	-	-	+	+	-	-	+	+	-
Chromium	-	+	-	-	-	-	-	-	-	-	-	-	-
Copper	-	+	-	-	-	-	+	-	-	-	+	+	-
Iron	-	-	-	-	-	-	+	-	-	-	+	+	-
Lead	+	+	+	+	+	-	+	+	-	+	+	+	-
Magnesium	+	-	-	-	-	-	+	-	-	-	+	+	+
Manganese	-	-	-	-	-	-	-	-	-	-	+	+	-
Mercury	-	+	-	-	-	-	+	+	-	-	+	-	-
Molybdenum	-	-	-	-	-	-	+	+	-	-	-	-	-
Nickel	-	+	-	-	-	-	+	-	-	-	+	+	+
Selenium	-	-	+	-	-	-	-	-	-	-	-	-	-
Silicon	-	+	-	-	-	-	+	+	-	-	+	+	-
Silver	-	-	-	-	-	-	+	+	-	-	+	-	-
Sodium	-	+	-	-	-	-	+	-	-	-	+	+	+
Strontium	-	+	-	-	-	-	+	+	-	-	+	+	-
Thallium	-	+	-	+	-	-	-	-	-	-	+	+	-
Zinc	-	+	-	-	-	-	+	-	-	-	-	-	-

Table 7.1. Analytes Above Background Remaining After Abiotic and Biotic Site-wide Screening (Page 2 of 3)

Analytes remaining after the site-wide screens	Surface Soil						Sediment[a]				Surface Water[b]		
								Exposure Unit 4					
	Exposure Unit 1	Exposure Unit 2	Exposure Unit 3	Exposure Unit 4	Exposure Unit 5	Exposure Unit 6	Exposure Unit 3	(0 to 1 mile)	(1 to 3 miles)	(3 to 15 miles)	Exposure Unit 3	Exposure Unit 4 (0 to 1 mile)	Exposure Unit 5
Anions	-	-	-	-	-	-	-	-	-	-	-	-	-
Chloride	-	+	-	-	-	-	+	+	-	-	+	+	-
Fluoride	+	+	-	-	-	-	+	+	+	-	+	+	-
Nitrate, as N	-	+	-	-	-	-	+	+	-	-	+	+	-
Phosphorus	-	-	-	-	-	-	-	-	-	-	+	+	+
Sulfate	-	+	-	-	-	-	+	+	-	-	+	+	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
Miscellaneous	-	-	-	-	-	-	-	-	-	-	-	-	-
Alkalinity	-	-	-	-	-	-	-	-	-	-	+	+	-
Ammonia, nitrogen	+	+	-	-	-	-	-	+	+	-	+	+	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
Organics	-	-	-	-	-	-	-	-	-	-	-	-	-
Semi-Volatiles	-	-	-	-	-	-	-	-	-	-	-	-	-
Acenaphthylene	+	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(a)anthracene	+	+	-	-	-	-	-	-	-	-	-	-	-
Benzo(a)pyrene	+	+	-	-	-	-	-	-	-	-	-	-	-
Benzo(b)fluoranthene	+	+	-	-	-	-	-	-	-	-	-	-	-
bis(2-ethylhexyl)phthalate	+	+	-	-	-	-	-	-	-	-	+	+	-
Bromodichloromethane	-	-	-	-	-	-	-	-	-	-	+	-	-
Carbazole	-	-	-	-	-	-	-	+	-	-	-	-	-
Chrysene	+	-	-	-	-	-	-	-	-	-	-	-	-
m,p-cresol	-	-	-	-	-	-	-	-	-	-	+	-	-
Diethyl phthalate	-	-	-	-	-	-	-	-	-	-	+	-	-
Fluoranthene	+	+	-	-	-	-	-	-	-	-	-	-	-
Phenanthrene	+	+	-	-	-	-	-	-	-	-	-	-	-
Pyrene	+	+	-	-	-	-	-	-	-	-	-	-	-

Table 7.1. Analytes Above Background Remaining After Abiotic and Biotic Site-wide Screening (Page 3 of 3)

Analytes remaining after the site-wide screens	Surface Soil						Sediment[a]				Surface Water[b]		
								Exposure Unit 4					
	Exposure Unit 1	Exposure Unit 2	Exposure Unit 3	Exposure Unit 4	Exposure Unit 5	Exposure Unit 6	Exposure Unit 3	(0 to 1 mile)	(1 to 3 miles)	(3 to 15 miles)	Exposure Unit 3	Exposure Unit 4 (0 to 1 mile)	Exposure Unit 5
Volatiles	-	-	-	-	-	-	-	-	-	-	-	-	-
Acetone	+	-	+	-	-	-	-	-	-	-	-	-	-
4-Methyl-2-pentanone	+	-	-	-	-	-	-	-	-	-	-	-	-
Toluene	+	+	+	+	+	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
Pesticides/PCBs	-	-	-	-	-	-	-	-	-	-	-	-	-
Aroclor-1254	+	-	-	-	-	-	-	-	-	-	-	-	-
Aroclor-1260	+	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
Radionuclides	-	-	-	-	-	-	-	-	-	-	-	-	-
Americium-241	-	+	-	-	-	-	-	-	-	-	-	-	-
Radium-226	+	+	+	-	-	-	-	-	-	-	-	-	-
Thorium-227	+	-	-	-	-	-	-	-	-	-	-	-	-
Thorium-230	+	+	-	-	-	-	-	-	-	-	-	-	-
Thorium-234	-	+	-	-	-	-	-	-	-	-	-	-	-
Uranium-233/234	-	+	+	-	-	-	-	-	-	-	-	-	-
Uranium-234	+	+	-	-	-	-	-	-	-	-	-	-	-
Uranium-238	+	+	-	-	-	-	-	-	-	-	-	-	-

[a] Sediment samples were not taken at Exposure Units 1, 2, and 5.

[b] Surface water samples were not taken at Exposure Units 1 and 2.

Table 7.2. Reasons for Selecting Receptors for Ecological Risk Assessment at the Luckey Site

Receptor	Selection Criteria (USEPA 1996a)		
	Criterion 1 **Ecological Relevance**	**Criterion 2** **Susceptibility**	**Criterion 3** **Represents Management Goals[a]**
Plants (*various species*)	+++	+	+++
Earthworms (*various species*)	++	+	+
Short-tailed shrew (*Blarina brevicauda*)	+	++	+
American robin (*Turdus migratorius*)	+	++	+
White-tailed deer (*Odocoileus virginianus*)	+	+	+++
Eastern cottontail (*Sylvilagus floridanus*)	+	++	+
Red-tailed hawk (*Buteo jamaicensis*)	++	+	++
Sediment-dwelling organisms	++	++	++
Aquatic organisms	++	++	+++
Great blue heron	++	++	+

[a] Includes protection of threatened or endangered (T&E) or other special status species
+++ = receptor very strongly meets criterion;
++ = receptor strongly meets criterion;
and + = receptor meets criteria.

Table 7.3. Policy Goals, Ecological Assessment Endpoints, Measurement Endpoints, and Decision Rules for Ecological Risk Assessment at the Luckey Site (Page 1 of 2)

Policy Goals	Assessment Endpoint	Measurement Endpoint	Decision Rule
Policy Goal 1: The preservation and conservation of T&E species and their critical habitats.	**Assessment Endpoint 1:** Preservation of any state- or federally-designated threatened or endangered species. Endpoint Species: none yet	**Measurement Endpoint 1:** Modeled contaminant concentrations in prey (shrews, robins, and rabbits) based on measured soil concentrations.	**Decision Rule for Assessment Endpoint 1:** If T&E species are not present, or EPCs in the media do not contribute to chronic NOAEL exceedance (i.e., EEQs <1), then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects, and, therefore, the T&E species are preserved. If the EEQ >1, a weight-of-evidence evaluation will be conducted to determine the potential for ecological risk and the need for any additional measurements or calculations.
Policy Goal 2: The maintenance and protection of terrestrial populations and ecosystems.	**Assessment Endpoint 2:** Maintenance of plant community for erosion control and energy production. Endpoint Species: plants of various species	**Measurement Endpoint 2:** Measured soil contaminant concentrations.	**Decision Rule for Assessment Endpoint 2:** If the EEQ is <1, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, the plant populations and communities are maintained. If the EEQ >1, a weight-of-evidence evaluation will be conducted to determine the potential for ecological risk and the need for any additional measurements or calculations.
	Assessment Endpoint 3: Maintenance of soil-dwelling invertebrate community for nutrient and energy processing. Endpoint Species: earthworms	**Measurement Endpoint 3:** Measured soil contaminant concentrations.	**Decision Rule for Assessment Endpoint 3:** If the EEQ is <1, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, the soil invertebrate community is maintained. If the EEQ >1, a weight-of-evidence evaluation will be conducted to determine the potential for ecological risk and the need for any additional measurements or calculations.
	Assessment Endpoint 4: Maintenance of populations of herbivorous animals. Endpoint Species: cottontail rabbits and deer	**Measurement Endpoint 4:** Modeled contaminant concentrations in food chain based on measured soil contaminant concentrations.	**Decision Rule for Assessment Endpoint 4:** If the EEQ is <1, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, populations of the herbivores, e.g., cottontail rabbits, are maintained. If the EEQ >1, a weight-of-evidence evaluation will be conducted to determine the potential for ecological risk and the need for any additional measurements or calculations.

Table 7.3. Policy Goals, Ecological Assessment Endpoints, Measurement Endpoints, and Decision Rules for Ecological Risk Assessment at the Luckey Site (Page 2 of 2)

Policy Goals	Assessment Endpoint	Measurement Endpoint	Decision Rule
	Assessment Endpoint 5: Maintenance of worm-eating and/or insectivorous animals. Endpoint Species: mammal - shrew; bird - robin	**Measurement Endpoint 5:** Modeled contaminant concentrations in earthworms and other prey based on measured soil contaminant concentrations.	**Decision Rule for Assessment Endpoint 5:** If the EEQ is <1, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, populations of worm-eating and/or insectivorous animals are maintained. If the EEQ >1, a weight-of-evidence evaluation will be conducted to determine the potential for ecological risk and the need for any additional measurements or calculations.
	Assessment Endpoint 6: Maintenance of terrestrial predators. Endpoint Species: mammal - red fox; bird - red-tailed hawk	**Measurement for Endpoint 6:** Modeled contaminant concentrations in prey (shrews, robins, and rabbits) based on measured soil contaminant concentrations.	**Decision Rule for Assessment Endpoint 6:** If the EEQ is <1, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects, and therefore, populations of terrestrial predators are maintained. If the EEQ >1, a weight-of-evidence evaluation will be conducted to determine the potential for ecological risk and the need for any additional measurements or calculations.
Policy Goal 3: The maintenance and protection of aquatic populations and ecosystems.	**Assessment Endpoint 7:** Maintenance of aquatic organisms. Endpoint Species: aquatic organisms	**Measurement Endpoint 7:** Measured surface water contaminant concentrations.	**Decision Rule for Assessment Endpoint 7:** If the EEQ is <1, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects, and therefore, populations of aquatic organisms are maintained. If the EEQ >1, a weight-of-evidence evaluation will be conducted to determine the potential for ecological risk and the need for any additional measurements or calculations.
	Assessment Endpoint 8: Maintenance of sediment-dwelling organisms. Endpoint Species: sediment-dwelling organisms	**Measurement Endpoint 8:** Measured sediment contaminant concentrations.	**Decision Rule for Assessment Endpoint 8:** If the EEQ is <1, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects, and therefore, populations of sediment-dwelling organisms are maintained. If the EEQ >1, a weight-of-evidence evaluation will be conducted to determine the potential for ecological risk and the need for any additional measurements or calculations.
	Assessment Endpoint 9: Maintenance of terrestrial piscivores predators. Endpoint Species: Great blue heron	**Measurement Endpoint 9:** Predicted food contaminant concentrations.	**Decision Rule for Assessment Endpoint 9:** If the EEQ is <1, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects, and therefore, populations of sediment-dwelling organisms are maintained. If the EEQ >1, a weight-of-evidence evaluation will be conducted to determine the potential for ecological risk and the need for any additional measurements or calculations.

EPC = exposure point concentration
T&E = threatened and endangered
NOAEL = no observed adverse effects level
EEQ = environmental effects quotient

Table 7.4. Derivation of Ingestion Rates for Receptors

Receptor	IR_F (kg/kgBW/d)	TUF (unitless)	PF (unitless)	I_P (kg/kgBW/d) IR_F *x* TUF *x* PF	AF (unitless)	I_A (kg/kgBW/d) IR_F *x* TUF *x* AF	SF (unitless)	I_S (kg/kgBW/d) IR_F *x* TUF *x* SF
Short-tailed shrew	0.560	1	0.13	7.28E-02	0.87	4.87E-01	0.13	7.28E-02
American robin	1.520	1	0.50	7.60E-01	0.50	7.60E-01	0.10	1.58E-01
Cottontail rabbit	0.205	1	1.00	2.05E-01	0.00	0.00E+00	0.06	1.29E-02
White-tailed deer	0.031	1	1.00	3.10E-02	0.00	0.00E+00	0.02	6.20E-04
Red-tailed hawk	0.110	1	0.00	0.00E+00	1.00	1.10E-01	0.00	0.00E+00
Red fox	0.069	1	0.05	3.17E-03	0.95	6.58E-02	0.03	1.93E-03
Great blue heron	0.180	1	0.00	0.00E+00	1.00	1.80E-01	0.00	0.00E+00

IR_F = Food ingestion rate; normalized to body weight
TUF = Temporal use factor
PF = Plant fraction
I_P = Plant intake rate
AF = Animal fraction
I_A = Animal intake rate
SF = Soil fraction
I_S = Soil intake rate

Table 7.5. Surface Soil EEQs >1 by Exposure Unit at the Luckey Site (Page 1 of 2)

Exposure Unit	Range of EEQs		
	1-9	**10-99**	**100-999**
Exposure Unit 1	Aroclor-1254 (5) Deer Benzo(a)pyrene (1) Rabbit Benzo(a)pyrene (3) Fox Benzo(a)pyrene (3) Shrew Beryllium (2) Rabbit Beryllium (5) Shrew Beryllium (7) Plants Fluoride (2) Robin Lead (4) Plants	Arochlor-1254 (13) Rabbit Arochlor-1254 (45) Robin Arochlor-1254 (30) Hawk Cadmium (10) Shrew Cadmium (12) Robin Lead (13) Shrew	Aroclor-1254 (145) Shrew Aroclor-1254 (201) Fox Lead (277) Robin
Exposure Unit 2	Beryllium (1) Fox Beryllium (3) Deer Cadmium (1) Deer Cadmium (2) Hawk Cadmium (3) Fox Cadmium (4) Earthworms Cadmium (4) Rabbit Chromium (7) Robin Copper (1) Earthworms Fluoride (1) Rabbit Fluoride (1) Shrew Fluoride (4) Hawk Lead (1) Fox Lead (3) Earthworms Lead (3) Rabbit Lead (6) Hawk Mercury (1) Hawk Mercury (2) Plants Mercury (5) Earthworms Nickel (2) Plants Thallium (2) Plants Thallium (6) Rabbit Zinc (2) Shrew Zinc (3) Earthworms Zinc (3) Fox	Beryllium (21) Rabbit Beryllium (53) Shrew Beryllium (77) Plants Boron (62) Plants Cadmium (21) Plants Chromium (51) Plants Fluoride (25) Robin Lead (28) Plants Lead (85) Shrew Thallium (42) Fox Thallium (84) Shrew Zinc (10) Plants Zinc (26) Robin Zinc (29) Hawk	Cadmium (221) Shrew Cadmium (252)Robin Chromium (127) Earthworms Lead (175) Robin
Exposure Unit 3	Beryllium (4) Rabbit Beryllium (1) Fox Lead (1) Plants Lead (5) Shrew Selenium (2) Robin Selenium (3) Plants Selenium (3) Shrew Selenium (1) Fox	Beryllium (16) Plants Beryllium (11) Shrew Lead (94) Robin	None

Table 7.5. Surface Soil EEQs >1 by Exposure Unit at the Luckey Site (Page 2 of 2)

Exposure Unit	Range of EEQs		
	1-9	**10-99**	**100-999**
Exposure Unit 4	Antimony (1) Shrew Beryllium (2) Shrew Beryllium (3) Plants Cadmium (6) Robin Cadmium (6) Shrew Lead (2) Shrew Thallium (2) Plants Thallium (6) Rabbit	Lead (33) Robin Thallium (81) Shrew Thallium (40) Fox	None
Exposure Unit 5	Lead (1) Plants Lead (4) Shrew	Lead (79) Robin	None
Exposure Unit 6	None	None	None

EEQ - environmental effects quotient

Table 7.6. Sediment-dwelling Biota EEQs >1 by Exposure Unit at the Luckey Site

Exposure Unit	Range of EEQs		
	1-9	**10-99**	**100-999**
Exposure Unit 3	Mercury (2) Sediment-dwelling biota Nickel (3) Sediment-dwelling biota Silver (5) Sediment-dwelling biota Zinc (5) Sediment-dwelling biota	Cadmium (95) Sediment-dwelling biota Copper (13) Sediment-dwelling biota Lead (11) Sediment-dwelling biota	Iron (1100) Sediment-dwelling biota
Exposure Unit 4	Copper (1) Sediment-dwelling biota Silver (1) Sediment-dwelling biota	Cadmium (46) Sediment-dwelling biota Lead (17) Sediment-dwelling biota	None

EEQ - environmental effects quotient

Table 7.7. Surface Water EEQs >1 by Exposure Unit at the Luckey Site

Exposure Unit	Range of EEQs		
	1-9	**10-99**	**100-999**
Exposure Unit 3	Bis(2-ethylhexyl)phthalate (2) Heron Cadmium (1) Aquatic biota Copper (2) Aquatic biota Fluoride (4) Heron Iron (2) Aquatic biota Lead (4) Heron Manganese (3) Aquatic biota Mercury (7) Heron Silver (2) Aquatic biota Strontium (8) Aquatic biota	Aluminum (12) Aquatic biota Barium (47) Aquatic biota Beryllium (16) Aquatic biota Lead (18) Aquatic biota	Boron (147) Aquatic biota Fluoride (200) Heron
Exposure Unit 4	Bis(2-ethylhexyl)phthalate (2) Heron Iron (1) Aquatic biota Lead (1) Aquatic biota Manganese (8) Aquatic biota Strontium (4) Aquatic biota	Aluminum (11) Aquatic biota Barium (17) Aquatic biota Boron (94) Aquatic biota Fluoride (12) Heron	None
Exposure Unit 5	None	None	None

EEQ - environmental effects quotient

Table 7.8. Site Hazard Indices for Radionuclide CPECs in Soil at the Luckey Site[a]

Receptor	Exposure Unit 1	Exposure Unit 2	Exposure Unit 3
Plants	4.13E-04	2.31E-04	1.91E-05
Earthworms	2.12E-02	2.99E-02	3.67E-04
Short-tailed shrew	4.59E-03	3.95E-03	3.06E-04
Robin	8.59E-03	6.57E-03	6.08E-04
Cottontail	9.52E-04	5.69E-04	5.75E-05
Red fox	4.59E-04	3.55E-04	1.98E-05
Red-tailed hawk	1.47E-05	1.22E-05	1.06E-06
White-tailed deer	6.04E-05	2.41E-05	4.34E-06

[a] Sum of EEQs for individual radionuclide CPECs for each receptor at each site. Data taken from results in Appendix Tables B.100 through B.123.

EEQ - environmental effects quotient

CPEC - constituent of potential ecological concern

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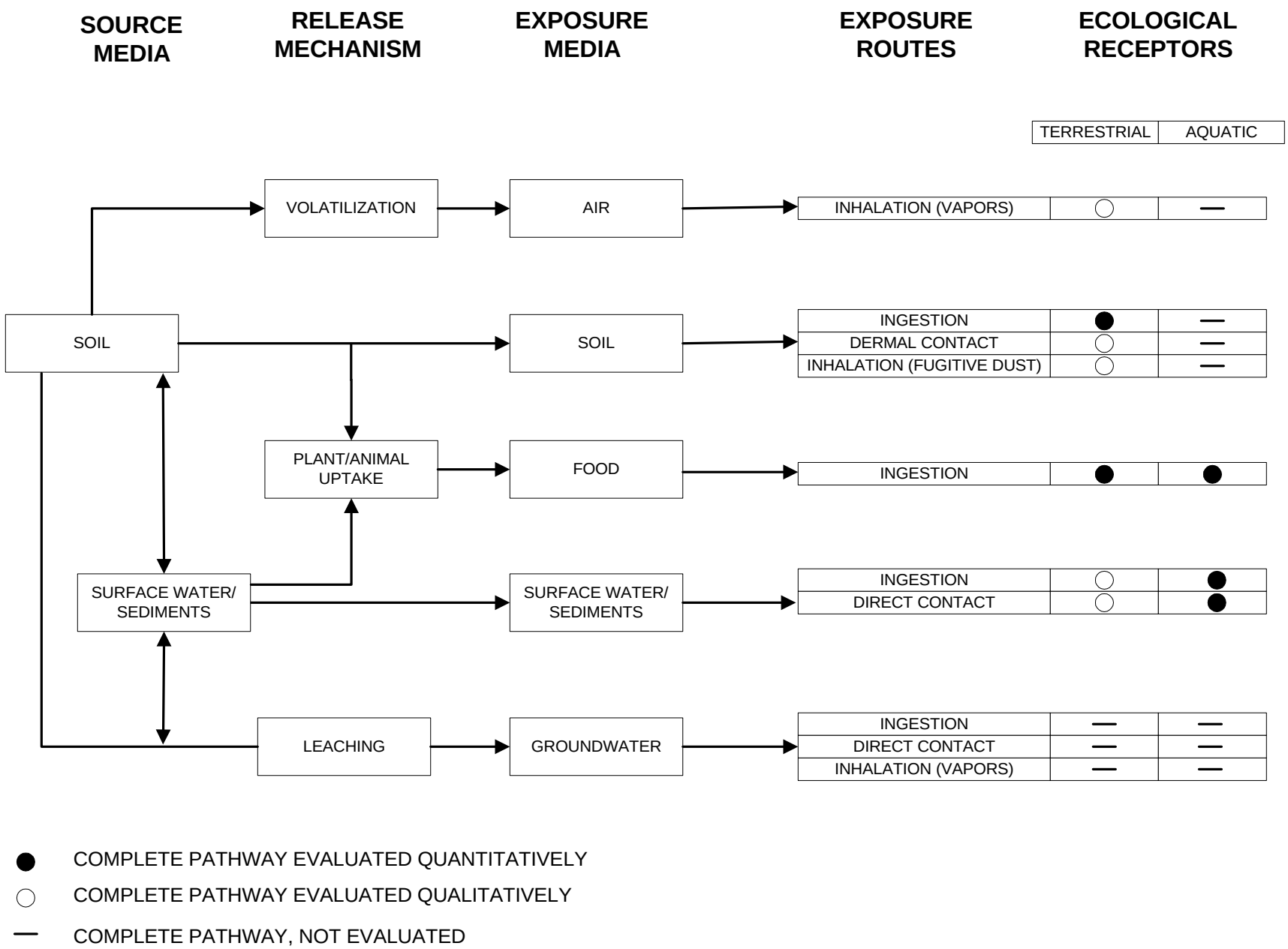


Figure 7.1. Exposure Pathways for Terrestrial and Aquatic Receptors at the Luckey Site

FIG7.1.EXP_PATH_TER_AQvsd.vsdWednesday, September 13, 2000

Roads

Tree Line

Water

0.1 0 0.1 0.2 Miles

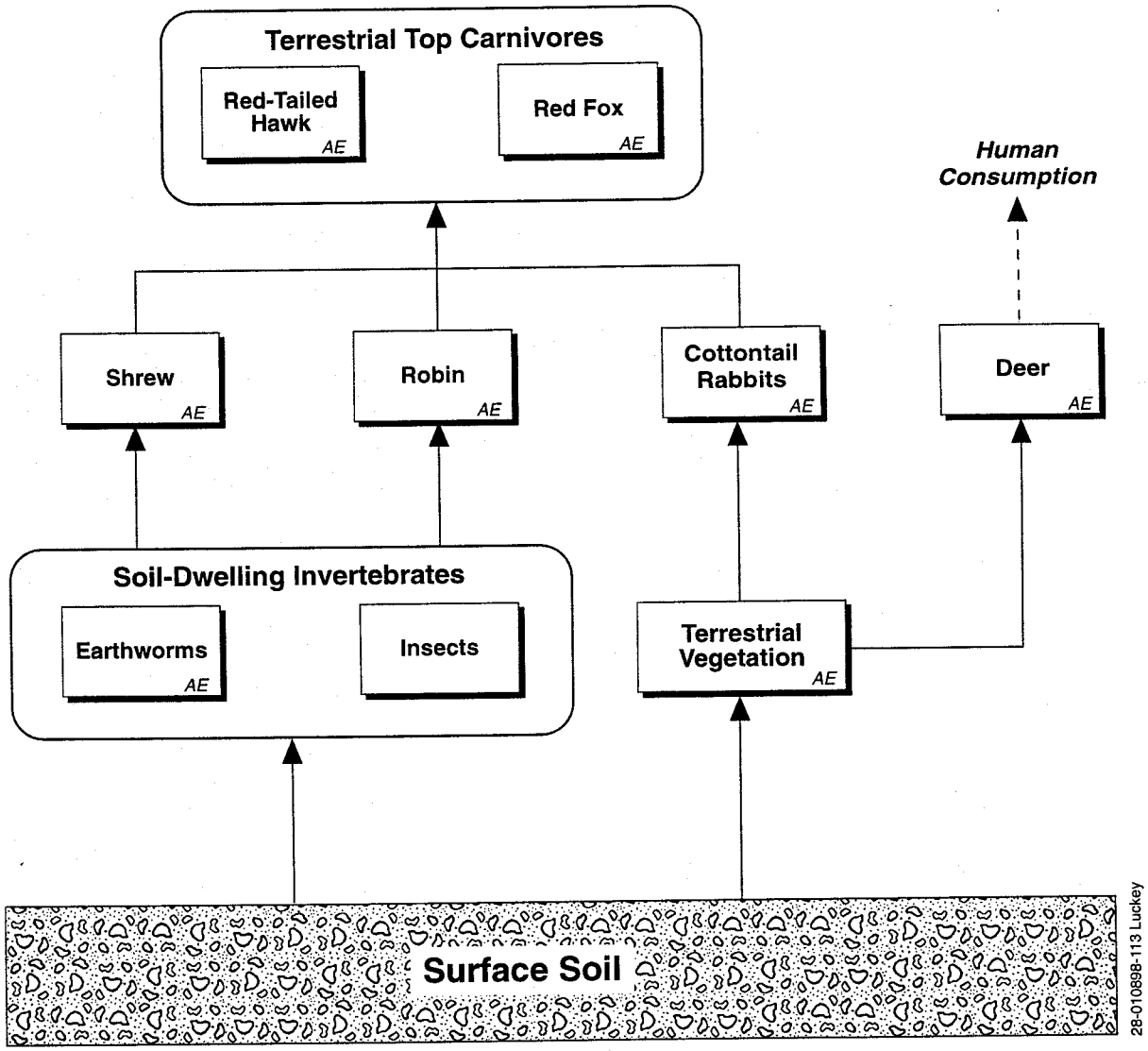
N W E S

U.S. ARMY CORPS OF ENGINEERS
BUFFALO DISTRICT
LUCKEY SITE

Habitats at Luckey Site

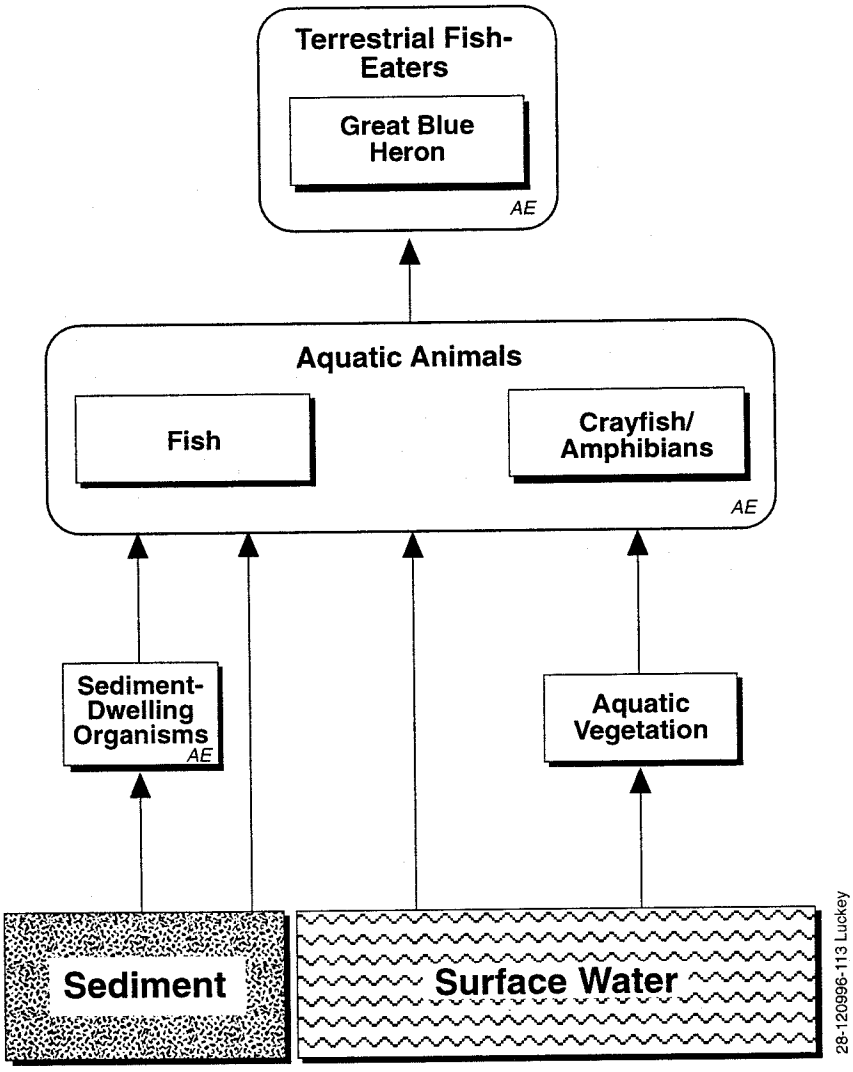
Science Applications International Corporation
An Employee-Owned Company
Columbus, Ohio

DRAWN BY	DATE	SCALE	PROJECT NO.	FIGURE NO.
LMA	02/09/00	AS SHOWN	04-1748-801	7.2



AE = assessment endpoint; organisms with no AE in box means they are intermediate in terms of transfers.

Figure 7.3. Simple Terrestrial Food Web at the Luckey site for Ecological Risk Assessment



AE = assessment endpoint; organisms with no AE in box means they are intermediate in terms of transfers.

Figure 7.4. Simple Aquatic Food Web at the Luckey site for Ecological Risk Assessment

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8.0 SUMMARY AND CONCLUSIONS

This RI Report presents a detailed analysis of environmental data for the Luckey site. Conclusions are conveyed through the conceptual model for nature and extent as well as fate and transport of contamination. The conceptual models and exposure models have been used to assess risks to human health and the environment at the Luckey site. This section summarizes the findings and conclusions of the Luckey RI.

8.1 SUMMARY

The following sub-sections summarize the nature and extent of contamination, fate and transport mechanisms, and the baseline human health and ecological risk assessments as they pertain to AEC-related constituents in media (on-site soils, off-site soils, surface water and sediment, groundwater, and buildings). Detailed discussions are provided in Sections 4, 5, 6, and 7.

Nature and Extent

Constituents detected at concentrations above background levels were evaluated for environmental media investigated in the RI. The nature and extent of AEC-related constituents are summarized below for each media unit.

Fate and Transport

The properties of constituents of concern identified in soil, groundwater, surface water, and sediment during the RI at the Luckey site were assessed qualitatively in conjunction with properties of the environmental media at the site. The major transport pathways for environmental contaminants at the site are listed below:

- surface water runoff and erosion of contaminated soil, (on-site soils to drainage ditches to Toussaint Creek)
- wind erosion (on-site soils to off-site adjacent areas), and
- surface water infiltration and leaching of soil contaminants to groundwater (beryllium in groundwater).

Analyses of soils and sediment indicate that surface water is the primary medium at Luckey with the potential for off-site contaminant migration. Overland flow of precipitation across contaminated soils mobilizes soil particles that have site contaminants such as beryllium, lead, PAHs, and radionuclides sorbed or otherwise bound to their surfaces. The soil particles are transported indirectly to Toussaint Creek via the drainage ditches that exit the facility, or directly into the creek where dredged spoils placed along the creek bed erode. Because of their high sorption coefficients, heavy metals and PAHs detected in soils are not expected to significantly dissolve in the surface water column as they are transported. Radiological constituents are not expected to cycle between sediment and surface water.

Fate and transport modeling of representative constituents in groundwater will be undertaken as a future task following submission of this RI Report. Realistic representation of the fate of contaminants in the groundwater system will rely on accurate characterization of the hydraulic gradients, the performance of the on-site production well, and the secondary-porosity flow system that is present in the bedrock beneath the Luckey site.

Human Health Risk Assessment

The results of the human health risk assessment indicate PAHs, Aroclor-1254, beryllium and manganese, contribute most significantly to potential risks, predominately through incidental ingestion of soil and dermal contact with soil or sediment. Of these constituents, beryllium is the only COC that can be attributed solely to AEC operations at the site. The following summary discussion focuses on the AEC-related constituents. COCs are identified by exposure unit (EU) and non-radiological COCs are summarized in Table 8.1:

- EU 1: on-site undisturbed soil area within the current fenced boundaries of the site,
- EU 2: on-site disturbed soil area within the current fenced boundaries of the site,
- EU 3: off-site land surrounding the facility currently used for residential/ agricultural purposes,
- EU 4: Toussaint Creek down-gradient from the Luckey site,
- EU 5: France Stone Quarry south of the site, and
- EU 6: landfill (Troy Township Dump) south of the site.

Risks from radiological constituents in soil and sediment were estimated using RESRAD code Version 5.82. Site-specific risk calculations were performed to select COCs from the list of radiological COPCs. Five radionuclides (Pa-231, Ra-226, Th-230, U-235, and U-238) are identified as COCs in soils and sediment (Table 8.2). Because there is a mixture of radionuclides, which will continue to decay and change with time, risk estimates were calculated covering a 1,000-year period. The maximum risk over this period was then selected for comparison to risk criteria. Risk from radiological constituents in groundwater were determined using the RAGS nethodology instead of RESRAD. Three radionuclides (U-234, U-235, and U-238) are identified as COCs in groundwater (Table 8.2).

A summation of carcinogenic risk to radiological and chemical constituents was presented in Section 6.8 and Table 6.33. The risk summary presented in this section focuses on risk from individual constituents exceeding 10E-6, i.e. COCs.

Uncertainties Associated with the HHRA

Benzo(a)pyrene and other PAHs show excess risk to human health via the dermal pathway. To calculate dermal risk using toxicological reference values derived from oral exposures, the toxicological reference values were adjusted using EPA recommended gastrointestinal (GI) absorption factors to adjust administered (oral) to absorbed (dermal) dose. When compound-specific gastrointestinal absorption efficiencies where greater than 50 percent, oral slope factors and RFDs were not adjusted. Dermal dose was estimated using chemical-specific dermal absorption factors and receptor-specific soil-to-skin adherence factors. Chemical-specific dermal efficiencies are available for few constituents. Quantification of potential risk from dermal exposure to contaminated soil was only performed for constituents with EPA recommended gastrointestinal absorption efficiencies and dermal absorption efficiencies. Of the COPCs identified for soil at the Luckey site, compound-specific gastrointestinal absorption factors and dermal absorption factors are available for cadmium, Aroclor-1254, benzo(a)pyrene and other PAHs, and other semi-volatile organic compounds.

Lead does not have toxicological reference values, therefore standard risk calculations could not be performed. RBCs were established using models which relate intake of lead from soil to blood lead concentrations in sensitive subpopulations. For current and future resident farmer scenarios EPA's *Integrated Exposure Uptake Biokinetic Model for Lead in Children* (IEUBK) (EPA 1994d) was used to establish an acceptable concentration of 400 mg/kg lead. Recommendations of EPA's Technical Review Workgroup (TRW) for lead were used to assess risks associated with adult worker exposures to lead in soil (EPA 1996f). Using the TRW algorithm and the input assumptions presented in Figure 6.7, the

acceptable concentration of lead in soil was calculated as 958 mg/kg.

Lead was detected below acceptable concentrations everywhere but in EU 2. In EU 2, the exposure point concentrations (EPCs) for lead were 1,380 mg/kg for industrial workers and future resident farmers (0-2 feet), and 561 mg/kg for future resident farmers (0-10ft). Most of the lead detected on site was detected in the first two feet of soil.

Ecological Risk Assessment

Ecological effects quotients (EEQs) were used to assess current and future risks to ecological receptors from constituents of potential ecological concern (CPECs) at the Luckey site and at nearby aquatic exposure units. EEQs were calculated for several different receptors for every CPEC for which toxicological reference values were available from published information. Each EEQ compared two concentrations: the estimated CPEC concentration in soil or other media or dietary dose from soil or other media to which a given receptor may be exposed, and the toxicity reference value for the CPEC and receptor. The ecological risk assessment is detailed in Section 7.

If the EEQ was greater than one, the CPEC was designated as a COC. EEQs in the range of 1 to 100 were designated as low ecological risk, in the range of 100 to 1000 as intermediate ecological risk and in excess of 1000 as high ecological risk (Section 7.0). The use of such a simple method to organize EEQs is designed to help manage risk; however, full acknowledgement was given any constituent with an EEQ of 1 or higher based on the screening ERA. There may be a need to better define this risk in the next phase or the baseline ERA. If so, the emphasis should be on field-observed effects to confirm predicted risk. Regardless, for this screening ERA an ecological COC was defined as any constituent for which EEQ >1. Ecological COCs are identified by exposure unit in Table 8.3. The majority of ecological COCs are in soil at Exposure Units 1 and 2 (Table 8.3).

The appearance of abundant vegetation and various animal life at, and surrounding, the Luckey site suggest no immediate threat from acute non-chronic exposures to site related contaminants. However, there are patches of soil where there is no vegetation growing (see Figure 7.2), and this lack of growth may be associated with soil contamination. Of the many observed plant and animal taxa, five terrestrial classes (vegetation, soil-dwelling invertebrates, worm-eating and/or insectivorous mammals, mammalian herbivores, and terrestrial top predators) were selected for terrestrial receptors. For aquatic classes, sediment-dwelling organisms, aquatic organisms, and great blue herons were selected. EEQs were calculated for CPECs at the surface soil and sediment/surface water exposure locations.

8.1.1 On-site Soils

COCs were identified for on-site *undisturbed* soils (EU 1) and on-site *disturbed* soils (EU 2). The COCs in soils for human health include beryllium, Ra-226, Th-230, U-235, and U-238. The COCs in soils for ecological receptors include beryllium, lead, and fluoride.

Nature and Extent

Results of the RI sampling program indicate that the pattern of contamination is closely related to site features such as lagoons and waste disposal. The principle features of interest for the investigation of on-site soils include:

- trenches and pits (used for disposal of sludge, scrap metal, and lime);
- Lagoons A, B, C, and D;
- former petroleum handling buildings and UST area;

- electrical transformer areas (past and present); and
- bare spots and areas of stressed vegetation.

The most significantly impacted areas for the on-site soils include the trenches and pits, the lagoons, and the filter bed areas and debris piles. Constituents were detected above background at the other features investigated, but usually at much lower levels.

Beryllium, lead, fluoride, Ra-226, Th-230, Th-234, U-233/234, and U-238 were the most commonly AEC-related constituents detected above background in soils from the disposal trenches and pits. Detections above background at depths greater than a few feet were generally encountered within and beneath the trench and pit fill materials. Contamination between the trenches and pits is generally confined to the surface soils. In addition to the constituents noted above, several additional metals (arsenic, cadmium, chromium, copper, mercury, nickel, selenium, and zinc), PAHs, and VOCs also were detected above background levels within the disposal trenches and pits. Typically, these metals have a low frequency of detection above background within the soils from the disposal trenches and pits. PAHs were detected in one sample from the northeast corner pits and trenches, and from samples collected in the scrap metal and disposal trenches. Low levels of several VOCs also were detected in each of the trenches and pits investigated.

Beryllium, lead, fluoride, Ra-226, Th-234, U-233/234, and U-238 were the most commonly detected AEC-related constituents detected above background in soils from the lagoons. Lead was not detected above background at Lagoon A. The radionuclides appear to be primarily associated with Lagoon B soils. Several other metals were identified above background levels at the lagoons. Typically, these metals have a low frequency of detection above background within the soils from the lagoons. Barium and cobalt were detected above background at Lagoon A. Antimony, cadmium (location of highest measured value in on site soils), chromium, and zinc were detected above background at Lagoon C.

At the filter bed area and debris piles beryllium and lead were the metals most commonly exceeding background levels. Other metals detected above background include barium, cadmium, nickel, and zinc. Five radionuclides (Ra-226, Th-230, Th-234, U-233/234, and U-238) also were detected above background levels. Low levels of PAHs and VOCs were detected in the soils here as well.

At the former petroleum handling buildings and UST area, the primary constituents detected included total recoverable petroleum hydrocarbons, several VOCs (vinyl chloride, benzene, carbon disulfide, ethyl benzene, toluene, and total xylenes) at low levels, and several PAHs. Beryllium also was detected above background in the soils, but the concentrations were significantly less than other areas on site.

At the, electrical transformer areas, the primary constituents detected included total recoverable petroleum hydrocarbons, several PAHs and aroclor-1254. Elevated concentrations of these constituents were generally limited to the shallow surface soils. Beryllium was also detected above background levels in the soils, but the levels were significantly less than other areas on site.

The soils at the bare spot and stressed vegetation areas had a number of constituents detected above background levels. Measured levels are similar to those detected at other areas on site that do not exhibit stressed vegetation. Beryllium, chromium, lead, and vanadium were detected above background in the bare spot along with several radionuclides, PAHs, VOCs at low levels.

At the existing buildings and associated areas, the primary constituents identified consist of PAHs in the shallow soils. Beryllium, lead, and cadmium were the metals most commonly exceeding background. Several radionuclides and VOCs were detected in the soils here as well, but at low levels.

Human Health Risk Assessment

The results of the risk characterization for non-radiological constituents for the Luckey site indicate that there are potential risks to human health in on-site soils (EUs 1 and 2). Table 8.1 lists the non-radiological COCs. PAHs, beryllium, lead and Aroclor-1254 are the constituents that drive risk in these areas. Radiological constituents of concern are identified in Table 8.2. Ra-226, Th-230, U-235, and U-238 present an ILCR greater than 1×10^{-6}.

For non-radiological constituents only the resident farmer scenarios produced risk estimates in excess of 1×10^{-4} and radiological COCs are only identified for soil based on the site-specific risk calculations. The total risk results indicate the resident farmer adult and child receptors could receive a risk greater than 1×10^{-4} in Exposure Units 1 and 2, but only from exposure to surface or subsurface soils. Risks from exposure to surface soil would exceed 1×10^{-4} under both RME and CT conditions. Risks from exposure to subsurface soil would only exceed 1×10^{-4} under RME conditions. Review of the risk calculations in Appendix 6B show that risk is driven by the external gamma pathway. Therefore, the adjustment of soil ingestion rates from RME to CT conditions has little impact on total risk. The only relevant adjustment is the reduction of the adult exposure duration from 30 years to 9 years, effectively lowering the CT risk estimate to 30 percent of the RME value. No adjustment in the exposure duration value for children was made between RME and CT scenarios, therefore the RME and CT risks are the same value within a few significant digits.

Due to uncertainty associated with minimal building data, no radiological COCs have been identified for buildings; although Ra-226, Th-230, and uranium isotopes have been identified in significantly elevated concentrations. A dose characterization was performed using the RESRAD-BUILD model. Results indicate that the total dose is approximately 1.5 mrem/yr (not including radon) approximately 100% coming from Ra-226 and the external gamma pathway. These relatively low results are likely due to the fact that only small (less than 1 m^2) and sparsely distributed areas of elevated activity were identified in site buildings.

Data Limitations

- Lateral extent of PAHs in soil is limited by the small number of results, however, appear to be co-mingled with beryllium.
- Determination of the horizontal and vertical extent of Aroclor-1254 contamination in soil would require further characterization.
- As mentioned above, PAHs and the PCB, Aroclor-1254, are not compounds associated with AEC processing activities at the site. These constituents are likely a direct result of the use and operation of these buildings and insufficient information currently exists to attribute the contamination to a particular occupant or period in time.

8.1.2 Off-site Soils

No non-radiological COCs were identified for the off-site residential /agricultural lands (EU 3). Radiological COCs (Pa-231 and Ra-226) were identified as COCs in EU 3.

Nature and Extent

The highest levels of beryllium (683-744 mg/kg) in the off-site soil are located along the eastern side of the central drainage ditch that leads to Toussaint Creek. The highest concentrations are located within 250 feet of the property line and the levels generally decrease toward Toussaint Creek. This

contaminant trend supports the hypothesis that the ditch was periodically dredged to maintain good flow and the dredged spoils were deposited along the ditch.

Two localized areas of elevated concentrations of beryllium are evident along the northern boundary of the site. The first area occurs approximately 400 feet east of Luckey Road. Beryllium ranges from approximately 14 to 21 mg/kg in this area. The second area occurs near the eastern edge of the property between the ditch and the former railroad line. Elevated concentations of radionuclides also were detected in this area. Levels of beryllium approach 50 mg/kg in soils along the fence line and the railroad bed in this area.

Based on this evaluation, it is apparent that soils in the northern farm field have been impacted by beryllium related to the Luckey site. Beryllium detected along the central drainage ditch is probably a result of past dredging operations to maintain flow from the site to Toussaint Creek. Sources for the contaminants located along the fence line and in the two areas described above could be from windblown deposits or from storm water runoff from the Luckey site and portions of the railroad bed.

Human Health Risk Assessment

The results of the risk characterization indicate that there are potential risks to human health in the offsite soils (EU 3) from radiological constituents (Table 8.2). There are no non-radiological COCs for this EU (Table 8.1). EU 3 also includes the sediments and surface water in ditches leading to Toussaint Creek. Benzo(a)pyrene and Ra-226 present risk to human health in the sediments. COCs were identified in surface water in EU 3.

Data Limitations

Lateral extent of lead and beryllium contamination in soils along the main ditch may require further characterization.

8.1.3 Toussaint Creek

Beryllium exceeded background in nearly all sediment samples analyzed (on-site and off-site), but is not a COC in Toussaint Creek for either human health or ecological receptors. None of the concentrations detected in off-site samples exceeds the RBC derived in the risk assessment. Analytical results from sediment sampling suggest that beryllium contamination has been transported off-site via surface water and sediment. The highest concentrations in sediment are found either on or directly adjacent to the Luckey site. However, beryllium is also detected in sediment samples at least 13 miles downstream and in soils of Toussaint Creek's meander bends. Beryllium concentrations in Toussaint Creek tend to decrease in a downstream direction moving away from the drainage ditches exiting the site.

Possible sources of the beryllium are on-site soils and trench and pit fill material, especially for contaminants observed in the northeastern corner of the site (IA01) and the main ditch.

PAHs were detected in ditches on site and in the immediate vicinity of the site leading to Toussaint Creek. However, the only samples exceeding RBC levels are located in the roadside ditch along Luckey Road. These occurrences are likely not site related, because PAHs are widespread in occurrence in most environments.

Human Health Risk Assessment

The results of the risk characterization for non-radiological constituents for the Luckey site indicate that there are potential risks to human health in Toussaint Creek (EU 4). Table 8.1 lists the non-radiological COCs for this EU. Benzo(a)pyrene is the only constituents that present risk from sediment in this area. There are no soil constituents presenting risk. Radiological constituents of concern are identified in Table 8.2. The total risk estimate did not exceed $1x10^{-4}$ for sediment in Toussaint Creek.

Data Limitations

Nature and extent of the COCs in sediment – beryllium and PAHs for human health, and lead and cadmium for ecological receptors – has not been adequately defined within the creek, because of the placement of sampling stations. Samples furthest downstream contain concentrations of some of these constituents above background criteria. (As mentioned above, PAHs are not strictly related to AEC activities at the Luckey site.)

EEQs>1 suggest that the Luckey site has negatively impacted ecological receptors. However, these calculations were made using conservative inputs because site-specific information on actual receptors was not available. As a result, the EEQs may grossly overestimate actual site risks to ecological receptors.

8.1.4 Groundwater

A network of 43 monitoring were installed and sampled as part of the RI. In addition to the monitoring well network, groundwater samples were collected from the east (PW[E]) and west(PW[W]) production wells, from three nearby residential wells (GW0002, GW0003, and GW0004), and from tap water at the Uretech facility (GW0001).

Monitoring wells were sampled twice in order to capture conditions during both high- and low water periods. The plant production wells, tap water, and the three nearby residential wells were sampled more frequently to monitor for potential contaminants in the groundwater at their respective locations.

Radiological constituents related to AEC activities at the Luckey site were identified as human health COCs in groundwater (U-234, U-235, and U-238); there are no ecological COCs for this medium. Although beryllium is also present in the groundwater, well-developed plumes are not apparent. Beryllium and radiological consituents do not appear to be migrating off site via the groundwater pathway.

Human Health Risk Assessment

The results of the risk characterization indicate that there are potential risks to human health in groundwater. Groundwater was evaluated site wide. Table 8.1 lists the non-radiological COCs for groundwater. Manganese is the only constituent that presents a risk in groundwater. It only presents risk to the future resident farmer child. Radiological constituents of concern are identified in Table 8.2. The total risk estimate did not exceed $1x10^{-4}$ for groundwater.

Data Limitations

Groundwater flow paths through secondary porosity in the Lockport bedrock (e.g., joints, fractures, solution pathways) is complex and variable. The changes in hydraulic conductivity with depth

are related to the interconnectivity of secondary pore space, which was not studied in this RI. Representations of groundwater flow in this report may oversimplify actual conditions.

Seasonal changes in water levels and flow directions were monitored during a prolonged drought in Ohio. It is not known whether the full range of seasonal high and low water levels has been captured during this period of possibly historic low water levels.

8.1.5 Buildings

COCs were not identified in the buildings because there are no recognized guidelines for settled dust, or non-radiological swipes. Direct readings for alpha and beta-gamma activity have recognized standards. These are considered for comparison purposes.

The direct radiation reading data clearly identify several significant areas within the Annex and two isolated locations in the Production Building that have activity above NRC 1.86 guidelines (for release to the public). The majority of the elevated activity is located in the beams. Areas occupied by employees have measured radioactivity comparable to background levels.

Beryllium swipes show significant contamination in the Annex, Production Building, Former Laboratory, and Maintenance Building. Lesser levels were detected in the Melting, Alloying, and Shipping Building, the Shack, and Sewage Disposal Treatment Building.

Bulk dust results indicate there is a significant possibility to exceed the proposed ACGIH TWA beryllium guideline for airborne beryllium (0.2 $\mu g/m^3$) if dust is re-suspended during disruptive maintenance activities. Because of the high concentrations detected in some dust samples, this is possible even if the nuisance dust levels are not exceeded.

The building materials samples indicate that, while there is significant beryllium contamination of the paint, brick, concrete, and other materials in the structure of the buildings, only a minor amount of radiological contamination seems to be present. Those buildings whose structures are significantly contaminated with beryllium include the Former Laboratory, the Maintenance Building, the Production Building, and the Annex.

Beryllium is clearly present in the building dust and in building materials from the Old Lab, Maintenance Building, Production Building, Annex, and the Bulk Storage Building. The largest concentrations of beryllium found in the buildings today are in areas not normally used under current operations. These occurrences could be relicts of past operations or could represent dust blown in before the lagoons were capped.

Human Health Risk Assessment

As explained in section 8.1.1 there are no radiological constituents of concern in the buildings. A non-radiological human health risk assessment was not performed in the buildings.

Data Limitations

A cursory survey (5% coverage) of beryllium swipes and direct and transferable radiological activity was conducted in the Production Building. Additional data may be useful in decision-making if remedial action is determined necessary and appropriate.

Building materials samples collected in the Production Building were not analyzed for radionuclides. Thus, nature and extent of radiological contamination in the buildings has not been determined.

8.2 CONCLUSIONS

8.2.1 Non-AEC-related COCs

Several COCs identified in the BRA are not considered AEC-related constituents: cadmium, manganese, PAHs, and PCBs. These constituents are briefly discussed below.

Cadmium was identified as a COC in onsite surface soils in EU 2. It is not associated with AEC activities or processes at the site. Cadmium is used in coatings and plating, welding and soldering, as a pigment, and in rechargeable batteries (nickel-cadmium). In the US, from the 1940s through the mid-1960s, cadmium was a very common coating on iron, steel, aluminum, and copper. It also occurs in nature with zinc. A previous occupant of the site was recycling zinc from metals and it is possible cadmium also was encountered. Cadmium is an excellent pigment having advantages of brilliance, color brightness, opacity, processability, and stability at high temperatures. It is commonly used in paints and as a colorant in plastics. Its heat stability is particularly beneficial in high temperature moldings. Operations using cadmium based paints or colorants for plastics also could act as a source of cadmium. Cadmium also is used as a plastic stabilizer. It helps prevent the degradation of PVC plastics by ultraviolet light.

Manganese was identified as a COC in groundwater. In the US, most manganese is used in the steel making industry. Manganese is introduced in the primary production of steel for its sulfur-fixing, deoxidizing, and alloying properties. As a primary component of steel, it is possible that an operation recovering zinc also would encounter manganese and may have considered it an unwanted by-product. Manganese also is used in small amounts in animal feed, brick coloring and other pigments, dry cell batteries, and plant fertilizers. Although use of manganese based pigments is unknown at the site, manganese dioxide is commonly used by industry to dry black paints. On average, manganese is the most abundant minor element found in carbonates and the second most abundant minor element found in shales (Krauskopf 1979). This may be the result of substitution of $Mn2^+$ for $Ca2^+$ and/or $Mg2^+$ in the limestone or dolomite. Further, there appears to be a correlation between high manganese concentrations and high iron concentrations in the ground water. Geographically, the wells encountering elevated manganese were grouped in the northeast part of the site or the south-central, and were predominantly in shallow wells It may be that locally-reducing conditions have been created in the ground water, resulting in the more-soluble +2 form of iron and manganese being released to ground water.

PAHs and one PCB were identified as COCs in on-site soils (EUs 1 and 2) and sediments in EU 3. The PAHs and PCB in soils are primarily associated with the area surrounding the existing buildings, the former petroleum handling buildings and UST area, and the electrical transformer areas (past and present). The constituents detected in these soils are a direct result of the use and operation of these buildings, and the rail spurs that were adjacent to them and insufficient information currently exists to attribute the contamination to a particular occupant or period in time. PAHs detected in the Luckey Road drainage ditch can be attributed to its proximity to a roadway. As a matter of definition of a release under CERCLA 101(22), to which CERCLA 104 gives authority to respond, as well as a common sense issue, an exemption to PAHs adjacent to roads exists in the CERCLA program (USAF 2000).

8.2.2 Recommended Remedial Action Objectives

Site-specific RBCs were developed for radiological and non-radiological COCs based on the exposure assumptions and pathways of concern identified in the HHRA. For non-radiological COCs, RBCs were calculated for each potential receptor using RME assumptions. The RBCs correspond to an incremental lifetime cancer risk (ILCR) of 1×10^{-6} or a hazard index of 1.

For radiological COCs action levels were derived for soil sediment, and groundwater considering risk-based, dose-based, and concentration-based endpoints. The concentration corresponding to the risk endpoint of 1×10^{-6} (the point of departure) using site-specific parameters is presented to replace the generic preliminary remediation goal (PRG) derived using RAGS defaults.

As previously stated, EEQs were used to identify ecological COCs and to assess current and future risks to ecological receptors from COCs at the Luckey site and at nearby aquatic exposure units. Per EPA guidance (EPA 1997), EEQs greater than unity indicate constituents that warrant additional, more thorough assessment because of the potential for adverse ecological effects. For ecological COCs a weight of evidence analysis was used to develop recommendations for further action at areas within Exposure Units 1 and 2 which currently lack vegetation and for Toussaint Creek. See Section 7.8 for a discussion of the weight-of-evidence findings of the screening ERA. This discussion suggests that there may be a need to better define ecological risks, or to devise strategies to properly manage ecological risks in these areas. Management strategies may need to consider field-observation data, overall land management goals for the property, and any future actions that may be taken to mitigate human health risks.

8.2.2.1 <u>Risk-Based Concentrations for Non-radiological COCs</u>

Site-specific RBCs have been developed for COCs based on the exposure assumptions and pathways of concern identified in the HHRA. The RBCI for the COCs have been developed based on guidance set forth in *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual -Part B* (EPA. 1991b). RBCI were calculated for each potential receptor using RME assumptions. The RBCs correspond to an ELCR of 1×10^{-6} or a hazard index of 1. The RBCs for non-radiological COCs are presented for the RME scenario in Table 8.4.

8.2.2.2 <u>Action Levels for Radiological IOCs</u>

Radiological action levels are summarized in Table 8.5 and correspond to applicable or relevant standards.

8.2.3 Recommendations for Future Work

The RI documented in this report adequately determined the nature and extent of FUSRAP-related contamination and provides an evaluation of the potential impacts to human health and the environment. Based on the results and the conclusions of the RI at the Luckey site, it is recommended that a feasibility study be conducted.

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Table 8.4. Risk-Based Concentrations for COCs for RME Scenarios
Table 8.5. Action Levels for Radiological COCs at the Luckey Site

Table 8.1. Human Health Non-Radiological Constituents of Concern Identified by Exposure Unit

Soil Human Health COCs (HI>1 or ILCR >10^{-6})	
Exposure Unit 1	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenz(a,h)anthracene Indeno(1,2,3-cd)pyrene Aroclor-1254
Exposure Unit 2	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Indeno(1,2,3-cd)pyrene Beryllium Cadmium Lead
Exposure Unit 3	Beryllium
Exposure Unit 4	No human health non-radiological COCs
Exposure Unit 5	No human health non-radiological COCs
Exposure Unit 6	No human health non-radiological COCs
Sediment Human Health COCs (HI>1 or ILCR >10^{-6})	
Exposure Unit 1	No human health non-radiological COCs
Exposure Unit 2	No human health non-radiological COCs
Exposure Unit 3	Benzo(a)pyrene
Exposure Unit 4	Benzo(a)pyrene
Exposure Unit 5	No human health non-radiological COCs
Exposure Unit 6	No human health non-radiological COCs
Surface Water Human Health COCs (HI>1 or ILCR >10^{-6})	
Exposure Unit 1	No human health non-radiological COCs
Exposure Unit 2	No human health non-radiological COCs
Exposure Unit 3	No human health non-radiological COCs
Exposure Unit 4	No human health non-radiological COCs
Exposure Unit 5	No human health non-radiological COCs
Exposure Unit 6	No human health non-radiological COCs
Site-Wide Groundwater Human Health COCs (HI>1 or ILCR >10^{-6})	
Exposure Units 1, 2 and 3	Manganese

Table 8.2. Human Health Radiological Constituents of Concern Identified by Exposure Unit

Soil Radiological COCs (HI>1 or ILCR >10^{-6})	
Exposure Unit 1	Radium-226 Thorium-230 Uranium-235 Uranium-238
Exposure Unit 2	Radium-226 Thorium-230 Uranium-235 Uranium-238
Exposure Unit 3	Protactinium-231 Radium-226
Exposure Unit 4	No human health radiological COCs
Exposure Unit 5	No human health radiological COCs
Exposure Unit 6	No human health radiological COCs
Sediment Human Health COCs (HI>1 or ILCR >10^{-6})	
Exposure Unit 3	Radium-226
Exposure Unit 4	No human health radiological COCs
Surface Water Human Health COCs (HI>1 or ILCR >10^{-6})	
Exposure Unit 3	No human health radiological COCs
Exposure Unit 4	No human health radiological COCs
Exposure Unit 5	No human health radiological COCs
Site-Wide Groundwater Human Health COCs (HI>1 or ILCR >10^{-6})	
Exposure Units 1, 2, and 3	Uranium-234, Uranium-235, Uranium-238

Table 8.3. Ecological Constituents of Concern Identified by Exposure Unit

Soil Ecological COCs (EEQ>1)		
Exposure Unit 1	Beryllium Cadmium Lead	Fluoride Benzo(a)pyrene Aroclor-1254
Exposure Unit 2	Beryllium Boron Cadmium Chromium Copper Lead	Mercury Nickel Thallium Zinc Fluoride
Exposure Unit 3	Beryllium Lead	Selenium
Exposure Unit 4	Antimony Beryllium Cadmium	Lead Thallium
Exposure Unit 5	Lead	
Exposure Unit 6	No ecological COC	
Sediment Ecological COCs (EEQ>1)		
Exposure Unit 1	No ecological COC	
Exposure Unit 2	No ecological COC	
Exposure Unit 3	Cadmium Copper Iron Lead	Mercury Nickel Silver Zinc
Exposure Unit 4	Cadmium Copper	Lead Silver
Exposure Unit 5	No ecological COC	
Exposure Unit 6	No ecological COC	
Surface Water Ecological COCs (EEQ>1)		
Exposure Unit 1	No ecological COC	
Exposure Unit 2	No ecological COC	
Exposure Unit 3	Aluminum Barium Beryllium Boron Cadmium Copper Iron	Lead Manganese Mercury Silver Strontium Fluoride Bis(2-ethylhexyl)phthalate
Exposure Unit 4	Aluminum Barium Boron Iron Bis(2-ethylhexyl)phthalate	Lead Manganese Strontium Fluoride
Exposure Unit 5	No ecological COC	
Exposure Unit 6	No ecological COC	

Table 8.4. Risk-Based Concentrations for COCs for RME Scenarios (Page 1 of 4)

EXPOSURE UNIT 1 SURFACE SOIL (0 - 2 FT)				
Receptor	**COC**	**EPC (mg/kg)**	**RBC - Cancer 1×10^{-6}**	**RBC – Non-cancer HI = 1**
Current/Future Industrial Worker	Benzo(a)anthracene	47.20	7.74E+00	--
	Benzo(a)pyrene	39.10	7.67E-01	--
	Benzo(b)fluoranthene	59.90	7.78E+00	--
	Aroclor-1254	3.20	2.67E+00	2.13E+06
Future Resident Farmer - Adult	Benzo(a)anthracene	47.20	6.08E-01	--
	Benzo(a)pyrene	39.10	6.08E-02	--
	Benzo(b)fluoranthene	59.90	6.08E-01	--
	Dibenz(a,h)anthracene	0.46	6.08E-02	--
	Indeno(1,2,3-c,d)pyrene	2.01	6.08E-01	--
	Aroclor-1254	3.20	2.10E-01	6.32E+00
Future Resident Farmer - Child	Benzo(a)anthracene	47.20	9.80E-01	--
	Benzo(a)pyrene	39.10	9.80E-02	--
	Benzo(b)fluoranthene	59.90	9.80E-01	--
	Dibenz(a,h)anthracene	0.46	9.80E-02	--
	Indeno(1,2,3-c,d)pyrene	2.01	9.80E-01	--
	Aroclor-1254	3.20	3.52E-01	1.53E+00

EXPOSURE UNIT 1 TOTAL SOIL (0 - 10 FT)				
Receptor	**COC**	**EPC (mg/kg)**	**RBC - Cancer 1×10^{-6}**	**RBC – Non-cancer HI = 1**
Future Resident Farmer - Adult	Benzo(a)anthracene	17.70	6.10E-01	--
	Benzo(a)pyrene	14.70	6.13E-02	--
	Benzo(b)fluoranthene	22.30	6.03E-01	--
	Dibenz(a,h)anthracene	0.46	6.11E-02	--
	Indeno(1,2,3-c,d)pyrene	2.01	6.09E-01	--
	Aroclor-1254	3.43	2.14E-01	6.35E+00
Future Resident Farmer - Child	Benzo(a)anthracene	17.70	9.83E-01	--
	Benzo(a)pyrene	14.70	9.80E-02	--
	Benzo(b)fluoranthene	22.30	9.70E-01	--
	Dibenz(a,h)anthracene	0.46	9.74E-02	--
	Indeno(1,2,3-c,d)pyrene	2.01	9.57E-01	--
	Aroclor-1254	3.43	3.54E-01	1.56E+00

EXPOSURE UNIT 2 SURFACE SOIL (0 - 2 FT)				
Receptor	**COC**	**EPC (mg/kg)**	**RBC - Cancer 1×10^{-6}**	**RBC – Non-cancer HI = 1**
Current/Future Industrial Worker	Benzo(a)pyrene	0.92	7.68E-01	--
	Lead	1380.00	--	9.58E+02
Future Resident Farmer - Adult	Benzo(a)anthracene	0.89	6.08E-01	--
	Benzo(a)pyrene	0.92	6.08E-02	--
	Benzo(b)fluoranthene	1.14	6.08E-01	--
	Indeno(1,2,3-cd)pyrene	0.72	6.08E-01	--
	Lead	1380.00	--	4.00E+02

Table 8.4. Risk-Based Concentrations for COCs for RME Scenarios (Page 2 of 4)

EXPOSURE UNIT 1 SURFACE SOIL (0 - 2 FT) (continued)				
Receptor	**COC**	**EPC (mg/kg)**	**RBC - Cancer 1 x 10^{-6}**	**RBC – Non-cancer HI = 1**
Future Resident Farmer - Child	Benzo(a)pyrene	0.92	9.80E-02	--
	Benzo(b)fluoranthene	1.14	9.80E-01	--
	Beryllium	765.00	1.68E+04	1.56E+02
	Cadmium	83.50	2.24E+04	3.75E+01
	Lead	1380.00	--	4.00E+02
EXPOSURE UNIT 2 TOTAL SOIL (0 - 10 FT)				
Receptor	**COC**	**EPC (mg/kg)**	**RBC - Cancer 1 x 10^{-6}**	**RBC – Non-cancer HI = 1**
Future Resident Farmer - Adult	Benzo(a)anthracene	0.92	6.13E-01	--
	Benzo(a)pyrene	0.89	5.92E-02	--
	Benzo(b)fluoranthene	1.01	5.94E-01	--
	Indeno(1,2,3-cd)pyrene	0.65	5.94E-01	--
	Lead	561.00	--	4.00E+02
Future Resident Farmer - Child	Benzo(a)pyrene	0.89	9.76E-02	--
	Benzo(b)fluoranthene	1.01	1.01E+00	--
	Beryllium	514.00	1.66E+04	1.56E+02
	Lead	561.00	--	4.00E+02
EXPOSURE UNIT 3 SURFACE SOIL (0 - 2 FT)				
Receptor	**COC**	**EPC (mg/kg)**	**RBC - Cancer 1 x 10^{-6}**	**RBC – Non-cancer HI = 1**
Current/Future Resident Farmer - Adult	None			
Current/Future Resident Farmer - Child	Beryllium	155.00	1.68E+04	1.56E+02
EXPOSURE UNIT 3 TOTAL SOIL (0 - 10 FT)				
Receptor	**COC**	**EPC (mg/kg)**	**RBC - Cancer 1 x 10^{-6}**	**RBC – Non-cancer HI = 1**
Current/Future Resident Farmer - Adult	None			
Current/Future Resident Farmer - Child	None			
EXPOSURE UNIT 3 SURFACE WATER				
Receptor	**COC**	**EPC (mg/L)**	**RBC - Cancer 1 x 10^{-6}**	**RBC – Non-cancer HI = 1**
Current/Future Resident Farmer - Adult	None			
Current/Future Resident Farmer - Child	None			

Table 8.4. Risk-Based Concentrations for COCs for RME Scenarios (Page 3 of 4)

EXPOSURE UNIT 3 SEDIMENT				
Receptor	**COC**	**EPC (mg/kg)**	**RBC - Cancer 1×10^{-6}**	**RBC – Non-cancer HI = 1**
Current/Future Resident Farmer - Adult	Benzo(a)pyrene	1.78	1.11E+00	--
Current/Future Resident Farmer - Child	None			
EXPOSURE UNITS 1, 2, AND 3 SITE-WIDE GROUNDWATER				
Receptor	**COC**	**EPC (mg/L)**	**RBC - Cancer 1×10^{-6}**	**RBC – Non-cancer HI = 1**
Current/Future Industrial Worker	None			
Current/Future Resident Farmer - Adult	None			
Current/Future Resident Farmer - Child	Manganese	0.37	--	2.66E-01
EXPOSURE UNIT 4 SURFACE SOIL (0 - 2 FT)				
Receptor	**COC**	**EPC (mg/kg)**	**RBC - Cancer 1×10^{-6}**	**RBC – Non-cancer HI = 1**
Current/Future Adolescent Trespasser	None			
EXPOSURE UNIT 4 SURFACE WATER				
Receptor	**COC**	**EPC (mg/L)**	**RBC - Cancer 1×10^{-6}**	**RBC – Non-cancer HI = 1**
Current/Future Adolescent Trespasser	None			
EXPOSURE UNIT 4 SEDIMENT				
Receptor	**COC**	**EPC (mg/kg)**	**RBC - Cancer 1×10^{-6}**	**RBC – Non-cancer HI = 1**
Current/Future Adolescent Trespasser	Benzo(a)pyrene	0.20	1.99E-01	--
EXPOSURE UNIT 5 SURFACE SOIL (0 - 2 FT)				
Receptor	**COC**	**EPC (mg/kg)**	**RBC - Cancer 1×10^{-6}**	**RBC – Non-cancer HI = 1**
Current/Future Adolescent Trespasser	None			
EXPOSURE UNIT 5 SURFACE WATER				
Receptor	**COC**	**EPC (mg/L)**	**RBC - Cancer 1×10^{-6}**	**RBC – Non-cancer HI = 1**
Current/Future Adolescent Trespasser	None			

Table 8.4. Risk-Based Concentrations for COCs for RME Scenarios (Page 4 of 4)

EXPOSURE UNIT 6 SURFACE SOIL (0 - 2 FT)				
Receptor	**COC**	**EPC (mg/kg)**	**RBC - Cancer 1×10^{-6}**	**RBC – Non-cancer HI = 1**
Current/Future Adolescent Trespasser	None			

COC = Constituent of Concern
RME = Reasonable Maximum Exposures
EPC = Exposure Point Concentration
HI = Hazard Index (Non Cancer Risk)
ILCR = Incremental Lifetime Cancer Risk
RBC = Risk Based Concentration

Table 8.5. Action Levels for the Luckey Site

Receptor	Medium (units)	Radionuclide	Action Level and Basis			
			10^{-6} Risk	40 CFR 192 [a]	Criterion 6(6) [b]	10 CFR 20 [c]
RFA	Soil (pCi/g)	Pa-231	0.17	-	77	59
		Ra-226	0.0092	5.0	5.0	3.8
		Th-230 [d]	0.061	-	34	26
		U-235	0.23	-	74	57
		U-238 [e]	0.90	-	370	290
	Sediment (pCi/g)	Ra-226	1.9	5.0	5.0	800
	Groundwater (pCi/L)	U-234	0.94	-	140	110
		U-235	0.88	-	150	120
		U-238 [e]	0.67	-	150	120
RFC	Soil (pCi/g)	Ra-226	0.044	5.0	5.0	3.7
		Th-230 [d]	0.30	-	34	25
		U-238 [e]	4.2	-	360	270
	Sediment (pCi/g)	Ra-226	4.5	5.0	5.0	400
	Groundwater (pCi/L)	U-234	8.3	-	260	190
		U-238 [e]	5.9	-	270	200
IW	Soil (pCi/g)	Ra-226	0.13	5.0	5.0	12
		Th-230 [d]	0.88	-	34	84
	Groundwater (pCi/L)	U-238 [e]	8.1	-	130	310

All values rounded to two significant digits.

[a] Concentration for surface soils - subsurface limit is 15 pCi/g
[b] Concentration corresponding to benchmark dose
32.5 mrem/yr = resident farmer – adult (RFA) benchmark
33.6 mrem/yr = resident farmer – child (RFC) benchmark
10.1 mrem/yr = industrial worker (IW) benchmark
[c] Concentration corresponding to 25 mrem/yr
[d] Value conservatively represents Th-230 limit for year 1,000 allowing ingrowth of Ra-226
[e] Concentration may be reduced if U-238 is used as a surrogate for other uranium isotopes

9.0 REFERENCES 9-1

9.0 REFERENCES

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