Science Applications International Corporation
An Employee-Owned Company

October 16, 2008

Dr. Thomas McLaughlin
Materials Decommissioning Branch
Division of Waste Management and Environmental Protection
Office of Nuclear Materials Safety and Safeguard
Two While Flint North
11545 Rockville Pike
Rockville, MD 20852-2738

Dear Dr. McLaughlin:

Through discussions with the U.S. Nuclear Regulatory Commission and the U.S. Army and at the direction of the U.S. Army, Science Applications International Corporation (SAIC) is proposing the following changes to *Field Sampling Plan (FSP) Addendum 7 – Depleted Uranium Impact Area Site Characterization: Soil Sampling and Analysis, Corrosion Study, Partition Coefficient Study, Modeling Overview, and Slug Testing*:

1. Change version throughout document from "Final" to "Revised Final" and date from "August 2008" to "October 2008."
2. Change the conceptual site model (CSM, Figure 3-1) to show a pathway for wildlife or livestock receptors potentially exposed to groundwater leaching/infiltrating through soil into surface water bodies.
3. Include Empirical Laboratories, LLC to perform non-radiological analyses of soil and rainwater associated with the corrosion and K_d studies in Sections 3, 4, 5, 6, and 8.
4. Clarify the distinction between the corrosion study and the leachability testing in Section 4. The corrosion study includes speciation testing and leachability testing.
5. Describe the rationale for collecting extent and depth samples 1m or further from DU penetrators in Section 4.2.2, which is to enable the dose modeling to evaluate potential exposures to a full distribution of the range of uranium concentrations expected within the DU Impact Area. Soil samples also will be collected above and under penetrators for bounding the upper end of possible uranium concentrations.
6. Clarify the sampling depths with respect to soil collected above and under penetrators for the corrosion and K_d studies in Section 4.2.4.
7. Describe the rationale for collecting subsurface penetrators from shallower versus deeper depths in Sections 4.2.4 and 5.2. Penetrators located more closely to the ground surface will be exposed to more atmospheric oxygen and moisture than deeper penetrators. These conditions are more conducive to oxidation.
8. Describe the approach for collecting samples above and below penetrators that partially extend underground and describing the orientation of the penetrator (i.e., azimuth, attitude, and relative location of sample) in Sections 4.2.4 and 5.2.
9. Clarify the definitions of "surface soil" and "subsurface soil" presented in Section 4.3.

An Employee-Owned Company

10. State objectives of corrosion study in Section 5, which is to identify the nature of the corrosion products, particularly the different uranium valence states and chemical species, and the rates of penetrator corrosion. In addition, re-ordered introductory paragraphs to follow a more logical thought process.
11. Add requirement for duplicate penetrator segments to be collected from adjacent portions to ensure that the tests are conducted on segments similarly exposed to oxidative conditions.
12. Describe the rationale for using rainwater as the leachant for leachability testing in Section 5.3. Rainwater is more representative because the majority of the penetrators are located at or near ground surface (limiting the applicability of deeper groundwater) and fewer are present in permanent streams and creeks (limiting the applicability of surface water).
13. Describe the tradeoffs and logic behind the selection of the leachability test duration (i.e., 30 weeks) in Section 5.3. Tradeoffs include required date for decommissioning plan, time needed to complete test and conduct modeling with data from test, duration that penetrators have been exposed to weathering at JPG, additional lines of evidence used to support conclusions, and option to extend duration of test if leaching is not observed during the planned test period.
14. Clarify the inter-relationships between the corrosion study, K_d study, and modeling in Section 5.4. The corrosion product speciation will identify specific forms and valence states of uranium present, which will assist in comparing K_d study results to values found in literature. The uranium speciation modeling will determine the equilibrium compositions of dilute aqueous solutions (mass distribution among dissolved species, adsorbed species, and multiple solid phases under a variety of conditions including a gas phase with constant partial pressures), which can be compared to the results of the corrosion product speciation tests.
15. Determined that ASTM D4319-93, Standard Test Method for Distribution Ratios by the Short-Term Batch Method has been withdrawn. Another method for conducting K_d studies is included in Appendix C of USEPA's *Understanding Variation In Partition Coefficient, K_d, Values* (1999). It is the *Standard Method Used at Pacific Northwest National Laboratory for Measuring Laboratory Batch K_d Values*, which is also a batch method like the withdrawn ASTM method. In the absence of a suitable replacement, we recommended using TestAmerica's Standard Operating Procedure, which is based on the ASTM method.
16. Change requirement from conducting 24 desorption K_d tests to 6 adsorption and 18 desorption tests in Section 6. The reason for this change is that both adsorption and desorption are believed to be occurring. Historical soil sampling and visual observations confirm that surface and near-surface adsorption appears to be limiting subsurface migration, so it appears that desorption reactions are more significant than adsorption for evaluating the fate and transport mechanisms related to the 1,000-year period of interest.

An Employee-Owned Company

17. Clarify statement in Section 6.1 that validity of K_d values are predicated on solutions reaching steady state and solutions must not be oversaturated (i.e., solubility limits have not been exceeded).
18. Add rationale in Section 6.3 for the 360 pCi/g upper concentration limit for K_d study that is based on tests conducted by Pacific Northwest National Laboratory (PNNL) involving various pH levels, carbonate concentrations, uranium concentrations, and total ionic strengths.
19. Add statement about the disposition of DU penetrators and fragments following the completion of the laboratory tests to Section 9. All penetrators and fragments will be returned to JPG and disposed of via the Joint Munitions Command at Rock Island, Illinois.
20. Define "low permeability skin" in Section 11.3.1. Skins or well-skins are near-well zones of the aquifer altered from drilling and well installation. The text also describes the potential effects of these skins and includes a reference for how the potential effects will be handled during the evaluation of the slug test results.
21. Clarify that sportspersons evaluated in residual dose modeling will drink incidental amounts of water in Table 12-1.
22. Expand the potential scope of the sensitivity/uncertainty analysis in Section 12.2.4 by including possible additional analyses for combinations of key model input parameters as necessary based on results of single-variable sensitivity analysis and site conditions.

Accordingly, SAIC is submitting six hard copies and 2 electronic copies on CD-ROM of the *Revised Final FSP Addendum 7 – Depleted Uranium Impact Area Site Characterization: Soil Sampling and Analysis, Corrosion Study, Partition Coefficient Study, Modeling Overview, and Slug Testing*. Note, three of the hard copies have been provided with the changes marked to facilitate your review. If you have any questions, please contact Mr. Paul Cloud, Jefferson Proving Ground (JPG) License Radiation Safety Officer, U.S. Army JPG at (410) 436-2381, E-mail address: paul.d.cloud@us.army.mil.

Sincerely,

Joseph N. Skibinski

Joseph N. Skibinski
Project Manager, Science Applications International Corporation (SAIC)
11251 Roger Bacon Drive
Reston, VA 20190
(703) 810-8994
(703) 709-1042 Fax
skibinskij@saic.com

cc: Paul Cloud
Brooks Evens
SAIC Central Records Project File (transmittal memo only)

U.S. Army Corps of Engineers

FIELD SAMPLING PLAN ADDENDUM 7

Depleted Uranium Impact Area Site Characterization: Soil Sampling and Analysis, Corrosion Study, Partition Coefficient Study, Modeling Overview, and Slug Testing Jefferson Proving Ground, Madison, Indiana

REVISED FINAL

Prepared for:

U.S. Department of Army
Installation Support Management Activity
5183 Blackhawk Road
Aberdeen Proving Ground, Maryland 21010-5424

and

U.S. Army Corps of Engineers
Louisville District
600 Dr. Martin Luther King, Jr. Place
Louisville, Kentucky 40202-2230

Submitted by:

Science Applications International Corporation
11251 Roger Bacon Drive
Reston, Virginia 20190

Contract No. DACW62-03-D-0003
Delivery Order No. CY07

~~August~~ October 2008

FIELD SAMPLING PLAN ADDENDUM 7

Depleted Uranium Impact Area Site Characterization: Soil Sampling and Analysis, Corrosion Study, Partition Coefficient Study, Modeling Overview, and Slug Testing Jefferson Proving Ground, Madison, Indiana

REVISED FINAL

Prepared for:

U.S. Department of Army
Installation Support Management Activity
5183 Blackhawk Road
Aberdeen Proving Ground, Maryland 21010-5424

and

U.S. Army Corps of Engineers
Louisville District
600 Dr. Martin Luther King, Jr. Place
Louisville, Kentucky 40202-2230

Submitted by:

Science Applications International Corporation
11251 Roger Bacon Drive
Reston, Virginia 20190

Contract No. DACW62-03-D-0003
Delivery Order No. CY07

~~August~~ October 2008

THIS PAGE WAS INTENTIONALLY LEFT BLANK

FIELD SAMPLING PLAN ADDENDUM 7
Depleted Uranium Impact Area Site Characterization: Soil Sampling and Analysis, Corrosion Study, Partition Coefficient Study, Modeling Overview, and Slug Testing
Jefferson Proving Ground, Madison, Indiana

Contract No. DACW62-03-D-0003
Delivery Order No. CY07

Nuclear Regulatory Commission License No. 24-32591-01

~~August~~ October 2008

Revised Final

	(703) 810-8994	10/15/08
Joseph N. Skibinski Project Manager	Telephone	Date
	(703) 318-4763	10/15/08
Joseph E. Peters Quality Assurance Officer	Telephone	Date
	(314) 770-3027	10/15/08
Randy C. Hansen Health and Safety Officer	Telephone	Date
	(314) 770-3068	10/15/08
Dennis R. Chambers Radiation Safety Officer	Telephone	Date
	(765) 278-3520	10/15/08
Seth T. Stephenson Field Manager	Telephone	Date
	(717) 901-9923	10/15/08
Todd D. Eaby Licensed Indiana Professional Geologist (Registration # 2215)	Telephone	Date

THIS PAGE WAS INTENTIONALLY LEFT BLANK

CERTIFICATION 4

CONTRACTOR STATEMENT OF INDEPENDENT TECHNICAL REVIEW

Science Applications International Corporation (SAIC) has prepared this Field Sampling Plan (FSP) Addendum 7 for performing site characterization at Jefferson Proving Ground's (JPG's) Depleted Uranium (DU) Impact Area, located in Madison, Indiana. Notice is hereby given that an independent technical review has been conducted that is appropriate to the level of risk and complexity inherent in the project, as defined in the Quality Control Plan (QCP). During the independent technical review, compliance with established policy principles and procedures, utilizing justified and valid assumptions, was verified. This included review of assumptions; methods, procedures, and material used in analyses; alternatives evaluated; the appropriateness of data used and level of data obtained; and reasonableness of the results, including whether the product meets the customer's needs consistent with law and existing USACE policy.

______________________________	10/15/08
Joseph N. Skibinski Project Manager Science Applications International Corporation	Date

______________________________	10/15/08
Joseph E. Peters Quality Assurance Officer Science Applications International Corporation	Date

______________________________	10/15/08
Michael L. Barta Independent Technical Review Science Applications International Corporation	Date

Significant concerns and explanation of the resolutions, if identified, are documented within the project file. As noted above, all concerns resulting from independent technical review of the project have been considered.

______________________________	10/15/08
Lisa D. Jones-Bateman Vice President Science Applications International Corporation	Date

THIS PAGE WAS INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

APPENDICES

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
ANS	American National Standard
ANSI	American National Standard Institute
ASTM	American Society for Testing and Materials
BLS	Below Land Surface
BRAC	Base Realignment and Closure
BU	Business Unit
CD	Compact Disc
CFR	Code of Federal Regulations
CHP	Certified Health Physicist
cm	Centimeter(s)
cm^2	Square Centimeter(s)
cm^3	Cubic Centimeter(s)
CoC	Chain of Custody
cpm	Counts per Minute
CSM	Conceptual Site Model
CSP	Certified Safety Professional
CWM	Chemical Warfare Material
CY	Calendar Year
dpm	Disintegrations per Minute
DQO	Data Quality Objective
DU	Depleted Uranium
E&I	Engineering and Infrastructure
EC&HS	Environmental Compliance & Health and Safety
EI	Electrical Imaging
EOD	Explosive Ordnance Disposal
ERM	Environmental Radiation Monitoring
FEHM	Finite Element Heat and Mass
FSP	Field Sampling Plan
ft	Feet/Foot
FTP	Field Technical Procedure
gal	Gallon(s)
GPL	GPL Laboratories, LLLP
GPS	Global Positioning System
HASP	Health and Safety Plan
HDPE	High-Density Polyethylene
HPT	Health Physics Technician
HSPF	Hydrologic Simulation Program–Fortran
I.D.	Identification
IDW	Investigation-derived Waste
in.	Inch(es)
in^3	Cubic Inch(es)
JPG	Jefferson Proving Ground
K	Permeability
K_d	Partition or Distribution Coefficient
kg	Kilogram(s)
L	Liter(s)
lb	Pound(s)
m	Meter(s)

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

m^2	Square Meter(s)
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MCLinc	Materials and Chemistry Laboratory, Inc.
MDC	Minimum Detectable Concentration
MDCR	Minimum Detectable Count Rate
mL	Milliliter(s)
mrem	Milli Radiation Equivalent Man
MS/MSD	Matrix Spike/Matrix Spike Duplicate
mSv	Milli Sievert
NaI	Sodium Iodide
NRC	U.S. Nuclear Regulatory Commission
NUREG	U.S. Nuclear Regulatory Commission Regulation
OE	Ordnance and Explosives
oz	Ounce(s)
PARCC	Precision, Accuracy, Representativeness, Comparability, and Completeness
pCi/g	Picocuries per Gram
PNNL	Pacific Northwest National Laboratory
POC	Point of Contact
psi	Pounds per Square Inch
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
QCP	Quality Control Plan
Rd	Distribution Ratio
redox	Reduction/Oxidation
RESRAD	Residual Radiation
RSO	Radiation Safety Officer
SAIC	Science Applications International Corporation
SEM-EDS	Scanning Electron Microscopy/Energy Dispersive Spectroscopy
SESOIL	Seasonal Soil Compartment
SHSO	Site Health and Safety Officer
SOP	Standard Operating Procedure
SSURGO	Soil Survey Geographic Database
SWMM	Storm Water Management Model
TEDE	Total Effective Dose Equivalent
TOC	Total Organic Carbon
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UXO	Unexploded Ordnance
XPS	X-Ray Photoelectron Spectroscopy
XRD	X-Ray Diffraction

THIS PAGE WAS INTENTIONALLY LEFT BLANK

1. INTRODUCTION

Jefferson Proving Ground (JPG), located in Madison, Indiana, is pursuing termination of their U.S. Nuclear Regulatory Commission (NRC) Source Material License, SUB-1435, which authorizes possession of depleted uranium (DU). To support the decommissioning and license termination process, the Army is performing additional characterization of the DU Impact Area, a 2,080-acre area located north of the firing line. The DU Impact Area is the location where DU penetrators impacted after being fired from three fixed gun positions located on the firing line.

This document is Addendum 7 to the Field Sampling Plan (FSP) (SAIC 2005a). Science Applications International Corporation (SAIC) has prepared this Addendum in accordance with the scope of work for "Continued Site Characterization of the Depleted Uranium Impact Area" under U.S. Army Corps of Engineers (USACE) Contract No. DACW62-03-D-0003, dated 29 August 2007.

This FSP Addendum documents and provides details that were not addressed or have been modified from the information presented in the original FSP (SAIC 2005a) for the following topics:

- Determination of the lateral and vertical extent of soil contamination
- Completion of a partition coefficient (K_d) study
- Investigation of DU corrosion products to include uranium speciation and corrosion rates
- Slug testing
- Modeling overview.

The Addendum incorporates data quality objectives (DQOs) for soil sampling and analysis and the site-specific corrosion and partition coefficient studies; procedures for soil sampling and laboratory analysis; actions relevant to collection of DU penetrators and soil and water for the corrosion investigation and partition coefficient studies; and procedures for completing and analyzing slug tests at site monitoring wells to obtain hydraulic conductivity data. Each of these actions provides critical, site-specific information for incorporation into modeling to evaluate contaminant fate and transport, which in turn will affect the resultant doses to the average member of the critical group required by 10 Code of Federal Regulations (CFR) 20, Subpart E.

Additional sampling not described or included in this Addendum that is determined to be necessary may be performed. Such sampling may be recommended to the Army by SAIC, may result from Army evaluation of project information, or may be a product of discussions between the Army and NRC. Such additional sampling will be conducted in accordance with the protocols described in this Addendum unless specific modifications to the described protocols are deemed necessary or are requested by the Army or NRC. If so, modifications to the requirements and protocols documented in this Addendum will be included in future addenda.

This Addendum follows the same format and includes relevant sections of the FSP by reference. This document is to be used in conjunction with the existing FSP, not as a replacement. SAIC assumes no liability for the use of this information for any other purpose than as stated in this Addendum or the original FSP.

The information provided in this plan was developed for use by SAIC and subcontractors to complete the collection and laboratory analysis of soil samples for total and isotopic uranium, and collection of other related field data. The updated project organization and responsibilities are presented in Section 2. Project DQOs are presented in Section 3. Soil sampling and analysis is summarized in Section 4. The procedures and protocols for the DU penetrator corrosion study are contained in Section 5. The K_d study is presented in Section 6. Section 7 discusses the forms used to document field operations. Section 8 summarizes sample handling, packaging, and shipment requirements. Information concerning the handling of investigation-derived waste (IDW) is provided in Section 9. Section 10 describes radiological responsibility and licensing. The methods for conducting and analyzing data collected during monitoring well slug tests are presented in Section 11. The general approach for conducting dose and fate and transport modeling is presented in Section 12. The references used in preparing this Addendum are provided in Section 13. The following appendices provide supporting documentation:

- ***Appendix A – Scan Detection of Depleted Uranium Fragments with 2- by 2-in. NaI Scintillation Detectors***—This appendix contains information relative to detectability of pieces of DU penetrators under field conditions.
- ***Appendix B – SAIC Field Forms***—This appendix (provided on accompanying compact disc [CD]) includes copies of applicable field forms that will be followed during the field program described in this Addendum.

2. PROJECT ORGANIZATION AND RESPONSIBILITIES

SAIC personnel and subcontractors are required to comply with all of the policies and procedures specified in this FSP Addendum, associated plans (SAIC 2005a, b, and c), the Health and Safety Plan (HASP) Addendum 6 (under development), and other related project documents. The following summarizes the roles and responsibilities of the SAIC personnel conducting and overseeing the collection and analysis of environmental media, DU penetrators, and associated field measurements:

- Mr. Joseph N. Skibinski is SAIC's JPG Project Manager. He is responsible for all activities conducted at JPG, including the sampling and analysis, as well as for all external coordination.
- Mr. Todd D. Eaby is SAIC's Hydrogeology and Multimedia Sampling and Analysis Lead for the sampling and analysis activities, hydrology, and hydrolgeologic investigation activities. He is responsible for developing the plans associated with the sampling, hydrology, and hydrogeologic investigations. While at JPG, he will be the primary point of contact (POC) for SAIC. Mr. Eaby is a Licensed Professional Geologist in the State of Indiana.
- Mr. Seth T. Stephenson will serve as the Field Manager and Site Health and Safety Officer (SHSO) and provide anomaly avoidance. He is a graduate of the Explosive Ordnance Disposal (EOD) School in Indian Head, Maryland. When Mr. Eaby is not at JPG, Mr. Stephenson will be the primary POC for SAIC. He is responsible for ensuring work activities are conducted in accordance with the procedures and policies specified in this FSP Addendum, the HASP Addendum 6 (under development), and other related project documents.
- Mr. Randy C. Hansen will serve as the Project Health and Safety Officer. He is a Certified Safety Professional (CSP) and a Certified Health Physicist (CHP) and has supervised the safety and radiation protection programs for remedial action projects involving radiological contamination to include experience supporting field operations at JPG. Mr. Hansen has served as a radiological risk assessor and will perform dose modeling using the Residual Radiation (RESRAD) OFFSITE computer code in support of JPG decommissioning efforts.
- Mr. Dennis R. Chambers will serve as the Radiation Safety Officer (RSO). He is a CHP in SAIC's St. Louis office and will provide radiation protection and health physics support for JPG decommissioning efforts. Mr. Chambers is responsible for developing plans for sampling associated with extent and depth of contamination determinations, background determinations, corrosion testing, and partition coefficient (K_d) determination studies. He also is responsible for developing plans for the gamma walkover surveys to be completed in conjunction with the previously mentioned sampling tasks as well as providing oversight of the health physics technicians (HPTs) providing health and safety monitoring, site-specific training, and completing the gamma walkover surveys.
- Mr. Joseph E. Peters will be the Quality Control (QC) Manager for all of SAIC's work at JPG. He will ensure that data collection is accomplished following the established procedures specified in the project plans and in compliance with established SAIC procedures.
- Mr. Tad C. Fox will conduct fate and transport modeling to evaluate the potential migration of DU in groundwater and surface water. This modeling will be conducted in parallel with modeling performed using RESRAD-OFFSITE and also will address RESRAD-OFFSITE model limitations. Mr. Fox is a Registered Professional Geologist in the State of Indiana.

THIS PAGE WAS INTENTIONALLY LEFT BLANK

3. DATA QUALITY OBJECTIVES

The DQO process is a strategic planning approach based on the scientific method that is implemented to prepare for a data collection activity. It provides a systematic procedure for defining the criteria that a data collection design should satisfy, including where and when to collect samples, how many samples to collect, and the tolerable level of decision errors for the study. The DQO process includes the seven steps (USEPA 2000) described in further detail in this section.

3.1 STEP 1 – STATE THE PROBLEM

The DQO process (USEPA 2000 and 2006) specifies that Step 1 identifies the planning team and decision makers, includes a statement of the problem, and describes available resources and the project schedule. Each element is discussed below.

3.1.1 Identification of Planning Team Members

The planning team consists of the Army and NRC. The Army is represented by Mr. Paul Cloud and NRC is represented by Dr. Tom McLaughlin. SAIC has been contracted by the Army to support the site characterization.

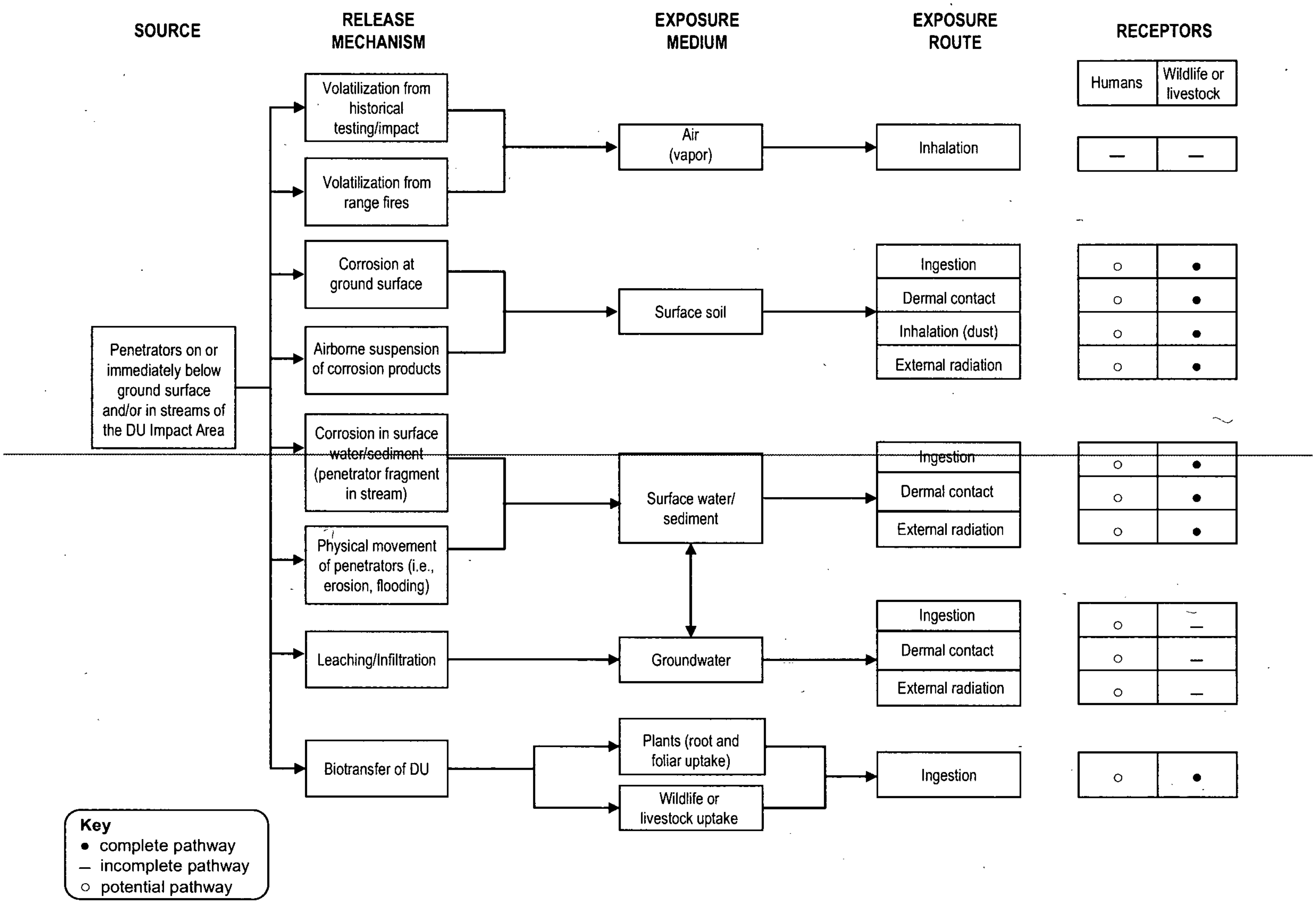
3.1.2 Description of Problem

The Army performed nondestructive testing of DU penetrators at JPG for approximately 11 years (March 1984 to May 1994) prior to closure of the installation pursuant to Base Realignment and Closure (BRAC) action. Although approximately 30,000 kg of DU were recovered, approximately 70,000 kg of residual DU exist at the site and the DU is co-located with extensive unexploded ordnance (UXO). The Army is obtaining additional technical information to determine the residual dose to the average member of the critical group over the 1,000-year period subsequent to decommissioning for comparison with criteria in Title 10, CFR (Part 20 (10 CFR 20), Subpart E.

The Army is committed to obtaining and analyzing information (including characterization data) as necessary to submit a final decommissioning plan to NRC the end of calendar year (CY) 2011 or earlier. This plan must include determination of the dose to the average member of the critical group from residual quantities of DU present within the JPG DU Impact Area. The characterization data also will be used for technical assessments pursuant to modification of the environmental radiation monitoring (ERM) program. The project is structured and phased to address the data gaps outlined in Army and NRC documentation subject to funding availability and adapted based on annual (or more frequent) meetings with NRC.

Figure 3-1 is a working graphical representation of the conceptual site model (CSM), including DU sources, release mechanisms, exposure mediums, potential exposure pathways, and potential receptors at JPG. This working draft of the CSM will be revised as data are collected and evaluated throughout the 5-year site characterization program.

The type of release affects the type and amount of DU released into the environment and the potential for exposure of humans and wildlife. In general, during the testing of DU penetrators, DU either can be released as particles in aerosols or as residual metallic pieces. These pieces are created upon impact with hard targets or can be nearly intact penetrators that missed the hard target or were fired at soft (nonarmored) targets. During DU testing at JPG between 1984 and 1994, humans and wildlife were subject to potential exposure to DU from inhalation or ingestion of particulate uranium released from the DU munitions. However, testing operations have not been conducted at JPG since 1994 and the generation of DU containing aerosols was limited due to the absence of hard-target testing. DU


SOURCE
RELEASE MECHANISM
EXPOSURE MEDIUM
EXPOSURE ROUTE
RECEPTORS
Humans
Wildlife or livestock
Penetrators on or immediately below ground surface and/or in streams of the DU Impact Area
Volatilization from historical testing/impact
Volatilization from range fires
Corrosion at ground surface
Airborne suspension of corrosion products
Corrosion in surface water/sediment (penetrator fragment in stream)
Physical movement of penetrators (i.e., erosion, flooding)
Leaching/Infiltration
Biotransfer of DU
Air (vapor)
Surface soil
Surface water/ sediment
Groundwater
Plants (root and foliar uptake)
Wildlife or livestock uptake
Inhalation
Ingestion
Dermal contact
Inhalation (dust)
External radiation
Ingestion
Dermal contact
External radiation
Ingestion
Dermal contact
External radiation
Ingestion
Key
● complete pathway
– incomplete pathway
○ potential pathway

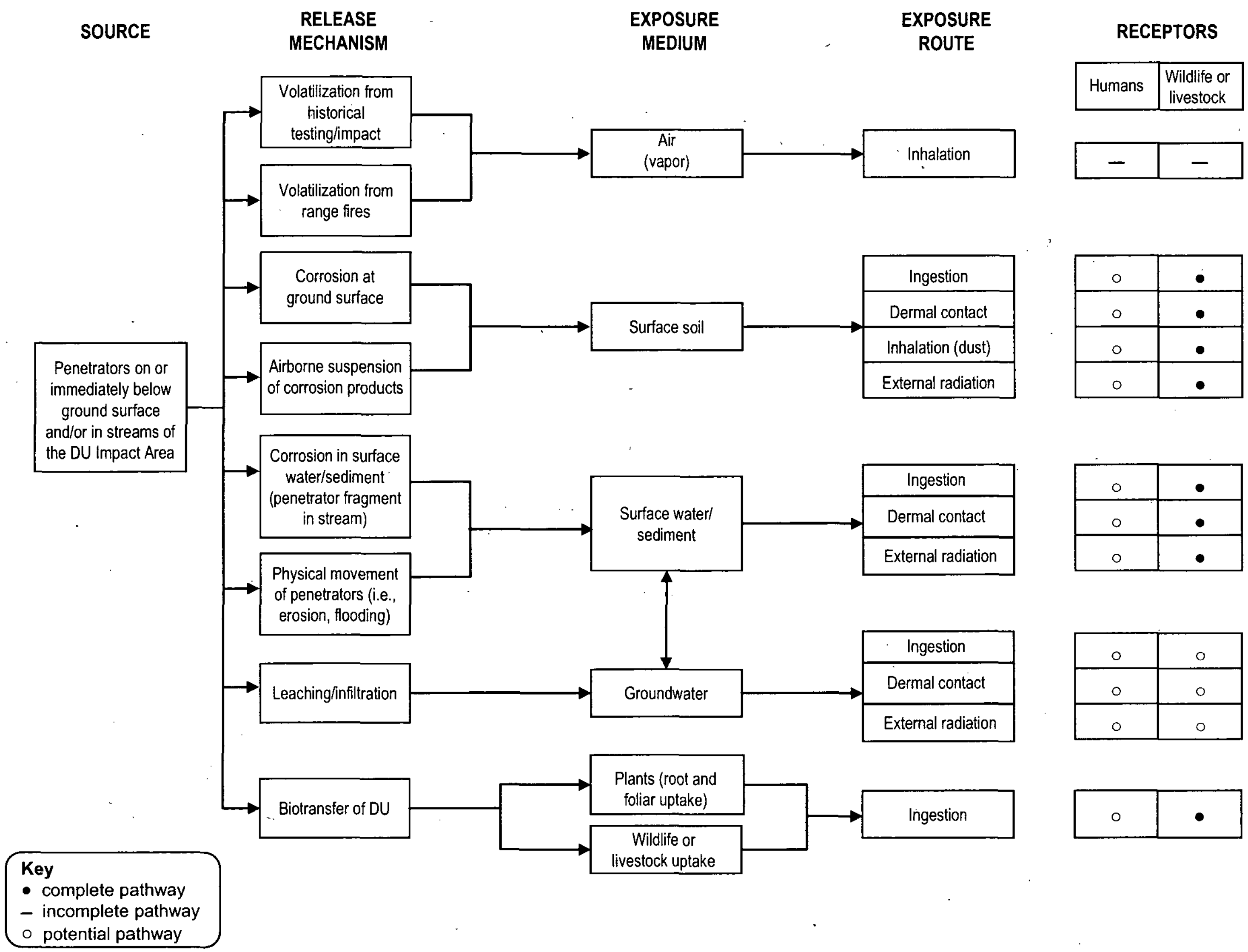


Figure 3-1. Working Conceptual Site Model of DU Transport Through the Environment at and in Close Proximity to the JPG DU Impact Area

penetrators test fired at JPG have been deposited in the DU Impact Area as fragments or nearly whole penetrators by impact with the ground surface during nondestructive testing on soft cloth (nonarmored) targets for trajectory purposes. The dose associated with the inhalation pathway is potentially significant based on uptake of resuspended uranium particles.

DU that had been distributed on or below the ground surface and/or within the surface water (streams) of the DU Impact Area as a result of the testing may be transported throughout the environment by several different processes. DU in soil or surface water can be subject to physical movement by erosion (during floods and high runoff events), and these processes may cause migration and transport of DU penetrators, fragments, or corrosion products along the ground surface and along the surface water drainageways. Corrosion of DU in the surface water or soil could enable soluble forms of DU to be absorbed by plants and incorporated within the plant matter for uptake by wildlife. Although vegetation is burned as part of a management effort or unintended fires (e.g., from lightning), the levels of DU carried in smoke associated with natural vegetation (such as the controlled burns at JPG) are not likely significant (Williams et al. 1998 and U.S. Army 2001). Leached DU from the penetrators in or on the soil and/or fragments in the surface water potentially could be transported to groundwater and surface water, which in turn could migrate to potential drinking water sources and be ingested by humans, livestock, and wildlife.

Humans at JPG may be exposed to DU from direct contact or incidental ingestion of leached DU or corrosion products from penetrators and/or fragments present in impacted surface water during recreational activities such as hunting. Fishing is not permitted in streams within the boundaries of the DU Impact Area and the nearest fishing permitted within JPG is at a lake several miles north of the DU Impact Area, in the upgradient direction; therefore, humans are not exposed to DU from direct contact while fishing. Possible exposure pathways for humans include ingestion of food (i.e., plants that have taken up uranium or meat and/or animal products from animals that have ingested DU impacted soil, water, or biota), water, or soil containing DU; inhalation of dust containing DU; or external radiation from the presence of DU.

Insoluble uranium from DU or natural sources that has been inhaled may deposit in the lungs and associated lymph nodes and may remain in the lungs for years. Soluble uranium taken into the body is transferred to the blood stream and subsequently transported to bones, liver, or kidneys. To a lesser degree, the uranium also may be deposited in muscle. Uptake from the stomach gut to the blood is low (0.2 to 5 percent) (IAEA 1989) and most ingested uranium is excreted, where it could be reingested or recycled via the soil into forage. Uptake factors of uranium from the gut to the blood for ruminants (e.g., deer, cattle, or goats) may vary depending upon environmental conditions, but are approximately five times greater than that of humans (Royal Society 2002).

Uranium characteristics, including environmental fate and transport and source-term characteristics, are critical input parameters for the estimation of radiation dose to the average member of the critical groups and are of special importance given the requirement to assess the resultant radiation doses for a period of 1,000 years after site decommissioning. The following information is, therefore, of special importance:

- Accurate characterization of the uranium source term (e.g., concentration and lateral and vertical variability) in soils within the impact area
- Measurement of site-specific parameters (e.g., corrosion rate, K_d and speciation, and slug testing), which would impact fate and transport and uptake of uranium and thus the doses to on and offsite receptors
- Determining background concentrations of uranium in site soils
- Calculating hydraulic conductivities from slug testing of the monitoring wells.

3.1.3 Resources and Relevant Deadlines for the Study

The Army provides the financial resources to conduct the investigation activities stated herein. Field investigation activities will be conducted by SAIC and specialty subcontractors (e.g., laboratories). SAIC provides the necessary technical expertise and resources to the project based on the technical requirements and schedule.

The overall project schedule of activities is summarized in Table 3-1. As project priorities are established and/or adjusted by the Army in coordination with NRC, they may adjust the project schedule to meet these priorities. Funding and technical resources can be shifted at the direction of the Army in order to meet the project priorities.

Table 3-1. Tentative Project Schedule
Jefferson Proving Ground, Madison, Indiana

Deliverable/Activity	Date
FSP	May 2005
FSP Addendum 1 – Deer Sampling	November 2005
Deer Sampling Field Work	November/December 2005 and February 2006
Fracture Trace Analysis Report	May 2006
Deer Sampling Report	August 2006
Fracture Trace Analysis Field Correlation	July 2006
FSP Addendum 2 – Soil Verification	July 2006
FSP Addendum 3 – Other Monitoring Equipment Installation and EI	July 2006
EI Field Work	July/August 2006
Soil Verification Field Work	August 2006
Stream and Cave Spring Gauge Installation	September 2006
Stream and Cave Spring Gauge Monitoring	Monthly: September 2006 – August 2007 Quarterly: October 2007 – 2010
Army/NRC Status Meeting	12 October 2006
FSP Addendum 4 – Monitoring Well Installation	January 2007
Well Location Selection Report	January 2007
Well Installation	May/June 2007 and November/December 2007
Army/NRC Status Meeting	3 December 2007
FSP Addendum 5 – DQOs for Groundwater, Surface Water, and Sediment Sampling and Analysis	January 2008
FSP Addendum 6 – Water Chemistry Sampling for Ground-Water Age Estimates and Comparison of Flowmeter-Based and Water-Level-Based Directions of Ground-Water Flow in a Karst Hydrogeologic Framework	March 2008
Well Construction and Surface Water Data Report	March 2008
Groundwater, Surface Water, and Sediment Sampling	April, July, and October 2008 and January 2009
FSP Addendum 7 – DQOs for Soil Sampling and Analysis, Corrosion Study, Partition Coefficient (K_d) Study, Modeling Overview, and Slug Testing	August 2008
Soil Sampling, Collection of DU Penetrators, Collection of Soil and Water (for K_d study), and Slug Testing	Fall 2008
Slug Testing	Fall 2008
Partition Coefficient (K_d) Study	Fall 2008 to Spring 2009
Corrosion Study	Fall 2008 to Spring 2009
Metal Speciation and Dose Modeling	2008 – 2010
Decommissioning Plan	2011

3.2 STEP 2 – IDENTIFY THE DECISION

This section identifies the question to be addressed in this investigation, the decision(s) that must be made based on the study results, and possible decision alternatives, depending on the results.

3.2.1 Principal Study Questions

Is uranium present from DU penetrators at levels distinguishable from background that could result in a dose to the average member of the critical group exceeding NRC criteria in Title 10, CFR, Part 20, Subpart E?

3.2.2 Alternative Actions that Could Result from Resolution of the Principal Study Question

The potential alternative actions for the principal study question are defined as follows:

- License termination (unrestricted release)
- License termination (restricted release)
- License amendment and Army/NRC coordination to address pathway(s) of concern followed by restricted or unrestricted release with license termination or continued licensure.

3.2.3 Decision Statement

If the peak annual total effective dose equivalent (TEDE) to the average member of the critical group from DU exposure is below release criteria, the Army will request termination of their possession-only NRC license (SUB-1435). If not, the Army will coordinate with NRC to address the pathway(s) of concern.

3.3 STEP 3 – IDENTIFY INPUTS TO THE DECISION

During the third step of the DQO process, the information that is required to resolve the decision statements, information sources required to establish release criteria, and appropriate analytical methods to provide adequate data to make the decisions are identified.

3.3.1 Information Required to Resolve the Decision Statement

The information needed to resolve the decision statement includes historical records, visual site observations, results from site characterization activities, dose modeling, NRC regulations (Title 10, CFR), and NRC guidance.

Results from site characterization activities will be required to enhance the current understanding of the nature and extent of contamination in the DU Impact Area and the fate and transport of DU in the environment. Field and laboratory studies will evaluate the properties and characteristics of DU penetrators and potential for corrosion products to form and migrate in the environment at the DU Impact Area. The site characterization will generate site-specific information to support informed decisions about the actual and expected distribution and concentrations of DU corrosion products in all appropriate site media (e.g., air, soil, surface water, sediment, groundwater, biological tissue). Field studies to evaluate site geologic (e.g., permeability, depth to groundwater, hydraulic gradients, surface water flow) and hydrologic conditions associated with the potential migration of DU have been initiated pursuant to previous FSP addenda.

The laboratory analytical results will be used to determine the lateral and vertical extent of uranium concentrations relative to site background, model contaminant fate and transport, and calculate radiation doses. Information on the current and future land use will be required to confirm the exposure pathways, receptors, and activities represented in the CSM and included in the dose modeling. Modeling will determine concentrations in media as necessary to determine the TEDE, distinguishable from background, to the average member of the critical group within 1,000 years after planned decommissioning.

The Army's possession only license (SUB-1435) will be considered acceptable for termination if the dose modeling conducted for DU Impact Area site characterization meets the release criteria defined in 10 CFR Section 20.1403:

- TEDE from residual radioactivity distinguishable from background to the average member of the critical group will not exceed 25 mrem (0.25 mSv) per year and achieves doses that are as low as reasonably achievable (ALARA)
- TEDE from residual radioactivity distinguishable from background to the average member of the critical group will not exceed 100 mrem (1.0 mSv) per year (if institutional controls fail) and achieves doses that are ALARA
- Criteria in Section 20.1403(a), (b), and (c) have been satisfied and criteria in Section 20.1403(e)(2) will not be used.

3.3.2 Primary Sources for Information Identified Above

Site characterization data will form the principal information source for background screening, fate and transport modeling, and calculation of the TEDE. Additional information not mentioned above is provided in Section 2 of the original FSP in addition to the following documents that have been or will be generated as a function of this site characterization:

- FSP Addendum 1 – Deer Sampling (SAIC 2005d)
- Fracture Trace Analysis Report (SAIC 2006a)
- Deer Tissue Sampling Report (SAIC 2006b)
- FSP Addendum 2 – Soil Verification (SAIC 2006c)
- FSP Addendum 3 – Other Monitoring Equipment Installation and Electrical Imaging (EI) (SAIC 2006d)
- Well Location Selection Report (SAIC 2007a)
- FSP Addendum 4 – Monitoring Well Installation (SAIC 2007b)
- FSP Addendum 5 – DQOs for Groundwater, Surface Water, and Sediment Sampling and Analysis (SAIC 2008a)
- FSP Addendum 6 – Ground-Water Age Estimates and Ground-Water Flow in Karst Framework (SAIC 2008b)
- Well Construction and Surface Water Data Report (SAIC 2008c)
- Data from groundwater, surface water, sediment, and soil sampling and analysis
- Results of corrosion and partition coefficient studies.

3.3.3 Information Needed to Establish Action Levels and Confirm that Appropriate Measurement Methods Exist to Provide the Necessary Data

The release criteria are defined in 10 CFR Section 20.1403 and were discussed above. Laboratory analytical methods have been chosen for sample analysis to provide detection limits for isotopic and total uranium that are sufficiently low to conduct background screens, fate and transport modeling, and dose modeling. These methods have inherent qualitative and quantitative quality assurance (QA) objectives, internal method requirements, and specific QC limits that are described in Appendix A – Quality Assurance Project Plan (QAPP) of the FSP (SAIC 2005a). In addition, these methods meet the data quality indicators of precision, accuracy, representativeness, comparability, and completeness (PARCC). The analytical methods and project detection limits for total and isotopic uranium and other water quality parameters are listed in Table 3-2.

3.4 STEP 4 – DEFINE THE STUDY BOUNDARIES

During the fourth step of the DQO process, the area for which the decision will apply, whether the area must be divided into like strata, and the timeframe and any practical constraints for the decisions are considered. The historical field investigation activities and results will be used to establish the study boundaries. Based on the results of historical investigation activities, additional data may be required to define the study boundaries (e.g., soil contamination may migrate beyond the initial sampling depth).

3.4.1 Characteristics that Define the Population of Interest

The TEDE, distinguishable from background, to the average member of the critical group within a period of 1,000 years after planned decommissioning is the characteristic that defines the population of interest for the JPG site characterization.

3.4.2 Spatial Boundary of the Decision Statement

The boundaries of the study area are established using historical records and observations made during previous investigations. The DU Impact Area is the primary study area of interest. Since there is a possibility of DU migration outside this area, the secondary areas of interest consist of the JPG areas immediately outside the DU Impact Area and the area outside the JPG boundaries immediately downgradient and downwind from the DU Impact Area.

Review of existing records (e.g., boring logs; soil maps; gamma walkover surveys; groundwater contour maps; groundwater, surface water, sediment, and soil sampling analytical results; and hydraulic conductivity) and the results of completed site characterization activities (e.g., soil verification, EI, and monitoring well installations) helped to determine the need to consider different subsurface strata. Because of the geologic nature of the area under the DU Impact Area and the surrounding environs, there is a need to divide the soil and bedrock units with a weathered/fractured zone between them.

3.4.3 Temporal Boundary of the Decision Statement

Temporal boundaries have been considered in establishing project requirements. These boundaries include corrosion rate and speciation variability with time. The partition coefficient also may be expected to vary significantly with time given that other characteristics such as isotopic concentration will likewise exhibit temporal variability. The temporal considerations also are incorporated in the calculation of the TEDE to the average member of the critical group expected within the first 1,000 years after decommissioning specified in 10 CFR Section 20.1401.

3.4.4 Scale of Decision Making

The definition of the scale of decision making involves considering whether the sampled area corresponds to the appropriately sized study area and to what extent inferences may be made from the samples. The scale of decision making will include the DU Impact Area.

Table 3-2. Summary of Sampling and Analysis Requirements
Jefferson Proving Ground, Madison, Indiana

Parameter	Medium	Analytical Method	Detection Limit
Soil Sampling (GPL)			
Total and Isotopic Uranium	Soil	ASTM D3972-90M	Total U: 1.0 pCi/g U Isotopes*: 0.1 pCi/g
K_d Study (TestAmerica/Empirical)			
Total and Isotopic Uranium	Water	ASTM D3972-90M	0.1 pCi/L
Nitrate	Water	E300/SW9056	600 µg/L
Chloride	Water	E300/SW9056	3,000 µg/L
Sulfate	Water	E300/SW9056	1,000 µg/L
Calcium, Sodium, Magnesium, and iron	Water	SW6010	1,000 µg/L
Potassium	Water	SW6010	5,000 µg/L
Manganese	Water	SW6010	100 µg/L
Alkalinity	Water	E310.1/SM 2329B EPA 402-R-99-004B	1 mg/L
Moisture Content	Soil	ASTM D2216-05	NA
Soil pH	Soil	ASTM D4972-01/ E9045C	NA
Particle Size Distribution	Soil	ASTM D422-63	NA
Total Organic Carbon	Soil	SW9060/415.2	200 mg/kg
Total Carbon	Soil	SW9060/415.2	2,000 mg/kg
Total Iron	Soil	SW6010	20 mg/kg
Total Manganese	Soil	SW6010	1 mg/kg
Corrosion Study (MCLinc/Empirical)			
Total and Isotopic Uranium	Water	ASTM D3972-90M	0.1 pCi/L
Calcium, Sodium, Magnesium, and Iron	Water	SW6010	1,000 mg/L
Potassium	Water	SW6010	5,000 µg/L
Manganese	Water	SW6010	100 µg/L
Nitrate	Water	E300/SW9056	600 µg/L
Chloride	Water	E300/SW9056	3,000 µg/L
Sulfate	Water	E300/SW9056	1,000 µg/L
Alkalinity	Water	EPA 310.1	1 mg/L
Uranium Corrosion Product Speciation by XRD	Water	ASTM D5744-96	Total U: 1.0 µg/L U Isotopes*: 0.1 pCi/L
Uranium Corrosion Product Speciation by XRD	Soil and U Corrosion Products	ASTM D934-80	NA
Uranium Corrosion products by XPS	Soil and U Corrosion Products	NA	NA
Uranium Corrosion products by SEM-EDS	Soil and U Corrosion Products	NA	NA
Total and Isotopic Uranium	Soil and U Corrosion Products	ASTM D3972-90M	Total U: 1.0 pCi/g U Isotopes*: 0.1 pCi/g

* Uranium isotopes include ^{234}U, ^{235}U, and ^{238}U

3.4.5 Practical Constraints on Data Collection

Practical constraints or obstacles that may interfere with full implementation of data collection include seasonal conditions when sampling is not possible (e.g. flooding, high surface water), controlled burns when accessing the site is dangerous, and UXO located throughout the DU Impact Area that requires additional anomaly avoidance procedures. Soil sampling and collection of DU penetrators ideally is completed when the ground is not frozen and is not overly wet. Collection of rainwater also may be problematic during dry portions of the year.

3.5 STEP 5 – DEVELOP A DECISION RULE

This section integrates the parameter of interest, action levels, and DQO outputs into a statement that describes the logical basis for choosing among alternative actions based on analysis of the sample data. The decision rule incorporates the parameters of interest, scale of decision making, release criteria, and action(s) that would result from the decision.

3.5.1 Specify the Parameter that Characterizes the Population of Interest

The parameter that characterizes the population of interest is the TEDE from residual radioactivity distinguishable from background to the average member of the critical group (10 CFR Section 20.1403).

3.5.2 Specify the Action Level for the Study

The action levels are defined as the release criteria specified in 10 CFR 20.1403:

- TEDE from residual radioactivity distinguishable from background to the average member of the critical group will not exceed 25 mrem (0.25 mSv) per year and achieves ALARA
- TEDE from residual radioactivity distinguishable from background to the average member of the critical group will not exceed 100 mrem/year (if institutional controls fail) and achieves ALARA
- Criteria in Section 20.1403(a), (b), and (c) have been satisfied and criteria in Section 20.1403(e)(2) will not be used.

3.5.3 Decision Rule

The decision rules for the JPG DU site characterization project are shown in Table 3-3 based on 10 CFR Section 20.1403.

Table 3-3. Decision Rules
Jefferson Proving Ground, Madison, Indiana

Action	Conclusion	Rationale
TEDEs from residual radioactivity distinguishable from background to the average member of the critical group equal or fall below limits of 25 and 100 (if institutional controls fail) mrem/year within the first 1,000 years after decommissioning.	Terminate Army's possession-only license	TEDEs achieve release criteria
TEDEs from residual radioactivity distinguishable from background to the average member of the critical group exceed either limit of 25 or 100 (if institutional controls fail) mrem/year within the first 1,000 years after decommissioning.	Further action required	TEDEs exceed release criteria

This decision rule incorporates the parameter of interest (TEDEs from residual radioactivity distinguishable from background to the average member of the critical group), scale of decision making (receptors in the DU Impact Area within the first 1,000 years after decommissioning), and action(s) that would result from the decision (terminate the Army's license or further action required).

3.6 STEP 6 – SPECIFY TOLERABLE LIMITS ON DECISION ERRORS

The sixth step of the DQO process defines the tolerable limits on decision errors. These limits are defined as the probability of making an incorrect decision based on data that inaccurately estimate the true condition of the site. The goal of this step is to develop a data collection design that reduces the chance of making a decision error to a level that is acceptable to the Army and NRC.

The four steps to defining where each decision error occurs and establishing which decision error should be defined as the null hypothesis (baseline condition) are described below:

- ***Two Types of Decision Errors***—The two decision errors for the JPG DU Impact Area site characterization are (1) deciding that radiation doses (total effective dose equivalent) to the average member of the critical group from residual concentrations of uranium present within the DU Impact Area comply with criteria in 10 CFR 20, Subpart E when, in fact, such doses actually exceed this standard; and (2) deciding that radiation doses to the average member of the critical group from residual concentrations of uranium present within the DU Impact Area exceeds criteria in 10 CFR 20, Subpart E when, in fact, such doses actually comply with the criteria.
- ***Potential Consequence of Each Decision Error***—The two potential consequences of each decision error are as follows: (1) The consequence of deciding that the doses due to site contamination do not exceed release criteria when they actually do could result in the potential for individuals to receive radiation doses exceeding NRC criteria stated in 10 CFR 20, Subpart E. (2) The consequence of deciding that doses due to site contamination exceed the release criteria when they actually do not will trigger additional unnecessary actions for the site (e.g., further investigation, implementation of additional controls, and/or a response action). Costs incurred for such unnecessary additional work would necessitate reallocation of financial resources from other government projects.
- ***Which Decision Error Has More Severe Consequences Near the Action Level?***—The consequence of deciding that the doses due to site contamination do not exceed release criteria when they actually do has the more severe consequences.
- ***The Null Hypothesis (Baseline Condition) and the Alternative Hypothesis***—The baseline condition or null hypothesis (H_0) for JPG is that, radiation doses from DU present within the Impact Area exceed restricted release criteria defined in 10 CFR 20, Subpart E. The alternative hypothesis (H_a) is that radiation doses from DU present within the Impact Area achieve restricted (or unrestricted) release criteria defined in 10 CFR 20, Subpart E. The information to be obtained pursuant to this Addendum will be statistically evaluated such that conservative, site-specific values, representative of the full range of site conditions, are utilized in dose calculations for both onsite and offsite receptors.

Tolerable limits will be determined at the time of dose modeling to calculate the dose to the average member of the critical group in the 1,000 years subsequent to site decommissioning and will be based on the impact of each parameter on the dose evaluation. Sensitivity analysis will be performed to determine which input parameters are most significant with respect to impact on dose evaluations and specific values will be selected for each parameter that are conservative but not overly so and are within a range that is representative of site conditions.

3.7 STEP 7 – OPTIMIZE THE DESIGN

During the seventh step of the DQO process, the most resource effective data collection design expected to generate data that satisfy the DQOs specified in the preceding steps are identified. The information and outputs from the previous six DQO process steps have been evaluated to ensure that they are internally consistent. A review of existing data was conducted, when data were available, to determine data gaps and was used to develop this FSP Addendum and will be used to develop future addenda. Table 3-4 lists the general phases of data collection activities for JPG site characterization. Phase I is currently ongoing while Phase II is being initiated by this Addendum. Each of the phases is scheduled for completion as required for submission of the updated decommissioning plan in accordance with the established project schedule.

Table 3-4. Site Characterization Phases
Jefferson Proving Ground, Madison, Indiana

Phase I: Offsite Migration Potential and Pathways	Phase II: Source and Release Characterization	Phase III: Modeling	Phase IV: Decommissioning Plan
▪ Stream and cave spring gauges ▪ Groundwater wells ▪ Distribution and concentrations of DU corrosion products in groundwater, surface water, sediment, and biota	▪ DU penetrator corrosion analysis ▪ Transport of DU corrosion products ▪ Distribution and concentrations of DU corrosion products in soil	▪ Fate and transport modeling ▪ Dose calculation	▪ Revised ERM program

4. SOIL SAMPLING AND ANALYSIS

Soil sampling is scheduled to occur at JPG in the fall of 2008 and is an integral part of the field effort as defined in this Addendum. This section summarizes the soil sampling activities to be conducted at JPG during the fall months of 2008 to address critical data needs. Soil samples collected under this FSP Addendum as described in this section will be used for the following purposes:

- Characterize the extent and depth of DU contamination more accurately than previous studies
- Determine the uranium concentrations present in site background soils
- Obtain soil for use in DU penetrator ~~corrosion and~~ leachability testing, which is one part of the corrosion study (Section 6)
- Obtain soil to determine the site-specific partition coefficient (K_d) for uranium (Section 7).

Areas where soil sampling will be completed to further and better characterize the horizontal extent and depth of contamination are derived from locations identified in the 1996 characterization survey (SEG 1996). These sampling areas will be subjected to gamma walkover surveys to assist in the selection of specific individual locations from each area. The following bullets describe the areas to be surveyed and sampled in general terms, which will be discussed in further detail in the following sections:

- ***Category 1***—Outside the presently defined perimeter of the DU Impact Area
- ***Category 2***—Immediately inside the presently defined perimeter of the DU Impact Area
- ***Category 3***—Approximately midway between the inside perimeter sample locations and the primary DU penetrator impact areas (trenches)
- ***Category 4***—Around and between trenches if trenches are identifiable
- ***Category 5***—Additional locations to expand the coverage of sampled areas and sample suspected areas impacted by penetrators
- ***Category 6***—Within trenches.

Background soil sampling areas, which are not included in the categories listed above, will be selected in coordination with site geologists and review of soil mapping in the Soil Survey Geographic Database (SSURGO) for Ripley County, Indiana. The areas identified for background sampling will be selected to exclude areas that are downgradient and downwind from the DU Impact Area and to specifically include areas representative of the following soil type groupings as determined during the soil verification study (SAIC 2007a) in the DU Impact Area:

- Avonsburg and Cobbsfork (covers approximately 55 percent of the DU Impact Area)
- Cincinnati and Rossmoyne (covers approximately 32 percent of the DU Impact Area)
- Grayford and Ryker (covers approximately 11 percent of the DU Impact Area and includes areas along Big Creek known to contain DU penetrators).

Section 4.1 describes the approach to be used in selecting locations for different soil sampling types (background, nature and extent, K_d/corrosion studies) and includes an overview of gamma walkover survey protocols to be used. Section 4.2 provides an overview of field activities including sampling to characterize background soils (Section 4.2.1), to determine the extent and depth of contamination (Section 4.2.2), and to use in corrosion testing (Section 4.2.3) and K_d study (Section 4.2.4). Section 4.3 summarizes soil sampling procedures including associated instruments, equipment, and supplies. Section 4.4 contains decontamination procedures that will be completed during soil sampling activities.

4.1 GAMMA WALKOVER SURVEYS

Soil sampling areas in the DU Impact Area and areas selected in association with the background will be subjected to gamma walkover surveys to assist in the selection of specific individual sampling locations. General areas where soil sampling is needed to better characterize the horizontal extent and depth of contamination were selected with full consideration being given to locations where contamination was identified in the 1996 characterization survey (SEG 1996) and historical information about the possible locations of DU penetrators (e.g., firing lines, targets, firing points, expected landing areas). In addition, gamma walkovers will be used to identify locations where DU penetrators are located and to collect soil for the leachability testing and K_d study.

Gamma walkover surveys serve as screening tools to identify areas that exhibit gamma radioactivity that is elevated with respect to background count rates to facilitate further investigation of such areas. These surveys are performed using a sodium iodide (NaI) gamma scintillation radiation detector, which is interconnected to a data collection (logging) device and a global positioning system (GPS). The detector is maintained about 10 cm (4 in.) above the ground surface and collects data each second consisting of the gamma count rate and location. The system provides both an audible response that is proportional to the count rate and a meter reading of the applicable count rate. To perform a gamma walkover survey, the surveyor proceeds forward at a speed of about 0.5 m per second while moving the detector in a serpentine manner. During the course of the survey, the surveyor investigates any elevated count rates that are identified. In addition, data subsequently are downloaded and printed, typically at the end of each day. Data are depicted on maps with color-coding that is indicative of the count rate at each location; thus, areas with elevated count rates are easily identified.

The average background count rate exhibited by a given detector is dependent in part on its size with count rates of 6,000 to 10,000 counts per minute (cpm) being common for a 2- by 2-in. detector. Further, although the surveyor constantly searches for elevated count rates, a count rate of 1,500 to 2,000 counts per minute above background is typically required for this detector to provide evidence of elevated count rates. The scan minimum detectable concentration (MDC) for DU in soil is reported in US Nuclear Regulatory Commission Regulation (NUREG)-1507, *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions,* as 56 picocuries per gram (pCi/g) when using a 2- by 2-in. NaI detector. A DU penetrator fragment that is as small as 6 cm^3 (0.37 in^3) is easily locatable on the soil surface during a typical scan using an investigation threshold of 2,000 cpm above background. Similarly, technical evaluation indicates that a DU penetrator fragment as small as 10 cm^3 (0.61 in^3) can be located easily below 5 cm (2 in.) of soil during a typical scan (again assuming an investigation threshold of 2,000 cpm above background). The evaluation of scan detection of DU fragments with a 2- by 2-in. NaI detector based on photon/gamma ray shielding and dose assessment modeling performed with MicroShield® (version 5.01) is provided in Appendix A. It includes modeled count rates for DU particles of different sizes beneath 5 and 25 cm of soil.

Gamma walkover surveys will be used to identify areas with elevated count rates to include those resulting from the presence of DU penetrators or portions thereof. Upon confirmation of an anomaly, the location of the maximum count rate will be physically identified with location (pin) flags and the GPS coordinates recorded. If satellite visibility is not available, the data will be geo-referenced at a later time. Gamma walkover surveys will be performed in the following areas:

- ***Background Soil Sampling Locations***—An area identified approximately 3 miles north of the DU Impact Area along the eastern boundary of the JPG property (Figure 4-1) has been identified for defining background concentrations of uranium. This area has been selected because it includes the three soil type groups of interest (Avonsburg and Cobbsfork, Cincinnati and Rossmoyne, and Grayford and Ryker) in a relatively small area. To ensure that these areas have not been impacted by potential onsite or offsite radiological sources, a ~~50~~15-m radius from the center of each proposed background sampling location will be surveyed with 2- by 2-

in. NaI detectors to identify any elevated areas that may be present. Tentative locations will be selected based on reviewing the soil maps for this area and confirmed in the field by an experienced geologist or soil scientist. If elevated readings are identified within the surveyed area, alternate locations will be selected and the surveys will be conducted in those areas.

- ***Extent and Depth Soil Sampling Locations (Categories 1 through 5)***—Soil samples will be collected from the centers of the circular locations shown in Figure 4-2. Surveys will be performed within a radius of approximately 15 m of each sampling location where soil samples are being obtained for the extent and depth determination. These surveys will facilitate the collection of soil samples in a manner that will ensure that results are appropriately representative of site concentrations and that sampling is not excessively biased high or low. The evaluation of bias will be completed by SAIC's Project Manager, Hydrogeology and Multimedia Sampling and Analysis Lead, and RSO in coordination with the Army during the soil sampling field program using the color-coded figures that show count rates. In addition, soil samples will be obtained no closer than 1 m (3.3 ft) from the nearest penetrator as indicated by gamma walkover surveys of sampling areas.
- ***Extent and Depth Soil Sampling Locations (Category 6)***—Using meandering path approaches, the gamma survey will be conducted in the vicinity of the DU Impact Area trenches located north of the firing points until dense numbers of penetrators are encountered. Once penetrators are encountered, the area of the DU Impact Area trenches and the surrounding vicinity to a distance of 3 m around each trench will be surveyed. Based on an action level of two times the background count rate, scan surveys will be used to assist in confirming the boundaries or general locations and dimensions of the DU Impact Area trenches that will be needed in the dose and fate and transport modeling. In addition, these surveys will be used to identify penetrators present in surface soils within and around the trenches for the corrosion study and collecting soil associated with the leachability testing and K_d study. Walkover information also will be used to more accurately reflect locations of trenches and will be evaluated as an indicator of the relative quantity of penetrators present in surface soils within the trench area.
- ***Additional Survey Areas***—Potential surface water sediment deposition areas identified by the project hydrogeologist, which have not been previously investigated, are expected to be surveyed in a possibly intermittent tributary or swale that extends from the area of the trenches, northwards toward Big Creek. No soil sampling is currently planned for this area, but the results of the gamma walkover in conjunction with soil sampling results from other areas can be used to draw inferences about possible migration associated with overland transport of rainfall runoff. This evaluation could show the potential need for additional soil sampling and/or altering the locations of surface water and sediment samples along Big Creek.

The performance of gamma walkover surveys and soil sampling require implementation of anomaly avoidance activities as specified in the HASP (under development).

4.2 OVERVIEW OF SOIL SAMPLING TO BE PERFORMED

Soil samples from locations within the DU Impact Area will be collected to serve multiple purposes and from specifically defined areas. The following sections discuss background soil sampling (Section 4.2.1), extent and depth of contamination sampling (Section 4.2.2), and sampling for the leachability study (Section 4.2.3) and K_d study (Section 4.2.4).

Table 4-1 summarizes the numbers, depths, and general locations where soil samples will be collected and which laboratories will perform the respective analyses.

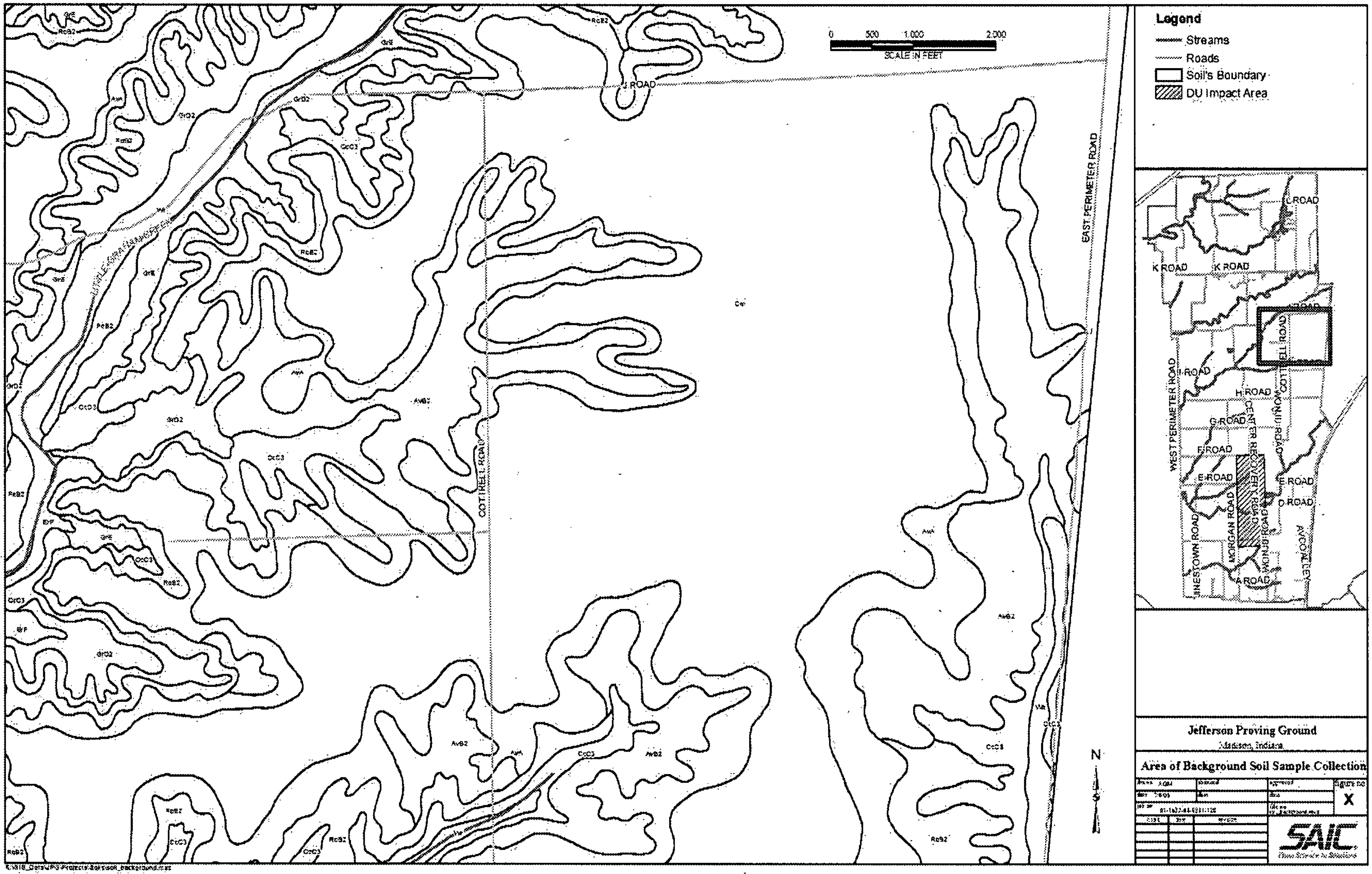


Figure 4-1. Areas Proposed for Sampling Background Soils

Figure 4-2. Proposed Soil Sampling Locations for Extent and Depth Evaluation

Table 4-1. Numbers of Soil Samples, Summary of Sampling Locations, and Designated Laboratories for Sample Analysis Jefferson Proving Ground, Madison, Indiana

Category	Locations	Location Description	Samples	Remarks	Laboratory
		Background Characterization			
BK	9	Avonsburg and Cobbsfork	36	Depths listed in Section 4.2.1	GPL
BK	9	Cincinnati and Rossmoyne	36	Depths listed in Section 4.2.1	GPL
BK	9	Grayford and Ryker	36	Depths listed in Section 4.2.1	GPL
Total	**27**		**108**		
		Extent and Depth Determination [a]			
1	12	Outside DU Impact Area Perimeter	48	Depths listed in Section 4.2.2	GPL
2	12	Immediately Inside DU Impact Area	48	Depths listed in Section 4.2.2	GPL
3	12	Midway to DU Impact Area Trenches	48	Depths listed in Section 4.2.2	GPL
4	12	Immediately Outside DU Impact Area Trenches	60		GPL
5	32	Other Nature and Extent Samples as Reflected in Figure 4-1	128	North of Big Creek in DU penetrator lines of fire; suspected DU impact areas; and additional locations to cover DU Impact Area	GPL
6	12	Trench Locations (~~(~~4 locations in each of the 3 trenches with 1 location at the end of each trench and 2 equidistant from the ends)	60	Additional interval to be collected from 120 to 180 cm (4 to 6 ft) BLS and stored for possible later analysis	GPL
Penetrator	24	Samples taken under penetrators	108	Depths listed in Section 4.2.4	GPL
Totals	**116**		**500**		
		Leachability Testing			
Leachability	1 [b]	Avonsburg and Cobbsfork	3.3 kg	Collected from one background location [a]	MCLinc/Empirical
Leachability	1 [b]	Cincinnati and Rossmoyne	3.3 kg	Collected from one background location [a]	MCLinc/Empirical
Leachability	1 [b]	Grayford and Ryker	3.3 kg	Collected from one background location [a]	MCLinc/Empirical
Total	**3**		**10 kg**		
		K_d Testing			
K_d	10 [c]	Avonsburg and Cobbsfork	40 kg	4 samples consisting of at least 1 kg (2.2 lb) of soil will be obtained from each location	TestAmerica/Empirical
K_d	10 [c]	Cincinnati and Rossmoyne	40 kg	4 samples consisting of at least 1 kg (2.2 lb) of soil will be obtained from each location	TestAmerica/Empirical
K_d	4 [c]	Grayford and Ryker	16 kg	4 samples consisting of at least 1 kg (2.2 lb) of soil will be obtained from each location	TestAmerica/Empirical
Total	**24**		**96 kg**		

[a] Soil samples will be obtained no closer than 1 m (3.3 ft) from the nearest penetrator as indicated by gamma walkover surveys of sampling areas.
[b] From the surface of one background location, 3.3 kg of additional soil is to be collected for the leachability test.
[c] Two samples from each of the soil type groupings will be collected from background locations (adsorption testing). Several samples will be collected under DU penetrators selected for the ~~corrosion~~ K_d study (desorption testing): ~~8~~eight from Avonsburg/Cobbsfork, ~~8~~ eight from Cincinnati/Rossmoyne, and ~~2~~two from Grayford/Ryker.

4.2.1 Soil Sampling for Background Characterization and for Use in Leachability Testing and Partition Coefficient (K_d) Tests

To quantify the background concentrations of uranium in soil, a background sampling area within the JPG facility has been selected from upgradient and cross-gradient areas outside the perimeter of the DU Impact Area and which are not downwind of the DU Impact Area in the predominant wind direction. Background sampling will consist of the collection of 108 samples from 27 locations to consist of relatively equal numbers of samples from each of the soil types (Avonsburg and Cobbsfork, Cincinnati and Rossmoyne, and Grayford and Ryker) as evaluated in the soil verification survey (SAIC 2007a) and described in Section 4.1. Figure 4-1 reflects planned background sampling areas. Nominal depth intervals for collection of samples for background determination are:

- Ground surface to 15 cm (0 to 0.5 ft) below land surface (BLS)
- 15 to 30 cm (0.5 to 1 ft) BLS
- 30 to 60 cm (1 to 2 ft) BLS
- 60 to 120 cm (2 to 4 ft) BLS.

Soils collected for the background characterization will be obtained by SAIC and transmitted to GPL Laboratories, LLLP (GPL). Additional background soil is needed to perform the ~~penetrator~~ leachability testing, which is part of the corrosion study, ~~studies~~ from one location from each of the three background soil type groupings. Additional information is provided in Sections 4.2.3 and 5 regarding the leachability testing. Soil samples will be submitted to Materials and Chemistry Laboratory, Inc. (MCLinc) in 1-gal plastic bags (approximately two bags needed for each soil type) and soil will be submitted to Empirical Laboratories, LLC for non-radiological analyses associated with the leachability test. Additional details regarding the leachability testing are provided in Section 6. Additional information regarding sample containers, handling, and shipment is provided in Section 8.

Additional background soil is needed to conduct the K_d study (Section 6.2). Soil will be collected from background areas with the Avonsburg and Cobbsfork soil types (~~2~~two samples), Cincinnati and Rossmoyne soil types (two~~2~~ samples), and Grayford and Ryker soil types (~~2~~two samples) to support the adsorption tests in the K_d study.

4.2.2 Sampling for Determination of Extent and Depth of Contamination

Soil sampling will be performed to augment existing data, enabling the concentration, lateral, and vertical extent of contamination to be more accurately assessed. A total of 392 soil samples will be obtained to assess the extent and depth of contamination consisting of samples from 92 locations (~~Figure~~ Table 4-1). The Field Manager will be provided with the coordinates of the 92 planned locations shown in Figure 4-~~1~~2 and will determine if the sampling and gamma walkover surveys of the 15-m radii from centers can safely be performed using anomaly avoidance procedures. Areas with numerous UXO, steep terrain, large water bodies, and other potential site-specific conditions will prevent the soil sampling and/or gamma survey, thereby necessitating moving some locations. If the Field Manager determines that locations must be moved, he will identify a suitable replacement location that is as close as possible to the originally planned location, but still far enough away to avoid encountering the hazard of concern. Any such change will be recorded and documented to describe why a particular location was not sampled and where it was moved.

Samples generally will be collected from the same depth intervals as background soils (Section 4.2.1) and include a deeper interval for most locations as follows:

- Ground surface to 15 cm (0 to 0.5 ft) BLS
- 15 to 30 cm (0.5 to 1 ft) BLS
- 30 to 60 cm (1 to 2 ft) BLS

- 60 to 120 cm (2 to 4 ft) BLS
- 120 to 180 cm (4 to 6 ft) BLS (not for Category 1, 2, and 5 locations).

Subsurface samples will be referenced to the surface sample locations for identification of the sample location. Samples may not be collected at certain depths if it is determined that the depth to bedrock is shallower than the desired bottom sample depth of 6 ft.

A gamma walkover survey will be completed within a 15-m area around each sampling location (discussed in Section 4.2.1) and will be used for (among other uses) confirming that no penetrators are located closer than 1 m to the selected sample locations. Results from samples 1 m or ~~fu~~arther away from penetrators will be used in conjunction with soil samples collected directly over and under penetrators (Section 4.2.4) to estimate average concentrations used in the dose modeling. Since potential receptors may be exposed to soils with and without penetrators, this approach enables the dose modeling to evaluate potential exposures to a full distribution of the range of uranium concentrations expected within the DU Impact Area.

~~Samples may not be collected at certain depths if it is determined that the depth to bedrock is shallower than the desired bottom sample depth of 6 ft.~~

Soils collected for the extent and depth of contamination characterization will be obtained by SAIC and transmitted to GPL.

4.2.3 Soil Sampling for Leachability Testing

Concurrent with sampling soil for background characterization, soil from the background sampling area also will be obtained for use in ~~penetrator~~ leachability testing, which is part of the corrosion study. The estimated mass of soil needed to complete the scope of work is approximately 10 kg (22 lb). As discussed in Section 6, six chamber tests are planned requiring 3.3 kg (7.3 lb) of soil from background locations for each of the following three soil type groups: Avonsburg and Cobbsfork, Cincinnati and Rossmoyne, and Grayford and Ryker.

Soil collected for background characterization will provide the analytical data needed to establish the baseline levels of uranium in the soil matrixes used in the leachability tests. The collection of background soil is discussed in Section 4.2.1.

Soils collected for the leachability test will be obtained by SAIC and transmitted to MCLinc together with other required materials and Empirical Laboratories for non-radiological analyses associated with the leachability test. Soil samples will be submitted to MCLinc in 1-gal plastic bags (approximately two bags needed for each soil type). Soil samples will be submitted to Empirical Laboratories using containers described in Section 8. Additional details regarding the leachability testing are provided in Section 6.

4.2.4 Soil Sampling Over/Under Penetrators and for Use in Partition Coefficient (K_d) Tests

Gamma walkover surveys and visual inspection will be used to locate 24 DU penetrators. From the locations of these 24 penetrators, 108 soil samples will be collected beneath penetrators and analyzed to characterize the vertical extent of contamination. Soil samples also will be collected above ~~nine~~ 12 of the penetrators that are located in subsurface soil to assess possible upward migration of DU corrosion products. Soil will be collected above/beneath ~~10~~ ~~8~~eight penetrators from areas with the Avonsburg and Cobbsfork soil types, soil above/beneath eight~~10~~ ~~8~~ penetrators from areas with the Cincinnati and Rossmoyne soil types, and soil above/beneath ~~4~~ ~~2~~two penetrators from areas with the Grayford and Ryker soil types.

Depending on the ability to find and locate penetrators in the subsurface, approximately half will be obtained from the soil surface and half from the area below but within approximately 3 in. of the surface. Given that penetrators will be located using gamma walkover surveys and it is not known beforehand how many can be located in the subsurface, the sample locations will be determined during the field effort. While the 3 in. estimate is primarily based on the ability to detect subsurface penetrators during the gamma walkover survey, collecting penetrators within 3 in. of surface is expected to be more conservative than collecting penetrators from deeper depths. Penetrators located more closely to the ground surface will be exposed to more atmospheric oxygen and moisture than deeper penetrators. These conditions are more conducive to oxidation. If penetrators located deeper in the subsurface are encountered during sampling, the field crew will collect up to ~~2~~two penetrators per soil type grouping (Avonsburg/Cobbsfork, Cincinnati/Rossmoyne, and Grayford/Ryker). In addition, the samplers will photograph and document the condition to compare the condition with penetrators collected in shallower soils.

Soil will be collected from the four intervals directly beneath DU penetrators as specified below irrespective of whether the penetrator is lying on the surface or in the subsurface. For DU penetrators located ~~15~~ 7.6 cm (~~6~~ 3 in.) or more inches below the soil surface, one soil sample also will be collected from the interval immediately above the penetrator and submitted for laboratory analysis. As noted in Section 4.1.1, four samples consisting of at least 1 kg (2.2 lb) of soils will be obtained from each of the 24 locations from which DU penetrators are collected. These samples will be obtained from the following four vertical intervals as measured relative to the bottom of the penetrator:

- Ground surface to 15 cm (0.5 ft) beneath penetrator
- 15 to 30 cm (0.5 to 1 ft) beneath penetrator
- 30 to 60 cm (1 to 2 ft) beneath penetrator
- 60 to 120 cm (2 to 4 ft) beneath penetrator.

The samplers will document the depths and orientation of the penetrators, including the primary azimuth (e.g., north to south), attitude (e.g., top of northern tip at ground surface and top of southern tip at 6 in~~ches~~. BLS), and relative location along the length of the penetrator where soil samples were collected (e.g., surface soil above southern tip, 6 in~~ches~~. below southern tip). For penetrators partially extending underground, all subsurface soil samples will be collected under the deepest point that the penetrator is located at the desired depths listed above. The sampler will document the relative location where samples were collected (e.g., all samples collected under southern tip).

Soils collected for the K_d study, in addition to the 108 samples specified above, will be obtained by SAIC and transmitted to TestAmerica together with rain water. Soil and rainwater also will be submitted to Empirical Laboratories for non-radiological analyses associated with the K_d study. Soil samples will be submitted to TestAmerica in 1-gal plastic bags (approximately one bag needed for each soil type). Additional details regarding the K_d study are provided in Section 7. Soil and water samples will be submitted to Empirical Laboratories using containers described in Section 8.

Given the collection of 96 soil samples from under penetrators and approximately 12 samples from above penetrators, a total of 108 samples are available from which to select 96 samples for use in K_d determination. SAIC will consult with TestAmerica to select the appropriate samples for use in the study (e.g., avoid exceeding high uranium levels that could create solubility limit issues). Sample analysis results from TestAmerica will be used in lieu of duplicative sample analysis by GPL.

4.3 SOIL SAMPLING PROCEDURES

As noted above, surface and subsurface soil samples will be collected for background determination, improved characterization of the extent and depth of contamination, for use in leachability testing, and for the K_d study. As used herein, unless otherwise specified, the term "surface soil" is defined as the uppermost layer of soil to a depth of 15 cm (0.5 ft) BLS. The term "~~Subsurface~~ subsurface soil" is defined as any soil below the upper 15 cm (0.5 ft) BLS. At least one surface soil sample will be collected from every location and subsurface soil samples will be collected at depths described in Sections 4.2.1 through 4.2.4. The~~se~~ soil depth assumptions for surface and subsurface soil coincide with assumptions regarding potential human exposures needed for the dose modeling (Section 12.1).

Surface and subsurface samples will be collected using approved sampling protocols, ensuring that the volume and mass of samples achieve project requirements. As such, collection of samples using a trowel or other suitable sampling equipment in accordance with project procedures is acceptable. If it is necessary to advance the sample hole to a deeper collection location, this may be conducted with a manually operated auger. Soil samples may be collected in an undisturbed (core) or disturbed state (auger or trowel) below penetrators when the sample is for leachability testing or K_d study.

Radiation exposure rate measurements will be taken at 1 m (3.3 ft) above the sample location and recorded on the field logbook. Any comments and notations that may be necessary for interpretation of the results should be recorded on the form or in the logbook. The soil sampling instructions are as follows:

1. The sampler will don clean nitrile or similar gloves.
2. Samples will be collected using a new or properly cleaned (Section 4.4) scoop, trowel, or hand auger.
3. The collected sample will be transferred from the sample collection equipment to a clean, new plastic sheeting or plastic trash bag for completion of soil descriptions with particular attention to mottling and appearance of iron oxide so as to estimate probable reduction/oxidation (redox) conditions of the soil.
4. Locations of samples will be measured using GPS.
5. Photographs of the soil samples and the collection locations will be taken.
6. Samples will be transferred from the plastic into the appropriate sample container (i.e., glass sample jar for characterization samples, 1-gal plastic bags for leachability testing and K_d study samples). Twigs, leaves, pebbles, debris, and possible penetrator fragments that are not components of the matrix of interest will be removed.
7. The sample container will be wiped clean so that a label and security seal may be placed on it. The sample container then will be placed into a sealed Ziploc® bag before being put into a cooler with ice.

Upon removal of the soil from the ground, soil descriptions will be recorded. Soil samples also will be subjected to radiological surveys to qualitatively assess whether elevated count rates indicative of contaminant migration or the existence of subsurface lenses of contamination may be present. The radiological surveys will be completed for each 6-inch sample interval and will be recorded in the field logbook. If radioactivity distinguishable from background is detected in the bottom sample at any location, additional soil will be collected from deeper depths until levels are consistent with background (as measured by the 2- by 2-in. NaI detectors). These samples will be archived pending a decision by the Army as to whether submission for laboratory analysis is appropriate.

Each sample to be analyzed by an offsite laboratory will be prepared, packaged, and sample integrity maintained in accordance with applicable project procedures summarized below. Except for soil collected for leachability tests and the K_d study, soil samples will be placed in new, laboratory provided, clean sample containers, and each container will be marked with a unique identification (I.D.) number, date and time of collection, location, depth interval, and collector's name. Soil collected for the leachability testing and K_d study will be placed in new 1-gal plastic bags, marked with a unique I.D. number, date and time of collection, location, depth intervals, and collector's name. A strict chain-of-custody (CoC) will be maintained for all samples. QC samples (i.e., duplicate samples, matrix spike/matrix spike duplicates [MS/MSDs], field blanks, and equipment rinsates) will be collected and analyzed in accordance with the QAPP (Appendix A of the FSP [SAIC 2005a]).

Samples will be prepared and shipped to laboratories, which are appropriately licensed by NRC or an Agreement State for analysis. Upon receipt, the laboratory will immediately initiate laboratory analysis consistent with the specifications made on the CoC form. Analytes will generally include total uranium and isotopic analysis for ^{238}U, ^{235}U, and ^{234}U by alpha spectrometry (ASTM-D3972-90M). Laboratory MDCs for uranium will comply with the QAPP (Appendix A of the FSP [SAIC 2005a]).

All field procedures, data collection, sampling, and analysis will be completed in accordance with the FSP (SAIC 2005a), this FSP Addendum, the Quality Control Plan (QCP) (SAIC 2005c), and HASP Addendum 6 (under development). Table 4-2 references SAIC's field technical procedures (FTPs) that will be followed during field operations defined in this Addendum. Electronic copies of the FTPs have been included in the attached CD.

4.4 DECONTAMINATION

Decontamination will be conducted in accordance with requirements in FTP-405. Generally, nondedicated equipment will be decontaminated after each piece of sampling equipment is used. The procedure for decontamination of equipment will be as follows:

1. Wash with approved water and phosphate-free detergent using various types of brushes required to remove particulate matter and surface films.
2. Rinse thoroughly with approved potable water.
3. Rinse thoroughly with deionized water.
4. Allow equipment to dry as long as possible.
5. Place equipment on clean plastic if immediate use is anticipated or wrap in aluminum foil or bags to prevent contamination if longer-term storage is required.

Decontamination water will be directed out of the work area and surface discharged. Nondedicated equipment will be subjected to radiological monitoring to confirm the absence of contamination prior to reuse. Equipment blanks will be collected at a frequency of one per day and will include all equipment that comes into contact with soil during that day. One field blank will be collected from every source of water used for decontamination during the soil sampling program.

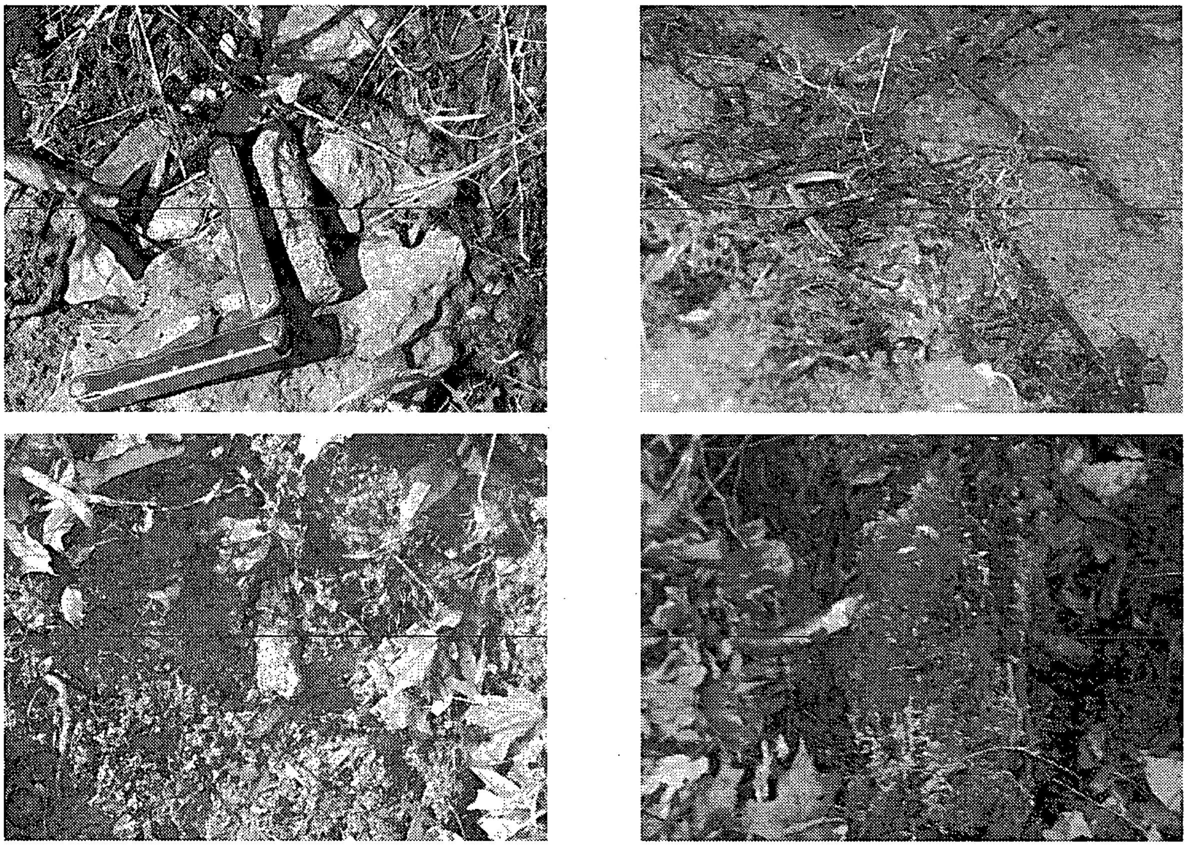
Table 4-2. Relevant SAIC Field Procedures for Soil Sampling Jefferson Proving Ground, Madison, Indiana

Number	Title	Latest Revision	Date
FTP-400	Equipment Decontamination	1	6/8/2001
FTP-405	Cleaning and Decontaminating Sample Containers and Sampling Equipment	1	8/15/2000
FTP-451	Field Measurement Procedures: Operation of Radiation Survey Equipment	2	10/13/1993
FTP-525	Soil Sampling Using an Auger	1	8/11/2000
FTP-526	Soil Sampling in Standing Water	0	5/15/2000
FTP-550	Soil Sampling Using a Spade or Scoop	1	8/11/2000
FTP-651	Hazardous Materials/Dangerous Goods Shipping for Field Work	2	11/20/2006
FTP-691	Composite Procedures	0	6/30/1993
FTP-1215	Field Logbooks and Field Forms	1	1/31/2007
FTP-1225	Field Demobilization Checklist for Project-Generated Waste	0	12/24/2003
EC&HS 4.1	Incident Reporting and Investigation	1	1/23/2008
EC&HS 12.1	Medical Surveillance	0	12/17/2007
EC&HS 13	Personal Protective Equipment	NA	5/2008
EC&HS 15	Hearing Conservation and Noise Control	NA	5/2008
EC&HS 19.1	Radiation Protection	0	11/17/2002
EC&HS 110	Vehicle Operation	2	6/2007
EC&HS 120	UXO/OE/CWM Safety	0	5/2002
EC&HS 130	Subsurface Asset and Hazard Avoidance	2	1/23/2006
EC&HS 140	Subcontractor Environmental Compliance and Health and Safety	3	10/25/2007
EC&HS 150	Manual Lifting	1	2/23/2006
EC&HS 170	Fall Protection	2	6/27/2007
EC&HS 200	Bloodborne Pathogen Exposure Control	0	5/17/2007
EC&HS 230	Hand and Power Tool Safety	0	11/20/2007
TP-DM-300-12	Handling and Control of Sampling Documentation	3	5/26/2006
QAAP 12.1	Control of Measuring and Test Equipment	3	7/3/2002
QAAP 15.1	Control of Nonconforming Items and Services	7	3/13/2002

NA = Not Applicable

5. DU PENETRATOR CORROSION STUDY

This section summarizes the DU penetrator corrosion study activities scheduled to begin in the fall of 2008 with penetrators collected from JPG. The objectives of the DU penetrator corrosion study are to identify the nature of the corrosion products, particularly the different uranium valence states and chemical species, and the rates of penetrator corrosion.



~~Figure 5-1. DU Penetrators Observed During April 2008 Gamma Walkover Survey~~

To meet the objectives, ~~The~~ the DU penetrator corrosion study is composed of two distinct components: ~~consisting of~~ corrosion product speciation (Section 5.1) and leachability testing (Section 5.2). Speciation will determine the nature of redox products present as a result of penetrator corrosion to include both that which is adhering to the penetrator and that which is present within adjacent soils. Leachability testing, by comparison, will determine the short-term, site-specific corrosion rate. Special consideration will be given to assuring that penetrators subjected to speciation include representative samples from each of the three soil type groupings (i.e., Avonsburg and Cobbsfork, Cincinnati and Rossmoyne, and Grayford and Ryker) to evaluate any possible soil-specific impacts on the corrosion rates or the corrosion products formed.

The rate at which the penetrators corrode and the nature of oxidation products formed affects the rate of movement of DU in the environment. Each of these components provides information that is important to the determination of the dose to the average member of the critical group over the required 1,000-year period of interest. Several DU penetrators have been identified in the DU Impact Area and were inspected visually (SEG 1996). This investigation revealed a variable degree of yellow surface corrosion products. Based upon physical appearance, this corrosion rind may be a relatively soluble (leachable) hexavalent uranium oxide U(VI), such as Schoepite (nominally $UO_3{\bullet}2H_2O$), with the increased solubility relative to other forms of DU corrosion products present onsite. Other chemical forms of uranium also may be formed in the vicinity of penetrators, depending upon the site-specific geochemical environment. Thus, uranium speciation, local groundwater and surface water properties (especially solution pH, redox potential, and alkalinity), local soil mineralogy (especially the content of iron-containing minerals), and possibly the presence of indigenous microbes (such as *Thiobacillus ferroxidans*) determines the potential solubility and subsequent potential for uranium migration. As such, soil mineralogy, including uranium and iron content, will be determined in the laboratory using representative composites of the soil samples collected from the location of penetrator removal (as discussed in Section 4).

Given that DU is not soluble, but some of the corrosion products are soluble, the potential impact of the uranium corrosion products available for transport in the environment on "the peak annual TEDE dose expected within the first 1,000 years after decommissioning" (10 CFR 20.1401) is dependent on the rate of corrosion and, therefore, must be appropriately assessed as it varies with time. This will be accomplished by determining site-specific short-term corrosion information for the range of soil types specified in Section 4 and applying such information to the range of conditions that may reasonably be expected over the 1,000-year period of interest. This will be accomplished, in part, by using the results of corrosion rate study and varying the corrosion rate with time in the modeling (Section 11) to determine the extent to which dose is sensitive to variation.

Scrape samples will be collected from corrosion products present on 24 DU penetrators at JPG to determine the nature of redox products resulting from corrosion. MCLinc will analyze the scrape samples to identify the specific mineral phases and identify uranium valence states that formed under actual field conditions at JPG. MCLinc also will analyze cross-sections of DU penetrators to identify the depths of oxide formation and elemental association within the oxide layer.

MCLinc also will conduct leachability testing in six controlled environmental chambers using three segments of penetrators with site-formed corrosion rinds and three other segments from which MCLinc has mechanically removed the surface rinds. The chamber tests will include one DU penetrator segment each and subject the segment to 10 cycles of environmentally simulated meteorological conditions (e.g., flood, drain, wet air, dry air) lasting 3 weeks each. GPL will analyze leachate samples collected at the conclusion of each cycle for total and isotopic uranium (^{234}U, ^{235}U, and ^{238}U) using American Society for Testing and Materials (ASTM) D3972-90M. At the conclusion of the leachability testing, scrape samples of the corrosion products and cross-sections from the six penetrators will be re-analyzed.

5.1 BACKGROUND

It is estimated that approximately 100,000 kg (220,462 lb) of DU penetrators were fired at JPG from March 1984 until May 1994. Approximately 30,000 kg (66,138 lb) were removed. Penetrators were fired from two weapons systems. Penetrators fired from 105-mm guns had a mass of 3.17 kg (8.5 lb) and were 39.5 in. long. Penetrators fired from 120-mm guns had a mass of 3.99 kg (10.7 lb) and were 38.7 in. long.

Of the total estimated 100,000 kg of DU penetrators that were fired, approximately 6,600 kg (approximately 7 percent) were fired from the J firing position, almost 90,000 kg (approximately 89 percent) were fired from the 500 Center firing position, and 3,888 kg (approximately 4 percent) were fired from the K5 firing position. Targets were placed at 1,000-m intervals starting 1,000 m from gun position extending to 4,000 m. A trench was formed from the penetrators fired approximately 2,500 m from the 500 Center firing position that was estimated to be 5 to 8 m wide, approximately 1,200 m long, and approximately 1 m deep. Smaller trenches allegedly were formed in the firing line from one or both of the other firing points, but very little information is available about the other trenches. Some of the penetrators that formed the trench then skipped to secondary impact locations while many remain in the vicinity of the trench. The trench is now overgrown and is barely discernable from the surrounding environment. Figure 5-1 shows the general conditions of penetrators and the oxidation products that have formed since they landed after firing between 1984 and 1994 that were observed in April 2008 during the gamma walkover survey conducted in JPG streams.

~~5.1~~5.2 CORROSION ~~STUDY~~ PRODUCT SPECIATION

To evaluate a range of corrosion conditions, SAIC will collect 24 penetrators located at or near the ground surface. Penetrators will include penetrators from each of the three predominant soil types that exist at JPG representing a range of corroding conditions. Ten penetrators will be collected from areas with the Avonsburg and Cobbsfork soil type groupings, 10 penetrators will be collected from areas with the Cincinnati and Rossmoyne soil type groupings, and 4 penetrators will be collected from areas with the Grayford and Ryker soil type groupings. Depending on the ability to find and locate penetrators in the subsurface, approximately half will be obtained from the soil surface and half from the area below but within about 3 in. of the surface for each soil type grouping, ~~.~~ which is expected to be more conservative than collecting penetrators from deeper depths because these conditions are more conducive to oxidation (i.e., closer to ground surface where moisture from precipitation and atmospheric oxygen are more abundant than deeper soils). If penetrators located deeper in the subsurface are encountered during sampling, the field crew will collect up to ~~2~~two penetrators per soil type grouping (Avonsburg/Cobbsfork, Cincinnati/Rossmoyne, and Grayford/Ryker). In addition, the samplers will photograph and document the condition to compare the condition with penetrators collected in shallower soils.

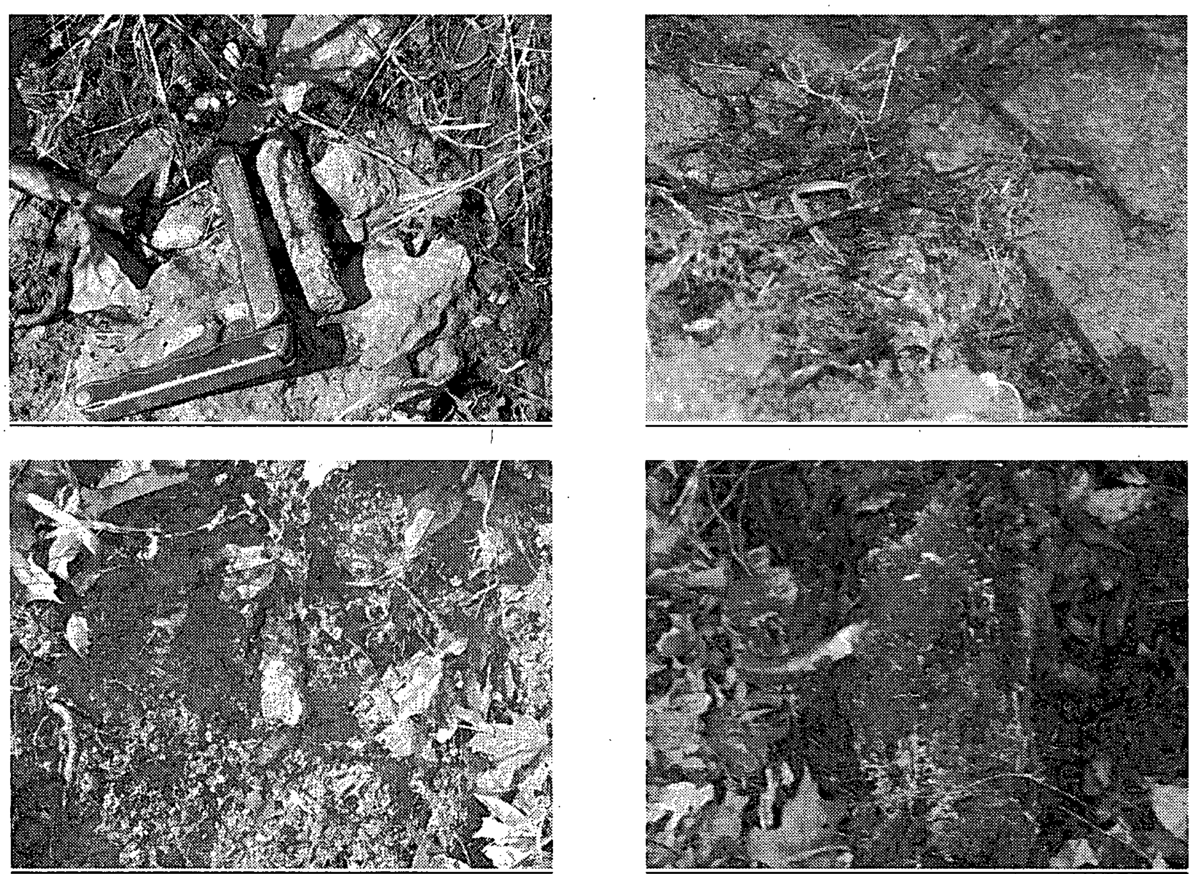


Figure 5-1. DU Penetrators Observed During April 2008 Gamma Walkover Survey

DU penetrators will be carefully removed, leaving corrosion material and/or soil adhering to the penetrator intact. The samplers will document the depth and orientation of the penetrators, including the primary azimuth (e.g., north to south), attitude (e.g., northern end exposed to ground surface and southern end 6 ~~inches~~. BLS), and relative location along the length of the penetrator where soil samples were collected (e.g., above and below southern end). Penetrators will be placed into plastic bags for subsequent submission for corrosion speciation analysis. SAIC will collect and physically examine penetrators at JPG. Each such penetrator will be archived onsite pending selection of representative specimens for transfer to MCLinc for testing. The selection of penetrators will be based on the presence of corrosion, selection of penetrators from each of the three predominant soil type groupings, and evaluation of both penetrators that were located on the ground surface as well as subsurface specimens. Penetrators selected for evaluation subsequently will be transferred to MCLinc.

Some or all of these penetrators may have been identified, removed, bagged, and stored during soil sampling for determination of areal and vertical extent of DU contamination or K_d determination. Regardless of when collected, however, the outside of each of the bagged DU penetrators is to be photographed and marked with the date and time of removal, location, depth to the top of the penetrator, and collector's name. The bagged penetrators will be staged in a predetermined collection area in the DU Impact Area for selection of penetrators for corrosion rate determination.

MCLinc will collect and analyze the scrape samples from 24 penetrators collected from the field at JPG and evaluate penetrators or portions thereof upon completion of leachability testing (Section 5.2). Analysis will use X-ray diffraction (XRD) using ASTM Method D934-80 and X-ray photoelectron spectroscopy (XPS). The initial XRD analysis is to identify the specific mineral phases that have been formed under actual field conditions at JPG. For example, UO_3 exists in an amorphous form and in at least four crystalline modifications, with some variability in solubility and dissolution rate. The XPS, by contrast, is to identify the average uranium valence states. In addition, cross-sections of penetrators will be analyzed by scanning electron microscopy-energy dispersive spectroscopy (SEM-EDS) to identify the depths of oxide formation and elemental association within the oxide layer.

A total of 24 penetrators will be sampled. At least three segments, each 7.6 to 10 cm (3 to 4 in.) in length, will be cut from each selected penetrator. Replicate segments per collected penetrator will permit the initial assessment of as-found corrosion condition on one of the replicate segments while maintaining an as-found replicate segment as a candidate for use in the corrosion testing (Section 5.2). One duplicate segment will be reserved in case a need for an additional evaluation is needed. All three replicate segments will be collected from either above land surface or BLS. The laboratory will avoid collecting segments exposed to different corrosive conditions (e.g., one or two segments exposed to atmospheric conditions and other segments buried underground).

One of the replicate sample segments will be scraped, and the loosely adherent corrosion rind will be collected for nondestructive analysis by XRD and XPS. Since these analyses are nondestructive, they can be performed either with separate subsamples of removed corrosion product or sequentially in each instrument with use of the same sample, depending upon the available mass of corrosion rind that can be removed. The replicate rod segment that has been scraped to obtain samples of loosely adherent corrosion product is now a candidate for the corrosion test. Note that only 3 of the total of 24 penetrators will be selected for testing in the "corrosion-free" (scraped) condition.

One end of one of the replicate sample segments (as-received, with corrosion rind) will be embedded in a shallow pool of epoxy resin. After the resin has cured, the protruding end of the rod will be cut off using a water-cooled diamond saw. The resin-embedded portion of the rod will be polished in cross-section and the projectile-oxide layer boundary will be imaged by SEM-EDS to determine the average depth and structure of the adherent corrosion rind.

Either the balance of corroded rod remaining after cutting off the small portion that has been embedded in resin, or a third segment, is now a candidate for the accelerated ~~corrosion/~~leachability test. Note that only 3 of the total of 24 penetrators will be selected for testing in the as-received (site-formed corrosion) condition. The penetrator segments selected for use in the accelerated corrosion testing will each be weighed and photographed for comparison to the post-testing condition.

~~5.2~~5.3 LEACHABILITY TESTING

Representative penetrator specimens for leachability testing will be selected from available penetrators by SAIC in consultation with MCLinc prior to performing the tests. Penetrators (or appropriate portions thereof) will be transmitted to the subcontracted laboratory with approximately 10 kg (22 lb) of background soil (Section 4.2.1) and 75 L (20 gals) of leaching solution (rainwater). Rainwater was selected as the leachant for this study because the majority of the penetrators are located at or near ground surface (limiting the applicability of deeper groundwater) and fewer are present in permanent streams and creeks (limiting the applicability of surface water). The rainwater will be collected from JPG using plastic sheeting directed onto plastic sheeting into a plastic drum. Soil and rainwater also will be provided to Empirical Laboratories for non-radiological analyses associated with the leachability test using containers described in Section 8.

Initial surface contaminant wash-off and subsequent longer-term effective dissolution kinetics will be estimated with use of a testing regime based upon the American National Standard/American National Standard Institute (ANS/ANSI)-16.1 protocols. This standard is intended to serve as a basis for indexing radionuclide release from solid forms in a short-term (≤ 3-month) test under controlled conditions in a well-defined leachant. For purposes of this evaluation, rainwater collected from the site will serve as the leachant. The ANS/ANSI-16.1 protocol recommends a leachant replacement interval frequency (up to 10 replacements for a 3-month test) and a nominal leachant volume (V, cubic centimeters) to specimen external surface area (S, square centimeters) ratio (V/S) of approximately 10 ± 0.2 cm. The radionuclide concentration and median leaching time will be analyzed to determine an effective leachability index, or effective diffusivity, of soluble uranium from the waste form surface.

Leachability testing in controlled environmental chamber tests will be performed in accordance with ASTM Method D5744-96, "Accelerated Weathering of Solid Materials Using a Modified Humidity Cell." The testing apparatus will consist of six chambers using three segments of DU penetrators with site formed corrosion rinds and three segments of DU penetrators from which the surface rinds have been mechanically removed. The chamber tests will include one DU penetrator segment each approximately 7.6 to 10 cm (3 to 4 in.) in length. MCLinc will artificially imbed the penetrator segments in soil collected from background locations at JPG. Processing of the soil for the test chambers will consist of screening to remove gravel less ¼-in. in size and then blending the bulk phase with use of a riffle splitter to prepare eight homogeneous nominal 1-kg test specimens. This will accommodate one control, six test specimens (with added penetrator segments), and one specimen to reserve for analytical characterization. A seventh chamber will be set up by MCLinc with soil, but without a penetrator to use as a blank control sample. This will confirm that the reference soil does not leach uranium in the absence of added penetrator.

Each chamber will be subjected to 10 cycles of environmentally simulated meteorological conditions (flood, drain, wet air, dry air) lasting 3 weeks each. Sample flooding will a include ratio of 4 L per kg of soil for 7 specimens (including a blank control) run for 10 cycles each (i.e., 30 weeks), thus requiring a minimum of 70 L (approximately 20 gals) of leachate. Leachate samples from each chamber will be analyzed at the conclusion of each cycle for total and isotopic uranium by alpha spectrometry with a MDC of 1.0 µg/L total uranium and 0.1 pCi/L for isotopic ^{238}U, ^{235}U, and ^{234}U, respectively.

The planned duration of the leachability testing in environmental chambers is based on a number of factors. Since the primary objective of the JPG DU Impact Area site characterization is to determine residual dose over a 1,000-year period, the corrosion study ideally would extend over several years, perhaps even decades. Unfortunately, such long-term tests have not been performed primarily because DU munitions were ~~only~~ developed only in the last few decades (i.e., JPG DU munitions are some of the oldest in existence in the environment). However, the primary limitation on the duration of the study is the requirement to submit a final decommissioning plan to NRC by the end of CY 2011 and the time needed to complete the modeling that will be completed after the tests conclude. To meet these conflicting factors, the JPG leachability testing is only one of multiple lines of evidence that will be used to support long-term corrosion estimates. Plus, the duration of the leachability tests can be extended if leaching is not observed in the planned duration of the study (30 weeks). The leachability testing will be supplemented by information available in literature. In addition, the results will be considered in conjunction with measurements of corrosion present in DU penetrators that have been exposed to the elements for 13 to 24 years (fired between 1984 and 1995) using XRD, XPS, and SEM-EDS.

The JPG soil is expected to include viable indigenous microbes, so that it will be unnecessary to inoculate the solids with *Thiobacillus ferroxidans* (as suggested in ASTM Method D5744-96). At the termination of testing, JPG rainwater and the control soil will be submitted to a MCLinc subcontractor (Microbial Insights) for characterization of the dominant microbial population. It is expected that this indigenous microbial population will be representative of the JPG soil and will contribute to the observed corrosion mechanisms. Uranium in the reduced valence state (i.e., U^{4+}) is much less soluble in aqueous phase (and hence less mobile in the geomedia). Microbial interactions may significantly affect the uranium redox condition and possible precipitation in the soil. Therefore, the contribution of the microbial corrosion and control of redox state is potentially important in the interpretation of results.

At the conclusion of the leachability testing, penetrator segments will be retrieved from the test soil matrix and will be weighed and photographed for comparison to the pre-test condition. MCLinc will scrape samples of the corrosion products from each of the six penetrators. These removed corrosion products will be analyzed using XRD (ASTM Method D934-80), XPS, and SEM-EDS.

QC requirements will include a blank control (with no penetrator fragment added) to evaluate leaching of uranium from reference soil in the absence of an added penetrator. Results obtained in leachability tests will be used to establish a "theoretical" estimate of DU penetrator corrosion/dissolution rate that represents the combined effects of a number of site-specific parameters.

The mass and initial appearance of the seeded projectile fragment will be documented, for comparison to the documented attributes of the fragment retrieved at the termination of the accelerated testing protocol. After the completion of the laboratory studies, the penetrators and all fragments will be returned to JPG and disposed of via the Joint Munitions Command at Rock Island.

~~5.~~35.4 EVALUATION OF CORROSION PRODUCT SPECIATION AND LEACHABILITY

The final report will include a description of the apparatus utilized in the study and details of the exposure cycles and a compilation of all the data generated with the raw data packages as appropriate for each test included as appendices. Corrosion study speciation investigations and soil sampling results will be performed to support uranium speciation modeling to calculate the equilibrium compositions of dilute aqueous solutions (mass distribution among dissolved species, adsorbed species, and multiple solid phases under a variety of conditions including a gas phase with constant partial pressures). These results ~~that~~ will be used for comparison ~~with the results of K_d study~~of species-specific K_d values documented in literature to the site- ~~specific~~ and species-specific values determined by the K_d study (Section 6). ~~and~~ The speciation modeling may be used ~~potentially~~ to evaluate temporal impacts that are beyond the available timeframe of the K_d study (e.g., reactions that may occur after the 6 months available for the K_d study). In addition, the uranium speciation modeling may be used in fate and transport modeling (Section 11). The corrosion rate estimated from the short-term leachability study also will be used to specify time-releases of the uranium source in the fate and transport modeling.

6. PARTITION COEFFICIENT STUDY

The partition (or distribution) coefficient (K_d) is used to determine the rate of contaminant transport relative to that of groundwater and, thus, is a very important site-related input parameter for contaminant modeling. Values for K_d vary greatly between contaminants and also as a function of aqueous and solid phase chemistry and can fluctuate over six orders of magnitude because they are "a lumped parameter representing a myriad of processes" (NRC 2006). As a result, NRC encourages licensees to perform site-specific K_d determination when values could be overly conservative. Development of a site-specific K_d value is also the approach recommended by the U.S. Environmental Protection Agency (USEPA) (USEPA 1999).

The primary objective of this study is to determine site-specific K_d values for uranium to be used for modeling radionuclides leaching from soils at JPG from laboratory-measured K_d values. This will be accomplished by deriving K_d measurements following ASTM D4319-93, *Standard Test Method for Distribution Ratios by the Short-Term Batch Method.* ASTM withdrew this method without replacement. Due to the lack of a widely accepted laboratory method (e.g., ASTM, USEPA~~U.S. Environmental Protection Agency~~), TestAmerica will conduct the K_d study using their standard operating procedure (SOP), which is ~~that is~~ based on ASTM D4319-93.

ASTM's short-term batch method measures ion exchange-adsorption reactions only, but historical soil sampling and visual observations confirm that surface and near-surface adsorption appears to be limiting subsurface migration. For this reason, it appears that desorption reactions are more significant than adsorption for evaluating the fate and transport mechanisms related to the 1,000-year period of interest. Therefore, this study includes six tests using background soils with radiotracers or spiked stable tracers to measure adsorption and 18 tests using uranium-contaminated soil collected from under DU penetrators with rainwater as the leachant to evaluate desorption. The duration of the contact between the leachant and the soil will be extended up to 45 days, which is well beyond the 14-day period recommended in the ASTM method, to ensure that the longer desorption processes have reached equilibrium.

Laboratory-measured K_d factors also will be compared with published studies involving similar soils. This section summarizes the K_d study planned to begin in the fall of 2008 using soil collected from JPG. Section 6.1 is an overview of analytical methods for the K_d study, Section 6.2 provides additional details with respect to the soil and leachant, and Section 6.3 summarizes how the site-specific K_d will be determined and used in modeling.

6.1 ANALYTICAL METHOD OVERVIEW

As NRC notes in NUREG-1757 (NRC 2006), the soil partition coefficient, K_d, can be a very important input parameter when calculating doses associated with residual quantities of environmental constituents. The K_d is defined as the concentration of a chemical species on the solid fraction divided by the concentration in the aqueous phase:

$$K_d = \frac{S}{C_w}$$

Where:

S = Mass of chemical species sorbed per unit mass of soil
C_w = Mass of chemical species per volume of solution.

Use of the K_d to evaluate the leaching of chemicals from contaminated soils assumes that rapid equilibrium is reached between the dissolved and sorbed concentrations of a chemical species, and that these two concentrations are linearly related through the K_d factor. In theory, the K_d is used to characterize the *reversible* adsorption of a chemical species on solid surfaces, including soil minerals and organic matter. However, other chemical processes, including mineral precipitation, diffusion into dead-end pores, and attachment to microbes, can influence the experimental measurement of K_d. Although research efforts have attempted to differentiate adsorption from these other processes, there are no universally accepted standard methods for doing so.

There are two laboratory approaches for measuring K_d: the "batch" and the "column" methods. The "batch" method for measuring K_d consists of equilibrating a measured mass of soil with a selected leaching solution (e.g., rainwater, synthetic, unimpacted site groundwater). In the more commonly used adsorption mode for K_d testing, the contact solution is spiked with a measured mass of the chemical species of interest, which then adsorbs onto the soil during equilibration. It is also possible to use contaminated soils, in which case the chemical species of interest desorbs from the soil into the contact solution. The concentration of the chemical species then is monitored in the contact liquid over time. When this concentration reaches a steady state and is not oversaturated (i.e., solubility limits have not been exceeded), it is assumed that the liquid and solid concentrations are in equilibrium, and K_d is calculated from their ratio. The liquid concentration is directly measured, while the solid concentration usually is inferred from a mass balance knowing the initial mass of chemical species in the soil/water mixture.

In the "column" procedure for measuring K_d, a soil column (i.e., a cylinder packed with soil) is flushed with the contact solution under a controlled flow rate. The K_d factor then is determined by analyzing the breakthrough of the chemical species of interest at the effluent end of the soil column. The "column" procedure is a closer simulation of the physical processes occurring in the field; however, the experimental set-up and data interpretation are more difficult when compared to the "batch" procedure. Moreover, batch and column loading of uranyl complexes was compared in one study, and no significant differences were observed (Bostick et al. 2002). Thus, the "batch" procedure is more commonly used when a large number of tests are needed to characterize spatial variability. Consistent with the RESRAD data collection manual (Yu et al. 1993), laboratory K_d measurements will be determined using ASTM D4319-93, *Standard Test Method for Distribution Ratios by the Short-Term Batch Method.*

ASTM D4319-93 explains that the "distribution coefficient" (or K_d) is derived from the laboratory measured "distribution ratio" (R_d). The test method is simply a measurement technique for determining the distribution ratio or degree of partitioning between liquid and solid, under a certain set of laboratory conditions, for the species of interest. The R_d is used for estimating the value of K_d for given underground geochemical conditions based on a knowledge and understanding of important site-specific factors. The measured R_d values will be evaluated statistically and using geochemical speciation modeling to define the K_d values used in RESRAD-OFFSITE and other fate and transport modeling codes. The uranium speciation modeling is planned to be conducted using either USEPA's MINTEQA2 or U.S. Geological Survey's (USGS') PHREEQC model geochemical model with sampling data from the groundwater wells and soil samples and results from the corrosion study speciation tests and K_d study to determine the predominant uranium species, mass distribution among dissolved species, adsorbed species, and multiple solid phases.

Given that site-specific K_d values are ideally available for the range of aqueous and geological conditions in the system to be modeled, SAIC will obtain a total of 96 soil samples for use in K_d determination.

6.2 SOIL AND LEACHANT FOR DETERMINATION OF K_d

Collection of soil and water to be used as leachant is an integral part of the fall 2008 field activities. Soil and rainwater collected at JPG will be used by TestAmerica for the K_d study. Soil and rainwater also will be provided to Empirical Laboratories for non-radiological analyses associated with the K_d study using containers described in Section 8.

Soil will be collected and processed as specified in Section 4 with a total of 1.5 to 2 kg of soil being provided for each sample. Soil will be collected beneath eight~~10~~ ~~8~~ penetrators from areas with the Avonsburg and Cobbsfork soil types, soil beneath ~~10~~ ~~8~~eight penetrators from areas with the Cincinnati and Rossmoyne soil types, and soil beneath ~~4~~ ~~2~~two penetrators from areas with the Grayford and Ryker soil types. Soil also will be collected from background areas with the Avonsburg and Cobbsfork soil types (2 samples), Cincinnati and Rossmoyne soil types (2 samples), and Grayford and Ryker soil types (2 samples). Additional details concerning the collection of soil are provided in Sections 4.1.1 and 4.2.4.

Leachant to be used in laboratory K_d testing will be supplied by SAIC. The rainwater will be collected from JPG using plastic sheeting directed into a plastic drum. Fifteen L of water will be placed directly into each of two 20-L (5.3-gal) containers for a total volume of 30 L. In addition to the 20-L containers, 1-L water samples will be provided for ^{234}U, ^{235}U, and ^{238}U activity analyses and one 500 milliliter (mL) sample container will be collected for determination of major cation analysis (Ca, K, Mg, Na) and another 500 mL container for anion (Cl^-, NO_3, and SO_4) analysis.

Upon receipt of soil and water from JPG, TestAmerica will analyze subsamples taken from soil and water aliquots for total and isotopic uranium using Eichrom resin technology, which provides results comparable to the methods outlined in ASTM-D3972-90M.

Nonradiological soil and water parameters to be measured ~~in the laboratory~~ by –Empirical Laboratories include:

- Moisture content (ASTM D2216-05)
- Soil pH (ASTM D4972-01/EPA 9045C)
- Particle size distribution (ASTM D422-63)
- Total organic carbon/soil (SW9060A; E 415.1)
- Total carbon/soil (SW9060A)
- Total iron (Fe)/soil and water (SW 6010)
- Total manganese (Mn)/soil and water (SW 6010)
- Major cations/water (SW 6010)
- Major anions/water (E 300.0)
- Alkalinity (E310.1).

The soil and water samples will be handled, packaged, and shipped to TestAmerica in accordance with specifications in Section 8.

6.3 DETERMINATION OF K_d

Before K_d testing is initiated, the subcontractor must review analytical results depicting the radionuclide concentrations in the soil samples and select samples containing the appropriate concentrations of uranium. TestAmerica will give special consideration to ensure that test results are not biased by solubility limits by selecting soil samples with total uranium less than 360 pCi/g. This limit is based on the highest concentration (989 mg/Kg) successfully tested by Pacific Northwest National Laboratory (PNNL 2002) in multiple K_d tests run with various pH levels, carbonate concentrations, uranium concentrations, and total ionic strengths.

For each soil sample, the laboratory will prepare soil/water mixtures to enable sampling of each mixture for uranium analysis of the supernatant at predetermined time intervals (e.g., 3, 7, 10, 14, 21, 28, 35, and 45 days). These time intervals/analyses test periods are believed to be sufficient to allow steady-state concentrations in the supernatant to be observed with the achievement of steady state anticipated about mid-way through the test period. Completed data from each time interval up through day 14 will be evaluated by TestAmerica in coordination with the SAIC Project Manager to determine whether a steady-state already has been achieved (i.e., verifying the same concentration in two subsequent samples upon completion of each test regimen) for particular samples such that testing on subsequent intervals for that sample(s) could be suspended without adversely affecting project results. Total and isotopic uranium in the supernatant/contact liquids will be quantified using method alpha spectrometry with individual samples being prepared using Eichrom resin technology. Total uranium will be calculated using a published specific activity value for ^{238}U and assuming that all mass originates from ^{238}U.

The results of the K_d study, to include uranium isotopic concentrations in the supernatant and in the soil and water samples provided to the laboratory, will be provided in a summary report. The K_d values provided in this report will serve as the basis for applicable RESRAD-OFFSITE input parameter values. TestAmerica will identify any outliers and recommend an approach for computation of the K_d. SAIC will evaluate possible outliers and, if present, consider eliminating the outliers from the determination of the resultant mean. Individual K_d values also will be obtained and used for sensitivity analyses. After evaluating and possibly eliminating outliers, SAIC will evaluate the results of the K_d study using geochemical speciation models and conduct sensitivity analyses in additional models as described in Section 13. Pending confirmation following completion of the studies and planned data analyses, the mean K_d value is proposed for use in RESRAD-OFFSITE dose modeling with additional K_d values to be used in the supporting modeling (Section 13.3).

7. FIELD OPERATIONS DOCUMENTATION

Sufficient information will be recorded in the logbooks to permit reconstruction of all site sampling activities conducted. Information recorded on other project documents will not be repeated in the logbooks except in summary form where determined necessary. All field logbooks will be kept in the possession of field personnel responsible for completing the logbooks, or in a secure place when not being used during fieldwork. Upon completion of the field activities, all logbooks will be submitted to the Project Manager to become part of the final project file.

The logs, diagrams, and forms that will be completed during soil sampling and collection of penetrators are included in Appendix B. The SAIC requirements related to field documentation are described in the SAIC FTPs listed in Table 7-1. These FTPs are provided in electronic format in the attached CD.

Table 7-1. Relevant SAIC Procedures for Field Documentation Jefferson Proving Ground, Madison, Indiana

Number	Title	Latest Revision	Date
FTP-625	CoC	1	06/08/2001
FTP-1215	Field Logbooks and Field Forms	1	01/31/2007
FTP-1220	Documenting and Controlling Field Changes to Approved Work Plans	2	4/20/2007

THIS PAGE WAS INTENTIONALLY LEFT BLANK

8. SAMPLE HANDLING, PACKAGING, AND SHIPPING

Sample handling, packaging, and shipping practices will be conducted in accordance with established SAIC procedures. The SAIC sample packaging and shipping requirements are described in the SAIC FTPs listed in Table 8-1. These FTPs are provided in electronic format on the attached CD.

Table 8-1. Relevant SAIC Procedures for Sample Handling, Packaging, and Shipping Jefferson Proving Ground, Madison, Indiana

Number	Title	Latest Revision	Date
FTP-405	Cleaning and Decontaminating Sample Containers and Sampling Equipment	1	8/15/2000
FTP-625	CoC	1	6/08/2001
FTP-650	Labeling, Packaging, and Shipping of Environmental Field Samples	1	2/11/2000
FTP-651	Hazardous Materials/Dangerous Goods Shipping for E&I BU Field Work	2	11/20/2006
FTP-1215	Field Logbooks and Field Forms	1	1/31/2007
QAAP 13.1	Handling, Storage, and Shipping	1	3/13/2002

Except for 1-gal plastic bags to hold soil for leachability testing and K_d tests and large plastic bags to ship penetrators, all sample containers will be provided by the analytical support laboratory. The laboratories also will provide the required types and volumes of preservatives with containers as they are delivered to JPG. In the event that sample integrity (e.g., holding times) is compromised, re-sampling will occur as directed by SAIC's Project Manager after discussions with the Army and NRC Project Managers. Any affected data will be flagged and qualified per data validation instructions and guidance.

8.1 LABORATORY RESPONSIBILITIES

The analytical responsibilities for the JPG DU Impact Area site characterization are shared between SAIC and supporting analytical laboratories. GPL will perform most soil sample analyses while MCLinc and TestAmerica will perform the corrosion and K_d studies, respectively. The analysis of soil and water samples needed for the corrosion and K_d studies will be handled by MCLinc and TestAmerica, respectively. Non-radiological analyses of soil and rainwater associated with the corrosion and K_d studies will be performed by Empirical Laboratories. Addresses for the supporting laboratory facilities are as follows:

- GPL Laboratories, LLLP, 7210A Corporate Court, Frederick, MD 21703
- Materials and Chemistry Laboratory, Inc., East Tennessee Technology Park, Building K-1006, 2010 Highway 58, Suite 1000, Oak Ridge, TN 37830-170
- TestAmerica, Inc., 13715 Rider Trail North, Earth City, MO 63045
- Empirical Laboratories, LLC, 227 French Landing Drive, Suite 550, Nashville, TN 37228.

8.2 SAMPLE CONTAINERS, PRESERVATION, AND HOLDING TIMES

Sample containers, chemical preservation techniques, and holding times are presented in Tables 8-2 and 8-3. Except for the plastic bags listed below, the laboratory will provide specified numbers of containers required for each sampling event. Additional sample volumes will be collected and provided, when necessary, for the express purpose of conducting associated laboratory QC (field blanks, equipment blanks, laboratory duplicates, and MS/MSDs).

Table 8-2. Summary of Sample Contaminant and Sample Preservation Methods for Soil, Corrosion Product Samples, and DU Penetrators Jefferson Proving Ground, Madison, Indiana

Parameter	Analytical Method	Sample Container		Preservation Methods	Holding Times
		Quantity	Type		
Total and isotopic uranium: ^{234}U, ^{235}U, and ^{238}U	ASTM D3972-90M/ SM 7500-UC using SC&A SOP 348 Rev 3	8 oz	Glass jar	None	6 months
Soil for ~~Corrosion Study~~ Leaching Test	ASTM D5744-96	1-gal	Plastic bag	None	None
Corrosion Products	ASTM D934-80 and XPS	— [a]	Plastic bag [b]	None	None
DU Penetrators	ASTM D5744-96 and SEM-EDS	— [a]	Plastic bag [b]	None	None
Soil for K_d Study	ASTM D4319-93	1-gal	Plastic bag	None	None
Moisture Content	ASTM D2216-05	8 oz	Glass jar	None	7 days
Soil pH	ASTM D4972-01/	8 oz	Glass jar	None	ASAP
Particle Size Distribution	E9045C	8 oz	Glass jar	None	6 months
Total Organic Carbon	ASTM D422-63	8 oz	Glass jar	None	28 days
Total Carbon	SW9060/415.2	8 oz	Glass jar	None	28 days
Total Iron	SW9060/415.2	8 oz	Glass jar	None	6 months
Total Manganese	SW6010	8 oz	Glass jar	None	6 months

[a] DU penetrators with corrosion material and/or soil adhering to the penetrator packed together
[b] DU penetrators double-wrapped in extra heavy plastic (6-mil or stronger) trash bags (20 to 30 gal)

Table 8-3. Summary of Sample Containment and Sample Preservation Methods for Water Samples Jefferson Proving Ground, Madison, Indiana

Parameter	Analytical Method	Sample Container		Preservation Methods	Holding Times
		Quantity	Type		
Total and isotopic uranium: ^{234}U, ^{235}U, and ^{238}U	ASTM D3972-90M	1	1-L polypropylene bottle	HNO_3 to pH<2	6 months
Anions (nitrate, chloride, and sulfate)	E300/SW9056	1	500-mL polyethylene bottle	Cool, 4°C	48 hour (nitrate) and 28 days (chloride and sulfate)
Metals (calcium, iron, potassium, magnesium, manganese, and sodium)	SW6010	1	500-mL polyethylene bottle	HNO_3 to pH<2 Cool, 4°C	6 months
Alkalinity	E310.1	1	500-mL polyethylene bottle	Cool, 4°C	14 days
TOC	E415.1	2	125-mL amber glass bottles	H_2SO_4 to pH <2 Cool, 4°C	28 days
Leachant for leaching test	ASTM D5744-96	5	5-gal HDPE Carboy	None	None
Leachant for K_d study	ASTM D4319-93	5	5-gal HDPE Carboy	None	None

8.3 SAMPLE IDENTIFICATION

A sample I.D. system will serve as a unique identification code for each sample collected. These sample I.D.s will be assigned before the sampling events begin. The sample numbering system will use letter codes to distinguish matrices and various QC samples. The purpose of this numbering scheme is to provide a tracking system for the retrieval of analytical and field data on each sample. Sample I.D. numbers will be used on all sample labels, field data sheets or logbooks, CoC records, and all other applicable documentation used during each project.

Unique serial number ranges will distinguish sample type categories (i.e., regular field samples versus field duplicates). The general sample identification format is JP-T-CCC. "JP" represents the JPG DU Impact Area site characterization. "T" represents the type of sample ("W" = water, "D" = sediment, "S" = soil, "L" = leachability, "K" = K_d study, "P" = penetrator). One or two additional characters are used to specify the type of sample (see descriptor column in Table 8-4). "CCC" represents the unique sample location numbered sequentially. All sample I.D.s will be maintained in a log by the Field Manager. The following QC test and flagging codes will be used to identify duplicate environmental and field QC blank samples:

- "D" entered in the flagging code field will be used to identify all field duplicates collected in the field
- "R" entered in the QC test code field will be used to identify all rinsate blanks collected in the field at a frequency of one blank per day
- "F" entered in the QC test code field will be used to identify all source water blanks collected in the field.

8.4 DU PENETRATOR SHIPMENT REQUIREMENTS

DU penetrators will be shipped as a "limited quantity of radioactive material" pursuant to the provisions of 49 CFR Section 173.403 (i.e., a quantity of material not exceeding the package limits specified in Section 174.425 and conforming with the requirements specified in Section 173.421). The applicable package limits specified in Section 174.425 are unlimited for DU. The requirements of Section 174.421 state that excepted packages for limited quantities of Class 7 radioactive material are excepted from requirements in this subchapter for specification packaging, labeling, and marking (except for United Nations [UN] identification number marking requirement described in Section 173.422[a]) provided:

1) Each package meets the general design requirements of 49 CFR Section 173.410 (e.g., the package must be capable of withstanding the effects normally incident in transportation without any loss of integrity of the package)
2) The radiation level at any point on the external surface of the package does not exceed 0.5 mrem per hour
3) Removable contamination does not exceed 220 or 22 disintegrations per minute (dpm)/cm2 for beta and alpha, respectively
4) The outside of the inner packaging or the outside of the packaging itself must bear the marking "Radioactive"
5) The outside of each package must be marked with the 4-digit UN identification number.

The hazardous material description and proper shipping name as specified in the Hazardous Material Table in 49 CFR Section 172.101 is "Radioactive Material, Excepted Package – Limited Quantity of Material," UN 2910.

Table 8-4. Summary of Sample Identification Scheme
Jefferson Proving Ground, Madison, Indiana

Sample Types	Descriptor	First	Last	Total Locations/ Samples
Soil				
Background – Avonsburg and Cobbsfork	AC	JP-SAC-001	JP-SAC-008	8 / 36
Background – Cincinnati and Rossmoyne	CR	JP-SCR-001	JP- SCR-008	8 / 36
Background – Grayford and Ryker	GR	JP-SGR-001	JP-SGR-008	8 / 36
Category 1 – Outside DU Impact Area Perimeter	C1	JP-SC1-001	JP-SC1-012	12 / 48
Category 2 – Immediately Inside DU Impact Area	C2	JP-SC2-001	JP-SC2-012	12 / 48
Category 3 – Midway to DU Impact Area Trenches	C3	JP-SC3-001	JP-SC3-012	12 / 48
Category 4 – Immediately Outside DU Impact Area Trenches	C4	JP-SC4-001	JP-SC4-012	12 / 60
Category 5 – Other Nature and Extent Samples	C5	JP-SC5-001	JP-SC5-032	32 / 128
Category 6 – Trench Locations	C6	JP-SC6-001	JP-SC6-012	12 / 60
Soil Under Penetrators – Avonsburg and Cobbsfork	PN	JP-PNAC-001	JP-PNAC-010	10/10
Soil Under Penetrators – Cincinnati and Rossmoyne	PN	JP-PNCR-001	JP-PNCR-010	10/10
Background – Grayford and Ryker	PN	JP-PNGR-001	JP-PNGR-004	4/4
Leachability – Avonsburg and Cobbsfork	AC	JP-LAC-001	—	1 / 1
Leachability – Cincinnati and Rossmoyne	CR	JP-LCR-001	—	1 / 1
Leachability – Grayford and Ryker	GR	JP-LGR-001	—	1 / 1
K_d – U~~u~~nder penetrators Avonsburg and Cobbsfork	AC	JP-KAC-001	JP-KAC-~~010~~008	~~10~~ 8 / ~~10~~8
K_d – ~~u~~Under penetrators Cincinnati and Rossmoyne	CR	JP-KCR-001	JP- KCR-~~010~~008	~~10~~ 8 / ~~10~~8
K_d – ~~u~~Under penetrators Grayford and Ryker	GR	JP-KGR-001	JP-KGR-~~004~~002	~~4~~ 2 / ~~4~~2
K_d – ~~b~~Background Avonsburg and Cobbsfork	AC	JP-KAC-009	JP-KAC-010	2 / 2
K_d – ~~b~~Background Cincinnati and Rossmoyne	CR	JP-KCR-009	JP- KCR-010	2 / 2
K_d – ~~b~~Background Grayford and Ryker	GR	JP-KGR-003	JP-KGR-004	2 / 2
Rain Water				
Leachability	GR	JP-WL-001	—	1 / 1
K_d	AC	JP-WK-001	—	1 / 1
Other				
Penetrators/Corrosion Products – Avonsburg and Cobbsfork	P	JP-PAC-001	PAC-010	10 / 10
Penetrators/Corrosion Products – Cincinnati and Rossmoyne	P	JP-PCR-001	JP-PCR-010	10 / 10
Penetrators/Corrosion Products – Grayford and Ryker	P	JP-PGR-001	JP-PGR-004	4 / 4

SAIC health physics personnel will perform the surveys and monitoring as necessary to ensure compliance with these provisions prior to shipping DU penetrators from JPG to MCLinc for the corrosion study.

9. INVESTIGATION-DERIVED WASTES

Following completion of field work, in the unlikely event that any radioactive waste (e.g., waste exceeding contamination release criteria) is generated, it shall be turned over to the Army for secure storage and proper disposal. No radioactive waste is anticipated to be generated under this work scope.

IDW generated during sampling tasks will consist of decontamination liquids; paper, cardboard, and plastic bagging and containers from sampling materials; Tyvek® coveralls; disposable tubing; and disposable gloves. Well purging fluids (groundwater) and decontamination liquids (if used) generated from equipment decontamination will be disposed of on the ground in the general area from which the materials originated. Any other wastes, if determined to be radioactive, will be turned over to the Army and will be surveyed, packaged, stored, and transported in accordance with applicable regulations, and disposed of as normal solid waste if determined not to be radioactive.

Any materials such as disposable gloves, Tyvek®, paper towels, paper and plastic bagging, containers from well materials, plastic sheeting, disposable tubing, and lumber will be surveyed or placed into plastic garbage bags and later surveyed by the HPT to determine if they are radioactive, and placed into the U.S. Fish and Wildlife Service (USFWS) dumpster for disposal as normal solid waste if determined to not be radioactive. If IDW disposal is determined to be necessary, the Army might handle it themselves or a change order may be requested to include the services of a qualified and experienced licensed radioactive waste broker (e.g., Clean Harbors or Onyx/Veolia). Radioactive wastes, if generated, will be stored temporarily in a secured location, as directed by the Army and will remain the property of the Army.

Following the completion of the corrosion study, the penetrators and all fragments will be returned to JPG. After that time, they will be disposed of via the Joint Munitions Command at Rock Island, Illinois.

THIS PAGE WAS INTENTIONALLY LEFT BLANK

10. RADIOLOGICAL RESPONSIBILITY AND LICENSING

The possession of radioactive materials at JPG is authorized and governed under a radioactive materials license granted by NRC to the Army. The license number is Source Material License SUB-1435. The current amendment is No. 15, dated 6 March 2008. The license authorizes the possession of up to 80,000 kg (approximately 177,000 lb) of DU metal, alloy, and/or other forms. Given that NRC regulations generally preclude transfer of radioactive materials to unlicensed organizations and individuals, copies of radioactive materials licenses for all test participants/subcontractors will be obtained prior to shipment of any materials for which a license is required. The Army has requested that SAIC be responsible for the work that is described in this FSP Addendum, and obtain and utilize a license from NRC that authorizes the contractor to provide radiological services for the Army. SAIC has obtained and will utilize such a license.

The SAIC St. Louis office is authorized to provide certain radiological services to clients under a radioactive materials license granted by NRC to SAIC. The license number is 24-32591-01. License condition No. 14 requires that SAIC enter into a written agreement with the Army so that roles, responsibilities, and lines of authority for work at the site are clearly defined. This written agreement will be issued in letter form and must be signed by authorized persons from both SAIC and the Army prior to initiating work under this FSP Addendum. Once the agreement is signed, Figure 10-1 will be used to document the true date and time that responsibilities are transferred between the Army and SAIC.

Samples will be prepared and shipped to laboratories that are appropriately licensed by NRC or an Agreement State for analysis.

Section 1 – Acceptance by SAIC Under NRC License No. 24-32591-01

Form ID No. (MM-DD-YYYY-XX):	
Task Description and Working location (be very specific):	
Governing Work Document(s) (e.g., FSP, HASP Addenda):	
Client Contacted (print name):	Method of Notification:
☐ Check to confirm that the client has agreed to remit the working area(s) to SAIC	
SAIC Approval to Accept	
SAIC Name (print):	Signature:
Date Accepted:	Time Accepted:
Follow-on Client Approval to Remit	
Client Name (print):	Signature:

Section 2 – Remittance by SAIC to the Army Under NRC License No. SUB-1435

Client Contacted (print name):	Method of Notification:
☐ Check to confirm that the client has agreed to accept the working area(s) from SAIC	
SAIC Approval to Remit	
SAIC Name (print):	Signature:
Date Remitted:	Time Remitted:
Follow-on Client Approval to Accept	
Client Name (print):	Signature:

Figure 10-1. Acceptance and Remittance of Radiological Responsibility at JPG

11. AQUIFER TESTING FOR HYDRAULIC CONDUCTIVITY

The exposure modeling proposed includes modeling the movement of groundwater and the potential migration of contaminants with groundwater. In order to complete this modeling, hydrogeologic parameters or inputs to the models either must be selected from acceptable ranges for the subsurface conditions believed to be present at the site, from literature, using default values provided with the models, or by collecting site-specific data or estimates based on professional judgment for those hydrogeologic parameters. Hydraulic conductivity (K) is one of the hydrogeologic model inputs and is defined as the volume of water that will move through a porous medium in a unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow (Kruseman and Ridder 1992). Many methods have been developed for measuring and estimating hydraulic conductivities. Slug testing is a widely used and accepted field method for collecting site- and well-specific slug response data that can be used to calculate an estimate of the hydraulic conductivity. This section summarizes the slug testing field methods and the basics of the analysis of the collected data.

A slug test is completed by causing a near-instantaneous change in hydraulic head and measuring and recording the resulting head response. This is completed by either removing or adding a solid object or "slug" into the water column present in a well. There are numerous types of "slugs," but probably the most prevalent and commonly used consist of a solid or sealed pipe of known volume that either is lowered into or raised from the water column in the well. Another commonly used "slug" consists of introducing into the well a known volume of water. We will not use water "slugs" during this investigation for several reasons. Generally, the wells at JPG have low yields and therefore will have low hydraulic conductivities. These wells also are being used for sample collection for other characterization and evaluation purposes. If "clean" water were introduced into the well, it could displace or dilute the water present within the aquifer. Without removing an appropriate volume of water following the completion of the slug testing, the quality and accuracy of the chemical samples collected following the slug testing could be impacted. Therefore, all of the slugs used during this investigation will consist of solid or sealed pipes.

By performing repeat slug tests at individual wells and comparing the responses, it is possible to verify if the conventional theory is valid for that well and if conventional analysis of the slug test response data can be completed (Butler 1998). Additional initial evaluations of the response data will be completed to determine characteristics of the well and/or aquifer that will affect the selected methods of analysis and calculations of the hydraulic conductivity estimates. Some of these initial evaluations will include, but not necessarily be limited to, the comparison of rising head versus falling head test results and evaluation of the measured initial head displacement with respect to the calculated estimate of the expected initial head displacement.

11.1 SLUG TESTING EQUIPMENT

Slug test execution and data collection is a rather simple field method and does not require a lot of equipment. One critical piece of equipment to be considered is how and what will be used to measure and record the head displacements or water level changes as a result of introduction or removal of the slug. In order to collect highly accurate head or water level changes, a pressure transducer attached to an electronic data recorder will be used for all of the tests. This combination of the pressure transducer and electronic data recorder will enable data collection faster than that possible by manually collecting the water level measurements and the data can be imported directly to Microsoft® Excel. Other equipment required will consist of an electronic water tape and the "slugs." The water tape will be used for confirming the set-up and calibration of the electronic data logger. As mentioned previously, only solid or sealed pipe slugs will be used during this investigation.

11.2 SLUG TEST METHOD

A series of tests will be completed at each well tested and will consist of a minimum of three separate tests. They will include both rising (slug out) and falling (slug in) head tests. An attempt will be made to vary the initial displacement by two times in at least one of the tests and the first and last tests will be made with the same slug size to attempt to have the same (or closely similar) sized initial displacement. During the tests, all equipment that will be deployed down hole will be properly decontaminated prior to placing into the well. Care will be taken to keep decontaminated equipment from contacting potentially contaminated materials (e.g., ground, dusty vehicles) and may be placed into new, clean plastic trash bags or onto new, clean plastic sheeting. If trash bags and/or plastic are used, they will be disposed of between wells and will not be re-used for the purpose of keeping equipment clean.

The following steps will be completed at each tested well. Modifications to these steps can be made with concurrence of SAIC's Project Manager based on evaluations of the collected data, with considerations of the individual well parameters, and through discussions with Army and NRC representatives. Any changes to the procedures will be documented and transmitted to the Army and NRC. An example of a modification that could be considered would be reducing or adding individual slug tests to the series of tests completed at an individual well. If modifications are made, the evaluations and rationale for the modification will be documented and included in follow-up reporting.

1. Remove the well cap and measure the depth to water. This will be completed in steps two and four and also with a final static water level to determine if there are any temporal trends in the water levels occurring during the test series time period, as well as confirming proper transducer operation.
2. Calculate the standing water column height with the known total depth of the completed well and the measured depth to water.
3. Select the transducer, appropriate cable length, and data logger based on the measured depth to water and the calculated standing water column height. The maximum depth of submergence for a pressure transducer can be calculated by multiplying 2.31 ft/lb per square inch (psi) by the psi. For example, a 30 psi transducer has a maximum submergence of 69.3 ft (2.31 ft/psi * 30 psi).
4. Re-measure the depth to water and compare to water level measured during step one to determine if the water level was static or if the well cap had sealed the well. If the water level is responding to having the sealed well cap removed, allow the water level to equilibrate to static conditions.
5. After the water level is determined to be static, install the transducer and data logger into the well deep enough to allow the un-hindered introduction of the slug as well as considering the maximum depth of submergence that will occur during the falling head tests, making sure that the transducer will not be over pressurized during any portion of the test. After the transducer is installed, connect the computer and collect a water level measurement. If the water level is determined to not be static such as due to response to a precipitation event, the test will have to be postponed until there are relatively static conditions.
6. Allow an appropriate temperature equilibration period (usually 10 to 20 minutes) for the pressure transducer based on static measurements and the difference in ambient outside temperature and groundwater temperature. Allow greater equilibration time for greater differential between the ambient and groundwater temperatures.
7. After it is confirmed that the transducer is equilibrated for temperature, set up a test in the data logger. The initial test will be set up to collect measurements a minimum of 1 second apart or logarithmically initially, followed by a linear measurements interval for the later time period of the tests. The measurement interval can be lengthened if it is known or demonstrated that the

response to slug is slow and the short measurement interval is not required to capture the critical response data. In wells with high hydraulic conductivities, the response can be very quick and can fully recover in seconds requiring a short measurement interval. The data file name will include the well name, the test number in the series and a designator for rising head (rh) or falling head (fh) (example JPGDU01DTest1fh, or MW11Test2rh). The tests in the series will be numbered sequentially.

8. Attach disposable nylon cord to the slugs that will be used for the individual well being tested. Record the unique slug I.D. number and known or calculated slug volume that is used during each test. Place the slug into the well casing and lower it to just above the water level marking at the ready position being sure to not place it into the water before initiating the data recording.
9. When the slug is in the ready position, start the data recorder and introduce the slug smoothly and as near to instantaneously as possible trying to complete the start of data recording and slug introduction as close to the same time as possible. It is better to have the data recording be started slightly before the slug introduction than the reverse order, which results in missing some of the very initial data. When introducing the slug, make sure to lower it below the static water level without hitting the top of the pressure transducer.
10. Using the pressure transducer, monitor the response to the slug and estimate how long it will be until the next test can be initiated. The water level should be allowed to return to approximately static conditions or at least to a point where the deviation from the static at test initiation (residual deviation) is less than 5 percent of the measured initial displacement. This should allow for repeat test results to agree within 10 percent (Butler 1998, p. 44-45).
11. When the water level has returned to pre-test static conditions or is within an acceptable residual deviation range of less than 5 percent, the test can be stopped in the data recorder. The second test in the series will be set up in the data recorder and the second test is initiated and the slug is rapidly and smoothly removed from the well taking care not to bump the transducer or cable while removing the slug. The end of the second test in the series is determined finished following the guidelines in step 10. If excessive lengths of time (e.g., 4 to 8 hours) are required for the residual deviation to reach 5 percent, the dimensionless storage parameter for that well can be considered. This should be discussed with the Project Manager and, if the dimensionless storage parameter is assumed to have a moderate or small value, the required residual deviation goal can be modified to less than 20 percent (Butler 1998, p. 44-45). If the residual deviation goal is modified to less than 20 percent, an additional graphical evaluation of the response data will be completed to confirm that the effects of complete recovery are small. This evaluation will be completed before concluding the slug testing activities at the site.
12. The third test in the series is completed using a larger slug (optimum is one that will cause an initial displacement of at least twice that measured during the first test and steps 8 through 11 should be followed for tests 3 and 4 of the series).
13. After test 4 of the series is completed at a minimum, at least one more test should be completed using the slug used for the initial test.
14. After all of the tests are completed and the water level has returned to static conditions, a water level should be measured for use in evaluating any potential temporal water level trends and proper transducer operation. Evaluation of static conditions will be completed by reviewing the data logger data for changing water levels or stable conditions.

Following completion of the slug test series at an individual well, the disposable cord will be removed from the slugs. Each slug, data logger, and water level indicator used will be properly decontaminated by completing a Alconox tapwater scrub followed with a deionized water rinse, prior to using in another well. The data logger will be downloaded into a field computer and the data will be viewed to make sure that it is complete and looks reasonable. A back-up copy of all downloaded field data will be made onto a second storage device prior to leaving the field. Once back to the field office or hotel, the raw data files will be copied onto a third storage device such as a portable hard drive or CDs so that at all times there are a minimum of two copies of the raw data files.

Due to a short water column at some of the existing site wells, slug-testing will be completed on a subset of the existing wells within and surrounding the DU Impact Area. The limited water level data collected were reviewed and the following bullets indicate the wells that appear to have sufficient water column height to accommodate the introduction of solid slugs based on water level measurements completed during the April and July 2008 quarterly groundwater monitoring events:

- JPG-DU-01I
- JPG-DU-01D
- JPG-DU-02I
- JPG-DU-03O
- JPG-DU-03I
- JPG-DU-04O
- JPG-DU-04I
- JPG-DU-04D
- JPG-DU-05I
- JPG-DU-06O
- JPG-DU-06I
- JPG-DU-06D
- JPG-DU-09O
- JPG-DU-09I
- JPG-DU-09D
- JPG-DU-10O
- JPG-DU-10D
- MW-2
- MW-3
- MW-5
- MW-6
- MW-7
- MW-10
- MW-11
- MW-RS2.

The water levels in the site wells will be measured at the beginning of the slug test task and the list of wells may be adjusted based on the water columns present at the time of the slug test. In addition to the available water columns for testing, the available well construction details will be considered for appropriateness of the well construction for slug testing. Some of the conditions that will remove wells from consideration for testing include wells with two screen intervals (MW-1 and MW-4) and wells with screen intervals in both unconsolidated and bedrock portions of the aquifer (MW-11). The subset of wells that will be tested will provide an adequate number of hydraulic conductivity estimates from the wells completed in the overburden, shallow, and deeper bedrock zones to provide suitable site-specific model inputs.

11.3 SLUG TEST DATA AND ANALYSIS

The preparation and analysis of the data consists of several steps, including pre-analysis, verification of applicability of conventional theory, and analysis. Several key aspects and evaluations that could be included in the preparation of the data and data analysis are summarized in the following subsections. This discussion is not intended to be a complete or exhaustive description of the analysis that could be completed since the conditions present within each well, in the aquifer at the location of the well installation, depth of and types of well construction, completeness of well development, and the response data collected will bear heavily on the types of evaluations and analysis that are needed and will be completed. It would be very difficult, if not impossible, to anticipate all of the variables, evaluations, and analysis types that will be required for the varied well installations present that will be tested prior to collecting the data and completing at least the initial data evaluations.

11.3.1 Pre-Analysis

The pre-analysis activities are completed primarily so that the data can be compared and used for the verification of the applicability of the conventional theory. Since pressure transducers and data recorders providing data as a deviation from the static conditions are being used, the pre-analysis activities will consist mainly of the following:

- The selection or determination of the actual time that the slug was introduced and the test was initialized. The data collection often precedes the slug introduction and therefore the pre-slug data (pre-slug response) needs to be removed and the time re-initialized.
- Selection or determination of the initial measured displacement.
- Normalization of the response data by dividing the measured deviations by the measured initial deviation.
- Evaluation for the presence of a skin with low ~~permeability~~ K ~~skin~~ and its effects. Skins or well skins are near-well zones of the aquifer altered from drilling and well installation. This skin can have hydraulic conductivities lower (low-K skin) or higher (high-K skin) than the bulk of the formation (Butler 1998, p. 13). Low-K skins can cause the most ~~a~~effect on slug test results and the impact of high-K skins has been shown to be quite small in most cases. The theory assumes a homogenous aquifer and the presence of a low K-skin can result in an underestimate of the hydraulic conductivity. Several analysis methods developed to account for the effect of well skins (Butler 1998, p.171) will be evaluated for the JPG slug tests.

11.3.2 Verification of Applicability of Conventional Theory

Evaluations of response data for verification of applicability of the conventional slug test analysis theory is completed initially to make sure that the completion of the test, individual well characteristics, and collected response data are consistent with the assumptions of the analysis theory model. In addition, several of these evaluations will aid in determining several specific inputs that should be used for individual wells. Several of these inputs that will be evaluated and are used in the response data analysis consist of effective casing radius, effective screen radius, effective screen length, etc. These evaluations will consist of some of the following:

- Comparison of measured initial displacements with calculated theoretical or estimated initial displacements
- Comparison of normalized rising head and falling head response data
- Comparison of the normalized response data of the first and last tests in the series with the similar initial displacements
- Comparison of the normalized response data for tests with different (~2 times larger) initial displacements

11.3.3 Analysis

Following the completion of the pre-analysis and verification of applicability of conventional theory, an appropriate analysis method will be selected based both on the well installation and construction specifics and the information gained during the verification of the applicability of conventional theory. It is anticipated that the electronic response data will be imported into the commercially available Aqtesolv® for Windows® Pro software package (Version 3.5). Aqtesolv® provides standardized data graphing, data input, input of individual well characteristics, analysis method selection (multiple choices), and automatic curve matching as well as user customizable curve matching. Once a curve match is completed, Aqtesolv® computes a hydraulic conductivity using the analysis method selected.

THIS PAGE WAS INTENTIONALLY LEFT BLANK

12. MODELING APPROACH

The basic modeling approach and major assumptions to model potential radiological doses at, and in the vicinity of, the JPG DU Impact Area is summarized in this section. The modeling objectives are to predict the fate and transport of DU over a 1,000-year period into the future. The modeling approach begins with the identification of potential receptors and viable exposure pathways. Key site characteristics affecting DU transport through the pathways then are assessed to select the model(s) used to evaluate DU fate and transport.

12.1 RECEPTORS AND EXPOSURE PATHWAYS

Modeling will be used to estimate radiation doses through a range of primary and secondary contaminated media, exposure pathways, and target receptors, as presented in Table 12-1. Primary media include soil and sediment plus impacted groundwater and surface water (primarily Big Creek). Secondary media include, for example, crops and foliage/feed grains that uptake DU or milk from dairy cattle that ingest contaminated soils and eat contaminated feed. Three potential receptors are considered, including a resident farmer that grows crops and raises beef and dairy cattle on a farm. This farm could be within the DU Impact Area (i.e., if institutional controls fail), resulting in direct exposure to all contaminated media or just outside the DU Impact Area boundary; thus, exposure occurs only through atmospheric transport or migration via groundwater or surface water. Receptor-specific inputs for the farmer are primarily taken from NUREG/CR-6937 and NUREG/CR-6697 (mean or most likely probabilistic values).

Table 12-1. Simplified Conceptual Model for JPG Receptors
Jefferson Proving Ground, Madison, Indiana

Primary Medium	Exposure Pathway	Receptors		
		FMR	SPT	FWS
Soil/Sediment	Fugitive dust inhalation	✓	✓	✓
	External gamma radiation	✓	✓	✓
	Incidental ingestion by humans	✓	✓	✓
	Incidental ingestion by cattle/game (meat)	✓	✓	
	Uptake into crops	✓		
	Uptake into foliage/feed (meat)	✓	✓	
	Uptake into foliage/feed (dairy)	✓		
Groundwater or Surface Water	Drinking water by humans	✓	<u>✓*</u>	✓
	~~Incidental ingestion by humans~~		~~✓~~	
	Crop irrigation	✓		
	Foliage/feed irrigation – (meat)	✓	✓	
	Foliage/feed irrigation – (dairy)	✓		
	Drinking water by cattle/game (meat)	✓	✓	
	Drinking water by cattle (dairy)	✓		
	Uptake by fish	✓	✓	

FMR = Resident Farmer
SPT = Sportsperson (hunter/fisherman)
FWS = USFWS Worker
<u>* = Incidental amount of surface water assumed to be ingested by sportsperson</u>

A local sportsperson also is assumed to hunt deer and consume fish impacted by the DU Impact Area. As with the farmer, the sportsperson may spend time either in the DU Impact Area or just outside the boundary. Receptor-specific inputs for the sportsperson are primarily taken from USEPA (1997) (mean values). Finally, a USFWS worker is assumed to spend a limited amount of time within the DU Impact Area, with the balance of exposure beyond the DU boundary where he would be exposed only via offsite transport of contaminants.

Note each receptor may spend time onsite or offsite depending primarily on whether the site will be maintained as is with institutional controls or whether those controls are lost. The institutional controls scenario assumes a 25-mrem/yr dose criterion and exposures to members of the general public at the site boundary. The loss of controls scenario assumes a 100-mrem/yr dose criterion and onsite occupation by members of the general public. The three receptors subject to these exposures and dose criteria are described in more detail in Table 12-2.

Table 12-2. JPG Receptor Descriptions
Jefferson Proving Ground, Madison, Indiana

Receptor	Description
Sportsperson	Sportsperson consumes the meat of deer and spends an equivalent period fishing in the DU Impact Area (loss of controls) or at the DU boundary (with controls). Incidental Big Creek surface water ingestion also is a potential pathway.
USFWS Worker	USFWS worker who spends up to 40 hours each month in the vicinity of the DU Impact Area for activities related to the operation of the site. Receptor works in an office building at the site boundary for 190 days per year. During office hours, drinking water is supplied from a potentially impacted well.
Resident Farmer	Farmer maintains a home, plants crops, and raises livestock either within the DU Impact Area (loss of controls) or offsite approximately 2.5 miles west of the DU impact area (with controls). Irrigation for crops and grass comes from surface water source. Livestock drink from surface water and graze on irrigated grass. The farmer drinks surface water and consumes animal products, fish, and crops from farm with minimal commercial sources.

12.2 ENVIRONMENTAL TRANSPORT, EXPOSURE, AND DOSE MODEL

Conceptually, the primary transport processes (most DU mass) are believed to occur through surface runoff of impacted soils and penetrator fragments to surface water bodies and as interflow within preferential pathways in shallow bedrock. The leaching of DU corrosion products from currently impacted soils to shallow groundwater followed by migration within the groundwater represents a secondary transport process (less DU mass). Wind transport also may play a role in the fate of DU in the environment, but this pathway has been shown to be negligible (NRC 2008). The primary environmental media that may be affected are soils, sediments, surface water, and groundwater.

Key site characteristics for the modeling approach includes the mass of DU associated with the penetrators and impacted soils. For example, DU penetrators can be found both north and south of Big Creek. Shallow surface soils in contact with the penetrators are impacted and the penetrators are expected to corrode over time. The magnitude and extent of impacted soils along with the release of DU through corrosion of the penetrators represents the source term for input to fate and transport models.

Soil texture, vegetation, slope, and precipitation govern surface water runoff and erosion to Big Creek as well as the infiltration to groundwater (recharge). DU sorption characteristics determine the amount of DU mass sorbed to silts and clays that run off from the trench and adjacent soils via the surface water pathway. The creek cross sectional area and contributing watersheds govern flow, sediment transport, and deposition along Big Creek and adjacent surface water drainages.

Within the groundwater pathway, lateral flow occurs primarily within the upper carbonate (40 to 60 ft) bedrock through secondary porosity features such as dissolution along bedding planes, fractures, and voids. Karst features (caves, sinkholes) are more prevalent along Big Creek, and therefore, more interconnectivity (higher transmissivity) is expected along Big Creek (and other surface water drainages) than in the upland areas between the creeks. Deeper carbonate bedrock (>60 ft below bedrock surface) exhibits much less secondary porosity and, as a result, has much lower transmissivity relative to the shallow bedrock.

Ideally, a single model would be appropriate to simulate the fate and transport of DU at JPG. However, given the importance of both the surface water and groundwater pathways, and the need to estimate potential future doses resulting from DU transport over a 1,000-year period, a single model can not adequately address DU fate and transport. For example, surface water modeling codes include only rudimentary treatment of groundwater processes. The same is true for groundwater codes in their handling of surface water and sediment transport. Therefore, a suite of modeling codes was selected based upon their ability to simulate the key site conditions, the conceptual understanding of mass release mechanisms, and to provide flexibility to include more detailed evaluations, if needed, of DU fate and transport.

Three primary models will be used to evaluate DU fate and transport and represent the majority of the modeling to be performed. Secondary codes help provide the ability to check estimates from primary models with a different model, a powerful and accepted method for verifying model input parameters and predictions. All are industry standard codes. The modeling codes selected, rationale, and intended uses are summarized below.

12.2.1 Primary Models

RESRAD-OFFSITE (Version 2.0) (see ANL 2007, also known as NUREG/CR-6937) has been selected as the tool to model environmental transport of DU contaminants, radiological decay and in-growth of decay products, direct and indirect exposure pathways, and the estimated radiological dose to potential human receptors. RESRAD-OFFSITE is an extension of the RESRAD code (ANL 2007), including the addition of a three-dimensional groundwater flow and radionuclide transport model, the Gaussian plume model for atmospheric dispersion, and the deposition model used to estimate the accumulation of radionuclides in offsite locations and in food (ANL 2007). The offsite code includes deterministic and probabilistic modules and associated default input parameters.

12.2.2 Parameter Selection Methodology

The hierarchy for dose modeling input parameter value selection is as follows:

- Empirical site-specific data whenever possible (e.g., from Final Phase 2 RI [MWH 2002], Well Location Selection Report [SAIC 2007a])
- Literature values based on site-specific conditions (e.g., density and porosity for silt loam [loess] from NUREG/CR-6697 tables)
- Calculated values from data presented in NUREG/CR-6697 and NUREG/CR-6937
- Most likely or expected values from NUREG/CR-6697 and NUREG/CR-6937
- Literature values and professional judgment (e.g., fish tissue ingestion rate).

When site-specific or literature-based inputs are not available, RESRAD-OFFSITE probabilistic defaults are used as defined in NUREG/CR-6937 and NUREG/CR-6697, though most often as deterministic inputs. This is accomplished by selecting, from the default distributions, the mean or most likely values. A simple example is the soil ingestion rate, represented as a triangular distribution with a most likely value of 18.3 g/yr (this rate is entered as a deterministic parameter given a site-specific rate is not available). The default probabilistic parameter is sometimes represented as a nonsite-specific continuous distribution. In these cases, the "expected value" is calculated and entered as a deterministic value. An example is the outdoor fraction described in terms of a cumulative frequency in NUREG/CR-6937 Appendix B. Calculated expected values typically fall in the 75th to 90th percentile range. The overall objective in selecting deterministic most likely and expected values is to represent the "average member of the critical group" as described in the Consolidated Decommissioning Guidance (NRC 2006).

In some cases, NUREG guidance does not provide receptor-specific information that matches the conceptual model summarized in Tables 12-1 and 12-2. In these cases, the input is defined based on professional judgment. An example is the sportsperson's onsite occupancy and game meat consumption rate. The proposed occupancy is based on the State of Indiana's two long-weekend firearms season (totaling seven 24-hour days) and the consumption rate is defined assuming the hunter eats the meat from two 50-lb (average-sized) deer per year.

A working version of the proposed exposure parameters for use in the RESRAD-OFFSITE model has been presented to NRC. As some of the field data specified for collection in this Addendum will affect the final exposure parameters selected for use in RESRAD-OFFSITE, the exposure parameters have not been presented with this Addendum. The Army will continue to refine the exposure parameters with NRC over the next year to refine them as more site-specific data are collected.

RESRAD-OFFSITE is selected for use based upon the integrated transport, exposure, and radiation dose modeling capabilities incorporated within the model for each exposure pathway. RESRAD-OFFSITE will be used to evaluate DU transport and radiation dose to the sportsperson and resident farmer receptors. Both receptors receive their dose from exposure within the DU area or at the DU boundary.

The groundwater flow model within RESRAD-OFFSITE does not allow for spatial heterogeneity in aquifer parameters as observed at JPG (recharge, discharge, hydraulic parameters). RESRAD-OFFSITE calculates surface water runoff and sediment transport to a receiving surface water body, but does not account for transport down the water body (e.g. Big Creek) nor contributions from other watershed areas. Due to these limitations, additional surface water and groundwater models are needed to assess DU transport at JPG.

- ***Hydrologic Simulation Program–FORTRAN (HSPF)***—HSPF is a USEPA watershed management and planning model developed primarily for agricultural watersheds with some capability to incorporate runoff from urban areas. HSPF is a comprehensive package for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants. HSPF incorporates watershed-scale models into a basin-scale analysis framework that includes fate and transport in one-dimensional stream channels. Output consists of the time history of runoff flow rate, sediment load, and nutrient and pesticide concentrations, along with a time history of water quantity and quality at any point in a watershed. Additional information on HSPF can be found at http://www.epa.gov/ceampubl/swater/hspf/index.htm.

  HSPF is selected because it is the only comprehensive model of watershed hydrology and water quality that allows the integrated simulation of land and soil contaminant runoff processes with in-stream hydraulic and sediment-chemical interactions. In addition, HSPF simulates three sediment types (sand, silt, and clay), allowing partitioning of DU sediment transport and deposition within each sediment type. HSPF permits evaluation of DU levels in surface water (e.g., Big Creek) and sediments over time to evaluate potential future doses to the sportsperson (downstream from the DU Impact Area) and potential impacts to the USFWS worker (via surface water to groundwater pathway [again downstream from the DU Impact Area]).

- ***MODFLOW-SURFACT***—This model is a finite difference code based upon the USGS MODFLOW model with additional modules added to include complex saturated/unsaturated modeling of air and water and simultaneous transport of up to five species. MODFLOW-SURFACT was developed by Dr. Peter Huyakorn and others of HydroGeoLogic, Inc. More information is available from http://www.hgl.com. MODFLOW-SURFACT will be used to develop a three-dimensional, groundwater flow model of JPG and to simulate future DU transport via the groundwater pathway.

MODFLOW-SURFACT is selected because of its ability to handle spatial heterogeneity in flow system parameters, ease of use, stability in handling areas of thin or partial saturation, transport package that minimizes numerical dispersion, and portability to other models if needed. A far-field approach (assumption of equivalent porous media) will be implemented. Groundwater flow model boundaries will be established at natural boundaries (e.g., flow divides) where possible and be of sufficient area to simulate DU transport beneath the DU Impact Area and to offsite areas. Industry standard practices will be implemented for model calibration, sensitivity/uncertainty analyses, and verification. Output will consist of the predicted maximum DU levels over time on and off site for the 1,000-year period. Output will be used to evaluate potential future doses to the sportsperson (groundwater discharge to surface water downstream from the DU Impact Area) and potential impacts to the USFWS worker (groundwater pathway [again downstream from the DU impact area]).

12.2.3 Supporting Models

- ***SESOIL***—The Seasonal Soil Compartment (SESOIL) model is a one-dimensional model that simulates constituent fate and transport through a soil column extending from the ground surface to the groundwater table. More information on SESOIL can be found at http://www.scisoftware.com/products/sesoil_overview/sesoil_overview.html. SESOIL will be used as to check recharge rates and DU transport in washload due to surface runoff applied in or determined from other models used to model DU fate and transport. SESOIL also will be used to determine the mass loading of DU to the groundwater table using results of the soil sampling, K_d study, and corrosion study as inputs. A range of potential source loading to groundwater will be developed based upon the uncertainty in input parameters (recharge, hydraulic conductivity, soil column thickness, K_d, and corrosion rates).
- ***Storm Water Management Model (SWMM)***—SWMM is a rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas with some applications from rural areas. The runoff component of SWMM operates on a collection of subcatchment areas that receive precipitation and generate runoff and pollutant loads. The routing portion of SWMM transports this runoff through a system of pipes, channels, storage/treatment devices, pumps, and regulators. SWMM tracks the quantity and quality of runoff generated within each subcatchment, and the flow rate, flow depth, and quality of water in each pipe and channel during a simulation period composed of multiple time steps. SWMM is selected for use to support development of input parameters for HSPF and provide independent verification of HSPF model components (e.g. surface water runoff from one or more basins). More information on SWMM can be found at http://www.epa.gov/ednnrmrl/models/swmm/.
- ***FEHM (Finite Element Heat and Mass) Transfer Code)***—This code models three-dimensional, time-dependent, multi-phase, multi-component, nonisothermal reactive flow through porous and fractured media. FEHM was developed by Dr. George Zyvoloski and others at Los Alamos National Laboratory. More information is available from http://www.ees5.lanl.gov/fehm. FEHM was selected for its abilities to simulate detailed geochemical processes affecting DU transport, including dual porosity effects and matrix diffusion. FEHM will be used to evaluate discrete fracture flow processes at JPG, primarily within the secondary porosity features in the shallow carbonate bedrock. Results from the FEHM modeling will be used to support groundwater flow and DU transport modeling with MODFLOW SURFACT.

12.2.4 Sensitivity/Uncertainty Analysis

A sensitivity/uncertainty analysis will be conducted on key model input parameters and combinations of key model input parameters as necessary based on results of single-variable sensitivity analysis and site conditions for each of the primary models. The key parameters will be varied over the observed or plausible range of values to assess the impact of parameter uncertainty on model predictions. Key parameters include:

- Meteorological data (precipitation total, duration, intensity)
- Runoff rate
- Soil type, texture, and vegetative cover
- Recharge rate
- Hydraulic conductivity
- Porosity (primary/secondary)
- K_d
- Source term (distribution of impacted soils and corrosion rate).

13. REFERENCES

ANL (Argonne National Laboratory). 2007. *User's Manual for RESRAD-OFFSITE Version 2.* ANL/EVS/TM/07-1, prepared for the U.S. Nuclear Regulatory Commission (NUREG/CR-6937) and the U.S. Department of Energy (DOE/HS-0005) by the Environmental Science Division. June.

Bostwick, B.C., S. Fendorf, M.O. Barneett, P.M. Jardine, and S.C. Brooks. 2002. *Uranyl Surface Complexes Formed on Subsurface Media from DOE Facilities.* Soil Science Society of America Journal. 66:99-108.

Butler, J.J., Jr. 1998. The Design, Performance, and Analysis of Slug Tests. Lewis Publishers. New York. United States.

IAEA (International Atomic Energy Agency). 1989. The application of the principles for limiting releases of radioactive effluents in the case of the mining and milling of radioactive ores. IAEA Safety Series, 90, IAEA, Vienna.

Kruseman, G.P. and N.A. de Ridder. 1992. Analysis and Evaluation of Pumping Test Data. International Institute for Land Reclamation and Improvement. Wageningen, The Netherlands. p.21.

MWH (Montgomery Watson Harza). 2002. Phase II Remedial Investigation, Jefferson Proving Ground, Indiana. Volumes I and II – Text, Tables, and Figures. Prepared for the U.S. Army Corps of Engineers, Louisville District. September.

NRC (U.S. Nuclear Regulatory Commission). 2006. Consolidated Decommissioning Guidance, Characterization, Survey and Determination of Radiological Criteria, NUREG-1757, Volume II, Revision I (I.6.4.4). September.

NRC. 2008. Initial Decision (LBP-08-04), United States Of America, Nuclear Regulatory Commission, Atomic Safety And Licensing Board, Before Administrative Judges: Alan S. Rosenthal, Chairman; Dr. Paul B. Abramson, and Dr. Richard F. Cole. Docket No. 40-8838-MLA. ASLBP No. 00-776-04-MLA. February 28.

PNNL (Pacific Northwest National Laboratory). 2002. 300 Area Uranium Leach and Adsorption Project. PNNL-14022. Prepared for Bechtel Hanford Company, Inc., and for the U.S. Department of Energy. November 25.

Royal Society. 2002. The Health Hazards of DU Munitions Part II. March.

SAIC (Science Applications International Corporation). 2005a. Field Sampling Plan, Site Characterization of the Depleted Uranium Impact Area. Jefferson Proving Ground, Madison Indiana. Final. May.

SAIC. 2005b. Health and Safety Plan, Site Characterization of the Depleted Uranium Impact Area. Jefferson Proving Ground, Madison Indiana. Final. May.

SAIC. 2005c. Quality Control Plan, Site Characterization of the Depleted Uranium Impact Area. Jefferson Proving Ground, Madison Indiana. Final. May.

SAIC. 2005d. Field Sampling Plan Addendum 1, Depleted Uranium Impact Area Site Characterization – Deer Sampling. Jefferson Proving Ground, Madison Indiana. Final. November.

SAIC. 2006a. Fracture Trace Analysis Report. Jefferson Proving Ground, Madison Indiana. Final. June.

SAIC. 2006b. Deer Tissue Sampling Results Report. Jefferson Proving Ground, Madison Indiana. Final. August.

SAIC. 2006c. Field Sampling Plan Addendum 2, Depleted Uranium Impact Area Site Characterization – Soil Verification. Jefferson Proving Ground, Madison Indiana. Final. July.

SAIC. 2006d. Field Sampling Plan Addendum 3, Depleted Uranium Impact Area Site Characterization – Other Monitoring Equipment Installation, Other Monitoring (Precipitation, Cave, and Stream/Cave Spring Gauges) and Electrical Imaging Survey. Jefferson Proving Ground, Madison Indiana. Final. July.

SAIC. 2007a. Well Location Selection Report. Depleted Uranium Impact Area Site Characterization: Soil Verification, Surface Water Gauge Installation, Fracture Trace Analysis, and Electrical Imaging Jefferson Proving Ground, Madison. Final. January.

SAIC. 2007b. Field Sampling Plan Addendum 4, Depleted Uranium Impact Area Site Characterization – Monitoring Well Installation. Jefferson Proving Ground, Madison Indiana. Final. January.

SAIC. 2008a. Field Sampling Plan Addendum 5, Depleted Uranium Impact Area Site Characterization – Data Quality Objectives for Groundwater, Surface Water, and Sediment Sampling and Analysis. Jefferson Proving Ground, Madison Indiana. Final. January.

SAIC. 2008b. Field Sampling Plan Addendum 6, Depleted Uranium Impact Area Site Characterization – Water Chemistry Sampling for Ground-Water Age Estimates and Comparison of Flowmeter-Based and Water-Level-Based Directions of Ground-Water Flow in a Karst Hydrogeologic Framework. Jefferson Proving Ground, Madison Indiana. Final. March.

SAIC. 2008c. Well Construction And Surface Water Data Report – Depleted Uranium Impact Area Site Characterization: Well Construction Details and Stream, Cave Spring, and Precipitation Gauge Data Presentation, Jefferson Proving Ground, Madison, Indiana. Final. March.

SEG (Scientific Ecology Group, Inc.). 1996. Jefferson Proving Ground Depleted Uranium Impact Area Characterization Survey Report, Volume 1. Revision 0. February.

U.S. Army. 2001. Controlled Burn Air Sampling Technical Report. Aberdeen Proving Ground. August.

USEPA (U.S. Environmental Protection Agency). 1997. *Exposure Factors Handbook, Volumes I, II, and III.* EPA/600/P-95/002Fa-c, Office of Research and Development, Washington, DC. August.

USEPA. 1999. Understanding Variation In Partition Coefficient, K_d, Values, Volumes I, II and III. EPA Office of Air and Radiation, EPA 402-R-99-004A. August.

USEPA. 2000. Data Quality Objectives Process for Hazardous Waste Site Investigations, EPA QA/G-4HW. Final. EPA/600/R-00/007. January.

USEPA. 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4. EPA/240/B-06/001. February.

Williams, G.P., A.M. Hermes, A.J. Policastro, H.M. Hartmann, and D. Tomasko. 1998. Potential Health Impacts from Range Fires at Aberdeen Proving Ground, Maryland. Argonne National Laboratory, Argonne, Illinois. 84 pp.

Yu, C., C. Loureiro, J.J. Cheng, L.G. Jones, Y.Y. Wang, Y.P. Chia, and E. Faillace. 1993. Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil. Argonne National Laboratory, Argonne, Illinois. April.

APPENDIX A

SCAN DETECTION OF DEPLETED URANIUM FRAGMENTS WITH 2- BY 2-IN. NAI SCINTILLATION DETECTORS

THIS PAGE WAS INTENTIONALLY LEFT BLANK

APPENDIX A
SCAN DETECTION OF DEPLETED URANIUM FRAGMENTS WITH 2- BY 2-IN. NAI SCINTILLATION DETECTORS

U.S. Nuclear Regulatory Commission Regulation (NUREG) 1507, Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions (NRC 1998), and NUREG 1575, Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), Revision 1 (USEPA 2000) provide examples of typical minimum detectable concentrations (MDCs) for various radionuclides using gamma scan detectors. These documents state that the MDCs provided are examples only and other scan MDC values may be equally justifiable depending on the values chosen for the various input parameters and site-specific conditions. The MDC value listed in NUREG 1507 for soil contaminated with depleted uranium (DU) is considered justifiable and sufficient. However, the use of this value is not appropriate for the detection of visible, solid DU fragments. Due to the specific activity of a DU fragment, there is little doubt that the typical hotspot modeled in NUREG 1507 (0.25-cm radius) could be detected. The question is how small of a fragmented piece of DU can be detected with confidence.

The steps for calculating the size of a DU fragment that can be detected generally follow the approach detailed in NUREG 1507. The steps include:

1. Calculating the minimum detectable count rate (MDCR) by selecting a given level of performance, scan speed, and background level of a 2- by 2-in. sodium iodide (NaI) detector
2. Selecting a surveyor efficiency
3. Relating the surveyor's MDCR ($MDCR_{surveyor}$) to a given exposure rate
4. Modeling the exposure rate of various size fragments
5. Comparing the MDCR exposure rate to the modeled exposure rates.

The development of this relationship in item three requires two significant steps. In step one, the relationship between the detector's net counting rate to net exposure rate in counts per minute per micro-Roentgen per hour (cpm/μR/hr) is established. In step two, the relationship between the specific activity of DU and exposure rate is determined. For particular gamma energies, the relationship of the 2- by 2-in. NaI detector's counting rate (in cpm) and exposure rate may be determined analytically. Once this relationship is known, the $MDCR_{surveyor}$ (in cpm) of the NaI detector can be related to the minimum detectable net exposure rate. This minimum rate is used to determine the minimum detectable DU fragment by modeling a specified postulated fragment.

For determining the MDCR, an average background for the 2- by 2-in. NaI detector of 10,000 cpm was selected. The observable background count is the number of background counts observed within the observation interval. This is commonly referred to as *b'*. The equation used for calculating *b'* is as follows:

$$b' = (\text{background count rate}) \times (\text{observation interval}) \times (1\ \text{min}/60\ \text{sec}) = \text{counts/interval}$$
$$b' = (10{,}000\ \text{cpm}) \times (1\ \text{sec}) \times (1\ \text{min}/60\ \text{sec}) = 166.67\ \text{counts}$$

The observational interval of 1 second is based on the selected instrument to be used during the global positioning system (GPS) assisted gamma walkover. The detector/meter combination will produce a data point or estimated cpm reading every second during operation. This reading will be married to a specific × Y coordinate and recorded in the associated data logger.

The MDCR is defined as the increase above background recognizable during a survey in a given period of time. The variable, *d'* is the alpha/beta error acceptable for a given survey. Alpha and beta errors of 95 percent (true positive rate) and 60 percent (false positive rate), respectively, were selected to be consistent with NUREG 1507. Selection of a high beta error signifies that the surveyor will stop the scan at very small increases in detection signal "clicks" in order to conduct an intensified scan. This slows down the survey but provides a higher level of confidence in the results of the survey. The value of 1.38 was obtained from Table 6.1 in NUREG 1507 (Table 6.5 in MARSSIM).

$$\text{MDCR} = (d') \times (\text{sq. root of } b') \times (\text{\# of observation/minute}) = \text{cpm}$$
$$\text{MDCR} = (1.38) \times (\text{sq. root } 166.67) \times (60 \text{ observations/min}) = 1{,}069 \text{ cpm}$$

The $MDCR_{surveyor}$ or minimum detectable count rate of the surveyor is defined as the increase above background during a survey that will be identified as an increase by the surveyor. Surveyor efficiency was selected to be 50 percent, consistent with NUREG 1507:

$$\text{MDCR}_{surveyor} = (\text{MDCR}) / (\text{sq. root of surveyor efficiency})$$
$$\text{MDCR}_{surveyor} = (1069) / (\text{sq. root of } 0.5) = 1512 \text{ cpm}$$

An estimated exposure rate for various sizes of square DU fragments was obtained by modeling with Microshield Version 5.01. A rectangular volume of DU with various lengths and a constant width and thickness of 1.0 cm was selected. The modeled exposure rate was used to calculate the expected increase in count rate above background for the 2- by 2-in. NaI detector. Using the same parameters as above, the same sizes of DU fragments were modeled with 5 cm (approximately 2 in.) of soil cover material. The density of the soil was estimated at 1.6 g/cm^3. Table A-1 shows the size of the DU fragment, associated cpm increase for a sodium iodide 2- by 2-in. modeled for a fragment located on the ground surface, and the associated cpm increase for a 2- by 2-in. NaI detector modeled for a fragment covered with 5 cm of soil.

Table A-1. Modeled Count Rate versus DU Fragment Size
Jefferson Proving Ground, Madison, Indiana

DU Fragment Size (cm^3)	Net Count Rate with DU Fragment on Ground Surface (cpm)*	Net Count Rate with DU Fragment Beneath 5 cm of Soil (cpm)*
1.0	2,058	1,081
2.0	4,065	2,147
3.0	5,976	3,186
4.0	7,756	4,186
5.0	9,385	5,137
6.0	10,853	6,032
7.0	12,162	6,865
8.0	13,321	7,637
9.0	14,337	8,347
10.0	15,227	8,994

* Net count rate using a 2- by 2-in. NaI detector.

Since the $MDCR_{surveyor}$ = 1,512 cpm, a 1 cm^3 DU fragment located on the surface of the survey area is capable of being detected. However, survey experience has shown that random background fluctuation interferes with recognizing a 1,500 cpm increase in count rates. An investigation level of 2,000 cpm above relevant background is typically established and used as a field screening value. Setting 2,000 cpm above background as the investigation level maintains the size of detectable DU fragments on the ground surface to 1.0 cm^3 when the detector is located directly above the fragment for 1 second. Maintaining the investigation level constant at 2,000 cpm above relevant background establishes that a 2 cm^3 DU fragment buried beneath 5 cm of soil can be detected when the detector is located directly above the fragment for 1 second. As shown in the table, in both cases, as the size of the fragment increases, the modeled count rate increases. The larger the fragment size, the easier it becomes to detect.

However, the detection of the above fragments is dependent on the detector being positioned directly above the fragment for the entire 1-second count interval. The typical scan rate employed during gamma walkovers is 0.5 m per second. This means that the detector will cover approximately 0.5 m^2 or 50 cm^2 in 1 second. Therefore, during a typical scan survey, the detector would only be positioned above the fragment for a fraction of the 1-second count time.

To maintain the required confidence that the fragment would be detected during a normal scan survey, the lowest count rate for a specific size DU fragment obtainable in the 1-second count rate window when normalized to cpm must be greater than 2,000 cpm. The lowest obtainable count rate within the 1-second count rate window when moving at 50 cm per second would occur 25 cm from the fragment.

An estimated exposure rate of 25 cm from various sizes of square DU fragments was obtained by modeling with Microshield Version 5.01. A rectangular volume of DU with various lengths and a constant width and thickness of 1.0 cm was selected. The modeled exposure rate was used to calculate the expected increase in count rate above background for the 2- by 2-in. NaI detector. Using the same parameters as above, the same sizes of DU fragments were modeled with 5 cm (2 in.) of soil cover material. The density of the soil was estimated at 1.6 g/cm^3. Table A-2 shows the size of the DU fragment, associated cpm increase for a 2- by 2-in. NaI detector modeled for a fragment located on the ground surface, and the associated cpm increase for a 2- by 2-in. NaI detector modeled for a fragment covered with 5 cm of soil.

Table A-2. Modeled Count Rate Versus DU Fragment Size at 25 cm

DU Fragment Size (cm^3)	Net Count Rate at 25 cm with DU Fragment on Ground Surface (cpm)*	Net Count Rate at 25 cm with DU Fragment Beneath 5 cm of Soil (cpm)*
5.0	1,717	1,113
6.0	2,047	1,326
7.0	2,370	1,534
8.0	2,684	1,736
9.0	2,990	1,932
10.0	3,286	2,121

* Net count rate using a 2- by 2-in. NaI detector.

Maintaining the investigation level constant at 2,000 cpm above relevant background establishes that a 6.0-cm^3 DU fragment on the surface of the survey area and that a 10.0-cm^3 DU fragment buried beneath 5 cm of soil can be detected with confidence during a normal scan survey. Once again, the larger the fragment, the higher the probability of detection.

In summary, the smallest piece of DU located on the surface of the survey area that can be detected is approximately a 1.0-cm^3 fragment. The smallest piece of DU that can be detected with confidence during a normal scan survey using conservative assumptions is a 6.0-cm^3 fragment. The smallest piece of DU that is covered with 5 cm of soil that can be detected is approximately a 2.0-cm^3 fragment. The smallest piece of DU that is covered with 5 cm of soil that can be detected with confidence during a normal scan survey using conservative assumptions is a 10-cm^3 fragment.

REFERENCES

NRC (U.S. Nuclear Regulatory Commission). 1998. Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions. NUREG/CR-1507. Final. Nuclear Regulatory Commission, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2000. EPA 402-R-97-016, *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM). Revision 1. August.

APPENDIX B

SAIC FIELD FORMS

(Provided on Accompanying CD)

THIS PAGE WAS INTENTIONALLY LEFT BLANK