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FINAL

Work Plan
Fort George G. Meade Ordnance Survey Data Analysis - Base Realignment and Closure Parcel
Anne Arundel County, Maryland

Prepared for:

U.S. ARMY ENVIRONMENTAL CENTER
Aberdeen Proving Ground, Maryland 21010-5401

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September 1995

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approved for Public Release

WORK PLAN
FOR
FORT GEORGE G. MEADE ORDNANCE SURVEY DATA ANALYSIS
BASE REALIGNMENT AND CLOSURE PARCEL
ANNE ARUNDEL COUNTY, MARYLAND

FINAL

Submitted to:

U.S. Army Environmental Center
Aberdeen Proving Ground, Maryland 21010-5401

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Science Applications International Corporation
1710 Goodridge Drive
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USAEC Contract DAAA15-91-D-0017
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LIST OF ACRONYMS AND ABBREVIATIONS

APSP	Accident Prevention and Safety Plan
ASP	Ammunition Storage Point
BLS	Below Land Surface
BRAC	Base Realignment and Closure
CAD	Computer-Assisted Design
CDF	Cumulative Density Function
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CWM	Chemical Warfare Material
DO	Delivery Order
DOI	U.S. Department of Interior
DRMO	Defense Reutilization and Marketing Office
EOD	Explosive Ordnance Disposal
EPA	U.S. Environmental Protection Agency
FFEH	Free From Explosive Hazards
FWS	Fish and Wildlife Service
GIS	Geographic Information System
GPS	Global Positioning Survey
mph	Miles per Hour
OSHA	Occupational Safety and Health Administration
PDF	Probability Density Function
PPE	Personnel Protective Equipment
PWRC	Patuxent Wildlife Research Center
QA	Quality Assurance
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RME	Reasonable Maximum Exposure
SAIC	Science Applications International Corporation
SHSO	Site Health and Safety Officer

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

SOP	Standard Operating Procedure
USAEC	U.S. Army Environmental Center
UXB	UXB International, Inc.
UXO	Unexploded Ordnance

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1. INTRODUCTION

Science Applications International Corporation (SAIC) has prepared this Work Plan to satisfy requirements of Delivery Order No. 0008 (DO #0008) of the U.S. Army Environmental Center (USAEC) Contract No. DAAA15-91-D-0017. DO #0008 requires SAIC to conduct an ordnance survey, data analysis, and risk assessment at a Base Realignment and Closure (BRAC) parcel at Fort George G. Meade (Fort Meade).

1.1 PURPOSE OF THE WORK PLAN

This Work Plan provides a detailed technical approach to the objectives of this assignment. This includes the approach to sampling design, the unexploded ordnance (UXO) survey, statistical analysis, and the risk assessment. Section 1 presents a brief introduction to the facility and the project objectives. Section 2 provides an overview of the sampling plan development for the UXO survey of the 9,000-acre BRAC parcel. Section 3 discusses the approach that will be used to conduct the UXO field survey. Section 4 examines statistical methods that will be employed to analyze the survey data and support the risk assessment. Section 5 describes the methods that will be used to estimate risk of detonation under various land use and exposure scenarios.

1.2 FORT GEORGE G. MEADE FACILITY DESCRIPTION

Fort Meade encompasses 13,760 acres in Anne Arundel County, Maryland, and has been an operating U.S. Army installation since 1917. In 1988, 9,000 acres of the facility were designated as a BRAC parcel as defined under the Base Realignment and Closure Act of 1988. The BRAC parcel is located in the southern portion of the Fort Meade facility and is approximately two-thirds of the total area of 13,760 acres. The remaining 4,600 acres outside of the BRAC parcel contain buildings for administrative and housing purposes, as well as recreational facilities. This area also supports other government organizations, such as the National Security Agency.

The 9,000-acre BRAC parcel historically has been used as an ordnance range and training area. The parcel also includes an active sanitary landfill, four inactive landfills, an ordnance demolition area, ammunition supply points, and the Tipton Army Air Field. On October 16, 1991, the U.S. Army transferred 7,600 acres of the BRAC parcel to the U.S. Department of the Interior (DOI), and since that time the property has been managed by the Patuxent Wildlife Research Center (PWRC). The inactive ordnance demolition area and inactive clean fill dump are located within this 7,600-acre DOI parcel. The remaining 1,400 acres contain a 500-acre DOI parcel consisting primarily of woodlands and wetlands, the Tipton Army Air Field, and the active sanitary landfill.

1.3 PROJECT PURPOSE AND DESCRIPTION

UXO is present within the BRAC parcel of Fort Meade, having resulted from activities involving the use of live ordnance (containing explosive or spotting charges) for training purposes. Live ordnance used in training may remain unexploded on and beneath the soil throughout the parcel, but is more prevalent in high-impact areas.

Two UXO surveys recently have been completed: one in the 1,400-acre portion of the BRAC parcel, and the other in the 7,600-acre portion of the BRAC parcel. These surveys were designed to confirm the presence of UXO to a depth of 6 inches below land surface (BLS). Detected UXO was subjected to visual confirmation after excavation to this depth. Upon confirmation, the UXO was either detonated in place by the responsible military Explosive Ordnance Disposal (EOD) unit or removed from the soil. UXO detected below 6 inches BLS was not removed because excavation below this level was not within the scope of the surveys.

The 6-inch survey depth was selected to minimize ecological impacts, which were of particular concern given the intended land use as a wildlife research center. Selection of the 6-inch survey depth was based on site history and conditions. The overall intent of the survey was to delineate and locate areas where UXO may be found. However, under the terms of the property transfer with DOI, detected UXO must be confirmed and removed to a depth of 12 inches BLS. Given this discrepancy, USAEC issued the current assignment (DO #0008) to determine the extent to which the recently completed UXO surveys meet the more stringent DOI UXO detection and removal requirements.

SAIC will evaluate the effectiveness of the previous UXO surveys through a series of analyses: 1) collect additional confirmatory UXO survey data, 2) conduct a statistical analysis of the UXO survey data, and 3) conduct a probabilistic human health risk assessment with detonation of UXO as the endpoint of concern.

As specified in a post-award meeting between SAIC and USAEC, the risk assessment will focus exclusively on risks to human health and will not address ecological impacts. The primary reason for adopting this simplifying assumption is that the risk assessment methods proposed in this Work Plan have been designed to characterize the worst-case safety risk presented by the explosive nature of the UXO present. This type of assessment may be termed an "acute catastrophic risk assessment." In addition, the corresponding ecological scenario is not being pursued because DOI/Fish and Wildlife Service (FWS) currently maintains an active hunting program at PWRC. The risks to ecological receptors from the hunting program far exceed safety risks presented by UXO.

The investigation is limited to UXO, and no chemical or biological agent exposures will be considered. Risks presented from the chemical nature of the UXO will not be undertaken in this study because they will be included in a separate study that is planned to begin in July 1995. This latter assessment may be termed a "chronic accumulative risk assessment."

The confirmatory survey will be a statistically based sampling of the 9,000-acre parcel. UXO will be identified to a depth of 18 inches BLS (5 feet BLS at Tipton Army Air Field). This depth extends beyond the 12 inches required by DOI, with the purpose of evaluating the relative effectiveness of 6-inch, 12-inch, and deeper surveys.

As specified in the scope of work, the UXO survey will not sample 100 percent of the BRAC parcel. The survey will be conducted on a sampled subset of the total 9,000 acres. A statistical approach will be used in which the smaller sampled areas are selected to project the horizontal and vertical distribution of UXO throughout the much larger 9,000-acre parcel. Risk assessment will be conducted to evaluate the baseline effectiveness of a 6-inch versus a 12- or

18-inch UXO survey, and to evaluate the risks to humans associated with several different land use scenarios.

A principal objective of DO #0008 is to determine the presence, type, and number of UXO at depth, for the 9,000-acre BRAC parcel under investigation. The investigation will evaluate the effectiveness of the 6-inch depth survey as it relates to the DOI 12-inch depth survey requirement. To accomplish this goal, the following data will be obtained:

- Available data from the 6-inch UXO survey of the 1,400-acre area of the BRAC parcel
- Available data from the 6-inch UXO survey of the 7,600-acre area of the BRAC parcel
- New survey data collected under this task (18-inch and 5-foot depth) using a statistically based sampling of the entire 9,000-acre parcel.

The objectives of the investigation require that sufficient data be obtained to:

- Evaluate the potential for UXO contact by humans under several land uses specified in the delivery order
- Locate and remove detected UXO to a depth of 18 inches BLS (5 feet BLS at Tipton Army Air Field)
- Determine the effectiveness of the existing survey data in relation to the DOI 12-inch depth requirement.

The data obtained from the UXO survey (both existing and planned) are required to support site characterization and human health risk assessment. The following sections provide a detailed presentation of the approach to sampling, the UXO survey, statistical analysis, and risk assessment. This Work Plan (for DO #0008) is one of three separate documents: Management Plan (ELIN A003), Work Plan (ELIN A004), and Accident Prevention and Safety Plan (APSP) (ELIN A008). Each of these documents is a required deliverable submitted to USAEC for review and comment.

2. SAMPLING PLAN

This section discusses the sampling plan for the 9,000-acre BRAC parcel at Fort Meade and provides an overview of the approach to the development of the plan. This sampling plan was prepared using the data from the previous 6-inch surveys of the 1,400-acre and 7,600-acre area. Data from the 1,400-acre survey have been provided to SAIC, although USAEC has not yet made available data from the 7,600-acre survey.

The primary purpose of the proposed UXO survey is to support the risk assessment by estimating the number of UXO and spatial distribution within the 9,000-acre Fort Meade parcel. This will be accomplished by: 1) sampling from 240 one-eighth acre blocks within the parcel, 2) surveying the sample blocks for UXO, and 3) extrapolating the results to the total 9,000 acres.

The sample design is characterized by specifying a procedure for locating the midpoint latitudes and longitudes of the 240 sample blocks to be allocated. The sampling plan will be designed to derive unbiased and minimum variance estimates of total UXO, subject to the constraint that the total number of surveyed blocks is limited to 240. SAIC and UXB International, Inc. (UXB) senior technical staff have determined that 240 blocks is the optimum number of blocks given constraints imposed by statistical requirements and the limited time available to complete the task. The primary consideration for the sampling plan was total acreage, which was limited to 30 acres. Within this constraint, the sample acreage was divided into as many sample blocks as could feasibly be located and surveyed within the project schedule. The strategy will minimize the size of the hot spot that can reliably be detected if significant spatial heterogeneity of UXO exists at the site.

An important objective of the study for quality assurance (QA) and risk assessment purposes is to estimate the remaining number of UXO per acre in the Fort Meade BRAC parcel. This estimate will be computed from the number found in a systematic random sample of 240 one-eighth acre blocks. The statistical precision of the estimate is a function of the total area of the sample blocks, assuming the distribution of UXO is approximately random.

The simplest sampling design is unrestricted random sampling, which positions the blocks according to 240 randomly selected pairs of latitude and longitude coordinates within the site boundaries. While this design yields unbiased estimates of total remaining UXO, it can generate extremely unbalanced sample layouts, and for this reason does not generally produce minimum variance estimates unless the UXO is homogeneously distributed across the site. However, historical evidence and the results of the previous 1,400-acre survey indicate that UXO found in the 0- to 6-inch vertical layer was clearly not spatially homogeneous, but rather clustered in high- and low-impact subareas. If the unremoved UXO (below 6 inches) is distributed in a similar heterogeneous pattern, unrestricted random sampling would be highly inefficient for estimating the total number of UXO remaining within the site boundaries.

Systematic random sampling is a widely recommended design for efficiently sampling spatially non-homogeneous elements (Ripley 1981). In a typical implementation of this design, a square or rectangular grid of points is randomly superimposed over the area to be sampled, and each grid node is used to locate a sample block midpoint. The blocks are arrayed in a triangular grid pattern (with random start) in order to spread the sample over the entire site and eliminate the possibility of "spatial clumping." The distance between sample blocks in the grid determines the size of the UXO hot spot that can be reliably detected if the distribution of UXO significantly diverges from a spatially random or Poisson model. For example, a hypothetical 30-acre hot spot would have about a 90 percent probability of detection with a grid of 240 sample blocks. In the 1,400-acre parcel, a slight variation of the grid design will ensure coverage of a possible compact hot spot.

Stratified random sampling will be used in combination with grid sampling in the 1,400-acre parcel. Three very compact subareas where large numbers of surface UXO were found and removed were identified from data collected in the previous 1,400-acre survey. These three high-impact areas or hot spots will comprise a "certainty" stratum, and a sample block will be located in each area. The assumption is that a high concentration of removed surface UXO signals possible high concentrations of deeper UXO. Estimated population UXO concentration in the 1,400-acre parcel will be derived by combining suitably weighted sample data from the certainty stratum and random grid according to standard stratified sample design formulas.

SAIC's review of the previous 7,600-acre survey did not identify any similar spatially compact hot spots. The high-impact areas identified around firing ranges are estimated to cover large acreage, as inferred from using surface UXO distributions as proxy indicators for the spatial distribution of any remaining UXO. Many sample blocks from the systematic random grid will necessarily fall into these large high-impact areas. Therefore, stratification is not necessary to ensure coverage or significantly increase sampling efficiency in the 7,600-acre parcel.

Based upon a review of both the 1,400- and 7,600-acre survey results, SAIC proposes to use systematic random grid-sampling for locating sampling blocks in both high- and low-impact subareas. The specific steps involved in implementing this design include:

- The data base of the previous UXO surveys will be used to delineate high- and low-impact subareas or strata on the basis of areal intensity of removed UXO (e.g., a high-impact area may be defined as a compact geographic area where more than 200 UXO per acre were found in the previous survey).
- The sample blocks will be optimally allocated between high- and low-impact strata to minimize the variance of survey estimates. This division of a sample among strata is called Neyman allocation in the statistical literature (Cochran 1963).
- Spacing between blocks will be calculated for high- and low-impact strata corresponding to the numbers of sample blocks allocated to these strata.
- The initial sample location (latitude and longitude) in each stratum will be randomly generated. The locations of the other blocks within each stratum will be calculated with reference to the initial location by adding or subtracting multiples of the calculated grid spacing increment.
- The sample locations will be reviewed to determine if any fall into inaccessible areas. Replacement locations will be randomly generated, as required.

The observations recorded for each sample block survey will include the latitude and longitude, type, and depth (0 to 6, 7 to 12, 13 to 18, and greater than 18 inches [at Tipton Army Air Field]) of the removed UXO, and the number of contacts greater than 18 inches BLS. These data will be used to compute estimates and associated confidence intervals for the number of UXO by depth interval in each stratum and in the total 9,000-acre site.

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3. UXO FIELD SURVEY

The UXO field investigation will be conducted by an SAIC subcontractor (UXB International, Inc.) and will include a survey of the approximately 9,000-acre BRAC parcel at Fort Meade. The field survey program is composed of the following elements:

- Visual reconnaissance
- Magnetometer survey
- Surface and subsurface detection.

The field survey program is designed to locate, identify, and remove detected UXO from the soil to a depth of 18 inches BLS. The only exception is at the Tipton Army Air Field, where the survey will be conducted to a depth of 5 feet (as specified in the delivery order) in order to penetrate fill material overlying the soils containing UXO. UXO that is determined to be unsafe to move will be reported to the responsible EOD unit at Fort Meade. Similarly, any materials suspected of being chemical or biological agents will be reported to the EOD unit for removal and disposal. Under such conditions, field activities will proceed according to the project APSP. Previous investigations do not indicate the presence of UXO containing chemical warfare material (CWM).

This section contains the detailed approach for the planned field procedures as well as equipment and other requirements as specified in the delivery order for this investigation. QA requirements necessary to ensure the location and elimination of UXO hazards also are addressed, as is a discussion of the planned sequence of operations for the ordnance survey. This Work Plan refers to the separate APSP for this project that will be used during field activities.

3.1 TASK OBJECTIVES

The objectives for the 9,000-acre survey are as follows:

- Selectively clear vegetation as necessary to allow access for ordnance survey activities
- Conduct a 100 percent surface and subsurface survey within each 1/8-acre block for UXO located at 0 to 6, 7 to 12, and 13 to 18 inches BLS (to 5 feet BLS at Tipton Army Air Field), and as required by the sampling plan
- Identify and document the areas surveyed for UXO and report the results in a format consistent with the requirements of the data analysis.

Vegetation clearance is required to maintain safety and efficiency, and to effectively locate, identify, and dispose of explosive hazards. Vegetation clearance of both grass and brush will be conducted in order to provide access to specified sample subareas.

3.2 APPROACH TO UXO FIELD SURVEY

The approach for the UXO survey of the 9,000-acre area described in this section has been developed to comply with procedures described in the delivery order to minimize adverse environmental impacts. SAIC and UXB have consulted with DOI/FWS staff to minimize the environmental impacts of this study. The work effort for the 9,000 acres has been divided into the following tasks:

- Determine and delineate 240 1/8-acre blocks
- Visually inspect for UXO in areas requiring selective vegetation removal
- Remove vegetation inhibiting access by the selective vegetation removal
- Conduct a subsurface survey of each block to depths of 0 to 6, 7 to 12, and 13 to 18 inches (to 60 inches at Tipton Army Air Field) in sample areas of the 9,000-acre BRAC parcel, as specified in the sampling plan
- Locate and excavate, if necessary, any UXO detected in the operation
- Report the location, and identify, if known, UXO to the Fort Meade EOD detachment daily
- Survey and map the 240 1/8-acre block areas to document the extent and progress of the UXO survey, and to record the location of all UXO encountered.

3.2.1 *Organization and Responsibilities*

Each UXO sweep team will be composed of a UXO team leader, an EOD specialist, and an ordnance locator operator. The UXO sweep team leader's responsibilities will include:

- Ensuring that the ordnance locator operator is properly trained and competent and that the proper operating procedures are being used
- Ensuring that the ordnance locator operator completely covers the 5-foot wide lane of the assigned survey area
- Ensuring that the ordnance locator operator complies with the requirements of the APSP
- Properly logging and recording all UXO contacts located during the sweep on the subarea grid map and in the survey log
- Marking all known and suspected UXO with a pin flag.

The ordnance locator operator will be under the authority of the UXO sweep team leader and the EOD specialist. Responsibilities of the ordnance locator operator include conducting safe and thorough searches for UXO within the assigned sweep lane, and complying with all requirements of the APSP.

3.2.1.1 Personnel Training

All field personnel will be provided with an overview of the task objectives, required to read and acknowledge understanding of the APSP and this Work Plan, and briefed daily on operations to be conducted to meet the task objectives. Personnel will be encouraged to maintain communication between the field operations personnel and supervisors to permit the free flow of information and exchange of ideas.

Personnel assigned to or entering the site will have received the required training to safely conduct ordnance avoidance actions at Fort Meade.

- *UXO Training*—All UXO personnel will be graduates of the Naval Explosive Ordnance Disposal School, Indian Head, Maryland.

- *UXO Refresher*—All UXO personnel will be refreshed on the ordnance items known to be onsite. As additional ordnance is encountered, training will be provided to ensure that all UXO personnel are alerted to the additional hazards.
- *Site-specific Training*—Site-specific training will consist of: names of personnel responsible for site safety and health; safety, health, and other hazards onsite; site-specific ordnance recognition; use of protective equipment; safe work practices expected; safe and effective use of equipment onsite; medical surveillance requirements, including recognition of symptoms and signs of exposure to hazards; and decontamination procedures.
- *Health and Safety Training*—Personnel will have participated in a 40-hour comprehensive training course with annual refresher (if required) that complies with the provisions of Occupational Safety and Health Administration (OSHA) 29 Code of Federal Regulations (CFR) 1910.120.

3.2.1.2 Field Survey Visitor Training

The UXO supervisor will be notified of planned visits, number of visitors in the visiting party, the duration, and the purpose of the visit. All hazardous UXO activities will halt while visitors are present.

All visitors to the site will receive a safety briefing, which will outline the tasks being conducted and the hazards present onsite. Visitors will be briefed on the boundaries of the work areas and the procedures for entrance and exit from the sites. Emergency evacuation and other contingencies procedures and assembly points will be addressed. Protective clothing items will be provided to the visitors before entering the site.

3.2.1.3 Daily Routine

Before work begins each day, all personnel entering the site will attend a tailgate safety meeting conducted by the senior UXO supervisor and the Site Health and Safety Officer (SHSO). The briefing will include, at a minimum, the potential hazards and risks associated with the site and confirmed encounters with hazardous materials to date. Briefings will be documented in the daily field log. As the project progresses, the briefings will include a refresher in the use of safety equipment, emergency medical procedures, emergency assistance notification procedures, accident prevention, and discussion of the Work Plan.

In addition to the daily tailgate safety meetings, the expected onsite daily routine will include:

- *Working Hours*

  0600 - 1600 Monday - Thursday

- *Rest Periods*

  Two 15-minute rest periods and a 30-minute lunch break. (Additional rest periods at the discretion of the Field Supervisor.)

- *Daily Briefings*

  The senior UXO supervisor will brief the site personnel on work planned for each day and provide other pertinent information.

3.2.2 Health and Safety

Because of the presence of potential hazards at the site posed by UXO, precautions are required to protect the health and safety of field workers. All employees assigned to the Fort Meade ordnance survey will receive training in the hazards that they are likely to encounter during field activities. Medical monitoring and basic health and safety training for hazardous waste site workers as specified by OSHA 29 CFR 1910.120 are not applicable to the ordnance survey, but will be required. SAIC has prepared a project-specific APSP to address foreseeable hazards associated with ordnance clearance activities.

3.2.3 Equipment

The equipment that will be used to conduct the subsurface UXO survey includes magnetometers such as the Forester Ferex Ordnance Locator and the Schonstedt GA 52-C Magnetometer. The Forester Ferex Ordnance Locator recently has been approved by the military and has been designated the MK 26 Ordnance Locator. It is a hand-held unit and uses two flux-gate magnetometers, aligned and mounted a fixed distance apart, to detect changes in the earth's ambient field caused by ferrous metal. It is nonintrusive and does not emit potentially hazardous electromagnetic radiation.

The magnetometer operator notes changes in an audio signal and a meter deflection to detect subsurface UXO. The detection capability of the Forester Ferex Ordnance Locator is dependent on the size of the UXO as well as its depth. It is calibrated at the factory service center to locate ordnance to the following depths, which are verified by extensive military field use and operational testing by the EOD Technology Center in Indian Head, Maryland:

Item	*Depth*
Small arms round	1 ft
Hand grenade	2 ft
Anti personnel mine	3 ft
Anti tank mine	4.5 ft
Medium projectile (105mm)	10 ft
Small bomb	15 ft
Large bomb	19 ft

The Schonstedt GA 52-C Magnetometer works under the same principles as the Forester Ferex Ordnance Locator. However, the GA 52-C Magnetometer is a less expensive instrument with very limited depth capabilities. This instrument is ideal for searching to a depth of 2 feet when mortars or other similar sized items are suspected.

Small hand tools such as shovels, knives, and pry bars will be used by UXO specialists to carefully excavate possible UXO contacts to a maximum depth of 2 feet. A commercial backhoe with the approximate size and capabilities of a standard Case 580 will be used as necessary by a UXO specialist to carefully excavate subsurface metallic contacts deeper than 18 inches.

3.2.4 Establishing the Survey Area

The sampling plan and maps will be used to identify each 1/8-acre survey block within the 9,000-acre survey area. The UXO field team will mark key locations with pin flags and block corners with wooden stakes. The global positioning survey (GPS) will be used to locate boundary markers and corners of the previously identified control points. Confirmation of these survey boundaries will be required to ensure the quality of information of the previous survey results.

After boundaries have been located and confirmed, a grid system utilizing the Maryland State Plane coordinate system as a reference will be overlaid on computer-assisted design (CAD) drawings. This grid will be based on the 240 1/8-acre sites provided in the sampling plan.

Systematic random grid samples will be established in the sampling plan. Roads, structures, areas delineated by wetlands, endangered flora and fauna, dense vegetation, or otherwise inaccessible areas will be excluded. The 1/8-acre survey blocks will contain approximately 5,500 square feet of survey area. Each subarea will be marked and flagged by surveyors in the field. A specially created grid sheet will be used for each subarea and the data will then be returned to the office for input into the geographic information system/computer-assisted design (GIS/CAD) data base.

Ordnance locations will be recorded in a GIS format using AutoCAD/ArcCAD (ESRI ArcInfo), an industry standard for GIS. ArcCAD links an AutoCAD data model with the ArcInfo data model, providing flexibility between data bases that are separate yet linked. Three types of data will be managed in one environment: graphics, tabular data, and geographic features. This will provide data users with flexibility, accuracy, and ease of use.

3.2.5 Delineation of the Survey Area

The field surveyors will navigate via GPS to pre-selected coordinates (latitude and longitude) and fix the southwestern corner of each 1/8-acre subarea. The point will be swept by a magnetometer and upon confirming a negative UXO condition, a wooden stake will be placed into the ground with an orange flag attached. A surveyor's chain will then be extended to the east for a distance of 25 feet with the point checked for UXO and secured with a wooden stake and flag. From this eastern point, the process will be repeated 220 feet to the north and then 25 feet to the west to complete the sample rectangle grid. The sample grid will form a rectangle of five 5- by 220-foot survey lanes.

3.2.6 UXO Surface and Subsurface Survey

Once established by the GPS survey crew, areas will be investigated for surface and subsurface UXO. The areas will be searched to a depth of 18 inches (60 inches at the Tipton

Army Air Field). Each 1/8-acre subarea grid will then be swept from boundary to boundary. Non-UXO personnel are permitted to walk on surface areas that are reported to be safe. However, activities by non-UXO personnel are restricted. Non-UXO personnel are magnetometer operators trained in EOD who are authorized to assist in the detection of subsurface metal objects. Magnetometer operators will sweep the surface of the site and pin-flag the locations of subsurface contacts that require intrusive investigation by UXO specialists.

For UXO located at the surface, the GPS team will conduct visual searches along grid lines spaced approximately 5 feet apart. This search will be augmented with the GA 52-C Magnetometer to locate surface contacts that may be obscured by ground vegetation. A systematic progressive boundary-to-boundary search will be conducted starting at the southwestern corner of the area and terminating at the northeastern corner.

After the surface search is complete, each pin-flagged location will be excavated to the depth of the magnetic contact(s). Soil will be removed manually with a shovel until the location of the contact is neared. Once within 6 inches of the suspect contact, probing will be used to determine the size and mass of the contact. Soil will be removed slowly by hand until a visual identification of the item can be made. If the contact is deeper than the desired excavation depth, the item will be flagged and recorded as an unknown contact. Once an item is determined to be UXO, excavation will stop. The item will be flagged in place for destruction by EOD units or transport by UXB to the holding area. All UXO will be recorded and accounted for, regardless of condition.

Once an area has been swept by magnetometer operators, the UXO specialist will excavate pin-flagged locations. The UXO excavation team will then manually excavate each contact to characterize the suspect ferrous item by direct inspection. UXO and munitions items that have been classified as intact ordnance materials will be marked on a grid map of the site and recorded by location. UXO that are safe to move may be transported to a temporary holding bunker in the ammunition storage point (ASP) until destruction by the EOD unit. Live UXO that is identified as unsafe to move will be destroyed in place by the Fort Meade EOD unit.

Contacts that remain below 18 inches (60 inches at Tipton Army Air Field) will remain unknown and will not be excavated. The position of each of these items will be recorded on the grid map.

Scrap metal residue (which may be of military or civilian origin) will not be removed from the site. It may be collected and staged in piles onsite for later actions by the appropriate Fort Meade personnel. All military munitions items that are designated as suspect will be collected and staged for inspection in the ASP for final disposal as determined by the appropriate Fort Meade personnel.

3.2.7 Data Management

Each UXO sweep team leader will be responsible for collecting and recording data acquired by his sweep team for the purpose of enabling project management personnel to completely reconstruct a detailed picture of any UXO contamination found during the surface/subsurface survey. Upon completion of a subarea survey, the sweep team leader will deliver the subarea map with the approximate suspected locations of UXO. UXO will be numbered sequentially in the order found, and a sweep log will be prepared with the following information for each known or suspected UXO contact:

- Log number corresponding to the number identifying the contact on the subarea map
- Date of discovery
- Whether the contact is known or suspected to be UXO or CWM
- Whether the contact is on or below the ground surface
- Positive identification for each known UXO or, if a positive identification cannot be determined, the size and other identifying features of the item.

3.2.8 Quality Control and Reporting

Quality control (QC) will be continuously maintained by means of thorough monitoring combined with detailed documentation of field operations. The senior UXO specialist is responsible for monitoring the quality of work performed by the field teams. The senior UXO specialist will conduct confirmatory spot checks and counter sweeps of areas already cleared.

The QC checks are used to evaluate investigation effectiveness and to take any corrective actions (e.g., repeating UXO sweep), if necessary.

3.2.9 Instrument Calibration

Before the sample subareas are surveyed, the UXO team will establish a control grid in a noncontaminated area for instrument calibration and sensitivity verification. This area will be "seeded" with ferrous and nonferrous items. The source materials will present ferrous and nonferrous signatures similar to UXO contamination suspected from the historical review. Seeded items will be of nonordnance construction and carry no explosive fillers or mechanical actuators of any kind. Buried source materials will be used only for instrument calibration and will later be removed.

Instrument checkout and calibration will be the responsibility of the senior UXO supervisor. Copies of instrument checkout and calibration verification will be maintained in the permanent project files. All equipment shipped to the field will be dedicated solely to the project until the project is completed. The senior UXO supervisor is responsible for checking and recording the condition of all equipment on a daily basis.

If equipment field checks indicate that any piece of equipment is not operating correctly and field repair cannot be made, the equipment will be tagged and immediately removed from service. Replacement equipment will meet the same specifications for accuracy and sensitivity as the equipment removed from service.

3.3 HANDLING AND DISPOSING OF HAZARDOUS MATERIALS

Chemical agents, hazardous materials, and medical waste are not included in the scope of the survey effort. These materials were not encountered during the previous survey effects. If, however, these materials are encountered, work will stop until the source of contamination is evaluated and it is determined that it is safe to resume work. Contingencies for such an event are presented in the APSP for the project. The decision to proceed must take into account personal protective equipment (PPE) requirements for UXO operations.

UXO encountered and determined to be hazardous through onsite evaluations and hazard assessments will be flagged and recorded on the UXO team's daily field report. The standard operating procedures (SOPs) concerning the handling and disposal of materials for field personnel when conducting UXO operations are listed below and include:

- *Non-munitions Scrap*—Materials excavated and determined to be non-munitions debris will remain onsite.
- *Safe Munitions Scrap*—Munitions-related items identified through EOD procedures and certified as free from explosive hazard (FFEH) will be staged onsite as safe munitions scrap. These staged items will be discarded at a Defense Reutilization and Marketing Office (DRMO) authorized landfill.
- *Potentially Hazardous Munitions Scrap*—Recovered munitions items that qualify as scrap and are determined to be potentially hazardous but do not function will be addressed on an individual basis. This will be determined through a hazard assessment conducted by the UXO field supervisor. These items will be turned over to the Fort Meade EOD unit for final disposition.

Items determined to be too hazardous to move will be turned over to the Fort Meade EOD Unit for destruction. Items that still incorporate raw explosives or partial fusing and are authorized to be moved by the senior UXO supervisor will be moved to a separate explosive holding area. Under no circumstances will any item viewed as potentially hazardous be moved, transported, or placed within 100 meters of items designated as safe munitions scrap or non-munitions scrap.

The UXO field team will assess the extent and type of UXO contamination as the ordnance survey is completed for each subarea. Information used in making this assessment will include:

- The types and locations of UXO found during the vegetation clearance, surface survey, and excavations of subsurface contacts
- The locations of subsurface contacts discovered during the surface and subsurface surveys.

This assessment will be used to determine the effectiveness of the ordnance survey. If appropriate, the UXO contractor will recommend areas in which subsurface surveys should be expanded beyond the areas specified in the sampling plan.

4. STATISTICAL ANALYSIS

Data obtained from the UXO survey will be analyzed statistically to measure the effectiveness of the previous surveys. SAIC will evaluate two measures of effectiveness. The first measure will examine whether the initial survey met the original objective of identifying and removing all UXO to a depth of 6 inches. The second measure will assess the magnitude of the potential risk to an individual coming in contact with UXO at the site under various exposure scenarios, assuming that the original objective of clearance to 6 inches was achieved. The initial survey clearly reduced the risk of detonation at the site. However, the second assessment is necessary to evaluate the extent of risk mitigation given the presence of ordnance in subsurface soil horizons (6 to 18 inches, and 60 inches at Tipton Army Air Field).

SAIC will estimate the spatial distribution of remaining UXO at the site to address components of effectiveness, as defined below. The statistical analysis will apply standard statistical survey methods to the followup sample data to estimate the amount of UXO remaining at selected depth intervals for the entire 9,000-acre parcel: surface to 6 inches BLS, between 7 and 12 inches BLS, between 13 and 18 inches BLS, and between 19 and 60 inches BLS. Deeper levels will not be considered in order to be consistent with the previous survey, and because they were specifically excluded from the task.

4.1 EFFECTIVENESS IN FINDING UXO

The effectiveness of the initial UXO surveys (survey depth to 6 inches BLS) will be assessed by examining whether any UXO is found at depths of less than 6 inches in the follow-up UXO survey. The effectiveness of the original UXO survey in meeting the 12-inch DOI requirement will be evaluated by comparing the density of contacts identified below 6 inches in the initial survey with the estimated density found in the follow-up sample.

UXO may be found at depths less than 6 inches for two reasons. First, it may be present as a result of an ineffective 6-inch removal (i.e., UXO was either missed or improperly disposed of). Second, UXO may have migrated to the surface subsequent to the original UXO survey. The migration may occur under the influence of factors such as frost upheavals.

SAIC will evaluate the likelihood of these two possibilities if UXO is found at depths less than 6 inches during the follow-up survey. To accomplish this, SAIC intends to compare the estimated amount of UXO remaining onsite (i.e., UXO density based on current study) with the amount of UXO identified in the original survey. This information will be used to assess the effectiveness of the original survey in removing UXO in the 0- to 6-inch depth interval. The estimate of reduction in UXO density between the first and second surveys will represent the effectiveness of the previous studies in removing UXO.

SAIC notes that it will not be possible to distinguish one of the two reasons from the other by means of such a comparison. However, this is not a concern, since the objective of the second UXO survey is to determine the effectiveness of the original UXO survey, and not to speculate if the UXO had migrated upward or was overlooked during the original survey.

To compare the results of the initial survey with the follow-up survey, SAIC will tabulate the actual number of contacts and UXO density from the initial survey with the estimated number and density of UXO based on the follow-up survey. Comparisons will be presented within each zone at selected depth intervals: 0 to 6 inches, 7 to 12 inches, 13 to 18 inches, and greater than 18 inches to 60 inches at the Tipton Army Air Field. SAIC will thus compare the actual versus predicted distribution of UXO, and highlight areas where the initial survey was ineffective in removing UXO down to 6 inches.

4.2 EFFECTIVENESS IN REDUCING RISK

The effectiveness of the initial UXO survey will be evaluated by comparing hypothetical risk attributable to UXO exposure before the initial survey was conducted to the risk remaining after the initial UXO survey was completed. A second evaluation will compare the risk related to UXO currently located between 0 to 6 inches and UXO located at depths greater than 6 inches to 12 inches. In a similar manner, a third comparison will be made of risk from UXO located at 0 to 6 inches with UXO located at 13 to 18 inches. For the Tipton Army Air Field, the analysis will consist of comparison of the initial and follow-up surveys to a depth of 60 inches.

The objective of the previous Fort Meade survey was to remove all identified UXO from the surface layer (0 to 6 inches BLS). The number of samples collected during the current study will be used to estimate the number of UXO remaining in the surface layer, as well as in the subsurface layer between 7 and 12 inches BLS. From these estimates, SAIC will be able to estimate: 1) the reduction in risk achieved by the original survey, and 2) the additional reduction that would have been achieved if UXO had been removed to a depth of 12 inches rather than 6 inches.

If R_0 represents the total risk of an exposed individual prior to the original survey of Fort Meade, and R_1 the risk after the surveys, then let R_2 be the risk that would have been experienced by an individual if the survey had removed UXO down to 12 inches. The effectiveness of the survey as actually conducted can be measured by the ratio of pre-survey to post-survey risk faced by an exposed individual, or R_1 divided by R_0. The corresponding risk ratio that would have been achieved had the survey cleared the subsurface layer is provided by R_2 divided by R_0.

The original survey removed a known number, s_{k0}, of UXO from subarea A(k), and the present study will generate estimates of the number of UXO, s_{k1}, that remain in the surface layer. The total number of surface UXO that is present and contributed to the risk of an exposed person (e.g., a hunter walking through the area) prior to the removal of UXO in the original survey can be estimated by the sum of these two numbers, $s_{k0} + s_{k1}$. To this must be added the subsurface UXO that was not removed by the original survey and therefore contributes to the risk; the number of these, denoted by r_k, will be estimated from the sample study. The risk ratio measuring the effectiveness of the surface survey in terms of these variables can be written as follows:

$$\frac{R_1}{R_0} = \frac{\sum_{k=1}^{m} (s_{k1}+r_k)w_k}{\sum_{k=1}^{m} (s_{k0}+s_{k1}+r_k)w_k} \quad \textbf{(1)}$$

where w_k is $F_k/A(k)$. The formula for what the risk ratio would be if the original survey had removed subsurface as well as surface UXO is as follows:

$$\frac{R_2}{R_0} = \frac{\sum_{k=1}^{m} s_{k1} w_k}{\sum_{k=1}^{m} (s_{k0} + s_{k1} + r_k) w_k} \tag{2}$$

These two formulas will quantify how much additional risk reduction would have been realized if the original survey objective had been to clear UXO to a depth of 12 inches.

Note that since the above risk ratio formulas involve random variables, they are subject to a certain amount of variability. SAIC will use bootstrap resampling methodology to compute 95 percent confidence intervals for the risk ratio estimates as well as the estimates of remaining UXO in the surface and subsurface layers.

5. UXO RISK ASSESSMENT

This section presents the approach to risk assessment for DO#0008. The risk assessment evaluates the potential for human contact with ordnance present at Fort Meade. General methods for human health risk assessment have been developed by the U.S. Environmental Protection Agency (EPA) under the Superfund program, and are provided in the Risk Assessment Guidance for Superfund (EPA 1989a,b). As specified in these documents, the risk assessment process may be divided into four fundamental components: 1) data evaluation and hazard identification, 2) exposure assessment, 3) toxicity or hazard assessment, and 4) risk characterization. A fifth component is uncertainty analysis, which defines the level of confidence underlying the risk estimates.

The risk assessment for Fort Meade will focus on a different endpoint or effect than is considered in a risk assessment of chemical exposures. This endpoint is contact with UXO. Subsequent endpoints, such as detonation, will not be included in this study. The risk assessment for Fort Meade is based on the likelihood of contacting UXO, not detonation. This type of analysis differs from chemical exposures in that adverse health effects resulting from chemical exposures are the endpoint of concern. EPA guidance does not specifically address UXO risk, and useful guidance from published literature for evaluating UXO risk is limited. The methods used to evaluate risk of UXO contact at Fort Meade are being developed as a task under this assignment, and will reflect conventional EPA procedures where appropriate. The methods for UXO risk assessment are described below.

5.1 EVALUATION OF SURVEY DATA AND RESULTS OF STATISTICAL ANALYSIS

The first step of the data analysis will be to evaluate the available UXO survey data. Following this, the results of the statistical analysis for the 9,000-acre BRAC parcel will be evaluated. The objective is to organize the data into a form appropriate for use in the UXO risk assessment. Existing survey data will be analyzed and additional data requirements related to the risk assessment will be identified and incorporated into the sampling plan. Data for use in the risk assessment will originate primarily from the statistical analysis of the UXO survey data.

The survey data will be analyzed to project the concentration of UXO throughout the 9,000-acre parcel. Using the results of the pre-existing surveys (1,400- and 7,600-acre), Fort Meade will be divided into high- and low-impact areas to develop the statistically based UXO sampling plan. Based upon the statistical analysis of the results of the new survey, concentrations of live ordnance will be projected for each of these areas at depths to 6 inches, 7 to 12 inches, 13 to 18 inches, and 5 feet (for Tipton Army Air Field only). The horizontal and vertical distribution of ordnance will be determined. The critical information needed is the number of live ordnance in a given area with which a human receptor may come into contact.

Data on the distribution, or concentration, of ordnance will be used for two purposes: 1) to verify the effectiveness of the previous survey, and 2) in developing probability estimates of finding live ordnance for use in risk assessment. It is essential that the survey data provide information that is useful for this effort.

5.2 EXPOSURE ASSESSMENT

Exposure assessment will evaluate the potential for coming into contact with UXO. Objectives of the assessment are as follows:

- Delineate locations where contact with UXO may be present using UXO survey information from maps and the statistical analysis
- Define and quantify activities leading to contact with UXO for human receptors (e.g., velocities, path widths, and/or areas covered)
- Project expected frequency distribution of UXO (i.e., concentration in a given area) that are available for contact.

5.2.1 Location of UXO at Fort Meade

Data on the location of UXO will be obtained from the statistical analysis of the UXO survey (see Section 4). As requested by USAEC, the risk assessment will assume that all detected UXO are present at the ground surface, regardless of the depth at which the UXO are found. This will result in a highly conservative risk analysis, and could be modified in subsequent studies to more realistically account for actual and projected locations of UXO by soil depth. The more realistic evaluation would examine UXO migration over time and project risk of human contact and detonation as a function of time.

5.2.2 Exposure Pathways, Points, and Receptors at Fort Meade

Past ordnance training activities have deposited an undetermined number of UXO remaining in soil at depths greater than 6 inches BLS. Exposure points are those locations where receptors may come into contact with UXO. Exposure points will be identified based on an understanding of past ordnance use at Fort Meade and the existing survey data. Human exposure may occur in all accessible areas, with greater likelihood in ordnance target areas.

Exposure scenarios that will be included in the risk assessment have been specified in the delivery order and are as follows:

- Unlimited or unrestricted public access
- Limited or restricted public access
- Continued use of the Tipton Army Air Field
- Continued use of the active sanitary landfill.

The existing and new UXO survey data will be used to locate exposure points across the accessible portions of the BRAC parcel. The exposure pathways and receptors at risk are presented in Table 5-1.

5.2.3 Quantifying the Potential for UXO Contact

The delivery order for this task specifies that each exposure scenario include both reasonable maximum exposure (RME) and probabilistic estimates for the risk of contact. EPA defines the RME as a point estimate—the highest exposure that is reasonably expected to occur at a site. Probabilistic estimates are based on continuous distributions that are essentially ranges of point estimates. By definition, the RME would be expected to fall as a single point in the high end of the distribution of possible values.

Table 5-1. Potential UXO Exposures Considered for the Fort George G. Meade BRAC Parcel UXO Investigation

Potentially Exposed Individual	When Exposed	Included In Evaluation?	Conditions of Exposure	How Exposed	Endpoint Type	Comment
Resident	Future (no residents currently at sites)	No	Unlimited access	Footsteps contact UXO around home, intrusive activity such as gardening.	Detonation	This is not included in the delivery order, and is specifically excluded by USAEC.
Workers (FGGM, PWRC)	Current or Future	Yes	Unlimited access	Wildlife refuge. Footsteps contact UXO around work areas, some intrusive activity consistent with wildlife research.	Detonation	This could apply regardless of the level of public access.
Workers (FGGM)	Current or Future	Yes	Unlimited access	Tipton Army Airfield. Footsteps contact UXO around work areas, some intrusive activity consistent with operation of airfield.	Detonation	This could apply regardless of the level of public access.
Workers (FGGM)	Current or Future	Yes	Unlimited access	Active sanitary landfill. Footsteps contact UXO around work areas, some intrusive activity consistent with operation of landfill.	Detonation	This could apply regardless of the level of public access.
Recreational, such as hunters	Current or Future	Yes	(1) Unlimited public access	Wildlife refuge. Footsteps contact UXO around areas traversed, some intrusive activity such as tent pegs or carcass burial.	Detonation	This is specified in the delivery order for the project.
Recreational, such as hunters	Current or Future	Yes	(2) Limited public access	Wildlife refuge with no access to high-impact areas. Footsteps contact UXO around areas traversed, some intrusive activity such as tent pegs or carcass burial.	Detonation	This is specified in the delivery order for the project.
Recreational, such as hunters	Current or Future	Yes	(3) No public access	Wildlife refuge with no access for public.	Detonation	This is specified in the delivery order for the project.

FGGM - Fort George G. Meade
PWRC - Patuxent Wildlife Research Center

Risk will be defined as the probability that a receptor, typically a person walking on the Fort Meade site, encounters at least one UXO. An encounter occurs when the receptor's path contacts the ground above a UXO, regardless of how deeply the UXO is buried within the vertical layer of 0 to 12 inches. The site is deemed to be composed of homogeneous subareas, such that within each subarea, the distribution of UXO is approximately random (a spatial Poisson distribution).

The risk within a subarea is derived as follows. Assume the receptor's path contacts "a_k" square feet of ground within the k^{th} subarea of "A(k)" square feet, and that there are "s_k" UXO buried in the subarea. The probability that the receptor avoids any particular UXO is given by equation (3):

$$1 - \frac{a_k}{A(k)} \qquad \textbf{(3)}$$

and the probability it avoids all s_k UXO in the subarea is shown in equation (4):

$$\left(1 - \frac{a_k}{A(k)}\right)^{s_k} \qquad \textbf{(4)}$$

The probability that the receptor does *not* avoid all UXO is by definition the risk, and is equal to 1 minus the above expression, or by equation (5):

$$R_k = 1 - \left(1 - \frac{a_k}{A(k)}\right)^{s_k} \qquad \textbf{(5)}$$

The number of UXO, s_k, will be estimated by multiplying the average number per acre, m_k, found in the sampled grids by the total acreage of subarea k, $s_k = m_k * A(k)$. Upper and lower confidence limits will be estimated for the Posson parameter m_k, and these will be used to construct confidence intervals for the estimated risk, R_k.

When the risk is small, the nonlinear formula can be closely approximated by a linear form that is analogous to the conventional EPA risk assessment equation. Thus, as shown in equation (6):

$$R_k = 1 - \left(1 - \frac{a_k}{A(k)}\right)^{s_k} \approx \frac{s_k a_k}{A(k)} \tag{6}$$

In general terms, the risk of contact may be expressed as a probability that is itself the product of two component probabilities. This includes the probability of finding or locating live ordnance (equivalent to UXO concentration), and the probability of encountering the live ordnance during different activities. Each of these probabilities may be expressed as a point estimate, or as probability distributions. Section 5.4 discusses probabilistic risk assessment.

Assume a particular homogeneous subarea of Fort Meade (labeled k) having A(k) square feet. Risk of contacting UXO would be evaluated under two scenarios: 1) the area is not cleared of all UXO, and 2) the area is cleared down to six inches. "Risk" is defined as the probability of at least one contact with UXO occurring in a given time period as a result of a specified level of activity.

Assume that the survey data will be used to estimate the number of UXO in the surface layer, s_k, and the number of subsurface UXO, r_k. Further, it is assumed that contact with surface UXO (0 to 6 inches BLS) occurs if a footstep contacts an area a_1 square feet above and around it, and with subsurface UXO (7 to 12 inches BLS) if a footstep occurs within an area of a_2 square feet above and around it.

Assume that one visit to Fort Meade generates F footsteps, which is a random variable. The probability that 1 footstep may contact a randomly located surface UXO is $1 - a_1/A(k)$, and the probability that F footsteps do not contact the UXO is shown in equation (7):

$$\left(1 - \frac{a_1}{A(k)}\right)^{F} \tag{7}$$

The probability that F footsteps do not contact any of the surface UXO may be estimated using equation (8):

$$\left(1 - \frac{s_k\ a_1}{A(k)}\right)^F \qquad \textbf{(8)}$$

The probability that a total of *n* hunting trips (or other appropriate exposure scenario) of F_i footsteps each (i = 1, 2, ... *n*) do not encounter a surface UXO in area k may be found by means of equation (9):

$$\prod_{i=1}^{n} \left(1 - \frac{s_k\ a_1}{A(k)}\right)^F \qquad \textbf{(9)}$$

One minus the above expression is the probability that F_i footsteps of *n* hunting trips will encounter or contact a surface UXO, which is the definition of risk for this analysis. Thus, using equation (10), the risk of contacting surface UXO (i.e., within the top 6 inches BLS) is:

$$R_k\ (\text{surface}) = 1 - \prod_{i=1}^{n} \left(1 - \frac{S_k\ a_1}{A(k)}\right)^F \qquad \textbf{(10)}$$

Similarly, the risk of subsurface contact (given no surface UXO) may be estimated using equation (11):

$$R_k\ (\text{subsurface}) = 1 - \prod_{i=1}^{n} \left(1 - \frac{r_k\ a_2}{A(k)}\right)^F \qquad \textbf{(11)}$$

If there are m homogeneous subareas at Fort Meade, the total surface or subsurface risk is estimated by means of equation (12):

$$R = 1 - \prod_{k=1}^{m} \left(1 - R_k\right) \tag{12}$$

If it is assumed that the subsurface UXO will gradually migrate to the surface over time, the estimated risk for scenario 2 (i.e., no initial surface UXO) will increase significantly as time elapses. The rate of this increase in risk is essentially governed by the assumed rate of UXO migration to the surface. This can be modeled by an estimated migration half-life, the time needed for one-half the subsurface UXO to move to the surface soil horizon. The above formulae can easily be modified to accommodate this analysis. As noted previously, at the request of the USAEC Project Officer, a conservative risk assessment will be conducted. The assumption will be made that all live ordnance detected below the surface is present at the surface and is available for contact. UXO migration to the surface will not be modeled as part of this study.

When the exposure and/or number of UXO are small, the nonlinear risk formula can be closely approximated by the linear form that is analogous to the conventional EPA risk assessment equation. This is shown in equation (13):

$$\prod_{i=1}^{n} \left(1 - \frac{s_k\, a_1}{A(k)}\right)^{F_i} \approx 1 - \sum_{i=1}^{n} \frac{s_k\, a_1\, F_i}{A(k)} \tag{13}$$

Under these conditions, risk may be estimated using equation (14):

$$R_k(\text{surface}) = \sum_{i=1}^{n} \frac{s_k\, a_1\, F_i}{A(k)} = \frac{s_k\, a_1}{A(k)} \sum_{i=1}^{n} F_i \tag{14}$$

Equation (8) has the form: risk in area k equals contaminant (i.e., UXO) concentration in area k (areal concentration is $s_k a_1/A(k)$), times the amount of contact by humans (sum of all footsteps from *n* hunting visits in F_i).

5.3 RISK CHARACTERIZATION

Risk characterization is the process of integrating the estimates of exposure (e.g., visits to UXO areas and distribution of UXO) with other risk factors to determine the likelihood of UXO contact. Risks estimated in this way are a function of the annual number of person-visits and the level of activity while traversing UXO areas. Risks are directly proportional to exposure frequency. For example, risks increase with the number of receptors as well as the number of UXO. The risk estimates thus provide an overall estimate of the risk of detonation.

5.3.1 Statistical Model for Risk Assessment

The UXO survey will provide estimates of the number and depth distribution of UXO remaining in the 9,000-acre Fort Meade parcel. From the previously conducted 1,400- and 7,600- acre surveys, SAIC knows the numbers of UXO counted and removed from the 0- to 6-inch depth layer. The objective of the risk assessment is to convert both sets of UXO concentrations to develop estimates of risk (probability of contact). These estimates will be based on plausible assumptions about the extent of human exposure to the UXO, corresponding to alternative land use scenarios. The risks can then be compared to determine what fraction of the initial risk remains after removal of UXO in the 0- to 6-inch soil layer.

The calculations for the risk of contact will be based upon the several assumptions about exposure to UXO at Fort Meade. Human activities associated with the land use scenarios can be characterized by: 1) the number of person-visits per year; 2) the velocity and time traveled by a person engaged in the activity (e.g., a hunter walking for 3 hours at an average speed of 2 miles per hour [mph]); and 3) whether and how much the activity disturbs subsurface soil.

The following steps will be used in the risk assessment to compare the relative effectiveness of different survey depths in terms of risk mitigation:

- Estimate risk of contact under baseline conditions, as it was before the 6-inch depth UXO survey of the 1,400- and 7,600-acre areas (now complete).
- Estimate risk of contact under current conditions, as it is after completion of the 6-inch depth UXO survey.
- Estimate risk of contact under conditions that would exist after completion of the 12-inch depth UXO survey.
- Estimate risk of contact under conditions that would exist after completion of the 18-inch depth UXO survey.
- Compare the relative effectiveness, or reduction in risk over baseline conditions, of the 6-inch, 12-inch, and 18-inch depth UXO surveys.

5.4 PROBABILISTIC RISK ASSESSMENT AND UNCERTAINTY ANALYSIS

A probabilistic risk assessment and quantitative analysis of uncertainty are included as part of the assignment. This section provides an overview of the methods that SAIC will use. The discussion includes an overview of probabilistic risk assessment and uncertainty analysis in general, and provides details of the approach for the Fort Meade UXO survey and analysis.

5.4.1 Overview

Uncertainty is inherent in risk assessment, in the selection or derivation of key input parameters, and in conducting every component analysis of the risk assessment process. Therefore, risk assessment must not be viewed as yielding single value, invariant results. Rather, the results of risk assessment are estimates that span a range of possible values and that may be understood only in light of the fundamental assumptions and methods used in the evaluation.

In traditional risk assessment of chemical contaminants conducted under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (Superfund) and the Resource Conservation and Recovery Act (RCRA) programs, the sources of uncertainty in risk assessment are the derivation of toxicity values, the determination of exposure point concentrations, the development of exposure scenarios and pathways, and the derivation of intake or dose estimates for the human receptors at risk. Each of the variables in the risk assessment equations is commonly taken as a point estimate. In actuality, each of these variables is characterized by a distribution of possible values: a probability distribution, or more accurately, a probability density function (PDF). Ideally, risk assessment should generate probabilistic estimates of risk that may be statistically evaluated to quantitatively characterize uncertainty.

The uncertainties in each component of the UXO risk assessment process are carried through to yield risk estimates (for UXO detonation) that reflect compounded uncertainties. Any given risk estimate for UXO detonation may be viewed as a single estimate existing within a distribution of potential outcomes. These distributions will include conservative estimates of risk (in the high end of the distribution) that are correspondingly less probable than risk estimates in the central portion of the distribution.

EPA has acknowledged the uncertainty surrounding point estimates of risk and has advocated the use of conservative assumptions in the development of RME estimates (EPA 1989a). The intention was to err on the side of protection of human health. Following this approach, a typical uncertainty analysis would be a qualitative, order-of-magnitude evaluation or discussion of sources of uncertainty. Difficulty arises in the derivation of RME exposure estimates, as no clear, definitive guidance currently exists as to how this should be accomplished. In addition, use of conservative high-end point estimates for input variables may result in risk projections that compound conservatism in a way that may not be meaningful or scientifically valid. Probabilistic risk assessment is an important approach in overcoming this limitation.

In the present study, probabilistic risk assessment has been used as a decisionmaking tool for assessing the effectiveness in protecting human health as a function of the depth to which UXO surveys have been conducted at Fort Meade. It is important to reiterate that the risk assessment examines the *potential* for UXO contact based upon a number of assumptions.

Uncertainty may originate in limitations of the UXO survey data, or it may be associated with the assumptions and procedures used during the risk assessment.

5.4.2 Approach to Probabilistic Risk Assessment for Fort Meade

Probabilistic risk assessment and quantitative uncertainty analysis will be incorporated into the risk assessment for Fort Meade. As discussed previously, the risk assessment for the assignment will examine the potential for human contact with UXO present in the 9,000-acre parcel at Fort Meade. Risk estimates will be derived as a function of land use and exposure scenarios. The probability of contact may be expressed as the combined probability of two principal component factors: 1) the probability of finding live ordnance at a given location, and 2) the probability that humans will encounter the ordnance. The equations for conducting risk assessment have been previously presented.

The risk estimates at Fort Meade will be expressed in two ways. First, a deterministic, single point estimate will be derived based upon conservative upper-bound assumptions for each variable in the risk assessment equation. Methods for accomplishing this have been discussed previously. Second, stochastic estimates will be derived and presented as probability distributions that depict the full range of possible risk estimates reflecting the uncertainty and variability in the input parameters.

In order to develop probabilistic risk estimates, a method is needed to propagate the uncertainty in each variable through to the final risk estimate. Although purely numeric methods may be used, Monte Carlo simulation is the best approach for accomplishing this for the current assignment. Briefly, Monte Carlo simulation is a technique for using random or pseudo-random numbers to sample from a probability distribution. The results of the sampling are used in the risk characterization equations. A distribution of possible outcomes is generated by letting a computer recalculate the risk estimates repeatedly by sampling each of the input distributions. In essence, the computer is trying to use all valid combinations of the input variables to develop (or simulate) an output distribution of risk to human health. Rather than single value results (e.g., the risk of UXO detonation is 1×10^{-4}), the results of risk assessment would be characterized by a distribution of possible values that could be evaluated statistically with regard to probability of exceeding a defined limit (e.g., 95 percent probability that the risk of detonation does not exceed 1 x 10^{-5}).

Figure 5-1 is a simplistic depiction of the use of Monte Carlo methods in risk calculation. Figure 5-2 presents an example PDF for ordnance distribution that would be used in the Monte Carlo simulation for Fort Meade. Note in Figure 5-2 that the probability distribution is presented in the form of a frequency distribution (PDF) as well as a cumulative density function (CDF: lower chart). The CDF depicts the cumulative probability density moving across the range of estimates presented in the frequency PDF (upper chart). The CDF can be thought of as the integral of the frequency PDF (i.e., it integrates the area under the curve). The frequency PDF is useful in examining the shape of the probability distribution and in identifying most likely (i.e., probable) values. On the other hand, the CDF facilitates the calculation of confidence intervals and the comparison of uncertain variables. For a given value along the X-axis, the PDF shows the relative probability of obtaining this particular value (e.g., 20 percent probability that the risk of UXO detonation is *equal* to 1 x 10^{-5}), whereas the CDF indicates the cumulative probability that the risk is less than or equal to this value (e.g., 95 percent probability that the risk is *less than or equal to* 1 x 10^{-5}). Identifying the principal sources of uncertainty in the final risk estimates is made easier by the simultaneous presentation and comparison of PDFs and CDFs.

The following briefly outlines the procedures SAIC will use in the probabilistic risk assessment and quantitative uncertainty analysis for Fort Meade:

Examine the uncertainty/variability in input variables:

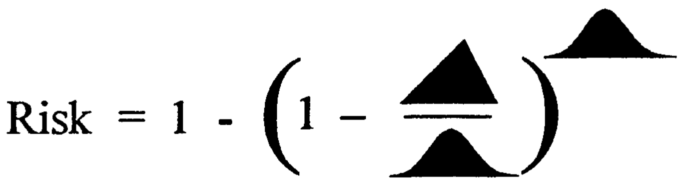
- Identify each variable in the risk assessment equations that should be treated stochastically (i.e., probabilistically).
- Identify or derive PDFs for each of these variables.
- Develop a computer spreadsheet model to conduct Monte Carlo simulations.
- Run computer simulations and generate a graphical depiction of the PDF for the variable.

Figure 5-1. Probabilistic Risk Assessment and Uncertainty Analysis Using Monte Carlo Techniques

Deterministic Approach to UXO Risk Characterization:

$$\text{Risk} = 1 - \left(1 - \frac{a}{A}\right)^{UXO}$$

Probabilistic Approach to UXO Risk Characterization:



Computer software repeatedly samples each probability distribution to generate an output risk distribution.

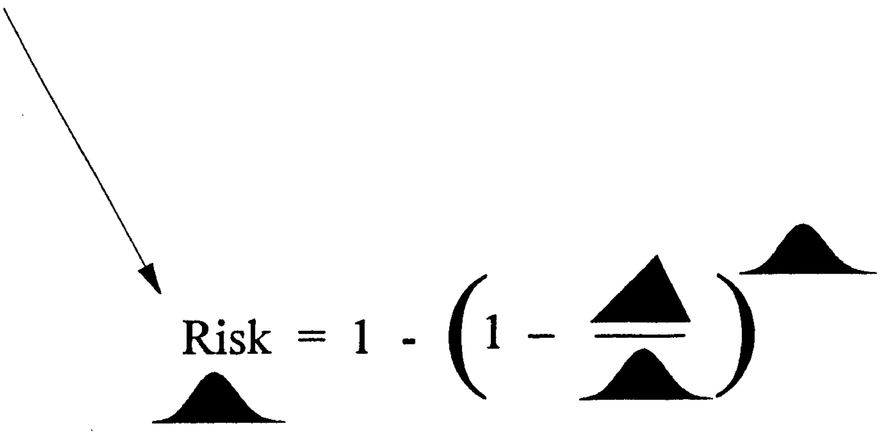


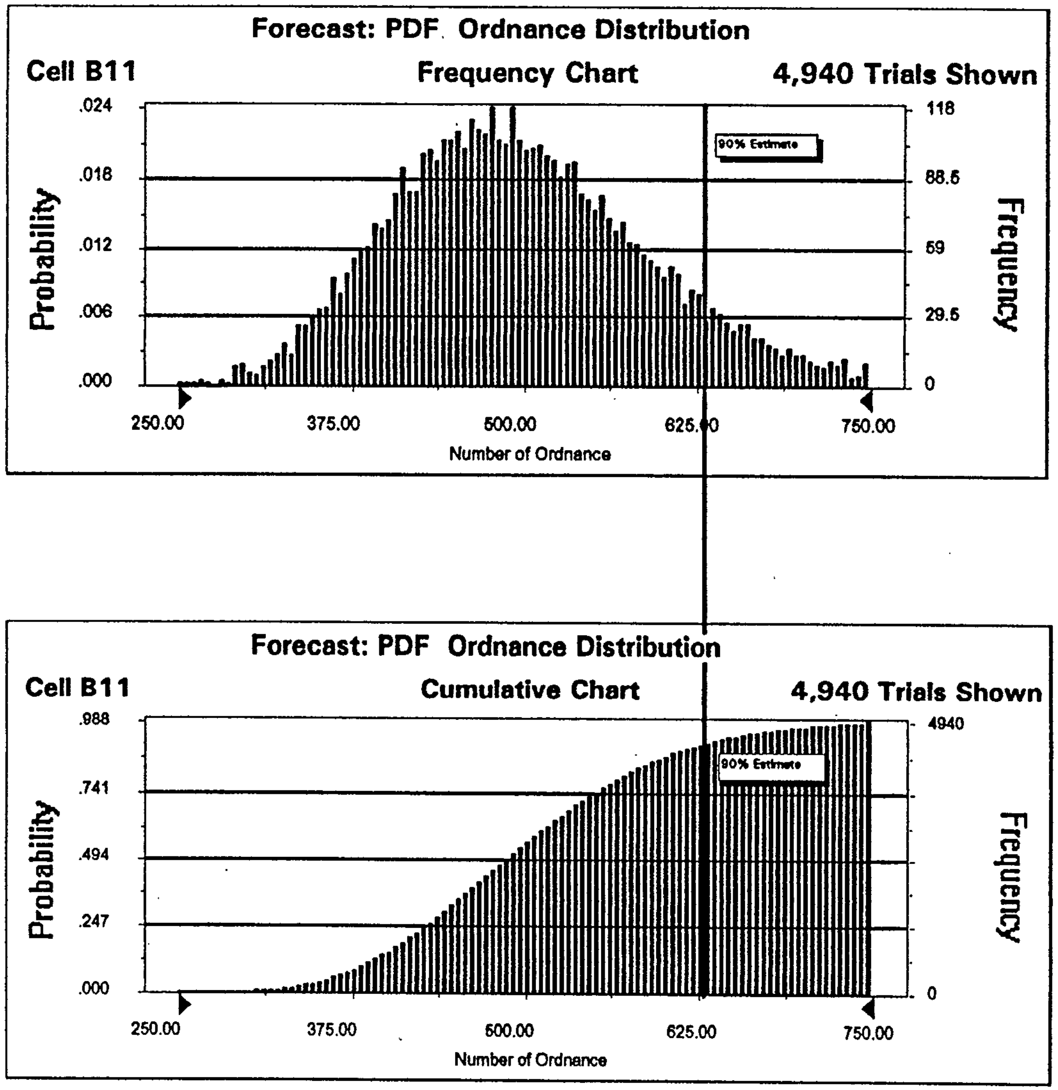
Figure 5-2. Example Probability Density Function (PDF) for Ordnance Distribution in High-Impact Area

PDF: Ordnance Distribution

Statistic	Value
Trials	5,000
Mean	500.01
Median (approx.)	491.2
Mode (approx.)	477.5
Standard Deviation	95.3
Variance	9,082.93
Skewness	0.59
Kurtosis	3.69
Coeff. of Variability	0.19
Range Minimum	239.13
Range Maximum	994.19
Range Width	755.06
Mean Std. Error	1.35

PDF: Ordnance Distribution

Percentile	Number of Ordnance
0%	239
10%	386
20%	419
30%	445
40%	468
50%	491
60%	515
70%	542
80%	576
90%	625
100%	994



- Statistically evaluate the data generated by the simulation in producing the PDF for the variable: minimum, maximum, expected value, standard deviation, skewness, kurtosis, percentile estimates.
- Examine the uncertainty surrounding the point estimate used for each variable in the deterministic assessment. Plot the RME point estimate (for the variable) on the graphical display of the distribution (PDF). In addition, plot the 90th and 50th percentile values derived from a statistical analysis of the generated distribution.

Generate probabilistic risk estimates and examine the uncertainty/variability surrounding deterministic RME results:

- Conduct Monte Carlo simulation and examine the distribution of risk estimates for a given exposure pathway (i.e., the uncertainty surrounding the risk estimate of UXO detonation). In this step, the PDFs for each uncertain variable are combined via Monte Carlo simulation to produce an output risk distribution.
- Statistically evaluate the data generated by the simulation in producing the output risk distribution (PDF): minimum, maximum, expected value, standard deviation, skewness, kurtosis, percentile estimates.
- Plot the RME risk estimates (deterministic point estimates) on the output risk distributions (i.e., on both PDFs and CDFs). In addition, plot the 90th and 50th percentile values derived from a statistical analysis of the distribution of risk estimates.

Identify major contributors to overall uncertainty:

- Conduct a sensitivity analysis to examine the contribution to the overall uncertainty in the risk estimate (i.e., for a given pathway) attributable to each exposure variable.

SAIC will build a spreadsheet model to conduct the risk assessment of UXO detonation. Microsoft® Excel and the Crystal Ball® (Decisioneering) add-in to Excel will be used to conduct the Monte Carlo simulation.

6. REFERENCES

Argonne National Laboratories. 1989. Fort George G. Meade, Maryland Enhanced Preliminary Assessment. Prepared for USATHAMA. October.

Cochran, W.G. 1963. Sampling Techniques. John Wiley and Sons, New York.

EPA (U.S. Environmental Protection Agency). 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency and Remedial Response. OSWER Directive 9335.3-01.

EPA. 1989a. Risk Assessment Guidance for Superfund: Human Health Evaluation Manual Part A. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency and Remedial Response. OSWER Directive 9285.701A.

EPA. 1989b. Exposure Factors Handbook. U.S. Environmental Protection Agency, Office of Health and Environmental Assessment. EPA/600/8-89/043.

EPA. 1989c. Risk Assessment Guidance for Superfund: Volume II Environmental Evaluation Manual. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency and Remedial Response. EPA/540/1-89/001.

ICF Technologies, Inc. 1990. Technical Report for Proposed Ordnance Clearance at Fort George G. Meade. Prepared for USATHAMA. December.

ICF Technologies, Inc. 1991a. Fort George G. Meade Ordnance Clearance Survey Draft Final Workplan. Prepared for USATHAMA. March.

ICF Technologies, Inc. 1991b. Fort George G. Meade Ordnance Clearance Survey Draft Final Site Health and Safety Plan. Prepared for USATHAMA. March.

IT Corporation. 1992a. Fort George G. Meade Ordnance Survey (1400-Acre Parcel), Interim #2 Active Sanitary Landfill Parcel. Prepared for USATHAMA. February.

IT Corporation. 1992b. Accident Prevention and Safety Plan for Unexploded Ordnance Clearance Survey at Fort George G. Meade, Maryland. Prepared for USATHAMA. April.

IT Corporation. 1992c. Workplan for Unexploded Ordnance Clearance Survey at Fort George G. Meade, Maryland. Prepared for USATHAMA. April.

IT Corporation. 1992d. Fort George G. Meade Ordnance Survey (1400-Acre Parcel), Interim #1 Report Tipton Army Airfield. Prepared for USATHAMA. November.

NRC (National Research Council). 1983. Risk Assessment in the Federal government: Managing the Process. National Academy Press, Washington, DC.

OHM Remediation Services Corporation. 1992a. Work Plan - Fort George G. Meade Ordnance Clearance Survey (7,600-Acre Parcel). Prepared for USATHAMA. June.

OHM Remediation Services Corporation. 1992b. Site Health and Safety Plan - Fort George G. Meade Ordnance Clearance Survey (7,600-Acre Parcel). Prepared for USATHAMA. June.

Ripley, B.D. 1981. Spatial Statistics. John Wiley and Sons, New York.