DEPARTMENT OF THE AIR FORCE
AIR FORCE REAL PROPERTY AGENCY

FINAL

DECISION DOCUMENT FOR NO FURTHER ACTION AT B-58 HUSTLER BURIAL SITE (AREA OF CONCERN 8)

Grissom Air Force Base, Indiana

NOVEMBER 2002

DEPARTMENT OF THE AIR FORCE
AIR FORCE REAL PROPERTY AGENCY

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GTSC 00-6108

08 Nov 02

MEMORANDUM FOR U.S. ENVIRONMENTAL PROTECTION AGENCY REGION V
ATTN: Tom Barounis
77 West Jackson Boulevard
Chicago, IL 60604-3590

INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
ATTN: Stephanie Riddle
100 North Senate Avenue
Indianapolis, IN 46204

FROM: OL-L, AFRPA/DA
1 Hoosier Blvd, Bldg 1
Grissom ARB, IN 46971-5000

SUBJECT: Final Decision Document (DD) for B-58 Hustler Burial Site (AOC 8)

Attached is the Final B-58 Hustler Burial Site (AOC 8) DD for your review and comment. Please provide your comments on the subject document by 9 Dec 02. Done 11/18/02.

If you have any questions, please call Kerry Settle at (765) 688-2248 Ext. #2.

Kerry S. Settle
for
MARLENE SENECA
Site Manager/BRAC Environmental
Coordinator

Attachment:
1. Final B-58 Hustler Burial Site (AOC 8) DD

cc:
AFBCA/DA

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

REPLY TO THE ATTENTION OF
SRF-5J

November 18, 2002

Ms. Marlene Seneca
BRAC Environmental Coordinator
Department of the Air Force
OL-L, AFBCA (Bldg. 1, Room 108)
Grissom ARB, IN 46971-5000

SUBJECT: **Final Decision Document (DD) for No Further Action at the B-58 Hustler Burial Site, (Area of Concern (AOC) 8), November 2002, Grissom Air Force Base, Indiana**

Dear Ms. Seneca:

The U.S. Environmental Protection Agency (EPA) has completed received and reviewed the **Final Decision Document (DD) for the B-58 Hustler Burial Site, (Area of Concern (AOC) 8), July 2002, Grissom Air Force Base, Indiana** (DD). Our comments on the draft version of the DD, which were forwarded to the Air Force by letter dated October 2, 2002 have been addressed and requested changes made. EPA has no additional comments on the DD and recommends that it be finalized

If you have any questions, or require additional information, please feel free to contact me by phone (312-353-5577) or e-mail (*barounis.thomas@epa.gov*).

Sincerely,

Tom Barounis

Tom Barounis
Remedial Project Manager

cc: Stephanie Riddle, IDEM
Nara Mantravadi, AFBCA
Kerry Settle, AFBCA

DEPARTMENT OF THE AIR FORCE
AIR FORCE REAL PROPERTY AGENCY

06 Dec 02

MEMORANDUM FOR U.S. ENVIRONMENTAL PROTECTION AGENCY REGION V
ATTN: Tom Barounis
77 West Jackson Boulevard
Chicago, IL 60604-3590

INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
ATTN: Stephanie Riddle
100 North Senate Avenue
Indianapolis, IN 46204

FROM: OL-L, AFRPA/DA
1 Hoosier Blvd, Bldg 1
Grissom ARB, IN 46971-5000

SUBJECT: Final Decision Document (DD) for B-58 Hustler Burial Site (AOC 8)

Due to minor format and rhetorical corrections by AFRPA/HQ's, the page numbers of the subject document have changed from the final version that you reviewed and commented on. As a result, I have attached a copy of the DD to be used as change pages to replace the final you reviewed. Since our next BCT meeting is via conference call, once I receive Stephanie's signed concurrence letter, I would like to circulate the signature page by fax to finalize the document.

If you have any questions, please call Kerry Settle at (765) 688-2248 Ext. #2.

Kerry Settle
for
MARLENE SENECA
Site Manager/BRAC Environmental
Coordinator

Attachment:
1. Final B-58 Hustler Burial Site (AOC 8) DD

cc:
AFRPA/DA

HUCO
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ENV

INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

We make Indiana a cleaner, healthier place to live

Frank O'Bannon
Governor

Lori F. Kaplan
Commissioner

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DEC 18 2002

December 12, 2002

Ms. Marlene Seneca
BRAC Environmental Coordinator
AFRPA/DA Grissom
1 Hoosier Boulevard, Building 1
Grissom ARB, IN 46971-5000

Dear Ms. Seneca:

Re: Final Decision Document (DD) to Support No Further Action at the B-58 Hustler Burial Site, Area of Concern (AOC) 8, Grissom Air Force Base (GAFB), Peru, Indiana

Staff of the Indiana Department of Environmental Management (IDEM) have reviewed the above referenced document. Our comments have been adequately addressed. Please accept this as our concurrence on the DD. If you have any questions, please feel free to contact me at (317) 234-0358.

Sincerely,

Stephanie Riddle

Stephanie Riddle, Senior Environmental Manager
Federal Programs Section
Office of Land Quality

SR:tr
cc: Tom Barounis, USEPA
Rex Osborn, IDEM

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DECLARATION

Name of Base/Installation/Facility

Grissom Air Force Base (AFB), Peru, Indiana.

Site Name and Location

B-58 Hustler Burial Site/Area of Concern (AOC) 8, Grissom AFB, Peru, Indiana.

Statement of Basis and Purpose

This decision is based on the results of the *Final Status Survey Report/B-58 Hustler Burial Site/AOC 8* (February 2002) conducted by Parsons Engineering Science, Inc., Denver Colorado, under Project Number CTGC20006108, prepared for the Grissom Air Force Real Property Agency (AFRPA) and the Air Force Institute for Environment, Occupational Safety and Health Risk (AFIERA).

Description of Selected Remedy

Based on current site condition, it has been determined that no significant risk or threat to public health or the environment exists. Therefore, no further action (NFA) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Nuclear Regulatory Commission (NRC) guidance is required.

Declaration of the Remedy

This decision document represents the selected action for this site developed in accordance with CERCLA and the NRC guidance. It has been determined that the NFA is protective of human health and environment, attains federal and state requirements that are applicable, or relevant and appropriate, and is cost effective. Based upon results of the intrusive survey activities conducted in Feb/Mar 2000 contaminant levels at the site have been determined to present no significant threat to human health or the environment; thus, no treatment is necessary and the site is suitable for unrestricted use.

Signatures:

Marlene Seneca — Marlene Seneca

Site Manager/BRAC Environmental Coordinator

Air Force Real Property Agency/DA, Grissom AFB

Date: 14 Jan 03

Stephanie Riddle — Stephanie Riddle

Project Manager

Indiana Department of Environmental Management

Date: 1/14/03

Thomas Barounis — Tom Barounis

Remedial Program Manager

United States Environmental Protection Agency, Region V

Date: 1/14/2003

Decision Summary

1.0 Purpose

The purpose of this NFA Report is to summarize existing data and describe the Air Force's rationale for selecting a particular remedial action, in this case, the NFA alternative for the B-58 Hustler Burial Site (AOC 8). The objectives of this decision document are:

- To describe the location, history, environmental setting and current status of the site;
- To summarize the results from previous investigations; and
- To assess the risk to human health and the environment.

2.0 Background Information

2.1 Base Location and Description

Grissom AFB is located approximately 15 miles north of Kokomo, Indiana on U.S. Route 31 in Cass and Miami counties, approximately two miles west of the town of Bunker Hill. See Appendix-A, Figure 1 for a map of Grissom AFB and the surrounding communities. The base, which was originally established in 1942, has undergone several transitions throughout its history. Grissom AFB was realigned to Grissom Air Reserve Base (ARB) on 30 September 1994. The Air Force Reserve 434th Air Refueling Wing is the host within the new cantonment area. The excess Air Force property, known as Base Realignment and Closure (BRAC) property, is being managed by the AFRPA pending redevelopment. The primary mission of the AFRPA is to cleanup BRAC property for transfer to the Grissom Redevelopment Authority for reuse. The former base was comprised of 2,722 acres of land, which is surrounded by actively managed agricultural land. Major population centers in the vicinity include the cities of Peru, Kokomo, and Logansport. In addition, several smaller towns and communities are scattered around the former Grissom AFB as shown in Appendix-A, Figure 1. Grissom AFB Facility Plan is shown in Appendix-A, Figure 2.

2.2 Base Geography

The base lies within the Tipton Till Plain section of the Interior Plains division of the Central Lowlands Province of the United States. The Tipton Till Plain section is generally characterized by nearly level plains with gently rolling hills and has a few small, localized, closed depressions. The topography of the base exhibits characteristics typical of the regional Tipton Till Plain. In general, the topography is a reflection of a glacially deposited till that has been affected to some extent by the shape of the underlying bedrock surface and by post-glacial erosion. Across the base, land surface elevations vary from approximately 810 feet above the National Geodetic Vertical Datum (NGCD), reference to feet above mean sea level (ft MSL) near the southeast boundary to approximately 780 feet NGVD near the northern boundary. The south edge of the base appears to be a topographic high, which slopes towards the north (on the base) and south (away from the base) (ESE, 1993a; United States Geological Survey [USGS], 1963).

2.3 Physiography and Climatography

The climate in north Central Indiana is temperate, with warm humid summers and cold winters. The region is characterized by wide variations in temperature from season to season, ranging from 20 degrees Fahrenheit (°F) in the winter to 80°F in the summer. The coolest month of the year is January, with a mean monthly temperature of 23°F and the warmest month of the year is July with a mean monthly temperature of 74°F. Precipitation in Central Indiana averages 36.6 inches annually, and is evenly distributed throughout the seasons. Snowfall in the region occurs mainly from December through February, and averages 32.2 inches per year.

2.4 Base Geology

Based on previous studies, the geology of the area consists of unconsolidated glacial and alluvial deposits overlying Silurian-age limestone and dolomitic limestone. See Appendix-A, Figure 3 for a generalized geologic cross-section. The unconsolidated deposits observed during previous investigations at sites across the base consist of three primary stratigraphic units. The upper unit is approximately 25 feet thick and consists of clay with silt, sand and gravel seams. The intermediate unit consists of silty clay with occasional stringers of silt ranging in thickness from 22 to 31 feet. The lower unconsolidated unit consists of interbedded sands and gravels with a thickness between 13 to 17 feet. Two of the unconsolidated units have been identified as water-bearing units, and are referred to as the "upper unconsolidated aquifer" (the upper clay unit with silt, sand, and gravel seams) and the "lower unconsolidated aquifer" (the interbedded sand and gravel unit which overlies the bedrock). Groundwater within the upper aquifer is associated with the sand and gravel seams and is considered "perched" water. As the water is "perched," a determination of a regional groundwater flow direction is not valid, as flow will vary widely from location to location. Shallow groundwater flow is generally toward discharge areas such as utility corridors, creeks, and drainage ditches. It can also be affected by localized mounding near landfills or surface water bodies. Dolomitic limestone aquifer is an important aquifer in the region surrounding the base. Generally, groundwater flows in a north-northeasterly direction; however, flow changes do occur due to heavy pumping of the bedrock aquifer. Groundwater within the lower aquifer exists under confined conditions, due to the confining pressure of the overlying clay. Vertical gradients calculated from groundwater elevation data indicate that a downward vertical gradient exists between the upper and lower aquifers. Based on the low permeability of the clay unit, which lies between the two units, poor hydraulic connection between the unconsolidated aquifer units is expected. A till layer is reportedly present above the surface bedrock, isolating the lower, unconsolidated aquifer from the underlying bedrock. Therefore, communication with the underlying Liston Creek (bedrock) Aquifer is also expected to be limited. Historical groundwater elevation data indicates that groundwater flow within the lower unconsolidated aquifer is generally toward the north-northeast.

2.5 Base Hydrology

Based on previous Installation Restoration Program investigations, shallow groundwater has been encountered at depths ranging from 6 to 10 feet below ground surface (bgs), and the groundwater flow at the base is generally north to northeast, towards Pipe Creek.

2.6 Base Surface Water Hydrology

Grissom AFB is located in the Wabash River basin of north central Indiana in the Pipe Creek drainage area. See Appendix-A, Figure 4 for a map of the regional surface water drainage, and Appendix-A, Figure 5 for a map of the facility surface water drainage on Grissom AFB. Surface water drainage on base is controlled by open drainage courses and underground storm drains. Surface drainage not routed into the underground drainage system flows off-site chiefly into the government ditch (to the northwest), Little Deer Creek (to the west), and Pipe Creek (to the east and northeast). There are several on-site ditches which drain specific areas of the base, the largest of which is McDowell Ditch, but also include Bennett-Campbell and Cline Ditches, and an unnamed ditch to the east of the base (ES, 1985).

2.7 Groundwater Supply Wells

The locations of the existing groundwater supply wells at Grissom AFB are presented in Appendix-A, Figure 6. Information on the depth, size, and use of the wells is presented in Appendix-B, Tables 1A, 1B, and 1C. Each of these wells reportedly produces from the Liston Creek Formation aquifer.

2.8 Base History

Grissom AFB was established in 1942 as "Bunker Hill Naval Air Station" (NAS), and remained an active naval training installation throughout World War II. Bunker Hill NAS was deactivated in 1946, with the land and facilities leased to local business and agricultural interests. The site was reactivated as "Bunker Hill AFB", and assigned to the Tactical Air Command. The Strategic Air Command assumed control of the base in 1957 and became the home of the 4041st Air Base Group (ABG). In 1959, the 4041st ABG was redesignated as the 305th Bombardment Wing. Bunker Hill AFB was renamed Grissom AFB in 1968 in honor of the late Lieutenant Colonel Virgil "Gus" Grissom, a native of Indiana and one of America's original seven astronauts. In 1970, the 305th Bombardment Wing was deactivated and the 305th Air Refueling Wing (ARW) was created to provide aerial refueling using KC-135 aircraft. The Base came under the control of Air Mobility Command in 1992 with the dis-establishment of the Strategic Air Command. Approximately half of the former Grissom AFB realigned to Grissom Air Reserve Base (ARB) on 30 September 1994; the Air Force Reserve Command 434th ARW is the host within the new cantonment area. The excess Air Force property is being managed by the AFRPA pending redevelopment.

2.9 Facility Ecological Assessment

2.9.1 Sensitive Habitats

Sensitive habitats include wetlands, plant communities that are unusual or of limited distribution and important seasonal use areas for wildlife. There is no indication that ecological conditions at this site vary significantly. The only sensitive habitat within the confines of Grissom AFB consists of a quarter acre wetland situated within the isolated woodland area on the southeastern side of the base. This area was part of a 200-acre parcel that transferred to the State of Indiana for the construction of a state prison. The area as such no longer exists. Although drainage ditches on the base meet all three wetland parameters, they have a statutory exemption from protection under the Clean Water Act to permit maintenance.

2.9.2 Threatened and Endangered Species

Consultation with the Indiana Department of Natural Resources and the U.S. Fish and Wildlife Service indicated that 20 threatened, endangered, or candidate species of plants or animals potentially occur in the region surrounding Grissom AFB. Of these, no federally listed species are known or expected to occur on Grissom AFB itself. Of the state-listed species that have been documented near the base, none were identified during the environmental baseline survey conducted on the base in 1993. However, the badger (State listed as threatened) may possibly utilize base land for temporary forage purposes.

3.0 Site Information

3.1 Location and Description

The B-58 Hustler Burial Site is located on BRAC property, outside the Grissom ARB cantonment area (i.e. outside the fence-line), between two closed fire training areas (see Appendix-A, Figure 7). The area is approximately 100 feet wide by 100 feet long, with a flat terrain. The vegetation at the site consists of sparse native grasses limited by remnants of asphalt from a former runway. There are no site restriction or security measures surrounding the burial site.

3.2 Geology

The geology at the burial site is similar to the features of the rest of the former Grissom AFB and consists of unconsolidated glacial and alluvial deposits overlying ancient marine deposits of the Silurian period. The glacial till typically consists of clays and silty clays with discontinuous layers of stratified lenses of silt, sand, and gravel.

3.3 Hydrology

Elevation differential at the burial site is minimal and surface drainage is generally to the north to northeast. The nearest bedrock well is located approximately 1200 feet south of the site. In addition, the most notable sub-surface feature for the former base as a whole (including areas surrounding the site) is a shallow water table occurring at depths of

6 to 15 feet across the former base. However, an underground storm drain line system runs approximately 200 feet to the north of the site, which empties into McDowell Ditch and ultimately into Pipe Creek.

3.4 Topography and Surface Hydrology

Elevation difference at the burial site is minimal and surface water drainage is generally to the northeast. The general area near the burial site is gradually sloped (approximately 10%) to the north, toward the storm drain lines. Therefore, surface water would tend to flow in a northerly direction toward the underground storm drain system, which empties into McDowell Ditch and ultimately into Pipe Creek.

3.5 History

On December 8, 1964, during a routine Operational Readiness Exercise, a B-58 Hustler strategic bomber skidded off a runway at Bunker Hill AFB, Indiana (later renamed Grissom AFB). The aircraft ran over several electrical fixtures and the landing gear subsequently collapsed, rupturing a fuel tank. The resulting aircraft fire burned portions of the five nuclear weapons on board to various extents, but did not cause detonation of the high explosives. Records indicate that site personnel had difficulty extinguishing the fire of one weapon. The fire was extinguished by placing the weapon in a pit (approximately 150 feet from the aircraft) and covering it with sand. After the fire was extinguished, the weapon was removed and sent to an Atomic Energy Commission (AEC) facility. The recovered weapons and weapon debris were sent to AEC facilities where analyses indicated that plutonium was not released to the environment during the accident because all plutonium-bearing components were intact. Portions of the runway and adjacent soils were subsequently excavated and buried nearby along with the remaining aircraft wreckage at the site referred to as AOC 8. With subsequent boundary restructuring, the burial site is currently located outside the Grissom ARB cantonment area (i.e. outside the fence-line) and is now considered BRAC property under the control of the AFRPA.

3.6 Previous Site Investigations

Previous facility information used in the documenting the remedy includes:

> *Geological Survey Report, B-58 Hustler Burial Site,* Grissom AFB, Indiana, United States Environmental Protection Agency (Region 5), (U.S. EPA, September 1998).

> *Radiological Characterization Survey Report, 1964 B-58 Accident Site, Area of Concern 3,* Grissom ARB, Indiana, Air Force Institute for Environment, Safety, and Occupational Health Risk Analysis, (AFIERA, May 2000).

Final Status Survey Work Plan, B-58 Burial Site, Area of Concern 8, Former Grissom AFB, Indiana, Parsons Engineering Science, Inc., (Parsons, August 2000).

Final Status Survey Report B-58 Hustler Burial Site, Area of Concern 8, Former Grissom AFB, Indiana, Parsons Engineering Science, Inc., (Parsons, February 2002).

Since the accident in 1964, several sampling events have been conducted at the accident site. Some information regarding the burial site can be derived from the accident site characterization studies, because this is the source of the radiological contamination. A radiological survey preformed by the Civil Engineering Squadron in June 1991 did not locate any areas of contamination at the accident site. In June 1996, the Air Force Safety Center concluded that sufficient information was not available to support a decision for unrestricted release of the site.

The United States Environmental Protection Agency (U.S. EPA) performed a radiological and geophysical survey of the suspected burial site (AOC 8) location in September 1998. Gamma radiation levels were consistent with background, and a large buried metallic anomaly was identified (see Appendix-A, Figure 8).

The Indiana State Department of Health (ISDH) performed gamma exposure rate measurements and collected soil samples from the accident site (AOC 3). The ISDH identified an area with gamma radiation exposure rates eight to ten times background rates. A soil sample collected at the accident site contained concentrations that were several hundred times higher than background for uranium-238 (U-238). Uranium-235 (U-235) and uranium-234 (U-234) concentrations were also elevated in proportions similar to that of depleted uranium (DU). It was concluded that the elevated levels maybe due to the presence of DU from the weapons. Plutonium concentrations were consistent with the typical background levels.

In October 1999, the AFIERA conducted a detailed characterization survey of the accident site (AOC 3). The results of this survey are presented in the AFIERA document *Radiological Characterization Survey Report* (AFIERA, 2000). No evidence of any other radiological (e.g., plutonium) or chemical (e.g., beryllium) contamination was found at the accident site. The report concludes that the contamination at the accident site is due to DU.

4.0 Initial Burial Site Scoping Survey (February 2000)

Parsons and AFIERA conducted a preliminary radiological walk-over survey (part of Final Status Survey) in February 2000 to verify the results of the radiological walk-over survey performed by the U.S. EPA in September 1998 which found no radiological contamination above background at the burial site. The walkover survey was first conducted over a background area and then over the burial site. The background location was located across an unmapped, gravel road approximately 300 ft southeast of the burial site. The burial site and the background locations are shown in Appendix-A, Figure 7.

4.1 Instrumentation

A Ludlum ratemeter (Model 2221) with 2 inch by 2 inch sodium iodide (NaI) probe (Model 44-10) and a Bicron Analyst ratemeter with a FIDLER (field instrument for the detection of low-energy radiation) probe were used in the walk-over survey. Both instruments can detect radioactive contamination to a depth of 1 ft below the ground surface (bgs).

4.2 Measurements

Direct and scanning measurements were collected from both the background area and the burial site. Because the nature of the survey was to detect presence or absence of radiation levels above background, the direct measurements were collected over the anomaly. Background measurements were collected at random locations. Direct measurements were collected in the scaler mode with integrated counts over 1 minute. [Scaler mode refers to an instrument that is set to take a counted measurement of radioactivity over a set period of time, typically one minute. The output is a discrete number of hits or counts per minute (i.e., 2545 cpm). Using the scaler mode to take a measurement increases the sensitivity of the instrument since the instrument is placed over one location for a set amount of time]. Scanning measurements were taken in the rate meter mode at an approximate rate of 0.5 meters per second (m/s). [Rate meter mode refers to an instrument that has an output of a continuous counting rate displayed on a gauge on the meter. The operator determines the amount of radioactivity present by watching the fluctuations of the needle on the meter, and recording the range (i.e., 2000-3000 counts per minute (cpm)). The type of instrument is generally used during scanning surveys].

4.3 Conclusions

The results of the radiological walk-over survey are summarized in Appendix-B, Table 2. From this table it can be seen that the radiological walk-over survey results at the burial site were indistinguishable from the background area levels and, therefore, are consistent with the results of the radiological survey performed by the U.S. EPA in September 1998.

5.0 Intrusive Scoping Survey (February-March 2000)

The primary purpose of the intrusive survey was to determine if the anomaly found in U.S. EPA's 1998 geophysical survey was a buried fuselage from the accident site and if radioactive contamination was present deeper than 1 ft bgs (As discussed in Section 4.1, 1 ft bgs is the maximum depth the instrumentation used in the walk-over survey can detect radiological contamination). The intrusive survey was performed in February and

March 2000. The information collected during the intrusive survey was used to estimate the volume of soil to be excavated for waste disposal. Sampling was performed based on a systematic grid that was overlaid on the geophysical anomaly detected by U.S. EPA, as shown in Appendix-A, Figure 8.

5.1 Instrumentation

Intrusive soil sampling was performed using the direct push Geoprobe® sampling technique. Soil samples were collected and sent to AFIERA laboratory for gammaspectroscopy analysis. In addition to samples being sent for laboratory analysis, *in situ* alpha radiation measurements were completed with a zinc sulfide (ZnS) alpha probe (Ludlum Model 44-1) which was used with a rate meter (Ludlum Model 2350). For health and safety purposes, a Micro-R survey meter (Ludlum Model 19) and Pancake Geiger-Mueller (GM) probe (Ludlum Model 44-9) with a ratemeter (Ludlum model 12) were used for area, personnel, container, sample, and equipment surveys.

5.2 *In Situ* Measurements

In situ measurements were collected for all soil samples collected by the Geoprobe® using the Micro-R meter, the GM probe, and the alpha probe. The Micro-Rmeter and GM probe were used primarily for health and safety purposes. The alpha probe was used to determine if elevated levels of alpha radiation were present and also provided an indication if DU was present in the soil. The combination of the beta-gamma GM probe and the alpha probe was used as field screening methods to determine presence or absence of high levels of alpha activity relative to background. This also assisted the sampling team in determining whether the extent of contamination was sufficiently delineated.

5.3 Soil Characteristics

The sampling logs for the grid locations are presented in Appendix-B, Table 3. Fifteen samples were collected within the area of the anomaly. Three background samples were collected west of the road. The nature of the native soil was clayey. Native clayey soil was observed in all samples collected outside the immediate area of the anomaly except at locations 9 and 13 (see Appendix-A, Figure 9). Aircraft debris was encountered between 3.5 to 4.5 ft bgs. Sample S-13 was a discretionary location because debris was encountered at S-9. Debris was encountered at S-13 at 3 to 3.5 ft bgs.

Soil retrieved from locations corresponding to the anomaly (S-0, S-6 and S-7) were distinctly different from the native clayey soil. Based on the on-site measurements no gross alpha or gamma measurements were detected above background soil levels. At location S-6, debris that appeared to be aircraft parts were retrieved between 6.5 and 7 ft bgs. This confirmed that the buried anomaly was most likely a burnt fuselage and associated aircraft wreckage.

5.4 Soil Concentrations

Results of the gamma spectroscopy performed in the laboratory are presented in Appendix-B, Table 4. These results show non-detects for americium-241 (Am-241) and U-235 in most samples. U-235, when detected, is present at background levels. Thorium-234 (Th- 234) was detected at levels exceeding background at location S-7 (14 pCi/g), indicating that U-238 was present above background levels. Th-234 is in secular equilibrium with U- 238 and is used as an indicator of U-238 levels. Results of the beryllium analysis are presented in Appendix-B, Table 5. Beryllium was not detected in three of the four site samples. However, beryllium was detected at location S-7b at 2.14 micrograms per gram (μg/G), which is not significantly greater than background. The ISDH preliminary remediation goal (PRG) for beryllium in subsurface soil is 16 μg/G. Based on historical record of the accident site, beryllium was not expected to be a contaminant of concern (COC). Based on this recent laboratory analysis and historical records, beryllium is not considered to be a COC at the burial site.

5.5 Conclusions

Based on soil characteristics from the intrusive survey, it was concluded that a fuselage corresponding to U. S. EPA's geophysical survey was buried between 3 and 8 ft bgs at the suspected burial site (approximately 50 x 50 ft with a 10 x 10 ft spur to the south west corner). The laboratory analysis showed that the extent of DU contamination was most likely confined to the area of the buried anomaly. As shown by the results in Appendix-B, Table 4, high levels of contamination were not found during the characterization survey.

6.0 Final Status Survey (October-November 2000)

6.1 Regulatory Criteria Summary

The U.S. EPA criteria for unrestricted use requires that the total effective dose equivalent (TEDE) be as low as is reasonably achievable (ALARA), but no more than 15 millirem per year (mrem/yr) (0.15 millisieverts per year [mSv/yr]) above background (U.S. EPA, 1997b). The radiological dose modeling software RESidual RADiation (RESRAD), developed at Argonne National Laboratory (USDOE, 1993), was used to establish soil activity levels that would result in doses less than 15 mrem/yr for each radionuclide of concern (ROC). In addition, a gross soil activity concentration for all ROCs resulting in a dose of less than 15 mrem/yr was developed using Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) guidance.

The RESRAD program was used to calculate the Derived Concentration Guideline Levels (DCGLws) that result in a dose of 15 mrem/yr to a critical receptor. A composite DCGL of 30 picocuries per gram of soil (pCi/g) was selected as a screening level based on ALARA considerations. In the American National Standards Institute/Health Physics Society (ANSI/HPS) N13.12-1999, *Surface and Volume Radioactivity Standards for*

Clearance, this value correlates to an exposure limit of 1 mrem/yr to a potential receptor for a group of radionuclides including all uranium isotopes and some beta-gamma emitters. While the ANSI standard is technically not applicable to soils that could be potentially used for agricultural purposes, it was determined reasonable in this case to use the standard as an applicable or relevant and appropriate requirement (ARAR) in the interest of ALARA considerations. For this remediation, it was reasonable to remediate to activity concentrations much lower than the DCGLws because contaminants in the soil were readily identified, removed, and disposed of in a cost-effective manner. The screening level of 30 pCi/g was selected to ensure that the soil sample results, which provide the objective evidence that the DCGLws are met, can easily demonstrate compliance with the appropriate DCGLws.

6.1.1 Radionuclides of Concern

The primary ROCs considered at the burial site were the uranium isotopes (U-234, U-235, and U-238) that are constituents of DU and enriched uranium (EU). Gross activity soil limits were developed for these two materials in the FSS Work Plan (Parsons, August 2000); isotopic DCGLws were also calculated as part of this report. Isotopic DCGLws were also determined for two secondary ROCs - Th-232 and Am-241. Thorium-232 (Th-232) can be found in magnesium thorium alloy (MagThor), a material commonly used in the construction of aircraft parts. This alloy is used due to its high melting point and strength. MagThor is readily identifiable in the field using gamma spectroscopy because of its unique radiation spectra. Although several pieces of MagThor were recovered from the excavation, it was not considered a primary ROC because of its low likelihood of residual contamination. It was not readily dispersible from the B-58 incident due to its form and high melting point. Contamination containing Th-232 was limited to large chunks or aircraft parts and, therefore, was easily removed. Am-241 is a daughter product of plutonium-241 (Pu-241), and is often used as an indicator for the presence of weapons-grade plutonium. Because of the nature of the B-58 Hustler incident and the perceived concern of the regulatory agencies related to the presence of weapons-grade plutonium in the burned weapons, a soil limit was calculated for Am-241.

6.1.2 Derived Concentration Guideline Levels

DCGLws are the concentrations of residual radioactivity distinguishable from background that, if distributed uniformly throughout a wide area, would result in a TEDE of a given value to a potential receptor. A dosage of 15 mrem/yr was used for the FSS (Parsons, February 2002). It was projected that a limit in excess of 15 mrem/yr would not be consistent with ALARA goals for this site and the 15 mrem/yr limit is in compliance with both CERCLA and Nuclear Regulatory Commission (NRC) guidance.

Consistent with NRC requirements and MARSSIM, a post-cleanup ALARA evaluation was performed to verify that remedial activities that resulted in concentrations below the DCGLws but still potentially above background were ALARA. Actions based on the ALARA evaluation were implemented as part of the cleanup activity.

6.1.3 RESRAD Exposure Scenarios

The modeling effort included five exposure scenarios: residential, residential farmer, prison resident, prison residential farmer, and excavation worker. These scenarios were chosen to provide an upper bound of any potential exposure that may be incurred to individuals due to residual contamination. The primary basis for the prison scenarios is the close proximity of the Indiana Department of Corrections Miami Correctional Facility. It is plausible that the site may someday be used for future prison expansion.

The residential scenario is the base case from which the other residential scenarios are developed. For many sites, the upper boundary limit for individual exposure is typically the residential farmer scenario, due to the amount of time spent on-site, the physical activities required to develop the land for agricultural use, and the consumption of food grown onsite. The prison residential farmer performs the same agricultural activities and also consumes food grown on-site. As a result, the residential and prison residential farmer scenarios differ only in the amount of time spent on-site which is much larger for a prisoner. The scenario of the non-farming prison resident is similar to that of the prison residential farmer, but without the consumption of on-site grown foods and the exposures during farming activities. The excavation worker scenario applies to that individual who is involved in intrusive activities such as excavation or construction. Specific differences in model inputs between these scenarios are shown in Appendix-B, Table 6.

6.1.4 RESRAD Input Parameters

RESRAD requires over 100 input parameters for the model. The input parameters describe the receptor and source specifications within various categories including: exposure pathways, soil concentrations, calculation times, contaminated zone, cover and contaminated zone hydrological data, saturated zone hydrological data, uncontaminated unsaturated zone parameters, occupancy, ingestion pathway (dietary data), ingestion pathway (non-dietary data), radon data, and storage time before use. Site-specific data for the burial site and the state of Indiana were used when available. When no site-specific data were available, conservative assumptions were used.

6.1.5 RESRAD Modeling Results

The calculated DCGLws are based on 15 mrem/yr and site-specific conditions. For comparison with gross activity measurements, gross activity DCGLws for DU and EU (enriched to 93.5 weight percent U-235) were calculated using the MARSSIM equation in Appendix-B, Table 7 and the activity fractions listed in Appendix-B, Table 8. By using the equation and the activity fractions, gross activity DCGLws were calculated for DU and EU for the five RESRAD modeled scenarios and are presented in Appendix-B, Table 9. It should be noted that for EU the gross DCGLw is dominated by the individual DCGL from U-234 due to it having the largest activity fraction. For DU, U-238 has the dominant individual DCGLw. The preliminary gross activity DCGLws that were developed in the FSS Work Plan (Parsons, August 2000) were calculated in the same manner and are also listed in Appendix-B, Table 9.

In the interest of ALARA considerations, Parsons and AFIERA also adopted a soil activity limit of 30 pCi/g for all radioactive contamination. For this remediation, it was reasonable to remediate to activity concentrations much lower than the DCGLws because contaminants in soil were readily identified, removed, and disposed of in a cost-effective manner. The use of isotopic DCGLws rather than gross DCGLws decreases the uncertainty in the results that could be introduced based on the assumptions of isotopic fractions that would need to be made to show compliance with gross activity DCGLws.

The individual isotopic DCGLw results for all five scenarios are given in Appendix-B, Table 10. The results for the residential farmer, prison resident, and prison residential farmer scenarios were relatively low, indicative of the longer residence times required for these scenarios to have any significant impact. The excavation worker scenario resulted in a high DCGLw, due primarily to the short residence time for the excavation worker. The RESRAD modeling results demonstrate that the prison residential farmer scenario is the most conservative receptor scenario.

Derived concentration guideline limits for smaller, more elevated areas (hot spots), known as DCGLEMCs were also calculated. The DCGLw corresponds to the average concentration of the entire site or survey unit, while the DCGLEMC sets the upper limit for a single highly localized measurement (i.e., hot spot). The single radionuclide DCGLEMCs for the five scenarios are also listed in Appendix-B, Table 10.

6.2 Burial Area Excavation Process

6.2.1 Excavation Instrumentation

The primary instruments used in the soil surveys were a Bicron FIDLER probe and a 3-inch by 3-inch NaI detector. These instruments were used to determine if contamination was EU or DU through a field screening protocol. The primary instruments used for health and safety purposes were an alpha scintillation detector and two GM detectors, used for contamination control surveys; and a MicroR meter, used for radiation field measurements. Additionally, a Quantrad Scout NaI system and a Canberra Intrinsic Germanium system, both owned and operated by AFIERA, were used for waste characterization purposes.

6.2.2 Excavation Activities

The excavation began with the removal of a one-foot interval across the entire burial area in order to check for backfill and shallow buried objects. This initial lift scraped sod and underlying asphalt remnants off of the area. The first pieces of airplane debris were found at one location under this first one-foot lift. Given this discovery, the excavation plan changed from making continuous one-foot lifts across the entire burial site, as described in the FSS Work Plan (Parsons, 2000), to digging outward from the center of the found debris. The excavation continued from the location of the first discovered airplane debris and proceeded downward following the debris and contamination.

Native soils were easily distinguishable from contaminated soils based on the field correlation of the survey results with the type of soil found; undisturbed, well packed clay or loose discolored soils. The edge of the excavation was determined by the change in soil type. Once a clean face was reached, an additional foot was excavated to ensure that no airplane debris remained. The excavation then continued on the next face containing contamination.

Any areas containing significant debris or contamination hot spots were scanned with the FIDLER and 3"x3" NaI probe to determine the extent of contamination. When the FIDLER displayed an elevated reading, a NaI 3"x3" detector was used to provisionally determine if EU or DU was present. The flag value for the FIDLER was approximately 10,000 cpm, which is distinguishable from background (*i.e.*, approximately 10 percent to 15 percent above the upper bound of the 95 percent confidence level background distribution). This count rate also corresponds to the Minimum Detectable Count Rate that was developed based on the MARSSIM guidance.

Once the soils were scanned, the area of contamination was removed and placed into the contaminated soil or debris piles. At each excavation interval, areas that previously contained debris and/or hot spots were treated as contaminated, visually inspected, and scanned on a bucket-by-bucket basis.

From each bucket, all contaminated pieces of debris were retrieved from the excavated soil, scanned, and placed in the contaminated debris piles. If the entire bucket was determined to be contaminated, the debris pieces were removed and the soil was placed in contaminated soil piles. If the soil was scanned and determined to be uncontaminated after debris was removed, the soil was placed in uncontaminated soil piles. This soil was eventually used as backfill for the completed excavation after a scanning survey was conducted to check for contamination. The activity concentration in the soil was verified to be below the DCGLs using the Brooks AFB laboratory.

Uncontaminated debris, as determined by radiological surveys, was placed in a lined roll-off box for further characterization and disposal by Cabrera Services. Contaminated debris was further scanned and tested using gamma spectrometry to determine the nature and extent of radiological contamination. All contaminated waste (both soil and debris) were characterized and disposed of by Cabrera Services.

In an attempt to minimize high-activity waste, the contaminated soil was scanned a second time in order to locate any more hotspots. Contaminated debris and soil were separated from the lower-activity concentration soil and set aside for further characterization. The remaining contaminated soil pile was placed in one roll-off box and designated for off-site disposal upon further characterization.

During this excavation, the primary contaminated materials were chunks and not prone to airborne resuspension. However, loose soil was sprayed with water as necessary to reduce the amount of dust released into the atmosphere. Radioactively contaminated dust posed a potential health risk if inhaled (albeit a minimal health risk for this material concentration).

Dewatering activities were necessary at a depth of approximately 8-9 ft bgs. The water was pumped out of the pit at regular intervals and held in the water holding tank located next to the excavation pit. Groundwater (i.e., perched water) removal continued until the excavation and final closure scanning and sampling were completed. Due to the relatively low solubility of uranium, groundwater was not expected to be contaminated. However, laboratory analyses were used to characterize the contamination of the water collected in the pit before its final release. The water removed from the excavation appeared to be perched water collected in the cavities of the aircraft debris, rather than water from a perched aquifer. The water was released to the Peru Utilities Wastewater Treatment Plant, consistent with the requirements of 10 CFR 20.2003.

The final excavation had a T-shape with two rectangular sections measuring approximately 53 ft by 25 ft and 57 ft by 27 ft, respectively. The final depth of the excavation was approximately 9 feet. At this depth, no more debris was encountered and no soil appeared to be present except for undisturbed native clay. No elevated measurements were found upon scanning.

6.3 Excavation Sampling

6.3.1 On-going Sampling

Soil samples were taken from the excavation whenever areas of elevated count rate were discovered. If the source of the elevated count rate could be localized (e.g., the chunk identified), it was placed in a sample bag for further analysis. The surrounding soil was then surveyed again to ensure that no contamination remained. These samples were analyzed for isotopic identification using the on-site gamma spectroscopy equipment.

6.3.2 Final Sampling

Once the excavation had reached its final depth, additional soil samples were taken from the excavation bottom for the MARSSIM final status survey and from the uncontaminated soil piles to clear these soils and allow them to be used as backfill.

At the point where the soil sample was taken, a one-minute total count was also performed using the FIDLER. The static counts were collected with the probe in contact with the ground surface at the point where the soil sample was to be taken. A one-minute areal scaler count was performed for the whole grid square by walking over the square area for the count duration at a constant speed while holding the probe no more than one foot above the ground. Each soil sample was labeled and appropriate chain-of-custody paperwork was completed prior to sending the samples to the AFIERA Analytical Chemistry Division laboratory for analysis. The analytical results, which confirms the presence of only uncontaminated soils and use of only uncontaminated backfill, provides the basis for permitting unrestricted reuse of the site.

6.3.2.1 Number of Measurements and Grid Spacing

As specified in the MARSSIM, a two-sample Wilcoxon Rank Sum (WRS) test was used to evaluate survey results when residual radioactivity contained radionuclides present in background or when survey measurements were not radionuclide-specific (i.e., gross scaler counts). The WRS test was used to determine if the residual radioactivity in a survey unit was statistically different from activity detected in a background reference area. The *a priori,* number of sample points necessary within a given survey unit and background reference area to perform the test, was calculated per Section 5.5.2.2 of MARSSIM.

The bottom of the excavation was T-shaped and was split into two rectangular sections, Area 1 and Area 2, upon which the FSS Work Plan (Parsons, 2000) grids were established (see Appendix-A, Figure 10). It was determined that a minimum of 24 samples be collected from the excavation bottom to reach the desired confidence level. The grid spacing calculations were performed again in the field, when the actual size of the excavation had been determined. For the length of the side calculation (using the equation in Appendix-B, Table 11), it was assumed that 20 samples taken from each excavation area would ensure a high level of confidence for each area.

Based on these sampling requirements, a grid spacing of 8 ft was established for each area (MARSSIM guidance requires the user to round down the calculation). Once this grid was laid out on the excavation floor, Area 1 yielded 18 sample locations and the Area 2 yielded 21 sample locations (see Appendix-A, Figures 11 and 12).

6.3.3 Backfill Soils Sampling

The grid spacing for the backfill soil piles was completed in a similar manner using a baseline requirement of 24 samples. This number of samples was not collected, but rather were only used to establish the grid spacing per the MARSSIM guidance (see Appendix-A, Figures 13-16). Information summarizing the grid size calculations is compiled in Appendix-B, Table 12. Once this was completed, the top half (approximately 1.5 feet) of the soil pile was removed and the process repeated. Once the final survey scan and sampling were performed, the soils below the DCGLws were backfilled into the excavation.

6.4 Analytical Data

6.4.1 Data Quality Objectives

The Data Quality Objectives (DQOs) were developed using the guidance presented in Appendix D of MARSSIM. These DQOs were developed prior to the start of the excavation and were promulgated by the project FSS Work Plan (Parsons, August 2000).

The Final Status Survey (Parsons, February 2002) collected 59 samples to meet the following DQOs:

- Investigate possible contamination at the burial site and determine the extent of any contamination.

- Compare survey and background data to determine if the survey area data is similar to the background area using the WRS test recommended in MARSSIM. The α- and β-levels for the WRS test at this site are both set at 0.05 for the analysis of the spectroscopy results.

- Compare analytical results to DCGLws for those radionuclides that do not have an established background using the Sign test (also recommended in MARSSIM).

- Determine if the area satisfies the release criteria (i.e., the DCGLws) after the B-58 wreckage and contaminated materials have been removed.

Samples were analyzed at the AFIERA laboratory at Brooks AFB, Texas.

Although MARSSIM guidance does not specifically apply to the investigation and release of sub-surface soils, the MARSSIM was used to help develop defensible and conservative remediation goals.

6.4.2 Background Radiation Levels

The radionuclides of interest are naturally-occurring in the environment or are present in the environment due to the fallout from atmospheric weapons testing. The concentration of these radionuclides in the natural environment varies significantly based on the source and types of soil. Background radioactivity material concentrations are a distribution of values. When evaluating whether a sample is above background it is important to assess if it is consistent with the background distribution or higher than background. In the FFS (Parsons, February 2002) concentrations falling outside this background distribution are referred to as "distinguishable from background."

Site soil background samples were collected and analyzed using gamma spectroscopy during the initial site scoping survey (see Section 4) and in the AFIERA Radiological Characterization Report of the B-58 Accident Site (AFIERA, May 2000). The average and standard deviation of the sample results is given in Appendix-B, Table 13 (Table 5-1 pg. 5-3).

Much of the background data available was comprised of non-detect values. It is possible to estimate values for these results based on two separate statistical papers: Strom, 1986 and Finkelstein and Verma, 2001 (FSS, (Parsons, February 2002)). The methods described in these papers require that the data be lognormally distributed, which is typical for background radiation. The method outlined in Strom, 1986 begins by testing the data for fitness within a lognormal distribution. The available background data fit such a distribution and, therefore, the two methodologies were applied. The results were compiled as shown in Appendix-B, Table 13. The U-234 values were projected based on the material type. For the natural uranium in background, the U-234 and U-238 activities are in equilibrium and as such are equal. The decay series of U-238 is presented in Appendix-A, Figure 17. For the sample results it was assumed that the U-234 values were representative of EU as a conservative measure. The U-234 concentration in EU was calculated from the concentration of U-235 and the relative activity fraction.

The background count rate for the soils using the FIDLER was 6,194 cpm, with a standard deviation of 790 cpm. This background count rate was based on a total of 15 random measurements of the ground surface outside the excavation.

6.4.3 Final Sampling Analytical Results

The final radionuclide results obtained from the laboratory were analyzed in order to ensure that any residual radioactive material remaining at the site would meet the DCGLs. The final sampling results were compared to DCGLw values, the ALARA value, and the established soil background levels. Additionally, the results were evaluated using statistical analyses (WRS and Sign tests). The sampling results were also evaluated with the unity rule per MARSSIM.

The WRS and Sign tests are selected in the MARSSIM procedures as the appropriate tests to determine whether or not the level of residual activity uniformly distributed throughout the survey unit exceeds the DCGLw. Since these methods are based on ranks, the results are generally expressed in terms of the median. When the underlying measurement distribution is symmetric, the mean is equal to the median. When the underlying distribution is not symmetric, these tests are still true tests of the median but only approximate tests of the mean. However, numerous studies show that this is a reasonable approximation. The assumption of symmetry is less restrictive than that of normality because the normal distribution is itself symmetric. If, however, the measurement distribution is skewed to the right, the average will generally be greater than the median. In severe cases, the average may exceed the DCGLw while the median does not. For this reason, MARSSIM recommends comparing the arithmetic mean of the survey unit data to the DCGLw as a first step in the interpretation of the data.

The WRS test is a two-sample test that compares the distribution of a set of measurements in a survey unit to that of a set of measurements in a reference area. The test was performed by first adding the value of the DCGLw to each measurement in the background area. The combined set of survey unit data and adjusted background area data are listed, or ranked, in increasing numerical order. If the ranks of the adjusted background site measurements are significantly higher than the ranks of the survey unit measurements, the survey unit demonstrates compliance with the release criterion.

The Sign test is a one-sample test that compares the distribution of a set of measurements in a survey unit to a fixed value, namely the DCGLw. First, the value for each measurement in the survey unit is subtracted from the DCGLw. The resulting distribution is tested to determine if the center of the distribution is greater than zero. If the adjusted distribution is significantly greater than zero, the survey unit demonstrates compliance with the release criterion by indicating that the sample results are less than the DCGLws.

Appendix-B, Table 14 summarizes the gamma spectroscopy results and Appendix-B, Table 15 summarizes the results from alpha spectroscopy. Detailed gamma spectroscopy analysis was performed for all soil and water samples, while alpha spectroscopy was completed only for the backfill soils and soils for off-site shipment. The initial gamma spectroscopy results for the excavation bottom soil and water samples did not justify further analyses (e.g., alpha spectroscopy) for those samples. The results are organized into four subsets: excavation pit results, backfill soil pile results, soils for off-site disposal, and water tank results. The excavation pit results represent the samples that were gathered at the bottom of the excavation after the plane wreckage and contaminated soil had been removed. The backfill soil pile results describe those samples taken from the excavated soil that was used as backfill. The results for soils for off-site disposal refer to the soils removed from the excavation that appeared to be contaminated with hydrocarbons. The water tank results represent the samples taken of the water that was removed from the excavation.

Because U-234 is not primarily a gamma-emitter, U-234 results were not reported with the gamma spectroscopy results. Rather, concentrations of U-234 were estimated for each sample based on the reported U-235 activities and the activity fraction for EU (fractions consistent with 93.5 weight percent U-235; listed in Appendix-B, Table 8. Using the enriched uranium activity fraction conservatively assumes that any uranium encountered within the excavation is EU. An estimate of the U-234 activity was not required for the backfill soil alpha spectroscopy results as it was readily identified.

Analyses for both Am-241 and Th-232 were also performed. The laboratory analysis demonstrated that Am-241 and Th-232 were below the established DCGLws and that Th-232 was indistinguishable from background. These results further demonstrate that no plutonium was released during the incident and that the presence of MagThor components did not result in residual Th-232 contamination at the burial site.

6.4.3.1 Excavation Bottom Results

This section presents the soil sampling results for the bottom and side walls (sides of excavation steps) of the entire excavation. Activity concentrations of U-234, U-235, and U-236 were compared to both background levels and individual DCGLws. Additionally, the contaminant levels were compared to the ALARA remediation goal of 30 pCi/g.

In accordance with MARSSIM guidance, basic statistical parameters (mean and standard deviation) were developed for each radionuclide analyzed. A total of four tests or comparisons were performed on the data to determine if radioactivity was present in the soil above the DCGLw. These tests are:

1. Compare the Mean to the DCGLw
2. WRS test
3. Sign test
4. Unity rule comparison summing all the ROCs

The DCGLws, calculated by RESRAD for the prison residential farmer scenario, was compared to the analytical results. All individual concentration results were below the DCGLws. In addition, the sum of the individual mean soil concentrations was below the remediation goal of 30 pCi/g for all radionuclides (see Appendix-B, Table 16).

In addition, the Sign and WRS tests were applied to further document that any residual radioactivity left at the site meets the release criteria. Both the Sign test and WRS test use a critical value to which the sampling results are compared. Based on the α and β parameters established with the FSS Work Plan (Parsons, August 2000) and guidance in MARSSIM, these critical values are determined. The results of these statistical tests are shown in Appendix-B, Table 17. These tests confirmed that the soils left at the bottom of the excavation meet the release criteria.

Finally, the unity rule was applied because of a mixture of radionuclides was present at the site. Typically, each radionuclide DCGLw corresponds to a specific release criterion (e.g., regulatory limit in term of dose or risk). However, in the presence of multiple radionuclides, the sum of the DCGLws for all radionuclides could exceed the applicable release criterion. The MARSSIM unity rule, represented in the equation in Appendix-B Table 18, is satisfied when radionuclide mixtures yield a combined fractional concentration limit that is less than or equal to one.

The result of applying the unity rule indicated that the mixture of radionuclides is well below the overall annual dose guideline of 15 mrem/yr. Appendix-B, Table 19 shows the unity rule calculation results. The unity rule does not correct for background concentrations; however, the DCGL was increased by the background amount to adjust for background. This has the effect of making the unity rule compensate for the fact that background will be present in all the measurements.

In addition to the comparisons and analyses of the laboratory results, on-site field measurements were collected (see Appendix-B, Table 20). Appendix-A, Figures 10 and 11 show the measurement locations and give the results of the one minute areal and one minute static counts using the FIDLER. The excavation bottom shape (see Appendix-A, Figure 10) required that the FSS (Parsons, February 2002) grid be broken up into two rectangular pieces. As shown by Appendix-A, Figures 11 and 12; 32 of the 39 squares scanned were below or within the background level of 6,194 ± 790 cpm. Statistical analysis of the scanning results (see Appendix-B, Table 20) indicates that both the average areal and average point scaler readings are similar to the average background measurement.

6.4.3.2 Backfill Soil Pile Results

Laboratory analysis of the backfill soil pile samples was performed using both gamma spectroscopy and alpha spectroscopy. The statistical analysis of these results was completed consistent with the method presented in Section 6.4.3.1 (Excavation Bottom Results). The comparison DCGLw values, average background values, and the results for the two analytical methods are shown in Appendix-B, Tables 21 and 22. Note: gamma spectroscopy results for U-234 are based on the EU activity ratio of 0.97 to 0.0297 for U-234 to U-235. However, the U-234 concentrations reported with the alpha spectroscopy results are actual measured concentrations. The differences between the two sets of U-234 concentrations are due to the assumptions made for the gamma spectroscopy results.

For both the gamma and alpha spectroscopy analyses, the U-234 and U-238 levels are above the average background concentrations but well within the DCGLw values. The average concentration of radionuclides within the soil is less than the 30 pCi/g remediation goal.

As with the excavation bottom results, the WRS and Sign tests were performed with the data. The application of the Sign and WRS tests to the gamma and alpha backfill soil pile sampling results are shown in Appendix-B, Tables 23 and 24, respectively. In addition, the WRS test was performed for the total uranium concentrations (based on the alpha spectroscopy results) in the backfill soil samples and the background samples plus the 30 pCi/g ALARA remediation goal. As shown in Appendix-B, Table 24, the concentrations of total uranium in the backfill soil meet the 30 pCi/g criterion. Based on these results, the excavated soils were deemed suitable for use as backfill.

Application of the MARSSIM unity rule to the backfill soil pile data indicates that the results do not exceed the annual dose guideline of 15 mrem/yr. This calculation was performed using the method of Section 6.4.3.1 (Excavation Bottom Results) with the background results added to the DCGLw values. The calculation results are shown in Appendix-B, Tables 25 and 26, respectively. Both the gamma and alpha spectroscopy results satisfy the unity rule.

In addition to the laboratory results, on-site scanning data was gathered (see Appendix-B, Table 27). Appendix-A, Figures 13-16 show the approximate soil sampling locations and give the results of the one-minute areal counts using the FIDLER. The background one-minute count rate for the soils using the FIDLER was 6,194 cpm with a standard deviation of 790 cpm.

6.4.3.3 Water Holding Tank Results

In order to release the water removed from the excavation and held within the water holding tank, the gamma spectroscopy results were compared to applicable release criteria. The release criteria used for comparison are the federal sanitary sewer criteria (10 CFR 20.2003) for NRC licensees. While 10 CFR 20.2003 applies only to NRC licensees, it is acceptable to implement the rule as a ARAR as it is applicable to this type of scenario (release to a sanitary sewer) and it is protective of human health and the environment. The release criteria for each ROC are contained in Appendix-B, Table 28. Requirements from 10 CFR 20.2003 state that: (1) the release must be less than the monthly average values, (2) for multiple radionuclides, the monthly release must meet a sum of fractions test, shown in Appendix-B, Table 29; (3) the total release of radioactivity must be less than 1 curie (Ci) per year, shown in Appendix-B, Table 30; and (4) the material must be readily soluble. Calculations were performed to assess that a release to a sanitary sewer would meet these requirements. As with the soil samples described above, the U-234 activities are conservatively estimated based on the reported U-235 activities and EU activity fractions. As shown in Appendix-B, Table 28, the estimated monthly release based on the water samples from the water holding tank and excavation are well below the federal sewer release criteria.

Given there are multiple radionuclides present in the water samples, a sum of fractions calculation must be completed for all of the radionuclides. The sum of fractions test was performed by summing the monthly release concentrations for each radionuclide and then dividing by the release criteria for that radionuclide. The equation listed in Appendix-B, Table 31 was used to complete this calculation. Appendix-A, Figure 18 displays how the sum of the fractions calculation varies as a function of sewer monthly average volume. Appendix-A, Figure 18 also shows that the additional minimum flow volume (i.e., volume other than the tank liquid) required to meet the sum of fractions requirement is 1000 gallons per month. However, since the actual flow volume is approximately 3,000 gallons per month, this was the value used in assessing this release. Also higher flow volumes would result in lower fractions. Appendix-B, Table 28 lists the monthly release fraction information for each radionuclide based on the tank volume of 2,750 gallons and sewer monthly average flow of 3,000 gallons.

The next requirement is to assess the total amount of radioactivity to be released over an entire year. The total amount of activity to be released from the water holding tank can be estimated by multiplying the water volume within the tank by the radionuclide concentrations. The volume of the tank was conservatively estimated to be 2,750 gallons. Appendix-B, Table 30 shows that no more than 15 microcuries (Ci) would be released, which is well below the limit of 1 Ci per year. Given the radionuclide concentrations present in the water samples, it would take over 65,000,000 gallons to exceed the 1 Ci per year release limit. It is assumed that the licensee will release no other sources of radioactive material to this system.

The final requirement is that the material to be released is readily soluble. The material analyzed in the sample was soluble.

6.5 Excavation Restoration

6.5.1 Backfilling Excavation

Once the sidewalls and floor of the excavation and the backfill soils were determined to be uncontaminated, the excavation was backfilled with the clean soils. Additional uncontaminated soil was brought in from off- site to complete the backfill and the site was restored to its original grade (all of the backfilling equipment was scanned with the FIDLER and GM probe prior to being filled uncontaminated, off-site soil and was determined that none of the equipment had measurements of radioactivity above regulatory levels). Approximately 2 cubic ft of soil across the site was required. The entire area was walked-over and scanned with the FIDLER to ensure that there were no areas with measurements of radioactivity above regulatory levels. Additionally, a final scan of the areas where the clean excavated soils were stored was completed in the same manner.

After completion of backfilling activities, the excavation and grading equipment were scanned for contamination with the FIDLER and GM probe. All contaminated soil was removed from the equipment and placed in the contaminated soil roll-off boxes. The water holding tank, which contained water that was removed during the excavation, remained at the site until water sampling results were determined by laboratory analysis.

6.5.2 Soil Transportation and Disposal

Contaminated soils in the roll-off boxes were transported by a Department of Defense approved waste broker, Cabrera Services,Inc. Contaminated soils and materials were transported either to WCS, in Texas, or to Envirocare, in Utah, for disposal. Waste profiles, manifests, and Certificates of Disposal are documented in a final report titled, *Radiological Characterization Waste Brokering and Shipping, B-58 Aircraft Burial Site,* (Cabrera, January 2002), and is available for review upon request in the Grissom AFRPA's Administrative Record.

6.5.3 Water Disposal

Water collected during dewatering activities in the excavation was stored in a water holding tank located next to the excavation pit. Samples were taken from the water holding tank for analysis of radionuclides by AFIERA. The water sample analyses showed levels of radioactivity to be below sanitary sewer release criteria. As a result, the water was released into the Peru Utilities Wastewater Treatment Plant for disposal.

6.6 Dose Comparison

This section compares the dose that could potentially be received by the scenario receptors to the background radiation exposure to which the general public is exposed. The background exposure which an average member of the U.S. population receives per year is 360 mrem (BEIR V, 1990). This background exposure includes radiation from three specific sources: naturally occurring radiation, medical uses of radiation, and radiation from consumer products. For the closure of the contaminated area, the DCGLws that were developed were based on a dose limit of 15 mrem/yr (USEPA, 1997b), or 4.2 percent of the typical background exposure. In addition, an ALARA remediation goal of 30 pCi/g, corresponding to a dose limit of 1 mrem/yr for total uranium, was adopted. A 1 mrem/yr dose limit is equivalent to approximately 0.3 percent of the typical background exposure.

Appendix-B, Table 32 shows the potential doses for the various soil sources. The extrapolated potential doses were calculated by taking the ratio of the mean concentration of each radionuclide (minus the background concentration) to its respective DCGLw and summing. This ratio was 0.023 (or 2.3 percent) for the excavation bottom and 0.059 (or 5.9 percent) for the backfill soil piles based on the gamma spectroscopy results and 0.11 (or 11 percent) for the backfill soil piles based on the alpha spectroscopy results. These ratios, in relation to the 15 mrem/yr dose limit, equate to 0.35 mrem/yr for the excavation bottom and 0.89 mrem/yr for the backfill soil piles based on the gamma spectroscopy results and 1.65 mrem/yr for the backfill soil piles based on the alpha spectroscopy results. Additionally, the percentage of the 15 mrem/yr dose limit corresponding to this value and the percentage of the typical background dose are given. Appendix-B, Table 32 shows that the dose to the potential exposure receptors is below a few percent of the typical background exposure that the average member of the U.S. population receives. With the $DCGL_w$ values developed using conservative assumptions, it is expected that any potential exposures to residual radioactivity left at the burial site will be minimal and will not significantly affect the health of a receptor.

To further investigate the potential exposure to the limiting case receptor (prison residential farmer), the RESRAD model that was used to develop the DCGLws was used to assess the potential exposure. This was completed by using the identical input parameters with the backfill soil pile radionuclide mean concentrations. Two runs were completed, one using the gamma spectroscopy results and the other with the alpha spectroscopy results. The output of these runs is shown in Appendix-A, Figures 19 and 20. As with the comparison depicted in Appendix-B, Table 32; Appendix-A, Figures 19 and 20 indicate that the potential exposure to the receptor is a small fraction of the ambient background radiation incurred annually and well below 15 mrem/yr. The peak dose represented in the figures indicates when radon-222 (Rn-222) has become a significant dose contributor due to radium-226 (Ra-226) ingrowth.

6.7 ALARA Assessment

The final step in the FSS (Parsons, February 2002) was to show that any residual radioactivity left after the remedial action meets the ALARA requirements, as well as the 15 mrem/yr dose goal, as outlined in the MARSSIM and in DG-4006 (NRC, 1998). The simplified method presented in DG-4006 is to estimate when further remedial action is cost effective. If the desired beneficial effects ("benefits") from the remedial action are greater than the undesirable effects or "costs" of the action, the remedial action is cost effective and should be performed. Conversely, if the benefits are less than the costs, the levels of residual radioactivity are already ALARA without taking the remedial action. In order to compare the benefits and costs of a remedial action, it is necessary to use a comparable unit of measure. The unit of measure used here is the dollar; all benefits and costs are given a monetary value. While materials potentially still remaining or recovered from the burial site are not NRC-licensed, it is acceptable to perform an ALARA assessment using NRC guidance because it is an industry-accepted practice and it is protective of human health.

As presented in DG-4006, the residual radioactivity level is ALARA when the impact of the concentration equals the cost associated with further remediation. DG-4006 uses an expression that equates the ratio of the ALARA concentration (Conc) over the DCGLw to the cost and benefit expressions (see Appendix-B, Table 33). This calculation is done for each of the radionuclides that are within the soils being remediated, and summed for the final evaluation. The total cost to further remediate the site is assumed to be the same as the current effort given that the burial site area would need to be excavated in a similar manner. To complete the benefit term (right side of the equation minus the cost) is first calculated for each of the soil sources. These values are then summed, and divided into the total cost for the remedial action to find the ALARA ratio. If this ratio is found to be less than one, further remediation may be warranted to satisfy ALARA. If the ratio is greater than one, the remediation is considered to meet the principles of ALARA. When this calculation is completed for the two source areas (excavation bottom and backfill soils), the ratio is equal to 136, given the above parameters. As a result, the remediation meets the principles of ALARA.

6.8 Summary of Findings

The following findings were made during the excavation, final status survey, and data analyses.

- The excavation procedure set forth in the Final Status Survey Work Plan (Parsons, August 2000) was successful in removing contaminated debris and soil at the B-58 Hustler Burial Site.

- Contaminated soil and debris characterized on-site and contaminated wastes were separated from clean soil that was utilized as backfill at the completion of the excavation.

- The survey instruments were calibrated to detect the ROCs and daily checks indicated acceptable instrument performance during the excavation and survey for field control of excavation activities.

- The DCGLw values established using RESRAD and presented in the FSS Work Plan (Parsons, August 2000) were adequate to ensure that the maximum exposure to on-site receptors would not exceed 15 mrem/yr.

- Comparisons of the mean results for all radionuclides for all soil were below DCGLw values.

• The sums of the mean results for total uranium were below the remediation goal of 30 pCi/g for uranium.

• Statistical analyses (WRS and Sign tests) of the soil and water results verify that the soil and water on-site are below DCGLw values. In addition, the statistical analyses performed on the alpha spectroscopy total uranium data demonstrate that the total uranium results at the site are below the ALARA goal of 30 pCi/g.

• The final regraded excavation site was scanned and found to be indistinguishable from background using both the FIDLER and the 3" x 3" NaI detectors.

6.9 Conclusions

Based on the findings listed above, it can be concluded that the excavation successfully removed the radioactively contaminated B-58 aircraft debris and soil from the B-58 Hustler Burial Site (AOC 8) near Grissom ARB, Indiana. Analysis of the soil samples taken during and after the excavation show that any residual contamination at the site is well below both the DCGLw values as determined by the MARSSIM protocol and the preliminary ALARA goal of 30 pCi/g of total uranium. As such, the burial site is suitable for unrestricted reuse.

7.0 Regulatory Agency Involvement

7.1 Regulatory Review and Approval of Final Status Survey Report

The *B-58 Final Status Survey* prepared by Parsons Engineering Science, Inc. in February 2002 under Project Number CTGC-2000-6108, was submitted to Indiana State Department of Health, IDEM, and U.S. EPA for review. Draft comments were received from IDEM and U.S. EPA in letters dated September 6, 2001 and October 12, 2000, respectively. IDEM and U.S. EPA had no comments and concurred with the findings of the report.

7.2 Regulatory Review and Approval of Decision Document

The draft decision document dated July 2002 was submitted to IDEM and U.S. EPA for review and comment in a letter dated 12 July 2002. IDEM's and U.S. EPA's draft comments were received by the Air Force in letters dated September 24, 2002 and October 2, 2002, respectively. Air Force responses to IDEM's and U.S. EPA's draft comments were submitted to the agencies in a letter dated November 8, 2002. IDEM and U.S. EPA concurred with the no further remedial action planned remedy in letters dated **TBD** and **TBD**, respectively. IDEM's and U.S. EPA's draft comments and the Air Force's responses to those draft comments are listed below:

IDEM Draft Comments/Air Force Responses

Specific Comments

Page 7, Declaration of the Remedy: Please remove "...the selected remedy of..." in the second sentence. No further action is not considered a remedy.

Air Force Response: *"the selected remedy of"* has been removed from the subject text.

Page 9: It is not necessary to obtain Rex Bowser's signature for closure unless the Air Force is adamant about doing so.

Air Force Response: Comment noted.

Page 22, Section 6.2.2, Last Paragraph: Please remove "that" from the first sentence.

Air Force Response: "that" has been removed from the subject text.

Page 27, Section 6.4.3.1, Last Paragraph: Please remove the extra line in the second sentence.

Air Force Response: The extra line has been removed from subject text.

Page 31, Section 6.5.1, First Paragraph: Please clarify whether the third sentence discusses "2 ft" of soil or "2 cubic ft" of soil.

Air Force Response: For clarification, the subject text has been changed to read "2 cubic ft of soil.

Page 34, Section 6.8: Please add a line between the second and third bullets.

Air Force Response: A line has been added between the second and third bullets of the subject text.

Page 34, Section 7.0, Second Sentence: An "and" is needed after "IDEM."

Air Force Response: "and" has been inserted after "IDEM" of the subject text.

U.S. EPA Draft Comments/Air Force Responses

General Comments

1. **The Draft Decision Document (DD) for the B-58 Hustler Burial Site, (Area of Concern (AOC) 8)** is a well-written, well thought out explication of the work that was done at the B-58 Burial Site (Site). The analysis of the data generated as a result of that work establishes a sound basis for the conclusion stated at the end of the document, that

the Site has satisfied all requirements for closure with unrestricted use and No Further Action (NFA). EPA concurs with the overall conclusions and recommendations presented in the DD. However, there are several instances where explanation is unclear, incomplete or ambiguous. Please see the specific comments below.

Air Force Response: Comment noted.

2. **EPA recommends that the DD include a list of acronyms.**

Air Force Response: A list of acronyms has been added to the document and is located in Appendix C.

Specific Comments

1. **Page 7, Declaration of the Remedy, last line**: The DD states that *"...no treatment is necessary and the site is suitable for clean closure and unrestricted us."* The use of the term "clean closure" may be misleading, insofar as the term is commonly used to describe complete remediation of contaminated sites pursuant to the requirements of the Resource Conservation and Recovery Act (RCRA). EPA agrees that the site is suitable for unrestricted use.

Air Force Response: The subject text has been changed to read: "*...no treatment is necessary and the site is suitable for unrestricted use.*

2. **Page 14, Section 3.5, History**: The end of this section states that plutonium was not released to the environment. The next sentence discusses contaminated portions of the runway and adjacent soils that were excavated and buried. Since plutonium is identified as a contaminant that was not released, the contaminants referred to should also be identified.

Air Force Response: For clarity the word "Contaminated" has been removed from the subject text since there was no "known" release of any radiological or chemical contamination above regulatory levels at AOC 3 (Temporary Nuclear Weapon Disposal Site/Accident Site) at the time in which portions of the runway, adjacent soils, and the remaining aircraft wreckage were excavated, transported, and buried at AOC 8 (B-58 Burial Site). The text now reads: *"Portions of the runway and adjacent soils were subsequently excavated and buried nearby along with the remaining aircraft wreckage at the site referred to as AOC 8."*

3. **Page 15, Section 3.6, Previous Site Investigations, last ¶, first line**: Spell out AFIERA. This appears to be the first instance of the use of the term in the DD.

Air Force Response: The acronym AFIERA (Air Force Institute for Environment, Occupational Safety and Health Risk) is previously used and spelled-out on Page 7 under Statement of Basis and Purpose.

4. **Page 16, Section 4.0, Initial Scoping Survey (February 2000), fourth line**: It is stated that the background location was across the street from the site. The background site should be identified more carefully. EPA does not recall a "street" in the area of the B-58 Burial Site.

Air Force Response: The text was ambiguous in stating that the background site location was located across the street from the B-58 Burial Site. It actually is located across an unmapped gravel road (not a street) approximately 300 ft southeast of the burial site. For clarity, the subject text has been changed to read: *"The background location was across an unmapped, gravel road approximately 300 ft southeast of the burial site."*

5. **Page 16, Section 4.2, Measurements, last two sentences**: Please expand on this explanation by discussing the terms "*scaler mode*" and "*rate meter mode.*"

Air Force Response: The subject text has been revised to include the following definitions of *"scaler mode"* and *"rate meter mode"*: *"Scaler mode"* refers to an instrument that is set to take a counted measurement of radioactivity over a set period of time, typically one minute. The output is a discrete number of hits or counts per minute (i.e., 2545 counts per minute (cpm)). Using the scaler mode to take a measurement increases the sensitivity of the instrument since the instrument is placed over one location for a set amount of time. *"Rate meter mode"* refers to an instrument that has an output of a continuous counting rate displayed on a gauge on the meter. The operator determines the amount of radioactivity present by watching the fluctuations of the needle on the meter, and recording the range (i.e., 2000-3000 cpm). The type of instrument is generally used during scanning surveys.

6. **Page 16, Section 5.0, Intrusive Scoping Survey (February-March 2000)**: The first sentence of this section does not follow from the conclusion of Section 4.3. If the site survey results were indistinguishable from background for both of the survey instruments, then there would be no reason, based upon survey results, to perform an intrusive survey. As suggested in the next statement in Section 5.0, "*The primary purpose of the intrusive survey was to determine if the anomaly was a buried fuselage from the accident site, and if contamination was present.*"

Air Force Response: For clarity, first sentence in Section 4.3 and the first and second sentences in Section 5.0 have been revised and read: Section 4.0, first sentence; "*Parsons and AFIERA conducted a preliminary radiological walk-over survey (part of Final Status Survey) in February 2000 to verify the results of the radiological walk-over survey performed by U.S. EPA in September 1998 which found no radiological contamination above background at the burial site.*" Section 5.0 first and second sentences; *"The primary purpose of the intrusive survey was to determine if the anomaly found in U.S. EPA's 1998 geophysical survey was a buried fuselage from the accident site and if radioactive contamination was present deeper than 1 ft bgs (As discussed in Section 4.1, 1 ft bgs is the maximum depth the instrumentation used in the walk-over survey can detect radiological contamination)."*

7. **Page 23, Section 6.2.2, Excavation Activities, last ¶, penultimate sentence**: This sentence would make sense if it state that "*...no more debris was encountered and ~~the~~ no soil appeared to be present except for undisturbed native clay.*" As it is, it is unclear.

Air Force Response: For clarity, the subject text has been changed to read: *"At this depth, no more debris was encountered and no soil appeared to be present except for undisturbed native clay."*

8. **Page 31, Section 6.5.1, Backfilling Excavation, first ¶, penultimate sentence**: EPA assumes that this sentence is intended to state that the entire area was walked-over and scanned with the FIDLER to ensure that there were no areas with measurements <u>*above the appropriate criteria*</u>.

Air Force Response: For clarity, the subject text has been changed to read: *"The entire area was walked-over and scanned with the FIDLER to ensure that there were no areas with measurements of radioactivity above regulatory levels."*

9. **Page 34, Section 6.9, Conclusions, first sentence**: It is assumed that the intent of this sentence is to state something like the following: "*...it can be concluded that the excavation successfully removed ~~of~~ the radioactively contaminated B-58 aircraft debris and soil ~~were successfully removed~~ from the B-58 Hustler Burial Site (AOC 8) near Grissom ARB, Indiana.*"

Air Force Response: For clarity, the subject text has been changed to read: *"Based on the objectives and findings listed above, it can be concluded that the excavation successfully removed the radioactively contaminated B-58 aircraft debris and soil from the B-58 Hustler Burial Site (AOC 8) near Grissom ARB, Indiana."*

10. **Page 34, Section 6.9, Conclusions, last line**: See Specific Comment No. 1.

Air Force Response: The subject text has been changed to read: *"As such, the burial site is suitable for unrestricted reuse."*

11. **Page 35, Section 9.0, Current Site Status, last line:** See Specific Comment No. 1.

Air Force Response: The subject text has been changed to read: *"...the B-58 Hustler Burial Site is suitable for unrestricted reuse."*

8.0 Community Participation

The community participation requirements for the former Grissom AFB, follow the guidance and procedures instituted by the Air Force. The community participation activities for this decision document are described below:

A Restoration Advisory Board (RAB) has been established for the former Grissom AFB with regularly scheduled quarterly meetings, in which all pertinent restoration related activities are communicated to the public. Notices of RAB meetings are published in the local community newspapers and a mailing list of over 125 citizens is being maintained. The quarterly meetings are attended and reported by local newspapers.

The public participation process to date for the B-58 Hustler Burial Site consists of the following:

The public was briefed on the B-58 Hustler Burial Site at the February 2000, August 2000, November 2000, February 2001, May 2001, September 2001, and February 2002 Grissom AFB RAB meetings. The comments and responses from the public at the meetings were recorded and addressed as appropriate.

9.0 Current Site Status

Based on the findings listed above, which documents that no radioactive B-58 aircraft debris or soil remain at the B-58 Hustler Burial Site (AOC 8) near Grissom ARB, IN that exceed regulatory standards and regulations, the B-58 Hustler Burial Site is suitable for unrestricted reuse.

10.0 Risk Determination

The criteria for unrestricted use require that the TEDE be less than 15 mrem/year (USEPA, 1997b) and excavation actions are ALARA. In order to determine that the site meets these standards, DCGLw values were calculated using RESRAD. Soil samples collected during and after the excavation process were below the DCGLw values. Therefore, there is no unacceptable risk to human health and the environment. The site meets all the above regulatory criteria for clean closure and unrestricted reuse.

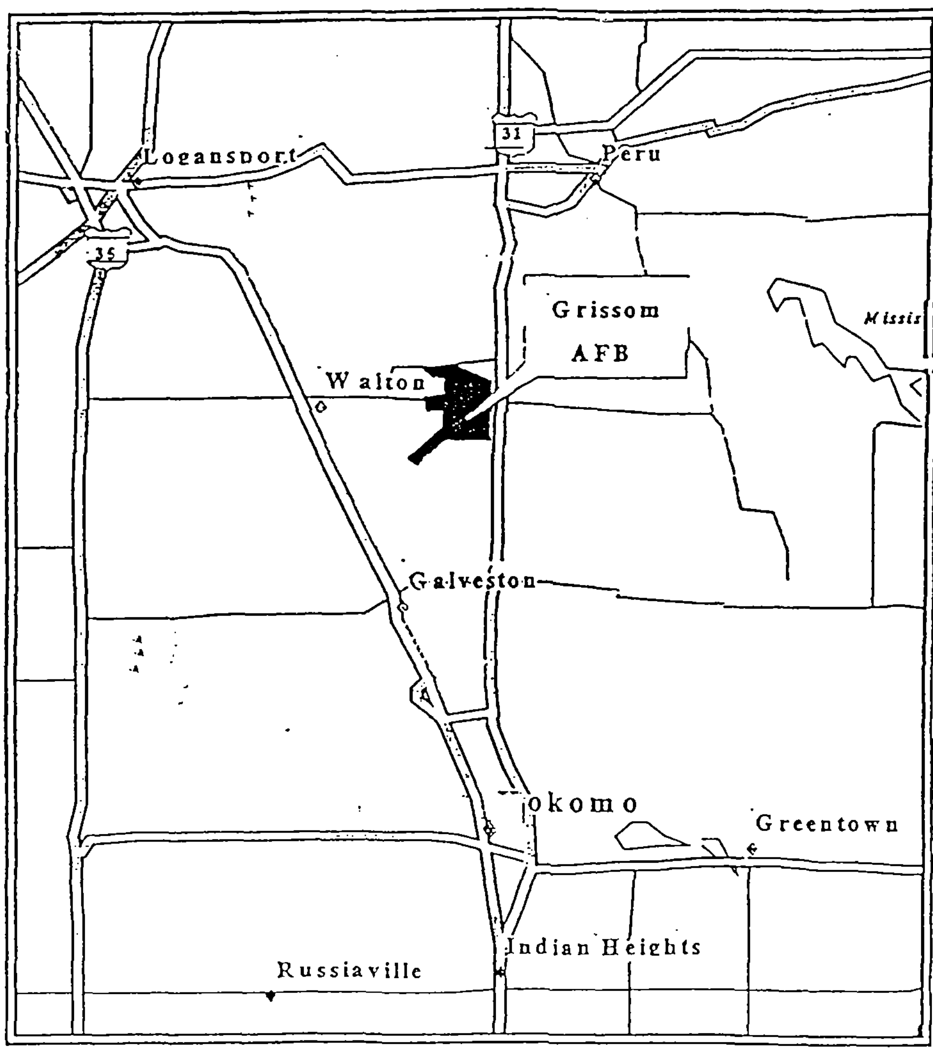
11.0 Selected Action: No Further Action

Based upon the fact there is no unacceptable risk to human health and the environment after successful completion of excavation activities as documented in the *Final Status Survey Report/B-58 Hustler Burial Site/AOC 8* (February 2002), the B-58 Hustler Burial Site (AOC 8) has satisfied all the requirements for closure with unrestricted reuse. Therefore the selected action for the B-58 Hustler Burial Site (AOC 8) is no further action necessary.

Appendix-A, Figures

Figure 1

Grissom AFB and Surrounding Communities



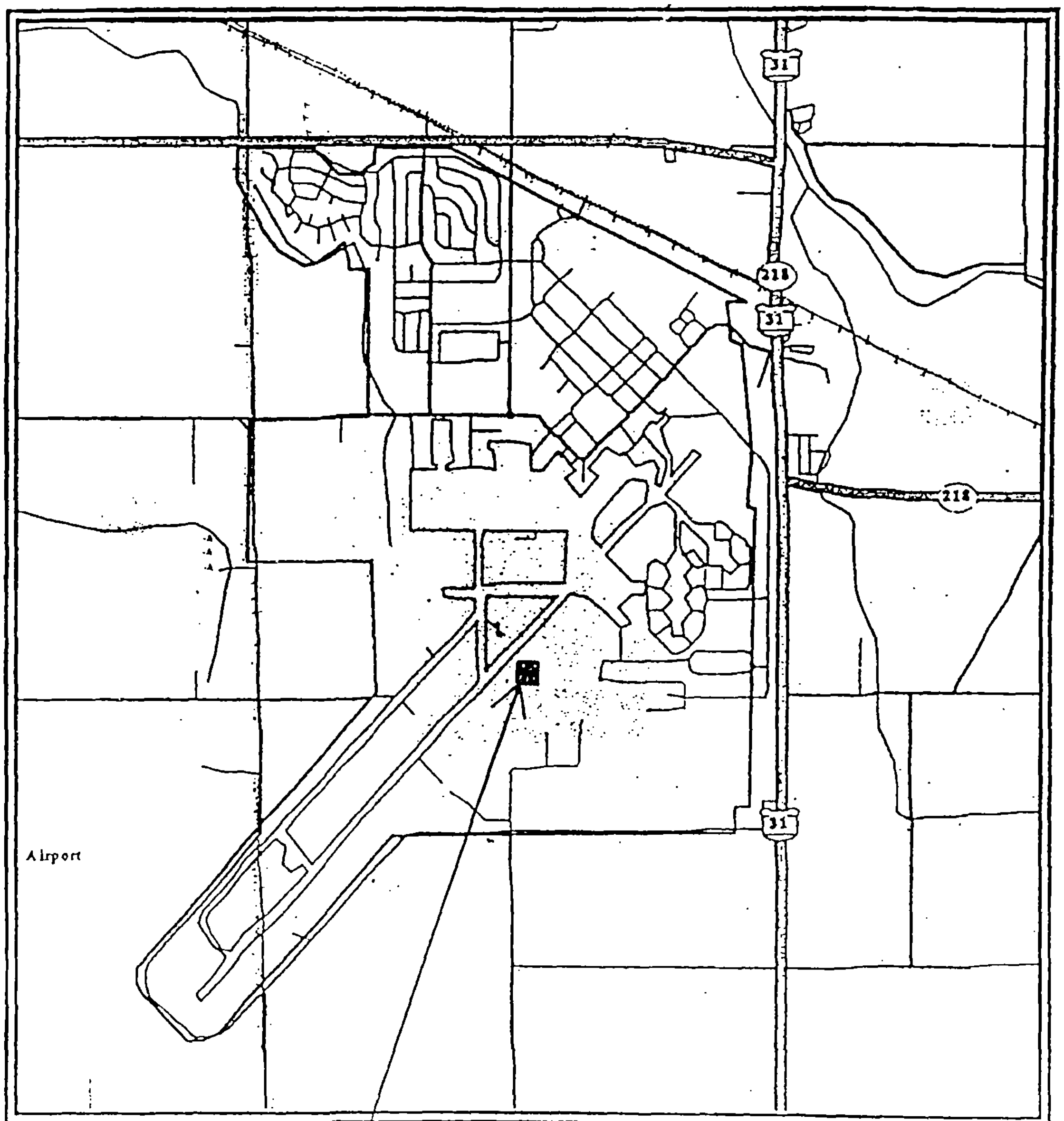
Approximate highway distances from Grissom AFB to selected neighboring communities:

Logansport	18.1 miles	Peru	9.1 miles	Galveston	8.5 miles
Kokomo	12.0 miles	Walton	7.5 miles		

Figure 2

Facility Plan, Grissom AFB

Grissom AFB Facility Plan



Approximate Location of B-58 Hustler Burial Site

Figure 3

Generalized Geologic Cross Section, Grissom AFB

Generalized Geologic Cross Section, Grissom AFB

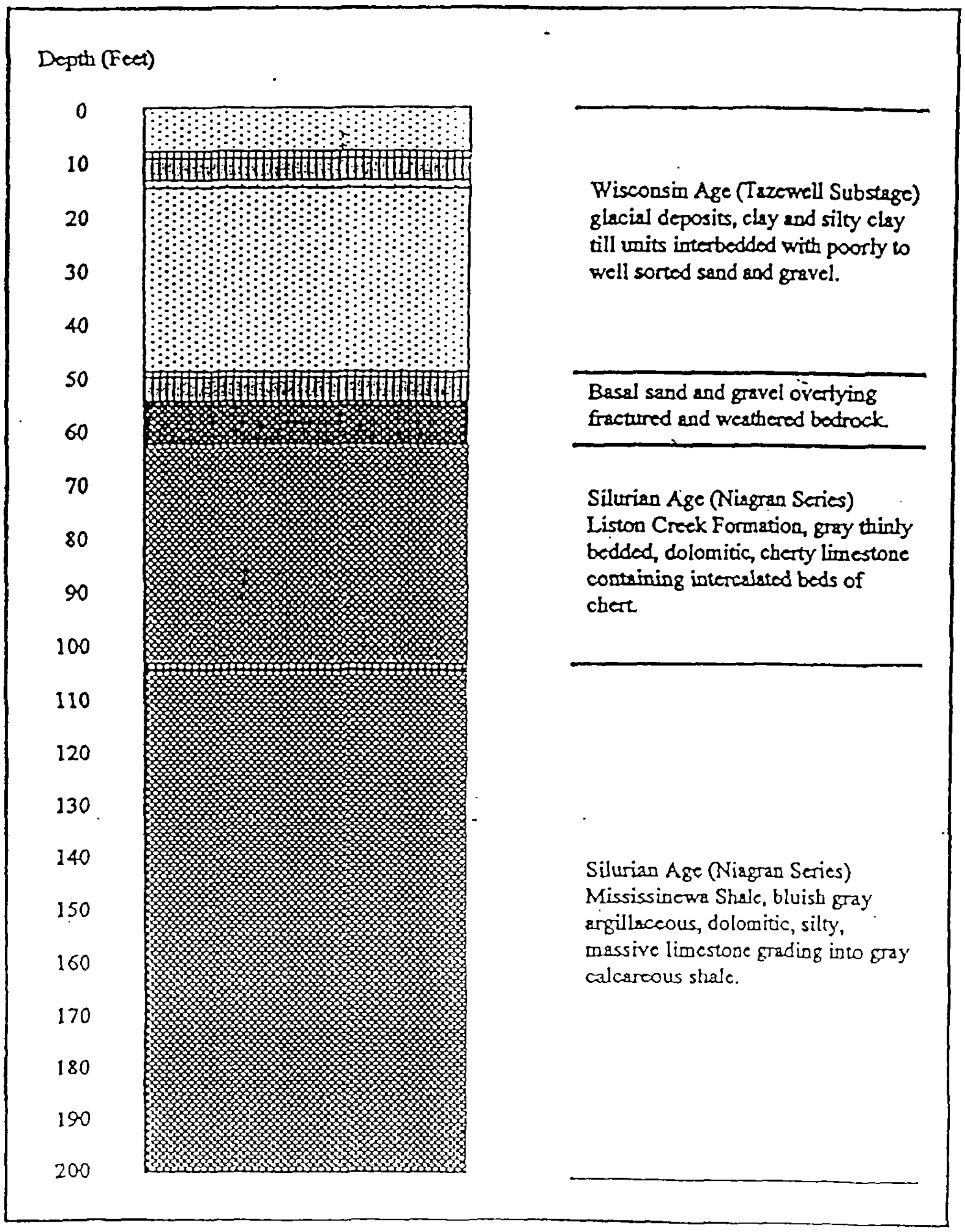


Figure 4

Regional Surface Drainage, Vacinity of Grissom AFB

Regional Surface Drainage, Vicinity of Grissom AFB

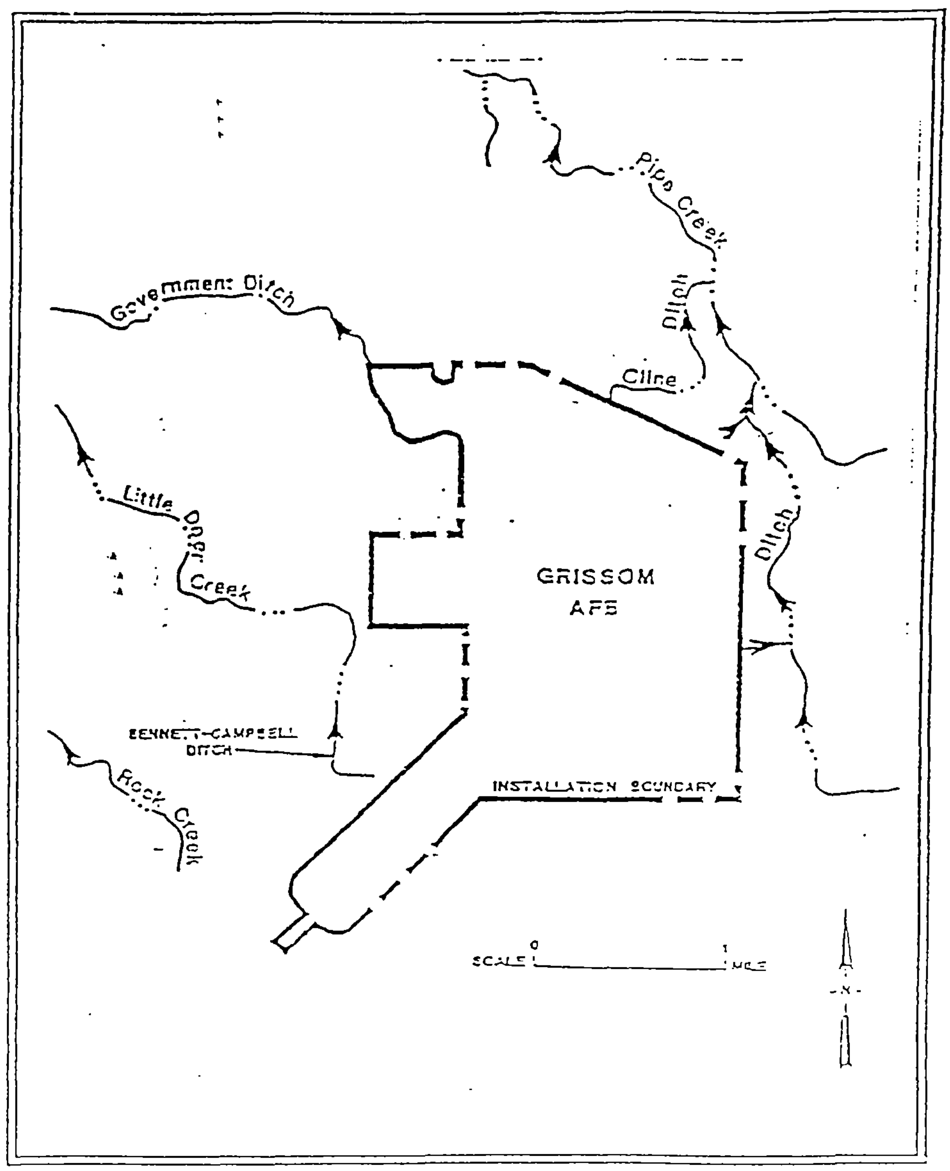


Figure 5

Facility Surface Drainage, Grissom AFB

Facility Surface Drainage, Grissom AFB

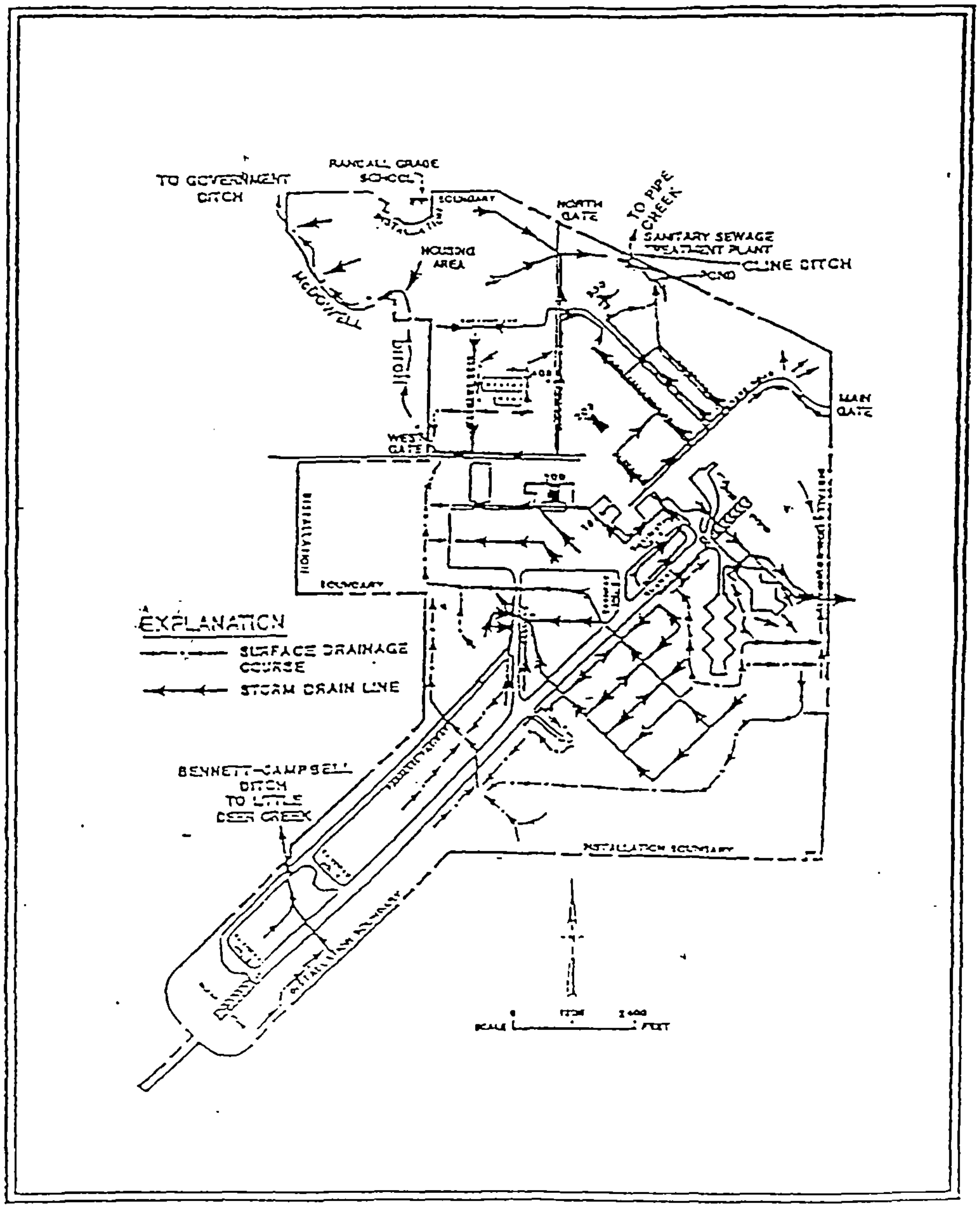


Figure 6

Groundwater Supply Well Locations, Grissom AFB

Groundwater Supply Well Locations, Grissom AFB

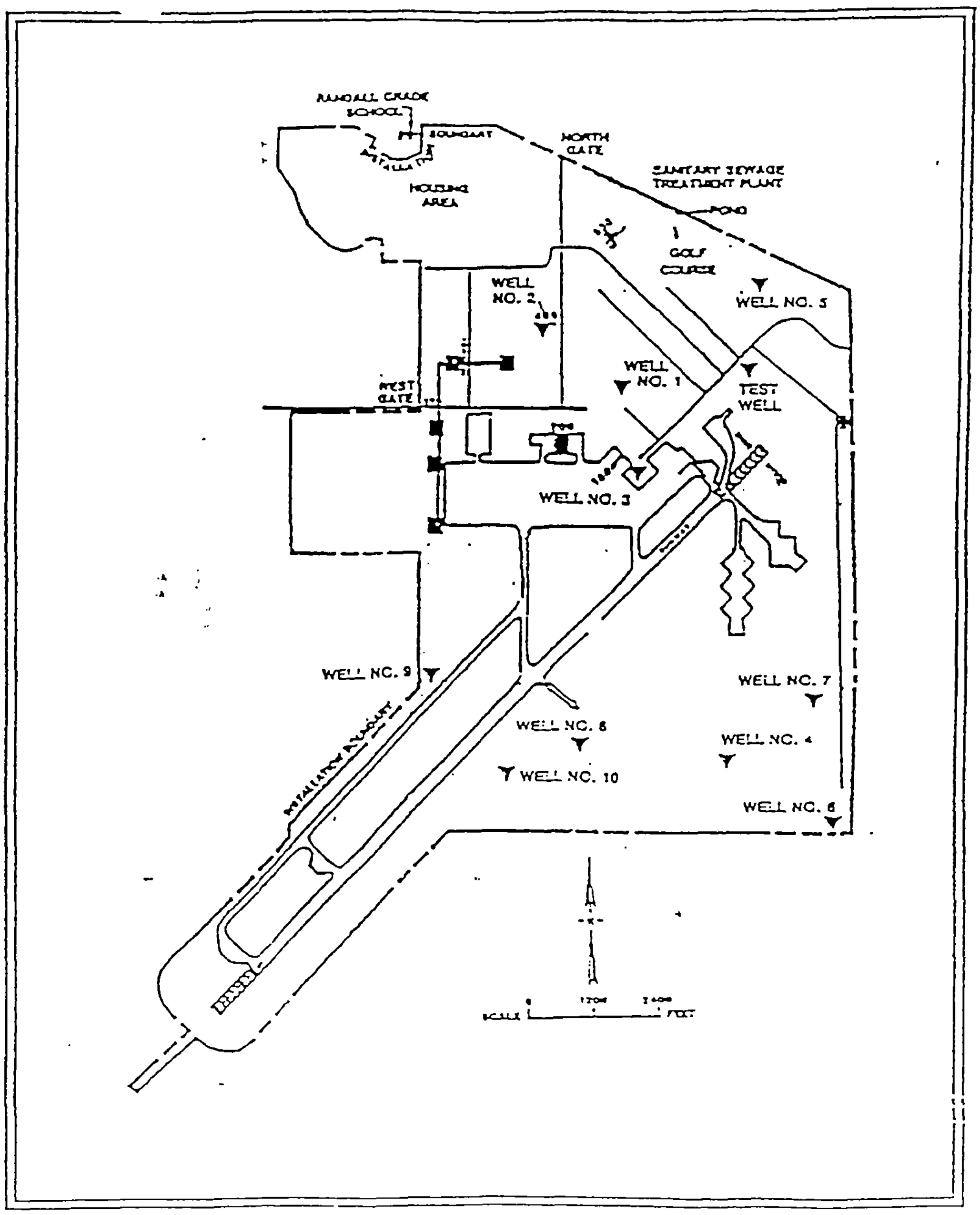
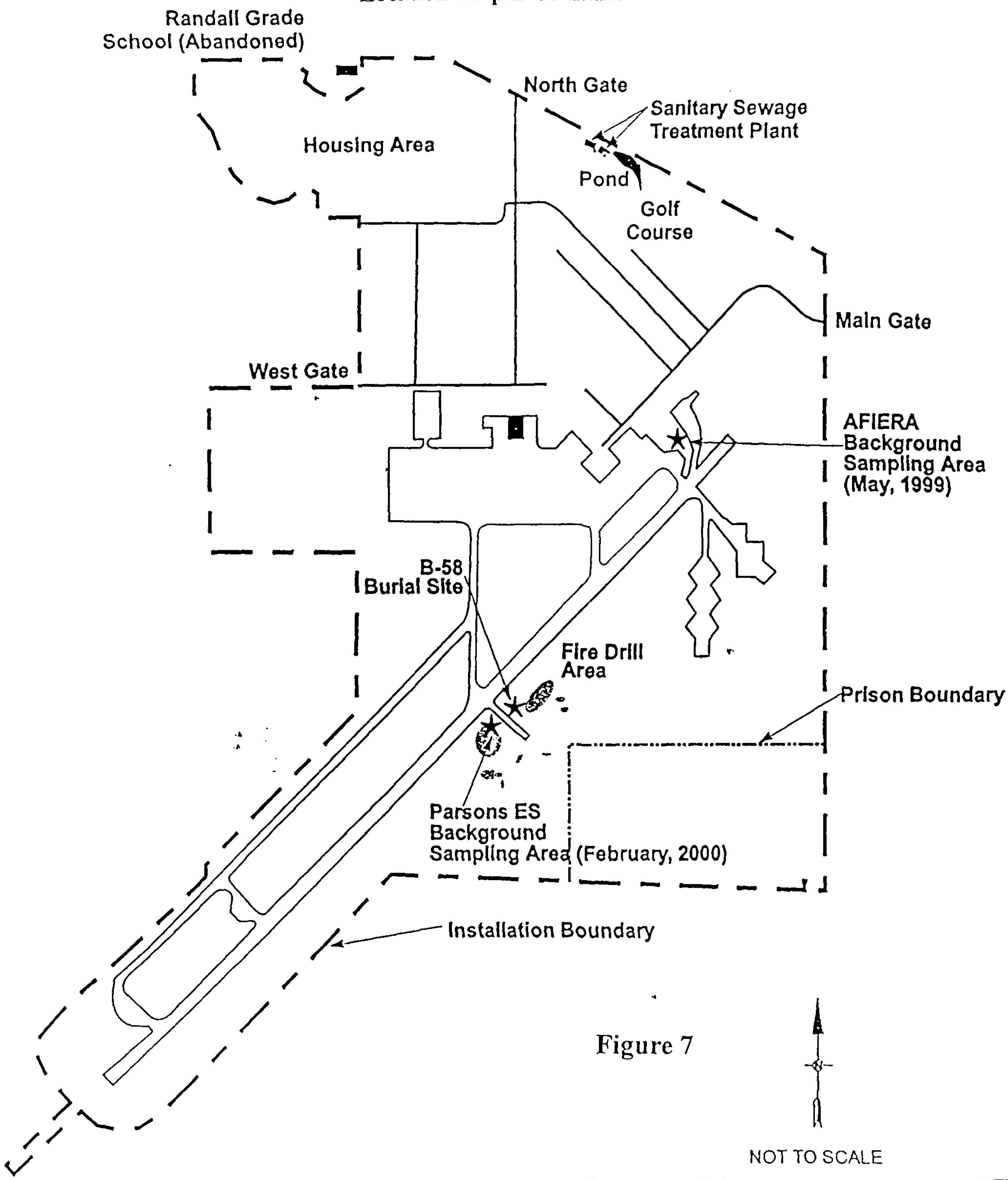


Figure 7

Location Map/B-58 Hustler Burial Site



LOCATION MAP FOR THE B-58 HUSTLER BURIAL SITE

Former Grissom AFB, Indiana

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Figure 8

Location of Metallic Anomaly

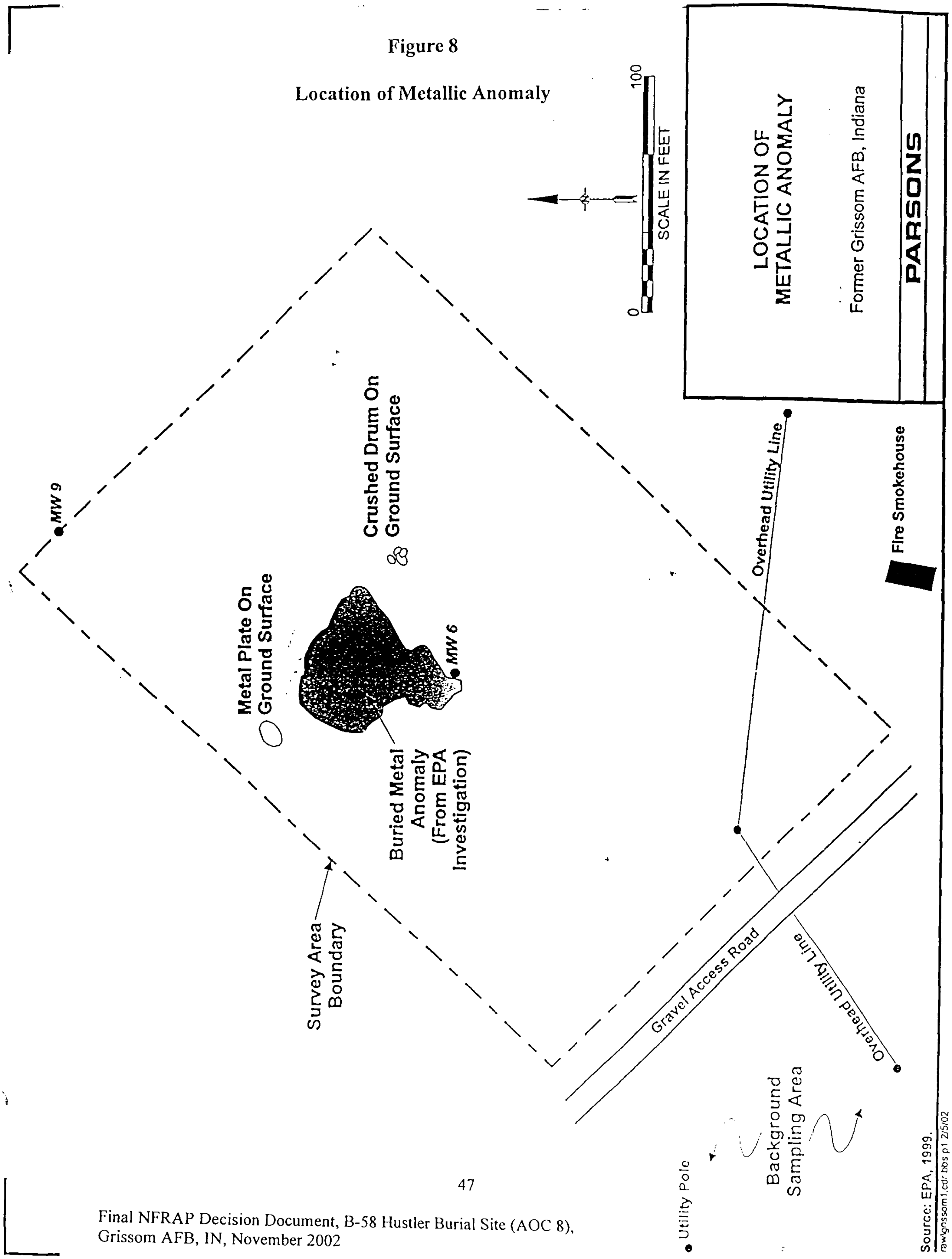


Figure 9

Intrusive Survey Sampling Locations

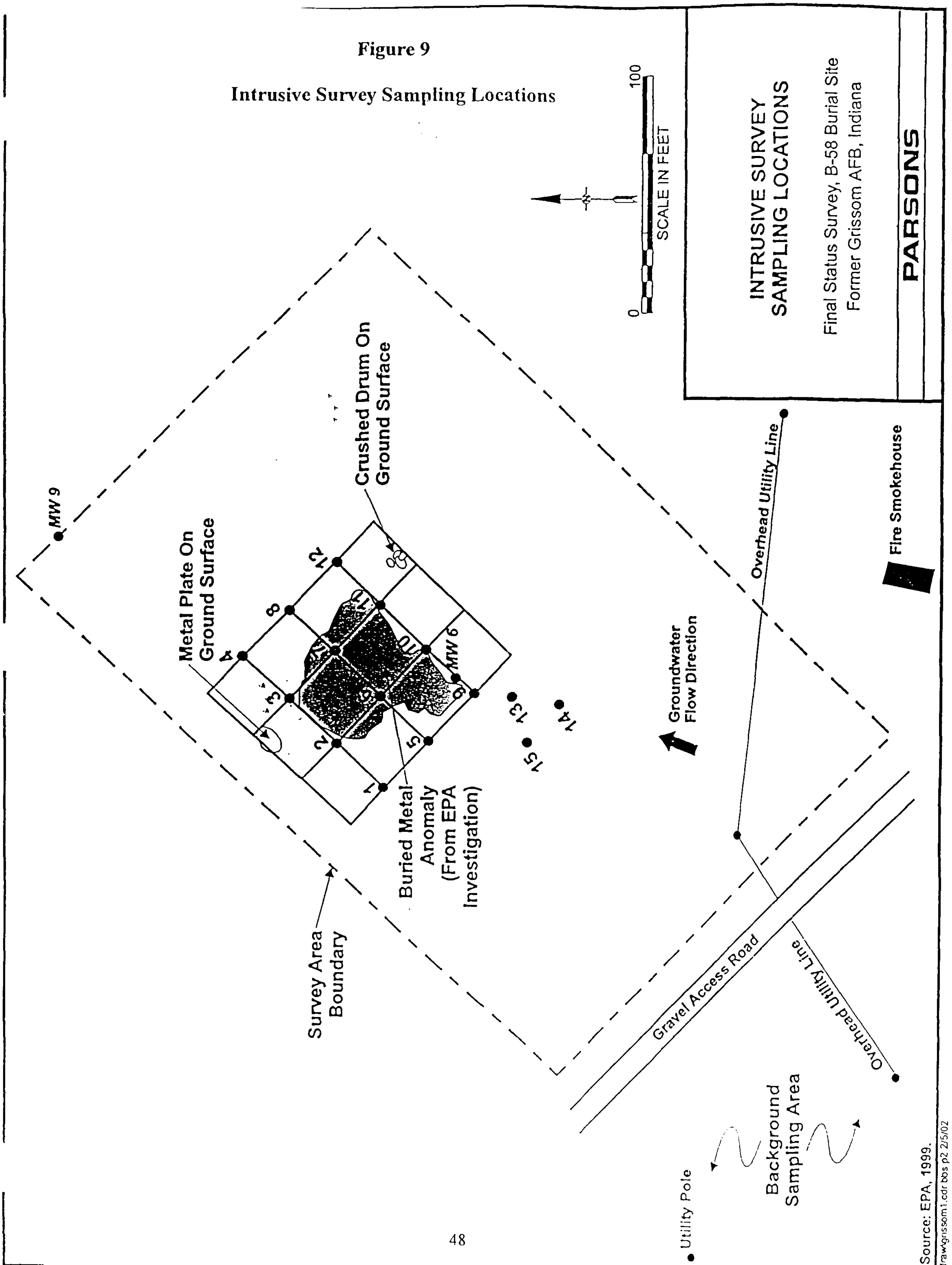
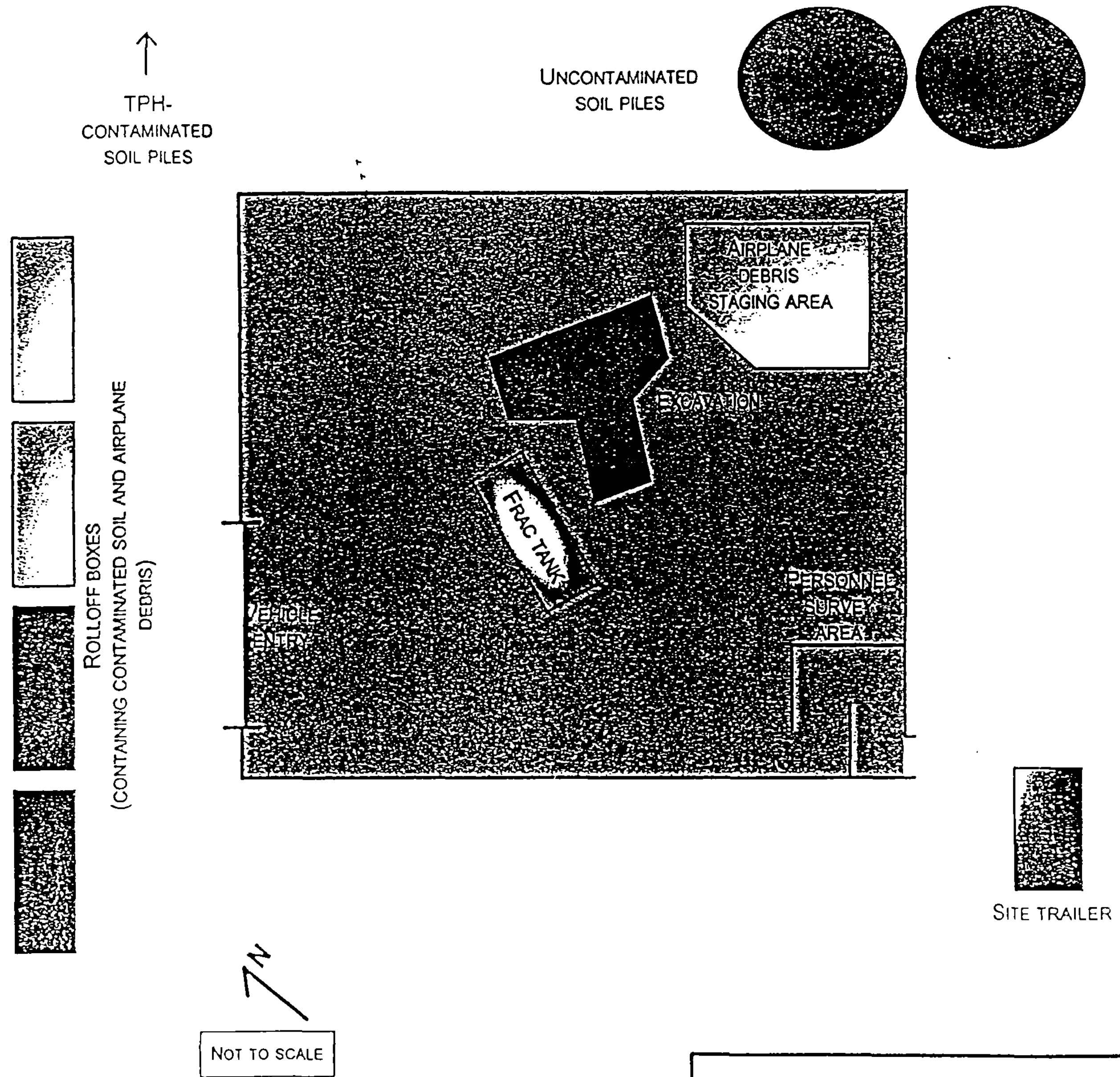


Figure 10

Layout of Excavation Site



LAYOUT OF EXCAVATION SITE

Final Status Survey, B-58 Burial Site
Former Grissom AFB, Indiana

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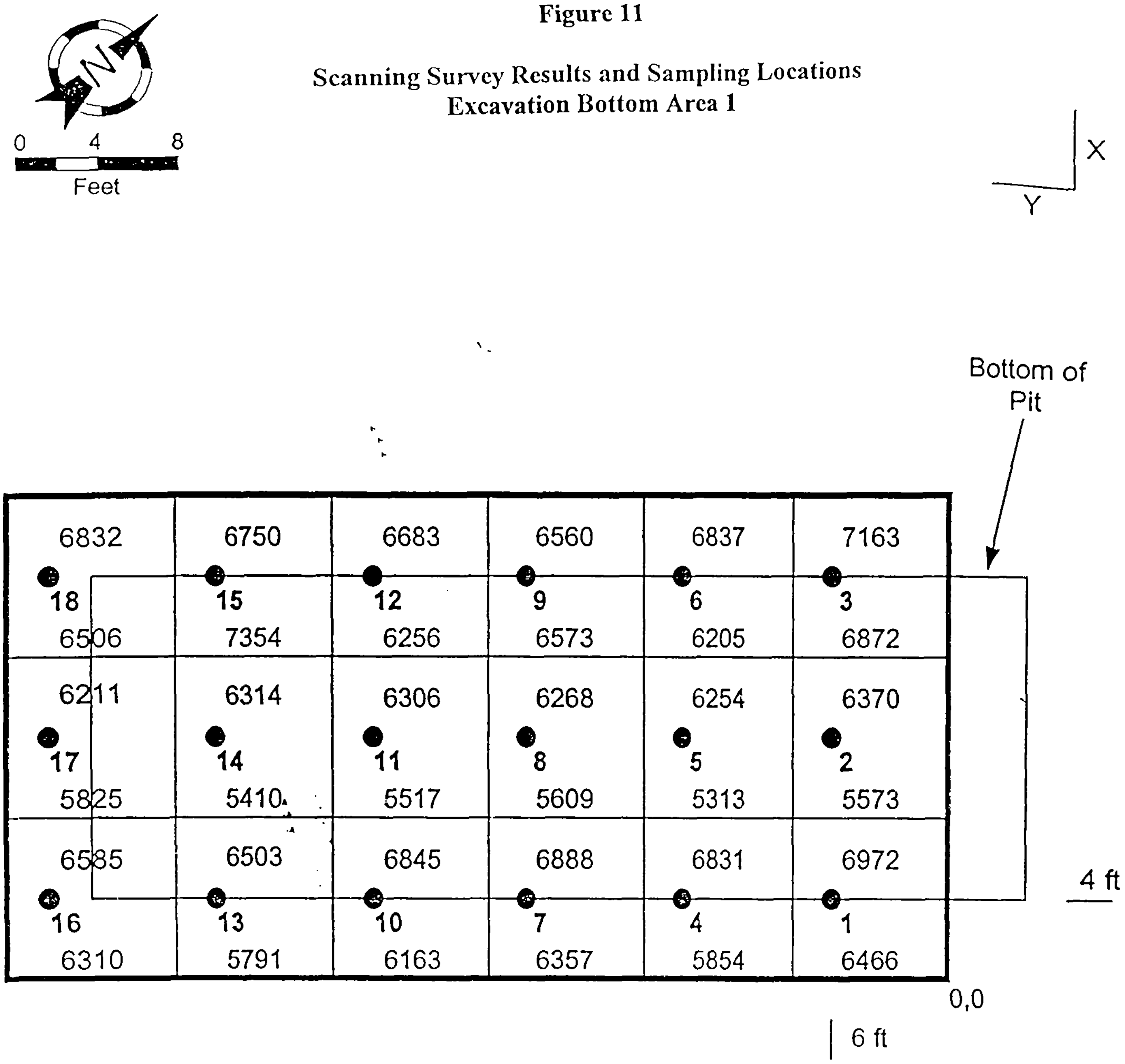
Figure 11

Scanning Survey Results and Sampling Locations
Excavation Bottom Area 1



1 Survey grid number
Location of excavation bottom soil sample
6972 Areal scaler reading (cpm)
6466 Point scaler reading (cpm)

Background: 6194 +/- 790 cpm

SCANNING SURVEY RESULTS AND SAMPLING LOCATIONS EXCAVATION BOTTOM AREA 1

Final Status Survey, B-58 Burial Site
Former Grissom AFB, Indiana

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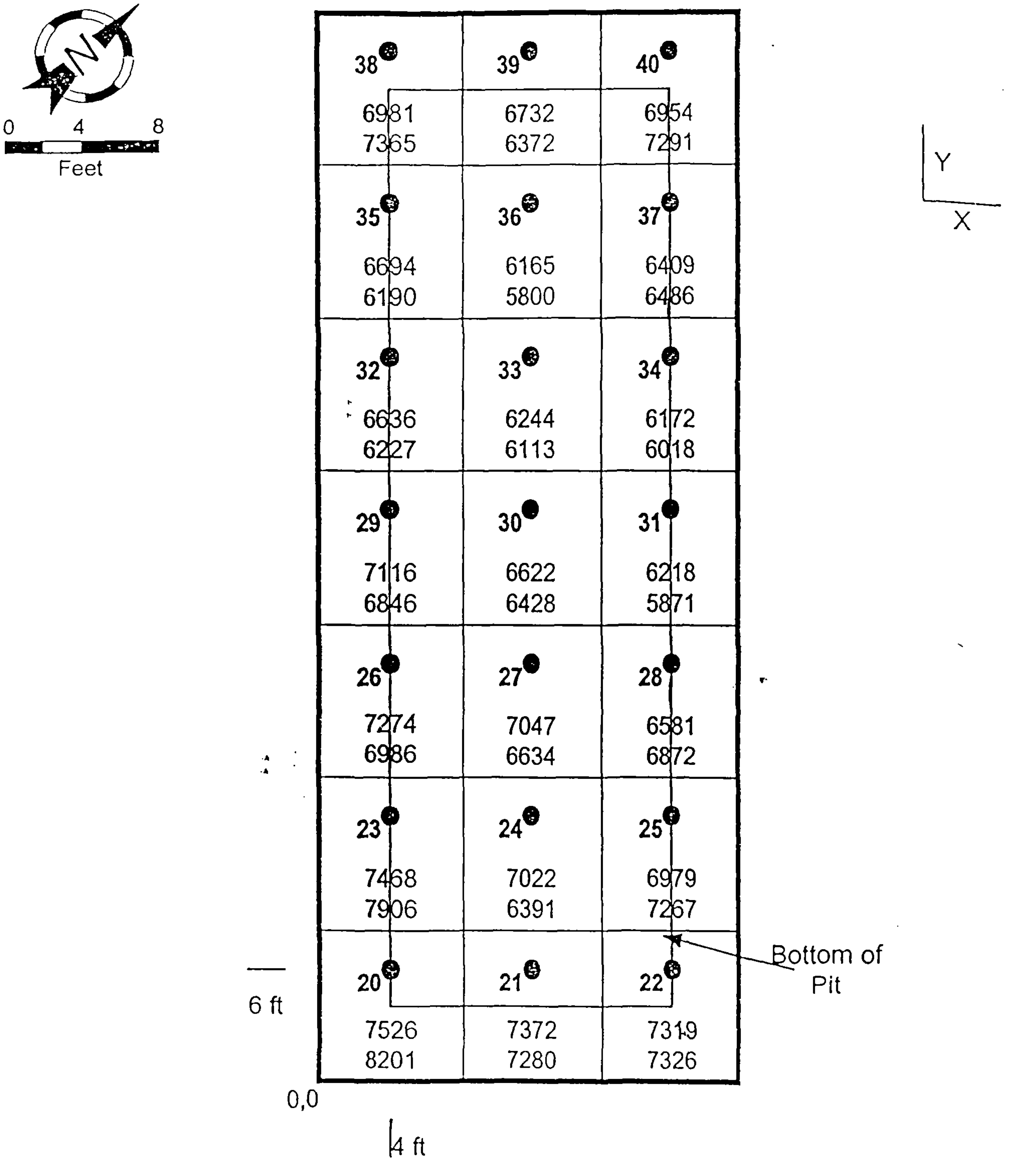
Figure 12 Scanning Survey Results and Sampling Locations Excavation Bottom Area 2



20 Survey grid number

⊛ Location of excavation bottom soil sample

7526 Areal scaler reading (cpm)

8201 Point scaler reading (cpm)

Background: 6194 +/- 790 cpm

SCANNING SURVEY RESULTS AND SAMPLING LOCATIONS EXCAVATION BOTTOM AREA 2

Final Status Survey, B-58 Burial Site
Former Grissom AFB, Indiana

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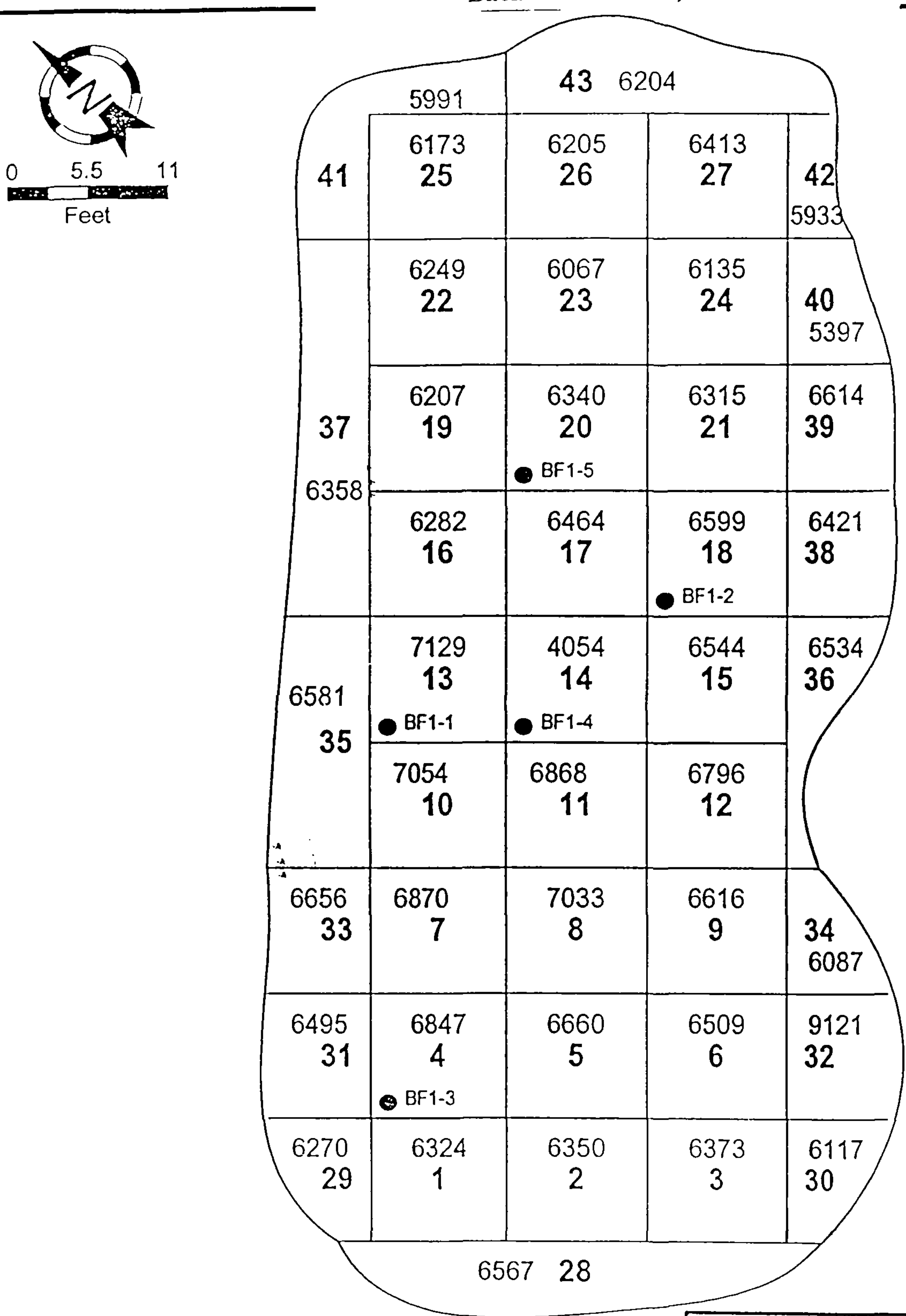
Figure 13

Scanning Survey Results and Sampling Locations
Backfill Soil Pile 1, Lift 1



1 Survey grid number
6324 Areal scaler reading (cpm)
BF1-1 Location of backfill soil sample

Background: 6194 +/- 790 cpm

SCANNING SURVEY RESULTS
AND SAMPLING LOCATIONS
BACKFILL SOIL PILE 1, LIFT 1

Final Status Survey, B-58 Burial Site
Former Grissom AFB, Indiana

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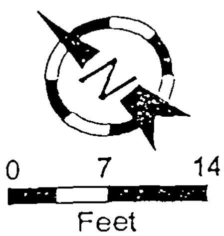
Figure 14

Scanning Survey Results and Sampling Locations
Backfill Soil Pile 1, Lift 2



6152 **32**	6038 **24**	5933 **16**	5630 **8**
6257 **31** BF3-5	6089 **23**	5898 **15**	6051 **7**
6288 **30**	6117 **22**	6190 **14**	6434 **6**
7021 **29**	7975 **21** BF3-3	6250 **13**	6694 **5**
6414 **28**	6809 **20**	6342 **12**	6788 **4** BF3-2
7202 **27**	6857 **19** BF3-4	6697 **11**	6696 **3**
6589 **26**	6643 **18**	7623 **10** BF3-1	6269 **2**
6181 **25**	6001 **17**	6608 **9**	6333 **1**

1 Survey grid number
6333 Areal scaler reading (cpm)
BF3-1 Location of backfill soil sample

Background: 6194 +/- 790 cpm

SCANNING SURVEY RESULTS
AND SAMPLING LOCATIONS
BACKFILL SOIL PILE 1, LIFT 2

Final Status Survey, B-58 Burial Site
Former Grissom AFB, Indiana

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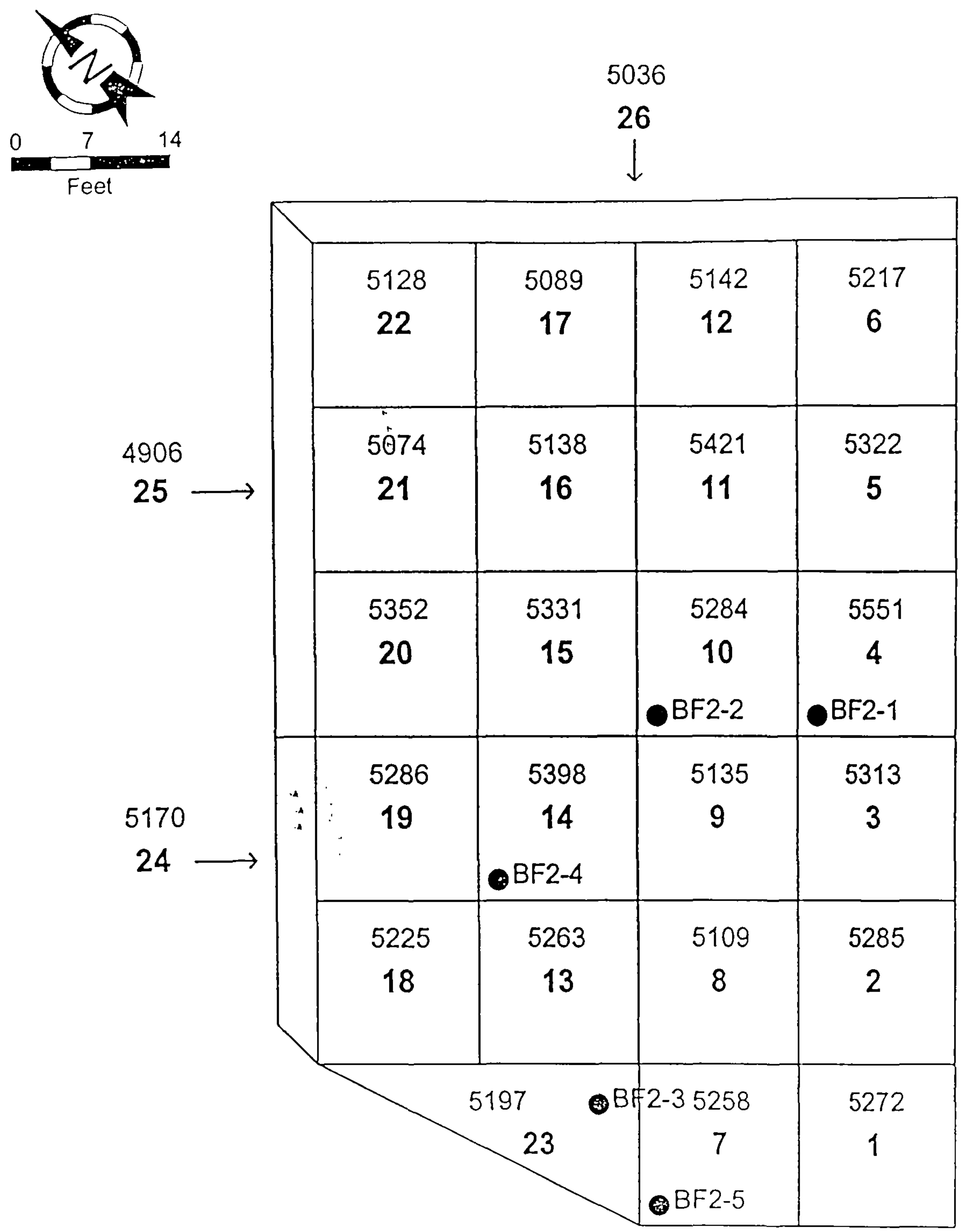
Figure 15

Scanning Survey Results and Sampling Locations
Backfill Soil Pile 2, Lift 1



1 Survey grid number

5272 Areal scaler reading (cpm)

BF2-1 Location of backfill soil sample

Background: 6194 +/- 790 cpm

SCANNING SURVEY RESULTS
AND SAMPLING LOCATIONS
BACKFILL SOIL PILE 2, LIFT 1

Final Status Survey, B-58 Burial Site
Former Grissom AFB, Indiana

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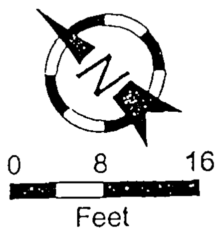
Figure 16 — **Scanning Survey Results and Sampling Locations Backfill Soil Pile 2, Lift 2**



4829 **20**	5084 **15**	5079 **10**	5053 **5**
5110 **19** ● BF4-4	5158 **14**	5321 **9**	5134 **4**
5308 **18**	5470 **13** ● BF4-5	5220 **8** ● BF4-2	5304 **3**
5296 **17**	5040 **12**	5140 **7**	5231 **2**
5053 **16**	5240 **11**	5161 **6** ● BF4-3	5338 **1** ● BF4-1

1 Survey grid number

5338 Areal scaler reading (cpm)

● BF4-1 Location of backfill soil sample

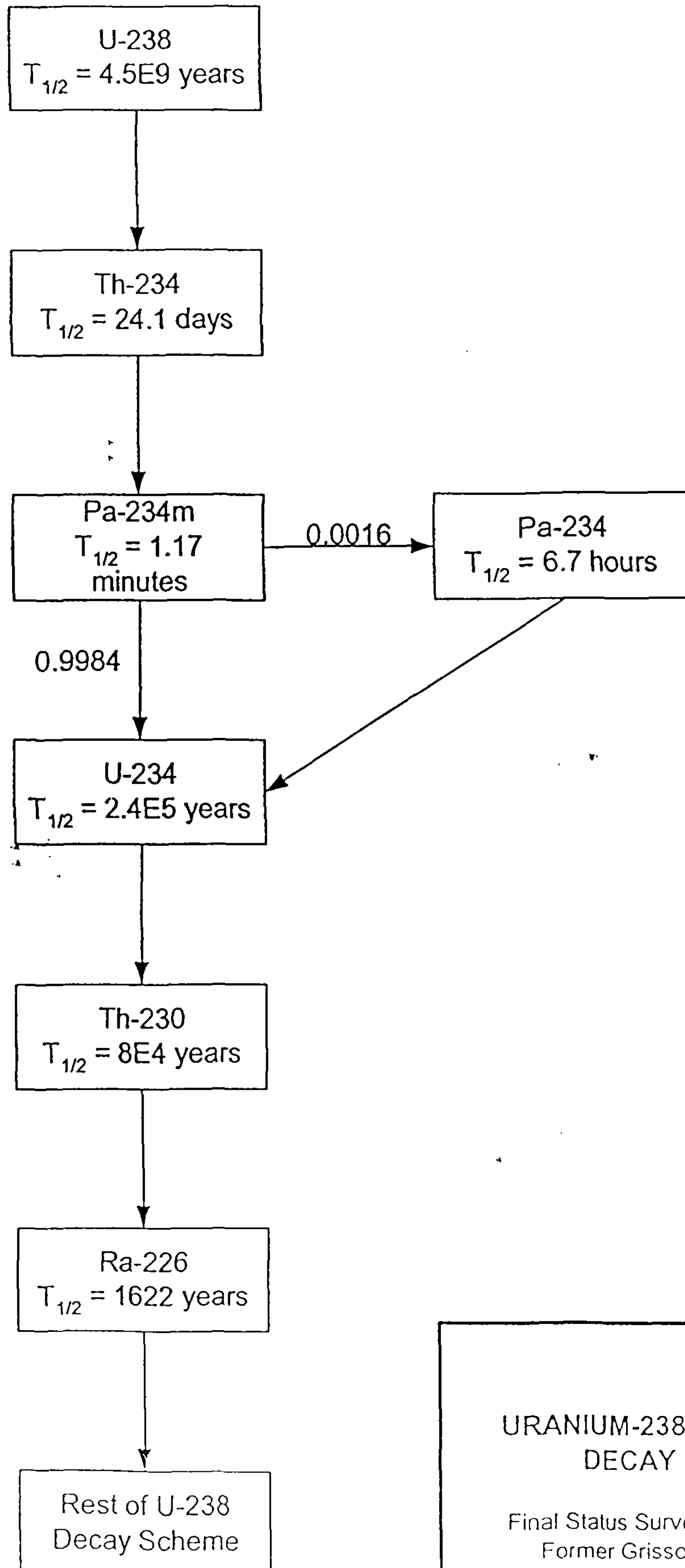
Background: 6194 +/- 790 cpm

SCANNING SURVEY RESULTS AND SAMPLING LOCATIONS BACKFILL SOIL PILE 2, LIFT 2

Final Status Survey, B-58 Burial Site
Former Grissom AFB, Indiana

PARSONS

Uranium-238 Radioactive Decay Scheme



URANIUM-238 RADIOACTIVE DECAY SCHEME

Final Status Survey, B-58 Burial Site
Former Grissom AFB, Indiana

PARSONS

Figure 18

Sewer Flow Volume Comparison

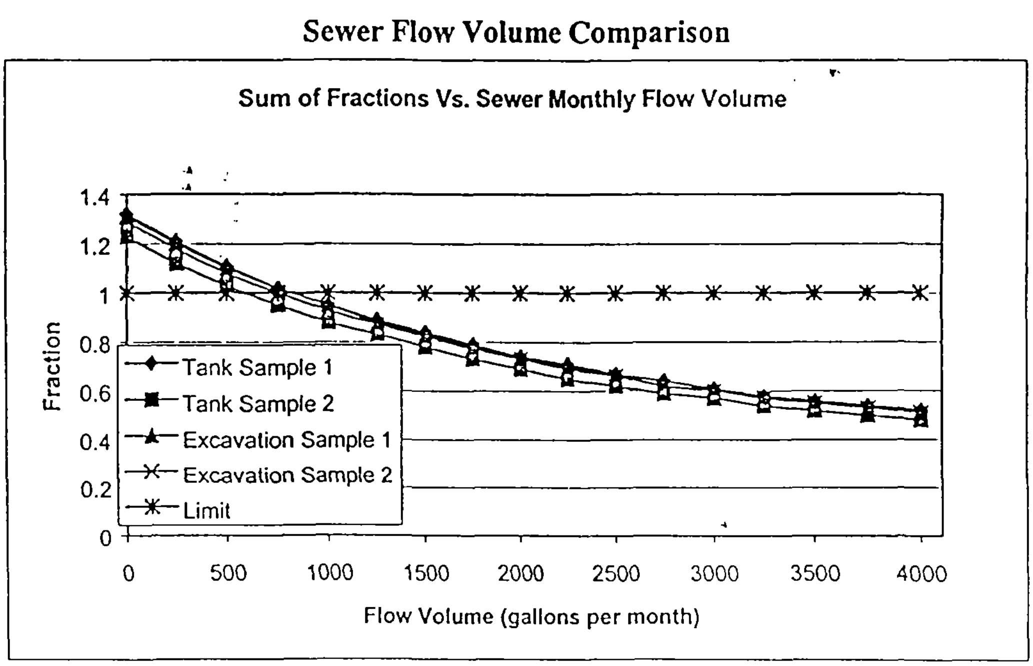


Figure 19

RESRAD Dose Calculation, based on Backfill Soil Alpha Spectroscopy Results

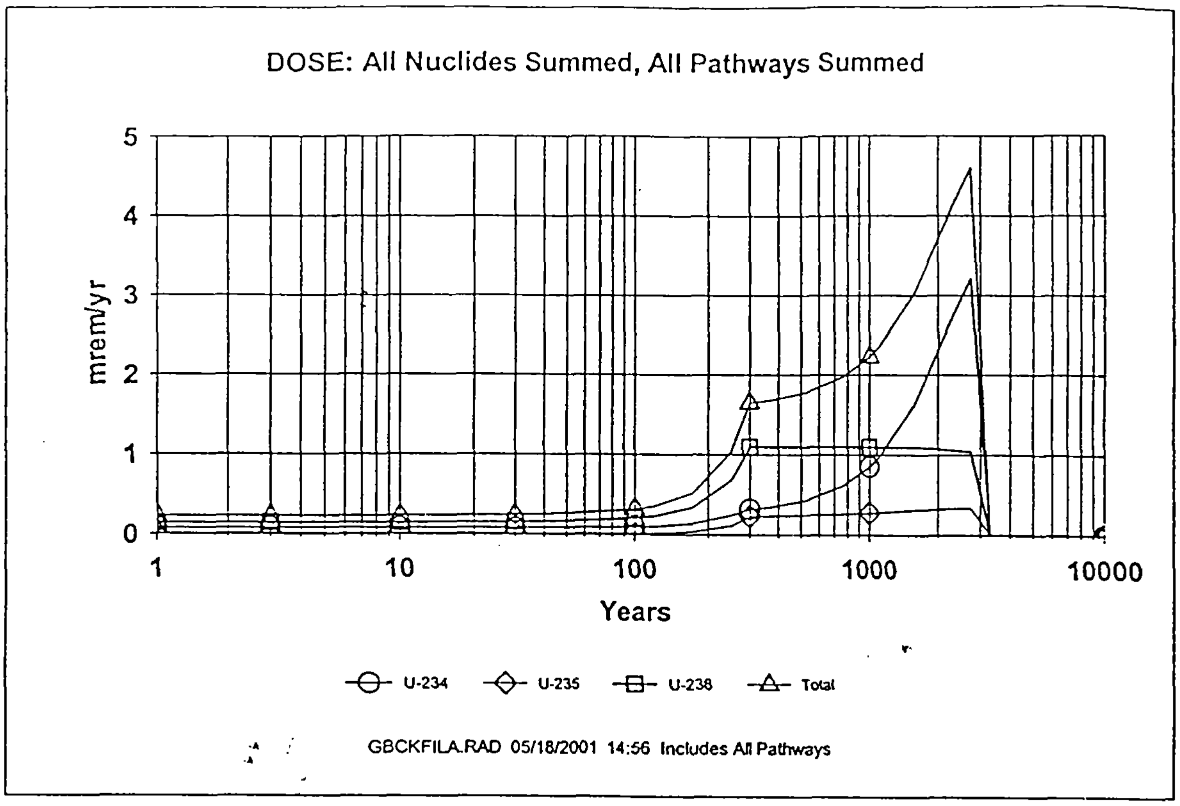
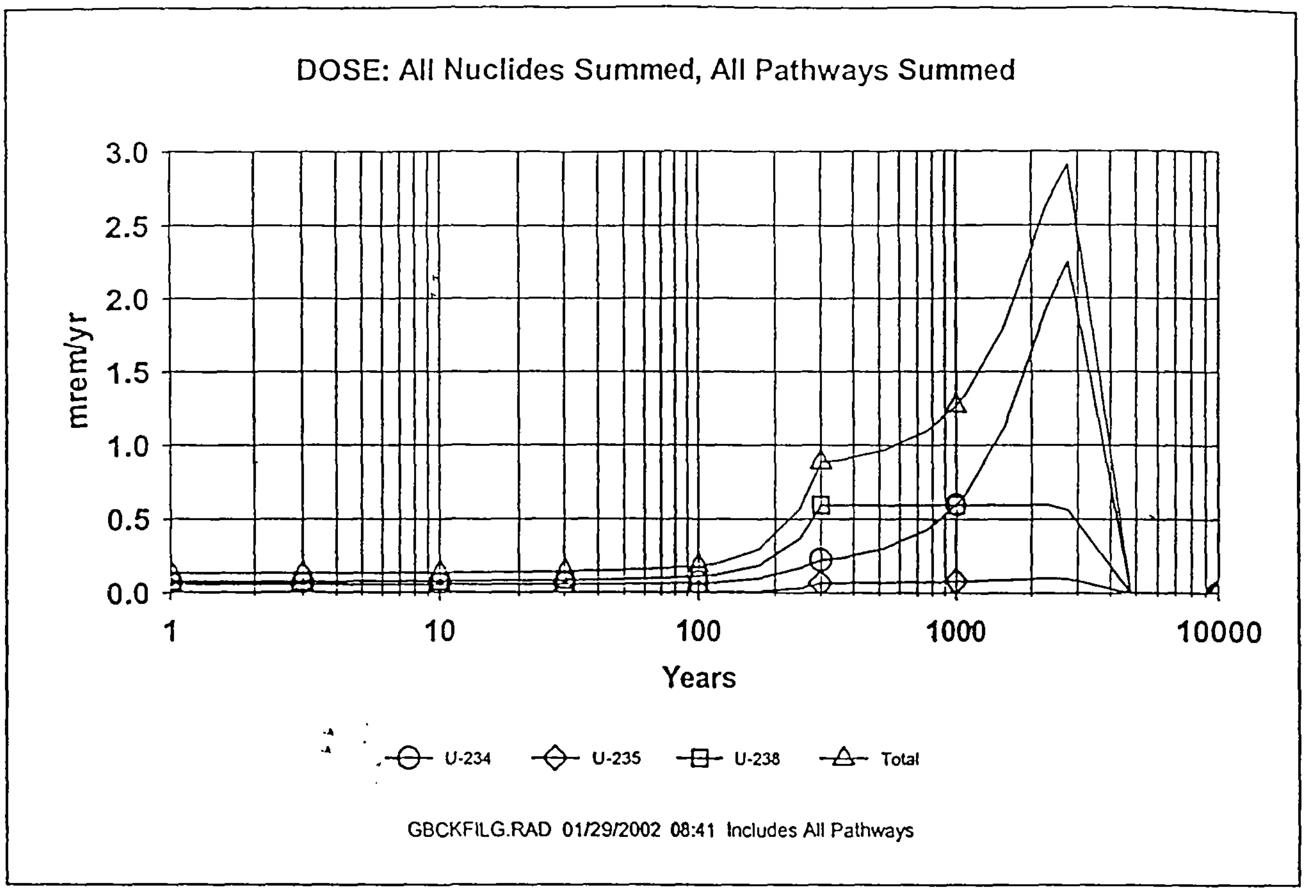


Figure 20

RESRAD Dose Calculation, based on Backfill
Soil Alpha Spectroscopy Results



Appendix-B, Tables

Table 1

Drinking Water Well Information

Table 1A Primary Drinking Water Wells

Well # and Location	Diameter (Inches)	Depth (Feet)	Screen Depth (Feet)	Drawdown (Feet)	Static Water Level (Feet)	Year Drilled
6, Bldg. 713	12	180	85	64	36	1959
7, Bldg.796	12	175	84	30	28	1967

Table 1B Supplemental drinking water sources when extra capacity is required.

Well # and Location	Diameter (Inches)	Depth (Feet)	Screen Depth (Feet)	Drawdown (Feet)	Static Water Level (Feet)	Year Drilled
1, Bldg.218	12	156	96	45	24	1942
2, Bldg 408	12	150	100	37	25	1942

Table 1C Drinking water source for remote sites (chlorinators present on site).

Well # and Location	Diameter (Inches)	Depth (Feet)	Screen Depth (Feet)	Drawdown (Feet)	Static Water Level (Feet)	Year Drilled
5, Bldg. 196*	10	165	Unknown	Unknown	34	1951
8, Bldg. 727	4	125	Unknown	Unknown	Unknown	Unknown
9, Bldg 741	4	150	Unknown	Unknown	Unknown	Unknown
10, Bldg. 715	4	150	Unknown	Unknown	26	1986

* Well 5 is not used for human consumption. It is only used for irrigating golf course greens.

Table 2

Walk-Over Survey Results

Location/ Measurement Type	2" x 2" NaI Detector (cpm) [1]	FIDLER (cpm)
Background Area/ Scanning (range, minimum to maximum)	6,500 to 9,000	6,000 to 10,000
Burial Site/ Scanning (range, minimum to maximum)	5,400 to 7,900	5,000 to 10,000
Background 1/Direct	6,944	7,317
Background 2/Direct	7,488	7,895
Background 3/Direct	9,722	9,858
Burial Site 1/Direct	7,635	8,554
Burial Site 2/Direct	7,700	8,788
Burial Site 3/Direct	7,600	9,356

[1] cpm = counts per minute.

Table 3

Scoping Survey Grid Location Sampling Log

Location	Measurement	43-1 Alpha, Scaler Mode (cpm) [1]	GM Rate Meter (cpm)	Model 19 Rate Meter (μR/hr) [2]	Sample Interval and Description
B-1	1	0	<100	5	Sample 5'-6'. Clay, brown to grey, soft.
	2	2			
	3	1			
B-2	1	5	<100	7	Sample 2.5'-3'. Clay
	2	5			
	3	3			
B-3	1	1	<100	7	
	2	5			
	3	5			
S-0	1	5			3'-3.5' - soil looks burnt/ashy/black/gravelly, not clayey. Pushed to 4.5', encountered variable resistance. No sample recovered. Groundwater encountered at 4'
	2	3			
	3	5			
S-1	1	8			Clayey, natural soil at 3'-3.5'. 43-1 readings appear high. Performed source check (92) and recounted sample. Instrument check was OK: readings were 4,3,and 1.
	2	7			
	3	9			
S-2	1	2	<100	<10	Sample 4.5-5'. Clayey, encountered water at about 5'-5.5'. Soil appeared native.
	2	6			
	3	3			
S-3	1	6	<100	<10	Sample at 3'-3.5', soil appeared native.
	2	4			
	3	5			
S-4	1	3			Clayey sample taken at 3'-3.5', similar to background.
	2	2			
	3	1			
S-5	1	3	<100	<10	4.5'-5' sample collected. Native clay throughout.
	2	8			
	3	3			
S-6	1	3	<100	<10	Drilled to 7.5', damage to barrel noted- probe looked scarred from rubbing against metal (fuselage). Sample taken at 3-3.5': black, ashy (same description as at center). When filling hole with bentonite, the hole took bentonite indefinitely. This confirmed that a cavity was hit.
	2	3			
	3	5			
S-6 Debris	Not Measured		<100	<10	Debris at 6.5'-7.5'.
S-7a	1	4			Sample 3'-3.5', black/burnt, resistance at 4.5'
	2	3			
	3	2			
S-7b	Not Measured		<100	7	Sample at 4' to 4.5'
S-8	1	3			Clayey sample taken at 3'-3.5'
	2	5	<100	<10	
	3	2			
S-9	1	6	<100	7	Sample 1.5'-2', much resistance at 2'. Pushed to 4'; similar material: burnt black with some clay mixed in.
	2	2			
	3	4			
S-10	1	6	<100	10	4.5'-5' - Clay, moist.
	2	4			
	3	2			
S-11A	1	2	<100	<10	Native clay
	2	5			
	3	3			
S-11B	Not Measured				Sample 0.5'-1'; ashy, black, grey, silty appearance
S-12	Not Measured				Hit asphalt at 0'-0.5'. Not enough sample to send to lab. Visual verification.
S-13	1	1	<100	7	Sample located 45° SW of S-9 by 15'. Pushed to 4', sampled 2.5'-3'. Burnt ashy soil, black with metal. Native clay above and below.
	2	5			
	3	5			
S-14	Not Measured				Resistance at 1'; auger refusal. Sampled 0.5 - 1', dark soil, appeared more like material surrounding airplane (fill/ash?) than native
S-15	Not Measured				Same as S14. Used trowel to dig to 1' and verify that resistance was natural material. No debris was visible. Looked like asphalt at 1'.

[1] cpm = counts per minute.
[2] μR/hr = microRoentgen per hour.

Table 4

Analytical Results from Intrusive Characterization Survey (Parsons, 2000)

	Analyte							
	Am-241		Th-232		Th-234		U-235	
Sample Location	Conc. (pCi/g) [1]	95% Uncertainty	Conc. (pCi/g)	95% Uncertainty	Conc. (pCi/g)	95% Uncertainty	Conc. (pCi/g)	95% Uncertainty
Background								
B1	<0.1 [2]		0.5	+/-0.3 [3]	<1		<0.1	
B2	<0.2		1	+/-0.4	<2		<0.2	
B3	<0.1		0.6	+/-0.3	<1.3		<0.1	
Site								
S0	<0.1		<0.4		2.7	+/-1.2	<0.1	
S1	<0.1		0.7	+/-0.3	<1.3		<0.1	
S2	<0.2		1.3	+/-0.4	<2.1		<0.2	
S3	<0.1		0.5	+/-0.3	<1.4		0.2	+/-0.1
S4	<0.2		<0.7		<2.1		<0.2	
S5	<0.2		0.6	+/-0.5	<2		<0.1	
S6	<0.2		0.9	+/-0.5	<2		<0.2	
S6 Debris	<0.2		0.4	+/-0.3	<2.5		<0.2	
S7A	<0.2		<0.6		14	+/-2.5	<0.2	
S7B	<0.1		0.4	+/-0.2	12	+/-1.7	0.2	+/-0.09
S8	<0.2		0.8	+/-0.5	<2		<0.2	
S9	<0.1		0.8	+/-0.3	<1.3		<0.1	
S10	<0.1		0.7	+/-0.4	1.8	+/-1.4	<0.1	
S11A	<0.2		0.7	+/-0.6	<2		<0.2	
S11B	<0.1		0.5	+/-0.3	<1.3		<0.1	
S12	<0.2		<0.6		<2		<0.2	
S13	<0.1		<0.4		<1.3		<0.1	
S14	<0.1		<0.3		<1.2		<0.1	

[1] pCi/g = picocuries per gram.

[2] < = Sample quantity was less than the minimum detectable concentration.

[3] +/- = For detected sample, the 95% uncertainty is reported.

Table 5

Beryllium Analytical Results

Sample Location	Beryllium Concentration (μg/g)[1/]
B-1	0.670
B-3	0.570
B-2	0.550
S6 Debris	<0.50
S7-A	<0.50
S6	<0.50
S7-B	2.14

[1/] μg/g = microgram per gram of soil.

Table 6

RESRAD Input Parameters for $DCGL_W$ Calculations

INPUT PARAMETER	DEFAULT VALUE		USER INPUT			
			Residential Scenario from Work Plan		FSS RESRAD Updates	
	Value	Units	Value	Basis	Value	Basis
PATHWAY						
External gamma	--	--	Active	--	Active	--
Inhalation (except radon)	--	--	Active	--	Active	--
Plant ingestion	--	--	Active	--	Active	--
Meat ingestion	--	--	Active	--	Active	--
Milk ingestion	--	--	Active	--	Active	--
Aquatic foods	--	--	Suppressed	Site location	Suppressed	Site location
Drinking water	--	--	Active	--	Active	--
Soil ingestion	--	--	Active	--	Active	--
Radon	--	--	Active	--	Active	--
SOIL CONCENTRATIONS						
Initial Concentration (pCi/g)						
Uranium-234	--	--	100	see Section 6.1.1	100	see Section 6.1.1
Uranium-235	--	--	100		100	
Uranium-238	--	--	100		100	
Americium-241	--	--	--	--	100	
Thorium-232	--	--	--	--	100	
Transport Factors						
Distribution coefficient						
Saturated Zone						
Uranium-234	50	cm^3/g	81.5 to 1,600	USDOE, 1993	1600	USDOE, 1993 and Parsons, 2000
Uranium-235	50	cm^3/g	81.5 to 1,600		1600	
Uranium-238	50	cm^3/g	81.5 to 1,600		1600	
Contaminated and Unsaturated Zones						
Uranium-234	50	cm^3/g	81.5 to 1,600	USDOE, 1993	1600	USDOE, 1993 and Parsons, 2000
Uranium-235	50	cm^3/g	81.5 to 1,600		1600	
Uranium-238	50	cm^3/g	81.5 to 1,600		1600	
Number of Unsaturated Zones	1	--	1	--	1	--

Table 6 (Cont.)

RESRAD Input Parameters for DCGLw Calculations

INPUT PARAMETER	DEFAULT VALUE		USER INPUT			
			Residential Scenario from Work Plan		FSS RESRAD Updates	
	Value	Units	Value	Basis	Value	Basis
Water Concentration						
Time since material placement	0	years	--	--	0	Based on Guidance in USDOE, 1993
Groundwater Concentration	0	pCi/L	--	No sources identified except those within natural background	0	No sources identified except those within natural background
Solubility Limit	0	mol/L	--		0	
Leach Rate	0	$year^{-1}$	--		0	
Use Plant Soil ratio	No	--	--		No	
CALCULATION TIMES						
Basic Radiation Dose Limit	30	mrem/yr	15	USEPA, 1997b	15	USEPA, 1997b
Calculation Times	1, 3, 10, 30, 100, 300, 1000	years	--	--	1, 3, 10, 30, 100, 300, 1000, 10000	--
CONTAMINATED ZONE						
Thickness of contaminated zone	2	m	0.3, 0.6, 1.2, 1.8	Varies with run	3	Table 3.6 of Parsons, 2000
For DCGLw						
Area of contaminated zone	10000	m^2	232	2,500 sq. feet area	232	2,500 sq. feet area
Length parallel to aquifer flow	100	m^2	15	One side of sq. area	15	One side of sq. area
For DCGLEMC						
Area of contaminated zone	--	--	6.3	2.5x2.5m sq. area (grid size)	6.3	2.5x2.5m sq. area (grid size)
Length parallel to aquifer flow	--	--	2.5	One side of sq. area	2.5	One side of sq. area
COVER AND CONTAMINATED ZONE HYDROLOGICAL DATA						
Cover depth	0	m	0.0, 0.3	Varies with run	0.3	Parsons, 2000
Density of cover material	1.5	g/cm^3	1.2	USDOE, 1993; Table 2.1	1.2	USDOE, 1993; Table 2.1
Cover erosion rate	0.001	m/yr	--	--	0.001	--
Density of contaminated zone	1.5	g/cm^3	1.2	USDOE, 1993; Table 2.1	1.2	USDOE, 1993; Table 2.1
Contaminated zone erosion rate	0.001	m/yr	--	--	0.001	--
Contaminated zone total porosity	0.4	--	0.42	USDOE, 1993; Table 3.2	0.42	USDOE, 1993; Table 3.2
Contaminated zone effective porosity	0.2	--	0.06	--	0.06	--
Contaminated zone hydraulic conductivity	10	m/yr	32.1	USDOE, 1993; Table 5.2	32.1	USDOE, 1993; Table 5.2
Contaminated zone b parameter	5.3	--	10.4	USDOE, 1993; Table 13.1	10.4	USDOE, 1993; Table 13.1
Humidity in air	8	g/m^3	NA	--	NA [1/]	--
Evapotranspiration coefficient	0.5	--	0.999	USDOE, 1993; Section 12	0.999	USDOE, 1993; Section 12
Wind speed	2	m/s	--	--	2	--
Precipitation	1	m/yr	1	40 inches/year	1	40 inches/year
Irrigation	0.2	m/yr	0	No irrigation on site	0	No irrigation on site

Table 6 (Cont.)

RESRAD Input Parameters for DCGLw Calculations

INPUT PARAMETER	DEFAULT VALUE		USER INPUT			
			Residential Scenario from Work Plan		FSS RESRAD Updates	
	Value	Units	Value	Basis	Value	Basis
Irrigation mode	Overhead		NA	For overhead	NA	For overhead
Runoff Coefficient	0.2	-	0.3	USDOE, 1993; Table 10.1	0.3	USDOE, 1993; Table 10.1
Watershed area for nearby stream or pond	1.00E+06	m^2	--	--	1.00E+06	--
Accuracy for water/soil computation	0.001		--	--	0.001	--
SATURATED ZONE HYDROLOGICAL DATA						
Density of saturated zone	1.5	g/cm^3	1.2	USDOE, 1993; Table 2.1	1.2	USDOE, 1993; Table 2.1
Saturated zone total porosity	0.4	-	0.42	USDOE, 1993; Table 3.2	0.42	USDOE, 1993; Table 3.2
Saturated zone effective porosity	0.2	--	0.06		0.06	
Saturated zone hydraulic conductivity	100	m/yr	32.1	USDOE, 1993; Table 5.2	32.1	USDOE, 1993; Table 5.2
Saturated zone hydraulic gradient	0.02	--	0.007	USDOE, 1993; Section 15	0.007	USDOE, 1993; Section 15
Saturated zone b parameter.	5.3	--	10.4	USDOE, 1993; Table 13.1	10.4	USDOE, 1993; Table 13.1
Water table drop rate	0.001	m/yr	--	--	0.001	--
Well pump intake depth (below water table)	10	m	4.4	Well logs	4.4	Well logs
Model: nondispersion (ND) or mass balance (MB)	ND		--	--	--	--
Well pumping rate	250	m^3/yr	--	Default, as no active wells in the area	250	Default, as no active wells in the area
UNCONTAMINATED UNSATURATED ZONE PARAMETERS						
Number of unsaturated zones	1	--	1	--	1	--
Unsaturated zone 1						
Thickness	4	m	varies with run	Varies with run; =Depth to GW (5 to 10 ft) - Thickness of Contaminated Zone	0	Conservative value based on analysis in Parsons, 2000
Soil density	1.5	g/cm^3	1.2	USDOE, 1993; Table 2.1	1.2	USDOE, 1993; Table 2.1
Total porosity	0.4	--	0.42	USDOE, 1993; Table 3.2	0.42	USDOE, 1993; Table 3.2
Effective porosity	0.2	--	0.06		0.06	
Hydraulic conductivity	10	m/yr	32.1	USDOE, 1993; Table 5.2	32.1	USDOE, 1993; Table 5.2
Soil-specific b parameter	5.3	--	10.4	USDOE, 1993; Table 13.1	10.4	USDOE, 1993; Table 13.1
OCCUPANCY						
Inhalation rate	8400	m^3/yr	11,000	USEPA, 1997a		
Mass loading for inhalation	0.0001	g/m^3	0.001	USDOE, 1993; Section 35		
Exposure duration	30	yr	30	USEPA, 1990		
Indoor dust filtration factor	0.4	--	--	--	--	--
External gamma shielding factor	0.7	--	--	--	--	--

Table 6 (Cont.)

RESRAD Input Parameters for DCGLw Calculations

INPUT PARAMETER	DEFAULT VALUE		USER INPUT			
			Residential Scenario from Work Plan		FSS RESRAD Updates	
	Value	Units	Value	Basis	Value	Basis
Indoor time fraction	0.5	--	0.65	USEPA, 1997a		
Outdoor time fraction	0.25	--	0.08	USEPA, 1997a		
Shape of the contaminated zone	Circular		Square	Site conditions	Square	Site conditions
INGESTION PATHWAY, DIETARY DATA						
Fruit, vegetable. and grain consumption	160	kg/yr	301	USEPA, 1997a	301	USEPA, 1999 Tables 9-29 & 12-23
Leafy vegetable consumption	14	kg/yr	--	USDOE, 1993	--	USDOE, 1993
Milk consumption	92	L/yr	82	USEPA, 1997a	82	USEPA, 1999
Meat and poultry consumption	63	kg/yr	45	USEPA, 1997a	45	USEPA, 1999
Soil ingestion	36.5	g/yr	73	USDOE, 1993	43.8	USDOE, 1993
Groundwater ingestion	510	L/yr	--	USDOE, 1993	--	USDOE, 1993
Contaminated fractions						
Livestock water	1	m/yr	1	Assumed all water from onsite	1	Assumed all water from onsite
Irrigation water	1	m/yr	1	USDOE, 1993	1	USDOE, 1993
Plant food	-1		0.5	Assumed half of plant food is from offsite	-1	RESRAD to calculate
Meat	-1		0.5	Assumed half of meat is from offsite	-1	
Milk	-1		0.5	Assumed half of milk is from offsite	-1	
INGESTION PATHWAY, NONDIETARY DATA						
Livestock fodder intake for meat	68	kg/d	11.8	USEPA, 1998 Table B-3-10	11.8	USEPA, 1998 Table B-3-10
Livestock fodder intake for milk	55	kg/d	20.3	USEPA, 1998 Table B-3-11	20.3	USEPA, 1998 Table B-3-11
Livestock water intake for meat	50	L/d	--	USDOE, 1993	--	USDOE, 1993
Livestock water intake for milk	160	L/d	--	USDOE, 1993	--	USDOE, 1993
Livestock soil intake	0.5	kg/d	0.5	USEPA, 1998 Table B-3-10	0.5	USEPA, 1998 Table B-3-10
Mass loading for foliar deposition	0.0001	g/m^3	--	USDOE, 1993	0.0001	USDOE, 1993
Depth of soil mixing layer	0.15	m	--		0.15	
Depth of roots	0.9	m	--		0.9	
Groundwater fractional usage						
Drinking water	1	--	--	Limiting case assumption	--	Limiting case assumption
Household water.	1	--	--		--	
Livestock water	1	--	--		--	
Irrigation water	1	--	--		--	
RADON DATA						
Cover total porosity	0.4	--	Default	Default parameters used in conjunction with site parameters and guidance of USDOE, 1993	Default	Default parameters used in conjunction with site parameters and guidance of USDOE, 1993
Cover volumetric water content	0.05	--	Default		Default	
Cover radon diffusion coefficient	2.00E-06	m^2/s	Default		Default	
Building foundation thickness	0.15	m	Default		Default	
Building foundation density	2.4	g/cm^3	Default		Default	

Table 6 (Cont.)

RESRAD Input Parameters for DCGLw Calculations

INPUT PARAMETER	DEFAULT VALUE		USER INPUT			
			Residential Scenario from Work Plan		FSS RESRAD Updates	
	Value	Units	Value	Basis	Value	Basis
Building foundation total porosity	0.1		Default		Default	Only exception is the excavation worker scenario, which sets the building foundation thickness parameter to zero.
Building foundation volumetric water content	0.03		Default		Default	
Building foundation radon diffusion coefficient	3.00E-07	m^2/s	Default		Default	
Contaminated radon diffusion coefficient	2.00E-06	m^2/s	Default		Default	
Radon vertical dimension of mixing	2	m	Default		Default	
Building air exchange rate	0.5	$hour^{-1}$	Default		Default	
Building room height	2.5	m	Default		Default	
Building indoor area factor	0		Default		Default	
Foundation depth below ground surface	-1	m	Default		Default	
Radon 222 emanation coefficient	0.25		Default		Default	
Radon 220 emanation coefficient	0.15		Default		Default	
STORAGE TIME BEFORE USE DATA						
Fruits, nonleafy vegetables, and grain	14	days	–	USDOE, 1993	–	USDOE, 1993
Leafy vegetables	1	days	–		–	
Milk	1	days	–		–	
Meat	20	days	–		–	
Fish	7	days	NA		NA	
Crustacea and mollusks	7	days	NA		NA	
Well water	1	days	–		–	
Surface Water	1	days	–		–	
Livestock fodder	45	days	–		–	

1/ NA - Not Applicable.

Table 7

Gross DCGL Equation

$$\text{Gross DCGL} = \frac{1}{\dfrac{f_{U\text{-}234}}{DCGL_{U\text{-}234}} + \dfrac{f_{U\text{-}235}}{DCGL_{U\text{-}235}} + \dfrac{f_{U\text{-}238}}{DCGL_{U\text{-}238}}}$$

Where:

f = expected activity fraction of isotope

Table 8

Uranium Isotope Activity Fractions

Uranium Isotope Activity Fractions

Radionuclide	Depleted Activity Fraction [1]	Enriched Activity Fraction [2]
U-234	0.13	0.97
U-235	0.01	0.03
U-238	0.86	3E-4

[1] The depleted activity fractions are based on the weight fractions of uranium depleted to 99.8 weight percent U-238 and 0.2 weight percent U-235 (AFIERA, 2000).

[2] The enriched uranium activity fractions are based on the generic fractions for uranium enriched to 93.5 weight percent U-235 (Derived from AFIERA).

Table 9

Gross DCGL Comparison

		Excavation Worker (15 mrem/yr)	Prison Resident (15 mrem/yr)	Prison Residential Farmer (15 mrem/yr)	Residential Farmer (15 mrem/yr)	Resident (15 mrem/yr)[2/]
$DCGL_W$ (pCi/g)[3/]	Depleted U	506.0	122.1	101.8	111.0	133.4
	Enriched U (93.5 wt %)[4/]	508.1	234.5	171.3	184.4	95.1
$DCGL_{EMC}$ (pCi/g)	Depleted U	3593.8	161.4	135.7	150.2	199.4
	Enriched U (93.5 wt %)	5648.0	677.0	384.6	422.3	289.5

[1/] mrem/yr = millirem per year.
[2/] Resident scenario results from Grissom FSS Work Plan (Parsons, 2000).
[3/] pCi/g = picocuries per gram.
[4/] 93.5 wt % = Uranium that has been enriched to a 93.5 weight percentage of uranium-235.

Table 10

Derived Concentration Guideline Limits

Radionuclide	$DCGL_W$ (pCi/g)[1/]				
	Resident (15 mrem/yr)[2/]	Residential Farmer (15 mrem/yr)	Excavation Worker (15 mrem/yr)	Prison Residential Farmer (15 mrem/yr)	Prison Resident (15 mrem/yr)
Am-241	ND[3/]	86.9	122.4	82.2	113.3
Th-232	ND	1.1	5.9	1.0	1.1
U-234	103.1	228.9	520.6	214.2	318.0
U-235	26.8	25.1	824.3	22.7	24.5
U-238	147.4	107.5	509.0	98.6	117.4
	$DCGL_{EMC}$ (pCi/g)				
Am-241	ND	266.7	2584.0	244.3	548.6
Th-232	ND	1.4	41.8	1.2	1.3
U-234	734.1	738.0	6726.0	677.7	2524.0
U-235	35.9	28.3	906.8	25.5	27.2
U-238	206.1	141.4	3486.0	127.7	150.1

[1/] pCi/g = picocuries per gram.
[2/] mrem/yr = millirem per year; Resident scenario results from Grissom FSS Work Plan (Parsons, 2000)
[3/] ND = Not determined.

Table 11

Length of Square Grid Equation

$$L = \sqrt{\frac{A}{n}}$$

where:

L = length of side,

A = area of excavation,

n = number of samples

Table 12

Final Status Survey
Grid Size Information

Area Name	Dimensions	Area (ft^2)	Req'd Number of Samples	Length of Side (ft)
Bottom Area 1	53 ft x 25 ft	1325	18	8
Bottom Area 2	57 ft x 27 ft	1539	21	8
Pile 1, Lift 1	75 ft x 45 ft	3375	24 [1/]	11
Pile 1, Lift 2	100 ft x 50 ft	5000	24 [1/]	14
Pile 2, Lift 1	80 ft x 65 ft	5200	24 [1/]	14
Pile 2, Lift 2	90 ft x 70 ft	6300	24 [1/]	16

[1/] Used in grid size calculation only.

Table 13

Background Radiation Levels

Analytical Background [1/]		
	Average Concentration	Standard Deviation
	(pCi/g)	(pCi/g)
Americium-241	0	0
Thorium-232	0.66	0.21
Uranium-234	0.82	0.48
Uranium-235	0.67	0.3
Uranium-238	0.77	0.48

[1/] Compiled from Scoping Survey (Parsons, 2000) and AFIERA Characterization Report (AFIERA, 2000).

Gamma Scanning Background		
Meter 102 (FIDLER)		
Measurement	Scaler (cpm)	Meter (cpm)
1	6799	7000
2	7089	7000
3	7222	7000
4	6990	7000
5	6797	7000
6	5067	5000
7	4972	5000
8	4900	5000
9	6591	6500
10	5492	5500
11	6233	6500
12	6501	7000
13	6331	6500
14	6278	6500
15	5641	6000
Average	6194	6300
Standard Deviation	790	897

Table 14

Gamma Spectroscopy Results Reported on March 22, 2001
AFBCA Grissom Air Reserve Base, Bunker Hill, Indiana

Sampling Identification Number			Activity Concentration (pCi/g) [1/]			
Parsons ID [2/]	Base Sample Number	AFIERA/SDRH ID	^{235}Uranium	^{238}Uranium	^{232}Thorium	^{241}Americium
BF 1-04	GS0100042	10001169	< 0.04	6.1 +/- 0.78	0.90 +/- 0.11	< 0.05
BF 1-13	GS0100043	10001170	< 0.04	5.9 +/- 0.73	0.93 +/- 0.12	< 0.05
BF 1-14	GS0100044	10001171	< 0.04	6.9 +/- 0.85	0.98 +/- 0.12	< 0.05
BF 1-18	GS0100045	10001172	< 0.04	3.4 +/- 0.54	0.92 +/- 0.12	< 0.04
BF 1-20	GS0100046	10001173	0.44 +/- 0.05	4.1 +/- 0.55	0.93 +/- 0.11	< 0.04
BF 2-04	GS0100027	10001154	< 0.03	0.89 +/- 0.38	0.64 +/- 0.10	< 0.04
BF 2-07	GS0100028	10001155	< 0.03	0.56 +/- 0.32	0.51 +/- 0.12	< 0.03
BF 2-10	GS0100029	10001156	< 0.03	0.91 +/- 0.35	0.61 +/- 0.09	< 0.05
BF 2-14	GS0100030	10001157	< 0.08	0.71 +/- 0.55	0.46 +/- 0.19	< 0.09
BF 2-23	GS0100031	10001158	< 0.03	0.79 +/- 0.36	0.55 +/- 0.09	< 0.06
BF 3-04	GS0100037	10001164	< 0.04	10.0 +/- 1.2	0.92 +/- 0.13	< 0.09
BF 3-10	GS0100038	10001165	0.58 +/- 0.07	11.0 +/- 1.2	0.84 +/- 0.12	< 0.09
BF 3-19	GS0100039	10001166	< 0.13	7.7 +/- 1.5	0.89 +/- 0.26	< 0.12
BF 3-21	GS0100040	10001167	< 0.15	9.9 +/- 1.9	0.79 +/- 0.39	< 0.13
BF 3-31	GS0100041	10001168	< 0.04	5.9 +/- 0.74	0.74 +/- 0.11	< 0.05
BF 4-01	GS0100032	10001159	< 0.02	0.58 +/- 0.34	0.45 +/- 0.07	< 0.05
BF 4-06	GS0100033	10001160	< 0.03	0.57 +/- 0.36	0.58 +/- 0.10	< 0.06
BF 4-08	GS0100034	10001161	< 0.02	0.72 +/- 0.36	0.52 +/- 0.08	< 0.05
BF 4-13	GS0100035	10001162	< 0.03	0.76 +/- 0.34	0.50 +/- 0.08	< 0.05
BF 4-19	GS0100036	10001163	0.10 +/- 0.02	0.92 +/- 0.40	0.51 +/- 0.09	< 0.06
BOT 01	GS0100015	10001142	< 0.11	1.1 +/- 0.92	0.46 +/- 0.23	< 0.10
BOT 02	GS0100012	10001139	< 0.03	0.50 +/- 0.27	0.60 +/- 0.09	< 0.03
BOT 03	GS0100024	10001151	0.19 +/- 0.13	1.8 +/- 1.5	1.1 +/- 0.62	< 0.16
BOT 04	GS0100018	10001145	< 0.03	0.69 +/- 0.36	0.89 +/- 0.12	< 0.04
BOT 05	GS0100017	10001144	< 0.02	0.41 +/- 0.24	0.50 +/- 0.08	< 0.03
BOT 06	GS0100013	10001140	0.11 +/- 0.02	0.45 +/- 0.26	0.63 +/- 0.09	< 0.03
BOT 07	GS0100023	10001150	< 0.04	0.75 +/- 0.41	0.95 +/- 0.15	< 0.04
BOT 08	GS0100016	10001143	< 0.03	0.74 +/- 0.30	0.54 +/- 0.09	< 0.03
BOT 09	GS0100014	10001141	< 0.03	0.65 +/- 0.32	0.68 +/- 0.09	< 0.04
BOT 10	GS0100009	10001136	< 0.03	0.69 +/- 0.32	0.67 +/- 0.10	< 0.04
BOT 11	GS0100022	10001149	< 0.03	0.66 +/- 0.34	0.63 +/- 0.10	< 0.04
BOT 12	GS0100021	10001148	< 0.04	0.66 +/- 0.39	0.87 +/- 0.13	< 0.04
BOT 13	GS0100020	10001147	< 0.03	0.74 +/- 0.33	0.63 +/- 0.10	< 0.04
BOT 14	GS0100019	10001146	< 0.03	0.78 +/- 0.29	0.42 +/- 0.10	< 0.03
BOT 15	GS0100025	10001152	< 0.04	1.1 +/- 0.44	0.89 +/- 0.14	< 0.04
BOT 16	GS0100011	10001138	< 0.03	0.65 +/- 0.30	0.78 +/- 0.10	< 0.04
BOT 17	GS0100026	10001153	< 0.03	0.79 +/- 0.32	0.59 +/- 0.10	< 0.03
BOT 18	GS0100010	10001137	< 0.03	0.72 +/- 0.32	0.68 +/- 0.09	< 0.03
BOT 20	GS0100065	10001192	< 0.04	1.9 +/- 0.51	0.89 +/- 0.13	< 0.07
BOT 21	GS0100058	10001185	< 0.04	1.5 +/- 0.45	0.74 +/- 0.13	< 0.04
BOT 22	GS0100051	10001178	< 0.18	4.0 +/- 1.7	0.66 +/- 0.53	< 0.15
BOT 23	GS0100063	10001190	< 0.10	1.3 +/- 0.71	0.64 +/- 0.22	< 0.10

Table 14 (Cont.)

Gamma Spectroscopy Results Reported on March 22, 2001
AFBCA, Grissom Air Reserve Base, Bunker Hill, Indiana

Sampling Identification Number			Activity Concentration in pCi/g [1]			
Parsons ID [2]	Base Sample Number	AFIERA/SDRH ID	^{235}Uranium	^{238}Uranium	^{232}Thorium	^{241}Americium
BOT 24	GS0100048	10001175	< 0.03	2.3 +/- 0.49	0.65 +/- 0.09	< 0.04
BOT 25	GS0100050	10001177	< 0.17	< 1.8	< 0.60	< 0.15
BOT 26	GS0100057	10001184	< 0.03	0.94 +/- 0.41	0.79 +/- 0.13	< 0.04
BOT 27	GS0100067	10001194	< 0.09	0.76 +/- 0.54	0.50 +/- 0.18	< 0.09
BOT 28	GS0100056	10001183	< 0.16	< 1.7	0.69 +/- 0.43	< 0.13
BOT 29	GS0100061	10001188	0.17 +/- 0.09	0.84 +/- 0.70	0.66 +/- 0.23	< 0.10
BOT 30	GS0100055	10001182	< 0.18	2.9 +/- 1.7	0.46 +/- 0.40	< 0.15
BOT 31	GS0100052	10001179	< 0.03	0.90 +/- 0.31	0.50 +/- 0.08	< 0.03
BOT 32	GS0100066	10001193	< 0.02	0.59 +/- 0.32	0.48 +/- 0.08	< 0.05
BOT 33	GS0100049	10001176	< 0.03	0.77 +/- 0.31	0.41 +/- 0.09	< 0.03
BOT 34	GS0100047	10001174	< 0.02	1.0 +/- 0.29	0.50 +/- 0.07	< 0.03
BOT 35	GS0100059	10001186	< 0.02	0.48 +/- 0.33	0.50 +/- 0.08	< 0.05
BOT 36	GS0100062	10001189	< 0.03	0.47 +/- 0.32	0.47 +/- 0.08	< 0.05
BOT 37	GS0100064	10001191	< 0.02	0.51 +/- 0.31	0.42 +/- 0.07	< 0.04
BOT 38	GS0100054	10001181	< 0.04	1.6 +/- 0.45	0.77 +/- 0.12	< 0.04
BOT 39	GS0100053	10001180	< 0.03	0.75 +/- 0.34	0.53 +/- 0.12	< 0.04
BOT 40	GS0100060	10001187	< 0.03	1.3 +/- 0.41	0.73 +/- 0.11	< 0.06
TSP 1	GS0100095	10100003	0.28 +/- 0.09	1.3 +/- 0.82	0.45 +/- 0.20	< 0.11
TSP 2	GS0100096	10100004	0.19 +/- 0.09	1.0 +/- 0.63	0.59 +/- 0.21	< 0.10
TSP 3	GS0100097	10100005	< 0.14	1.1 +/- 0.64	0.70 +/- 0.24	< 0.10

[1] pCi/g = picocuries per gram.
[2] The following abbreviations are used in the Parsons ID: BF – Backfill soil pile; BOT – Bottom of excavation; TSP – Potentially TPH-contaiminated soil piles.

Table 15

Alpha Spectroscopy Results Reported on March 8, 2001
AFBCA Grissom Air Reserve Base, Bunker Hill, Indiana

Sampling Identification Number			Activity Concentration in pCi/g [1]		
Parsons ID [2]	Base Sample Number	AFIERA/SDRH ID	^{234}Uranium	^{235}Uranium	^{238}Uranium
B-58 Site	GS0100047	10100060	0.92 +/- 0.16	0.08 +/- 0.05	1.1 +/- 0.19
BF 1-04	GS0100042	10100055	7.1 +/- 0.76	0.40 +/- 0.10	15.0 +/- 1.6
BF 1-13	GS0100043	10100056	8.0 +/- 0.88	0.55 +/- 0.13	13.0 +/- 1.4
BF 1-14	GS0100044	10100057	11.0 +/- 1.0	0.77 +/- 0.14	17.0 +/- 1.6
BF 1-18	GS0100045	10100058	2.8 +/- 0.34	0.33 +/- 0.09	7.1 +/- 0.74
BF 1-20	GS0100046	10100059	8.2 +/- 0.85	0.73 +/- 0.15	13.0 +/- 1.3
BF 2-04	GS0100027	10100040	0.82 +/- 0.14	0.10 +/- 0.05	0.82 +/- 0.14
BF 2-07	GS0100028	10100041	0.59 +/- 0.13	0.08 +/- 0.05	0.61 +/- 0.13
BF 2-10	GS0100029	10100042	0.76 +/- 0.14	0.06 +/- 0.04	0.79 +/- 0.14
BF 2-14	GS0100030	10100043	0.56 +/- 0.11	0.06 +/- 0.04	0.83 +/- 0.15
BF 2-23	GS0100031	10100044	7.5 +/- 0.89	0.52 +/- 0.12	0.96 +/- 0.17
BF 3-04	GS0100037	10100050	4.4 +/- 0.49	0.50 +/- 0.11	18.0 +/- 1.8
BF 3-10	GS0100038	10100051	16.0 +/- 1.8	1.2 +/- 0.22	27.0 +/- 3.0
BF 3-19	GS0100039	10100052	4.6 +/- 0.57	0.33 +/- 0.10	7.8 +/- 0.90
BF 3-21	GS0100040	10100053	7.0 +/- 0.69	0.53 +/- 0.12	11.0 +/- 1.0
BF 3-31	GS0100041	10100054	5.7 +/- 0.72	0.56 +/- 0.13	12.0 +/- 1.4
BF 4-01	GS0100032	10100045	5.0 +/- 0.57	0.29 +/- 0.08	1.2 +/- 0.18
BF 4-06	GS0100033	10100046	0.75 +/- 0.15	0.07 +/- 0.04	0.91 +/- 0.17
BF 4-08	GS0100034	10100047	0.70 +/- 0.14	0.06 +/- 0.04	0.88 +/- 0.16
BF 4-13	GS0100035	10100048	2.2 +/- 0.26	0.11 +/- 0.05	0.91 +/- 0.14
BF 4-19	GS0100036	10100049	0.60 +/- 0.12	0.07 +/- 0.04	0.58 +/- 0.11

[1] pCi/g = picocuries per gram.
[2] The following abbreviations are used in the Parsons ID: BF – Backfill soil pile; BOT – Bottom of excavation; TSP – Potentially TPH-contaiminated soil piles.

Table 16

Comparison Of Gamma Spectroscopy Results From Excavation Bottom With Background And $DCGL_W$s

Soil Concentrations					
Radionuclide	Average Background Concentration (pCi/g) [1]	$DCGL_W$ (pCi/g)	Mean Sample Results (pCi/g)	Comparison to:	
				Average Background	$DCGL_W$
U-234	0.71	214	1.96 [2]	Above	Below
U-235	0.67	222.7	0.06	Below	Below
U-238	0.77	98.6	1.08	Above	Below
Sum for comparison with 30 pCi/g level:			3.1	Less than 30 pCi/g	

[1] pCi/g = picocuries per gram.

[2] The U-234 results are conservatively based on the U-235 analytical results and the activity fractions of uranium enriched to 93.5 weight percent U-235.

Table 17

Results From Sign And WRS Tests, Excavation Bottom Soil Sampling

Radionuclide	Sign Test			WRS Test		
	# Below the $DCGL_W$	% Below	Pass Sign Test?	Sum of Background Ranks	MARSSIM Critical Value	Pass WRS Test?
U-234	39 [1]	100	Yes	1705	1238	Yes
U-235	39	100	Yes	1705	1238	Yes
U-238	39	100	Yes	1705	1240	Yes

[1] Critical value for Sign test is 14.

Table 18

MARSSIM Unity Rule Equation

$$\frac{C_1}{DCGL_{W_1}} + \frac{C_2}{DCGL_{W_2}} + \ldots \frac{C_n}{DCGL_{W_n}} \leq 1$$

Where:

C = concentration, in pCi/g

$DCGL_W$ = guideline value for each individual radionuclide (1,2,..., n), in pCi/g

Table 19

Unity Rule Calculation Results, Excavation Bottom Soil Sampling

Radionuclide	Mean Concentration (pCi/g) [1/]	$DCGL_W$ (pCi/g)	Ratio
U-234	1.96	214	0.0091
U-235	0.06	22.7	0.0026
U-238	1.1	98.7	0.011
		Sum	0.023
		Is Sum of Ratios < 1?	Yes

[1/] pCi/g = picocuries per gram.

Table 20

Results of Excavation Bottom Scanning Survey

Grid Location	Areal Scaler Reading (cpm) [1/]	Point Scaler Reading (cpm)	Remarks
1	6972	6466	Area 1
2	6370	5573	
3	7163	6872	
4	6831	5854	
5	6254	5313	
6	6837	6205	
7	6888	6357	
8	6268	5609	
9	6560	6573	
10	6845	6163	
11	6306	5517	
12	6683	6256	
13	6503	5791	
14	6314	5410	
15	6750	7354	
16	6585	6310	
17	6211	5825	
18	6832	6506	
20	7526	8201	Area 2
21	7372	7280	
22	7319	7326	
23	7468	7906	
24	7022	6391	
25	6979	7267	
26	7274	6986	
27	7047	6634	
28	6581	6872	
29	7116	6846	
30	6622	6428	
31	6218	5871	
32	6636	6227	
33	6244	6113	
34	6172	6018	
35	6694	6190	
36	6165	5800	
37	6409	6486	
38	6981	7365	
39	6732	6372	
40	6954	7291	Background
Average	6736	6457	6194
St. Dev.	385	685	790

[1/] cpm = counts per minute.

Table 21

Comparison of Soil Sampling Gamma Spectroscopy Results From Backfill Soil Piles With Background And $DCGL_W$s

Soil Concentrations					
Radionuclide	Mean Background Concentration (pCi/g) [1]	$DCGL_W$ (pCi/g)	Mean Sample Results (pCi/g)	Comparison to: Mean Background	Comparison to: $DCGL_W$
U-234	0.71	214	3.17 [2]	Above	Below
U-235	0.67	22.7	0.10	Below	Below
U-238	0.77	98.6	3.9	Above	Below
Sum for comparison with 30 pCi/g level:			7.17	Less than 30 pCi/g	

[1] pCi/g = picocuries per gram.
[2] The U-234 results are conservatively based on the U-235 analytical results and the activity fractions of uranium enriched to 93.5 weight percent U-235.

Table 22

Comparison Of Soil Sampling Alpha Spectroscopy Results From Backfill Soil Piles With Background And $DCGL_W$s

Soil Concentrations					
Radionuclide	Mean Background Concentration (pCi/g) [1]	$DCGL_W$ (pCi/g)	Mean Sample Results (pCi/g)	Comparison to: Mean Background	Comparison to: $DCGL_W$
U-234	0.71	214	4.54	Above	Below
U-235	0.67	22.7	0.35	Below	Below
U-238	0.77	98.6	7.21	Above	Below
Sum for comparison with 30 pCi/g level:			12.1	Less than 30 pCi/g	

[1] pCi/g = picocuries per gram.

Table 23

Results From Sign And WRS Tests, Backfill Soil Pile Sampling Gamma Spectroscopy

Radionuclide	Sign Test			WRS Test		
	# Below the $DCGL_W$	% Below	Pass Sign Test?	Sum of Background Ranks	MARSSIM Critical Value	Pass WRS Test?
U-234	20[1/]	100	Yes	1116	891	Yes
U-235	20	100	Yes	1116	891	Yes
U-238	20	100	Yes	1116	891	Yes

[1/] Critical value for Sign test is 14.

Table 24

Results From Sign And WRS Tests, Backfill Soil Pile Sampling Alpha Spectroscopy

Radionuclide	Sign Test			WRS Test		
	# Below the $DCGL_W$	% Below	Pass Sign Test?	Sum of Background Ranks	MARSSIM Critical Value	Pass WRS Test?
U-234	21[1/]	100	Yes	1147	909	Yes
U-235	21	100	Yes	1147	909	Yes
U-238	21	100	Yes	1147	910	Yes
Total U [2/]	20	95	Yes	966	781	Yes

[1/] Critical value for Sign test is 14.
[2/] The $DCGL_W$ for total uranium is 30 pCi/g.

Table 25

Unity Rule Calculation Results, Backfill Soil Pile Sampling Gamma Spectroscopy

Radionuclide	Mean Concentration (pCi/g) [1/]	$DCGL_W$ (pCi/g)	Ratio
U-234	3.17	214	0.015
U-235	0.097	22.7	0.0043
U-238	3.9	98.6	0.040
		Sum	0.059
		Is Sum of Ratios < 1?	Yes

[1/] pCi/g = picocuries per gram.

Table 26

Unity Rule Calculation Results, Backfill Soil Pile Sampling Alpha Spectroscopy

Radionuclide	Mean Concentration (pCi/g) [1/]	$DCGL_W$ (pCi/g)	Ratio
U-234	4.5	214	0.021
U-235	0.35	22.7	0.015
U-238	7.2	98.6	0.073
		Sum	0.11
		Is Sum of Ratios < 1?	Yes

[1/] pCi/g = picocuries per gram.

Table 27

Results of Backfill Soil Pile Field Measurements

Pile 1, Lift 1		Pile 1, Lift 2		Pile 2, Lift 1		Pile 2, Lift 2	
Grid Location	Areal Scaler Reading (cpm)	Grid Location	Areal Scaler Reading (cpm)	Grid Location	Areal Scaler Reading (cpm)	Grid Location	Areal Scaler Reading (cpm)
1	6324	1	6333	1	5272	1	5338
2	6350	2	6269	2	5285	2	5231
3	6373	3	6696	3	5393	3	5304
4	6847	4	6788	4	5557	4	5134
5	6660	5	6694	5	5322	5	5053
6	6509	6	6434	6	5217	6	5161
7	6870	7	6051	7	5258	7	5140
8	7033	8	5630	8	5109	8	5220
9	6616	9	6608	9	5135	9	5321
10	7054	10	7623	10	5284	10	5079
11	6868	11	6697	11	5421	11	5240
12	6796	12	6342	12	5142	12	5040
13	7129	13	6250	13	5263	13	5470
14	7054	14	6190	14	5398	14	5158
15	6544	15	5898	15	5331	15	5084
16	6282	16	5933	16	5138	16	5053
17	6464	17	6001	17	5089	17	5296
18	6599	18	6643	18	5225	18	5308
19	6207	19	6857	19	5286	19	5110
20	6340	20	6809	20	5352	20	4829
21	6315	21	7975	21	5074		
22	6249	22	6117	22	5128	Average	5178
23	6067	23	6089	23	5197	St. Dev.	143
24	6135	24	6038	24	5170		
25	6173	25	6181	25	4906		
26	6205	26	6589	26	5036		
27	6413	27	7202				
28	6567	28	6414	Average	5230		
29	6270	29	7021	St. Dev.	139		
30	6117	30	6288				
31	6495	31	6257				
32	6121	32	6152				
33	6656	33	5933				
34	6087						
35	6581	Average	6455				
36	6534	St. Dev.	498				
37	6358						
38	6421						
39	6614						
40	5397						
41	5991						
42	5933						
43	6204						
Average	6438						
St. Dev.	344						

Background	
Average	6194
St. Dev.	790

Table 28

Monthly Average Water Release Concentration Criteria

	10 CFR 20 App B Table 3	Tank Water Sample 1	Tank Water Sample 2	Excavation Water Sample 1	Excavation Water Sample 2
Radionuclide	Release Criteria (pCi/L/month)	Release Concentration [1/] (pCi/L/month) [2/]	Release Concentration (pCi/L/month)	Release Concentration (pCi/L/month)	Release Concentration (pCi/L/month)
U-234	3.0E+03	3.1E+03	2.9E+03	3.1E+03	3.0E+03
U-235	3.0E+03	9.6E+01	9.0E+01	9.6E+01	9.3E+01
U-238	3.0E+03	7.5E+02	6.7E+02	7.2E+02	7.6E+02

[1/] Assuming a frac tank volume of 2750 gallons.
[2/] pCi/L/month = picocuries per liter of water released per month.

Table 29

Sum Of Fractions Criteria

	Tank Water Sample 1	Tank Water Sample 2	Excavation Water Sample 1	Excavation Water Sample 2
Radionuclide	Release Fraction [1/]	Release Fraction	Release Fraction	Release Fraction
U-234	0.5	0.47	0.5	0.48
U-235	0.015	0.014	0.015	0.015
U-238	0.12	0.11	0.11	0.12
Sum	0.63	0.59	0.63	0.62

[1/] Assuming a frac tank volume of 2750 gallons and a sewer flow of 3000 gallons per month.

Table 30

Total Activity Release Calculation Results

	Total Activity (pCi) [1/]			
Radionuclide	Tank Water Sample 1	Tank Water Sample 2	Excavation Water Sample 1	Excavation Water Sample 2
U-234	3.3E+07	3.0E+07	3.3E+07	3.1E+07
U-235	1.0E+06	9.3E+05	1.0E+06	9.6E+05
U-238	7.8E+06	7.0E+06	7.5E+06	7.9E+06
Sum	4.1E+07	3.8E+07	4.1E+07	4.0E+07

[1/] pCi = picocuries; total activity release calculation performed assuming a frac tank volume of 2750 gallons.

Table 31

Sum of Fractions Equation

$$Sum_{RF} = \sum \frac{\text{Result} * V_{TL}}{C_A * (V_{TL} + V_{SW})}$$

Where:

Sum_{RF} = Sum of Release Fraction; the sum of the radionuclide specific monthly average release fractions

Result = Sample Result, the spectroscopy result for the specific radionuclide (pCi/g)

V_{TL} = Tank Liquid Volume, the volume of water collected estimated from tank dimensions of 8' x 21.5' by 2' (2,570 gal = 9,740 L)

C_A = Allowable Average Concentration, the radionuclide specific allowable monthly average concentration limit from 10 CFR 20 Appendix B Table 3

V_{SW} = Sewer Water Volume, the monthly volume of water passing through the sewer where the release will occur (3,000 gal = 11,355 L)

Table 32

Comparison Of Potential Doses From Excavation Sites And Background

Soil Sample Source	Dose Limit (% of 15 mrem/yr)	% Typical Background
Excavation Bottom	0.35 mrem/yr (2.3%)	0.097%
Backfill Soil Pile	0.89 mrem/yr (5.9%) -- gamma spec	0.25%
	1.65 mrem/yr (11%) -- alpha spec	0.46%

Table 33

ALARA Compliance Equation

$$\frac{Conc}{DCGL_w} = \frac{Cost_T}{\$2000 * P_D * 0.015 * F * A} * \frac{r + \lambda}{1 - e^{-(r+\lambda)*N}}$$

Where:

Conc = ALARA concentration, pCi/g.

$Cost_T$ = total cost of the additional remedial action, $150,000 per project baseline.

$2000 = monetary conversion factor of dose to dollars, from DG-4006.

P_D = population density of 4E-04 person/m^2, from DG-4006.

0.015 = dose limit of 15 mrem/yr in rem/yr.

F = remediation effectiveness factor, 1 for this type of action.

A = area being evaluated, 232 m^2.

r = monetary discount rate of 0.03, from DG-4006.

= radionuclide decay constant, yr^{-1}.

N = number of years over which the dose is calculated, 1000 for this case.

Appendix C, List of Acronyms

ACRONYMS AND ABBREVIATIONS

μCi	microcurie
μg/G	micrograms per gram
AEC	Atomic Energy Commission
AFB	Air Force Base
AFBCA	Air Force Base Conversion Agency
AFIERA	Air Force Institute for Environment, Safety, and Occupational Health Risk Analysis
ALARA	as low as is reasonably achievable
Am-241	americum-241
ANSI	American National Standards Institute
ARB	Air Reserve Base
ARAR	applicable or relevant and appropriate requirement
BRAC	Base Realignment and Closure (Act)
Ci	curie
cm	centimeter
COC	contaminant of concern
cpm	counts per minute
DCGL	derived concentration guideline level
$DCGL_{EMC}$	DCGL elevated measurement comparison
$DCGL_W$	derived concentration guideline level, wide area
DOD	Department of Defense
DQO	data quality objective
DU	depleted uranium
EU	enriched uranium
FIDLER	field instrument for the detection of low energy radiation
FSS	Final Status Survey
ft bgs	feet below ground surface
ft^2	square feet
Ge	germanium
GM	Geiger-Mueller
ISDH	Indiana State Department of Health
keV	kiloelectron volts
m	meters
m/s	meters per second
m^3/yr	cubic meters per year
MagThor	magnesium thorium alloy
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	minimum detectable concentration
MDCR	minimum detectable count rate
mg/d	milligrams per day
ml/g	milliliters per gram
mR/hr	milliroentgen per hour

mrem/hr	millirem per hour
mrem/yr	millirem per year
mSv/yr	millisievert per year
NaI	sodium iodide
NRC	Nuclear Regulatory Commission
Pa-234m	protactinium-234m
Parsons	Parsons Engineering Science, Inc.
pCi	picocurie
pCi/g	picocurie per gram
Philip	Philip Environmental Services
PID	photoionization detector
PRG	preliminary remediation goals
Pu-241	plutonium-241
Ra-226	radium-226
RESRAD	RESidual RADiation model
Rn-222	radon-222
ROC	radionuclide of concern
TEDE	total effective dose equivalent
Th-232	thorium-232
Th-234	thorium-234
TPH	total petroleum hydrocarbons
U-234	uranium-234
U235	uranium-235
U-238	uranium-238
USAF	United States Air Force
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
WRS	Wilcoxon Rank Sum
ZnS	zinc sulfide

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DECLARATION

Name of Base/Installation/Facility

Grissom Air Force Base (AFB), Peru, Indiana.

Site Name and Location

B-58 Hustler Burial Site/Area of Concern (AOC) 8, Grissom AFB, Peru, Indiana.

Statement of Basis and Purpose

This decision is based on the results of the *Final Status Survey Report/B-58 Hustler Burial Site/AOC 8* (February 2002) conducted by Parsons Engineering Science, Inc., Denver Colorado, under Project Number CTGC20006108, prepared for the Grissom Air Force Real Property Agency (AFRPA) and the Air Force Institute for Environment, Occupational Safety and Health Risk (AFIERA).

Description of Selected Remedy

Based on current site condition, it has been determined that no significant risk or threat to public health or the environment exists. Therefore, no further action (NFA) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Nuclear Regulatory Commission (NRC) guidance is required.

Declaration of the Remedy

This decision document represents the selected action for this site developed in accordance with CERCLA and the NRC guidance. It has been determined that the NFA is protective of human health and environment, attains federal and state requirements that are applicable, or relevant and appropriate, and is cost effective. Contaminant levels at the site have been determined to present no significant threat to human health or the environment; thus, no treatment is necessary and the site is suitable for unrestricted use.

Signatures:

Marlene Seneca ________________________

Site Manager/BRAC Environmental Coordinator

Air Force Base Conversion Agency, Grissom AFB

Date: ____________________

Stephanie Riddle ________________________

Project Manager

Indiana Department of Environmental Management

Date: ____________________

Thomas Barounis ________________________

Remedial Program Manager

United States Environmental Protection Agency, Region V

Date: ____________________

Decision Summary

1.0 Purpose

The purpose of this NFA Report is to summarize existing data and describe the Air Force's rationale for selecting a particular remedial action, in this case, the NFA alternative for the B-58 Hustler Burial Site (AOC 8). The objectives of this decision document are:

- To describe the location, history, environmental setting and current status of the site;
- To summarize the results from previous investigations; and
- To assess the risk to human health and the environment.

2.0 Background Information

2.1 Base Location and Description

Grissom AFB is located approximately 15 miles north of Kokomo, Indiana on U.S. Route 31 in Cass and Miami counties, approximately two miles west of the town of Bunker Hill. See Appendix-A, Figure 1 for a map of Grissom AFB and the surrounding communities. The base, which was originally established in 1942, has undergone several transitions throughout its history. Grissom AFB was realigned to Grissom Air Reserve Base (ARB) on 30 September 1994. The Air Force Reserve 434th Air Refueling Wing is the host within the new cantonment area. The excess Air Force property, known as Base Realignment and Closure (BRAC) property, is being managed by the AFBCA pending redevelopment. The primary mission of the AFBCA is to cleanup BRAC property for transfer to the Grissom Redevelopment Authority for reuse. The former base was comprised of 2,722 acres of land, which is surrounded by actively managed agricultural land. Major population centers in the vicinity include the cities of Peru, Kokomo, and Logansport. In addition, several smaller towns and communities are scattered around the former Grissom AFB as shown in Appendix-A, Figure 1. Grissom AFB Facility Plan is shown in Appendix-A, Figure 2.

2.2 Base Geography

The base lies within the Tipton Till Plain section of the Interior Plains division of the Central Lowlands Province of the United States. The Tipton Till Plain section is generally characterized by nearly level plains with gently rolling hills and has a few small, localized, closed depressions. The topography of the base exhibits characteristics typical of the regional Tipton Till Plain. In general, the topography is a reflection of a glacially deposited till that has been affected to some extent by the shape of the underlying bedrock surface and by post-glacial erosion. Across the base, land surface elevations vary from approximately 810 feet above the National Geodetic Vertical Datum (NGCD), reference to feet above mean sea level (ft MSL) near the southeast boundary to approximately 780 feet NGVD near the northern boundary. The south edge of the base appears to be a topographic high, which slopes towards the north (on the base) and south (away from the base) (ESE, 1993a; United States Geological Survey [USGS], 1963).

2.3 Physiography and Climatography

The climate in north Central Indiana is temperate, with warm humid summers and cold winters. The region is characterized by wide variations in temperature from season to season, ranging from 20 degrees Fahrenheit (°F) in the winter to 80°F in the summer. The coolest month of the year is January, with a mean monthly temperature of 23°F and the warmest month of the year is July with a mean monthly temperature of 74°F. Precipitation in Central Indiana averages 36.6 inches annually, and is evenly distributed throughout the seasons. Snowfall in the region occurs mainly from December through February, and averages 32.2 inches per year.

2.4 Base Geology

Based on previous studies, the geology of the area consists of unconsolidated glacial and alluvial deposits overlying Silurian-age limestone and dolomitic limestone. See Appendix-A, Figure 3 for a generalized geologic cross-section. The unconsolidated deposits observed during previous investigations at sites across the base consist of three primary stratigraphic units. The upper unit is approximately 25 feet thick and consists of clay with silt, sand and gravel seams. The intermediate unit consists of silty clay with occasional stringers of silt ranging in thickness from 22 to 31 feet. The lower unconsolidated unit consists of interbedded sands and gravels with a thickness between 13 to 17. Two of the unconsolidated units have been identified as water-bearing units, and are referred to as the "upper unconsolidated aquifer" (the upper clay unit with silt, sand, and gravel seams) and the "lower unconsolidated aquifer" (the interbedded sand and gravel unit which overlies the bedrock). Groundwater within the upper aquifer is associated with the sand and gravel seams and is considered "perched" water. As the water is "perched," a determination of a regional groundwater flow direction is not valid, as flow will vary widely from location to location. Shallow groundwater flow is generally toward discharge areas such as utility corridors, creeks, and drainage ditches. It can also be affected by localized mounding near landfills or surface water bodies. Dolomitic limestone aquifer is an important aquifer in the region surrounding the base. Generally, groundwater flows in a north-northeasterly direction; however, flow changes do occur due to heavy pumping of the bedrock aquifer. Groundwater within the lower aquifer exists under confined conditions, due to the confining pressure of the overlying clay. Vertical gradients calculated from groundwater elevation data indicate that a downward vertical gradient exists between the upper and lower aquifers. Based on the low permeability of the clay unit, which lies between the two units, poor hydraulic connection between the unconsolidated aquifer units is expected. A till layer is reportedly present above the surface bedrock, isolating the lower, unconsolidated aquifer from the underlying bedrock. Therefore, communication with the underlying Liston Creek (bedrock) Aquifer is also expected to be limited. Historical groundwater elevation data indicates that groundwater flow within the lower unconsolidated aquifer is generally toward the north-northeast.

2.5 Base Hydrology

Based on previous Installation Restoration Program investigations, shallow groundwater has been encountered at depths ranging from 6 to 10 feet below ground surface (bgs), and the groundwater flow at the base is generally towards the north to northeast, towards Pipe Creek.

2.6 Base Surface Water Hydrology

Grissom AFB is located in the Wabash River basin of north central Indiana in the Pipe Creek drainage area. See Appendix-A, Figure 4 for a map of the regional surface water drainage, and Appendix-A, Figure 5 for a map of the facility surface water drainage on Grissom AFB. Surface water drainage on base is controlled by open drainage courses and underground storm drains. Surface drainage not routed into the underground drainage system flows off-site chiefly into the government Ditch (to the northwest), Little Deer Creek (to the west), and Pipe Creek (to the east and northeast). There are several on-site ditches which drain specific areas of the base, the largest of which is McDowell Ditch, but also include Bennett-Campbell and Cline Ditches, and an unnamed ditch to the east of the base (ES, 1985).

2.7 Groundwater Supply Wells

The location of the existing groundwater supply wells at Grissom AFB is presented in Appendix-A, Figure 6. Information on the depth, size, and use of the wells is presented in Appendix-B, Tables 1A, 1B, and 1C. Each of these wells reportedly produces from the Liston Creek Formation aquifer.

2.8 Base History

Grissom AFB was established in 1942 as "Bunker Hill Naval Air Station" (NAS), and remained an active naval training installation throughout World War II. Bunker Hill NAS was deactivated in 1946, with the land and facilities leased to local business and agricultural interests. The site was reactivated as "Bunker Hill Air Force Base", and assigned to the Tactical Air Command. The Strategic Air Command assumed control of the Base in 1957 and became the home of the 4041st Air Base Group. In 1959, the 4041st Air Base Group was redesignated as the 305th Bombardment Wing. Bunker Hill AFB was renamed Grissom AFB in 1968 in honor of the late Lieutenant Colonel Virgil "Gus" Grissom, a native of Indiana and one of America's original seven astronauts. In 1970, the 305th Bombardment Wing was deactivated and the 305th Air Refueling Wing was created to provide aerial refueling using KC-135 aircraft. The Base came under the control of Air Mobility Command in 1992 with the dis-establishment of the Strategic Air Command. Approximately half of the former Grissom AFB realigned to Grissom Air Reserve Base (ARB) on 30 September 1994; the Air Force Reserve Command 434th Air Refueling Wing is the host within the new cantonment area. The excess Air Force property is being managed by the AFBCA pending redevelopment.

2.9 Facility Ecological Assessment

2.9.1 Sensitive Habitats

Sensitive habitats include wetlands, plant communities that are unusual or of limited distribution and important seasonal use areas for wildlife. There is no indication that ecological conditions at this site vary significantly. The only sensitive habitat within the confines of Grissom AFB consists of a quarter acre wetland situated within the isolated woodland area on the southeastern side of the base. This area was part of a 200-acre parcel that transferred to the State of Indiana for the construction of a state prison. The area as such no longer exists. Although drainage ditches on the base meet all three wetland parameters, they have a statutory exemption from protection under the Clean Water Act to permit maintenance.

2.9.2 Threatened and Endangered Species

Consultation with the Indiana Department of Natural Resources and the U.S. Fish and Wildlife Service indicated that 20 threatened, endangered, or candidate species of plants or animals potentially occur in the region surrounding Grissom AFB. Of these, no federally listed species are known or expected to occur on Grissom AFB itself. Of the state-listed species that have been documented near the base, none were identified during the environmental baseline survey conducted on the base in 1993. However, the badger (State listed as threatened) may possibly utilize base land for temporary forage purposes.

3.0 Site Information

3.1 Location and Description

The B-58 Hustler Burial Site is located on BRAC property, outside the Grissom ARB cantonment area (i.e. outside the fence-line), between two closed fire training areas (see Appendix-A, Figure 7). The area is approximately 100 feet wide by 100 feet long, with a flat terrain. The vegetation at the site consists of sparse native grasses limited by remnants of asphalt from a former runway. There are no site restriction or security measures surrounding the burial site.

3.2 Geology

The geology at the burial site is similar to the features of the rest of the former Grissom AFB and consists of unconsolidated glacial and alluvial deposits overlying ancient marine deposits of the Silurian period. The glacial till typically consists of clays and silty clays with discontinuous layers of stratified lenses of silt, sand, and gravel.

3.3 Hydrology

Elevation differential at the burial site is minimal and surface drainage is generally to the north to northeast. The nearest bedrock well is located approximately 1200 feet south of the site. In addition, the most notable sub-surface feature for the former base as a whole (including areas surrounding the site) is a shallow water table occurring at depths of

6 to 15 feet across the former base. However, an underground storm drain line system runs approximately 200 feet to the north of the site, which empties into McDowell Ditch and ultimately into Pipe Creek.

3.4 Topography and Surface Hydrology

Elevation difference at the burial site is minimal and surface water drainage is generally to the northeast. The general area near the burial site is gradually sloped (approximately 10%) to the north, toward the storm drain lines. Therefore, surface water would tend to flow in a northerly direction toward the underground storm drain system, which empties into McDowell Ditch and ultimately into Pipe Creek.

3.5 History

On December 8, 1964, during a routine Operational Readiness Exercise, a B-58 strategic bomber skidded off a runway at Bunker Hill AFB, Indiana (later renamed Grissom AFB). The aircraft ran over several electrical fixtures and the landing gear subsequently collapsed, rupturing a fuel tank. The resulting aircraft fire burned portions of the five nuclear weapons on board to various extents, but did not cause detonation of the high explosives. Records indicate that site personnel had difficulty extinguishing the fire of one weapon. The fire was extinguished by placing the weapon in a pit (approximately 150 feet from the aircraft) and covering it with sand. After the fire was extinguished, the weapon was removed and sent to an Atomic Energy Commission (AEC) facility. The recovered weapons and weapon debris were sent to AEC facilities where analyses indicated that plutonium was not released to the environment during the accident because all plutonium-bearing components were intact. Portions of the runway and adjacent soils were subsequently excavated and buried nearby along with the remaining aircraft wreckage at the site referred to as AOC 8. With subsequent boundary restructuring, burial site is currently located outside the Grissom ARB cantonment area (i.e. outside the fence-line) and is now considered BRAC property under the control of the AFRPA.

3.6 Previous Site Investigations

Previous facility information used in the documenting the remedy includes:

> *Geological Survey Report, B-58 Hustler Burial Site,* Grissom AFB, Indiana, United States Environmental Protection Agency (Region 5), (U.S. EPA, September 1998).

> *Radiological Characterization Survey Report, 1964 B-58 Accident Site, Area of Concern 3,* Grissom ARB, Indiana, Air Force Institute for Environment, Safety, and Occupational Health Risk Analysis, (AFIERA. May 2000).

Final Status Survey Work Plan, B-58 Burial Site, Area of Concern 8, Former Grissom AFB, Indiana, Parsons Engineering Science, Inc., (Parsons, August 2000).

Final Status Survey Report B-58 Hustler Burial Site, Area of Concern 8, Former Grissom AFB, Indiana, Parsons Engineering Science, Inc., (Parsons, February 2002).

Since the accident in 1964, several sampling events have been conducted at the accident site. Some information regarding the burial site can be derived from the accident site characterization studies, because this is the source of the radiological contamination. A radiological survey preformed by the Civil Engineering Squadron in June 1991 did not locate any areas of contamination at the accident site. In June 1996, the Air Force Safety Center concluded that sufficient information was not available to support a decision for unrestricted release of the site.

The United States Environmental Protection Agency (U.S. EPA) performed a radiological and geophysical survey of the suspected burial site (AOC 8) location in September 1998. Gamma radiation levels were consistent with background, and a large buried metallic anomaly was identified (see Appendix-A, Figure 8).

The Indiana State Department of Health (ISDH) performed gamma exposure rate measurements and collected soil samples from the accident site (AOC 3). The ISDH identified an area with gamma radiation exposure rates eight to ten times background rates. A soil sample collected at the accident site contained concentrations that were several hundred times higher than background for uranium-238 (U-238). Uranium-235 (U-235) and uranium-234 (U-234) concentrations were also elevated in proportions similar to that of depleted uranium (DU). It was concluded that the elevated levels maybe due to the presence of DU from the weapons. Plutonium concentrations were consistent with the typical background levels.

In October 1999, the AFIERA conducted a detailed characterization survey of the accident site (AOC 3). The results of this survey are presented in the AFIERA document *Radiological Characterization Survey Report* (AFIERA, 2000). No evidence of any other radiological (e.g., plutonium) or chemical (e.g., beryllium) contamination was found at the accident site. The report concludes that the contamination at the accident site is due to DU.

4.0 Initial Burial Site Scoping Survey (February 2000)

Parsons and AFIERA conducted a preliminary radiological walk-over survey (part of Final Status Survey) in February 2000 to verify the results of the radiological walk-over survey performed by the U.S. EPA in September 1998 which found no radiological contamination above background at the burial site. The walkover survey was first conducted over a background area and then over the burial site. The background location was located across an unmapped, gravel road approximately 300 ft southeast of the burial site. The burial site and the background locations are shown in Appendix-A, Figure 7.

4.1 Instrumentation

A Ludlum ratemeter (Model 2221) with 2 inch by 2 inch sodium iodide (NaI) probe (Model 44-10) and a Bicron Analyst ratemeter with a FIDLER (field instrument for the detection of low-energy radiation) probe were used in the walk-over survey. Both instruments can detect radioactive contamination to a depth of 1 ft below the ground surface (bgs).

4.2 Measurements

Direct and scanning measurements were collected from both the background area and the burial site. Because the nature of the survey was to detect presence or absence of radiation levels above background, the direct measurements were collected over the anomaly. Background measurements were collected at random locations. Direct measurements were collected in the scaler mode with integrated counts over 1 minute. [Scaler mode refers to an instrument that is set to take a counted measurement of radioactivity over a set period of time, typically one minute. The output is a discrete number of hits or counts per minute (i.e., 2545 cpm). Using the scaler mode to take a measurement increases the sensitivity of the instrument since the instrument is placed over one location for a set amount of time]. Scanning measurements were taken in the rate meter mode at an approximate rate of 0.5 meters per second (m/s). [Rate meter mode refers to an instrument that has an output of a continuous counting rate displayed on a gauge on the meter. The operator determines the amount of radioactivity present by watching the fluctuations of the needle on the meter, and recording the range (i.e., 2000-3000 counts per minute (cpm)). The type of instrument is generally used during scanning surveys].

4.3 Conclusions

The results of the radiological walk-over survey are summarized in Appendix-B, Table 2. From this table it can be seen that the radiological walk-over survey results at the burial site were indistinguishable from the background area levels and, therefore, are consistent with the results of the radiological survey performed by the U.S. EPA in September 1998.

5.0 Intrusive Scoping Survey (February-March 2000)

The primary purpose of the intrusive survey was to determine if the anomaly found in U.S. EPA's 1998 geophysical survey was a buried fuselage from the accident site and if radioactive contamination was present deeper than 1 ft bgs (As discussed in Section 4.1, 1 ft bgs is the maximum depth the instrumentation used in the walk-over survey can detect radiological contamination). The intrusive survey was performed in February and

March 2000. The information collected during the intrusive survey was used to estimate the volume of soil to be excavated for waste disposal. Sampling was performed based on a systematic grid that was overlaid on the geophysical anomaly detected by U.S. EPA, as shown in Appendix-A, Figure 8.

5.1 Instrumentation

Intrusive soil sampling was performed using the direct push Geoprobe® sampling technique. Soil samples were collected and sent to AFIERA laboratory for gammaspectroscopy analysis. In addition to samples being sent for laboratory analysis, *in situ* alpha radiation measurements were completed with a zinc sulfide (ZnS) alpha probe (Ludlum Model 44-1) which was used with a rate meter (Ludlum Model 2350). For health and safety purposes, a Micro-R survey meter (Ludlum Model 19) and Pancake Geiger-Mueller (GM) probe (Ludlum Model 44-9) with a ratemeter (Ludlum model 12) were used for area, personnel, container, sample, and equipment surveys.

5.2 *In Situ* Measurements

In situ measurements were collected for all soil samples collected by the Geoprobe® using the Micro-R meter, the GM probe, and the alpha probe. The Micro-Rmeter and GM probe were used primarily for health and safety purposes. The alpha probe was used to determine if elevated levels of alpha radiation were present and also provided an indication if DU was present in the soil. The combination of the beta-gamma GM probe and the alpha probe was used as field screening methods to determine presence or absence of high levels of alpha activity relative to background. This also assisted the sampling team in determining whether the extent of contamination was sufficiently delineated.

5.3 Soil Characteristics

The sampling logs for the grid locations are presented in Appendix-B, Table 3. Fifteen samples were collected within the area of the anomaly. Three background samples were collected west of the road. The nature of the native soil was clayey. Native clayey soil was observed in all samples collected outside the immediate area of the anomaly except at locations 9 and 13 (see Appendix-A, Figure 9). Aircraft debris was encountered between 3.5 to 4.5 ft bgs. Sample S-13 was a discretionary location because debris was encountered at S-9. Debris was encountered at S-13 at 3 to 3.5 ft bgs.

Soil retrieved from locations corresponding to the anomaly (S-0, S-6 and S-7) were distinctly different from the native clayey soil. Based on the on-site measurements no gross alpha or gamma measurements were detected above background soil levels. At location S-6, debris that appeared to be aircraft parts were retrieved between 6.5 and 7 ft bgs. This confirmed that the buried anomaly was most likely a burnt fuselage and associated aircraft wreckage.

5.4 Soil Concentrations

Results of the gamma spectroscopy performed in the laboratory are presented in Appendix-B, Table 4. These results show non-detects for americium-241 (Am-241) and U-235 in most samples. U-235, when detected, is present at background levels. Thorium-234 (Th- 234) was detected at levels exceeding background at location S-7 (14 pCi/g), indicating that U-238 was present above background levels. Th-234 is in secular equilibrium with U- 238 and is used as an indicator of U-238 levels. Results of the beryllium analysis are presented in Appendix-B, Table 5. Beryllium was not detected in three of the four site samples. However, beryllium was detected at location S-7b at 2.14 micrograms per gram (μg/G), which is not significantly greater than background. The ISDH preliminary remediation goal (PRG) for beryllium in subsurface soil is 16 μg/G. Based on historical record of the accident site, beryllium was not expected to be a contaminant of concern (COC). Based on this recent laboratory analysis and historical records, beryllium is not considered to be a COC at the burial site.

5.5 Conclusions

Based on soil characteristics from the intrusive survey it was concluded that a fuselage corresponding to U. S. EPA's geophysical survey was buried between 3 and 8 ft bgs at the suspected burial site (approximately 50 x 50 ft with a 10 x 10 ft spur to the south west corner). The laboratory analysis showed that the extent of DU contamination was most likely confined to the area of the buried anomaly. As shown by the results in Appendix-B, Table 4, high levels of contamination were not found during the characterization survey.

6.0 Final Status Survey (October-November 2000)

6.1 Regulatory Criteria Summary

The U.S. EPA criteria for unrestricted use requires that the total effective dose equivalent (TEDE) be as low as is reasonably achievable (ALARA), but no more than 15 millirem per year (mrem/yr) (0.15 millisieverts per year [mSv/yr]) above background (U.S. EPA, 1997b). The radiological dose modeling software RESidual RADiation (RESRAD), developed at Argonne National Laboratory (USDOE, 1993), was used to establish soil activity levels that would result in doses less than 15 mrem/yr for each radionuclide of concern (ROC). In addition, a gross soil activity concentration for all ROCs resulting in a dose of less than 15 mrem/yr was developed using Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) guidance.

The RESRAD program was used to calculate the Derived Concentration Guideline Levels (DCGLws) that result in a dose of 15 mrem/yr to a critical receptor. A composite DCGL of 30 picocuries per gram of soil (pCi/g) was selected as a screening level based on ALARA considerations. In the American National Standards Institute/Health Physics Society (ANSI/HPS) N13.12-1999, *Surface and Volume Radioactivity Standards for*

Clearance, this value correlates to an exposure limit of 1 mrem/yr to a potential receptor for a group of radionuclides including all uranium isotopes and some beta-gamma emitters. While the ANSI standard is technically not applicable to soils that could be potentially used for agricultural purposes, it was determined reasonable in this case to use the standard as an applicable or relevant and appropriate requirement (ARAR) in the interest of ALARA considerations. For this remediation, it was reasonable to remediate to activity concentrations much lower than the DCGLws because contaminants in the soil were readily identified, removed, and disposed of in a cost-effective manner. The screening level of 30 pCi/g was selected to ensure that the soil sample results, which provide the objective evidence that the DCGLws are met, can easily demonstrate compliance with the appropriate DCGLws.

6.1.1 Radionuclides of Concern

The primary ROCs considered at the burial site were the uranium isotopes (U-234, U-235, and U-238) that are constituents of DU and enriched uranium (EU). Gross activity soil limits were developed for these two materials in the FSS Work Plan (Parsons, August 2000); isotopic DCGLws were also calculated as part of this report. Isotopic DCGLws were also determined for two secondary ROCs - Th-232 and Am-241. Thorium-232 (Th-232) can be found in magnesium thorium alloy (MagThor), a material commonly used in the construction of aircraft parts. This alloy is used due to its high melting point and strength. MagThor is readily identifiable in the field using gamma spectroscopy because of its unique radiation spectra. Although several pieces of MagThor were recovered from the excavation, it was not considered a primary ROC because of its low likelihood of residual contamination. It was not readily dispersible from the B-58 incident due to its form and high melting point. Contamination containing Th-232 was limited to large chunks or aircraft parts and, therefore, was easily removed. Am-241 is a daughter product of plutonium-241 (Pu-241), and is often used as an indicator for the presence of weapons-grade plutonium. Because of the nature of the B-58 Hustler incident and the perceived concern of the regulatory agencies related to the presence of weapons-grade plutonium in the burned weapons, a soil limit was calculated for Am-241.

6.1.2 Derived Concentration Guideline Levels

DCGLws are the concentrations of residual radioactivity distinguishable from background that, if distributed uniformly throughout a wide area, would result in a TEDE of a given value to a potential receptor. A dosage of 15 mrem/yr was used for the FSS (Parsons, February 2002). It was projected that a limit in excess of 15 mrem/yr would not be consistent with ALARA goals for this site and the 15 mrem/yr limit is in compliance with both CERCLA and Nuclear Regulatory Commission (NRC) guidance.

Consistent with NRC requirements and MARSSIM, a post-cleanup ALARA evaluation was performed to verify that remedial activities that resulted in concentrations below the DCGLws but still potentially above background were ALARA. Actions based on the ALARA evaluation were implemented as part of the cleanup activity.

6.1.3 RESRAD Exposure Scenarios

The modeling effort included five exposure scenarios: residential, residential farmer, prison resident, prison residential farmer, and excavation worker. These scenarios were chosen to provide an upper bound of any potential exposure that may be incurred to individuals due to residual contamination. The primary basis for the prison scenarios is the close proximity of the Indiana Department of Corrections Miami Correctional Facility. It is plausible that the site may someday be used for future prison expansion.

The residential scenario is the base case from which the other residential scenarios are developed. For many sites, the upper bound for individual exposure is typically the residential farmer scenario, due to the amount of time spent on-site, the physical activities required to develop the land for agricultural use, and the consumption of food grown onsite. The prison residential farmer performs the same agricultural activities and also consumes food grown on-site. As a result, the residential and prison residential farmer scenarios differ only in the amount of time spent on-site which is much larger for a prisoner. The scenario of the non-farming prison resident is similar to that of the prison residential farmer, but without the consumption of on-site grown foods and the exposures during farming activities. The excavation worker scenario applies to that individual who is involved in intrusive activities such as excavation or construction. Specific differences in model inputs between these scenarios are shown in Appendix-B, Table 6.

6.1.4 RESRAD Input Parameters

RESRAD requires over 100 input parameters for the model. The input parameters describe the receptor and source specifications within various categories including: exposure pathways, soil concentrations, calculation times, contaminated zone, cover and contaminated zone hydrological data, saturated zone hydrological data, uncontaminated unsaturated zone parameters, occupancy, ingestion pathway (dietary data), ingestion pathway (non-dietary data), radon data, and storage time before use. Site-specific data for the burial site and the state of Indiana were used when available. When no site-specific data were available, conservative assumptions were used.

6.1.5 RESRAD Modeling Results

The calculated DCGLws are based on 15 mrem/yr and site-specific conditions. For comparison with gross activity measurements, gross activity DCGLws for DU and EU (enriched to 93.5 weight percent U-235) were calculated using MARSSIM equation in Appendix-B, Table 7 and the activity fractions listed in Appendix-B, Table 8. By using the equation and the activity fractions, gross activity DCGLws were calculated for DU and EU for the five RESRAD modeled scenarios and are presented in Appendix-B, Table 9. It should be noted that for EU the gross DCGLw is dominated by the individual DCGL from U-234 due to it having the largest activity fraction. For DU, U-238 has the dominant individual DCGLw. The preliminary gross activity DCGLws that were developed in the FSS Work Plan (Parsons, August 2000) were calculated in the same manner and are also listed in Appendix-B, Table 9.

In the interest of ALARA considerations, Parsons and AFIERA also adopted a soil activity limit of 30 pCi/g for all radioactive contamination. For this remediation, it was reasonable to remediate to activity concentrations much lower than the DCGLws because contaminants in soil were readily identified, removed, and disposed of in a cost-effective manner. The use of isotopic DCGLws rather than gross DCGLws decreases the uncertainty in the results that could be introduced based on the assumptions of isotopic fractions that would need to be made to show compliance with gross activity DCGLws.

The individual isotopic DCGLw results for all five scenarios are given in Appendix-B, Table 10. The results for the residential farmer, prison resident, and prison residential farmer scenarios were relatively low, indicative of the longer residence times required for these scenarios to have any significant impact. The excavation worker scenario resulted in a high DCGLw, due primarily to the short residence time for the excavation worker. The RESRAD modeling results demonstrate that the prison residential farmer scenario is the most conservative receptor scenario.

Derived concentration guideline limits for smaller, more elevated areas (hot spots), known as DCGLEMCs were also calculated. The DCGLw corresponds to the average concentration of the entire site or survey unit, while the DCGLEMC sets the upper limit for a single highly localized measurement (i.e., hot spot). The single radionuclide DCGLEMCs for the five scenarios are also listed in Appendix-B, Table 10.

6.2 Burial Area Excavation Process

6.2.1 Excavation Instrumentation

The primary instruments used in the soil surveys were a Bicron FIDLER probe and a 3-inch by 3-inch NaI detector. These instruments were used to determine if contamination was EU or DU through a field screening protocol. The primary instruments used for health and safety purposes were an alpha scintillation detector and two GM detectors, used for contamination control surveys; and a MicroR meter, used for radiation field measurements. Additionally, a Quantrad Scout NaI system and a Canberra Intrinsic Germanium system, both owned and operated by AFIERA, were used for waste characterization purposes.

6.2.2 Excavation Activities

The excavation began with the removal of a one-foot interval across the entire burial area in order to check for backfill and shallow buried objects. This initial lift scraped sod and underlying asphalt remnants off of the area. The first pieces of airplane debris were found at one location under this first one-foot lift. Given this discovery, the excavation plan changed from making continuous one-foot lifts across the entire burial site, as described in the FSS Work Plan (Parsons, 2000), to digging outward from the center of the found debris. The excavation continued from the location of the first discovered airplane debris and proceeded downward following the debris and contamination.

Native soils were easily distinguishable from contaminated soils based on the field correlation of the survey results with the type of soil found; undisturbed, well packed clay or loose discolored soils. The edge of the excavation was determined by the change in soil type. Once a clean face was reached, an additional foot was excavated to ensure that no airplane debris remained. The excavation then continued on the next face containing contamination.

Any areas containing significant debris or contamination hot spots were scanned with the FIDLER and 3"x3" NaI probe to determine the extent of contamination. When the FIDLER displayed an elevated reading, a NaI 3"x3" detector was used to provisionally determine if EU or DU was present. The flag value for the FIDLER was approximately 10,000 cpm, which is distinguishable from background *(i.e.,* approximately 10 percent to 15 percent above the upper bound of the 95 percent confidence level background distribution). This count rate also corresponds to the Minimum Detectable Count Rate that was developed based on the MARSSIM guidance.

Once the soils were scanned, the area of contamination was removed and placed into the contaminated soil or debris piles. At each excavation interval, areas that previously contained debris and/or hot spots were treated as contaminated, visually inspected, and scanned on a bucket-by-bucket basis.

From each bucket, all contaminated pieces of debris were retrieved from the excavated soil, scanned, and placed in the contaminated debris piles. If the entire bucket was determined to be contaminated, the debris pieces were removed and the soil was placed in contaminated soil piles. If the soil was scanned and determined to be uncontaminated after debris was removed, the soil was placed in uncontaminated soil piles. This soil was eventually used as backfill for the completed excavation after a scanning survey was conducted to check for contamination. The activity concentration in the soil was verified to be below the DCGLs using the Brooks AFB laboratory.

Uncontaminated debris, as determined by radiological surveys, was placed in a lined roll-off box for further characterization and disposal by Cabrera Services. Contaminated debris was further scanned and tested using gamma spectrometry to determine the nature and extent of radiological contamination. All contaminated waste (both soil and debris) were characterized and disposed of by Cabrera Services.

In an attempt to minimize high-activity waste, the contaminated soil was scanned a second time in order to locate any more hotspots. Contaminated debris and soil were separated from the lower-activity concentration soil and set aside for further characterization. The remaining contaminated soil pile was placed in one roll-off box and designated for off-site disposal upon further characterization.

During this excavation, the primary contaminated materials were chunks and not prone to airborne resuspension. However, loose soil was sprayed with water as necessary to reduce the amount of dust released into the atmosphere. Radioactively contaminated dust posed a potential health risk if inhaled (albeit a minimal health risk for this material concentration).

Dewatering activities were necessary at a depth of approximately 8-9 ft bgs. The water was pumped out of the pit at regular intervals and held in the water holding tank located next to the excavation pit. Groundwater (i.e., perched water) removal continued until the excavation and final closure scanning and sampling were completed. Due to the relatively low solubility of uranium, groundwater was not expected to be contaminated. However, laboratory analyses were used to characterize the contamination of the water collected in the pit before its final release. The water removed from the excavation appeared to be perched water collected in the cavities of the aircraft debris, rather than water from a perched aquifer. The water was released to the Peru Utilities Wastewater Treatment Plant, consistent with the requirements of 10 CFR 20.2003.

The final excavation had a T-shape with two rectangular sections measuring approximately 53 ft by 25 ft and 57 ft by 27 ft, respectively. The final depth of the excavation was approximately 9 feet. At this depth, no more debris was encountered and no soil appeared to be present except for undisturbed native clay. No elevated measurements were found upon scanning.

6.3 Excavation Sampling

6.3.1 On-going Sampling

Soil samples were taken from the excavation whenever areas of elevated count rate were discovered. If the source of the elevated count rate could be localized (e.g., the chunk identified), it was placed in a sample bag for further analysis. The surrounding soil was then surveyed again to ensure that no contamination remained. These samples were analyzed for isotopic identification using the on-site gamma spectroscopy equipment.

6.3.2 Final Sampling

Once the excavation had reached its final depth, additional soil samples were taken from the excavation bottom for the MARSSIM final status survey and from the uncontaminated soil piles to clear these soils and allow them to be used as backfill.

At the point where the soil sample was taken, a one-minute total count was also performed using the FIDLER. The static counts were collected with the probe in contact with the ground surface at the point where the soil sample was to be taken. A one-minute areal scaler count was performed for the whole grid square by walking over the square area for the count duration at a constant speed while holding the probe no more than one foot above the ground. Each soil sample was labeled and appropriate chain-of-custody paperwork was completed prior to sending the samples to the AFIERA Analytical Chemistry Division laboratory for analysis. The analytical results, which confirms the presence of only uncontaminated soils and use of only uncontaminated backfill, provides the basis for permitting unrestricted reuse of the site.

6.3.2.1 Number of Measurements and Grid Spacing

As specified in MARSSIM, a two-sample Wilcoxon Rank Sum (WRS) test was used to evaluate survey results when residual radioactivity contained radionuclides present in background or when survey measurements were not radionuclide-specific (i.e., gross scaler counts). The WRS test was used to determine if the residual radioactivity in a survey unit was statistically different from activity detected in a background reference area. The *a priori,* number of sample points necessary within a given survey unit and background reference area to perform the test, was calculated per Section 5.5.2.2 of MARSSIM.

The bottom of the excavation was T-shaped and was split into two rectangular sections, Area 1 and Area 2, upon which the FSS Work Plan (Parsons, 2000) grids were established (see Appendix-A, Figure 10). It was determined that a minimum of 24 samples be collected from the excavation bottom to reach the desired confidence level. The grid spacing calculations were performed again in the field, when the actual size of the excavation had been determined. For the length of the side calculation (using the equation in Appendix-B, Table 11), it was assumed that 20 samples taken from each excavation area would ensure a high level of confidence for each area.

Based on these sampling requirements, a grid spacing of 8 ft was established for each area (MARSSIM guidance requires the user to round down the calculation). Once this grid was laid out on the excavation floor, Area 1 yielded 18 sample locations and the Area 2 yielded 21 sample locations (see Appendix-A, Figures 11 and 12).

6.3.3 Backfill Soils Sampling

The grid spacing for the backfill soil piles was completed in a similar manner using a baseline requirement of 24 samples. This number of samples was not collected, but rather were only used to establish the grid spacing per MARSSIM guidance (see Appendix-A, Figures 13-16). Information summarizing the grid size calculations is compiled in Appendix-B, Table 12. Once this was completed, the top half (approximately 1.5 feet) of the soil pile was removed and the process repeated. Once the final survey scan and sampling were performed, the soils below the DCGLws were backfilled into the excavation.

6.4 Analytical Data

6.4.1 Data Quality Objectives

The Data Quality Objectives (DQOs) were developed using the guidance presented in Appendix D of MARSSIM. These DQOs were developed prior to the start of the excavation and were promulgated by the project FSS Work Plan (Parsons, August 2000).

The Final Status Survey (Parsons, February 2002) collected 59 samples to meet the following DQOs:

- Investigate possible contamination at the burial site and determine the extent of any contamination.

- Compare survey and background data to determine if the survey area data is similar to the background area using the WRS test recommended in MARSSIM. The α- and β-levels for the WRS test at this site are both set at 0.05 for the analysis of the spectroscopy results.

- Compare analytical results to DCGLws for those radionuclides that do not have an established background using the Sign test (also recommended in MARSSIM).

- Determine if the area satisfies the release criteria (i.e., the DCGLws) after the B-58 wreckage and contaminated materials have been removed.

Samples were analyzed at the AFIERA laboratory at Brooks AFB, Texas.

Although MARSSIM guidance does not specifically apply to the investigation and release of sub-surface soils, MARSSIM was used to help develop defensible and conservative remediation goals.

6.4.2 Background Radiation Levels

The radionuclides of interest are naturally-occurring in the environment or are present in the environment due to the fallout from atmospheric weapons testing. The concentration of these radionuclides in the natural environment varies significantly based on the source and types of soil. Background radioactivity material concentrations are a distribution of values. When evaluating whether a sample is above background it is important to assess if it is consistent with the background distribution or higher than background. In the FFS (Parsons, February 2002) concentrations falling outside this background distribution are referred to as "distinguishable from background."

Site soil background samples were collected and analyzed using gamma spectroscopy during the initial site scoping survey (see Section 4) and in the AFIERA Radiological Characterization Report of the B-58 Accident Site (AFIERA, May 2000). The average and standard deviation of the sample results is given in Appendix-B, Table 13 (Table 5-1 pg. 5-3).

Much of the background data available was comprised of non-detect values. It is possible to estimate values for these results based on two separate statistical papers: Strom, 1986 and Finkelstein and Verma, 2001 (FSS, (Parsons, February 2002)). The methods described in these papers require that the data be lognormally distributed, which is typical for background radiation. The method outlined in Strom, 1986 begins by testing the data for fitness within a lognormal distribution. The available background data fit such a distribution and, therefore, the two methodologies were applied. The results were compiled as shown in Appendix-B, Table 13. The U-234 values were projected based on the material type. For the natural uranium in background, the U-234 and U-238 activities are in equilibrium and as such are equal. The decay series of U-238 is presented in Appendix-A, Figure 17. For the sample results it was assumed that the U-234 values were representative of EU as a conservative measure. The U-234 concentration in EU was calculated from the concentration of U-235 and the relative activity fraction.

The background count rate for the soils using the FIDLER was 6,194 cpm, with a standard deviation of 790 cpm. This background count rate was based on a total of 15 random measurements of the ground surface outside the excavation.

6.4.3 Final Sampling Analytical Results

The final radionuclide results obtained from the laboratory were analyzed in order to ensure that any residual radioactive material remaining at the site would meet the DCGLs. The final sampling results were compared to DCGLw values, the ALARA value, and the established soil background levels. Additionally, the results were evaluated using statistical analyses (WRS and Sign tests). The sampling results were also evaluated with the unity rule per MARSSIM.

The WRS and Sign tests are selected in the MARSSIM procedures as the appropriate tests to determine whether or not the level of residual activity uniformly distributed throughout the survey unit exceeds the DCGLw. Since these methods are based on ranks, the results are generally expressed in terms of the median. When the underlying measurement distribution is symmetric, the mean is equal to the median. When the underlying distribution is not symmetric, these tests are still true tests of the median but only approximate tests of the mean. However, numerous studies show that this is a reasonable approximation. The assumption of symmetry is less restrictive than that of normality because the normal distribution is itself symmetric. If, however, the measurement distribution is skewed to the right, the average will generally be greater than the median. In severe cases, the average may exceed the DCGLw while the median does not. For this reason, MARSSIM recommends comparing the arithmetic mean of the survey unit data to the DCGLw as a first step in the interpretation of the data.

The WRS test is a two-sample test that compares the distribution of a set of measurements in a survey unit to that of a set of measurements in a reference area. The test was performed by first adding the value of the DCGLw to each measurement in the background area. The combined set of survey unit data and adjusted background area data are listed, or ranked, in increasing numerical order. If the ranks of the adjusted background site measurements are significantly higher than the ranks of the survey unit measurements, the survey unit demonstrates compliance with the release criterion.

The Sign test is a one-sample test that compares the distribution of a set of measurements in a survey unit to a fixed value, namely the DCGLw. First, the value for each measurement in the survey unit is subtracted from the DCGLw. The resulting distribution is tested to determine if the center of the distribution is greater than zero. If the adjusted distribution is significantly greater than zero, the survey unit demonstrates compliance with the release criterion by indicating that the sample results are less than the DCGLws.

Appendix-B, Table 14 summarizes the gamma spectroscopy results and Appendix-B, Table 15 summarizes the results from alpha spectroscopy. Detailed gamma spectroscopy analysis was performed for all soil and water samples, while alpha spectroscopy was completed only for the backfill soils and soils for off-site shipment. The initial gamma spectroscopy results for the excavation bottom soil and water samples did not justify further analyses (e.g., alpha spectroscopy) for those samples. The results are organized into four subsets: excavation pit results, backfill soil pile results, soils for off-site disposal, and water tank results. The excavation pit results represent the samples that were gathered at the bottom of the excavation after the plane wreckage and contaminated soil had been removed. The backfill soil pile results describe those samples taken from the excavated soil that was used as backfill. The results for soils for off-site disposal refer to the soils removed from the excavation that appeared to be contaminated with hydrocarbons. The water tank results represent the samples taken of the water that was removed from the excavation.

Because U-234 is not primarily a gamma-emitter, U-234 results were not reported with the gamma spectroscopy results. Rather, concentrations of U-234 were estimated for each sample based on the reported U-235 activities and the activity fraction for EU (fractions consistent with 93.5 weight percent U-235; listed in Appendix-B, Table 8. Using the enriched uranium activity fraction conservatively assumes that any uranium encountered within the excavation is EU. An estimate of the U-234 activity was not required for the backfill soil alpha spectroscopy results as it was readily identified.

Analyses for both Am-241 and Th-232 were also performed. The laboratory analysis demonstrated that Am-241 and Th-232 were below the established DCGLws and that Th-232 was indistinguishable from background. These results further demonstrate that no plutonium was released during the incident and that the presence of MagThor components did not result in residual Th-232 contamination at the burial site.

6.4.3.1 Excavation Bottom Results

This section presents the soil sampling results for the bottom and side walls (sides of excavation steps) of the entire excavation. Activity concentrations of U-234, U-235, and U-236 were compared to both background levels and individual DCGLws. Additionally, the contaminant levels were compared to the ALARA remediation goal of 30 pCi/g.

In accordance with MARSSIM guidance, basic statistical parameters (mean and standard deviation) were developed for each radionuclide analyzed. A total of four tests or comparisons were performed on the data to determine if radioactivity was present in the soil above the DCGLw. These tests are:

1. Compare the Mean to the DCGLw
2. WRS test
3. Sign test
4. Unity rule comparison summing all the ROCs

The DCGLws, calculated by RESRAD for the prison residential farmer scenario, was compared to the analytical results. All individual concentration results were below the DCGLws. In addition, the sum of the individual mean soil concentrations was below the remediation goal of 30 pCi/g for all radionuclides (see Appendix-B, Table 16).

In addition, the Sign and WRS tests were applied to further document that any residual radioactivity left at the site meets the release criteria. Both the Sign test and WRS test use a critical value to which the sampling results are compared. Based on the α and β parameters established with the FSS Work Plan (Parsons, August 2000) and guidance in MARSSIM, these critical values are determined. The results of these statistical tests are shown in Appendix-B, Table 17. These tests confirmed that the soils left at the bottom of the excavation meet the release criteria.

Finally, the unity rule was applied because of a mixture of radionuclides was present at the site. Typically, each radionuclide DCGLw corresponds to a specific release criterion (e.g., regulatory limit in term of dose or risk). However, in the presence of multiple radionuclides, the sum of the DCGLws for all radionuclides could exceed the applicable release criterion. The MARSSIM unity rule, represented in the equation in Appendix-B Table 18, is satisfied when radionuclide mixtures yield a combined fractional concentration limit that is less than or equal to one.

The result of applying the unity rule indicated that the mixture of radionuclides is well below the overall annual dose guideline of 15 mrem/yr. Appendix-B, Table 19 shows the unity rule calculation results. The unity rule does not correct for background concentrations; however, the DCGL was increased by the background amount to adjust for background. This has the effect of making the unity rule compensate for the fact that background will be present in all the measurements.

In addition to the comparisons and analyses of the laboratory results, on-site field measurements were collected (see Appendix-B, Table 20). Appendix-A, Figures 10 and 11 show the measurement locations and give the results of the one minute areal and one minute static counts using the FIDLER. The excavation bottom shape (see Appendix-A, Figure 10) required that the FSS (Parsons, February 2002) grid be broken up into two rectangular pieces. As shown by Appendix-A, Figures 11 and 12; 32 of the 39 squares scanned were below or within the background level of 6,194 ± 790 cpm. Statistical analysis of the scanning results (see Appendix-B, Table 20) indicates that both the average areal and average point scaler readings are similar to the average background measurement.

6.4.3.2 Backfill Soil Pile Results

Laboratory analysis of the backfill soil pile samples was performed using both gamma spectroscopy and alpha spectroscopy. The statistical analysis of these results was completed consistent with the method presented in Section 6.4.3.1 (Excavation Bottom Results). The comparison DCGLw values, average background values, and the results for the two analytical methods are shown in Appendix-B, Tables 21 and 22. Note: gamma spectroscopy results for U-234 are based on the EU activity ratio of 0.97 to 0.0297 for U-234 to U-235. However, the U-234 concentrations reported with the alpha spectroscopy results are actual measured concentrations. The differences between the two sets of U-234 concentrations are due to the assumptions made for the gamma spectroscopy results.

For both the gamma and alpha spectroscopy analyses, the U-234 and U-238 levels are above the average background concentrations but well within the DCGLw values. The average concentration of radionuclides within the soil is less than the 30 pCi/g remediation goal.

As with the excavation bottom results, the WRS and Sign tests were performed with the data. The application of the Sign and WRS tests to the gamma and alpha backfill soil pile sampling results are shown in Appendix-B, Tables 23 and 24, respectively. In addition, the WRS test was performed for the total uranium concentrations (based on the alpha spectroscopy results) in the backfill soil samples and the background samples plus the 30 pCi/g ALARA remediation goal. As shown in Appendix-B, Table 24, the concentrations of total uranium in the backfill soil meet the 30 pCi/g criterion. Based on these results, the excavated soils were deemed suitable for use as backfill.

Application of the MARSSIM unity rule to the backfill soil pile data indicates that the results do not exceed the annual dose guideline of 15 mrem/yr. This calculation was performed using the method of Section 6.4.3.1 (Excavation Bottom Results) with the background results added to the DCGLw values. The calculation results are shown in Appendix-B, Tables 25 and 26, respectively. Both the gamma and alpha spectroscopy results satisfy the unity rule.

In addition to the laboratory results, on-site scanning data was gathered (see Appendix-B, Table 27). Appendix-A, Figures 13-16 show the approximate soil sampling locations and give the results of the one-minute areal counts using the FIDLER. The background one-minute count rate for the soils using the FIDLER was 6,194 cpm with a standard deviation of 790 cpm.

6.4.3.3 Water Holding Tank Results

In order to release the water removed from the excavation and held within the water holding tank, the gamma spectroscopy results were compared to applicable release criteria. The release criteria used for comparison are the federal sanitary sewer criteria (10 CFR 20.2003) for NRC licensees. While 10 CFR 20.2003 applies only to NRC licensees, it is acceptable to implement the rule as a ARAR as it is applicable to this type of scenario (release to a sanitary sewer) and it is protective of human health and the environment. The release criteria for each ROC are contained in Appendix-B, Table 28. Requirements from 10 CFR 20.2003 state that: (1) the release must be less than the monthly average values, (2) for multiple radionuclides, the monthly release must meet a sum of fractions test, shown in Appendix-B, Table 29; (3) the total release of radioactivity must be less than 1 curie (Ci) per year, shown in Appendix-B, Table 30; and (4) the material must be readily soluble. Calculations were performed to assess that a release to a sanitary sewer would meet these requirements. As with the soil samples described above, the U-234 activities are conservatively estimated based on the reported U-235 activities and EU activity fractions. As shown in Appendix-B, Table 28, the estimated monthly release based on the water samples from the water holding tank and excavation are well below the federal sewer release criteria.

Given there are multiple radionuclides present in the water samples, a sum of fractions calculation must be completed for all of the radionuclides. The sum of fractions test was performed by summing the monthly release concentrations for each radionuclide and then dividing by the release criteria for that radionuclide. The equation listed in Appendix-B, Table 31 was used to complete this calculation. Appendix-A, Figure 18 displays how the sum of the fractions calculation varies as a function of sewer monthly average volume. Appendix-A, Figure 18 also shows that the additional minimum flow volume (i.e., volume other than the tank liquid) required to meet the sum of fractions requirement is 1000 gallons per month. However, since the actual flow volume is approximately 3,000 gallons per month, this was the value used in assessing this release. Also higher flow volumes would result in lower fractions. Appendix-B, Table 28 lists the monthly release fraction information for each radionuclide based on the tank volume of 2,750 gallons and sewer monthly average flow of 3,000 gallons.

The next requirement is to assess the total amount of radioactivity to be released over an entire year. The total amount of activity to be released from the water holding tank can be estimated by multiplying the water volume within the tank by the radionuclide concentrations. The volume of the tank was conservatively estimated to be 2,750 gallons. Appendix-B, Table 30 shows that no more than 15 microcuries (Ci) would be released, which is well below the limit of 1 Ci per year. Given the radionuclide concentrations present in the water samples, it would take over 65,000,000 gallons to exceed the 1 Ci per year release limit. It is assumed that the licensee will release no other sources of radioactive material to this system.

The final requirement is that the material to be released is readily soluble. The material analyzed in the sample was soluble.

6.5 Excavation Restoration

6.5.1 Backfilling Excavation

Once the sidewalls and floor of the excavation and the backfill soils were determined to be uncontaminated, the excavation was backfilled with the clean soils. Additional uncontaminated soil was brought in from off- site to complete the backfill and the site was restored to its original grade (all of the backfilling equipment was scanned with the FIDLER and GM probe prior to being filled uncontaminated, off-site soil and was determined that none of the equipment had measurements of radioactivity above regulatory levels). Approximately 2 cubic ft of soil across the site was required. The entire area was walked-over and scanned with the FIDLER to ensure that there were no areas with measurements of radioactivity above regulatory levels. Additionally, a final scan of the areas where the clean excavated soils were stored was completed in the same manner.

After completion of backfilling activities, the excavation and grading equipment were scanned for contamination with the FIDLER and GM probe. All contaminated soil was removed from the equipment and placed in the contaminated soil roll-off boxes. The water holding tank, which contained water that was removed during the excavation, remained at the site until water sampling results were determined by laboratory analysis.

6.5.2 Soil Transportation and Disposal

Contaminated soils in the roll-off boxes were transported by a Department of Defense approved waste broker, Cabrera Services,Inc. Contaminated soils and materials were transported either to WCS, in Texas, or to Envirocare, in Utah, for disposal. Waste profiles, manifests, and Certificates of Disposal are documented in a final report titled, *Radiological Characterization Waste Brokering and Shipping, B-58 Aircraft Burial Site,* (Cabrera, January 2002), and is available for review upon request in the Grissom AFBCA's Administrative Record.

6.5.3 Water Disposal

Water collected during dewatering activities in the excavation was stored in a water holding tank located next to the excavation pit. Samples were taken from the water holding tank for analysis of radionuclides by AFIERA. The water sample analyses showed levels of radioactivity to be below sanitary sewer release criteria. As a result, the water was released into the Peru Utilities Wastewater Treatment Plant for disposal.

6.6 Dose Comparison

This section compares the dose that could potentially be received by the scenario receptors to the background radiation exposure to which the general public is exposed. The background exposure which an average member of the U.S. population receives per year is 360 mrem (BEIR V, 1990). This background exposure includes radiation from three specific sources: naturally occurring radiation, medical uses of radiation, and radiation from consumer products. For the closure of the contaminated area, the DCGLws that were developed were based on a dose limit of 15 mrem/yr (USEPA, 1997b), or 4.2 percent of the typical background exposure. In addition, an ALARA remediation goal of 30 pCi/g, corresponding to a dose limit of 1 mrem/yr for total uranium, was adopted. A 1 mrem/yr dose limit is equivalent to approximately 0.3 percent of the typical background exposure.

Appendix-B, Table 32 shows the potential doses for the various soil sources. The extrapolated potential doses were calculated by taking the ratio of the mean concentration of each radionuclide (minus the background concentration) to its respective DCGLw and summing. This ratio was 0.023 (or 2.3 percent) for the excavation bottom and 0.059 (or 5.9 percent) for the backfill soil piles based on the gamma spectroscopy results and 0.11 (or 11 percent) for the backfill soil piles based on the alpha spectroscopy results. These ratios, in relation to the 15 mrem/yr dose limit, equate to 0.35 mrem/yr for the excavation bottom and 0.89 mrem/yr for the backfill soil piles based on the gamma spectroscopy results and 1.65 mrem/yr for the backfill soil piles based on the alpha spectroscopy results. Additionally, the percentage of the 15 mrem/yr dose limit corresponding to this value and the percentage of the typical background dose are given. Appendix-B, Table 32 shows that the dose to the potential exposure receptors is below a few percent of the typical background exposure that the average member of the U.S. population receives. With the $DCGL_W$ values developed using conservative assumptions, it is expected that any potential exposures to residual radioactivity left at the burial site will be minimal and will not significantly affect the health of a receptor.

To further investigate the potential exposure to the limiting case receptor (prisonresidential farmer), the RESRAD model that was used to develop the DCGLws was used to assess the potential exposure. This was completed by using the identical input parameters with the backfill soil pile radionuclide mean concentrations. Two runs were completed, one using the gamma spectroscopy results and the other with the alpha spectroscopy results. The output of these runs is shown in Appendix-A, Figures 19 and 20. As with the comparison depicted in Appendix-B, Table 32; Appendix-A, Figures 19 and 20 indicate that the potential exposure to the receptor is a small fraction of the ambient background radiation incurred annually and well below 15 mrem/yr. The peak dose represented in the figures indicates when radon-222 (Rn-222) has become a significant dose contributor due to radium-226 (Ra-226) ingrowth.

6.7 ALARA Assessment

The final step in the FSS (Parsons, February 2002) was to show that any residual radioactivity left after the remedial action meets the ALARA requirements, as well as the 15 mrem/yr dose goal, as outlined in MARSSIM and in DG-4006 (NRC, 1998). The simplified method presented in DG-4006 is to estimate when further remedial action is cost effective. If the desired beneficial effects ("benefits") from the remedial action are greater than the undesirable effects or "costs" of the action, the remedial action is cost effective and should be performed. Conversely, if the benefits are less than the costs, the levels of residual radioactivity are already ALARA without taking the remedial action. In order to compare the benefits and costs of a remedial action, it is necessary to use a comparable unit of measure. The unit of measure used here is the dollar; all benefits and costs are given a monetary value. While materials potentially still remaining or recovered from the burial site are not NRC-licensed, it is acceptable to perform an ALARA assessment using NRC guidance because it is an industry-accepted practice and it is protective of human health.

As presented in DG-4006, the residual radioactivity level is ALARA when the impact of the concentration equals the cost associated with further remediation. DG-4006 uses an expression that equates the ratio of the ALARA concentration (Conc) over the DCGLw to the cost and benefit expressions. If this ratio (ALARA ratio) is greater than one then the remedial action meets the goals of ALARA and no further action is required. Conversely, if the ratio is less than one then further remediation should be implemented. This is shown in the equation listed in Appendix-B, Table 33.

This calculation is done for each of the radionuclides that are within the soils being remediated, and summed for the final evaluation. The total cost to further remediate the site is assumed to be the same as the current effort given that the burial site area would need to be excavated in a similar manner. To complete the benefit term (right side of the equation minus the cost) is first calculated for each of the soil sources. These values are then summed, and divided into the total cost for the remedial action to find the ALARA ratio. If this ratio is found to be less than one, further remediation may be warranted to satisfy ALARA. If the ratio is greater than one, the remediation is considered to meet the principles of ALARA. When this calculation is completed for the two source areas (excavation bottom and backfill soils), the ratio is equal to 136, given the above parameters. As a result, the remediation meets the principles of ALARA.

6.8 Summary of Findings

The following findings were made during the excavation, final status survey, and data analyses.

- The excavation procedure set forth in the Final Status Survey Work Plan (Parsons, August 2000) was successful in removing contaminated debris and soil at the B-58 Hustler Burial Site.

- Contaminated soil and debris characterized on-site and contaminated wastes were separated from clean soil that was utilized as backfill at the completion of the excavation.

- The survey instruments were calibrated to detect the ROCs and daily checks indicated acceptable instrument performance during the excavation and survey for field control of excavation activities.

• The DCGLw values established using RESRAD and presented in the FSS Work Plan (Parsons, August 2000) were adequate to ensure that the maximum exposure to on-site receptors would not exceed 15 mrem/yr.

• Comparisons of the mean results for all radionuclides for all soil were below DCGLw values.
• The sums of the mean results for total uranium were below the remediation goal of 30 pCi/g for uranium.

• Statistical analyses (WRS and Sign tests) of the soil and water results verify that the soil and water on-site are below DCGLw values. In addition, the statistical analyses performed on the alpha spectroscopy total uranium data demonstrate that the total uranium results at the site are below the ALARA goal of 30 pCi/g.

• The final regraded excavation site was scanned and found to be indistinguishable from background using both the FIDLER and the 3" x 3" NaI detectors.

6.9 Conclusions

Based on the findings listed above, it can be concluded that the excavation successfully removed the radioactively contaminated B-58 aircraft debris and soil from the B-58 Hustler Burial Site (AOC 8) near Grissom ARB, Indiana. Analysis of the soil samples taken during and after the excavation show that any residual contamination at the site is well below both the DCGLw values as determined by MARSSIM protocol and the preliminary ALARA goal of 30 pCi/g of total uranium. As such, the burial site is suitable for unrestricted reuse.

7.0 Regulatory Agency Involvement

7.1 Regulatory Review and Approval of Final Status Survey Report

The *B-58 Final Status Survey* prepared by Parsons Engineering Science, Inc. in February 2002 under Project Number CTGC-2000-6108, was submitted to Indiana State Department of Health, IDEM, and U.S. EPA for review. Draft comments were received from IDEM and U.S. EPA in letters dated September 6, 2001 and October 12, 2000, respectively. IDEM and U.S. EPA had no comments and concurred with the findings of the report.

7.2 Regulatory Review and Approval of Decision Document

The draft decision document dated July 2002 was submitted to IDEM and U.S. EPA for review and comment in a letter dated 12 July 2002. IDEM's and U.S. EPA's draft comments were received by the Air Force in letters dated September 24, 2002 and October 2, 2002, respectively. Air Force responses to IDEM's and U.S. EPA's draft comments were submitted to the agencies in a letter dated November 8, 2002. IDEM and

U.S. EPA concurred with the no further remedial action planned remedy in letters dated **TBD** and **TBD**, respectively. IDEM's and U.S. EPA's draft comments and the Air Force's responses to those draft comments are listed below:

IDEM Draft Comments/Air Force Responses

Specific Comments

Page 7, Declaration of the Remedy: Please remove "...the selected remedy of..." in the second sentence. No further action is not considered a remedy.

Air Force Response: *"the selected remedy of"* has been removed from the subject text.

Page 9: It is not necessary to obtain Rex Bowser's signature for closure unless the Air Force is adamant about doing so.

Air Force Response: Comment noted.

Page 22, Section 6.2.2, Last Paragraph: Please remove "that" from the first sentence.

Air Force Response: "that" has been removed from the subject text.

Page 27, Section 6.4.3.1, Last Paragraph: Please remove the extra line in the second sentence.

Air Force Response: The extra line has been removed from subject text.

Page 31, Section 6.5.1, First Paragraph: Please clarify whether the third sentence discusses "2 ft" of soil or "2 cubic ft" of soil.

Air Force Response: For clarification, the subject text has been changed to read "2 cubic ft of soil.

Page 34, Section 6.8: Please add a line between the second and third bullets.

Air Force Response: A line has been added between the second and third bullets of the subject text.

Page 34, Section 7.0, Second Sentence: An "and" is needed after "IDEM."

Air Force Response: "and" has been inserted after "IDEM" of the subject text.

U.S. EPA Draft Comments/Air Force Responses

General Comments

1. **The Draft Decision Document (DD) for the B-58 Hustler Burial Site, (Area of Concern (AOC) 8)** is a well-written, well thought out explication of the work that was done at the B-58 Burial Site (Site). The analysis of the data generated as a result of that work establishes a sound basis for the conclusion stated at the end of the document, that the Site has satisfied all requirements for closure with unrestricted use and No Further Action (NFA). EPA concurs with the overall conclusions and recommendations presented in the DD. However, there are several instances where explanation is unclear, incomplete or ambiguous. Please see the specific comments below.

Air Force Response: Comment noted.

2. **EPA recommends that the DD include a list of acronyms.**

Air Force Response: A list of acronyms has been added to the document and is located in Appendix C.

Specific Comments

1. **Page 7, Declaration of the Remedy, last line**: The DD states that "*...no treatment is necessary and the site is suitable for clean closure and unrestricted us.*" The use of the term "clean closure" may be misleading, insofar as the term is commonly used to describe complete remediation of contaminated sites pursuant to the requirements of the Resource Conservation and Recovery Act (RCRA). EPA agrees that the site is suitable for unrestricted use.

Air Force Response: The subject text has been changed to read: "*...no treatment is necessary and the site is suitable for unrestricted use.*

2. **Page 14, Section 3.5, History**: The end of this section states that plutonium was not released to the environment. The next sentence discusses contaminated portions of the runway and adjacent soils that were excavated and buried. Since plutonium is identified as a contaminant that was not released, the contaminants referred to should also be identified.

Air Force Response: For clarity the word "Contaminated" has been removed from the subject text since there was no "known" release of any radiological or chemical contamination above regulatory levels at AOC 3 (Temporary Nuclear Weapon Disposal Site/Accident Site) at the time in which portions of the runway, adjacent soils, and the remaining aircraft wreckage were excavated, transported, and buried at AOC 8 (B-58 Burial Site). The text now reads: *"Portions of the runway and adjacent soils were subsequently excavated and buried nearby along with the remaining aircraft wreckage at the site referred to as AOC 8."*

3. **Page 15, Section 3.6, Previous Site Investigations, last ¶, first line**: Spell out AFIERA. This appears to be the first instance of the use of the term in the DD.

Air Force Response: The acronym AFIERA (Air Force Institute for Environment, Occupational Safety and Health Risk) is previously used and spelled-out on Page 7 under Statement of Basis and Purpose.

4. **Page 16, Section 4.0, Initial Scoping Survey (February 2000), fourth line**: It is stated that the background location was across the street from the site. The background site should be identified more carefully. EPA does not recall a "street" in the area of the B-58 Burial Site.

Air Force Response: The text was ambiguous in stating that the background site location was located across the street from the B-58 Burial Site. It actually is located across an unmapped gravel road (not a street) approximately 300 ft southeast of the burial site. For clarity, the subject text has been changed to read: *"The background location was across an unmapped, gravel road approximately 300 ft southeast of the burial site."*

5. **Page 16, Section 4.2, Measurements, last two sentences**: Please expand on this explanation by discussing the terms "*scaler mode*" and "*rate meter mode*."

Air Force Response: The subject text has been revised to include the following definitions of *"scaler mode"* and *"rate meter mode"*: *"Scaler mode"* refers to an instrument that is set to take a counted measurement of radioactivity over a set period of time, typically one minute. The output is a discrete number of hits or counts per minute (i.e., 2545 counts per minute (cpm)). Using the scaler mode to take a measurement increases the sensitivity of the instrument since the instrument is placed over one location for a set amount of time. *"Rate meter mode"* refers to an instrument that has an output of a continuous counting rate displayed on a gauge on the meter. The operator determines the amount of radioactivity present by watching the fluctuations of the needle on the meter, and recording the range (i.e., 2000-3000 cpm). The type of instrument is generally used during scanning surveys.

6. **Page 16, Section 5.0, Intrusive Scoping Survey (February-March 2000)**: The first sentence of this section does not follow from the conclusion of Section 4.3. If the site survey results were indistinguishable from background for both of the survey instruments, then there would be no reason, based upon survey results, to perform an intrusive survey. As suggested in the next statement in Section 5.0, "*The primary purpose of the intrusive survey was to determine if the anomaly was a buried fuselage from the accident site, and if contamination was present.*"

Air Force Response: For clarity, first sentence in Section 4.3 and the first and second sentences in Section 5.0 have been revised and read: Section 4.0, first sentence; "*Parsons and AFIERA conducted a preliminary radiological walk-over survey (part of Final Status Survey) in February 2000 to verify the results of the radiological walk-over survey performed by U.S. EPA in September 1998 which found no radiological* *contamination above background at the burial site."* Section 5.0 first and second sentences; *"The primary purpose of the intrusive survey was to determine if the anomaly found in U.S. EPA's 1998 geophysical survey was a buried fuselage from the accident site and if radioactive contamination was present deeper than 1 ft bgs (As discussed in Section 4.1, 1 ft bgs is the maximum depth the instrumentation used in the walk-over survey can detect radiological contamination)."*

7. **Page 23, Section 6.2.2, Excavation Activities, last ¶, penultimate sentence**: This sentence would make sense if it state that "*...no more debris was encountered and ~~the~~ no soil appeared to be present except for undisturbed native clay.*" As it is, it is unclear.

Air Force Response: For clarity, the subject text has been changed to read: *"At this depth, no more debris was encountered and no soil appeared to be present except for undisturbed native clay."*

8. **Page 31, Section 6.5.1, Backfilling Excavation, first ¶, penultimate sentence**: EPA assumes that this sentence is intended to state that the entire area was walked-over and scanned with the FIDLER to ensure that there were no areas with measurements <u>above the appropriate criteria</u>.

Air Force Response: For clarity, the subject text has been changed to read: *"The entire area was walked-over and scanned with the FIDLER to ensure that there were no areas with measurements of radioactivity above regulatory levels."*

9. **Page 34, Section 6.9, Conclusions, first sentence**: It is assumed that the intent of this sentence is to state something like the following: "*...it can be concluded that the excavation successfully removed ~~of~~ the radioactively contaminated B-58 aircraft debris and soil ~~were successfully removed~~ from the B-58 Hustler Burial Site (AOC 8) near Grissom ARB, Indiana.*"

Air Force Response: For clarity, the subject text has been changed to read: *"Based on the objectives and findings listed above, it can be concluded that the excavation successfully removed the radioactively contaminated B-58 aircraft debris and soil from the B-58 Hustler Burial Site (AOC 8) near Grissom ARB, Indiana."*

10. **Page 34, Section 6.9, Conclusions, last line**: See Specific Comment No. 1.

Air Force Response: The subject text has been changed to read: *"As such, the burial site is suitable for unrestricted reuse."*

11. **Page 35, Section 9.0, Current Site Status, last line:** See Specific Comment No. 1.

Air Force Response: The subject text has been changed to read: *"...the B-58 Hustler Burial Site is suitable for unrestricted reuse."*

8.0 Community Participation

The community participation requirements for the former Grissom AFB, follow the guidance and procedures instituted by the Air Force. The community participation activities for this decision document are described below:

A Restoration Advisory Board (RAB) has been established for the former Grissom AFB with regularly scheduled quarterly meetings, in which all pertinent restoration related activities are communicated to the public. Notices of RAB meetings are published in the local community newspapers and a mailing list of over 125 citizens is being maintained. The quarterly meetings are attended and reported by local newspapers.

The public participation process to date for the B-58 Hustler Burial Site consists of the following:

The public was briefed on the B-58 Hustler Burial Site at the February 2000, August 2000, November 2000, February 2001, May 2001, September 2001, and February 2002 Grissom AFB RAB meetings. The comments and responses from the public at the meetings were recorded.

9.0 Current Site Status

Based on the findings listed above (documents that no radioactive B-58 aircraft debris or soil remain at the B-58 Hustler Burial Site (AOC 8) near Grissom ARB, IN which exceed regulatory standards and regulations), the B-58 Hustler Burial Site is suitable for unrestricted reuse.

10.0 Risk Determination

The criteria for unrestricted use require that the TEDE be less than 15 mrem/year (USEPA, 1997b) and excavation actions are ALARA. In order to determine that the site meets these standards, DCGLw values were calculated using RESRAD. Soil samples collected during and after the excavation process were below the DCGLw values. Therefore, there is no unacceptable risk to human health and the environment. The site meets all the above regulatory criteria for clean closure and unrestricted reuse.

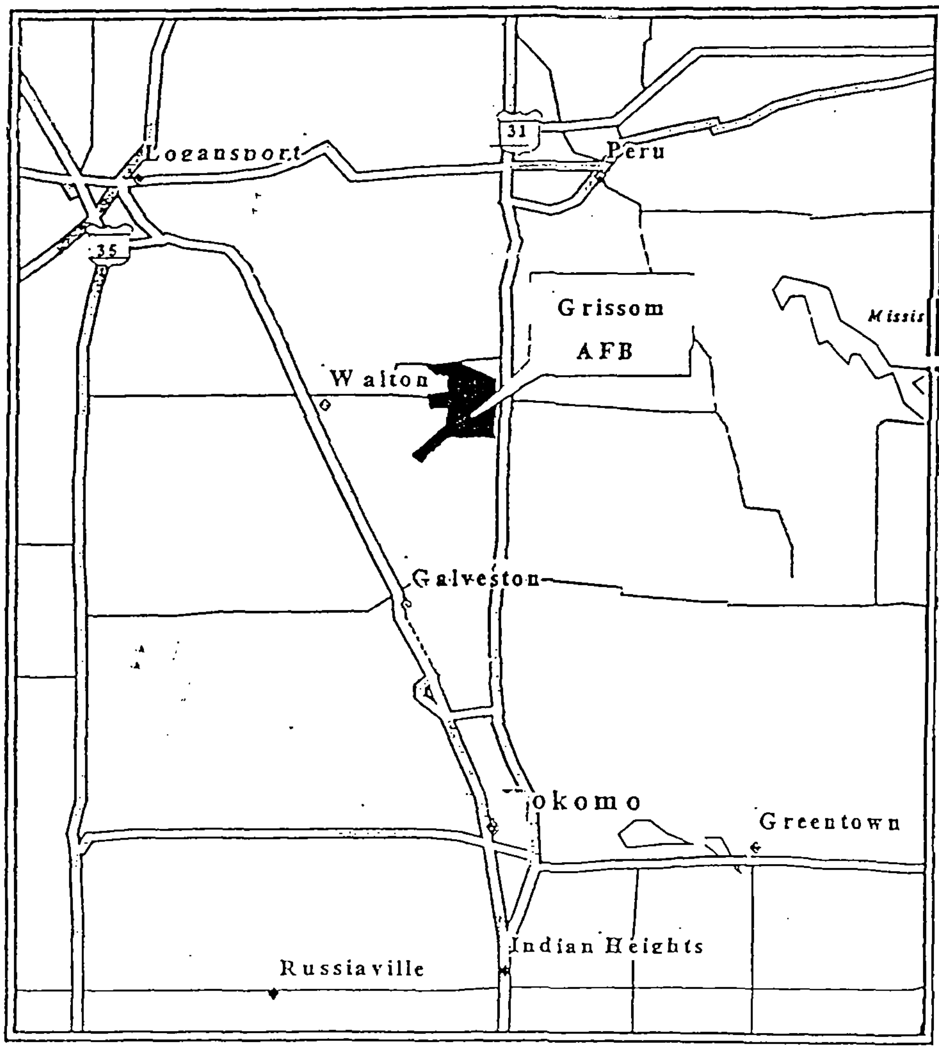
11.0 Selected Action: No Further Action

Based upon the fact there is no unacceptable risk to human health and the environment after successful completion of excavation activities as documented in the *Final Status Survey Report/B-58 Hustler Burial Site/AOC 8* (February 2002), the B-58 Hustler Burial Site (AOC 8) has satisfied all the requirements for closure with unrestricted reuse. Therefore the selected action for the B-58 Hustler Burial Site (AOC 8) is no further action necessary.

Appendix-A, Figures

Figure 1

Grissom AFB and Surrounding Communities



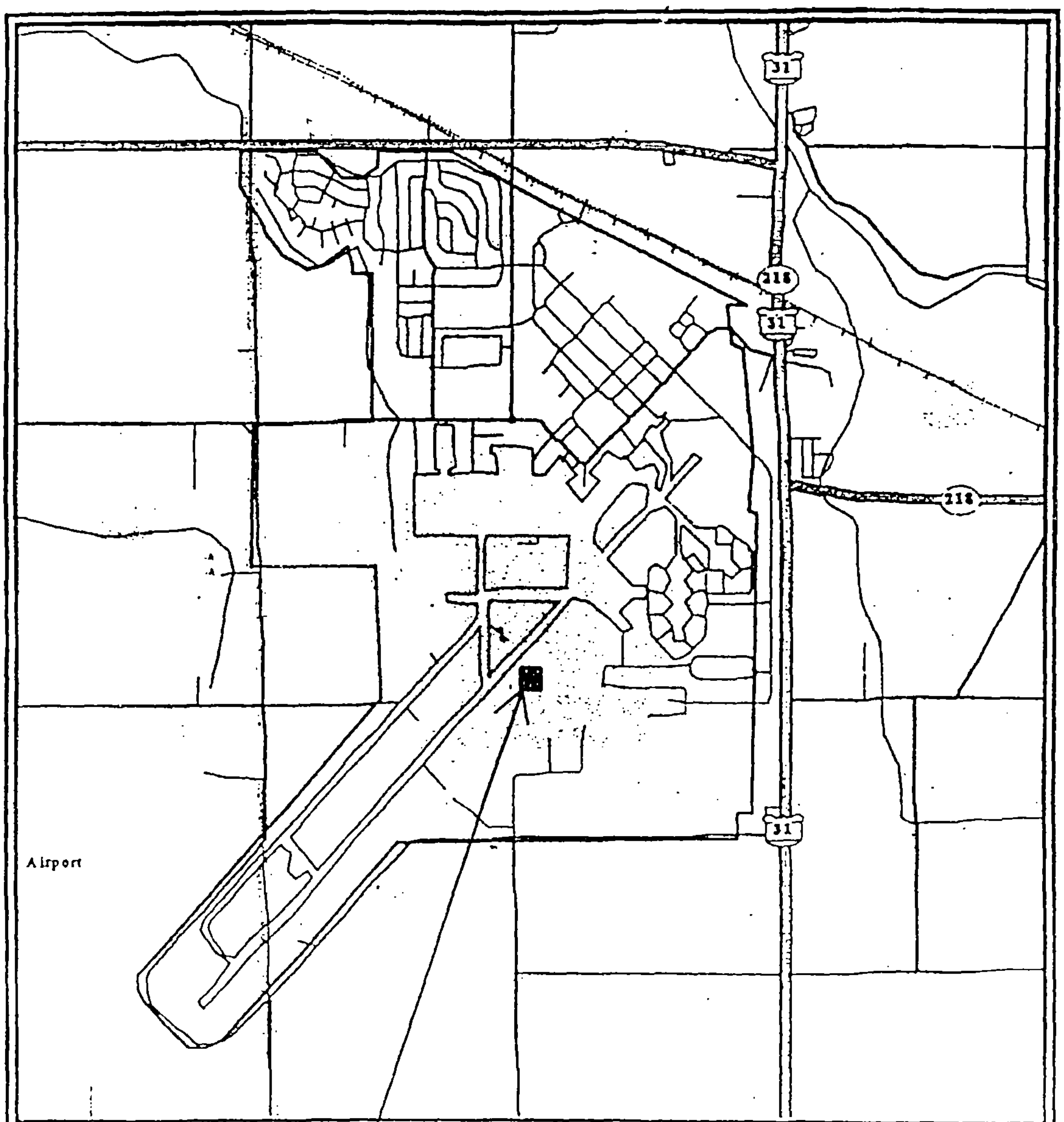
Approximate highway distances from Grissom AFB to selected neighboring communities:

Logansport	18.1 miles	Peru	9.1 miles	Galveston	8.5 miles
Kokomo	12.0 miles	Walton	7.5 miles		

Figure 2

Facility Plan, Grissom AFB

Grissom AFB Facility Plan



Approximate Location of B-58 Hustler Burial Site

Figure 3

Generalized Geologic Cross Section, Grissom AFB

Generalized Geologic Cross Section, Grissom AFB

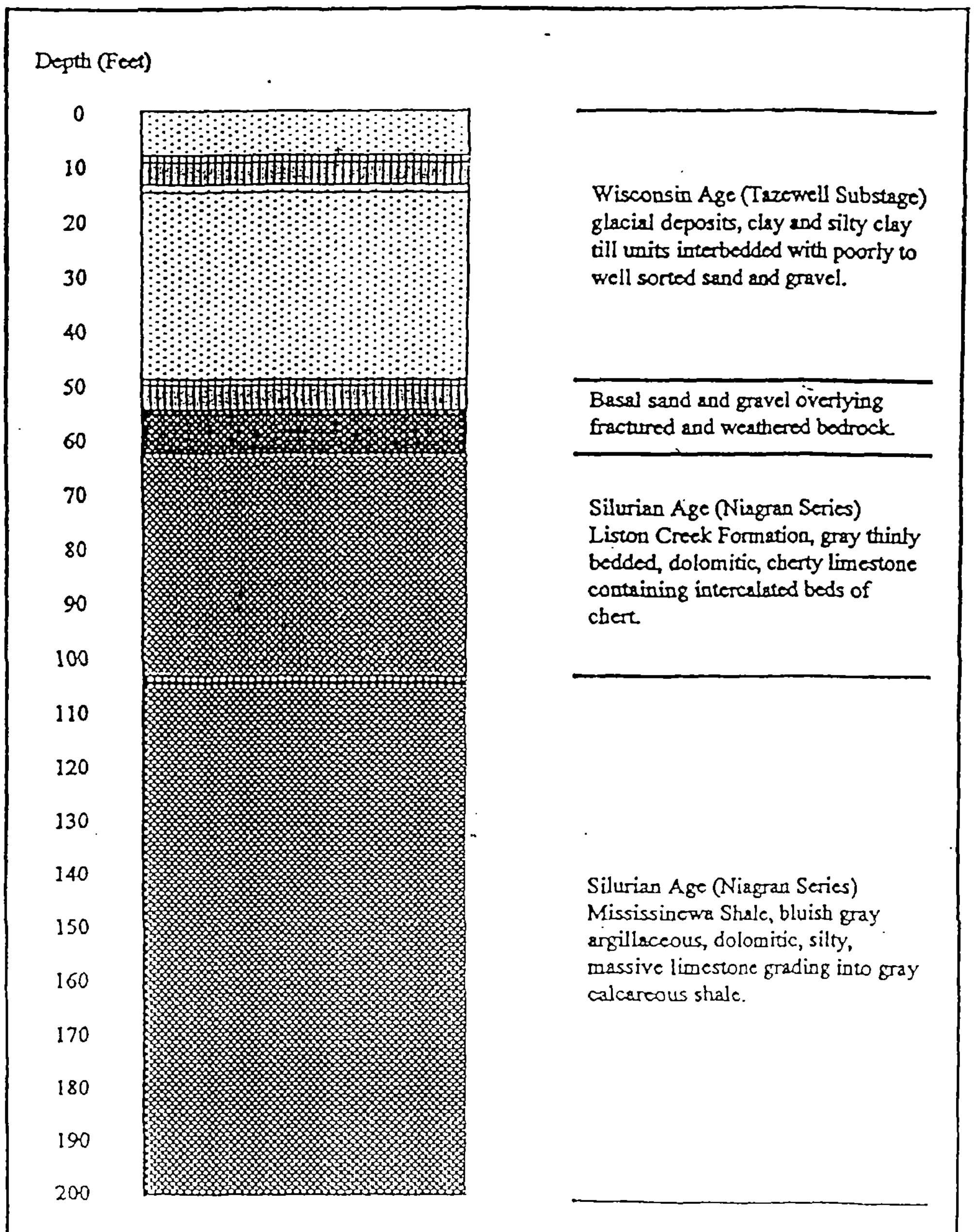


Figure 4

Regional Surface Drainage, Vacinity of Grissom AFB

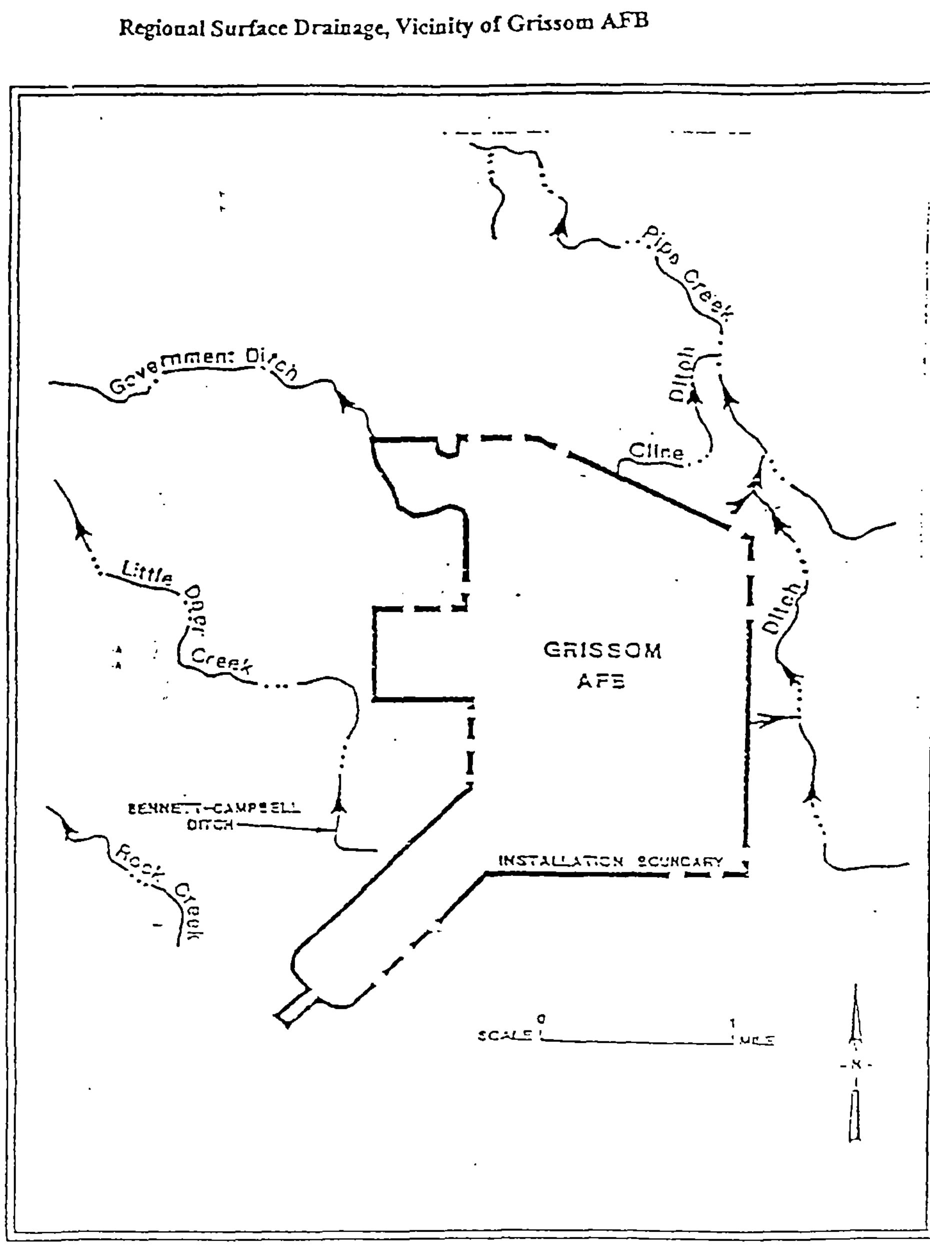


Figure 5

Facility Surface Drainage, Grissom AFB

Facility Surface Drainage, Grissom AFB

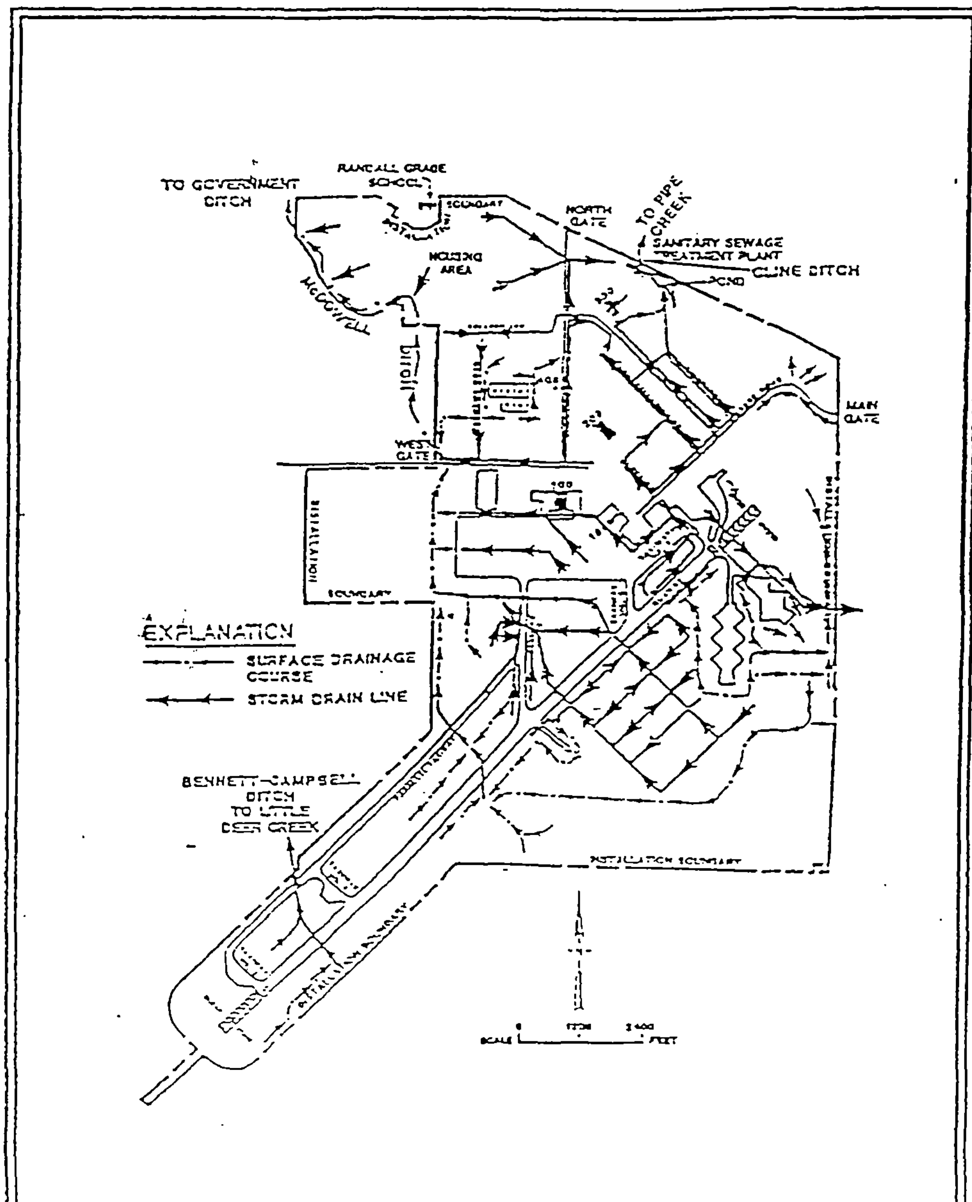


Figure 6

Groundwater Supply Well Locations, Grissom AFB

Groundwater Supply Well Locations, Grissom AFB

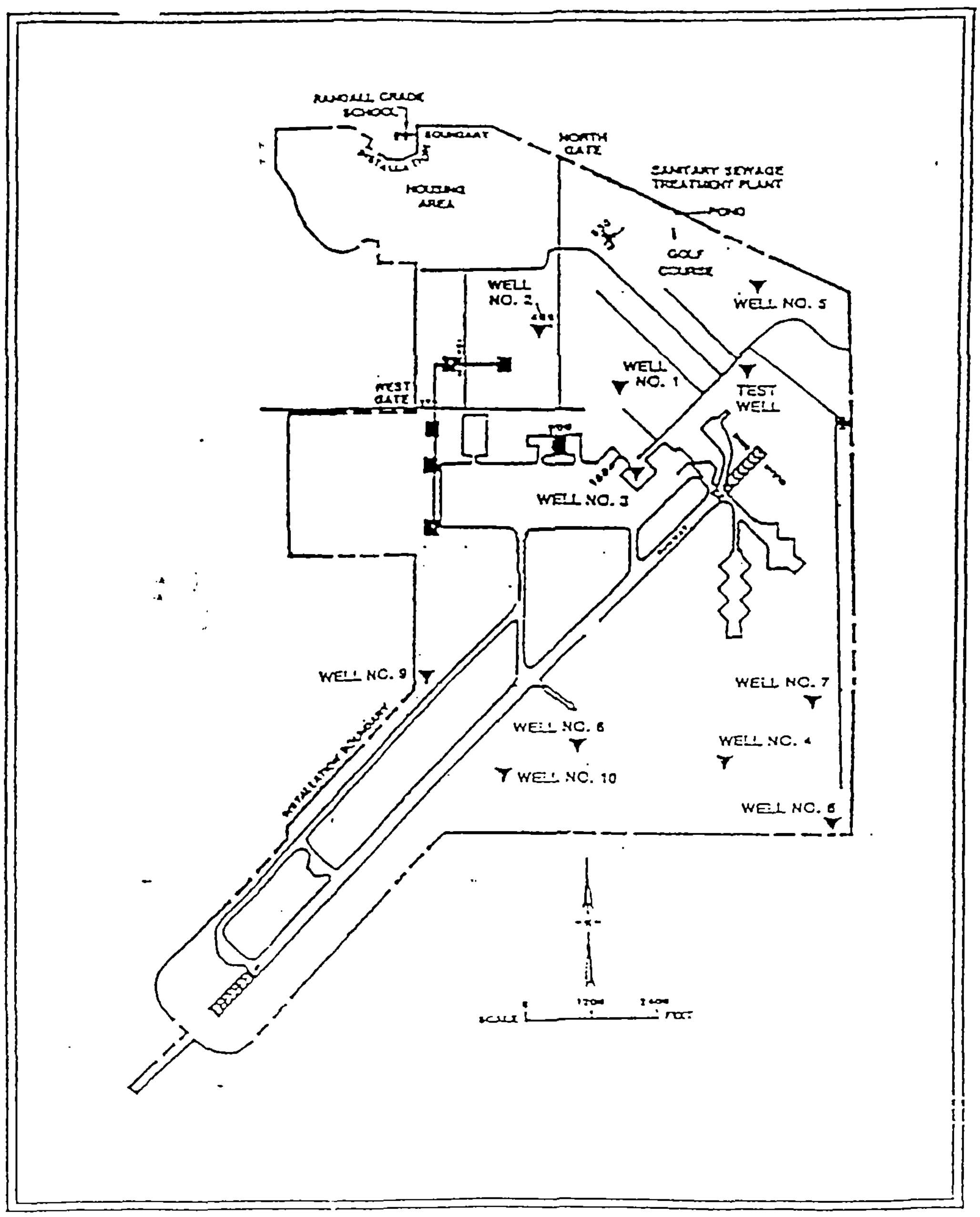


Figure 7

Location Map/B-58 Hustler Burial Site

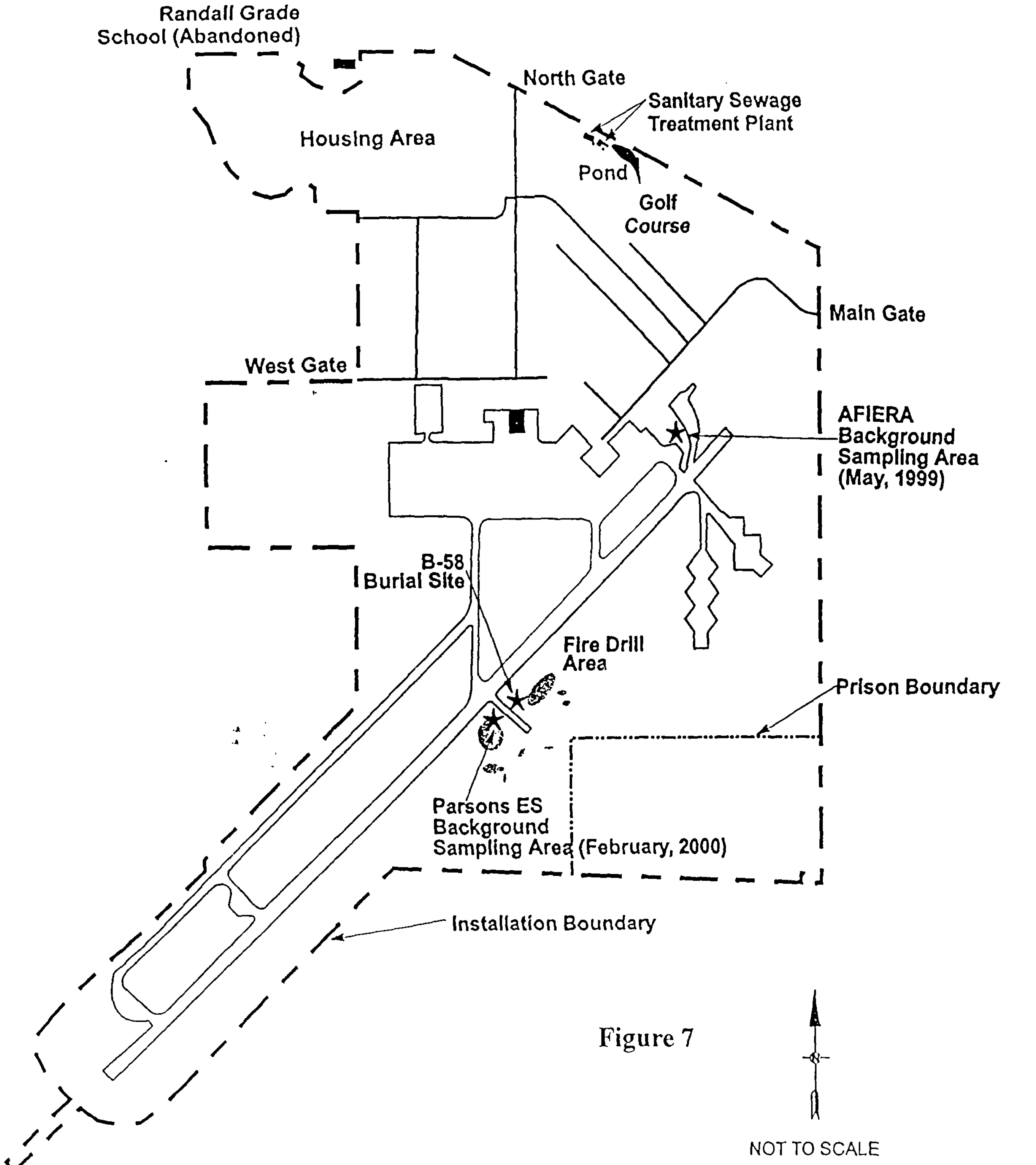


Figure 7

LOCATION MAP FOR THE B-58 HUSTLER BURIAL SITE

Former Grissom AFB, Indiana

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Figure 8

Location of Metallic Anomaly

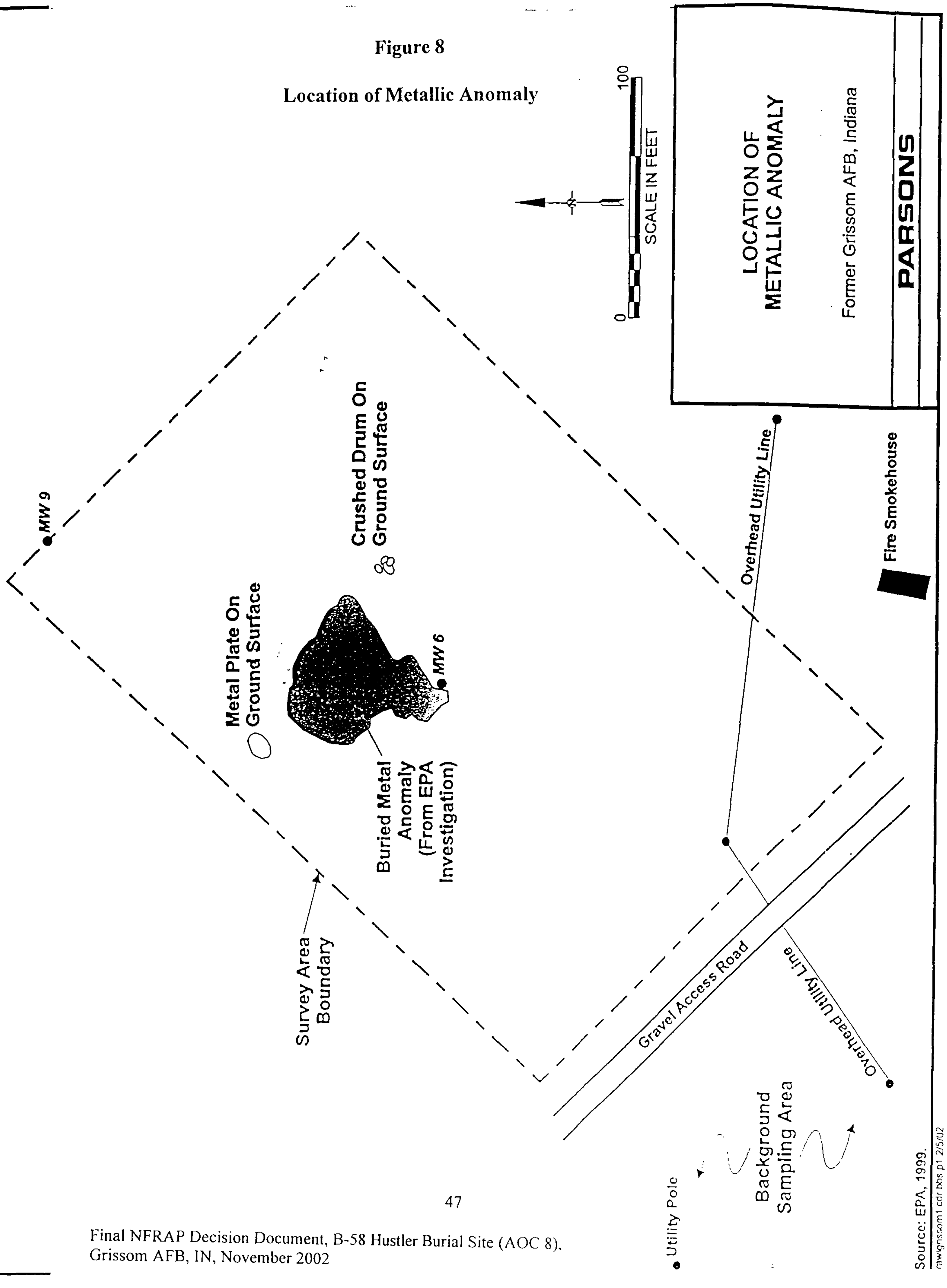


Figure 9

Intrusive Survey Sampling Locations

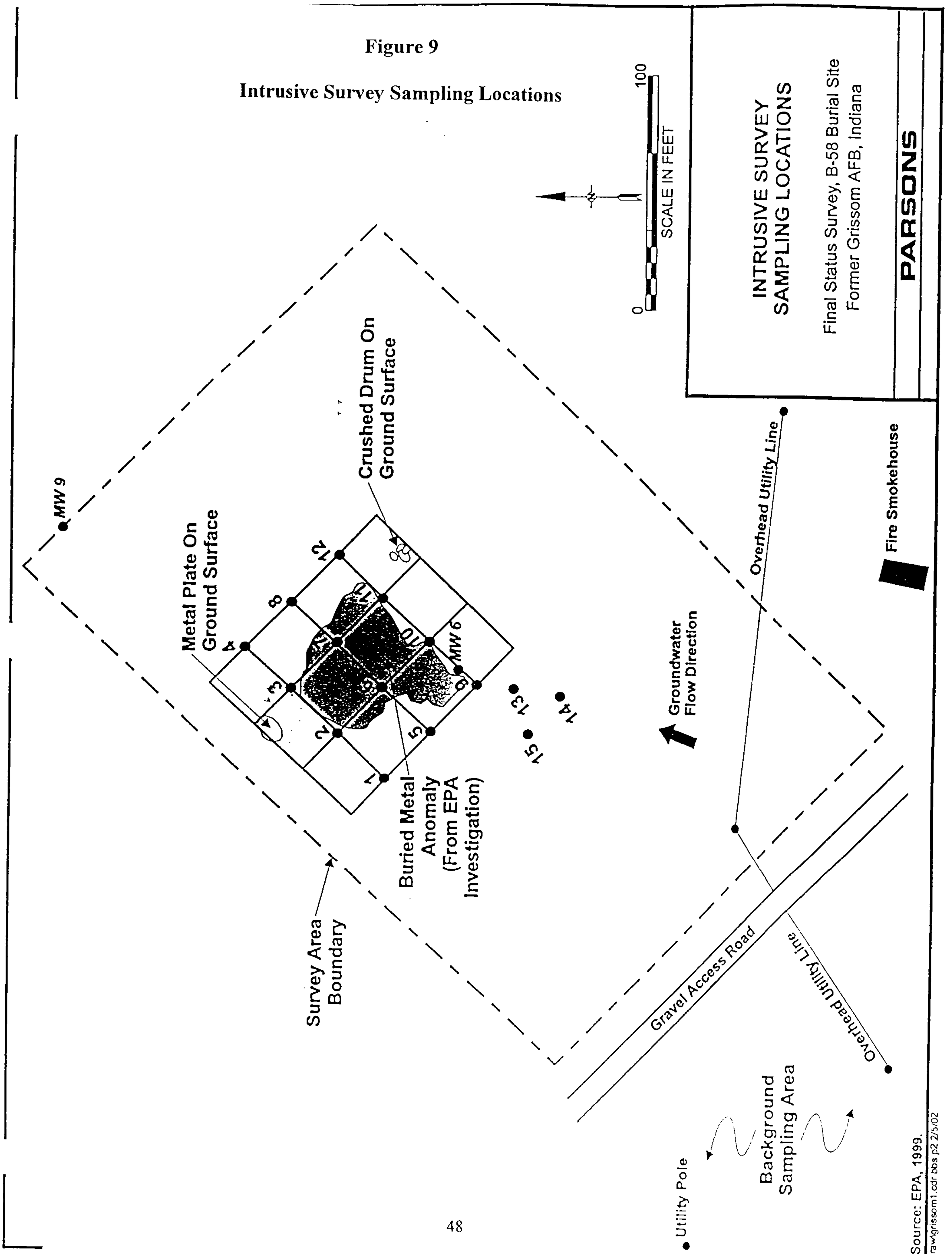
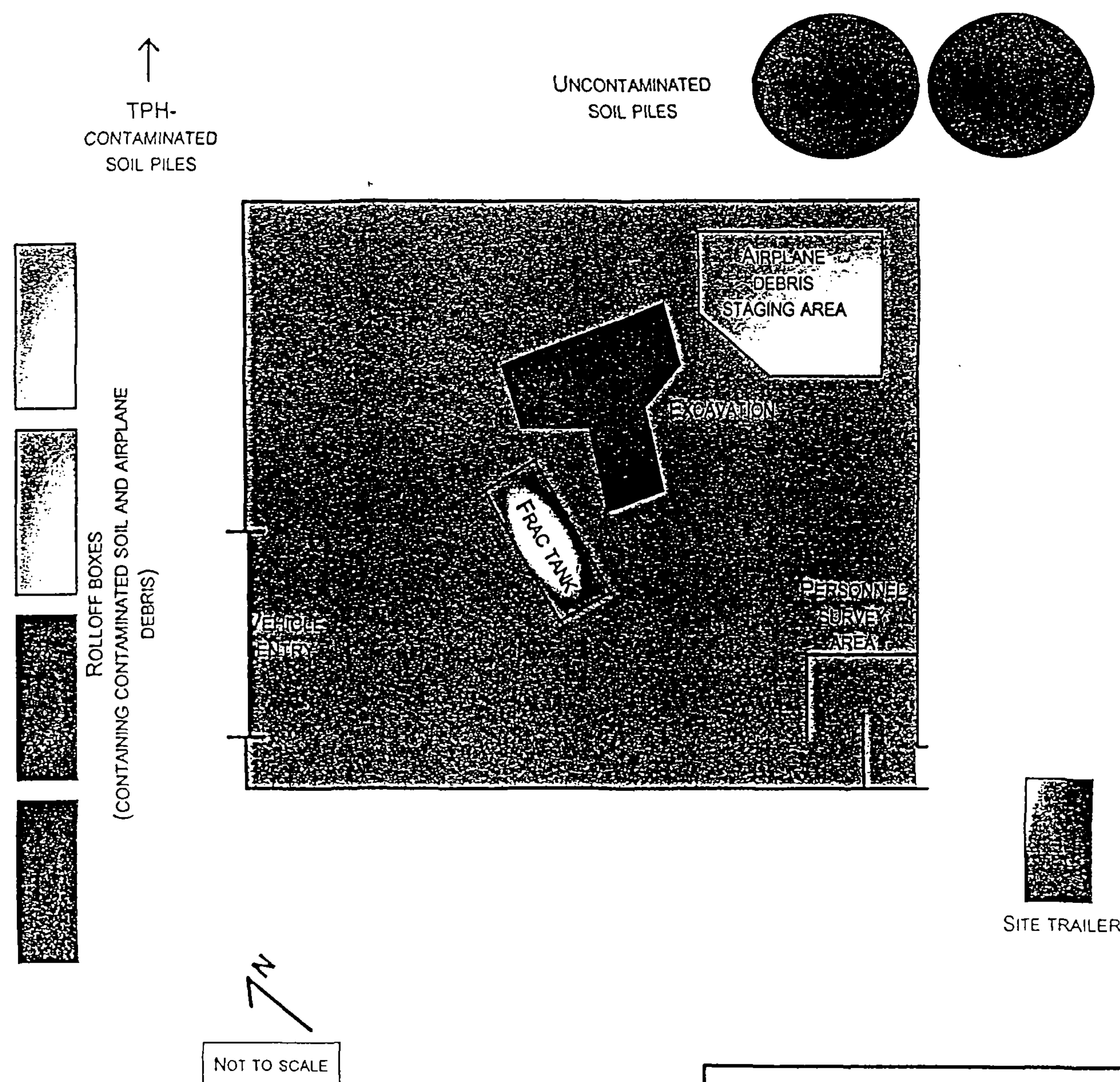


Figure 10

Layout of Excavation Site



LAYOUT OF EXCAVATION SITE

Final Status Survey, B-58 Burial Site
Former Grissom AFB, Indiana

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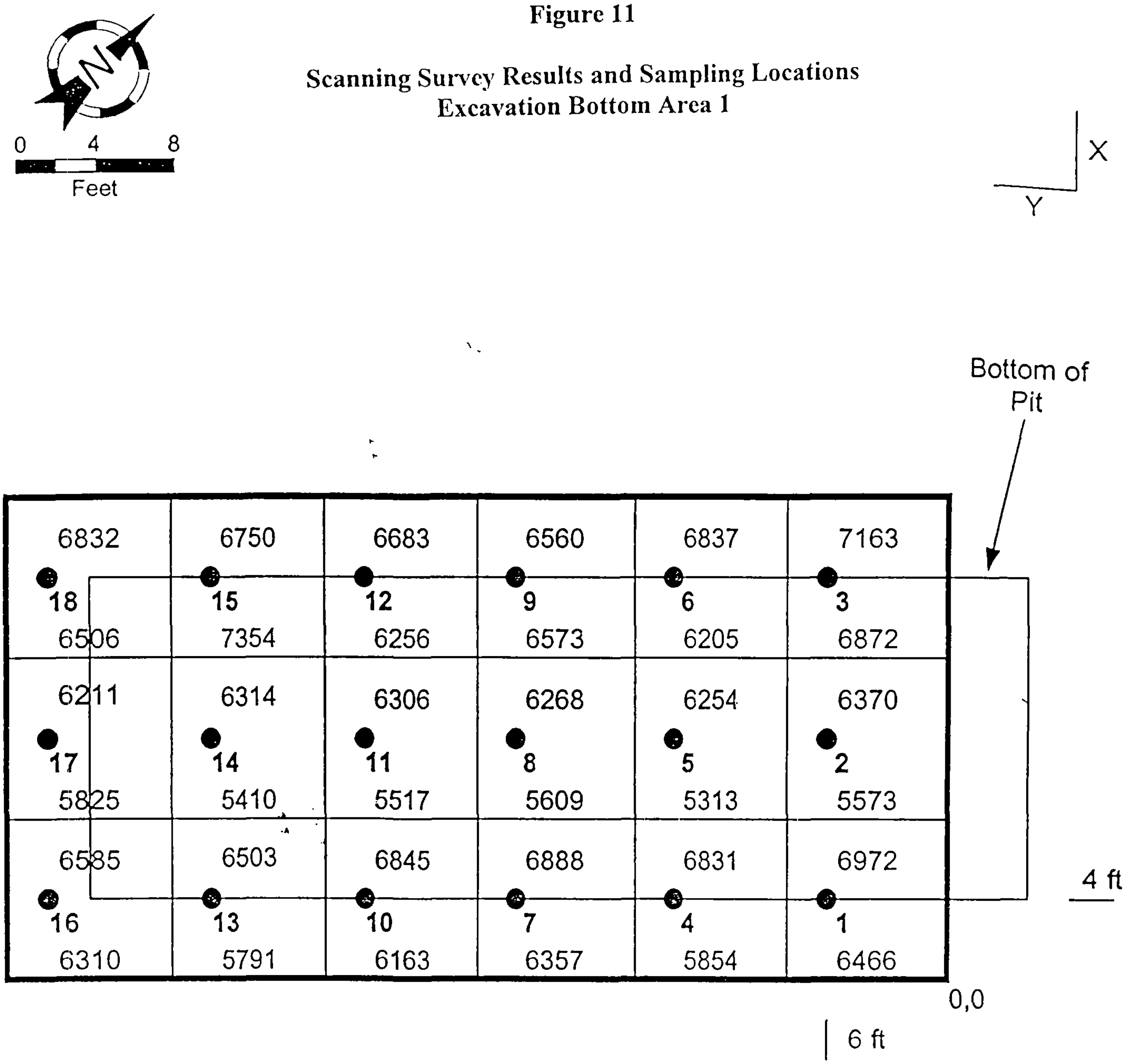
Figure 11

Scanning Survey Results and Sampling Locations
Excavation Bottom Area 1



1 Survey grid number

Location of excavation bottom soil sample

6972 Areal scaler reading (cpm)

6466 Point scaler reading (cpm)

Background: 6194 +/- 790 cpm

SCANNING SURVEY RESULTS AND SAMPLING LOCATIONS
EXCAVATION BOTTOM AREA 1

Final Status Survey, B-58 Burial Site
Former Grissom AFB, Indiana

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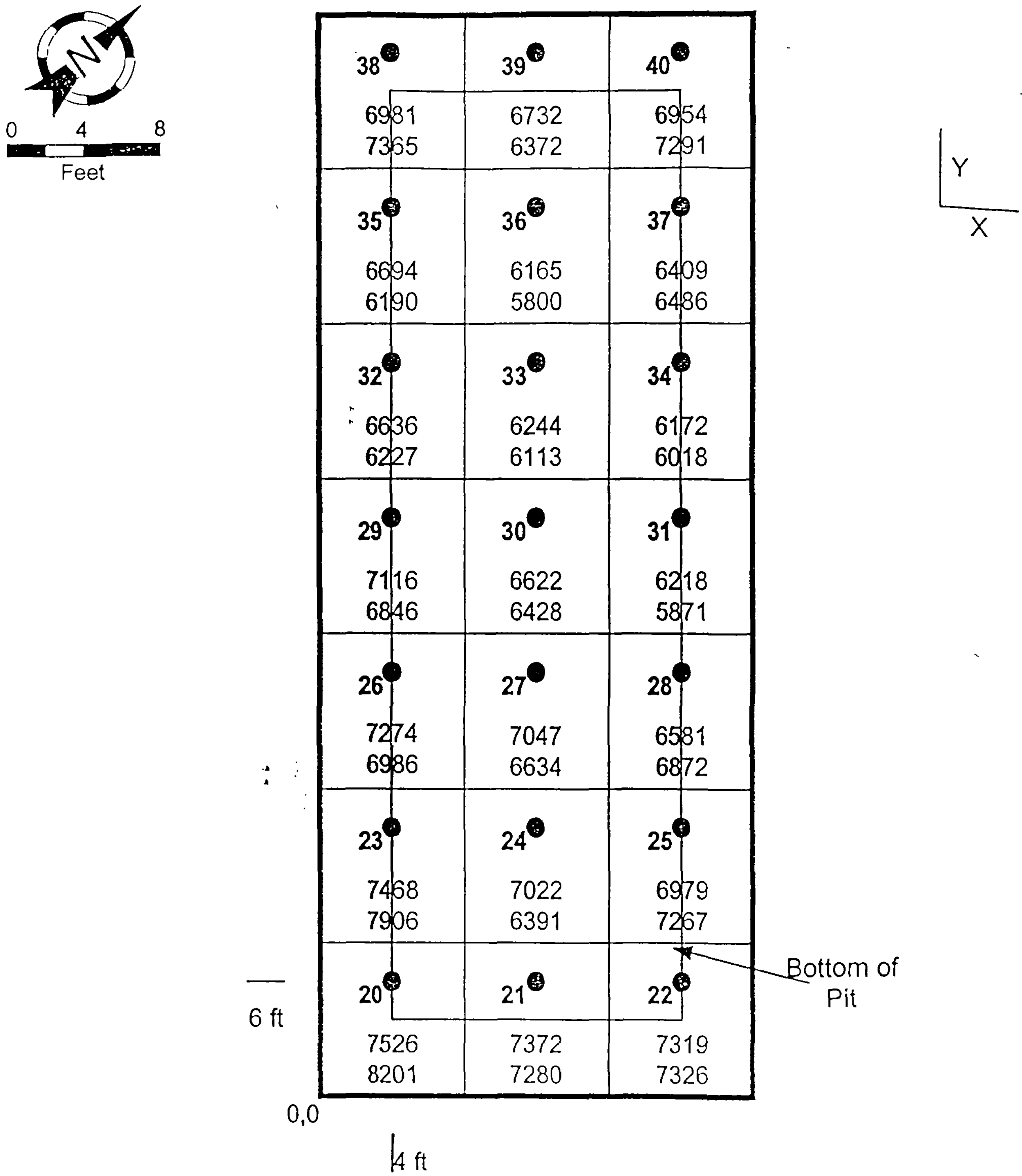
Figure 12 Scanning Survey Results and Sampling Locations Excavation Bottom Area 2



20 Survey grid number

⊛ Location of excavation bottom soil sample

7526 Areal scaler reading (cpm)

8201 Point scaler reading (cpm)

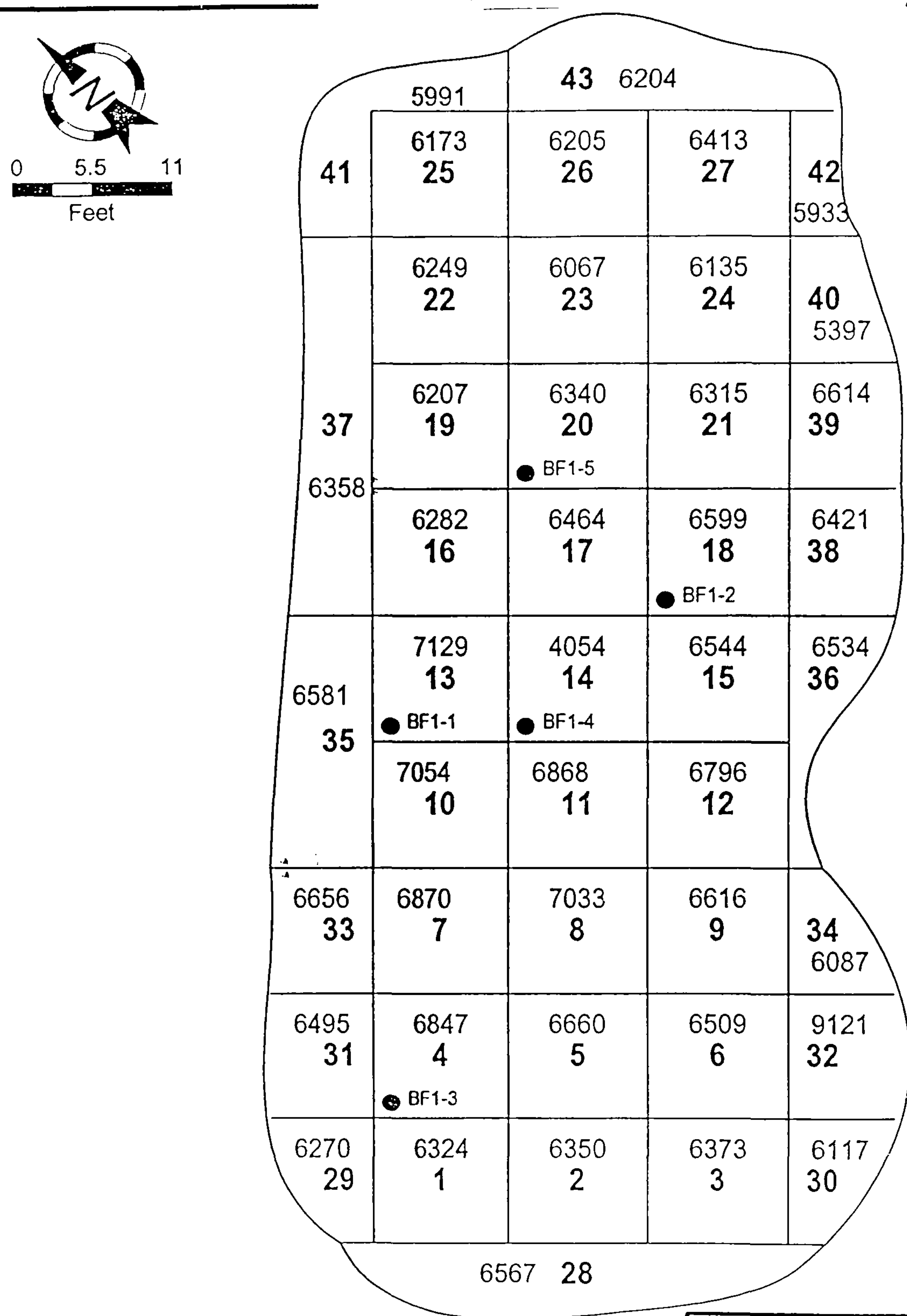
Background: 6194 +/- 790 cpm

SCANNING SURVEY RESULTS
AND SAMPLING LOCATIONS
EXCAVATION BOTTOM AREA 2

Final Status Survey, B-58 Burial Site
Former Grissom AFB, Indiana

PARSONS

Figure 13 **Scanning Survey Results and Sampling Locations**
Backfill Soil Pile 1, Lift 1



1 Survey grid number

6324 Areal scaler reading (cpm)

BF1-1 Location of backfill soil sample

Background: 6194 +/- 790 cpm

SCANNING SURVEY RESULTS
AND SAMPLING LOCATIONS
BACKFILL SOIL PILE 1, LIFT 1

Final Status Survey, B-58 Burial Site
Former Grissom AFB, Indiana

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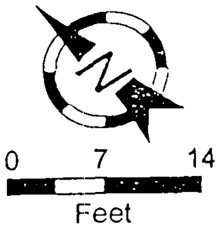
Figure 14

Scanning Survey Results and Sampling Locations
Backfill Soil Pile 1, Lift 2



6152 **32**	6038 **24**	5933 **16**	5630 **8**
6257 **31** BF3-5	6089 **23**	5898 **15**	6051 **7**
6288 **30**	6117 **22**	6190 **14**	6434 **6**
7021 **29**	7975 **21** BF3-3	6250 **13**	6694 **5**
6414 **28**	6809 **20**	6342 **12**	6788 **4** BF3-2
7202 **27**	6857 **19** BF3-4	6697 **11**	6696 **3**
6589 **26**	6643 **18**	7623 **10** BF3-1	6269 **2**
6181 **25**	6001 **17**	6608 **9**	6333 **1**

1 Survey grid number
6333 Areal scaler reading (cpm)
BF3-1 Location of backfill soil sample

Background: 6194 +/- 790 cpm

SCANNING SURVEY RESULTS
AND SAMPLING LOCATIONS
BACKFILL SOIL PILE 1, LIFT 2

Final Status Survey, B-58 Burial Site
Former Grissom AFB, Indiana

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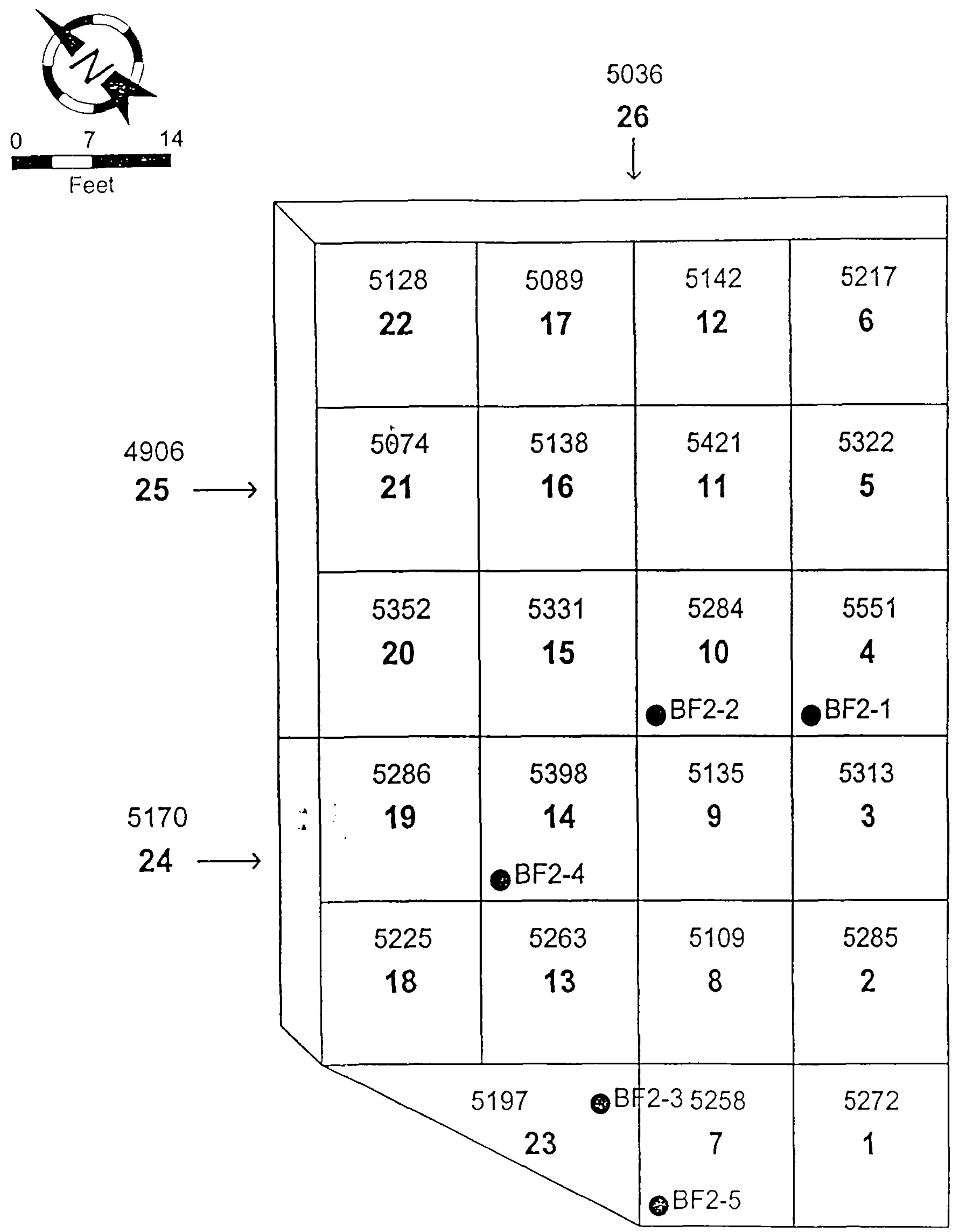
Figure 15

Scanning Survey Results and Sampling Locations
Backfill Soil Pile 2, Lift 1



1 Survey grid number

5272 Areal scaler reading (cpm)

BF2-1 Location of backfill soil sample

Background: 6194 +/- 790 cpm

SCANNING SURVEY RESULTS
AND SAMPLING LOCATIONS
BACKFILL SOIL PILE 2, LIFT 1

Final Status Survey, B-58 Burial Site
Former Grissom AFB, Indiana

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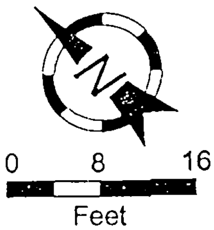
Figure 16 Scanning Survey Results and Sampling Locations
Backfill Soil Pile 2, Lift 2



4829 **20**	5084 **15**	5079 **10**	5053 **5**
5110 **19** ● BF4-4	5158 **14**	5321 **9**	5134 **4**
5308 **18**	5470 **13** ● BF4-5	5220 **8** ● BF4-2	5304 **3**
5296 **17**	5040 **12**	5140 **7**	5231 **2**
5053 **16**	5240 **11**	5161 **6** ● BF4-3	5338 **1** ● BF4-1

1 Survey grid number
5338 Areal scaler reading (cpm)
● BF4-1 Location of backfill soil sample

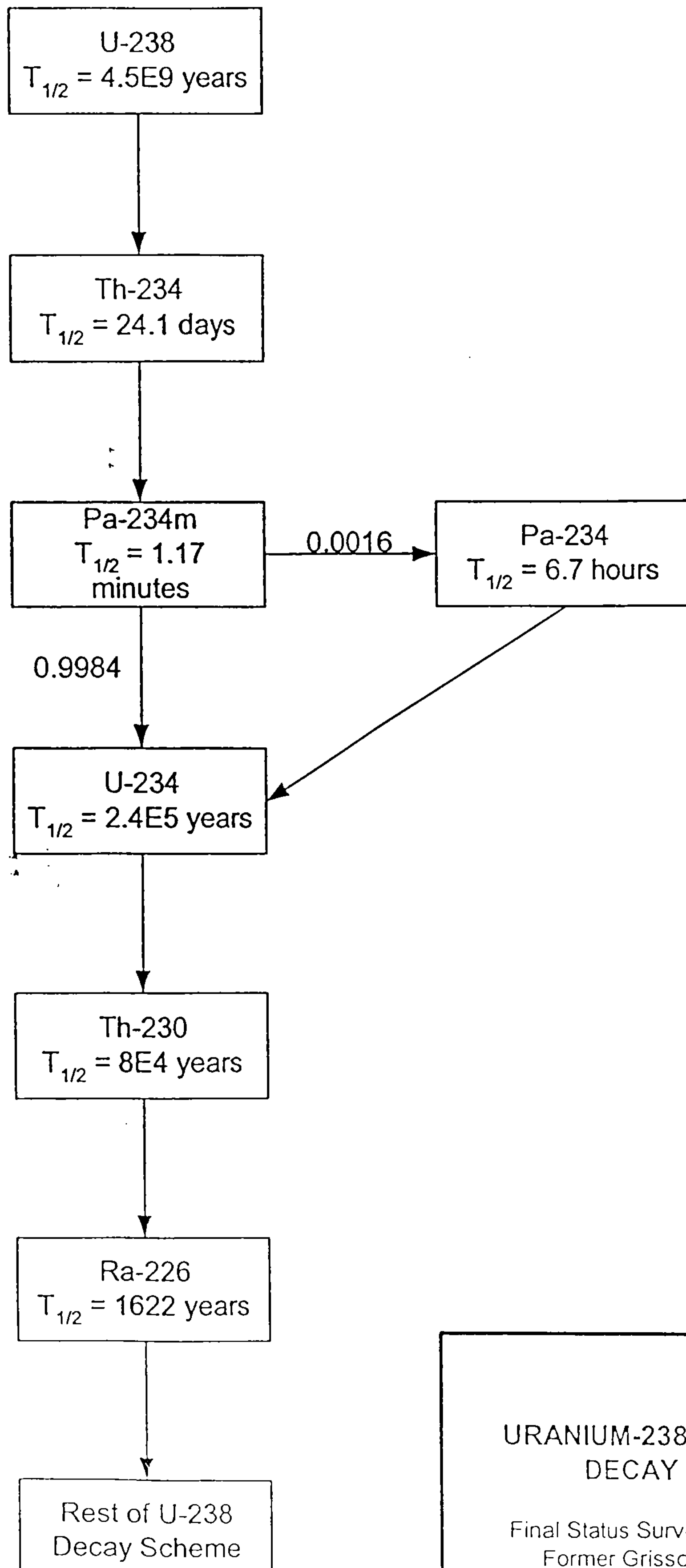
Background: 6194 +/- 790 cpm

SCANNING SURVEY RESULTS
AND SAMPLING LOCATIONS
BACKFILL SOIL PILE 2, LIFT 2

Final Status Survey, B-58 Burial Site
Former Grissom AFB, Indiana

PARSONS

Figure 17 **Uranium-238 Radioactive Decay Scheme**



URANIUM-238 RADIOACTIVE DECAY SCHEME

Final Status Survey, B-58 Burial Site
Former Grissom AFB, Indiana

PARSONS

Figure 18

Sewer Flow Volume Comparison

Sewer Flow Volume Comparison

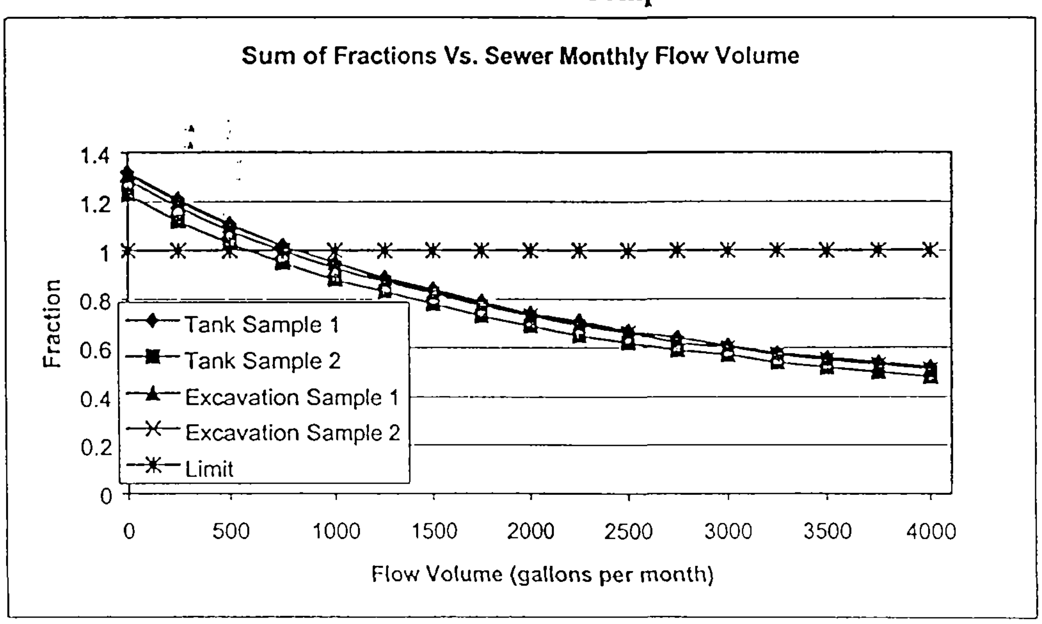


Figure 19

RESRAD Dose Calculation, based on Backfill Soil Alpha Spectroscopy Results

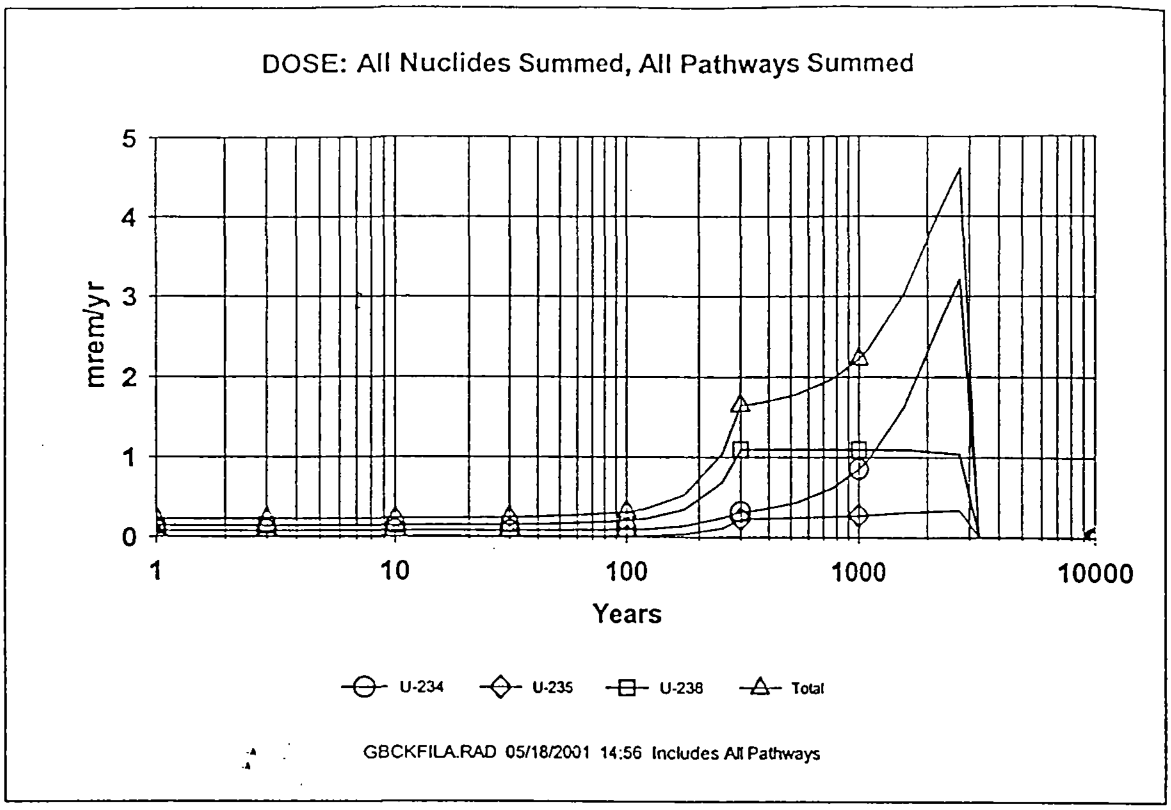
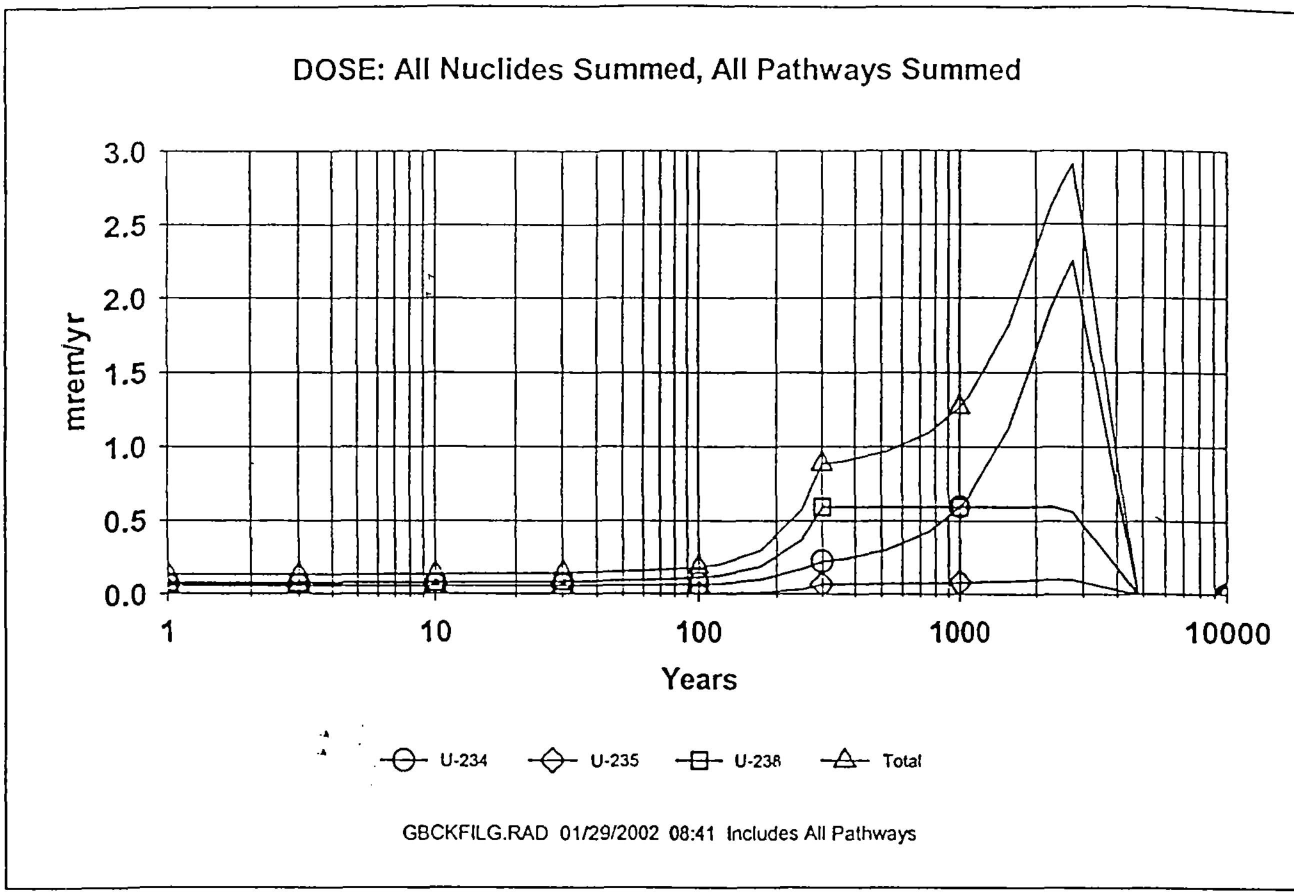


Figure 20

RESRAD Dose Calculation, based on Backfill Soil Alpha Spectroscopy Results



Appendix-B, Tables

Table 1

Drinking Water Well Information

Table 1A Primary Drinking Water Wells

Well # and Location	Diameter (Inches)	Depth (Feet)	Screen Depth (Feet)	Drawdown (Feet)	Static Water Level (Feet)	Year Drilled
6, Bldg. 713	12	180	85	64	36	1959
7, Bldg.796	12	175	84	30	28	1967

Table 1B Supplemental drinking water sources when extra capacity is required.

Well # and Location	Diameter (Inches)	Depth (Feet)	Screen Depth (Feet)	Drawdown (Feet)	Static Water Level (Feet)	Year Drilled
1, Bldg.218	12	156	96	45	24	1942
2, Bldg 408	12	150	100	37	25	1942

Table 1C Drinking water source for remote sites (chlorinators present on site).

Well # and Location	Diameter (Inches)	Depth (Feet)	Screen Depth (Feet)	Drawdown (Feet)	Static Water Level (Feet)	Year Drilled
5, Bldg. 196*	10	165	Unknown	Unknown	34	1951
8, Bldg. 727	4	125	Unknown	Unknown	Unknown	Unknown
9, Bldg 741	4	150	Unknown	Unknown	Unknown	Unknown
10, Bldg. 715	4	150	Unknown	Unknown	26	1986

* Well 5 is not used for human consumption. It is only used for irrigating golf course greens.

Table 2

Walk-Over Survey Results

Location/ Measurement Type	2" x 2" NaI Detector (cpm) [1]	FIDLER (cpm)
Background Area/ Scanning (range, minimum to maximum)	6,500 to 9,000	6,000 to 10,000
Burial Site/ Scanning (range, minimum to maximum)	5,400 to 7,900	5,000 to 10,000
Background 1/Direct	6,944	7,317
Background 2/Direct	7,488	7,895
Background 3/Direct	9,722	9,858
Burial Site 1/Direct	7,635	8,554
Burial Site 2/Direct	7,700	8,788
Burial Site 3/Direct	7,600	9,356

[1] cpm = counts per minute.

Table 3

Scoping Survey Grid Location Sampling Log

Location	Measurement	43-1 Alpha, Scaler Mode (cpm) [1]	GM Rate Meter (cpm)	Model 19 Rate Meter (μR/hr) [2]	Sample Interval and Description
B-1	1	0	<100	5	Sample 5'-6'. Clay, brown to grey, soft.
	2	2			
	3	1			
B-2	1	5	<100	7	Sample 2.5'-3'. Clay
	2	5			
	3	3			
B-3	1	1	<100	7	
	2	5			
	3	5			
S-0	1	5			3'-3.5' - soil looks burnt/ashy/black/gravelly, not clayey. Pushed to 4.5', encountered variable resistance. No sample recovered. Groundwater encountered at 4'
	2	3			
	3	5			
S-1	1	8			Clayey, natural soil at 3'-3.5'. 43-1 readings appear high. Performed source check (92) and recounted sample. Instrument check was OK: readings were 4,3,and 1.
	2	7			
	3	9			
S-2	1	2	<100	<10	Sample 4.5-5'. Clayey, encountered water at about 5'-5.5'. Soil appeared native.
	2	6			
	3	3			
S-3	1	6	<100	<10	Sample at 3'-3.5', soil appeared native.
	2	4			
	3	5			
S-4	1	3			Clayey sample taken at 3'-3.5', similar to background.
	2	2			
	3	1			
S-5	1	3	<100	<10	4.5'-5' sample collected. Native clay throughout.
	2	8			
	3	3			
S-6	1	3	<100	<10	Drilled to 7.5', damage to barrel noted- probe looked scarred from rubbing against metal (fuselage). Sample taken at 3-3.5': black, ashy (same description as at center). When filling hole with bentonite, the hole took bentonite indefinitely. This confirmed that a cavity was hit.
	2	3			
	3	5			
S-6 Debris	Not Measured		<100	<10	Debris at 6.5'-7.5'.
S-7a	1	4			Sample 3'-3.5', black/burnt, resistance at 4.5'
	2	3			
	3	2			
S-7b	Not Measured		<100	7	Sample at 4' to 4.5'
S-8	1	3			Clayey sample taken at 3'-3.5'
	2	5	<100	<10	
	3	2			
S-9	1	6	<100	7	Sample 1.5'-2', much resistance at 2'. Pushed to 4'; similar material: burnt black with some clay mixed in.
	2	2			
	3	4			
S-10	1	6	<100	10	4.5' - 5' - Clay, moist.
	2	4			
	3	2			
S-11A	1	2	<100	<10	Native clay
	2	5			
	3	3			
S-11B	Not Measured				Sample 0.5'-1'; ashy, black, grey, silty appearance
S-12	Not Measured				Hit asphalt at 0'-0.5'. Not enough sample to send to lab. Visual verification.
S-13	1	1	<100	7	Sample located 45° SW of S-9 by 15'. Pushed to 4', sampled 2.5'-3'. Burnt ashy soil, black with metal. Native clay above and below.
	2	5			
	3	5			
S-14	Not Measured				Resistance at 1'; auger refusal. Sampled 0.5 - 1', dark soil, appeared more like material surrounding airplane (fill/ash?) than native
S-15	Not Measured				Same as S14. Used trowel to dig to 1' and verify that resistance was natural material. No debris was visible. Looked like asphalt at 1'.

[1] cpm = counts per minute.
[2] μR/hr = microRoentgen per hour.

Table 4

Analytical Results from Intrusive Characterization Survey (Parsons, 2000)

	Analyte							
	Am-241		Th-232		Th-234		U-235	
Sample Location	Conc. (pCi/g) [1]	95% Uncertainty	Conc. (pCi/g)	95% Uncertainty	Conc. (pCi/g)	95% Uncertainty	Conc. (pCi/g)	**95% Uncertainty**
Background								
B1	<0.1 [2]		0.5	+/-0.3 [3]	<1		<0.1	
B2	<0.2		1	+/-0.4	<2		<0.2	
B3	<0.1		0.6	+/-0.3	<1.3		<0.1	
Site								
S0	<0.1		<0.4		2.7	+/-1.2	<0.1	
S1	<0.1		0.7	+/-0.3	<1.3		<0.1	
S2	<0.2		1.3	+/-0.4	<2.1		<0.2	
S3	<0.1		0.5	+/-0.3	<1.4		0.2	**+/-0.1**
S4	<0.2		<0.7		<2.1		<0.2	
S5	<0.2		0.6	+/-0.5	<2		<0.1	
S6	<0.2		0.9	+/-0.5	<2		<0.2	
S6 Debris	<0.2		0.4	+/-0.3	<2.5		<0.2	
S7A	<0.2		<0.6		14	+/-2.5	<0.2	
S7B	<0.1		0.4	+/-0.2	12	+/-1.7	0.2	**+/-0.09**
S8	<0.2		0.8	+/-0.5	<2		<0.2	
S9	<0.1		0.8	+/-0.3	<1.3		<0.1	
S10	<0.1		0.7	+/-0.4	1.8	+/-1.4	<0.1	
S11A	<0.2		0.7	+/-0.6	<2		<0.2	
S11B	<0.1		0.5	+/-0.3	<1.3		<0.1	
S12	<0.2		<0.6		<2		<0.2	
S13	<0.1		<0.4		<1.3		<0.1	
S14	<0.1		<0.3		<1.2		<0.1	

[1] pCi/g = picocuries per gram.

[2] < = Sample quantity was less than the minimum detectable concentration.

[3] +/- = For detected sample, the 95% uncertainty is reported.

Table 5

Beryllium Analytical Results

Sample Location	Beryllium Concentration (µg/g)[1/]
B-1	0.670
B-3	0.570
B-2	0.550
S6 Debris	<0.50
S7-A	<0.50
S6	<0.50
S7-B	2.14

[1/] **µg/g = microgram per gram of soil.**

Table 6

RESRAD Input Parameters for $DCGL_W$ Calculations

INPUT PARAMETER	DEFAULT VALUE		USER INPUT			
			Residential Scenario from Work Plan		FSS RESRAD Updates	
	Value	Units	Value	Basis	Value	Basis
PATHWAY						
External gamma	--	--	Active	--	Active	--
Inhalation (except radon)	--	--	Active	--	Active	--
Plant ingestion	--	--	Active	--	Active	--
Meat ingestion	--	--	Active	--	Active	--
Milk ingestion	--	--	Active	--	Active	--
Aquatic foods	--	--	Suppressed	Site location	Suppressed	Site location
Drinking water	--	--	Active	--	Active	--
Soil ingestion	--	--	Active	--	Active	--
Radon	--	--	Active	--	Active	--
SOIL CONCENTRATIONS						
Initial Concentration (pCi/g)						
Uranium-234	--	--	100	see Section 6.1.1	100	see Section 6.1.1
Uranium-235	--	--	100		100	
Uranium-238	--	--	100		100	
Americium-241	--	--	--	--	100	
Thorium-232	--	--	--	--	100	
Transport Factors						
Distribution coefficient						
Saturated Zone						
Uranium-234	50	cm^3/g	81.5 to 1,600	USDOE, 1993	1600	USDOE, 1993 and Parsons, 2000
Uranium-235	50	cm^3/g	81.5 to 1,600		1600	
Uranium-238	50	cm^3/g	81.5 to 1,600		1600	
Contaminated and Unsaturated Zones						
Uranium-234	50	cm^3/g	81.5 to 1,600	USDOE, 1993	1600	USDOE, 1993 and Parsons, 2000
Uranium-235	50	cm^3/g	81.5 to 1,600		1600	
Uranium-238	50	cm^3/g	81.5 to 1,600		1600	
Number of Unsaturated Zones	1	--	1	--	1	--

Table 6 (Cont.)

RESRAD Input Parameters for DCGLw Calculations

INPUT PARAMETER	DEFAULT VALUE		USER INPUT			
			Residential Scenario from Work Plan		FSS RESRAD Updates	
	Value	Units	Value	Basis	Value	Basis
Water Concentration						
Time since material placement	0	years	--	--	0	Based on Guidance in USDOE, 1993
Groundwater Concentration	0	pCi/L	--	No sources identified except those within natural background	0	No sources identified except those within natural background
Solubility Limit	0	mol/L	--		0	
Leach Rate	0	year $^{-1}$	--		0	
Use Plant Soil ratio	No	--	--		No	
CALCULATION TIMES						
Basic Radiation Dose Limit	30	mrem/yr	15	USEPA, 1997b	15	USEPA, 1997b
Calculation Times	1, 3, 10, 30, 100, 300, 1000	years	--	--	1, 3, 10, 30, 100, 300, 1000, 10000	--
CONTAMINATED ZONE						
Thickness of contaminated zone	2	m	0.3, 0.6, 1.2, 1.8	Varies with run	3	Table 3.6 of Parsons, 2000
For DCGL$_W$						
Area of contaminated zone	10000	m^2	232	2,500 sq. feet area	232	2,500 sq. feet area
Length parallel to aquifer flow	100	m^2	15	One side of sq. area	15	One side of sq. area
For DCGL$_{EMC}$						
Area of contaminated zone	--	--	6.3	2.5x2.5m sq. area (grid size)	6.3	2.5x2.5m sq. area (grid size)
Length parallel to aquifer flow	--	--	2.5	One side of sq. area	2.5	One side of sq. area
COVER AND CONTAMINATED ZONE HYDROLOGICAL DATA						
Cover depth	0	m	0.0, 0.3	Varies with run	0.3	Parsons, 2000
Density of cover material	1.5	g/cm^3	1.2	USDOE, 1993; Table 2.1	1.2	USDOE, 1993; Table 2.1
Cover erosion rate	0.001	m/yr	--	--	0.001	--
Density of contaminated zone	1.5	g/cm^3	1.2	USDOE, 1993; Table 2.1	1.2	USDOE, 1993; Table 2.1
Contaminated zone erosion rate	0.001	m/yr	--	--	0.001	--
Contaminated zone total porosity	0.4	--	0.42	USDOE, 1993; Table 3.2	0.42	USDOE, 1993; Table 3.2
Contaminated zone effective porosity	0.2	--	0.06	--	0.06	--
Contaminated zone hydraulic conductivity	10	m/yr	32.1	USDOE, 1993; Table 5.2	32.1	USDOE, 1993; Table 5.2
Contaminated zone b parameter	5.3	--	10.4	USDOE, 1993; Table 13.1	10.4	USDOE, 1993; Table 13.1
Humidity in air	8	g/m^3	NA	--	NA	--
Evapotranspiration coefficient	0.5	--	0.999	USDOE, 1993; Section 12	0.999	USDOE, 1993; Section 12
Wind speed	2	m/s	--	--	2	--
Precipitation	1	m/yr	1	40 inches/year	1	40 inches/year
Irrigation	0.2	m/yr	0	No irrigation on site	0	No irrigation on site

Table 6 (Cont.)

RESRAD Input Parameters for DCGLw Calculations

INPUT PARAMETER	DEFAULT VALUE		USER INPUT			
			Residential Scenario from Work Plan		FSS RESRAD Updates	
	Value	Units	Value	Basis	Value	Basis
Irrigation mode	Overhead		NA	For overhead	NA	For overhead
Runoff Coefficient	0.2	-	0.3	USDOE, 1993; Table 10.1	0.3	USDOE, 1993; Table 10.1
Watershed area for nearby stream or pond	1.00E+06	m^2	--	--	1.00E+06	--
Accuracy for water/soil computation	0.001		--	--	0.001	--
SATURATED ZONE HYDROLOGICAL DATA						
Density of saturated zone	1.5	g/cm^3	1.2	USDOE, 1993; Table 2.1	1.2	USDOE, 1993; Table 2.1
Saturated zone total porosity	0.4	-	0.42	USDOE, 1993; Table 3.2	0.42	USDOE, 1993; Table 3.2
Saturated zone effective porosity	0.2	--	0.06		0.06	
Saturated zone hydraulic conductivity	100	m/yr	32.1	USDOE, 1993; Table 5.2	32.1	USDOE, 1993; Table 5.2
Saturated zone hydraulic gradient	0.02	--	0.007	USDOE, 1993; Section 15	0.007	USDOE, 1993; Section 15
Saturated zone b parameter.	5.3	--	10.4	USDOE, 1993; Table 13.1	10.4	USDOE, 1993; Table 13.1
Water table drop rate	0.001	m/yr	--	--	0.001	--
Well pump intake depth (below water table)	10	m	4.4	Well logs	4.4	Well logs
Model: nondispersion (ND) or mass balance (MB)	ND		--	--	--	--
Well pumping rate	250	m^3/yr	--	Default, as no active wells in the area	250	Default, as no active wells in the area
UNCONTAMINATED UNSATURATED ZONE PARAMETERS						
Number of unsaturated zones	1	--	1	--	1	--
Unsaturated zone 1						
Thickness	4	m	varies with run	Varies with run; =Depth to GW (5 to 10 ft) - Thickness of Contaminated Zone	0	Conservative value based on analysis in Parsons, 2000
Soil density	1.5	g/cm^3	1.2	USDOE, 1993; Table 2.1	1.2	USDOE, 1993; Table 2.1
Total porosity	0.4	--	0.42	USDOE, 1993; Table 3.2	0.42	USDOE, 1993; Table 3.2
Effective porosity	0.2	--	0.06		0.06	
Hydraulic conductivity	10	m/yr	32.1	USDOE, 1993; Table 5.2	32.1	USDOE, 1993; Table 5.2
Soil-specific b parameter	5.3	--	10.4	USDOE, 1993; Table 13.1	10.4	USDOE, 1993; Table 13.1
OCCUPANCY						
Inhalation rate	8400	m^3/yr	11,000	USEPA, 1997a		
Mass loading for inhalation	0.0001	g/m^3	0.001	USDOE, 1993; Section 35		
Exposure duration	30	yr	30	USEPA, 1990		
Indoor dust filtration factor	0.4	--	--	--	--	--
External gamma shielding factor	0.7	--	--	--	--	--

Table 6 (Cont.)

RESRAD Input Parameters for DCGLw Calculations

INPUT PARAMETER	DEFAULT VALUE		USER INPUT			
			Residential Scenario from Work Plan		FSS RESRAD Updates	
	Value	Units	Value	Basis	Value	Basis
Indoor time fraction	0.5	–	0.65	USEPA, 1997a		
Outdoor time fraction	0.25	–	0.08	USEPA, 1997a		
Shape of the contaminated zone	Circular		Square	Site conditions	Square	Site conditions
INGESTION PATHWAY, DIETARY DATA						
Fruit, vegetable. and grain consumption	160	kg/yr	301	USEPA, 1997a	301	USEPA, 1999 Tables 9-29 & 12-23
Leafy vegetable consumption	14	kg/yr	--	USDOE, 1993	–	USDOE, 1993
Milk consumption	92	L/yr	82	USEPA, 1997a	82	USEPA, 1999
Meat and poultry consumption	63	kg/yr	45	USEPA, 1997a	45	USEPA, 1999
Soil ingestion	36.5	g/yr	73	USDOE, 1993	43.8	USDOE, 1993
Groundwater ingestion	510	L/yr	–	USDOE, 1993	–	USDOE, 1993
Contaminated fractions						
Livestock water	1	m/yr	1	Assumed all water from onsite	1	Assumed all water from onsite
Irrigation water	1	m/yr	1	USDOE, 1993	1	USDOE, 1993
Plant food	-1		0.5	Assumed half of plant food is from offsite	-1	
Meat	-1		0.5	Assumed half of meat is from offsite	-1	RESRAD to calculate
Milk	-1		0.5	Assumed half of milk is from offsite	-1	
INGESTION PATHWAY, NONDIETARY DATA						
Livestock fodder intake for meat	68	kg/d	11.8	USEPA, 1998 Table B-3-10	11.8	USEPA, 1998 Table B-3-10
Livestock fodder intake for milk	55	kg/d	20.3	USEPA, 1998 Table B-3-11	20.3	USEPA, 1998 Table B-3-11
Livestock water intake for meat	50	L/d	–	USDOE, 1993	–	USDOE, 1993
Livestock water intake for milk	160	L/d	–	USDOE, 1993	–	USDOE, 1993
Livestock soil intake	0.5	kg/d	0.5	USEPA, 1998 Table B-3-10	0.5	USEPA, 1998 Table B-3-10
Mass loading for foliar deposition	0.0001	g/m^3	--		0.0001	
Depth of soil mixing layer	0.15	m	--	USDOE, 1993	0.15	USDOE, 1993
Depth of roots	0.9	m	--		0.9	
Groundwater fractional usage						
Drinking water	1	--	--		–	
Household water.	1	--	--	Limiting case assumption	--	Limiting case assumption
Livestock water	1	–	--		--	
Irrigation water	1	--	--		--	
RADON DATA						
Cover total porosity	0.4	--	Default		Default	
Cover volumetric water content	0.05	--	Default	Default parameters used in conjunction with site parameters and guidance of USDOE, 1993	Default	Default parameters used in conjunction with site parameters and guidance of USDOE, 1993
Cover radon diffusion coefficient	2.00E-06	m^2/s	Default		Default	
Building foundation thickness	0.15	m	Default		Default	
Building foundation density	2.4	g/cm^3	Default		Default	

Table 6 (Cont.)

RESRAD Input Parameters for DCGLw Calculations

INPUT PARAMETER	DEFAULT VALUE		USER INPUT			
			Residential Scenario from Work Plan		FSS RESRAD Updates	
	Value	Units	Value	Basis	Value	Basis
Building foundation total porosity	0.1		Default		Default	Only exception is the excavation worker scenario, which sets the building foundation thickness parameter to zero.
Building foundation volumetric water content	0.03		Default		Default	
Building foundation radon diffusion coefficient	3.00E-07	m^2/s	Default		Default	
Contaminated radon diffusion coefficient	2.00E-06	m^2/s	Default		Default	
Radon vertical dimension of mixing	2	m	Default		Default	
Building air exchange rate	0.5	$hour^{-1}$	Default		Default	
Building room height	2.5	m	Default		Default	
Building indoor area factor	0		Default		Default	
Foundation depth below ground surface	-1	m	Default		Default	
Radon 222 emanation coefficient	0.25		Default		Default	
Radon 220 emanation coefficient	0.15		Default		Default	
STORAGE TIME BEFORE USE DATA						
Fruits, nonleafy vegetables, and grain	14	days	--		--	
Leafy vegetables	1	days	--		--	
Milk	1	days	--		--	
Meat	20	days	--		--	
Fish	7	days	NA	USDOE, 1993	NA	USDOE, 1993
Crustacea and mollusks	7	days	NA		NA	
Well water	1	days	--		--	
Surface Water	1	days	--		--	
Livestock fodder	45	days	--		--	

[1] NA - Not Applicable.

Table 7

Gross DCGL Equation

$$\text{Gross DCGL} = \frac{1}{\frac{f_{U\text{-}234}}{DCGL_{U\text{-}234}} + \frac{f_{U\text{-}235}}{DCGL_{U\text{-}235}} + \frac{f_{U\text{-}238}}{DCGL_{U\text{-}238}}}$$

Where:

f = expected activity fraction of isotope

Table 8

Uranium Isotope Activity Fractions

Uranium Isotope Activity Fractions

Radionuclide	Depleted Activity Fraction 1/	Enriched Activity Fraction 2/
U-234	0.13	0.97
U-235	0.01	0.03
U-238	0.86	3E-4

1/ The depleted activity fractions are based on the weight fractions of uranium depleted to 99.8 weight percent U-238 and 0.2 weight percent U-235 (AFIERA, 2000).

2/ The enriched uranium activity fractions are based on the generic fractions for uranium enriched to 93.5 weight percent U-235 (Derived from AFIERA).

Table 9

Gross DCGL Comparison

		Excavation Worker (15 mrem/yr)	Prison Resident (15 mrem/yr)	Prison Residential Farmer (15 mrem/yr)	Residential Farmer (15 mrem/yr)	Resident (15 mrem/yr)[2]
$DCGL_W$ (pCi/g)[3]	Depleted U	506.0	122.1	101.8	111.0	133.4
	Enriched U (93.5 wt %)[4]	508.1	234.5	171.3	184.4	95.1
$DCGL_{EMC}$ (pCi/g)	Depleted U	3593.8	161.4	135.7	150.2	199.4
	Enriched U (93.5 wt %)	5648.0	677.0	384.6	422.3	289.5

[1] mrem/yr = millirem per year.
[2] Resident scenario results from Grissom FSS Work Plan (Parsons, 2000).
[3] pCi/g = picocuries per gram.
[4] 93.5 wt % = Uranium that has been enriched to a 93.5 weight percentage of uranium-235.

Table 10

Derived Concentration Guideline Limits

Radionuclide	$DCGL_W$ (pCi/g)[1]				
	Resident (15 mrem/yr)[2]	Residential Farmer (15 mrem/yr)	Excavation Worker (15 mrem/yr)	Prison Residential Farmer (15 mrem/yr)	Prison Resident (15 mrem/yr)
Am-241	ND[3]	86.9	122.4	82.2	113.3
Th-232	ND	1.1	5.9	1.0	1.1
U-234	103.1	228.9	520.6	214.2	318.0
U-235	26.8	25.1	824.3	22.7	24.5
U-238	147.4	107.5	509.0	98.6	117.4
	$DCGL_{EMC}$ (pCi/g)				
Am-241	ND	266.7	2584.0	244.3	548.6
Th-232	ND	1.4	41.8	1.2	1.3
U-234	734.1	738.0	6726.0	677.7	2524.0
U-235	35.9	28.3	906.8	25.5	27.2
U-238	206.1	141.4	3486.0	127.7	150.1

[1] pCi/g = picocuries per gram.
[2] mrem/yr = millirem per year; Resident scenario results from Grissom FSS Work Plan (Parsons, 2000)
[3] ND = Not determined.

Table 11

Length of Square Grid Equation

$$L = \sqrt{\frac{A}{n}}$$

where:

L = length of side,

A = area of excavation,

n = number of samples

Table 12

Final Status Survey
Grid Size Information

Area Name	Dimensions	Area (ft^2)	Req'd Number of Samples	Length of Side (ft)
Bottom Area 1	53 ft x 25 ft	1325	18	8
Bottom Area 2	57 ft x 27 ft	1539	21	8
Pile 1, Lift 1	75 ft x 45 ft	3375	24 [1/]	11
Pile 1, Lift 2	100 ft x 50 ft	5000	24 [1/]	14
Pile 2, Lift 1	80 ft x 65 ft	5200	24 [1/]	14
Pile 2, Lift 2	90 ft x 70 ft	6300	24 [1/]	16

[1/] Used in grid size calculation only.

Table 13

Background Radiation Levels

Analytical Background [1/]		
	Average Concentration	Standard Deviation
	(pCi/g)	(pCi/g)
Americium-241	0	0
Thorium-232	0.66	0.21
Uranium-234	0.82	0.48
Uranium-235	0.67	0.3
Uranium-238	0.77	0.48

[1/] Compiled from Scoping Survey (Parsons, 2000) and AFIERA Characterization Report (AFIERA, 2000).

Gamma Scanning Background		
Meter 102 (FIDLER)		
Measurement	Scaler (cpm)	Meter (cpm)
1	6799	7000
2	7089	7000
3	7222	7000
4	6990	7000
5	6797	7000
6	5067	5000
7	4972	5000
8	4900	5000
9	6591	6500
10	5492	5500
11	6233	6500
12	6501	7000
13	6331	6500
14	6278	6500
15	5641	6000
Average	6194	6300
Standard Deviation	790	897

Table 14

Gamma Spectroscopy Results Reported on March 22, 2001
AFBCA Grissom Air Reserve Base, Bunker Hill, Indiana

Sampling Identification Number			Activity Concentration (pCi/g) 1/			
Parsons ID 2/	Base Sample Number	AFIERA/SDRH ID	^{235}Uranium	^{238}Uranium	^{232}Thorium	^{241}Americium
BF 1-04	GS0100042	10001169	< 0.04	6.1 +/- 0.78	0.90 +/- 0.11	< 0.05
BF 1-13	GS0100043	10001170	< 0.04	5.9 +/- 0.73	0.93 +/- 0.12	< 0.05
BF 1-14	GS0100044	10001171	< 0.04	6.9 +/- 0.85	0.98 +/- 0.12	< 0.05
BF 1-18	GS0100045	10001172	< 0.04	3.4 +/- 0.54	0.92 +/- 0.12	< 0.04
BF 1-20	GS0100046	10001173	0.44 +/- 0.05	4.1 +/- 0.55	0.93 +/- 0.11	< 0.04
BF 2-04	GS0100027	10001154	< 0.03	0.89 +/- 0.38	0.64 +/- 0.10	< 0.04
BF 2-07	GS0100028	10001155	< 0.03	0.56 +/- 0.32	0.51 +/- 0.12	< 0.03
BF 2-10	GS0100029	10001156	< 0.03	0.91 +/- 0.35	0.61 +/- 0.09	< 0.05
BF 2-14	GS0100030	10001157	< 0.08	0.71 +/- 0.55	0.46 +/- 0.19	< 0.09
BF 2-23	GS0100031	10001158	< 0.03	0.79 +/- 0.36	0.55 +/- 0.09	< 0.06
BF 3-04	GS0100037	10001164	< 0.04	10.0 +/- 1.2	0.92 +/- 0.13	< 0.09
BF 3-10	GS0100038	10001165	0.58 +/- 0.07	11.0 +/- 1.2	0.84 +/- 0.12	< 0.09
BF 3-19	GS0100039	10001166	< 0.13	7.7 +/- 1.5	0.89 +/- 0.26	< 0.12
BF 3-21	GS0100040	10001167	< 0.15	9.9 +/- 1.9	0.79 +/- 0.39	< 0.13
BF 3-31	GS0100041	10001168	< 0.04	5.9 +/- 0.74	0.74 +/- 0.11	< 0.05
BF 4-01	GS0100032	10001159	< 0.02	0.58 +/- 0.34	0.45 +/- 0.07	< 0.05
BF 4-06	GS0100033	10001160	< 0.03	0.57 +/- 0.36	0.58 +/- 0.10	< 0.06
BF 4-08	GS0100034	10001161	< 0.02	0.72 +/- 0.36	0.52 +/- 0.08	< 0.05
BF 4-13	GS0100035	10001162	< 0.03	0.76 +/- 0.34	0.50 +/- 0.08	< 0.05
BF 4-19	GS0100036	10001163	0.10 +/- 0.02	0.92 +/- 0.40	0.51 +/- 0.09	< 0.06
BOT 01	GS0100015	10001142	< 0.11	1.1 +/- 0.92	0.46 +/- 0.23	< 0.10
BOT 02	GS0100012	10001139	< 0.03	0.50 +/- 0.27	0.60 +/- 0.09	< 0.03
BOT 03	GS0100024	10001151	0.19 +/- 0.13	1.8 +/- 1.5	1.1 +/- 0.62	< 0.16
BOT 04	GS0100018	10001145	< 0.03	0.69 +/- 0.36	0.89 +/- 0.12	< 0.04
BOT 05	GS0100017	10001144	< 0.02	0.41 +/- 0.24	0.50 +/- 0.08	< 0.03
BOT 06	GS0100013	10001140	0.11 +/- 0.02	0.45 +/- 0.26	0.63 +/- 0.09	< 0.03
BOT 07	GS0100023	10001150	< 0.04	0.75 +/- 0.41	0.95 +/- 0.15	< 0.04
BOT 08	GS0100016	10001143	< 0.03	0.74 +/- 0.30	0.54 +/- 0.09	< 0.03
BOT 09	GS0100014	10001141	< 0.03	0.65 +/- 0.32	0.68 +/- 0.09	< 0.04
BOT 10	GS0100009	10001136	< 0.03	0.69 +/- 0.32	0.67 +/- 0.10	< 0.04
BOT 11	GS0100022	10001149	< 0.03	0.66 +/- 0.34	0.63 +/- 0.10	< 0.04
BOT 12	GS0100021	10001148	< 0.04	0.66 +/- 0.39	0.87 +/- 0.13	< 0.04
BOT 13	GS0100020	10001147	< 0.03	0.74 +/- 0.33	0.63 +/- 0.10	< 0.04
BOT 14	GS0100019	10001146	< 0.03	0.78 +/- 0.29	0.42 +/- 0.10	< 0.03
BOT 15	GS0100025	10001152	< 0.04	1.1 +/- 0.44	0.89 +/- 0.14	< 0.04
BOT 16	GS0100011	10001138	< 0.03	0.65 +/- 0.30	0.78 +/- 0.10	< 0.04
BOT 17	GS0100026	10001153	< 0.03	0.79 +/- 0.32	0.59 +/- 0.10	< 0.03
BOT 18	GS0100010	10001137	< 0.03	0.72 +/- 0.32	0.68 +/- 0.09	< 0.03
BOT 20	GS0100065	10001192	< 0.04	1.9 +/- 0.51	0.89 +/- 0.13	< 0.07
BOT 21	GS0100058	10001185	< 0.04	1.5 +/- 0.45	0.74 +/- 0.13	< 0.04
BOT 22	GS0100051	10001178	< 0.18	4.0 +/- 1.7	0.66 +/- 0.53	< 0.15
BOT 23	GS0100063	10001190	< 0.10	1.3 +/- 0.71	0.64 +/- 0.22	< 0.10

Table 14 (Cont.)

Gamma Spectroscopy Results Reported on March 22, 2001
AFBCA, Grissom Air Reserve Base, Bunker Hill, Indiana

Sampling Identification Number			Activity Concentration in pCi/g [1/]			
Parsons ID [2/]	Base Sample Number	AFIERA/SDRH ID	^{235}Uranium	^{238}Uranium	^{232}Thorium	^{241}Americium
BOT 24	GS0100048	10001175	< 0.03	2.3 +/- 0.49	0.65 +/- 0.09	< 0.04
BOT 25	GS0100050	10001177	< 0.17	< 1.8	< 0.60	< 0.15
BOT 26	GS0100057	10001184	< 0.03	0.94 +/- 0.41	0.79 +/- 0.13	< 0.04
BOT 27	GS0100067	10001194	< 0.09	0.76 +/- 0.54	0.50 +/- 0.18	< 0.09
BOT 28	GS0100056	10001183	< 0.16	< 1.7	0.69 +/- 0.43	< 0.13
BOT 29	GS0100061	10001188	0.17 +/- 0.09	0.84 +/- 0.70	0.66 +/- 0.23	< 0.10
BOT 30	GS0100055	10001182	< 0.18	2.9 +/- 1.7	0.46 +/- 0.40	< 0.15
BOT 31	GS0100052	10001179	< 0.03	0.90 +/- 0.31	0.50 +/- 0.08	< 0.03
BOT 32	GS0100066	10001193	< 0.02	0.59 +/- 0.32	0.48 +/- 0.08	< 0.05
BOT 33	GS0100049	10001176	< 0.03	0.77 +/- 0.31	0.41 +/- 0.09	< 0.03
BOT 34	GS0100047	10001174	< 0.02	1.0 +/- 0.29	0.50 +/- 0.07	< 0.03
BOT 35	GS0100059	10001186	< 0.02	0.48 +/- 0.33	0.50 +/- 0.08	< 0.05
BOT 36	GS0100062	10001189	< 0.03	0.47 +/- 0.32	0.47 +/- 0.08	< 0.05
BOT 37	GS0100064	10001191	< 0.02	0.51 +/- 0.31	0.42 +/- 0.07	< 0.04
BOT 38	GS0100054	10001181	< 0.04	1.6 +/- 0.45	0.77 +/- 0.12	< 0.04
BOT 39	GS0100053	10001180	< 0.03	0.75 +/- 0.34	0.53 +/- 0.12	< 0.04
BOT 40	GS0100060	10001187	< 0.03	1.3 +/- 0.41	0.73 +/- 0.11	< 0.06
TSP 1	GS0100095	10100003	0.28 +/- 0.09	1.3 +/- 0.82	0.45 +/- 0.20	< 0.11
TSP 2	GS0100096	10100004	0.19 +/- 0.09	1.0 +/- 0.63	0.59 +/- 0.21	< 0.10
TSP 3	GS0100097	10100005	< 0.14	1.1 +/- 0.64	0.70 +/- 0.24	< 0.10

[1/] pCi/g = picocuries per gram.
[2/] The following abbreviations are used in the Parsons ID: BF – Backfill soil pile; BOT – Bottom of excavation; TSP – Potentially TPH-contaiminated soil piles.

Table 15

Alpha Spectroscopy Results Reported on March 8, 2001
AFBCA Grissom Air Reserve Base, Bunker Hill, Indiana

Sampling Identification Number			Activity Concentration in pCi/g [1/]		
Parsons ID [2/]	Base Sample Number	AFIERA/SDRH ID	^{234}Uranium	^{235}Uranium	^{238}Uranium
B-58 Site	GS0100047	10100060	0.92 +/- 0.16	0.08 +/- 0.05	1.1 +/- 0.19
BF 1-04	GS0100042	10100055	7.1 +/- 0.76	0.40 +/- 0.10	15.0 +/- 1.6
BF 1-13	GS0100043	10100056	8.0 +/- 0.88	0.55 +/- 0.13	13.0 +/- 1.4
BF 1-14	GS0100044	10100057	11.0 +/- 1.0	0.77 +/- 0.14	17.0 +/- 1.6
BF 1-18	GS0100045	10100058	2.8 +/- 0.34	0.33 +/- 0.09	7.1 +/- 0.74
BF 1-20	GS0100046	10100059	8.2 +/- 0.85	0.73 +/- 0.15	13.0 +/- 1.3
BF 2-04	GS0100027	10100040	0.82 +/- 0.14	0.10 +/- 0.05	0.82 +/- 0.14
BF 2-07	GS0100028	10100041	0.59 +/- 0.13	0.08 +/- 0.05	0.61 +/- 0.13
BF 2-10	GS0100029	10100042	0.76 +/- 0.14	0.06 +/- 0.04	0.79 +/- 0.14
BF 2-14	GS0100030	10100043	0.56 +/- 0.11	0.06 +/- 0.04	0.83 +/- 0.15
BF 2-23	GS0100031	10100044	7.5 +/- 0.89	0.52 +/- 0.12	0.96 +/- 0.17
BF 3-04	GS0100037	10100050	4.4 +/- 0.49	0.50 +/- 0.11	18.0 +/- 1.8
BF 3-10	GS0100038	10100051	16.0 +/- 1.8	1.2 +/- 0.22	27.0 +/- 3.0
BF 3-19	GS0100039	10100052	4.6 +/- 0.57	0.33 +/- 0.10	7.8 +/- 0.90
BF 3-21	GS0100040	10100053	7.0 +/- 0.69	0.53 +/- 0.12	11.0 +/- 1.0
BF 3-31	GS0100041	10100054	5.7 +/- 0.72	0.56 +/- 0.13	12.0 +/- 1.4
BF 4-01	GS0100032	10100045	5.0 +/- 0.57	0.29 +/- 0.08	1.2 +/- 0.18
BF 4-06	GS0100033	10100046	0.75 +/- 0.15	0.07 +/- 0.04	0.91 +/- 0.17
BF 4-08	GS0100034	10100047	0.70 +/- 0.14	0.06 +/- 0.04	0.88 +/- 0.16
BF 4-13	GS0100035	10100048	2.2 +/- 0.26	0.11 +/- 0.05	0.91 +/- 0.14
BF 4-19	GS0100036	10100049	0.60 +/- 0.12	0.07 +/- 0.04	0.58 +/- 0.11

[1/] pCi/g = picocuries per gram.
[2/] The following abbreviations are used in the Parsons ID: BF – Backfill soil pile; BOT – Bottom of excavation; TSP – Potentially TPH-contaiminated soil piles.

Table 16

Comparison Of Gamma Spectroscopy Results From Excavation Bottom With Background And $DCGL_W$s

Soil Concentrations					
Radionuclide	Average Background Concentration (pCi/g) [1]	$DCGL_W$ (pCi/g)	Mean Sample Results (pCi/g)	Comparison to:	
				Average Background	$DCGL_W$
U-234	0.71	214	1.96 [2]	Above	Below
U-235	0.67	222.7	0.06	Below	Below
U-238	0.77	98.6	1.08	Above	Below
Sum for comparison with 30 pCi/g level:			3.1	Less than 30 pCi/g	

[1] pCi/g = picocuries per gram.
[2] The U-234 results are conservatively based on the U-235 analytical results and the activity fractions of uranium enriched to 93.5 weight percent U-235.

Table 17

Results From Sign And WRS Tests, Excavation Bottom Soil Sampling

Radionuclide	Sign Test			WRS Test		
	# Below the $DCGL_W$	% Below	Pass Sign Test?	Sum of Background Ranks	MARSSIM Critical Value	Pass WRS Test?
U-234	39 [1]	100	Yes	1705	1238	Yes
U-235	39	100	Yes	1705	1238	Yes
U-238	39	100	Yes	1705	1240	Yes

[1] Critical value for Sign test is 14.

Table 18

MARSSIM Unity Rule Equation

$$\frac{C_1}{DCGL_{W_1}} + \frac{C_2}{DCGL_{W_2}} + \ldots \frac{C_n}{DCGL_{W_n}} \leq 1$$

Where:

C = concentration, in pCi/g

$DCGL_W$ = guideline value for each individual radionuclide (1,2,..., n), in pCi/g

Table 19

Unity Rule Calculation Results, Excavation Bottom Soil Sampling

Radionuclide	Mean Concentration (pCi/g) [1/]	$DCGL_W$ (pCi/g)	Ratio
U-234	1.96	214	0.0091
U-235	0.06	22.7	0.0026
U-238	1.1	98.7	0.011
		Sum	0.023
		Is Sum of Ratios < 1?	Yes

[1/] pCi/g = picocuries per gram.

Table 20

Results of Excavation Bottom Scanning Survey

Grid Location	Areal Scaler Reading (cpm) [1/]	Point Scaler Reading (cpm)	Remarks
1	6972	6466	Area 1
2	6370	5573	
3	7163	6872	
4	6831	5854	
5	6254	5313	
6	6837	6205	
7	6888	6357	
8	6268	5609	
9	6560	6573	
10	6845	6163	
11	6306	5517	
12	6683	6256	
13	6503	5791	
14	6314	5410	
15	6750	7354	
16	6585	6310	
17	6211	5825	
18	6832	6506	
20	7526	8201	Area 2
21	7372	7280	
22	7319	7326	
23	7468	7906	
24	7022	6391	
25	6979	7267	
26	7274	6986	
27	7047	6634	
28	6581	6872	
29	7116	6846	
30	6622	6428	
31	6218	5871	
32	6636	6227	
33	6244	6113	
34	6172	6018	
35	6694	6190	
36	6165	5800	
37	6409	6486	
38	6981	7365	
39	6732	6372	
40	6954	7291	Background
Average	6736	6457	6194
St. Dev.	385	685	790

[1/] cpm = counts per minute.

Table 21

Comparison of Soil Sampling Gamma Spectroscopy Results From Backfill Soil Piles With Background And $DCGL_W$s

Soil Concentrations					
Radionuclide	Mean Background Concentration (pCi/g) [1]	$DCGL_W$ (pCi/g)	Mean Sample Results (pCi/g)	Comparison to:	
				Mean Background	$DCGL_W$
U-234	0.71	214	3.17 [2]	Above	Below
U-235	0.67	22.7	0.10	Below	Below
U-238	0.77	98.6	3.9	Above	Below
Sum for comparison with 30 pCi/g level:			7.17	Less than 30 pCi/g	

[1] pCi/g = picocuries per gram.
[2] The U-234 results are conservatively based on the U-235 analytical results and the activity fractions of uranium enriched to 93.5 weight percent U-235.

Table 22

Comparison Of Soil Sampling Alpha Spectroscopy Results From Backfill Soil Piles With Background And $DCGL_W$s

Soil Concentrations					
Radionuclide	Mean Background Concentration (pCi/g) [1]	$DCGL_W$ (pCi/g)	Mean Sample Results (pCi/g)	Comparison to:	
				Mean Background	$DCGL_W$
U-234	0.71	214	4.54	Above	Below
U-235	0.67	22.7	0.35	Below	Below
U-238	0.77	98.6	7.21	Above	Below
Sum for comparison with 30 pCi/g level:			12.1	Less than 30 pCi/g	

[1] pCi/g = picocuries per gram.

Table 23

Results From Sign And WRS Tests, Backfill Soil Pile Sampling Gamma Spectroscopy

Radionuclide	Sign Test			WRS Test		
	# Below the $DCGL_W$	% Below	Pass Sign Test?	Sum of Background Ranks	MARSSIM Critical Value	Pass WRS Test?
U-234	20[1]	100	Yes	1116	891	Yes
U-235	20	100	Yes	1116	891	Yes
U-238	20	100	Yes	1116	891	Yes

[1] Critical value for Sign test is 14.

Table 24

Results From Sign And WRS Tests, Backfill Soil Pile Sampling Alpha Spectroscopy

Radionuclide	Sign Test			WRS Test		
	# Below the $DCGL_W$	% Below	Pass Sign Test?	Sum of Background Ranks	MARSSIM Critical Value	Pass WRS Test?
U-234	21[1]	100	Yes	1147	909	Yes
U-235	21	100	Yes	1147	909	Yes
U-238	21	100	Yes	1147	910	Yes
Total U [2]	20	95	Yes	966	781	Yes

[1] Critical value for Sign test is 14.
[2] The $DCGL_W$ for total uranium is 30 pCi/g.

Table 25

Unity Rule Calculation Results, Backfill Soil Pile Sampling Gamma Spectroscopy

Radionuclide	Mean Concentration (pCi/g) [1/]	$DCGL_W$ (pCi/g)	Ratio
U-234	3.17	214	0.015
U-235	0.097	22.7	0.0043
U-238	3.9	98.6	0.040
		Sum	0.059
		Is Sum of Ratios < 1?	Yes

[1/] pCi/g = picocuries per gram.

Table 26

Unity Rule Calculation Results, Backfill Soil Pile Sampling Alpha Spectroscopy

Radionuclide	Mean Concentration (pCi/g) [1/]	$DCGL_W$ (pCi/g)	Ratio
U-234	4.5	214	0.021
U-235	0.35	22.7	0.015
U-238	7.2	98.6	0.073
		Sum	0.11
		Is Sum of Ratios < 1?	Yes

[1/] pCi/g = picocuries per gram.

Table 27

Results of Backfill Soil Pile Field Measurements

Pile 1, Lift 1		Pile 1, Lift 2		Pile 2, Lift 1		Pile 2, Lift 2	
Grid Location	Areal Scaler Reading (cpm)	Grid Location	Areal Scaler Reading (cpm)	Grid Location	Areal Scaler Reading (cpm)	Grid Location	Areal Scaler Reading (cpm)
1	6324	1	6333	1	5272	1	5338
2	6350	2	6269	2	5285	2	5231
3	6373	3	6696	3	5393	3	5304
4	6847	4	6788	4	5557	4	5134
5	6660	5	6694	5	5322	5	5053
6	6509	6	6434	6	5217	6	5161
7	6870	7	6051	7	5258	7	5140
8	7033	8	5630	8	5109	8	5220
9	6616	9	6608	9	5135	9	5321
10	7054	10	7623	10	5284	10	5079
11	6868	11	6697	11	5421	11	5240
12	6796	12	6342	12	5142	12	5040
13	7129	13	6250	13	5263	13	5470
14	7054	14	6190	14	5398	14	5158
15	6544	15	5898	15	5331	15	5084
16	6282	16	5933	16	5138	16	5053
17	6464	17	6001	17	5089	17	5296
18	6599	18	6643	18	5225	18	5308
19	6207	19	6857	19	5286	19	5110
20	6340	20	6809	20	5352	20	4829
21	6315	21	7975	21	5074		
22	6249	22	6117	22	5128	Average	5178
23	6067	23	6089	23	5197	St. Dev.	143
24	6135	24	6038	24	5170		
25	6173	25	6181	25	4906		
26	6205	26	6589	26	5036		
27	6413	27	7202				
28	6567	28	6414	Average	5230		
29	6270	29	7021	St. Dev.	139		
30	6117	30	6288				
31	6495	31	6257				
32	6121	32	6152				
33	6656	33	5933				
34	6087						
35	6581	Average	6455				
36	6534	St. Dev.	498				
37	6358						
38	6421						
39	6614						
40	5397						
41	5991						
42	5933						
43	6204						
Average	6438						
St. Dev.	344						

Background	
Average	6194
St. Dev.	790

Table 28

Monthly Average Water Release Concentration Criteria

	10 CFR 20 App B Table 3	Tank Water Sample 1	Tank Water Sample 2	Excavation Water Sample 1	Excavation Water Sample 2
Radionuclide	Release Criteria (pCi/L/month)	Release Concentration [1] (pCi/L/month) [2]	Release Concentration (pCi/L/month)	Release Concentration (pCi/L/month)	Release Concentration (pCi/L/month)
U-234	3.0E+03	3.1E+03	2.9E+03	3.1E+03	3.0E+03
U-235	3.0E+03	9.6E+01	9.0E+01	9.6E+01	9.3E+01
U-238	3.0E+03	7.5E+02	6.7E+02	7.2E+02	7.6E+02

[1] Assuming a frac tank volume of 2750 gallons.
[2] pCi/L/month = picocuries per liter of water released per month.

Table 29

Sum Of Fractions Criteria

	Tank Water Sample 1	Tank Water Sample 2	Excavation Water Sample 1	Excavation Water Sample 2
Radionuclide	Release Fraction [1]	Release Fraction	Release Fraction	Release Fraction
U-234	0.5	0.47	0.5	0.48
U-235	0.015	0.014	0.015	0.015
U-238	0.12	0.11	0.11	0.12
Sum	0.63	0.59	0.63	0.62

[1] Assuming a frac tank volume of 2750 gallons and a sewer flow of 3000 gallons per month.

Table 30

Total Activity Release Calculation Results

	Total Activity (pCi) [1]			
Radionuclide	Tank Water Sample 1	Tank Water Sample 2	Excavation Water Sample 1	Excavation Water Sample 2
U-234	3.3E+07	3.0E+07	3.3E+07	3.1E+07
U-235	1.0E+06	9.3E+05	1.0E+06	9.6E+05
U-238	7.8E+06	7.0E+06	7.5E+06	7.9E+06
Sum	4.1E+07	3.8E+07	4.1E+07	4.0E+07

[1] pCi = picocuries; total activity release calculation performed assuming a frac tank volume of 2750 gallons.

Table 31

Sum of Fractions Equation

$$Sum_{RF} = \sum \frac{\text{Result} * V_{TL}}{C_A * (V_{TL} + V_{SW})}$$

Where:

Sum_{RF} = Sum of Release Fraction; the sum of the radionuclide specific monthly average release fractions

Result = Sample Result, the spectroscopy result for the specific radionuclide (pCi/g)

V_{TL} = Tank Liquid Volume, the volume of water collected estimated from tank dimensions of 8' x 21.5' by 2' (2,570 gal = 9,740 L)

C_A = Allowable Average Concentration, the radionuclide specific allowable monthly average concentration limit from 10 CFR 20 Appendix B Table 3

V_{SW} = Sewer Water Volume, the monthly volume of water passing through the sewer where the release will occur (3,000 gal = 11,355 L)

Table 32

Comparison Of Potential Doses From Excavation Sites And Background

Soil Sample Source	Dose Limit (% of 15 mrem/yr)	% Typical Background
Excavation Bottom	0.35 mrem/yr (2.3%)	0.097%
Backfill Soil Pile	0.89 mrem/yr (5.9%) -- gamma spec	0.25%
	1.65 mrem/yr (11%) -- alpha spec	0.46%

Table 33

ALARA Compliance Equation

$$\frac{Conc}{DCGL_w} = \frac{Cost_T}{\$2000 * P_D * 0.015 * F * A} * \frac{r + \lambda}{1 - e^{-(r+\lambda)*N}}$$

Where:

Conc = ALARA concentration, pCi/g.

$Cost_T$ = total cost of the additional remedial action, $150,000 per project baseline.

$2000 = monetary conversion factor of dose to dollars, from DG-4006.

P_D = population density of 4E-04 person/m^2, from DG-4006.

0.015 = dose limit of 15 mrem/yr in rem/yr.

F = remediation effectiveness factor, 1 for this type of action.

A = area being evaluated, 232 m^2.

r = monetary discount rate of 0.03, from DG-4006.

= radionuclide decay constant, yr^{-1}.

N = number of years over which the dose is calculated, 1000 for this case.

Appendix C, List of Acronyms

ACRONYMS AND ABBREVIATIONS

µCi	microcurie
µg/G	micrograms per gram
AEC	Atomic Energy Commission
AFB	Air Force Base
AFBCA	Air Force Base Conversion Agency
AFIERA	Air Force Institute for Environment, Safety, and Occupational Health Risk Analysis
ALARA	as low as is reasonably achievable
Am-241	americum-241
ANSI	American National Standards Institute
ARB	Air Reserve Base
ARAR	applicable or relevant and appropriate requirement
BRAC	Base Realignment and Closure (Act)
Ci	curie
cm	centimeter
COC	contaminant of concern
cpm	counts per minute
DCGL	derived concentration guideline level
$DCGL_{EMC}$	DCGL elevated measurement comparison
$DCGL_W$	derived concentration guideline level, wide area
DOD	Department of Defense
DQO	data quality objective
DU	depleted uranium
EU	enriched uranium
FIDLER	field instrument for the detection of low energy radiation
FSS	Final Status Survey
ft bgs	feet below ground surface
ft^2	square feet
Ge	germanium
GM	Geiger-Mueller
ISDH	Indiana State Department of Health
keV	kiloelectron volts
m	meters
m/s	meters per second
m^3/yr	cubic meters per year
MagThor	magnesium thorium alloy
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	minimum detectable concentration
MDCR	minimum detectable count rate
mg/d	milligrams per day
ml/g	milliliters per gram
mR/hr	milliroentgen per hour

mrem/hr	millirem per hour
mrem/yr	millirem per year
mSv/yr	millisievert per year
NaI	sodium iodide
NRC	Nuclear Regulatory Commission
Pa-234m	protactinium-234m
Parsons	Parsons Engineering Science, Inc.
pCi	picocurie
pCi/g	picocurie per gram
Philip	Philip Environmental Services
PID	photoionization detector
PRG	preliminary remediation goals
Pu-241	plutonium-241
Ra-226	radium-226
RESRAD	RESidual RADiation model
Rn-222	radon-222
ROC	radionuclide of concern
TEDE	total effective dose equivalent
Th-232	thorium-232
Th-234	thorium-234
TPH	total petroleum hydrocarbons
U-234	uranium-234
U235	uranium-235
U-238	uranium-238
USAF	United States Air Force
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
WRS	Wilcoxon Rank Sum
ZnS	zinc sulfide