DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON DC

12 May 2005

MEMORANDUM FOR NRC REGION IV
ATTENTION: MRS. BROWDER

FROM: AFMSA/SGPR
110 Luke Avenue, Room 405
Bolling AFB, DC 20032-7050

SUBJECT: Final Status Survey Report of OT-10 Radiation Training Sites Located at Kirtland AFB, Under AF Master Material License No. 42-23539-01AF, Docket No. 030-28641.

Please find enclosed two copies of the " Final Status Survey Report for Environmental Restoration Program Site OT-10 Volume 1 and 2" (Atch 1) and two CD-ROMs (Atch 2) under Air Force Permit NM-03110-02/01AFP. The surveys were performed in accordance with Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) survey methodology. Additionally, the area was properly surveyed and decommissioned in accordance with the guidance outlined in NUREG 1757, Consolidated NMSS Decommissioning Guidance. Any remaining residual radioactivity is within the limits of 10 CFR Part 20 Subpart E, and is ALARA. Based on these conclusions, no further remediation or actions with respect to Nuclear Regulatory Commission (NRC) material is required

Radiation training sites OT-10 consist of Sites TS5, TS6, TS7 and TS8. As per our letter dated 25 June 2003 addressed to Mr. Cain of NRC Region IV (Atch 3), we have transferred training site TS8 to Defense Nuclear Weapon School of the Defense Threat Reduction Agency. However, we have removed all contaminated soil above the Derived Concentration Guideline Level of Thorium-232 from the TS8 site (outside the Bunker/Building 28005) and decontaminated Building 28010 as per the radiological release criteria for unrestricted use of 10 CFR Part 20.1402. However, Building 28005 at TS8 remains contaminated above the radiological release criteria.

Please, review the attachments 1/ 2 and request that you release training sites TS5, TS6, TS7 and TS8 (including Building 28010) except Building 28005 for unrestricted use as per 10 CFR Part 20.1402.

If you have any questions or need further input, please contact me at 202-767-4306 or e-mail at ramachandra.bhat@pentagon.af.mil. Our telefax is 202-404-8089.

R K Bhat

Ramachandra K. Bhat Ph.D., CHP
Health Physicist
Radiation Protection Division and
USAF Radioisotope Committee Secretariat
Air Force Medical Operations Agency
Office of the Surgeon General

Attachments:

1. Two Hard Copies of Final Status Survey Report of OT-10
2. Two CD-ROMs of Final Status Survey Report of OT-10
3. Letter Dated 25 June 2003 Addressed to Mr. Cain

cc:
377 MSG/CEVR (Mr. Lanz) w/o Atch
377 AMDS/SGPB (Capt Murren) w/o Atch
377 AMDS/SGPB (Mr. Volza) w/o Atch
HQ AFMC/SG (Maj Martilla) w/o Atch
AFIA/SGI (Lt Col Rademacher) w/o Atch
AFIERA/SDR (Mr. Renaghan) w/o Atch
NRC REGION IV (Mr. Gaines)

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON DC

25 June 2003

MEMORANDUM FOR NRC REGION IV
ATTENTION: Mr. CHARLES CAIN

FROM: AFMOA/SGZR
110 Luke Avenue, Room 405
Bolling AFB, DC 20032-7050

SUBJECT: Supplement to Decommissioning Plan for Installation Restoration Site OT-10 Radiation Training Sites located at Kirtland AFB, Under AF Master Material License No. 42-23539-01AF, Docket No. 030-28641.

Your office approved the Decommissioning Plan (DP) of the referenced OT-10 site dated August 2002, on 8 January 2003. The DP included the decommissioning of the four training sites TS5, TS6, and TS7 and TS8. The actual excavation of the soil at TS5, TS6 and TS7 at the OT-10 site started on the first week of March 2003 and may continue until August 2003. Meanwhile, the Defense Threat Reduction Agency (DTRA) has made a formal request to take possession of training site TS8 (see the Attachments) for use as an additional training facility at the DTRA operated Defense Nuclear Weapon School (DNWS). Kirtland AFB has agreed to transfer the site to DTRA. As a result of this transfer, the demolition and disposal of the Bunker 28005 at TS8 will not take place as stated in the approved DP (fourth paragraph of the page 3-19 of the DP). However, we will remove and dispose of soil above the Derived Concentration Guideline Level of Thorium-232 from the TS8 site (outside the Bunker 28005), remove and dispose the two drums currently stored in the Bunker and vacuum inside the Bunker. We will also establish a baseline radiological characterization of the Bunker inside floors, walls, and ceilings.

The DTRA will assume all future responsibility for clean up of the Bunker 28005 at TS8. The purpose of this letter is to inform the NRC of our departure from the NRC approved decommissioning plan.

If you have any questions or need further input, please contact me at 202-767-4306 or e-mail at ramachandra.bhat@pentagon.af.mil. Our telefax is 202-404-8089.

RKBhat

Ramachandra K. Bhat Ph.D., CHP
Health Physicist
Radiation Protection Division and
USAF Radioisotope Committee Secretariat
Air Force Medical Operations Agency
Office of the Surgeon General

ATCH 3

\\rammis\rammis\Permits\Kirtland AFB NM\03022516\CO20030625

Attachment:
1. The Letter from Mr. Lanz
2. The DTRA Form 1

cc:
377 MSG/CEVR (Mr. Sillerud)
377 MSG/CEVR (Mr. Lanz) w/o Atch
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ENVIRONMENTAL RESTORATION PROGRAM
KIRTLAND AIR FORCE BASE
ALBUQUERQUE, NEW MEXICO

FINAL STATUS SURVEY REPORT
FOR
ENVIRONMENTAL RESTORATION PROGRAM SITE OT-10,
RADIATION TRAINING SITES

JANUARY 2005

Prepared for
HQ AFCEE/ERD
ENVIRONMENTAL RESTORATION DIVISION
BROOKS CITY BASE, TEXAS 78253-5112

USAF CONTRACT NO. F41624-97-D-8013 DELIVERY ORDER NO. 0037

Prepared by
MWH AMERICAS
ALBUQUERQUE, NEW MEXICO

470562

NOTICE

This *Final Status Survey Report* has been prepared for the U.S. Air Force by MWH Americas, Inc., to aid in the implementation of a final remedial action under the Environmental Restoration Program (IRP). As the report relates to actual or possible releases of potentially hazardous substances, its release prior to an Air Force final decision on remedial action may be in the public's interest. The limited objectives of this report and the ongoing nature of the ERP, along with the evolving knowledge of site conditions and chemical effects on the environment and health, must be considered when evaluating this report, because subsequent facts may become known that may make this report premature or inaccurate.

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Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This Final Status Survey Report presents the results of the final status surveys performed in support of decommissioning at Environmental Restoration Program Site OT-10, Radiation Training Sites, Kirtland AFB, New Mexico.

14. SUBJECT TERMS

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PREFACE

This document presents the results of the final status surveys performed at Environmental Restoration Program Site OT-10, Radiation Training Sites, Kirtland Air Force Base, New Mexico. The report addresses the requirements of the U.S. Air Force statement of work, dated March 2, 2001.

This report was prepared by MWH Americas, Inc., from January through September 2004. Rodney C. Arnold of the Air Force Center for Environmental Excellence served as the Contracting Officer's Representative.

Jeffrey W. Johnston
MWH Project Manager

Chris Timm
MWH Task Manager

40 CFR 270.11
DOCUMENT CERTIFICATION

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

CARL J. LANZ, P.G., GS-13
Chief, Restoration Section

This document has been approved for public release.

ROBERT S. MILLIGAN
Environmental Public Affairs Officer

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ACRONYMS

AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
ALARA	as low as reasonably achievable
ANL	Argonne National Laboratory
bgs	below ground surface
cf	conversion factor
CFR	*Code of Federal Regulations*
Ci	Curies
cm	centimeter
cm^2	square centimeters
cpm	counts per minute
DAC	derived-air concentration
DCGL	derived-concentration guideline level
DNA	Defense Nuclear Agency
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
dpm	disintegrations per minute
DTRA	Defense Threat Reduction Agency
EMC	Elevated Measurement Comparison
EPA	U.S. Environmental Protection Agency
ERP	Environmental Restoration Program
FEMA	Federal Emergency Management Agency
ft	feet/foot
ft/sec	feet per second
GIS	geographical information system
GPS	global positioning system
KeV	kilo electron volt
kg	kilograms
LBGR	lower bound of the gray region
m^2	square meters
MARSSIM	*Multi-Agency Radiation Survey and Site Investigation Manual*
MDC	minimum detectable concentration
mrem/yr	millirem per year
MWH	MWH Americas, Inc.

ACRONYMS (Concluded)

NAS	National Academy of Sciences
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
NUREG	Nuclear Regulation
pCi/g	picocuries per gram
QA	quality assurance
QC	quality control
r^2	Pearson's Correlation
RASS	remedial action support surveys
RER	replicate error ratio
RESRAD	residual radiation
RIC	Radioisotope Committee
RPD	relative percent difference
STL	Severn Trent Laboratories
TEDE	total effective dose equivalent
TS	Training Site
µR/hr	microRoentgens per hour
U.S.	United States
USAF	U.S. Air Force
WRS	Wilcoxon Rank Sum
ZnS	zinc sulfide

EXECUTIVE SUMMARY

This report presents the results of the final status surveys performed in support of Environmental Restoration Program (ERP) Site OT-10, Radiation Training Sites, Kirtland Air Force Base (AFB), New Mexico. The OT-10 Radiation Training Sites are owned by the United States (U.S.) government and regulated by the Nuclear Regulatory Commission (NRC) under the U.S. Air Force (USAF) Master Materials License 42-23539-01AF. Decommissioning activities at the sites were performed in accordance with an NRC-approved *Decommissioning Plan* (USAF, 2000) and monitored under NRC Docket Number 030-28641.

The final status surveys demonstrate that the sites meet the criteria for unrestricted use as specified in 10 *Code of Federal Regulations* (CFR) Part 20 Subpart E, "Radiological Criteria for License Termination." The radiological criteria for unrestricted use as defined in 10 CFR 20.1402 are 1) The total effective dose equivalent (TEDE) from residual radioactivity that is distinguishable from background must not be greater than 25 millirems per year (mrem/yr), and 2) the residual radioactivity level must be as low as reasonably achievable (ALARA).

The primary objectives of the final status surveys were to perform the following:

- Verify survey unit classification,
- Demonstrate that the potential dose from residual radioactivity is below the release criterion for each survey unit, and
- Demonstrate that the potential dose from small areas of elevated activity is below the release criterion for each survey unit.

The primary objective of the final status survey report is to present sufficient information for NRC staff to determine that the site meets the radiological criteria for license termination (NRC, 2002). Prior to remediation, contamination at the OT-10 Training Sites did not meet the release criteria for unrestricted use. Derived-concentration guideline levels (DCGLs) were developed to quantify the risks and provide evaluation criteria for the final status survey results. DCGLs for land areas were developed using residual radiation (RESRAD), Model Version 6.1, and for buildings using RESRAD-Build, Version 3.0 (NRC, 2000). The site-specific doses for exposed individuals were modeled using the contaminants identified during the site characterization surveys. The contaminants of potential concern were predominately thorium-232 and its decay progeny with lesser amounts of uranium-238 and uranium-235 and their decay progeny.

Table ES-1 presents the modified DCGLs for long-lived radionuclides in the top 15 centimeters of surface soil for a residential exposure scenario.

Table ES-1. Land Area Modified Derived-Concentration Guideline Levels, Environmental Restoration Program Site OT-10

Radionuclide	Modified DCGLs above background (pCi/g)[a]
Thorium-232 Decay Series	
Thorium-232	5.7
Radium-228	5.7
Thorium-228	5.7
Uranium-238 Decay Series	
Uranium-238	0.31
Uranium-234	0.31
Thorium-230	0.62
Radium-226	0.28
Lead-210	0.28
Uranium-235 Decay Series	
Uranium-235	0.02
Actinium-227	0.03
Protactinium-231	0.03

Notes:
[a]Uranium-235 background concentration assumed as natural abundance of 2.2 percent of uranium-234 plus uranium-238 activity.
DCGL = derived-concentration guideline level
pCi/g = picocuries per gram

The DCGL for total surface activity on buildings is 250 disintegrations per minute (dpm)/100 square centimeters (cm^2). For thorium-232 surface contamination, 68 percent of the particle emissions are expected to be alpha particles and 32 percent of the emissions will be beta particles. This corresponds to alpha particle emission rates of 170 dpm/100cm^2 and beta particle emission rates of 80 dpm/100 cm^2. Removable contamination limits are 20 percent of the total, or 34 dpm/100 cm^2 alpha and 16 dpm/100cm^2 beta.

The final status surveys of land areas included scanning and static-gamma radiation measurements in *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) Class 1 and Class 2 survey units and soil sampling in MARSSIM Class 1 survey units (EPA, 1997). Exposure rate measurements were also collected to define the correlation between gamma radiation count rates and exposure rates. Final status surveys of buildings included total and removable alpha radiation measurements and gamma radiation-exposure rate measurements. Evaluations were conducted on alpha emissions only because no contaminants of concern present beta/gamma emissions.

The land area final status survey data were evaluated using the Mean, Wilcoxon Rank Sum (WRS), Elevated Measurement Comparison (EMC), and unity rule tests. All land area survey units pass these statistical tests. Therefore, all land areas meet the release criteria for unrestricted use.

The minimum detectable concentration (MDC) for the land area survey instruments was recalculated using the final status survey data. Calculations of the scanning and static MDCs were made using several methods. The empirically derived values of scanning and static MDCs comply with the MARSSIM-recommended guidance of less than 50 percent of the DCGL or 2.85 picocuries per gram (pCi/g) thorium-232.

During the OT-10 decommissioning, Training Site (TS) 8 and the two buildings within its boundaries were transferred to the Defense Threat Reduction Agency (DTRA) for use as a training facility. The TS8 land area and Building 28010 were decontaminated, and Building 28005 was left in its contaminated state. Therefore, building final status surveys were only conducted at Building 28010. All final status survey measurements at Building 28010 meet the release criteria of 170 dpm/100 cm^2 total alpha and 34 dpm/100 cm^2 removable alpha above natural background. Because all measurements comply with the release criteria, no statistical tests were performed on the building final status survey data.

The static MDCs for total alpha of the building survey instruments were calculated to be 12 dpm/100 cm^2 and 28 dpm/100 cm^2. These MDCs comply with the MARSSIM-recommended guidance of less than 50 percent of the DCGL or 85 dpm/100 cm^2. The MDCs for removable alpha of the survey instruments ranged from 2.4 to 3.3 dpm/100 cm^2 and are well below the MARSSIM recommended guidance of 50 percent of the 34-dpm/100 cm^2 criteria

Site conditions at TS5, TS6, TS7, Building 28010, and TS8 with the exception of Building 28005 meet the radiological criteria for unrestricted use. During the decommissioning, TS8 was transferred to DTRA for use as a training facility. The TS8 land areas and Building 28010 were decontaminated and meet the radiological release criteria. However, Building 28005 at TS8 remains contaminated above the radiological release criteria. Installation of a fence to segregate Building 28005 from the remainder of TS8 and prevent recontamination of the site is planned for the summer of 2005.

It is recommended that a petition be submitted to the NRC for unrestricted release of TS5, TS6, TS7, Building 28010, and TS8 with the exception of Building 28005.

1.0 INTRODUCTION

This report presents the results of the final status surveys performed in support of decommissioning activities at Environmental Restoration Program (ERP) Site OT-10, Radiation Training Sites, Kirtland Air Force Base (AFB), New Mexico. While this report presents the radiological status of the sites after decommissioning, it does not discuss the procedures used to decontaminate the sites. This report was prepared in accordance with the guidance in Nuclear Regulation (NUREG)-1757, *Consolidated Nuclear Material Safety and Safeguards (NMSS) Decommissioning Guidance* (U.S. Nuclear Regulatory Commission [NRC], 2002) and NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)* (U.S. Environmental Protection Agency [EPA], 2000). This report also addresses the requirements in the NRC approval of the OT-10 decommissioning application and Safety Evaluation Report (SER) for the sites (NRC, 2003a and b).

1.1 Authority of the Work

The OT-10 Radiation Training Sites are owned by the United States government and regulated by the NRC under the U.S. Air Force (USAF) Master Materials License 42-23539-01AF. Decommissioning activities at the sites were performed according to an NRC-approved decommissioning plan (USAF, 2002). NRC approval of the decommissioning plan is dated January 8, 2003, and referred to under NRC Docket Number 030-28641. As part of the approval process, the USAF Master Materials License was amended to allow decommissioning of the OT-10 sites. Following NRC approval of the decommissioning plan, the USAF Radioisotope Committee (RIC) approved the plan on January 23, 2003.

MWH Americas, Inc. (MWH), was contracted by the Air Force Center for Environmental Excellence (AFCEE) under Contract F41624-97-D8013, Delivery Orders 37 and 80, to decommission the OT-10 Radiation Training Sites. This report is a deliverable under Contract F41624-97-D-8013, Delivery Order 37.

1.2 Final Status Survey Objectives

The final status survey is used to demonstrate compliance with regulations. For the OT-10 sites, the final status surveys demonstrate that the criteria have been met for unrestricted use as specified in 10 *Code of Federal Regulations* (CFR) Part 20 Subpart E, "Radiological Criteria for License Termination." The radiological criteria for unrestricted use as defined in 10 CFR 20.1402 are that the total effective dose equivalent (TEDE) from residual radioactivity that is distinguishable from background must not be greater than 25 millirem per year (mrem/yr) and that the residual radioactivity level must be as low as reasonably achievable (ALARA).

The primary objectives of the final status surveys are to

- Verify survey unit classification,
- Demonstrate that the potential dose from residual radioactivity is below the release criterion for each survey unit, and
- Demonstrate that the potential doses from small areas of elevated activity are below the release criterion for each survey unit.

The primary objective of the final status survey report is to present sufficient information for NRC staff to determine that the sites meet the radiological criteria for license termination (NRC, 2002).

1.3 Report Organization

This report is divided into six text sections. Section 1 provides the introduction and defines the report objectives. Section 2 presents a brief description and history of the sites. The operating history, license number, and the history of OT-10 as a NRC docket are provided. The types and quantities of radioactive material introduced into the sites are also presented in Section 2.

Section 3 presents the decommissioning criteria used to support site closure and license termination. Training site contaminants are identified and used in residual radiation (RESRAD) dose modeling to establish the derived-concentration guideline levels (DCGLs) for land areas and buildings. Area factors for use in the elevated measurement comparison and unity rule analysis, as determined by RESRAD, are also presented. Reference areas identified to support the decommissioning criteria evaluation and their radiological status are presented.

The final survey procedures for land areas and building surfaces are presented in Section 4. Sampling methodologies, field techniques, and laboratory techniques are discussed. Analytical methods for quantifying radionuclides in soil using alpha spectroscopy and gamma spectroscopy are provided. Justification for the overall statistical approach used in the final status survey evaluation is also presented, including calculations for sample number determination.

Section 5 presents the final status survey results and their interpretation. The results of the three survey methodologies, gamma scanning surveys, static gamma measurements, and soil sample analysis, employed for the final status surveys, are presented in report subsections. The survey data are subdivided by site into MARSSIM Class survey units. The summary statistics for each MARSSIM Class 1 and Class 2 survey unit are presented and evaluated for compliance with the decommissioning criteria.

Section 5 also presents the statistical evaluation of the final status survey data from each MARSSIM survey unit. The mean and Wilcoxon Rank Sum (WRS) test results for soil radionuclide concentrations are presented. Results of the elevated measurement comparison (EMC) and unity rule analysis are also presented for areas that exceeded the soil DCGL. Judgmental and miscellaneous sample data sets that were not collected for performing the statistical evaluation; for example, NRC split samples, are reported separately in this section.

Section 6 presents the conclusions and recommendations for the report.

2.0 SITE DESCRIPTION

2.1 Site Description

In November 1961, eight radiation training sites were established at Kirtland AFB. The sites are owned by the United States government and are regulated by the NRC under USAF Master Materials License No. 42-23539-01AF. Training sites (TS) 1 through 4 (TS1 through TS4) remain active. The four inactive sites, TS5 through TS8, comprise ERP Site OT-10. TS5, TS6, TS7, and a portion of TS8 were decommissioned under this contract. During the decommissioning process, TS8 was transferred to the Defense Threat Reduction Agency (DTRA) for use as a training facility. Figure 2-1 shows the general location of the OT-10 Radiation Training Sites and the reference land area at Kirtland AFB. ERP Site SS-69, located within the boundaries of TS6, was approved for No Further Action by the New Mexico Environment Department (NMED) in a letter dated August 13, 2004.

TS8 contains two buildings, 28005 and 28010, within the fenced area, which were used as training and storage facilities. Each building is approximately 10 feet (ft) by 20 ft with a maximum height of 10 ft. The buildings have concrete floors, steel doors and front walls, and corrugated steel ceilings and back walls. The ceilings, side walls, and back walls are covered under earth. There are no utilities in the buildings. Figure 2-2 is a photograph of Building 28010 and is also representative of Building 28005.

2.2 Operating History

The training sites were used to train U.S. Department of Defense (DoD), U.S. Department of Energy (DOE), Federal Emergency Management Agency (FEMA), and other federal and state personnel to detect dispersed contamination resulting from nuclear weapons accidents. Known quantities of thorium oxide sludge were applied and tilled into site soils to simulate dispersed radiological contamination. The thorium oxide sludge served as a low hazard analog for plutonium. A total inventory of 1,710 kilograms (kg) of thorium sludge, containing approximately 602 kg of thorium-232, was applied to the inactive sites (Defense Nuclear Agency [DNA], 1994). Table 2-1 presents the estimated thorium inventory by training site. Analysis of the thorium sludge by the Air Force Institute for Environment, Safety and Occupational Health Risk Analysis (AFIERA) in 1993 quantified thorium-232 activity at 18,000 picoCuries per gram (pCi/g). Using the sludge thorium-232 activity of 18,000 pCi/g and the sludge inventory of 1,710 kilograms (kg), the total site activity is estimated to be 0.0308 Curies (Ci) thorium-232.

Training activities were discontinued at TS5 through TS8 in 1990. Large pieces of military equipment, such as fuselages, vehicles, parts, and other debris, present at TS5 through TS8 were removed and redistributed at active sites TS1 through TS4. The military equipment was placed on TS1 through TS4 to simulate accident and crash sites.

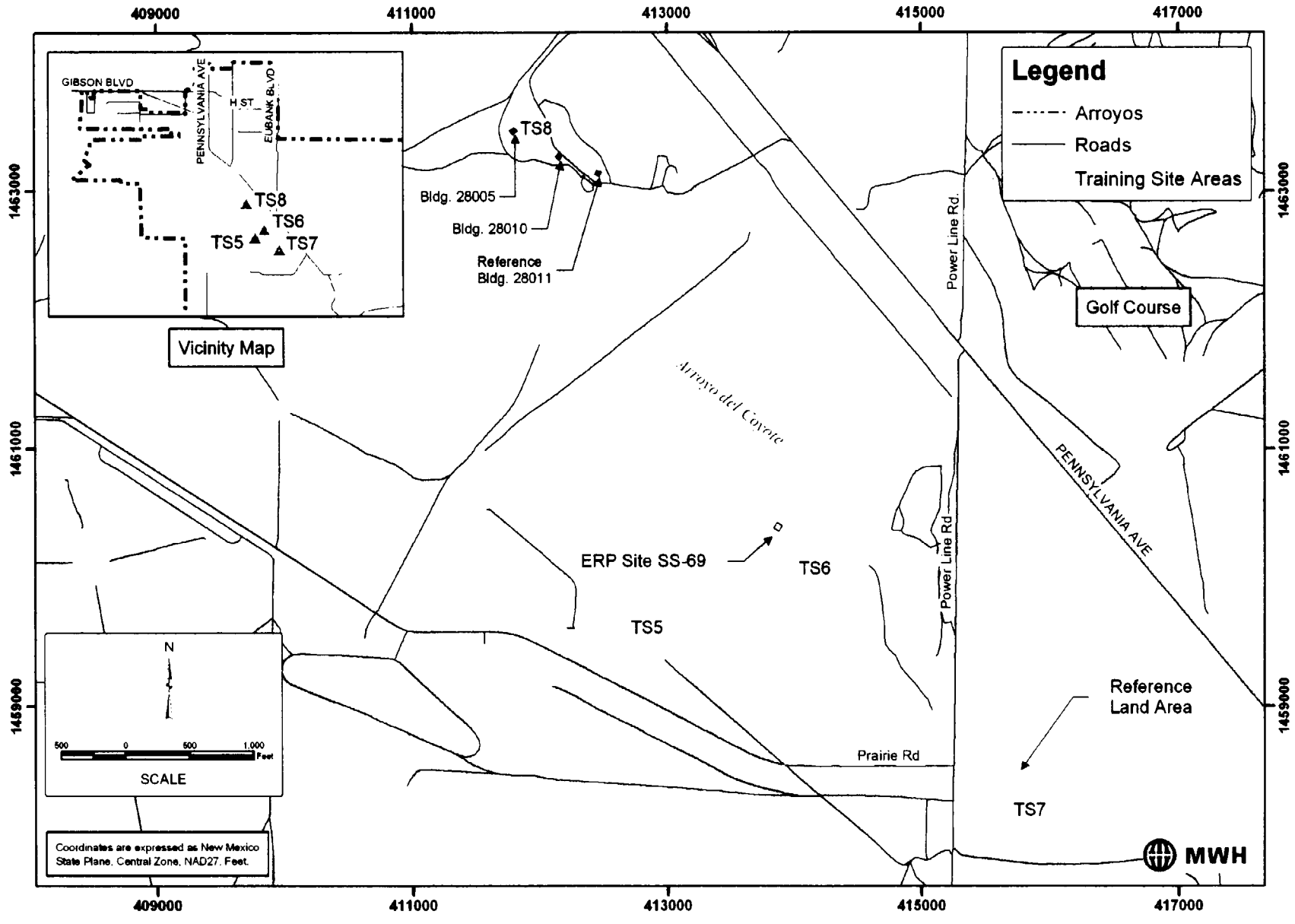

Figure 2-1. Site Location Map of Environmental Restoration Program Site OT-10, Kirtland Air Force Base, New Mexico

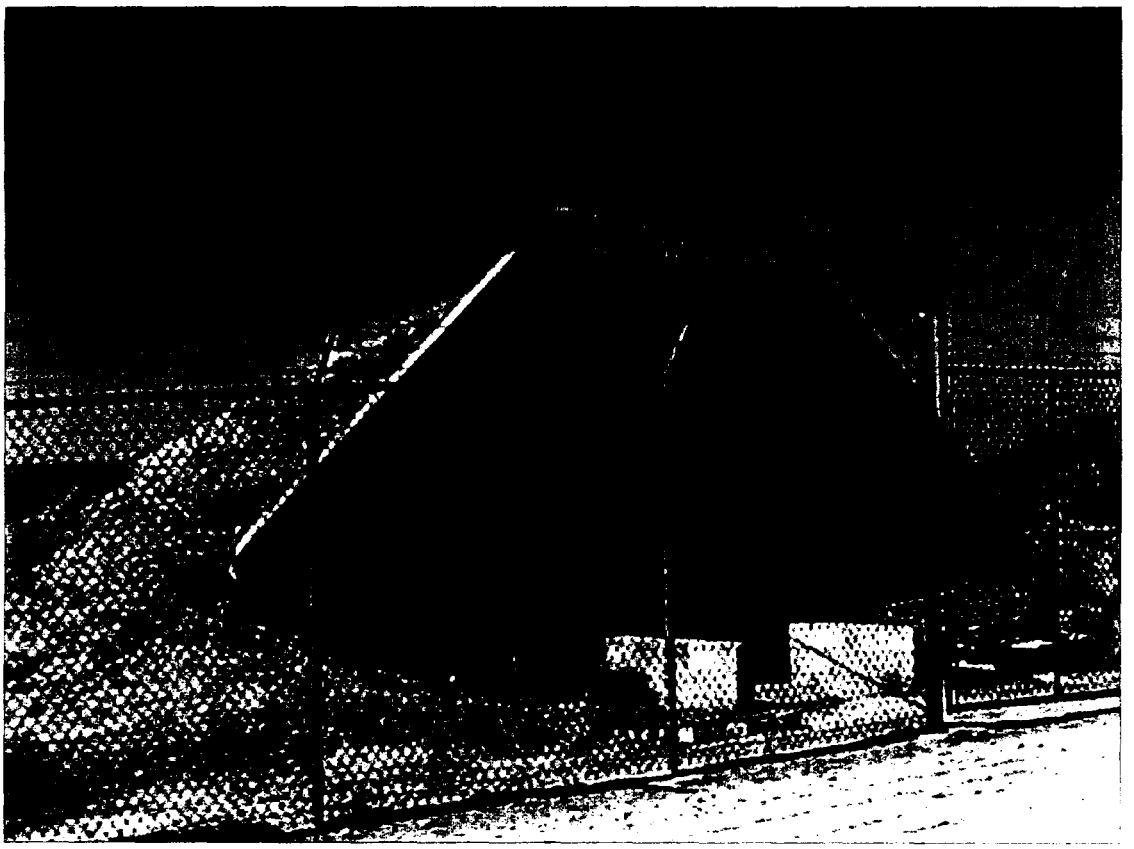

Figure 2-2. Photograph of Building 28010 at Training Site 8, Environmental Restoration Program Site OT-10

Table 2-1. Training Site Acreage and Thorium-232 Inventory, Environmental Restoration Program Site OT-10

Training Site	Approximate Area [acres]	Inventory of Thorium Sludge Applied (kg)	Estimated Thorium-232 Applied [kg][a]
TS5	13.4	611	215
TS6	19	872	307
TS7	8.4	102	36
TS8	2.4	125	44

Notes:
[a]Thorium-232 inventory from DNA, 1994. The author of this report used the following assumptions to determine the mass of thorium-232: Mass of thorium-232 = 0.88 * Mass thorium oxide; and Mass thorium oxide = 0.4 * Mass of thorium sludge. Inventories reported in USAF, 1997, and USAF, 1999a, are for thorium sludge.
DNA = Defense Nuclear Agency
kg = kilogram
USAF = U.S. Air Force

On July 14, 2000, the USAF submitted an application to the NRC requesting review and approval of the OT-10 Training Sites Decommissioning Plan. The Decommissioning Plan was revised in response to NRC comments and resubmitted to the NRC on November 19, 2002. The NRC approved the decommissioning application and plan for unrestricted release of the OT-10 Radiation Training Sites on January 8, 2003. The USAF Master Materials License 42-23539-01AF was amended to allow decommissioning of the OT-10 Radiation Training Sites, and decommissioning activities were monitored under NRC docket number 030-28641.

The OT-10 decommissioning activities were mobilized on January 20, 2003. The first waste shipment departed the site for the Envirocare of Utah disposal facility on March 7, 2003. The final waste shipment was on October 29, 2003. A total of 373,145 cubic feet (ft^3) of waste were manifested and shipped to Envirocare of Utah for disposal. The activity of the waste shipped for disposal was calculated to be 0.1518 Ci thorium-232. Site operations were demobilized during November 2003.

3.0 DECOMMISSIONING CRITERIA

Due to the historical practices, contamination at the OT-10 Radiation Training Sites did not meet the release criteria for unrestricted use. This section presents the decommissioning criteria developed to mitigate these risks. Based on the radionuclide mixture identified during the site characterization surveys, DCGLs were developed for the sites. DCGLs for OT-10 are defined as the mass or surface activity concentrations corresponding to a TEDE of 25 mrem/yr above background. The derivation of the DCGLs was originally presented in the Decommissioning Plan (USAF, 2002) and is summarized in the following sections to provide evaluation criteria for the final status survey results.

3.1 Derived-Concentration Guideline Level Development

DCGLs for the OT-10 land areas were developed using RESRAD, version 6.1 (NRC, 2000). DCGLs for the buildings were developed using RESRAD-Build, version 3.0 (Argonne National Laboratory [ANL], 1994; NRC, 2000). The site characterization surveys identified thorium-232, uranium-238, uranium-235, and their decay progeny as contaminants of potential concern at the sites. These radionuclides were used to model site-specific doses for exposed individuals.

3.1.1 Decommissioning Criteria for Land Areas

RESRAD version 6.1 was used to calculate site-specific radiation doses posed by land areas to exposed individuals. Exposure scenarios were modeled for two variables, receptors and assumed land use, using RESRAD default, site-specific, and EPA parameters (USAF, 2002). The assumed land use is a residential-unrestricted use scenario. External radiation, incidental soil ingestion, inhalation of radon, and consumption of contaminated drinking water were the exposure pathways considered in the dose modeling.

Model runs generated modified DCGLs in surface soil for thorium-232, uranium-238, and uranium-235, including their decay progeny. The modified DCGLs consider the dose contribution from all radionuclides present at the site, not just a single radionuclide. Table 3-1 presents the modified DCGLs for long-lived radionuclides in the top 15 centimeters (cm) of surface soil for a residential exposure scenario. This analysis was conducted based on a 10,000-square-meter (m^2) land area (EPA, 1997).

Table 3-1. Land Area Modified Derived-Concentration Guideline Levels, Environmental Restoration Program Site OT-10

Radionuclide	Modified DCGLs above background (pCi/g)[a]
Thorium-232 Decay Series	
Thorium-232	5.7
Radium-228	5.7
Thorium-228	5.7
Uranium-238 Decay Series	
Uranium-238	0.31
Uranium-234	0.31
Thorium-230	0.62
Radium-226	0.28
Lead-210	0.28
Uranium-235 Decay Series	
Uranium-235	0.02
Actinium-227	0.03
Protactinium-231	0.03

Notes:
[a]Uranium-235 background concentration assumed as natural abundance of 2.2 percent of uranium-234 plus uranium-238 activity.
DCGL = derived-concentration guideline level
pCi/g = picocuries per gram

When a radionuclide is present in background, as is the case at the OT-10 sites, the WRS test is used to evaluate whether site data are less than the DCGL. The modified DCGL for thorium-232, used for the WRS test of each MARSSIM Class 1 survey unit, is referred to as the $DCGL_w$. As specified in the OT-10 Decommissioning Plan, thorium-232 was measured by gamma spectroscopy using actinium-228 as a surrogate (USAF, 2002). All other radionuclide activities were calculated using the established radionuclide ratios from the site characterization surveys.

3.1.2 Decommissioning Criteria for Buildings

RESRAD-Build 3.0 (ANL, 1994; NRC, 2000) was used to evaluate the dose to industrial workers occupying the two storage buildings at TS8 (Buildings 28005 and 28010). The exposure pathways included in the evaluation were external radiation exposure due to the source, inhalation of airborne radioactive material, and inadvertent ingestion of radioactive material. Parameter analysis was based upon guidance provided in NUREG-5512, Volumes 1 and 3 (NRC, 1992a and NRC, 1999), and NUREG/CR-6697 (NRC, 2000).

Conservative surface contamination limits were based only on the presence of thorium-232 and its progeny that would result in a maximum dose of 25 mrem/yr to the site workers. Based upon RESRAD-Build sensitivity analysis, a mixture of the uranium-238 series and thorium-232 series would be less hazardous per disintegration than just the thorium-232 series.

The RESRAD-Build modeling indicates that the total surface activity on structures must be limited to 250 disintegrations per minute (dpm) per 100 square centimeters (cm^2) to limit the dose for workers in the buildings to a TEDE of 25 mrem/yr. It is expected that 68 percent of the particles emitted by thorium-232

contamination would be alpha particles and 32 percent of the emissions would be beta particles. This corresponds to an alpha emission rate of 0.68*250=170 dpm/100 cm^2 and a beta emission rate of 0.32*250=80 dpm/100 cm^2.

Removable activity is defined as the activity that may be removed by taking a wipe sample or by other non-chemical or highly abrasive methods. The removable activity corresponds to material that is more readily transportable from the surface and thus may lead to greater exposure. Therefore, it has a separate exposure limit. In RESRAD-Build dose assessment modeling, the model default assumes that 20 percent of the total activity is removable. Therefore, the removable alpha limit is 0.2*170=34 dpm/100 cm^2 and the removable beta limit is 0.2*80=16 dpm/100 cm^2.

3.1.3 Decommissioning Criteria for Areas of Elevated Activity

The WRS test applies only to uniform distributions of residual activity in a MARSSIM survey unit. Radioactive hot spots in surface soils are addressed using the EMC method and unity rule analysis (EPA, 1997). The primary components of the EMC include area factors and required scan minimum detectable concentrations (MDCs). The $DCGL_{EMC}$ is equivalent to the $DCGL_w$ times the area factor.

3.1.3.1 Area Factors

Area factors, the magnitudes by which potential elevated areas can exceed the $DCGL_w$, were determined using RESRAD 6.1.

The modeled training site area was replaced with a range of smaller elevated areas that may be encountered in the remedial action support and final status surveys. Indoor and outdoor resident exposure scenarios were considered. In addition, only land areas were adjusted (modifying area only) in a third model run.

Table 3-2 lists the thorium-232 and uranium-238 concentrations above background that would result in a dose of 25 mrem/yr to a site resident in various areas. In the range of 1 to 110 m^2, the indoor exposure results are the least conservative followed by the outdoor exposure and then the modifying area only.

The modifying area only scenario is the most conservative and was adopted for the Site OT-10 decommissioning project for the smallest elevated areas (1 to 110 m^2). The three scenarios yield the same results in the range of 140 m^2 to 1,000 m^2.

Table 3-2. Area Factors for the Elevated Measurement Comparison, Environmental Restoration Program Site OT-10

	Primarily Indoor Exposure			Primarily Outdoor Exposure			Modifying Area Only		
Area (m^2)	Thorium-232 (pCi/g)	Uranium-238 (pCi/g)	Area Factor (multiple of the DCGL)	Thorium-232 (pCi/g)	Uranium-238 (pCi/g)	Area Factor (multiple of DCGL)	Thorium-232 (pCi/g)	Uranium-238 (pCi/g)	Area Factor (multiple of the DCGL)
1	123.1	6.70	21.6	81.5	4.43	14.3	20.8	1.13	3.65
10	24.5	1.33	4.3	15.4	0.84	2.7	10.8	0.43	1.9
60	13.1	0.71	2.3	7.7	0.43	1.4	7.7	0.43	1.4
80	11.9	0.65	2.1	7.4	0.40	1.3	7.4	0.40	1.3
110	7.4	0.40	1.3	6.8	0.37	1.2	6.8	0.37	1.2
140	6.7	0.36	1.17	6.7	0.36	1.17	6.7	0.36	1.17
170	6.6	0.36	1.15	6.6	0.36	1.15	6.6	0.36	1.15
200	6.4	0.35	1.13	6.4	0.35	1.13	6.4	0.35	1.13
1000	5.8	0.31	1.01	5.8	0.31	1.01	5.8	0.31	1.01

Notes:
DCGL = derived-concentration guideline level
m^2 = square meters
pCi/g = picocuries per gram

3.2 Reference Areas

The contaminants of concern, thorium-232, uranium-238, uranium-235, and their decay progeny, are present in background at the OT-10 sites. Therefore, reference areas were identified near the OT-10 sites to evaluate the final status survey data. Two reference areas were selected: one land area and one building.

3.2.1 Reference Land Area

The reference land area was selected north of TS7 because that land area has soil and vegetation types similar to the four inactive training sites. A 2,000-m^2 land area was used for the reference area, equivalent to the MARSSIM Class 1 survey unit adopted for OT-10 decommissioning. The location of the reference land area in relation to the OT-10 Training Sites is shown on Figure 2-1.

The reference land area data used in the decommissioning evaluation were collected during the April 2001 site characterization survey. The site characterization survey included a gamma radiation scanning survey, static-gamma radiation measurements, and surface soil sampling. The methods used to collect the survey data are presented in the OT-10 Decommissioning Plan (USAF, 2002). The results of the reference area surveys are summarized below.

The gamma scanning survey data were mapped using ArcView GIS software. The spatial distribution of the survey data is shown in Figure 3-1. Summary statistics for the gamma scanning data are presented in Table 3-3. Gamma radiation scanning measurements ranged from 10,427 to 15,379 counts per minute (cpm) and averaged 12,407 cpm (arithmetic mean).

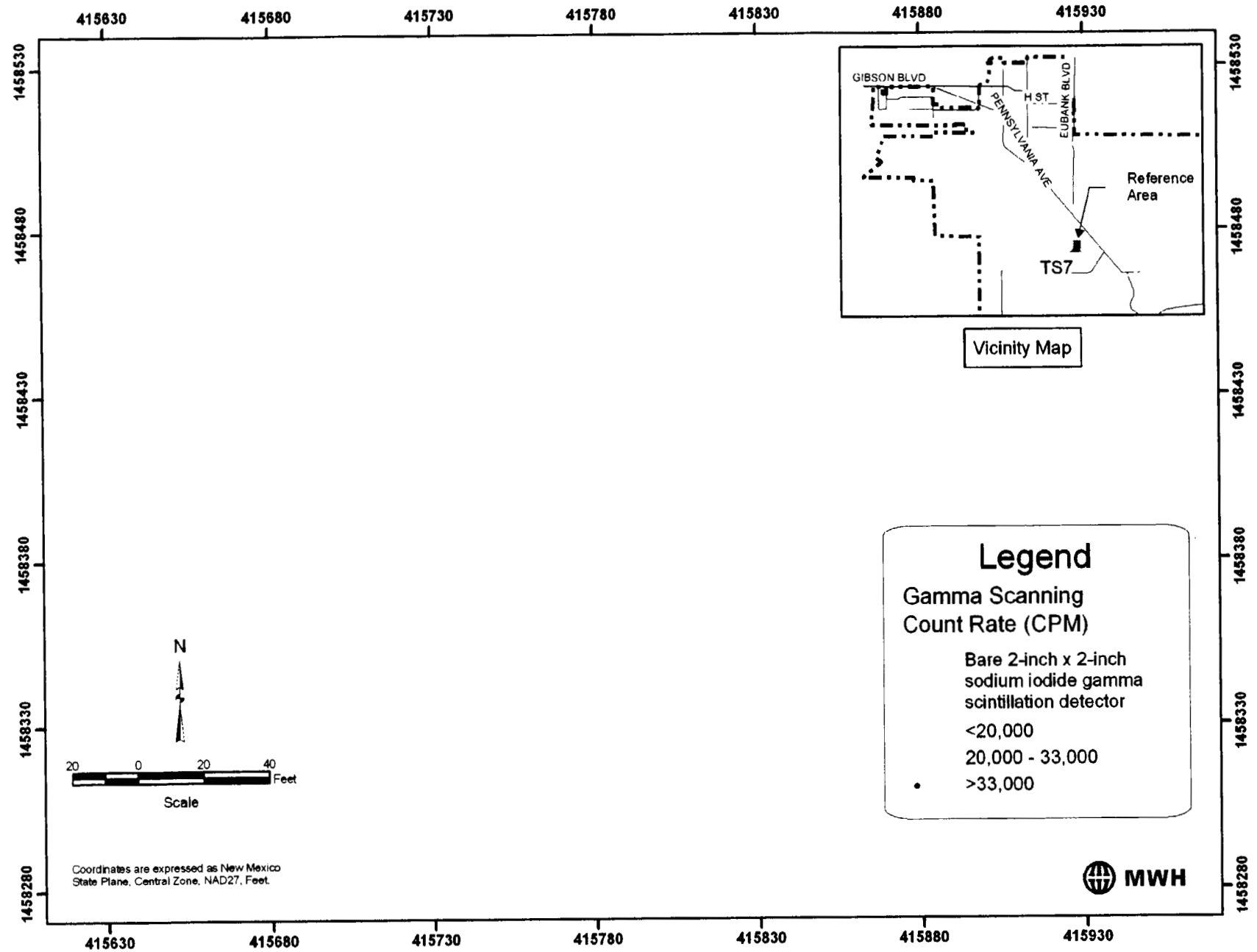

Figure 3-1. Reference Land Area, Gamma Radiation Scanning Survey Data, Environmental Restoration Program Site OT-10

Table 3-3. Reference Land Area Gamma Scanning Data Summary Statistics, Environmental Restoration Program Site OT-10

Survey Unit	Reference Area
Mean (cpm)	12,407
Median (cpm)	12,376
Number of Measurements	892
Maximum (cpm)	15,379
Minimum (cpm)	10,427
Standard Deviation (cpm)	700

Notes:
cpm = counts per minute

The locations and results of the static gamma measurements are shown in Figure 3-2. Summary statistics for the measurements are presented in Table 3-4. Static gamma measurements ranged from 12,102 cpm to 13,045 cpm and averaged 12,542 cpm (arithmetic mean).

Table 3-4. Reference Land Area Static Gamma Measurements Summary Statistics, Environmental Restoration Program Site OT-10

Survey Unit	Reference Area
Mean (cpm)	12,542
Median (cpm)	12,500
Number of Measurements	20
Maximum (cpm)	13,045
Minimum (cpm)	12,102
Standard Deviation (cpm)	300

Notes:
cpm = counts per minute

Twenty-two soil samples were collected from the surface of the 2,000-m^2 reference land area. The sample group consisted of 20 field samples and 2 replicate samples. The sampling frequency corresponds to 1 sample collected for each 100 m^2. Soil samples were analyzed by Severn Trent Laboratories in St. Louis, Missouri, for isotopic thorium by alpha spectroscopy (National Academy of Sciences [NAS] / U.S. Department of Energy [DOE] Method 3004/RP modified) (NAS/DOE, 1994) and for gamma-emitting radionuclides by gamma spectroscopy (EPA Method 901.1 modified) (EPA, 1980). The soil sample results are presented in Table 3-5. Summary statistics for the results are presented in Table 3-6. The average soil concentration of thorium-232 is 0.91 picocuries per gram (pCi/g) with a standard deviation of 0.15 pCi/g. The soil sample locations and corresponding thorium-232 concentrations are presented on Figure 3-3.

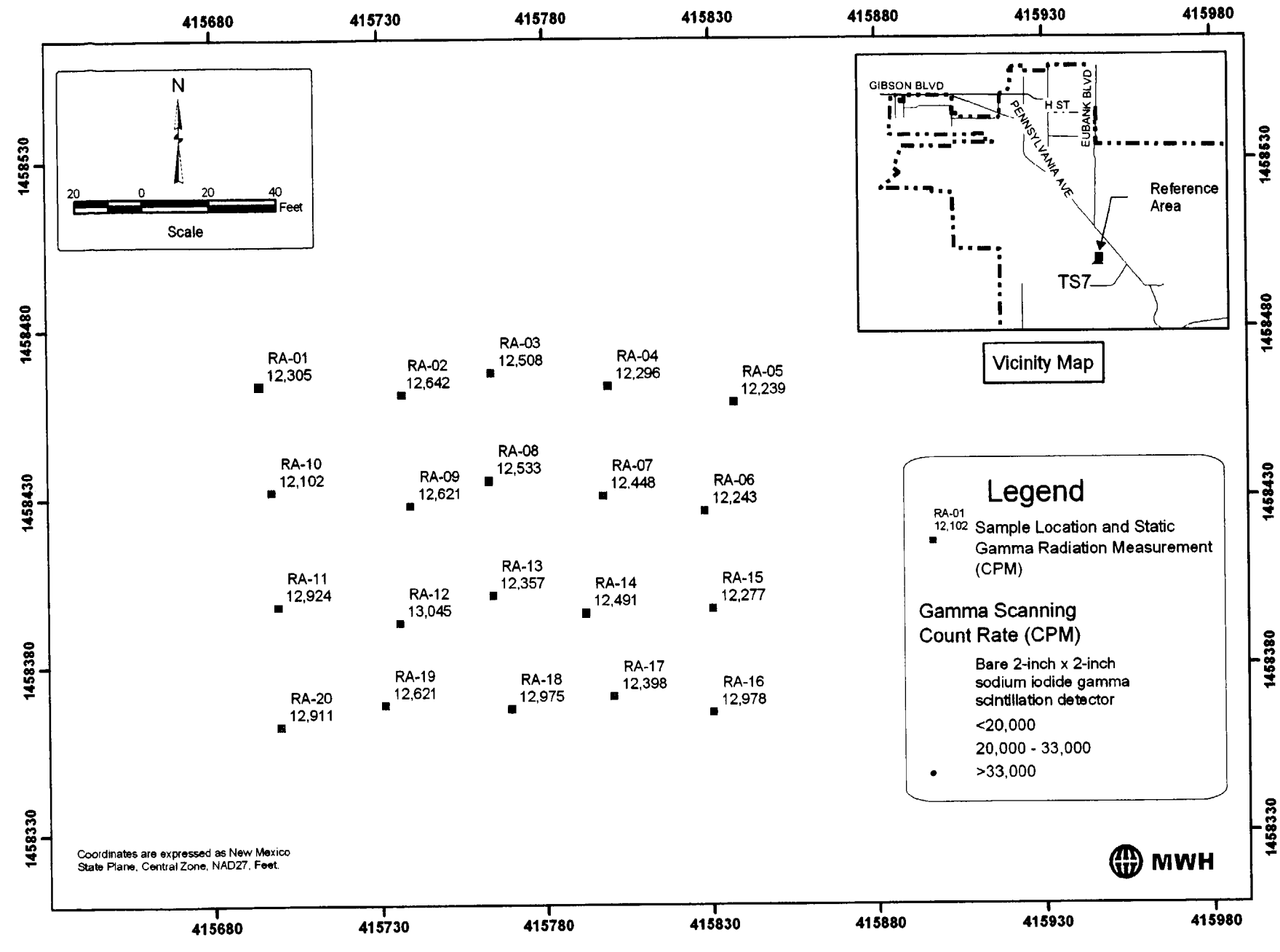

Figure 3-2. Reference Land Area, Static Gamma Radiation Measurements, Environmental Restoration Program Site OT-10

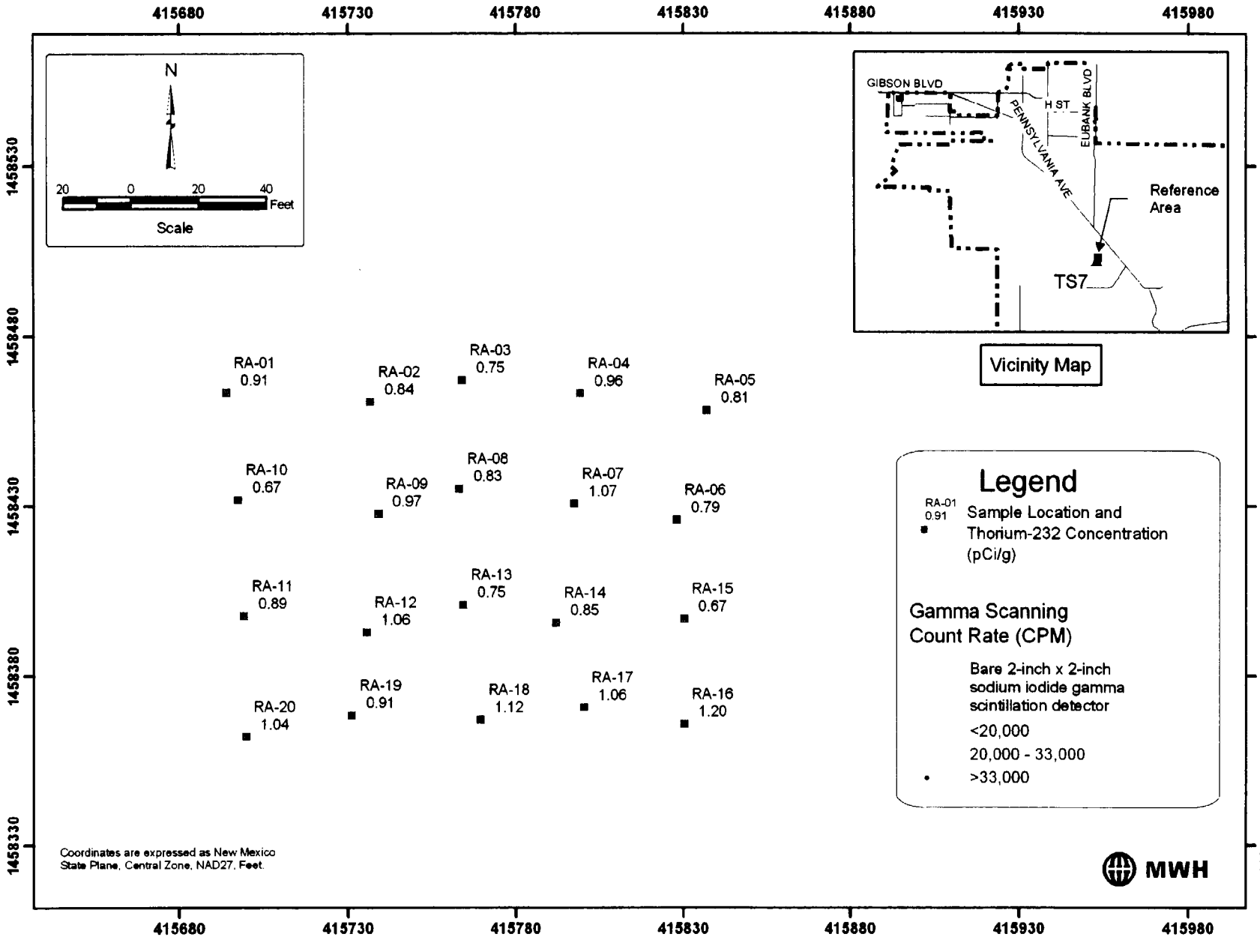

Figure 3-3. Reference Land Area, Soil Sample Thorium-232 Concentrations, Environmental Restoration Program Site OT-10

Table 3-5. Reference Land Area Soil Sample Analytical Results, Environmental Restoration Program Site OT-10

Location ID	RA-01	RA-02	RA-03	RA-04	RA-05	RA-06	RA-07	RA-08
Borehole Number	01	02	03	04	05	06	04	08
Depth Interval(ft bgs)	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5
Sample ID[a]	RA-SS-01-0000	RA-SS-02-0000	RA-SS-03-0000	RA-SS-04-0000	RA-SS-05-0000	RA-SS-06-0000	RA-SS-07-0000	RA-SS-08-0000
Date Collected	04/17/01	04/17/01	04/17/01	04/17/01	04/17/01	04/17/01	04/17/01	04/17/01
Analytical Method (Units)								
Gamma Emitting Radionuclides EPA 901.1 Modified (pCi/g)[b]								
Radium-226	0.98±0.23	0.64±0.2	0.79±0.23	0.87±0.26	0.69±0.23	0.85±0.22	0.89±0.23	0.84±0.23
Actinium 228	1.04±0.45	0.91±0.39	<0.79	<0.76	0.67±0.41	0.68±0.48	1.0±0.47	0.72±0.35
Bismuth-214	0.98±0.23	0.65±0.2	0.80±0.24	0.88±0.27	0.69±0.23	0.85±0.22	0.89±0.24	0.84±0.23
Cobalt-60	<0.12	<0.12	<0.13	<0.13	<0.12	<0.073	<0.13	<0.12
Cesium-137	0.261±0.089	<0.13	0.137±0.096	0.25±0.1	<0.11	0.14±0.11	0.126±0.068	0.116±0.083
Potassium-40	18.2±03.5	14.9±2.7	16.3±3.7	17.0±3.7	18.3±3.4	18.8±3.7	18.0±3.4	18.6±3.4
Lead-212	0.69±0.2	0.65±0.2	0.74±0.2	0.74±0.21	0.72±0.2	0.58±0.17	0.78±0.2	0.57±0.17
Lead-214	0.91±0.26	0.90±0.26	0.90±0.25	0.84±0.25	0.54±0.22	0.89±.27	0.73±0.23	0.66±0.22
Radium-224	7.6±4.7	5.8±3.7	7.8±4.8	2.6±1.7	<2.3	4.4±2.8	4.3±2.8	6.5±4.1
Thorium-234	<1.4	<1.2	<1.4	<1.3	<1.1	<1.2	1.24±0.68	<1.4
Thallium-208	0.34±0.12	0.28±0.11	0.41±0.13	0.22±0.12	0.23±0.091	0.298±0.0998	0.31±0.11	0.27±0.1
Uranium-235	<0.14	<0.12	<0.14	<0.12	<0.11	0.14±0.25	<0.09	<0.13
Bismuth-212	<1.8	<1.8	<2.3	<1.9	<1.8	<1.7	<1.8	<2.0
Isotopic Thorium by NAS/DOE 3004/RP (pCi/g)[c]								
Thorium-228	0.65±0.35	0.67±0.31 B	0.99±0.49 J	0.74±0.31 B	0.70±0.36	0.43±0.24 B	1.01±0.49	1.00±0.39 B
Thorium-230	1.01±0.43 UB	1.02±0.4 UB	1.1±0.51 UB	0.76±0.3 UB	0.78±0.37 UB	0.88±0.36 UB	0.92±0.45 UB	0.87±0.36 UB
Thorium-232	0.91±0.4	0.84±0.35	0.75±0.4	0.96±0.35	0.81±0.37	0.79±0.33	1.07±0.49	0.83±0.34

Location ID	RA-09	RA-10	RA-10	RA-11	RA-12	RA-13	RA-14	RA-15
Borehole Number	09	10	10	11	12	13	14	15
Depth Interval (ft bgs)	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5
Sample ID[a]	RA-SS-09-0000	RA-SS-10-0000	RA-SS-10A-0000	RA-SS-11-0000	RA-SS-12-0000	RA-SS-13-0000	RA-SS-14-0000	RA-SS-15-0000
Date Collected	04/17/01	04/17/01	04/17/01	04/17/01	04/17/01	04/17/01	04/17/01	04/17/01
Analytical Method (Units)								
Gamma Emitting Radionuclides EPA 901.1 Modified (pCi/g)[b]								
Radium-226	0.80±0.25	0.75±0.22	0.62±0.22	0.88±0.24	1.03±0.25	0.75±0.23	0.93±0.24	0.55±0.21
Actinium 228	1.1±0.43	0.86±0.36	0.93±0.4	1.04±0.46	0.86±0.39	<0.61	1.22±0.48	0.87±0.47
Bismuth-214	0.81±0.25	0.76±0.22	0.62±0.22	0.89±0.25	1.03±0.25	0.76±0.24	0.94±0.24	0.56±0.22
Cobalt-60	<0.12	<0.068	<0.093	<0.13	<0.13	<0.11	<0.1	<0.12
Cesium-137	0.169±0.091	<0.083	0.12±0.077	0.149±0.084	<0.14	0.325±.095	<0.13	<0.099
Potassium-40	16.5±3.3	16.7±3.2	15.6±3.6	19.0±4	17.3±3.3	20.3±3.4	18.6±3.5	15.2±3.1
Lead-212	0.83±0.23	0.77±0.2	0.78±0.22	0.76±0.23	0.86±0.22	0.93±0.21	0.81±0.23	0.64±0.22
Lead-214	0.78±0.24	0.63±0.19	0.69±0.23	0.92±0.28	1.07±0.25	0.78±0.22	0.86±0.25	0.51±0.2
Radium-224	<2.8	1.9±1.3	<2.7	<3.1	5.3±3.5	6.1±3.8	2.8±1.8	6.8±4.2
Thorium-234	<1.5	<1.1	<1.3	<1.4	<1.7	<1.5	<1.4	<1.3
Thallium-208	0.34±0.11	0.243±0.089	0.33±0.11	0.29±0.14	0.37±0.11	0.3±0.11	0.35±0.12	0.28±0.11
Uranium-235	<0.14	<0.1	<0.12	<0.11	<0.14	<0.14	<0.13	<0.12
Bismuth-212	<1.9	<1.6	<1.8	<1.9	<1.7	1.92±0.91	<2.1	<1.8
Isotopic Thorium by NAS/DOE 3004/RP (pCi/g)[c]								
Thorium-228	1.04±0.43	0.82±0.34	0.83±0.37	0.90±0.38	1.07±0.48 JB	0.69±0.29 B	1.01±0.35	0.80±0.32
Thorium-230	0.87±0.36 UB	0.91±0.37 UB	0.89±0.38 UB	1.05±0.41 UB	0.77±0.37 UBJ	0.62±0.26 UB	0.94±0.32 UB	0.91±0.34 UB
Thorium-232	0.97±0.39	0.6±0.27	0.74±0.33	0.89±0.36	1.06±0.47 J	0.75±0.29	0.85±0.3	0.67±0.28

Table 3-5. Reference Land Area Soil Sample Analytical Results, Environmental Restoration Program Site OT-10 (concluded)

Location ID	RA-16	RA-17	RA-18	RA-19	RA-20	RA-20
Borehole Number	16	17	18	19	20	20
Depth Interval (ft bgs)	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5
Sample ID[a]	RA-SS-16-0000	RA-SS-17-0000	RA-SS-18-0000	RA-SS-19-0000	RA-SS-20-0000	RA-SS-20A-0000
Date Collected	04/17/01	04/17/01	04/17/01	04/17/01	04/17/01	04/17/01
Analytical Method (Units)						
Gamma Emitting Radionuclides EPA 901.1 Modified (pCi/g)[b]						
Radium-226	0.75±0.28	0.90±0.25	0.89±0.23	1.22±0.31	0.71±0.24	0.71±0.22
Actinium 228	<0.80	0.80±0.47	0.74±0.41	0.87±0.49	<0.66	1.16±0.49
Bismuth-214	0.75±0.28	0.90±0.25	0.90±0.24	1.22±0.31	0.71±0.24	0.71±0.23
Cobalt-60	<0.15	<0.13	<0.12	<0.12	<0.16	<0.13
Cesium-137	<0.14	<0.11	0.132±0.075	<0.16	0.33±0.12	0.17±0.1
Potassium-40	17.4±3.4	18.6±3.5	20.0±3.3	20.1±4.2	17.7±3.3	17.3±3.1
Lead-212	0.73±0.22	0.89±0.24	1.13±0.26	0.96±0.27	0.84±0.25	0.5±0.23
Lead-214	0.98±0.32	0.98±0.25	1.11±0.27	0.91±0.29	0.74±0.25	0.90±0.31
Radium-224	7.9±5	3.4±2.3	4.2±2.6	<3.1	<2.9	7.4±4.7
Thorium-234	<1.5	<1.7	<1.7	<1.4	<1.4	<1.4
Thallium-208	0.32±0.13	0.24±0.11	0.45±0.12	0.35±0.13	0.25±0.11	0.21±0.13
Uranium-235	<0.15	<0.16	0.16±0.11	0.19±0.11	<0.14	<0.14
Bismuth-212	<2.3	<1.9	<1.9	<2.3	<2.2	<2.1
Isotopic Thorium by NAS/DOE 3004/RP (pCi/g)[c]						
Thorium-228	1.2±0.43	0.98±0.38	0.92±0.32	1.11±0.4	1.1±0.43	0.98±0.4
Thorium-230	1.08±0.4 UB	1.12±0.4 UB	0.96±0.32 UB	1.08±0.38 UB	0.81±0.34 UB	0.97±0.38 UB
Thorium-232	1.2±0.43	1.06±0.39	1.12±0.36	0.91±0.34	0.92±0.37	1.15±0.43

Notes:
[a]Samples identified with A are field replicates. No replicate was collected for TS7-SS-10-000 but the sample bag was mislabeled as TS7-SS-10A-0000.
[b]EPA, 1980. Samples analyzed after 21-day in-growth period.
[c]NAS/DOE, 1994.
B = Analyte detected in an associated blank.
bgs = below ground surface
DOE = U.S. Department of Energy
EPA = U.S. Environmental Protection Agency
ft = feet
ID = identifier
J = estimated value
NA = not analyzed
NAS = National Academy of Sciences
pCi/g = picocuries per gram
RA = reference area
SB = subsurface sample
SS = surface sample
TS5 = Training Site 5
TS6 = Training Site 6
TS7 = Training Site 7
TS8 = Training Site 8
U = not detected

Table 3-6. Reference Land Area Soil Sample Summary Statistics, Environmental Restoration Program Site OT-10

Survey Unit	Reference Area
Mean Thorium-232 (pCi/g)	0.91
Median Thorium-232 (pCi/g)	0.90
Number of Samples	22
Maximum Thorium-232 (pCi/g)	1.2
Minimum Thorium-232 (pCi/g)	0.67
Standard Deviation	0.15

3.2.2 Reference Building Area

Building 28011, located east of TS8, was selected as a reference area for the building surveys. Building 28011 is the same size and is constructed of the same materials as the contaminated buildings within TS8. The location of reference area Building 28011 in relation to the OT-10 radiation training sites is shown on Figure 2-1. A photograph of the reference area Building 28011 is shown in Figure 3-4.

Figure 3-4. Photograph of Reference Area, Building 28011, Environmental Restoration Program Site OT-10

The reference building survey data were collected during the May 30, 2001, to June 1, 2001, site characterization surveys of the TS8 buildings. The site characterization surveys included total and removable alpha radiation measurements. The interior surfaces of the reference building were divided into 1-m^2 grid blocks for the survey. The methods used to collect the survey data are presented in the OT-10 Decommissioning Plan (USAF, 2002).

Figure 3-5 is a drawing of the reference building. The reference building, like the TS8 buildings, is covered with several feet of soil on the top and back. The building is approximately 10 ft by 20 ft with a maximum height of 10 ft. The 1-m^2 survey grid blocks were established over the floor, two walls, and the ceiling. Figure 3-6 presents the total alpha activity for each grid block. The average surface activity was 0.56 cpm with a maximum surface activity of 5 cpm.

Equation 3-1 was used to calculate the average surface activity in terms of dpm/100 cm^2:

$$A_d = A_c / (\varepsilon * Area / 100), \qquad \text{Eq. 3-1}$$

Where

A_d is surface activity in dpm/100 cm^2,

A_c is surface activity in cpm,

ε is probe efficiency in cpm/dpm, and

Area is the probe area in cm^2.

With a probe efficiency of 0.13 cpm/dpm and an active probe area of 76 cm^2, 0.56 corresponds to an average surface activity of 6 dpm/100 cm^2, and 5 cpm corresponds to 51 dpm/100 cm^2, averaged over 1 m^2.

The results of the wipe sample analysis are presented in Table 3-7. The net removable contamination readings were the calculated differences between the gross and background count rates. The average removable levels of contamination were 0.2 dpm/100 cm^2 for alpha and –9 dpm/100 cm^2 for beta.

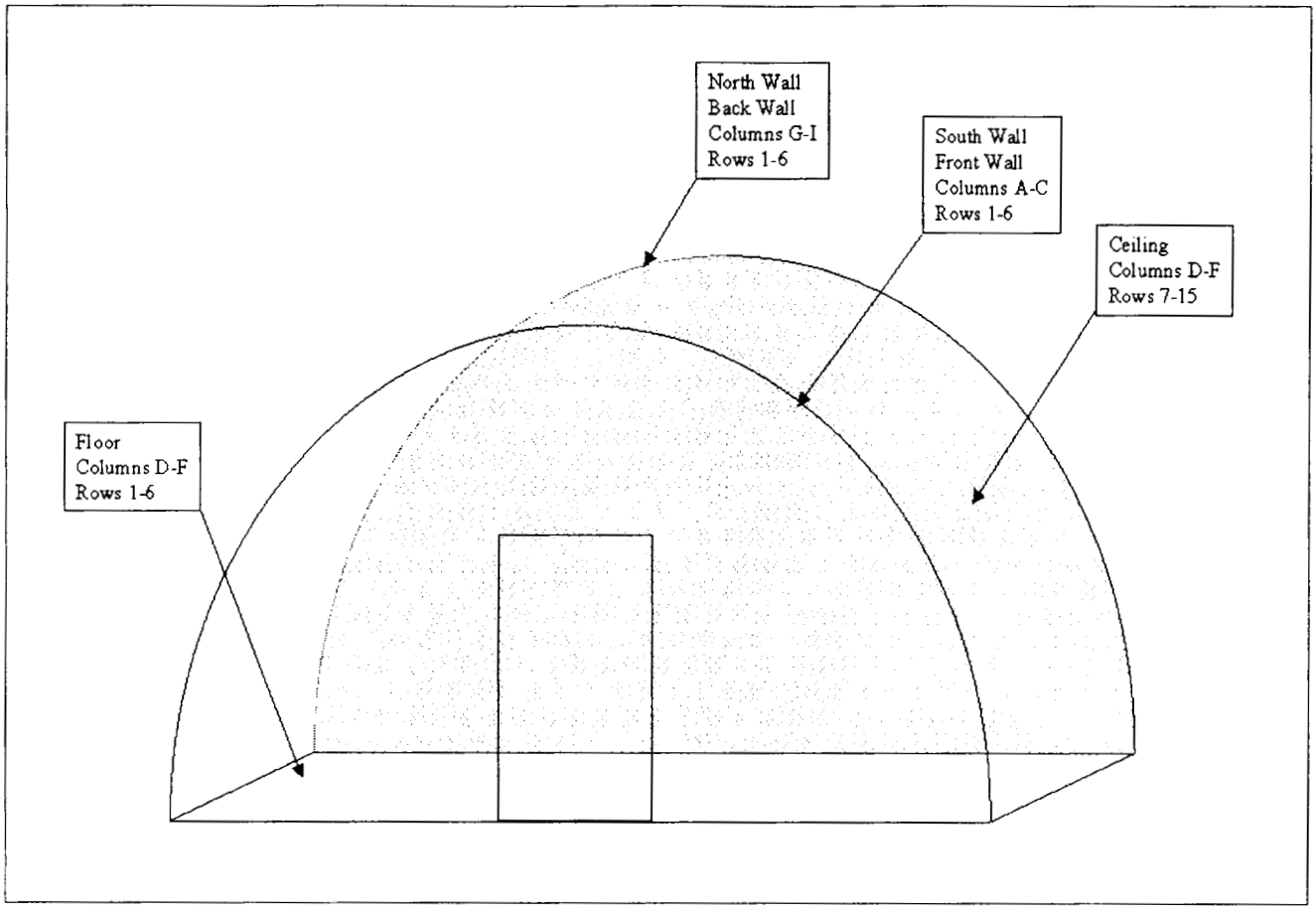

Figure 3-5. Reference Building 28011 Survey Areas, Environmental Restoration Program Site OT-10

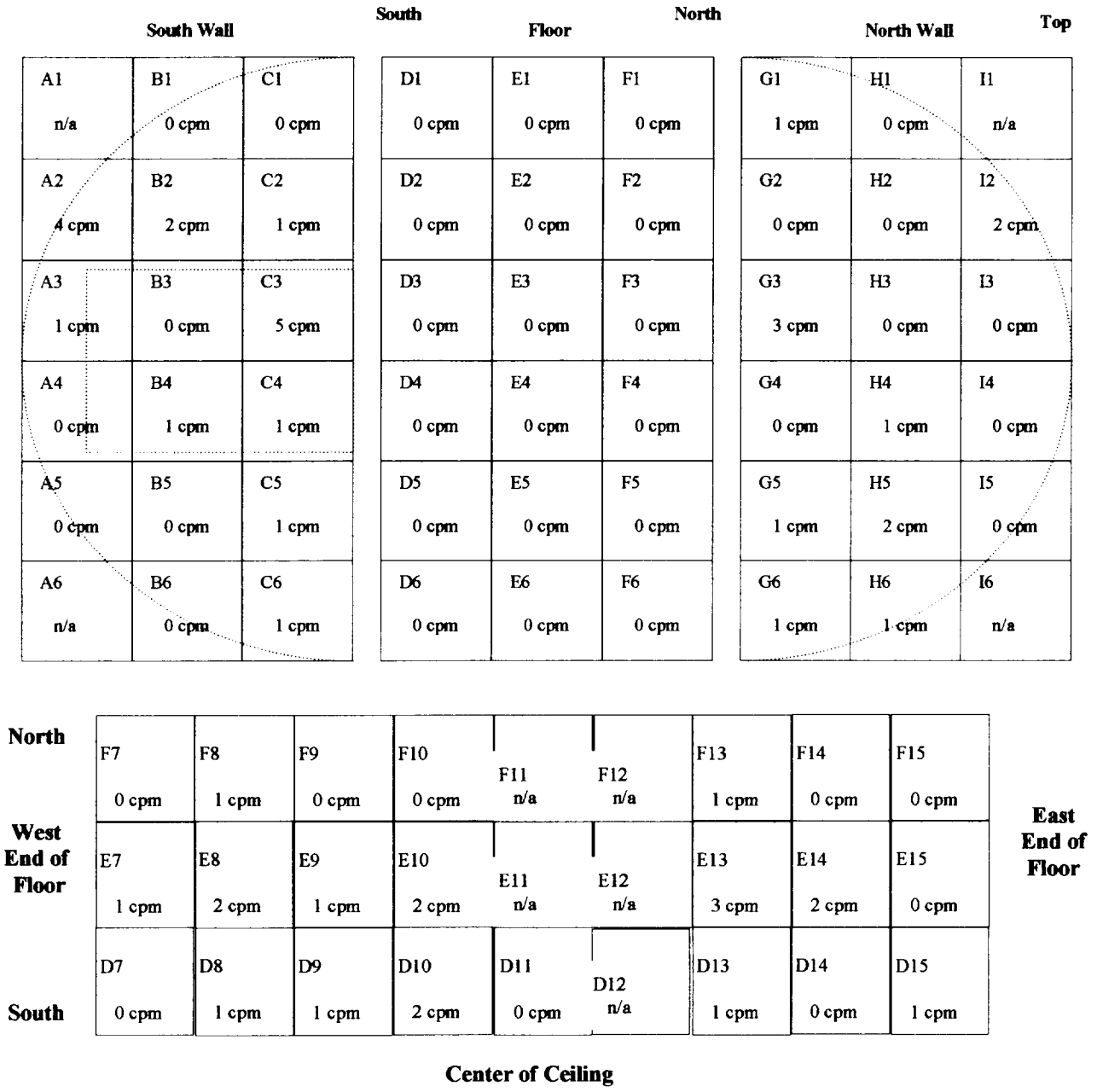

Figure 3-6. Total Alpha Surface Contamination in Reference Building 28011 on Floor, Walls, and Ceiling,, Environmental Restoration Program Site OT-10

Table 3-7. Removable Surface Contamination in Reference Building Grid Blocks on Floor, Walls, and Ceiling, Building 28011, Environmental Restoration Program Site OT-10

Grid Location	Gross Alpha Count Rate (cpm)	Alpha Efficiency Factor	Alpha Contamination Level (dpm/100 cm^2)	Gross Beta Count Rate (cpm)	Beta Efficiency Factor	Beta Contamination Level (dpm/100 cm^2)
A-1	NA	NA	NA	NA	NA	NA
A-2	0	0.366	0	85	0.215	395
A-3	0	0.366	0	96	0.215	447
A-4	0	0.366	0	83	0.215	386
A-5	0	0.366	0	79	0.215	367
A-6	NA	NA	NA	NA	NA	NA
B-1	0	0.366	0	80	0.215	372
B-2	0	0.366	0	79	0.215	367
B-3	1	0.366	2.73	80	0.215	372
B-4	0	0.366	0	78	0.215	363
B-5	0	0.366	0	95	0.215	442
B-6	0	0.366	0	77	0.215	358
C-1	0	0.366	0	97	0.215	451
C-2	1	0.366	2.73	93	0.215	433
C-3	0	0.366	0	86	0.215	400
C-4	0	0.366	0	78	0.215	363
C-5	0	0.366	0	76	0.215	353
C-6	0	0.366	0	70	0.215	326
D-1	1	0.366	2.73	80	0.215	372
D-2	1	0.366	2.73	83	0.215	386
D-3	1	0.366	2.73	86	0.215	400
D-4	0	0.366	0	82	0.215	381
D-5	0	0.366	0	83	0.215	386
D-6	0	0.366	0	76	0.215	353
D-7	0	0.366	0	87	0.215	405
D-8	0	0.366	0	66	0.215	307
D-9	0	0.366	0	92	0.215	428
D-10	0	0.366	0	83	0.215	386
D-11	0	0.366	0	86	0.215	400
D-12	1	0.366	2.73	71	0.215	330
D-13	1	0.366	2.73	77	0.215	358
D-14	0	0.366	0	75	0.215	349
D-15	0	0.366	0	96	0.215	447
E-1	0	0.366	0	85	0.215	395
E-2	0	0.366	0	83	0.215	386
E-3	0	0.366	0	87	0.215	405
E-4	0	0.366	0	87	0.215	405
E-5	0	0.366	0	64	0.215	298
E-6	1	0.366	2.73	77	0.215	358
E-7	1	0.366	2.73	89	0.215	414
E-8	0	0.366	0	64	0.215	298
E-9	1	0.366	2.73	73	0.215	340
E-10	0	0.366	0	80	0.215	372
E-11	0	0.366	0	85	0.215	395
E-12	0	0.366	0	72	0.215	335
E-13	1	0.366	2.73	101	0.215	470
E-14	0	0.366	0	92	0.215	428
E-15	1	0.366	2.73	75	0.215	349
F-1	0	0.366	0	98	0.215	456
F-2	2	0.366	5.46	88	0.215	409

Table 3-7. Removable Surface Contamination in Reference Building Grid Blocks on Floor, Walls, and Ceiling, Building 28011, Environmental Restoration Program Site OT-10 (concluded)

Grid Location	Gross Alpha Count Rate (cpm)	Alpha Efficiency Factor	Alpha Contamination Level (dpm/100 cm^2)	Gross Beta Count Rate (cpm)	Beta Efficiency Factor	Beta Contamination Level (dpm/100 cm^2)
F-3	0	0.366	0	70	0.215	3226
F-4	0	0.366	0	71	0.215	330
F-5	0	0.366	0	70	0.215	326
F-6	0	0.366	0	72	0.215	335
F-7	1	0.366	2.73	74	0.215	344
F-8	1	0.366	2.73	73	0.215	340
F-9	0	0.366	0	100	0.215	465
F-10	1	0.366	2.73	67	0.215	312
F-11	0	0.366	0	68	0.215	316
F-12	0	0.366	0	80	0.215	372
F-13	1	0.366	2.73	91	0.215	423
F-14	0	0.366	0	68	0.215	316
F-15	0	0.366	0	76	0.215	353
G-1	0	0.366	0	85	0.215	395
G-2	0	0.366	0	73	0.215	340
G-3	0	0.366	0	79	0.215	367
G-4	0	0.366	0	78	0.215	363
G-5	0	0.366	0	77	0.215	358
G-6	0	0.366	0	76	0.215	353
H-1	0	0.366	0	96	0.215	447
H-2	0	0.366	0	74	0.215	344
H-3	0	0.366	0	77	0.215	358
H-4	1	0.366	2.73	90	0.215	419
H-5	0	0.366	0	78	0.215	363
H-6	0	0.366	0	74	0.215	344
I-1	NA	NA	NA	NA	NA	NA
I-2	0	0.366	0	84	0.215	391
I-3	0	0.366	0	96	0.215	447
I-4	1	0.366	2.73	79	0.215	366
I-5	0	0.366	0	95	0.215	442
I-6	NA	NA	NA	NA	NA	NA

Notes:
α = alpha
β = beta
cm^2 = square centimeters
cpm = counts per minute
dpm = disintegrations per minute
NA = not analyzed
alpha background = 8 counts per hour; 0.13 cpm
beta background = 5024 counts per hour; 84 cpm

The background counts were used to calculate minimum detectable activity (MDA) for alpha (14 dpm/100 cm^2) and beta (214 dpm/100 cm^2), using the following MARSSIM equation:

$$MDA = \frac{100 * \left(3 + 4.65\sqrt{S_b}\right)}{T\varepsilon A} \qquad \text{Eq. 3-2}$$

Where

MDA is in dpm/100 cm^2,

S_b is the standard deviation of background counts in cpm,

T is the counting in minutes,

ε is probe efficiency in cpm/dpm, and

A is the probe area in cm^2 (EPA, 1997).

For the wipe sample, the Ludlum Model 43-10-1 alpha/beta tray counter had an alpha efficiency of 0.366 cpm/dpm and a beta efficiency of 0.214 cpm/dpm for thorium-230 and technetium-99 sources, respectively. Fifteen 1-minute background counts were taken with the counter. The alpha background averaged 0.2 cpm with a standard deviation of 0.4. The beta background averaged 83 cpm with a standard deviation of 10.

The average removable levels of alpha (0.2 dpm/100 cm^2) and beta (-9 dpm/100 cm^2) contamination were three orders of magnitude below their associated MDAs. It can be concluded that, on average, no detectable activity was removed from the reference building surfaces by the wipe samples.

4.0 FINAL STATUS SURVEY PROCEDURES FOR LAND AREAS AND BUILDING SURFACES

The final status surveys of land areas included scanning and static gamma radiation measurements in MARSSIM Class 1 and Class 2 survey units and soil sampling in MARSSIM Class 1 survey units. Exposure rate measurements were also collected to define the correlation between gamma radiation count rates and exposure rates. Final status surveys of buildings included total and removable alpha radiation measurements and gamma radiation-exposure rate measurements. The certificates of calibration for the final status survey equipment are presented in Appendix E.

4.1 Land Area Surveys

4.1.1 Gamma Radiation Scanning Surveys

Gamma radiation scanning surveys were performed over 100 percent of the Class 1 and Class 2 land areas, using an estimated 3-ft transect spacing. Data were collected using Ludlum 44-10, 2-inch by 2-inch, sodium iodide detectors coupled to a Ludlum 2221 ratemeter/scaler set in ratemeter mode. Where site terrain permitted, measurements were collected using a push cart with two detectors fixed to opposing sides of the push cart, at 18 inches above ground surface. In areas of difficult site access, a health physics technician walked the survey transect holding the detector at 18 inches above ground surface. Detector windows were opened completely and the scaler/ratemeter threshold was set at 40 (kiloelectron volt) keV. Scanning speed for the final status surveys was approximately 1.5 feet per second (ft/sec).

During scanning, measurements were automatically collected every 2 seconds and tagged with location coordinates as the count rates were recorded, using a differential correction global-positioning system (GPS) with submeter accuracy. GPS coordinates were referenced to the central zone of the New Mexico State Plane Coordinate System. Similar procedures were used for data collection during the site characterization and remedial action support surveys.

ArcView Geographical Information System (GIS®) software was used to present the spatial distribution of gamma-ray counts at each training site. The gamma radiation scanning data were also downloaded into Microsoft Excel to facilitate statistical analysis.

4.1.2 Static Gamma Radiation Measurements

Static gamma radiation measurements were taken using a Ludlum 44-10, 2-inch by 2-inch, sodium iodide detector coupled to a Ludlum 2221 ratemeter/scaler set in scaler (integration) mode. At each measurement location, the detector was held 18 inches above the ground surface and a 1-minute integrated count was taken.

Static gamma radiation-measurements were used for correlation studies of gamma count rates and soil radionuclide concentrations during the remedial action process. Static gamma radiation measurements were also collected during the final status surveys at each soil sample location prior to sample collection and at selected Class 2 survey unit locations. The same procedures were used for data collection during the site characterization and remedial action support surveys.

4.1.3 Soil Sampling

The number of soil samples collected during the final status surveys was based on statistical analysis of the gamma radiation scanning survey data. The statistical methodology used for determining the appropriate sample group size in each survey unit is discussed in Section 4.5.

Final status survey soil sample locations were preselected for each MARSSIM Class 1 survey unit using GIS® and located at the sites using a GPS unit. The first sample location in each survey unit was selected at random using the random function feature of Microsoft Excel®. Remaining sample locations in the survey unit were selected at a set, predetermined distance from the previous sample.

Immediately prior to soil sampling, a 1-minute static gamma radiation count was collected at each sample location using the Ludlum 44-10 sodium iodide detector coupled to a Ludlum 2221 ratemeter/scaler set in scaler (integration) mode. The bare detector was held approximately 18 inches above ground during the static count. The gamma count was recorded on a Final Status Sampling Form with other sample information.

Surface soil samples were collected immediately after recording the static gamma radiation count. A five-point composite method was used to collect the samples. A 3-ft-diameter circle was drawn in the soil at each sample location. Soil samples were collected at the center of the circle and at four other points within the circle, each 9 inches away from the center. Soil was collected at each point from zero to 6 inches below ground surface (bgs), using a Macrocore® sampler. One plastic sample sleeve was dedicated to each composite sample. After sample collection, the contents of the plastic sample sleeve were transferred to a Ziploc bag. The probe shoe, probe cap, and 2-inch core barrel of the Macrocore® sampler were decontaminated prior to collecting the next sample. The samples were then transferred from the site to the onsite laboratory under chain of custody.

Replicate samples were collected at 10 percent of the soil sample locations for quality assurance/quality control (QA/QC). These samples were thoroughly mixed onsite in a Ziploc bag and divided into two sample volumes.

All samples were shipped to Severn Trent Laboratories (STL) in St. Louis, Missouri, where they were analyzed for gamma-emitting radionuclides by gamma spectroscopy (EPA Method 901.1 modified) (EPA, 1980).

After initial analysis of the soil samples was completed by STL, 10 percent of the samples were forwarded by STL to Armstrong Laboratories for QA analysis. Upon sample receipt, Armstrong Laboratories recombined the sample portions (the samples had been homogenized, dried, and split into different portions by STL for analysis) and the sample was prepared following the procedures in modified method EPA 901.1.

Both STL and Armstrong Laboratories followed the same procedures for sample analysis with the following exceptions:

- STL used a 21-day, in-growth period and Armstrong Laboratories used a 28-day, in-growth period to allow for secular equilibrium between radium-226 and its decay progeny.

- STL's sample size was 300 to 400 grams and Armstrong Laboratories' sample size was approximately 130 grams.

- STL's count time was 30 minutes and Armstrong Laboratories count time was 167 minutes.

Both laboratories used the following procedures to quantify the sample results:

- A single nuclide was considered identified if it passed the abundance test limit of 70 percent (that is, 70 percent of the line abundances listed in the library were found).

- If a single line was found and the nuclide passed the 70 percent abundance test, that nuclide was calculated based upon that single line.

- If multiple lines were found, the activity was calculated based upon the error-weighted mean of the lines found.

- Activity concentrations were reported for the following gamma-emitting radionuclides:

  - Actinium-228
  - Bismuth-212
  - Bismuth-214
  - Cesium-137
  - Cobalt-60
  - Lead-212
  - Lead-214
  - Potassium-40
  - Radium-224
  - Radium-226 (bismuth-214 to report radium-226)
  - Thallium-208
  - Thorium-228 (Armstrong only)
  - Thorium-234
  - Uranium-235 and -236 (STL only)

4.1.4 Exposure Rate Measurements

Exposure rate measurements, in microRoentgens per hour (μR/hr), were collected to develop a correlation between gamma count rates and gamma exposure rates. The correlation was evaluated over a range of gamma count rates.

Static gamma radiation measurements were taken using a Ludlum 44-10, 2-inch by 2-inch, sodium iodide detector coupled to a Ludlum 2221 ratemeter/scaler set in scaler (integration) mode. At each measurement location, the detector was held 18 inches above the ground surface and a 1-minute integrated count was taken. Exposure rates were measured using a Ludlum Model 19 micro-R ratemeter, held at approximately 18 inches and 3 ft above ground. Exposure rates were recorded at 53 locations during the final status survey of the TS5 Class 2 survey units. Gamma counts and exposure rates at each location were recorded and later entered into a Microsoft Excel spreadsheet.

4.2 Building Surveys

During the implementation of OT-10 decommissioning activities, TS8 and the two buildings within its boundaries were transferred to the Defense Threat Reduction Agency (DTRA) for use as a training facility. The TS8 land area and Building 28010 were decontaminated. Building 28005 was kept in its contaminated state for use in training exercises. The following procedures were used in the final status survey of Building 28010.

4.2.1 Survey Grid Areas

All interior surfaces of Building 28010, including the double doors, were divided into grid blocks no larger than 1 m^2 each. There were 28 grid blocks on the floor, 24 grid blocks on the west wall, 25 grid blocks on the east wall, and 44 grid blocks on the ceiling. While most grid blocks were square in shape and 1 m^2 in area, some grid blocks were less than 1 m^2 in area and irregular in shape. Figure 4-1 presents a schematic of Building 28010.

4.2.2 Exposure Rate Measurements

Gamma-ray exposure rate measurements were taken on contact at all grid intersection points with a Ludlum Model 19 micro-R survey meter. The Model 19 was function-checked daily using a National Institute of Standards and Technology (NIST) traceable cesium-137 button source. A total of 165 exposure rate readings were taken inside the building including 40 from the floor, 60 from the ceiling, 34 from the east wall, and 31 from the west wall. Additional exposure rate readings were taken on the outside of the building including 35 on the front, 23 along the top ledge, and 9 on the concrete entryway

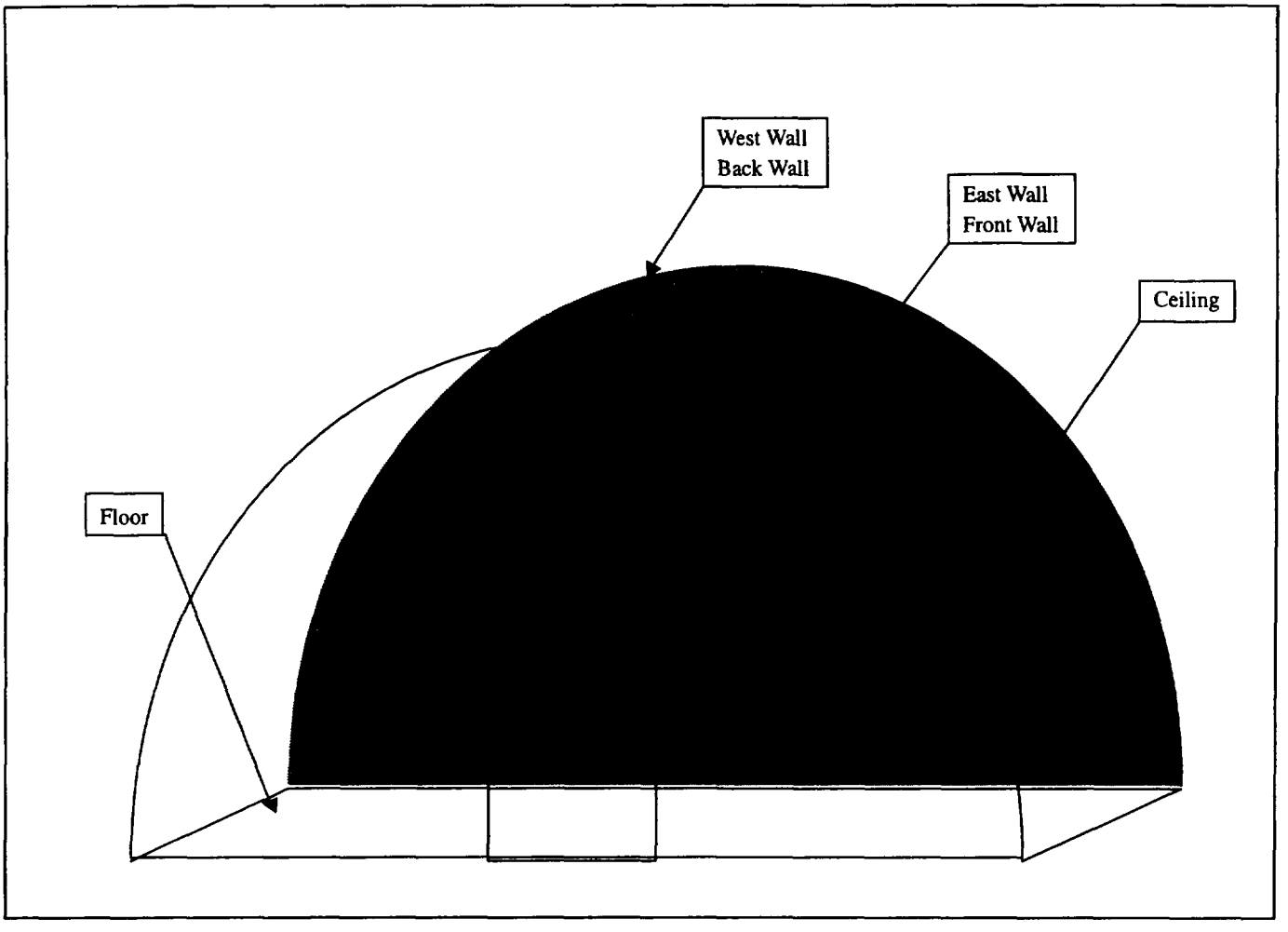

Figure 4-1. Survey Schematic for Building 28010, Environmental Restoration Program Site OT-10

4.2.3 Alpha Survey Measurements

Total alpha surface contamination within each grid block was measured with either a Ludlum Model 43-5 or Ludlum Model 43-90 Zinc Sulfide (ZnS) alpha scintillation detector coupled to a Ludlum Model 2221 ratemeter/scaler. The Model 43-5, with an active area of 76 cm^2, was used to collect measurements from the walls and ceiling because its geometry fit into the corrugated metal of these areas. The Model 43-90, with an active area of 125 cm^2, was used to collect measurements on the floor, outside wall, concrete entry stoop, and exhaust vent due to its superior efficiency.

A 2-minute scan of each grid block was performed with the ratemeter/scaler in the scaler (integration) mode. While scanning, the technician observed through audio level or ratemeter reading if the contamination level varied within the grid block. If a hot spot was observed within the grid block, a second static 2-minute integrated count was taken and recorded as the maximum count rate for the grid block.

Equation 4-1 was used to calculate the surface activity in terms of dpm/100 cm^2.

$$A_d = A_c / (\varepsilon * Area / 100), \qquad \text{Eq. 4-1}$$

Where

A_d is surface activity in dpm/100 cm^2,

A_c is surface activity in cpm,

ε is probe efficiency in cpm/dpm, and

Area is the probe area in cm^2.

To measure removable alpha contamination, a 100-cm^2 wipe sample was taken from each of the 121 interior grid blocks and 69 exterior grid blocks. Wipe samples were analyzed using a Ludlum Model 2929 scaler and a Ludlum Model 43-10-1 tray counter for 5 minutes. The alpha efficiency for all the detectors was determined using a NIST traceable thorium-230 source.

The results for the total and removable surface contamination were entered into a Microsoft Excel spreadsheet. Accounting for detector efficiency, detector surface area, and count time, the spreadsheet would generate alpha contamination results in disintegrations per minute per 100 square centimeters per minute (dpm/100 cm^2). These values were compared to the DCGLs of 170 dpm/100 cm^2 and 34 dpm/100 cm^2 for total and removable alpha contamination, respectively.

4.3 Conversion of Gamma Count Rates to Derived-Concentration Guideline Levels

Investigation levels were developed to correlate gamma radiation count rates to the thorium-232 $DCGL_w$. During the decommissioning process, the gamma radiation investigation levels were used to guide excavation of soil exceeding the $DCGL_w$. To develop the correlation, static gamma radiation measurements were taken using the methodology described in Section 4.1.2. Surface soil samples were collected at each location immediately after recording the static gamma radiation count rate. Soil samples were analyzed for thorium-232, using actinium-228 as a surrogate, by gamma spectroscopy.

Investigation levels were originally developed for each training site using the site characterization survey data. These site-specific investigation levels were presented in Section 2.4.5.7 of the Decommissioning Plan (USAF, 2002) and are summarized in Table 4-1.

Table 4-1. Decommissioning Plan Site-Specific Investigation Levels, Environmental Restoration Program Site OT-10

	Collimated Detector			Bare Detector		
Data Set	Linear Equation	r^2	IL[a] (cpm)	Linear Equation	r^2	IL[a] (cpm)
All	$Gamma = 977 xC_{thorium-232} + 4099$	0.67	9,000	$Gamma = 2596 xC_{thorium-232} + 15427$	0.61	33,000
TS5	$Gamma = 1059 xC_{thorium-232} + 6172$	0.55	12,000	$Gamma = 3121 xC_{thorium-232} + 22835$	0.44	44,000
TS6	$Gamma = 808 xC_{thorium-232} + 5583$	0.71	10,000	$Gamma = 2060 xC_{thorium-232} + 22081$	0.54	36,000
TS7	$Gamma = 642 xC_{thorium-232} + 4526$	0.77	8,000	$Gamma = 1652 xC_{thorium-232} + 15024$	0.79	26,000
TS8	$Gamma = 1320 xC_{thorium-232} + 1947$	0.75	9,000	$Gamma = 3547 xC_{thorium-232} + 8990$	0.75	33,000

Notes:
USAF, 2002
[a] Residential investigation level is rounded to the nearest lower thousand.
c = concentration
cpm = counts per minute
DCGL = derived-concentration guideline level
IL = investigation level
r^2 = Pearson's correlation
TS = Training Site

During decommissioning, these site-specific investigation levels were used to guide the initial stages of soil excavation.

The investigation levels, based on the site characterization survey data, are biased high due to gamma shine from the source material present at the sites. The gamma shine effect is illustrated by the relationship between the site inventory of source material and the site-specific investigation levels. The greater the amount of source material at a site, the greater the site-specific investigation level and

corresponding gamma shine effect. TS5 and TS6, with the largest inventories of thorium, had the highest site-specific investigation levels.

Following removal of the majority of the source material from the sites, a new correlation was developed between the gamma radiation count rate and the thorium-232 soil concentration to eliminate the gamma shine bias. The revised investigation level was developed from the TS5 remedial action support survey data using static gamma radiation measurements and soil samples collected at 26 locations. The 26 soil samples were analyzed by gamma spectroscopy using the onsite laboratory. The data used to develop the correlation are presented in Table 4-2.

Table 4-2. Remedial Action Support Survey Data Used to Develop Investigation Levels for Environmental Restoration Program Site OT-10

Sample ID	Gamma Count Rate (cpm)	Thorium-232 Concentration (pCi/g)
TS5-RASS-B-70	20262	3.90
TS5-RASS-C-71	23709	8.81
TS5-RASS-D-72	24961	9.03
TS5-RASS-E-73	20226	3.70
TS5-RASS-F-74	18743	2.46
TS5-RASS-G-75	24613	6.48
TS5-RASS-H-76	27485	10.32
TS5-RASS-K-79	23686	11.31
TS5-RASS-I-80	19298	2.64
TS5-RASS-M-81	21086	3.90
TS5-RASS-N-82	21141	2.70
TS5-RASS-O-83	26152	8.24
TS5-RASS-P-84	22185	3.90
TS5-RASS-85	23030	7.03
TS5-RASS-86	24067	7.62
TS5-RASS-87	24353	6.93
TS5-RASS-88	22742	3.10
TS5-RASS-89	23171	10.91
TS5-RASS-90	19771	3.89
TS5-RASS-91	24551	7.04
TS5-RASS-92	20798	3.95
TS5-RASS-94	20483	2.83
TS5-RASS-95	20205	3.59
TS5-RASS-96	22005	3.92
TS5-RASS-97	20487	3.55
TS5-RASS-98	21537	5.56

Notes:
cpm = count per minute
ID = identifier
pCi/g = picocuries per gram
TS = Training Site

Two distributions of the gamma count rate and thorium-232 concentration data were identified during the remedial action support surveys. One distribution occurs near background concentrations of thorium-232 (0.91 pCi/g) and the other in soils affected by the source material. The two distributions are treated separately. A thorium-232 threshold of 2.0 pCi/g was established as the dividing point for the two distributions. The data above the 2.0 pCi/g threshold are believed to be representative of thorium-contaminated soil. The data presented in Table 4-2 are limited to thorium-232 soil concentrations of 2.0 pCi/g and above.

The linear regression obtained by using the method of least squares is shown in Figure 4-2 along with upper and lower 95th percentile confidence lines.

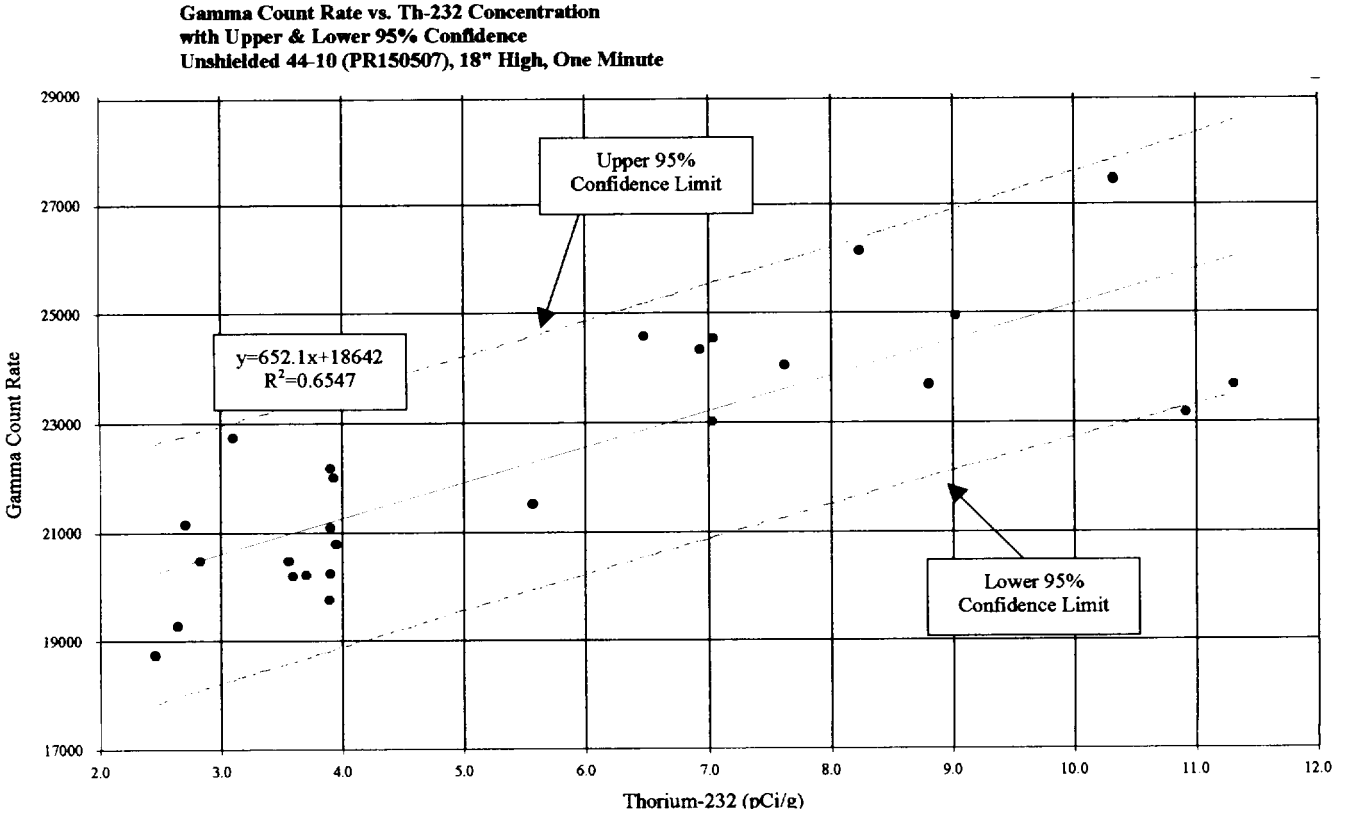

Figure 4-2. Correlation between Thorium-232 Soil Concentrations and Static Gamma Radiation Measurements for Contaminated Soil, Environmental Restoration Program Site OT-10

The linear regression has the form y = mx + b. The method used for calculating the confidence interval of y for each x is described in *Probability and Statistics for Engineers and Scientists* (Wapole and Myers, 1985, p.289). The linear regression relationship is presented in equation 4-1.

$$\text{Gamma Counts} = 652.1 * C_{\text{thorium-232}} + 18{,}642, \qquad \text{Eq. 4-2}$$

Where

Gamma counts are in counts per minute (cpm), and

C is concentration in pCi/g.

The equation is linear, with squared Pearson's Correlation (r^2) of 0.65.

Using equation 4-2, the thorium-232 concentration of 6.61 pCi/g, equal to the $DCGL_w$ plus background, produces a gamma count rate of approximately 23,000 cpm. To account for the uncertainty in the correlation, the investigation level for the 6.61 pCi/g thorium-232 was set to the intercept with the lower 95th percentile confidence line or approximately 20,000 cpm. This 20,000-cpm investigation level was used for the mean and median evaluation of the final status survey data. The 23,000-cpm level was used in the EMC and unity rule analysis of the final status survey data.

Using equation 4-2, a third gamma count rate was calculated for the thorium-232 concentration of 21.7 pCi/g, equal to the $DCGL_{EMC}$ for a one square meter area plus background. This calculation produces a gamma count rate of approximately 33,000-cpm. The 33,000-cpm level was used to visually identify areas that are potentially above the $DCGL_{EMC}$ for a one square meter area.

4.4 Classification of Areas into Multi-Agency Radiation Survey and Site Investigation Manual (MARRSIM) Survey Units

Using the excavation boundaries of the decommissioning activities and final status survey investigation level of 20,000 cpm, the sites were divided into MARSSIM class areas. The MARSSIM class areas presented in this report differ from and encompass a larger land area than the provisional MARSSIM class areas presented in the Decommissioning Plan (USAF, 2002). Each MARSSIM class area is considered an individual survey unit. MARSSIM classifies areas by contamination potential. Affected areas are areas that have some potential for containing contaminated material. They are divided into the following three classes:

- Class 1 Areas: Class 1 areas are affected areas that, prior to remediation, are expected to have concentrations of residual radioactivity that exceed the $DCGL_w$.

- Class 2 Areas: Class 2 areas are affected areas that, prior to remediation, are not likely to have concentration of residual radioactivity that exceed the $DCGL_w$.

- Class 3 Areas: Class 3 areas are affected areas that have a low probability of containing residual radioactivity or that are expected to contain levels of residual radioactivity at a small fraction of the $DCGL_w$.

Consistent with MARSSIM, any area that was remediated was identified as a Class 1 area. Survey unit size was assigned in accordance with the MARSSIM suggested areas for survey units (EPA, 1997). Class 1 land areas were given a uniform size of 2,000 square meters (m^2). Class 2 land areas were established around the perimeter of the Class 1 areas and were given a maximum size of 10,000 m^2. No site areas were classified as Class 3 areas. Buildings 28005 and 28010 at TS8 were each classified as Class 1 areas.

The MARSSIM survey units and decommissioning excavation boundaries for each site are presented in Figures 4-3 through 4-6. Figures 4-7 through 4-10 present the site characterization survey data, collected prior to decommissioning, and the MARSSIM survey units for each site. Due to the large inventory of source material placed at TS5 and TS6 and the resultant gamma shine from the source material, these figures should be used with caution. Areas at TS6 exceeding the 20,000-cpm investigation level located outside the Class 1 survey unit boundaries result from gamma shine.

4.5 Statistical Sample Size Determination

The number of soil samples required from each Class 1 survey unit was based on statistical analysis of the gamma scanning survey data. The method used to calculate the number of soil samples is consistent with the guidance provided in MARSSIM (EPA, 1997).

When a radionuclide is present in background, the Wilcoxon Rank Sum (WRS) test is used to evaluate whether site data are significantly less than the $DCGL_w$. The WRS test is a non-parametric test and is independent of the distribution of the underlying data. The null hypothesis used in this determination is that the radionuclide activity in the survey unit exceeds background by more than the $DCGL_w$.

The null hypothesis is structured such that the burden of proof is to show that the survey unit contains radionuclide activities that are statistically lower than the $DCGL_w$. This requires a minimum number of samples. The required sample number increases as the average activity in the survey unit approaches the $DCGL_w$ and/or as the variability in the data increases. Parameters required to determine the number of samples include the standard deviation of the data, the width of a gray region where decision errors have a low consequence (known as the shift), and acceptable levels of errors in decision making.

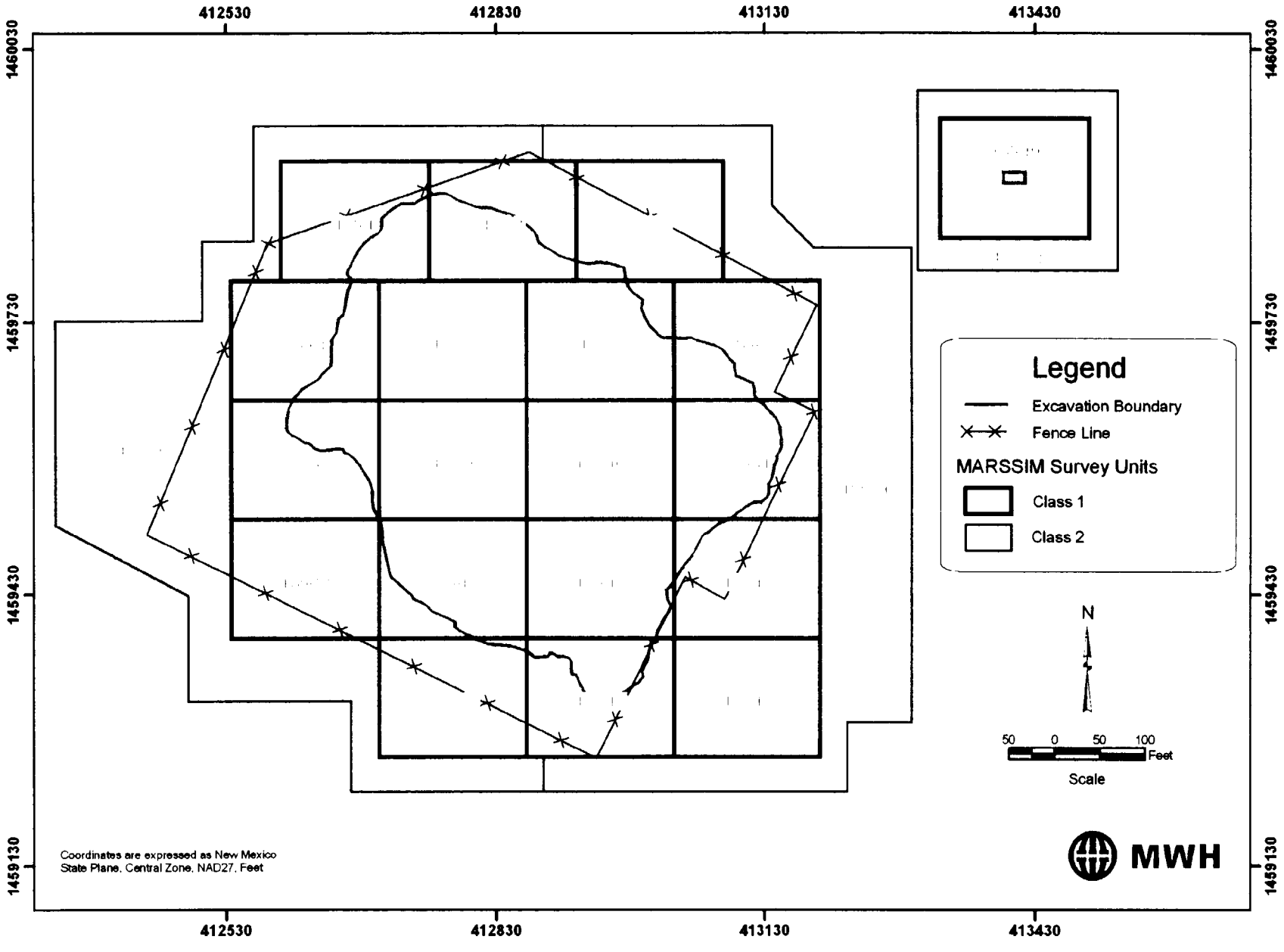

Figure 4-3. Excavation Boundaries and MARSSIM Survey Units at Training Site 5, Environmental Restoration Program Site OT-10

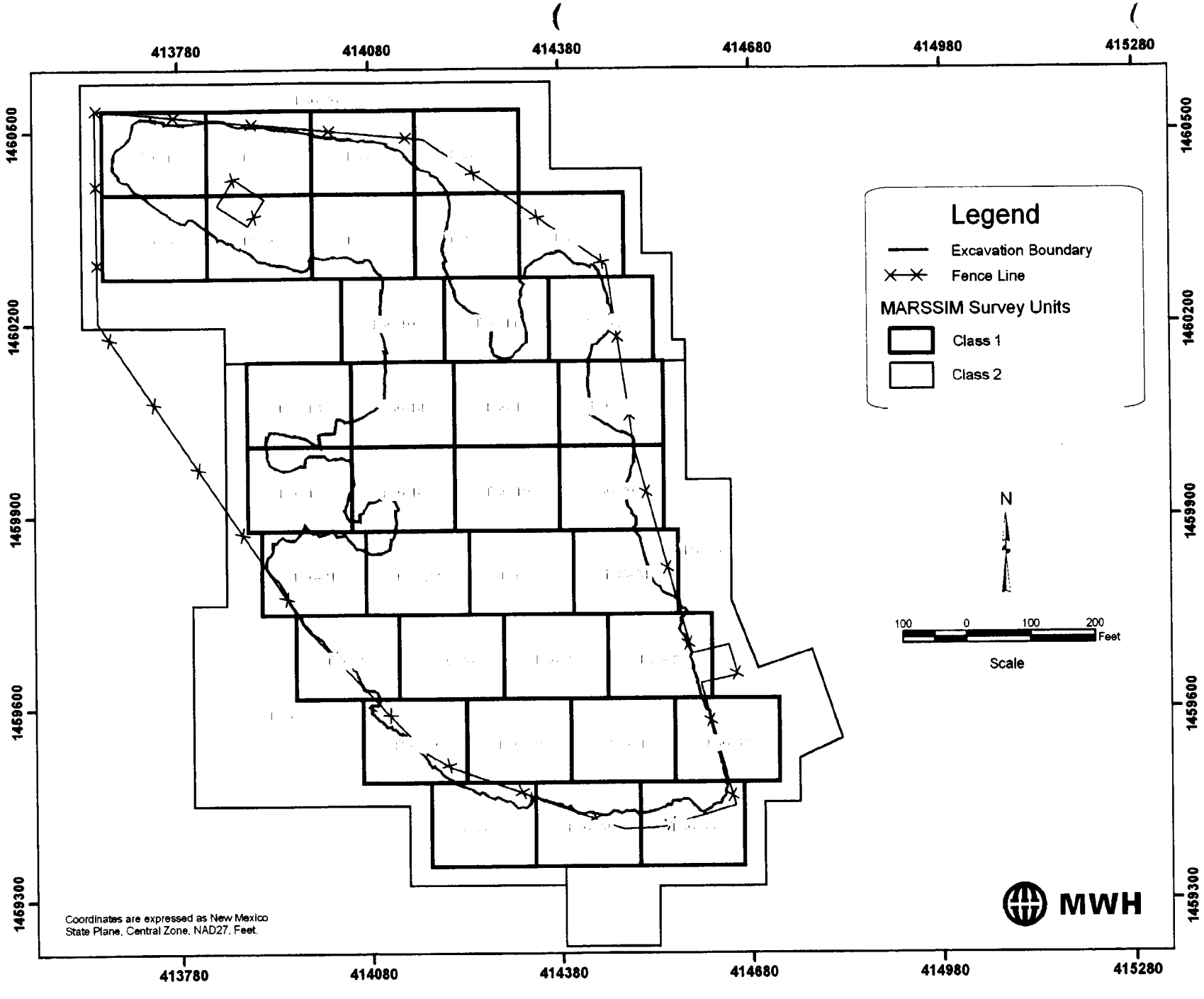

Figure 4-4. Excavation Boundaries and MARSSIM Survey Units at Training Site 6, Environmental Restoration Program Site OT-10

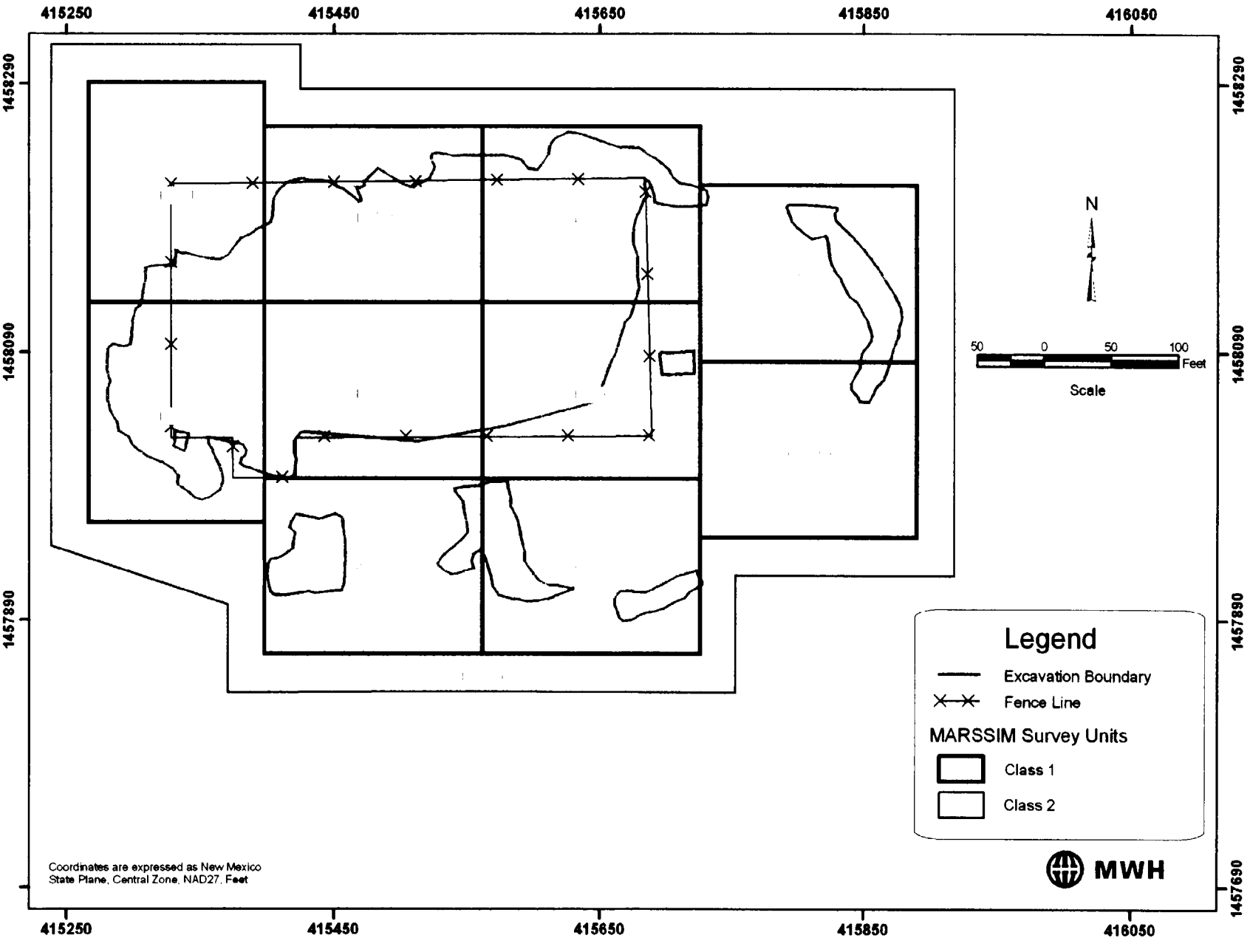

Figure 4-5. Excavation Boundaries and MARSSIM Survey Units at Training Site 7, Environmental Restoration Program Site OT-10

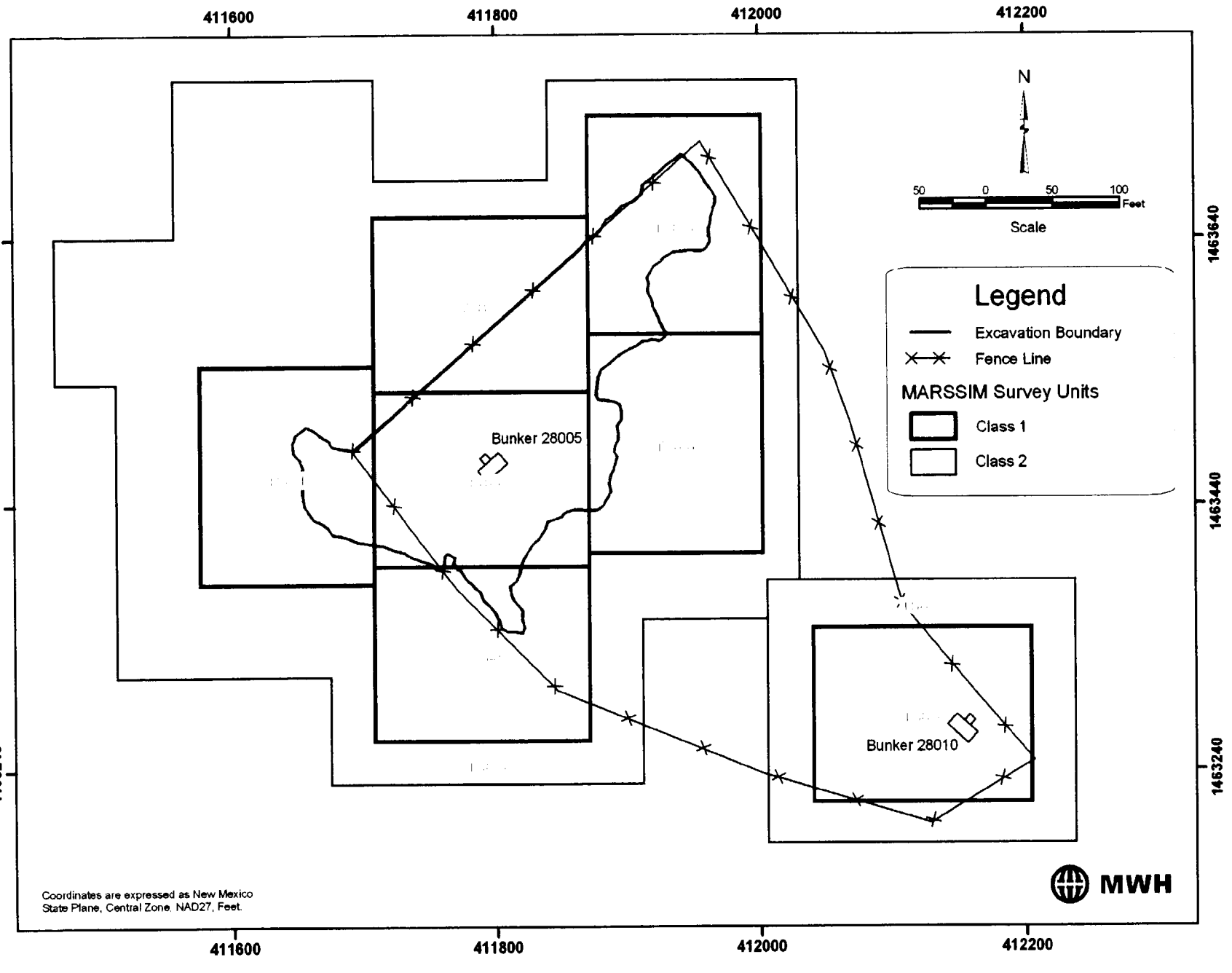

Figure 4-6. Excavation Boundaries and MARSSIM Survey Units at Training Site 8, Environmental Restoration Program Site OT-10

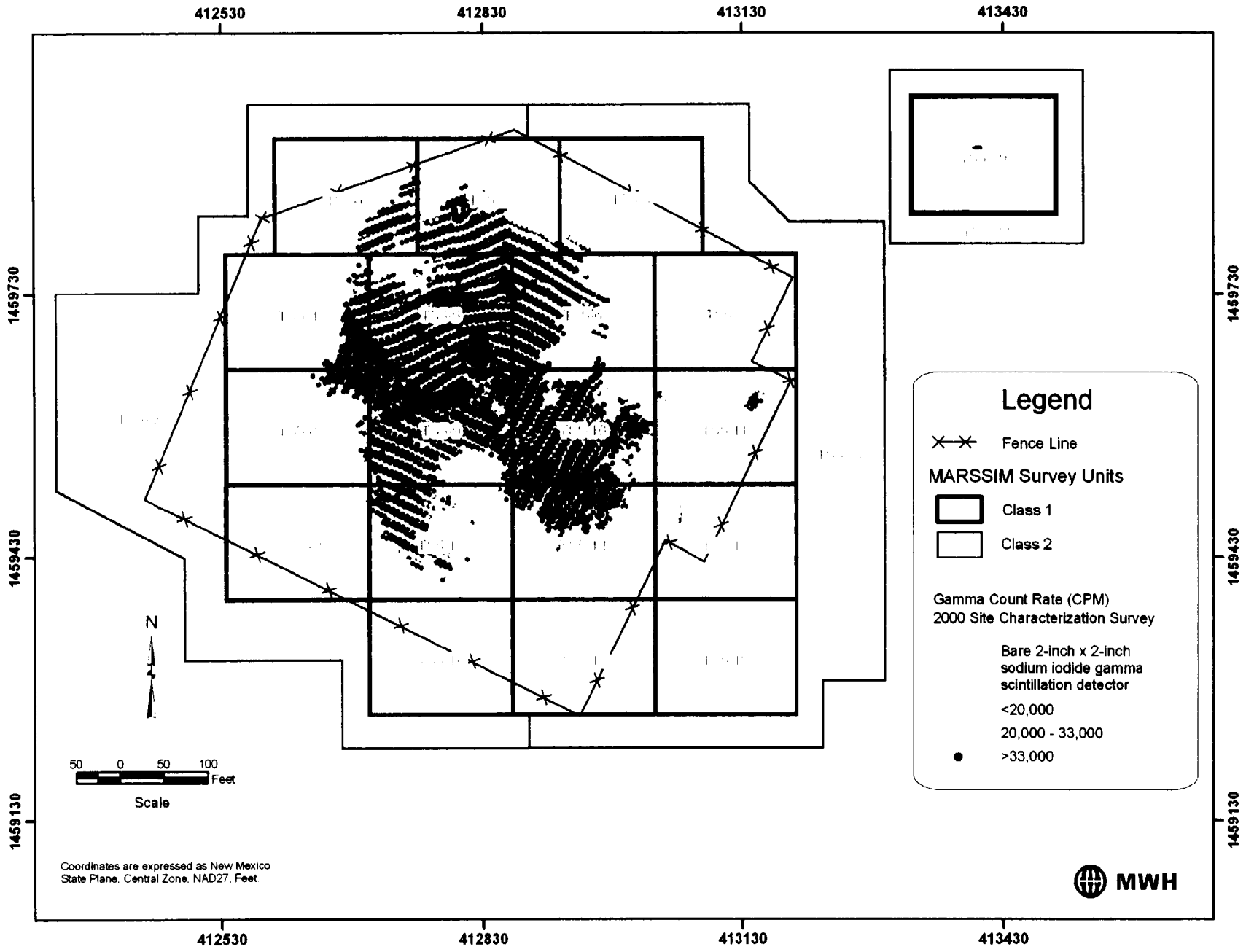

Figure 4-7. Site Characterization Survey Data and MARSSIM Survey Units at Training Site 5, Environmental Restoration Program Site OT-10

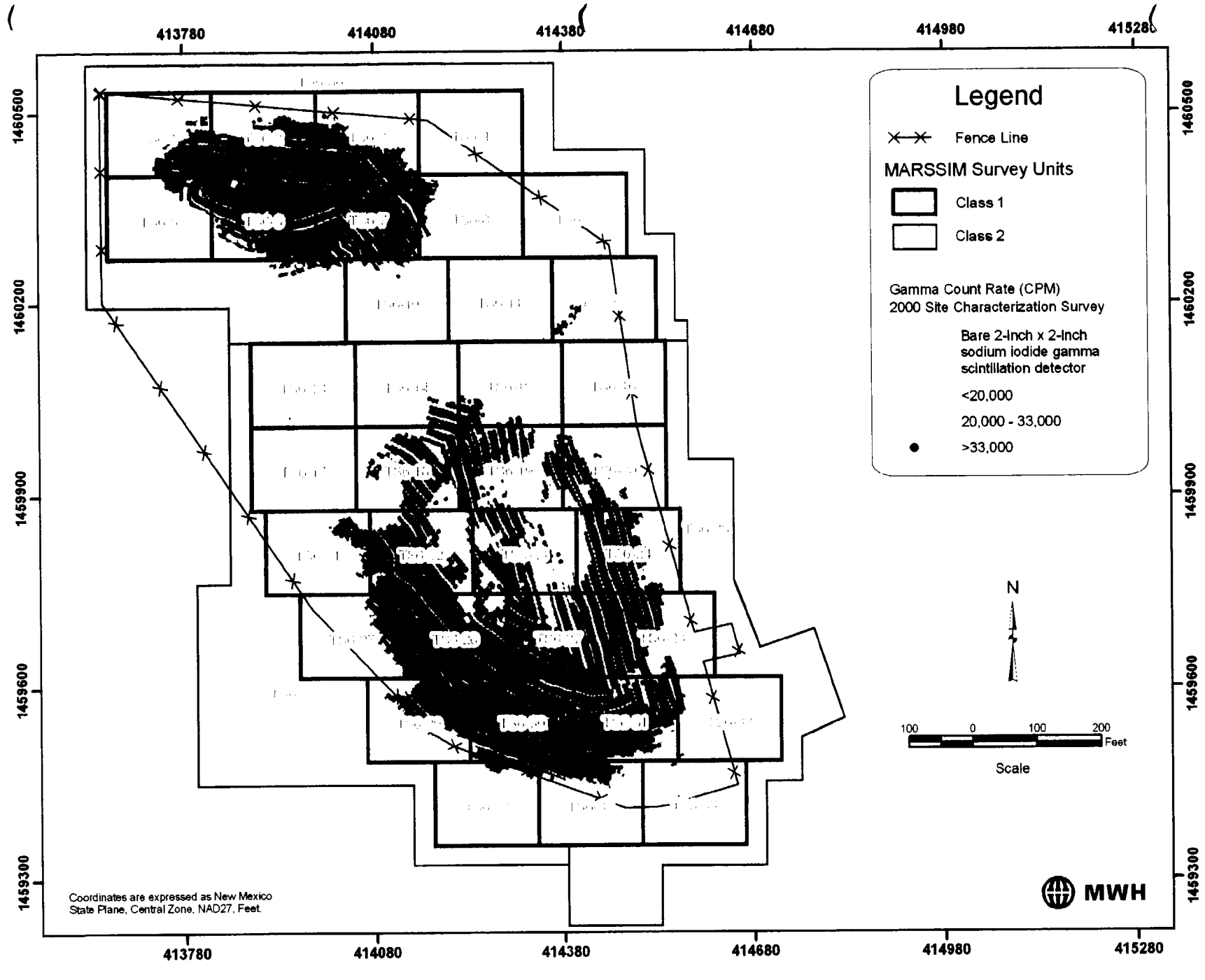

Figure 4-8. Site Characterization Survey Data and MARSSIM Survey Units at Training Site 6, Environmental Restoration Program Site OT-10

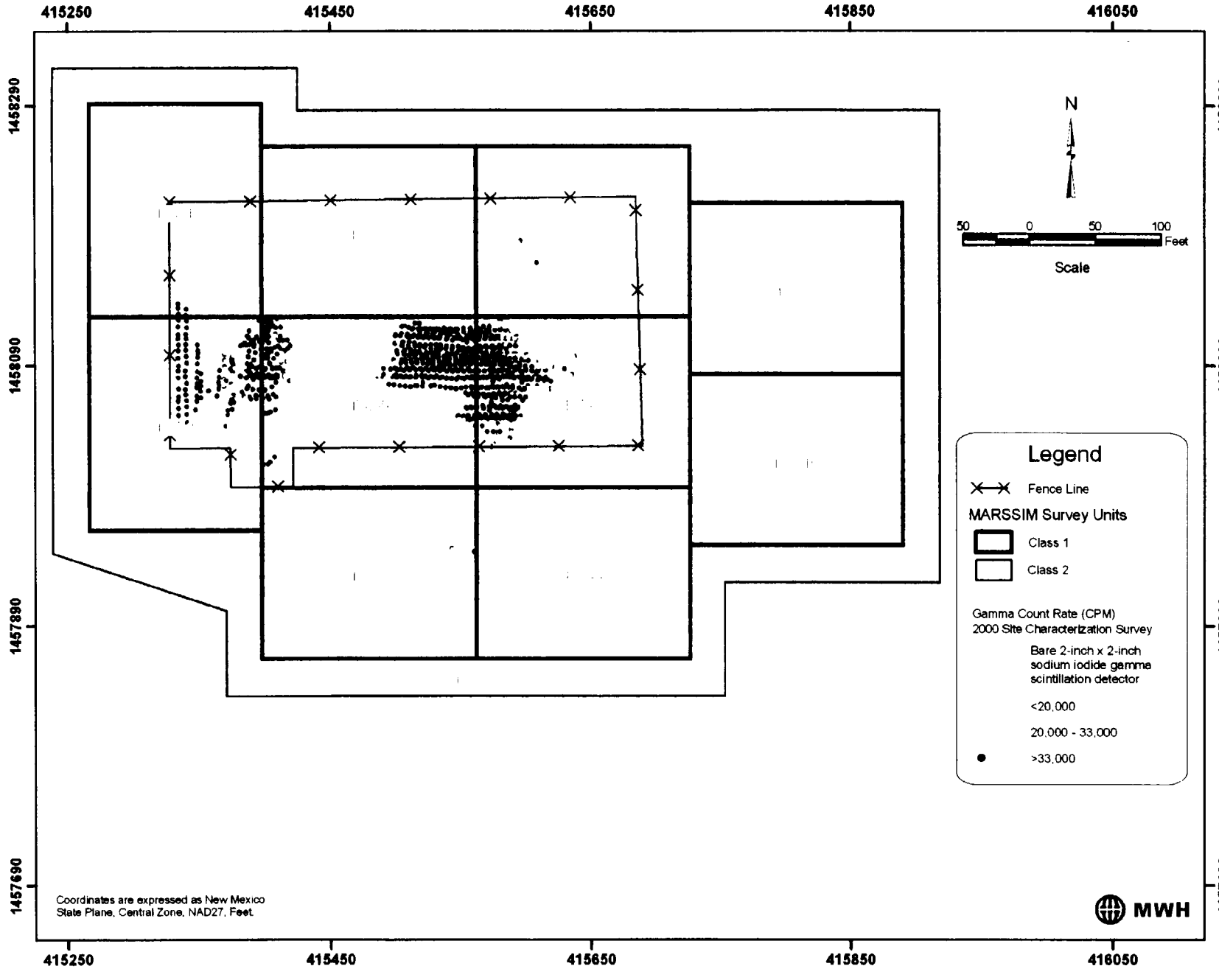

Figure 4-9. Site Characterization Survey Data and MARSSIM Survey Units at Training Site 7, Environmental Restoration Program Site OT-10

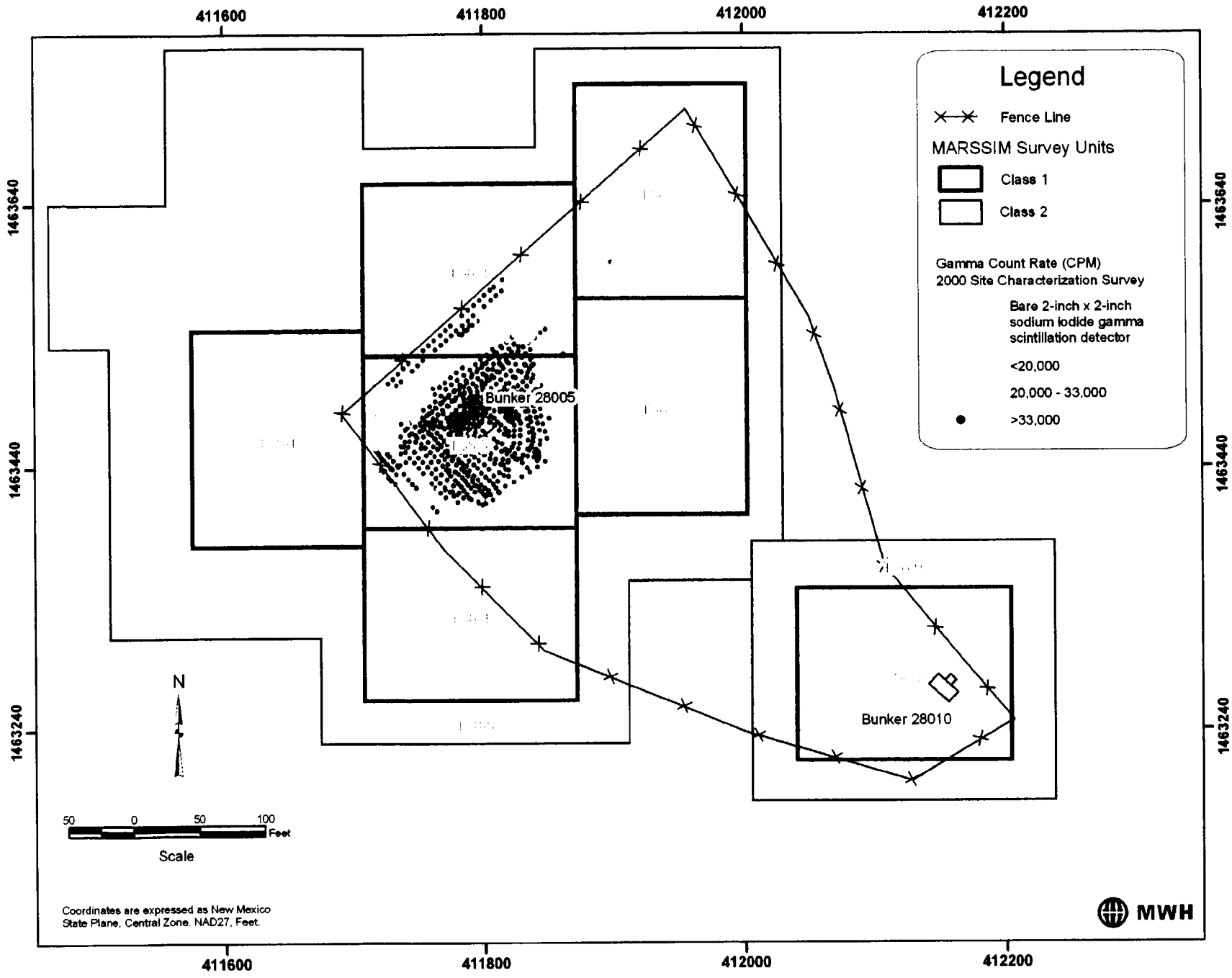

Figure 4-10. Site Characterization Survey Data and MARSSIM Survey Units at Training Site 8, Environmental Restoration Program Site OT-10

4.5.1 Number of Samples Required for Class 1 Land Areas

The equation used to calculate the number of samples for land-based Class 1 Survey Units, where soil is the contaminated medium, is as follows:

$$N = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{3(P_r - 0.5)^2} \qquad \text{Eq. 4-3}$$

Where

$Z_{1-\alpha}$ = Critical value for the normal distribution for the error rate alpha, where alpha is the potential for a false positive (where the survey unit is released as being below the $DCGL_w$, even though the average activity is above the $DCGL_w$);

$Z_{1-\beta}$ = Critical value for the normal distribution for the error rate beta, where beta is the potential for a false negative (where the survey unit is classified as being above the $DCGL_w$, even though the average activity is below the $DCGL_w$); and

P_r = Probability that a random measurement from the survey unit exceeds a random measurement from a background reference area by less than the $DCGL_w$, under certain conditions.

The parameters α and β are specified for the site, whereupon $Z_{1-\alpha}$ and $Z_{1-\beta}$ can be determined from Table 5-2 in MARSSIM (EPA, 1997). The parameter P_r is dependent upon the standard deviation and shift of the data.

The values $Z_{1-\alpha}$ and $Z_{1-\beta}$ are dependent upon α and β. The parameter α represents the probability of making a Type I decision error, releasing a survey unit, even though the average radionuclide activity exceeds background by an amount greater than the $DCGL_w$. The parameter β is the power of the test. It reflects the likelihood of making a Type II decision error, failing to release a survey unit, even though the level of radioactivity is less than the $DCGL_w$ above background. The result of a Type II error is that additional unnecessary remediation is performed. The consequence of a lower β value is an increase in the number of samples. A value of 0.05 was established for both α and β in the OT-10 Decommissioning Plan (USAF, 2002). The corresponding values of $Z_{1-\alpha}$ and $Z_{1-\beta}$ are 1.645 from Table 5.2 in MARSSIM (EPA, 1997).

P_r is the probability that a random measurement from the survey unit exceeds a random measurement from a background reference area by less than the $DCGL_w$ under certain conditions. One of these conditions is that the survey unit median is above background by an amount known as the lower bound of the gray region (LBGR). Above the LBGR, the likelihood of making a Type II error increases above β. The difference between the $DCGL_w$ and the LBGR is known as the shift (Δ). The starting point for the value of Δ under MARSSIM is half the $DCGL_w$. With a $DCGL_w$ of 5.7 picocuries per gram (pCi/g), both Δ and the LBGR equal 2.85 pCi/g. A larger value of Δ (a lower LBGR value so that it is further from the $DCGL_w$) requires a greater number of samples to be collected in order to increase the confidence that the survey unit will pass the WRS test. With a smaller value of Δ (a higher LBGR value closer to the $DCGL_w$), fewer samples are collected, increasing the risk of failing the WRS test.

The actual value of Δ is less important than the relative shift. The relative shift is equal to the Δ divided by the standard deviation (σ). The value of σ is an estimate of the standard deviation of the data collected during the final status survey, in units of pCi/g. For planning purposes, σ must be inferred from the data available prior to conduct of the final status survey. Once Δ/σ is estimated, the value of P_r can be determined from Table 5-1 in MARSSIM (EPA, 1997). If the value of Δ/σ is outside the range of 1 to 3, the value of Δ (and the LBGR) is reconsidered.

The WRS test is conducted using laboratory analyses of the soil activity of specific radionuclides. However, prior to soil sample collection, the primary data available were gamma radiation survey results. Thus, it was necessary to establish a correlation between the gamma survey data and soil radionuclide concentrations.

At OT-10, scanning gamma surveys were performed over 100 percent of the Class 1 survey units. As mentioned in Section 4.3, two distributions of the gamma radiation count rate and thorium-232 concentration data were identified during the remedial action support surveys. The two data distributions required that two correlations be developed for the OT-10 sites. One correlation focused on areas with radionuclide concentrations near or above the $DCGL_w$; the second correlation focused on samples with concentrations only slightly elevated with respect to background. Two correlations were necessary because local contamination creates a gamma shine that elevates the gamma survey results for nearby clean soil. Thus, clean soil adjacent to more clean soil will have lower gamma count rates than clean soil adjacent to contaminated soil.

The high-end correlation used collocated static gamma survey measurements and soil samples collected during a TS5 remedial action support survey. Twenty-six soil samples were analyzed in an onsite laboratory and the results are presented in Table 4-3. These locations were biased high, with the lowest gamma rate being 18,743 cpm. Most of the samples in this data set had count rates of 20,000 cpm or higher whereas only about 5 percent of the total TS5 gamma scanning survey measurements were at least 20,000 cpm. Thus, the collocated data are representative of the highest gamma measurements collected during the remedial action support survey.

A linear regression was performed using the 26 samples and is shown in Figure 4-11. This is the same correlation used to develop the investigation level. The relationship between the thorium-232 soil concentration and gamma count rate is defined by Equation 4-4.

$$\text{Soil concentration thorium-232 (pCi/g)} = (\text{Gamma Count Rate (cpm)} - 18{,}642)/652.1 \qquad \text{Eq.4-4}$$

The r^2 value for this regression is 0.65.

Table 4-3. High-End Correlation Data for Thorium-232 Soil Concentrations and Static Gamma Radiation Measurements, Environmental Restoration Program Site OT-10

Sample ID	Thorium-232 Concentration (pCi/g)	Integrated Gamma Count Rate (cpm)
TS5-RASS-B-70	3.9	20262
TS5-RASS-C-71	8.81	23709
TS5-RASS-D-72	9.03	24961
TS5-RASS-E-73	3.7	20226
TS5-RASS-F-74	2.46	18743
TS5-RASS-G-75	6.48	24613
TS5-RASS-H-76	10.32	27485
TS5-RASS-K-79	11.31	23686
TS5-RASS-I-80	2.64	19298
TS5-RASS-M-81	3.9	21086
TS5-RASS-N-82	2.7	21141
TS5-RASS-O-83	8.24	26152
TS5-RASS-P-84	3.9	22185
TS5-RASS-85	7.03	23030
TS5-RASS-86	7.62	24067
TS5-RASS-87	6.93	24353
TS5-RASS-88	3.1	22742
TS5-RASS-89	10.91	23171
TS5-RASS-90	3.89	19771
TS5-RASS-91	7.04	24551
TS5-RASS-92	3.95	20798
TS5-RASS-94	2.83	20483
TS5-RASS-95	3.59	20205
TS5-RASS-96	3.92	22005
TS5-RASS-97	3.55	20487
TS5-RASS-98	5.56	21537

Notes:
cpm = counts per minute
ID = identifier
pCi/g = picocuries per gram
TS = training site

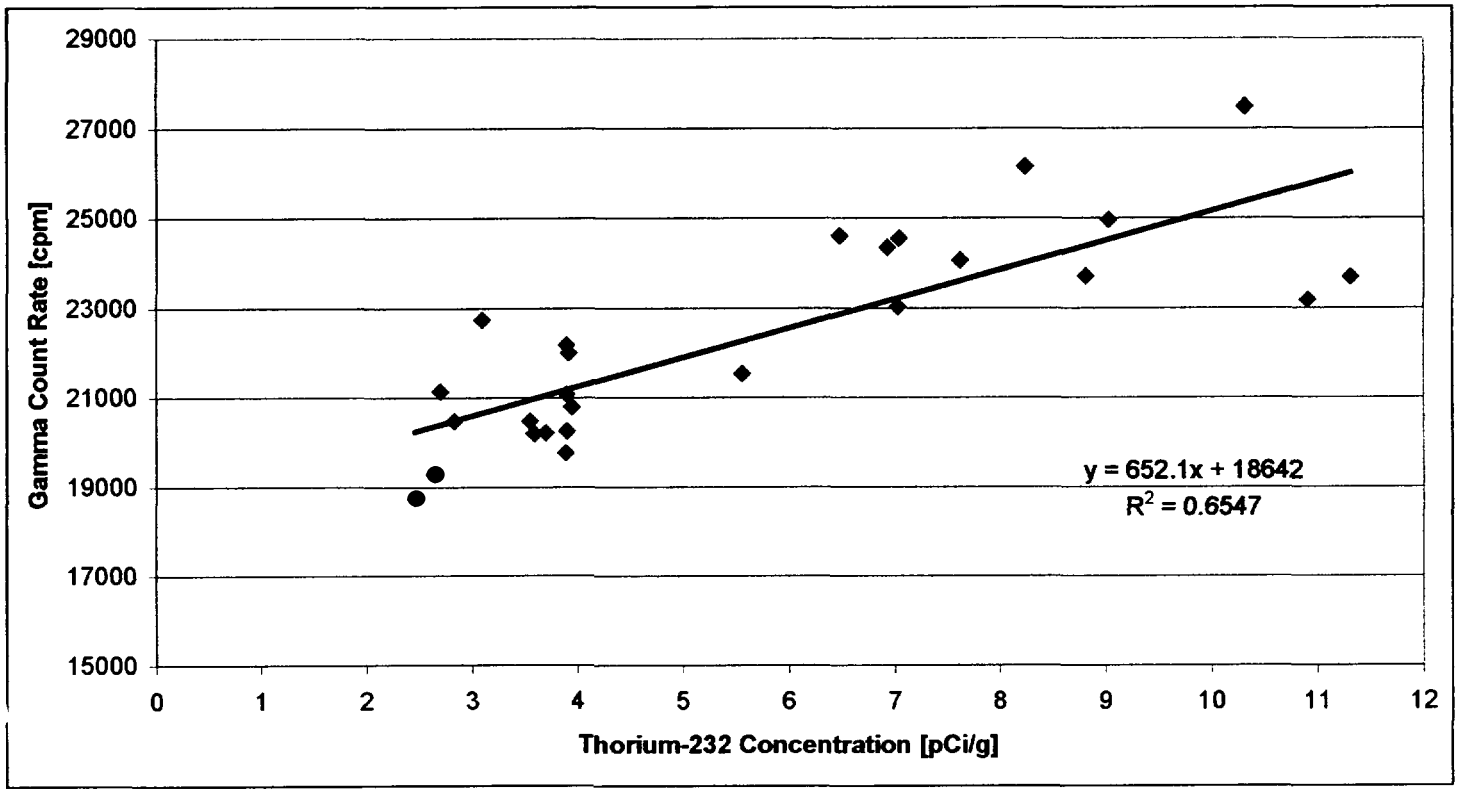

Figure 4-11. High End Correlation Between Thorium-232 Soil Concentrations and Static Gamma Radiation Measurements, Environmental Restoration Program Site OT-10

A similar analysis was performed for thorium-232 concentrations near background. Nineteen samples were collected from TS7 with static gamma counts ranging from 10,855 to 17,488 cpm. The soil samples were analyzed using the onsite laboratory and the results are presented in Table 4-4. The linear regression of the data is shown in Figure 4-12. The relationship between thorium-232 soil concentration and gamma count rate is defined by Equation 4-5.

Soil concentration thorium-232 (pCi/g) = (Gamma Count Rate (cpm) – 11,609)/2,933.8 Eq.4-5

The r^2 value for this regression was 0.63.

Table 4-4. Low-End Correlation Data for Thorium-232 Soil Concentrations and Static Gamma Radiation Measurements, Environmental Restoration Program Site OT-10

Sample number	Thorium-232 Concentration (pCi/g)	Integrated Gamma Count Rate (cpm)
TS7-SS-102	1.18	14193
TS7-SS-104	1.39	15696
TS7-SS-106	0.41	13103
TS7-SS-108	1.92	17488
TS7-SS-112	1.89	17251
TS7-SS-113	1.27	15993
TS7-SS-29	0.71	13650
TS7-SS-31	0.23	10855
TS7-SS-32	0.92	14605
TS7-SS-35	0.86	16051
TS7-SS-37	1.8	16870
TS7-SS-45	1.3	15077
TS7-SS-46	1.29	16793
TS7-SS-48	0.68	12881
TS7-SS-51	0.95	13915
TS7-SS-52	0.58	14168
TS7-SS-63	0.65	15191
TS7-SS-72	1.26	12112
TS7-SS-77	0.25	12008

Notes:
cpm = counts per minute
pCi/g = picocuries per gram
TS = training site

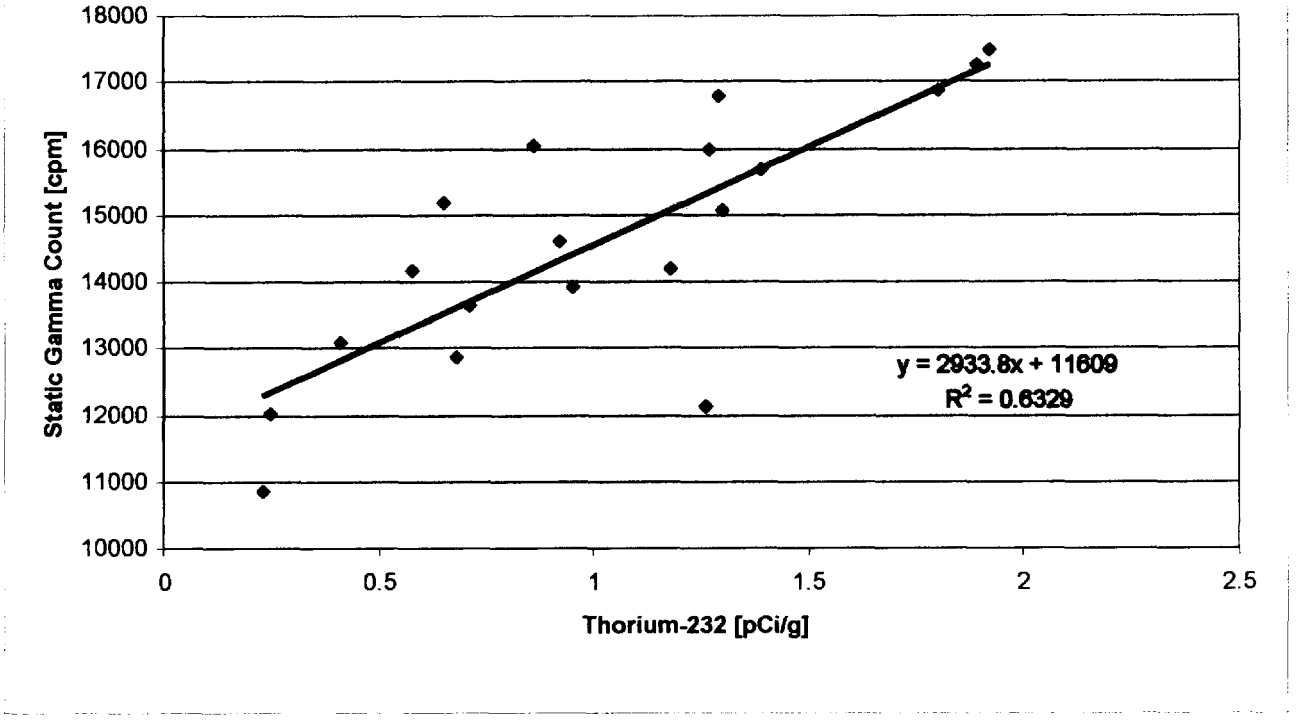

Figure 4-12. Low End Correlation Between Thorium-232 Soil Concentrations and Static Gamma Radiation Measurements, Environmental Restoration Program Site OT-10

To estimate a standard deviation for the total population within a Class 1 unit, all of the gamma survey data were converted to pCi/g, using the appropriate regression. The data were kept in separate populations, based on which regression relationship was used, and the standard deviations of these subpopulations were calculated. However, it was recognized that the calculated standard deviation might not account for the total variability that could be observed in the final status survey data. This is because the calculated standard deviation alone does not account for the scatter that exists in converting the data to pCi/g. Consequently, the standard deviations of the two subpopulations were multiplied by the standard error of the calculated slope factor in the respective regressions. These were factors of 1.15 for the higher subpopulation and 1.18 for the lower subpopulation.The overall standard deviation for the data set was estimated using the following formula for a pooled standard deviation:

$$\sigma = \sqrt{\frac{(m-1)s_1^{\,2} + (n-1)s_2^{\,2}}{m+n-2}} \qquad \text{Eq. 4-6}$$

Where

m = Number of data points in sub-population 1,

s_1 = Estimated standard deviation for sub-population 1,

n = Number of data points in sub-population 2, and

s_2 = Estimated standard deviation for sub-population 2.

For example, at TS5-1, there were 3,416 samples with gamma survey counts less than 18,750 and 15 samples with gamma survey counts greater than 18,750. After converting the data using the respective regressions, the low-count subpopulation had a standard deviation of 0.498 pCi/g. Increasing this by 18 percent, the adjusted standard deviation of this subpopulation is 0.588 pCi/g. For the higher subpopulation, the standard deviation was 1.02 pCi/g; multiplying by 1.15 yields an adjusted standard deviation for this subpopulation of 1.17 pCi/g. In summary:

m = 15

s_1 = 1.17 pCi/g

n = 3,416

s_2 = 0.59 pCi/g

The pooled standard deviation is then:

$$\sigma = \sqrt{\frac{(15-1)(1.17)^2 + (3{,}416-1)(0.59)^2}{15+3{,}416-2}} = 0.59 \text{ pCi/g} \qquad \text{Eq. 4-7}$$

Using a value for Δ of 2.85 pCi/g (as described above), the relative shift is calculated as,

$$\Delta/\sigma = 2.85 \text{ pCi/g} \div 0.59 \text{ pCi/g} = 4.8 \qquad \text{Eq. 4-8}$$

The MARSSIM design goal for the relative shift is $1 < \Delta/\sigma < 3$. This value is outside the range of 1 and 3; thus, it was appropriate to adjust the shift (Δ) downward. Doing so increased the number of samples to be collected in the final status survey, decreasing the probability that the Class 1 unit would fail the WRS test. Adjusting the shift (Δ) value down to 1.84 pCi/g results in a relative shift (Δ/σ) of approximately 3. Using the relative shift value of 3, Table 5.1 of MARSSIM indicates that P_r is 0.983. The value of N was then calculated from the following parameters:

P_r = 0.983,

$Z_{1-\alpha}$ = 1.645, and

$Z_{1-\beta}$ = 1.645.

From these input parameters, the number of samples to be collected in the final status survey was calculated as:

$$N = \frac{(1.645 + 1.645)^2}{3(0.983 - 0.5)^2} = 15.5 \qquad \text{Eq. 4-9}$$

MARSSIM recommends applying a 20-percent safety factor to ensure that enough samples are collected. Using this factor, at least 19 samples would need to be collected, with half to come from the Class 1 unit and half to come from the reference area. Thus, 10 samples were collected from this Class 1 unit. In fact, at most Class 1 units, it was necessary to reduce the value of Δ such that the relative shift would equal 3; therefore, 10 samples were collected from most Class 1 units. There were a small number of units where more than 10 samples were collected. The actual sample number calculations for each Class 1 survey unit are presented in Section 5.1 of this report.

4.6 Significant Changes from the Decommissioning Plan

Several changes were made in the final status surveys from what was originally proposed in the decommissioning plan (USAF, 2002). These changes included:

- A decrease in the gamma radiation investigation level from 33,000 cpm to 20,000 cpm. The new investigation level was developed to eliminate the gamma shine bias resulting from the pre-remediation source material present at the sites.

- An increase in the number of MARSSIM Class 1 survey units at each training site. The areal extent of soil contamination above the $DCGL_w$ was greater than originally identified in the decommissioning plan.

5.0 FINAL STATUS SURVEY RESULTS AND INTERPRETATION

5.1 Land Area Survey Results

This section presents the land area final status survey results, judgmental and miscellaneous sample results, and the calculation of the minimum detectable concentration (MDC) for the land area surveys.

5.1.1 Gamma Radiation Scanning Surveys

The results of the gamma radiation scanning surveys were mapped using ArcView® GIS software. Figures 5-1 through 5-4 present the scanning gamma radiation measurements at TS5 through TS8, respectively. Figures 5-5 through 5-8 present the gamma scanning data superimposed on the MARSSIM survey units. A data presentation threshold corresponding to the 20,000-cpm investigation level is used to identify areas potentially above 6.61 pCi/g of thorium-232 ($DCGL_w$ plus background). Very few areas at the sites remain above the investigation level. The major exception is the gamma radiation anomaly present at TS8 in survey unit 3. Because building 28005 will remain in use as a training facility, the interior of the building will remain contaminated. Gamma shine from the contaminated building affected the gamma scanning survey results in the building vicinity.

Gamma scanning survey data gaps exist in several locations. At TS5, data gaps are visible in survey units 5, 10, 14, 17, 18, and 19. The data gaps in survey units 5, 10, and 14 result from excavated burial pits present in these areas. Therefore, soil samples were collected from the burial pits as part of the final status surveys. The data gaps in survey units 17, 18, and 19 result from bushes or shrubs in these areas. Areas that were not scanned due to the presence of shrubs or bushes were small in area and represented a small fraction of the survey unit area. These areas were not expected to have significantly different residual contamination than closely adjacent areas.

At TS6, data gaps are prominent in survey units 4, 9, and 16. These data gaps result from the arroyo bank in these areas. The arroyo bank areas were outside of the contaminated area identified during the site characterization surveys and were considered to be non-contaminated. Data gaps present in the TS8 survey data result from bushes or shrubs in these areas. Areas that were not scanned due to the presence of shrubs or bushes were small in area and represented a small fraction of the survey unit area. These areas were not expected to have significantly different residual contamination than closely adjacent areas.

The gamma scanning survey data for each site was subdivided by survey unit. The summary statistics for each Class 1 survey unit are presented in Tables 5-1 through 5-4. The mean and median gamma count rates for all Class 1 survey units are below the 20,000-cpm investigation level. The summary statistics for each Class 2 survey unit are presented in Tables 5-5 through 5-8. The mean and median gamma count rates for all Class 2 survey units are also below the 20,000-cpm investigation level.

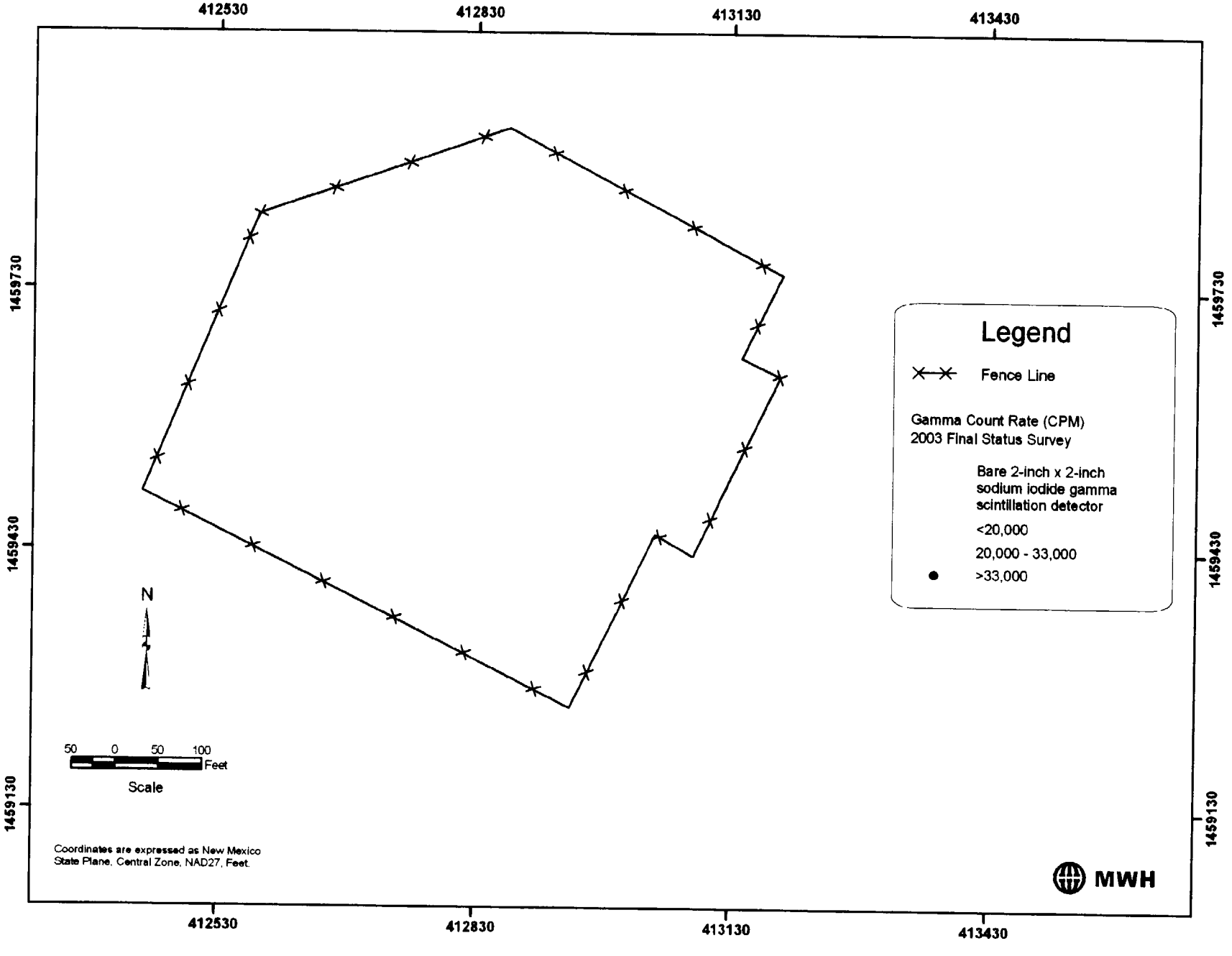

Figure 5-1. Final Status Survey Gamma Scanning Data for Training Site 5, Environmental Restoration Program Site OT-10

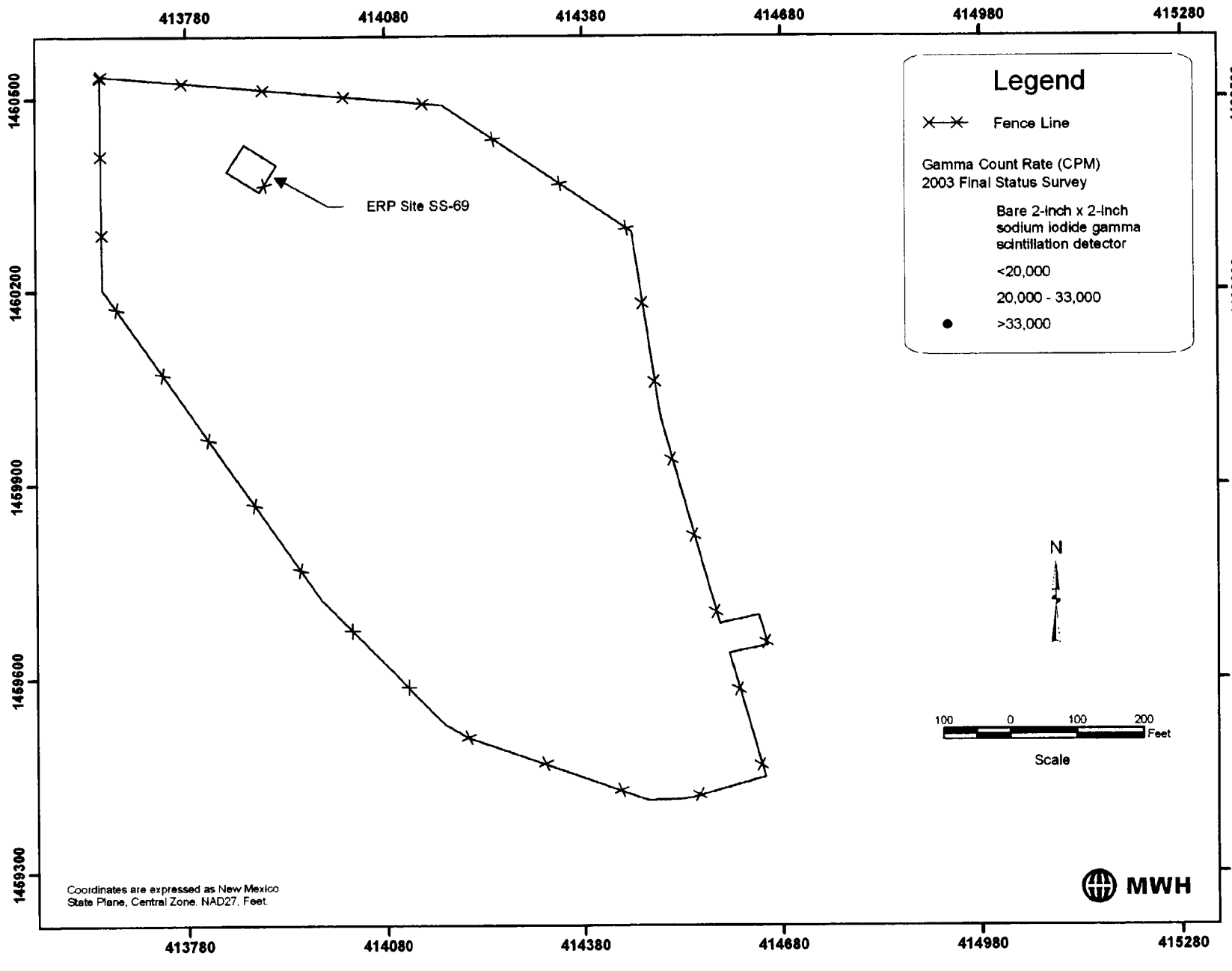

Figure 5-2. Final Status Survey Gamma Scanning Data for Training Site 6, Environmental Restoration Program Site OT-10

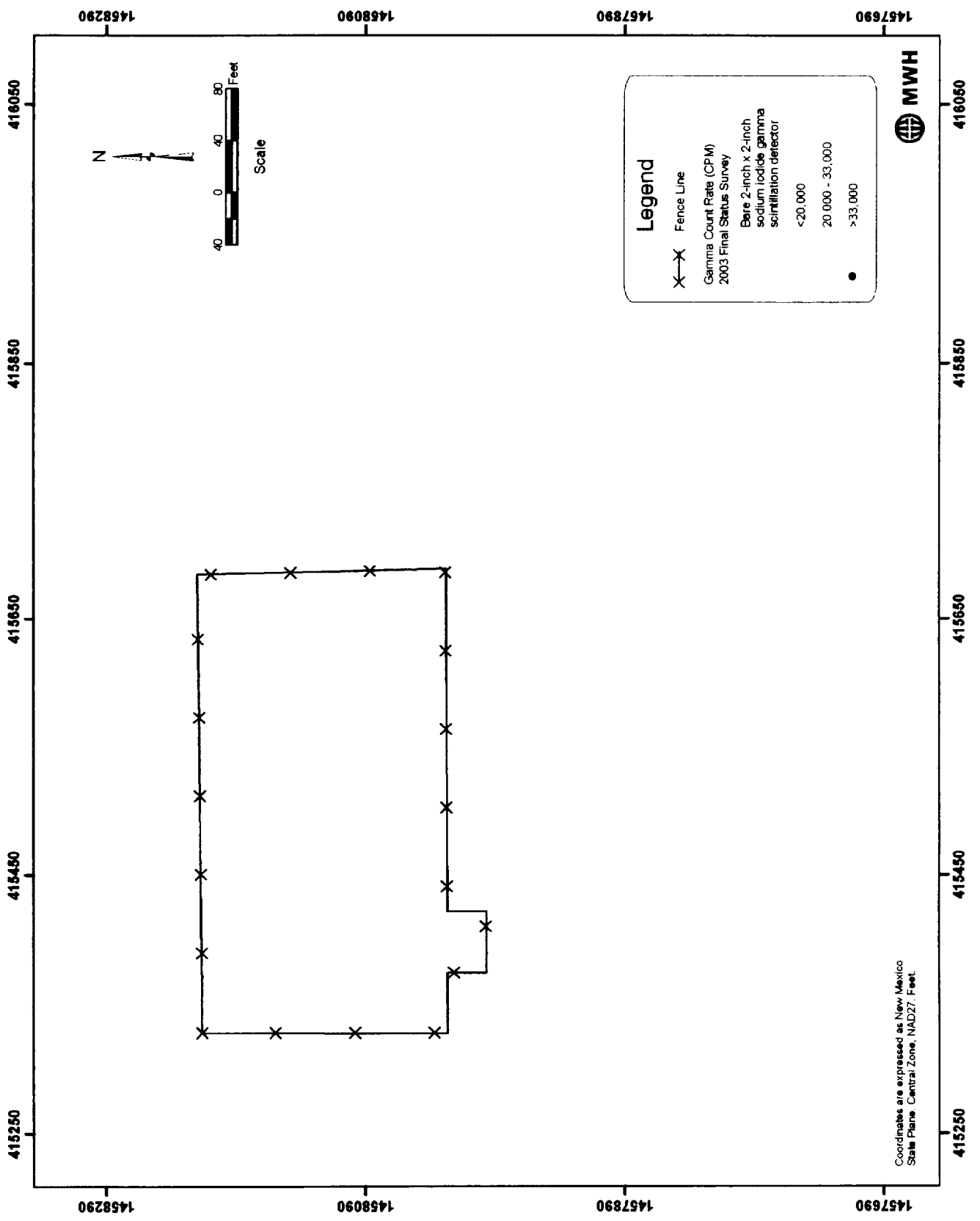

Figure 5-3. Final Status Survey Gamma Scanning Data for Training Site 7, Environmental Restoration Program Site OT-10

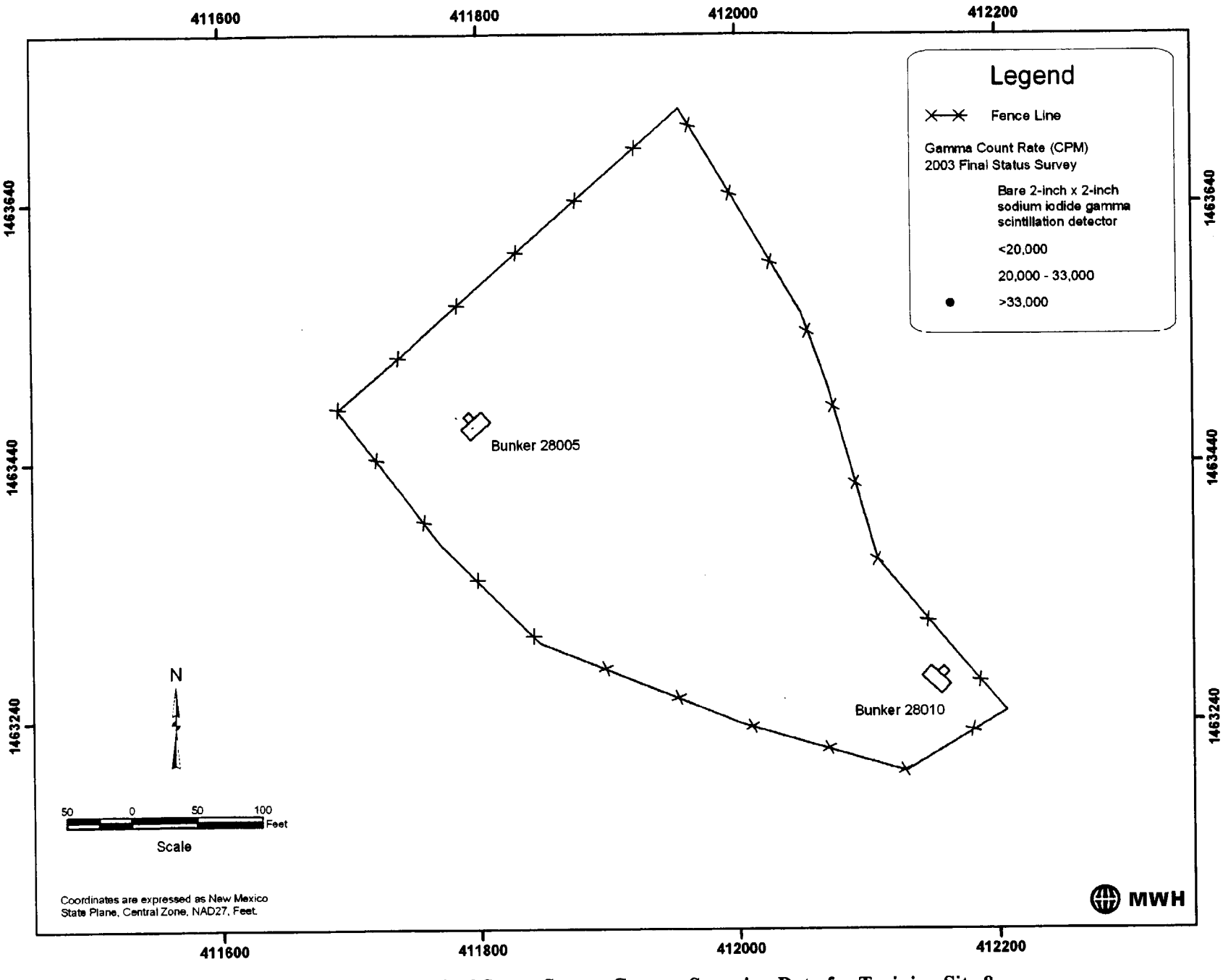

Figure 5-4. Final Status Survey Gamma Scanning Data for Training Site 8, Environmental Restoration Program Site OT-10

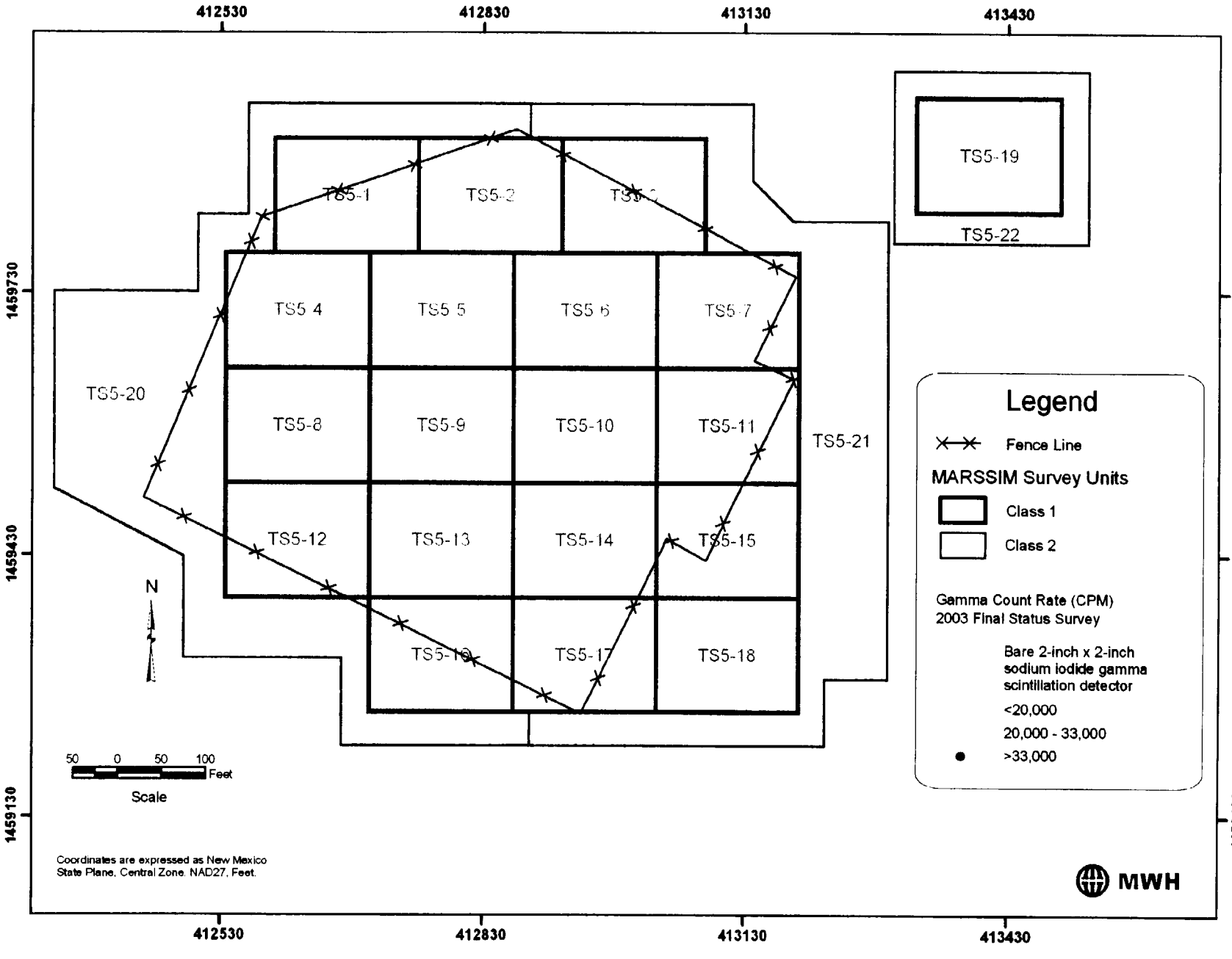

Figure 5-5. Final Status Survey Gamma Scanning Data with MARSSIM Survey Unit Boundaries for Training Site 5, Environmental Restoration Program Site OT-10,

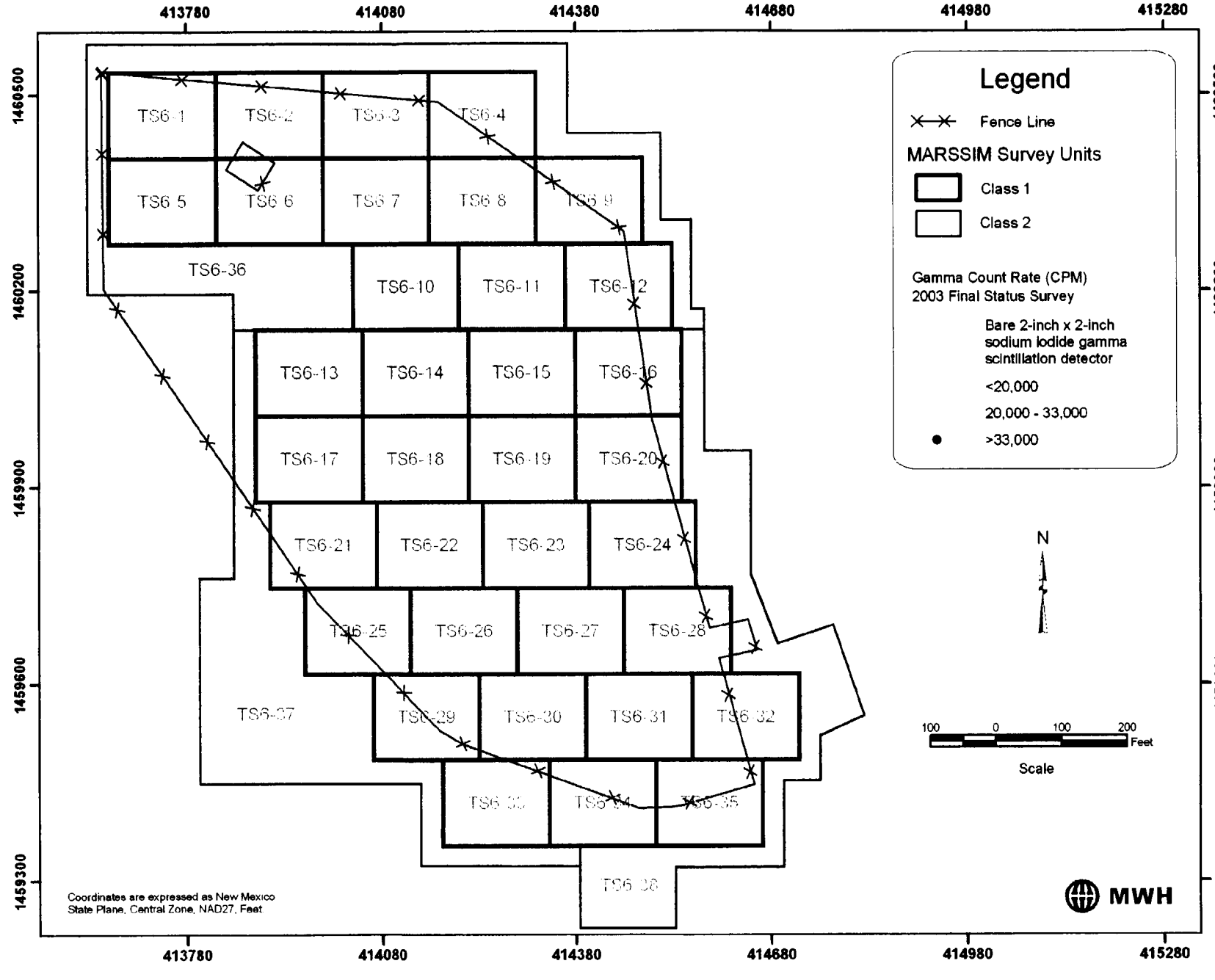

Figure 5-6. Final Status Survey Gamma Scanning Data with MARSSIM Survey Unit Boundaries for Training Site 6, Environmental Restoration Program Site OT-10,

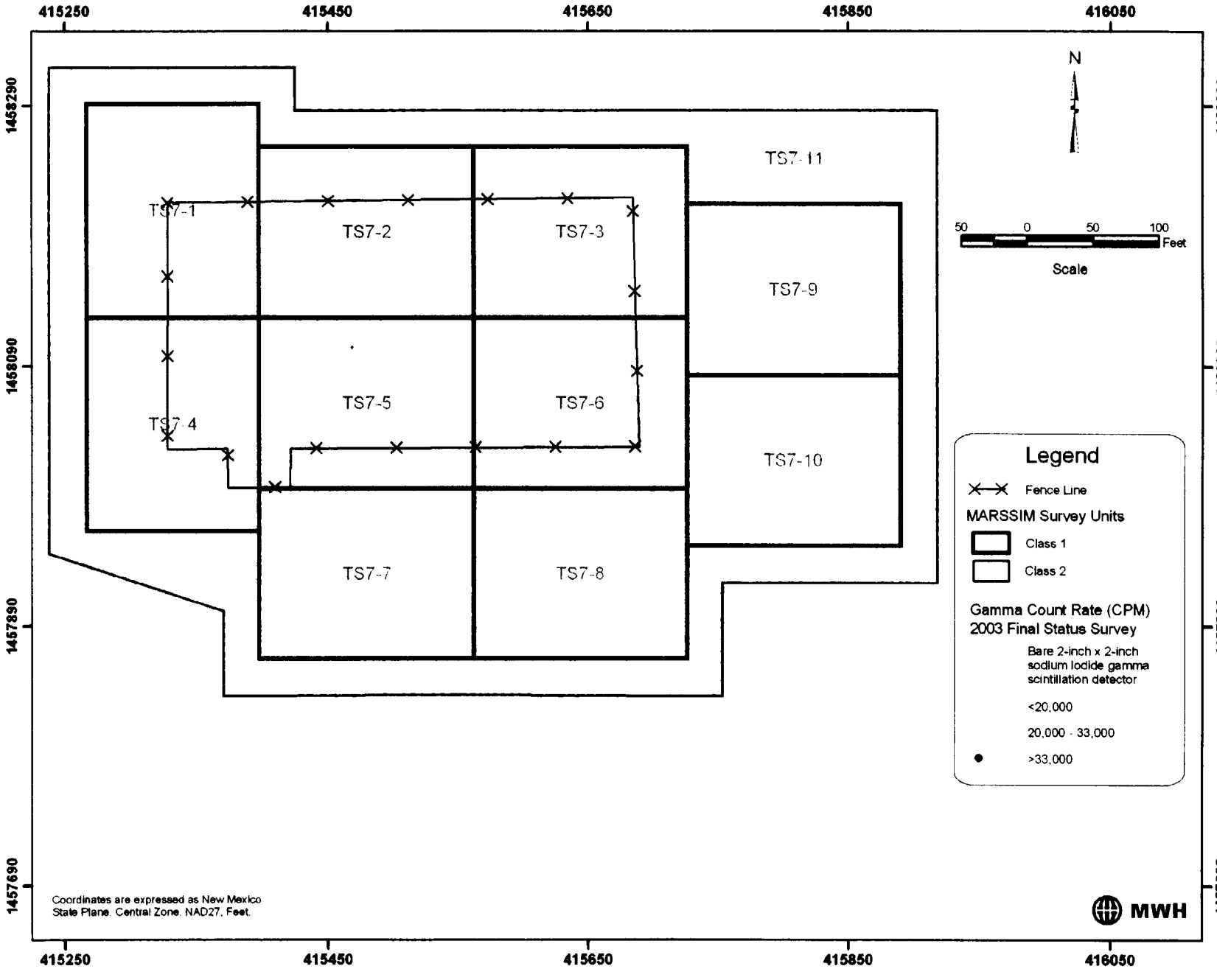

Figure 5-7. Final Status Survey Gamma Scanning Data with MARSSIM Survey Unit Boundaries for Training Site 7, Environmental Restoration Program Site OT-10

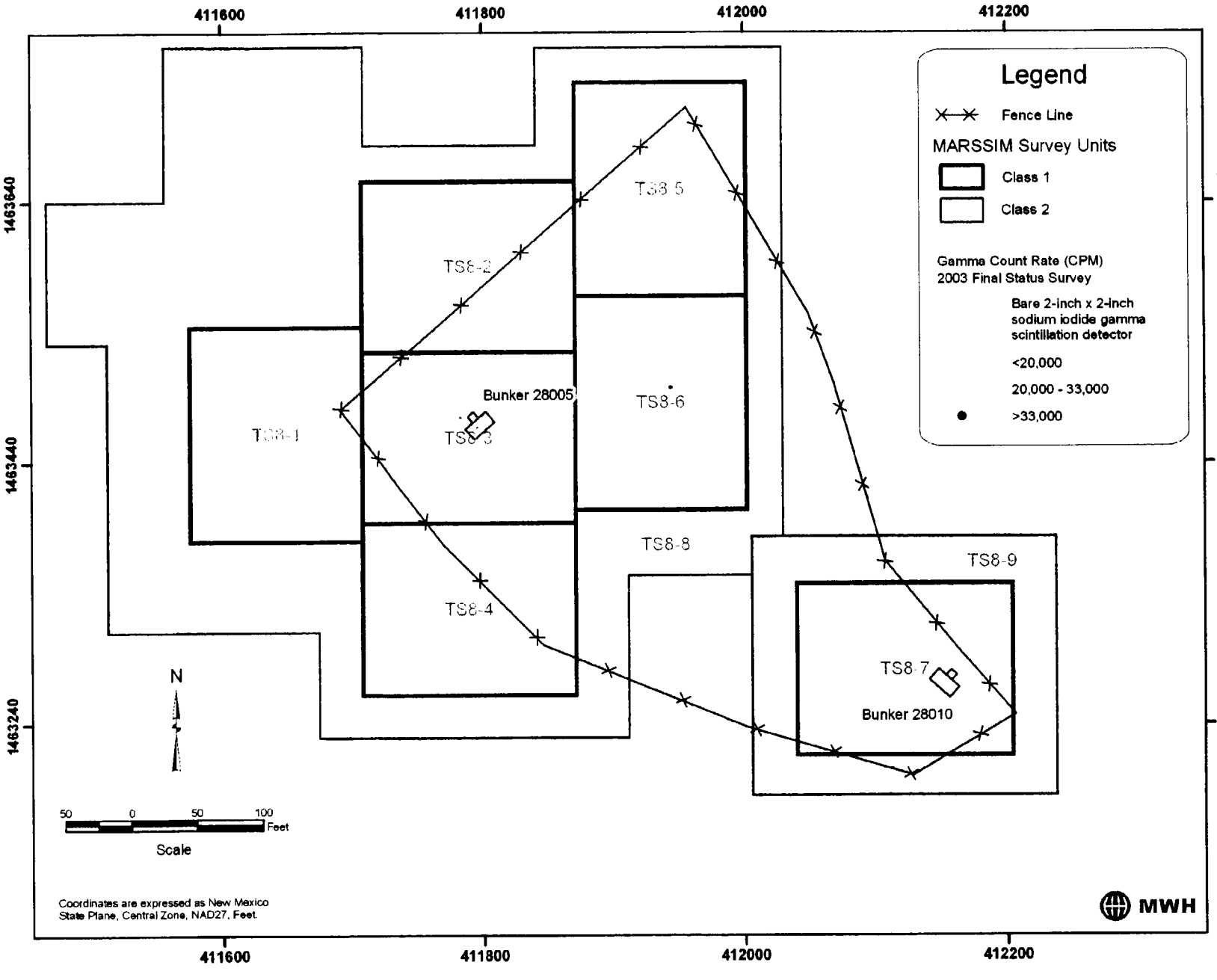

Figure 5-8 Final Status Survey Gamma Scanning Data with MARSSIM Survey Unit Boundaries For Training Site 8, Environmental Restoration Program Site OT-10

Table 5-1. Gamma Scanning Data Summary Statistics for Class 1 Survey Units, Training Site 5, Environmental Restoration Program Site OT-10

Survey Unit	TS5-1	TS5-2	TS5-3	TS5-4	TS5-5	TS5-6	TS5-7	TS5-8	TS5-9	TS5-10
Mean (cpm)	13,950	14,175	13,412	14,998	14,595	15,133	14,745	15,321	14,938	14,433
Median (cpm)	13,630	14,017	13,857	149,04	14,440	15,022	14,586	15,210	14,779	14,303
Number of measurements	3,431	2,876	3,893	2,782	3,518	3,077	2,708	2,340	2,873	3,318
Maximum (cpm)	21,093	20,680	19,540	20,103	22,963	22,546	20,438	20,096	23,543	20,705
Minimum (cpm)	9,973	10,086	8,342	11,581	10,730	11,160	10,671	11,633	10,953	9,978
Standard deviation	1,502	1,411	2,009	1,351	1,476	1,395	1,455	1,441	1,402	1,389

Survey Unit	TS5-11	TS5-12	TS5-13	TS5-14	TS5-15	TS5-16	TS5-17	TS5-18	TS5-19
Mean (cpm)	15,148	14,348	15,054	14,395	14,098	13,311	13,853	12,449	12,931
Median (cpm)	15,013	14,194	14,993	14,193	13,938	13,055	13,690	12,415	12,922
Number of measurements	3,184	2,635	2,404	2,966	2,807	2,822	2,974	2,532	1,914
Maximum (cpm)	20,872	19,093	20,075	21,060	20,580	19,300	19,769	18,123	15,726
Minimum (cpm)	11,251	10,988	10,720	10,802	10,490	10,193	9,646	8,620	10,667
Standard deviation	1,455	1,270	1,326	1,399	1,518	1,364	1,567	901	794

Notes:
cpm = counts per minute
TS = Training Site

Table 5-2. Gamma Scanning Data Summary Statistics for Class 1 Survey Units, Training Site 6, Environmental Restoration Program Site OT-10

Survey Unit	TS6-1	TS6-2	TS6-3	TS6-4	TS6-5	TS6-6	TS6-7	TS6-8
Mean (cpm)	14,296	13,720	12,640	11,080	12,428	13,056	12,702	12,475
Median (cpm)	14,131	13,613	12,287	10,934	12,342	12,871	12,534	12,268
Number of measurements	4,427	3,772	3,958	3,004	3,904	4,609	4,367	3,901
Maximum (cpm)	19,714	21,273	20,480	16,501	17,306	22,107	20,615	19,167
Minimum (cpm)	10,735	9,592	8,641	7,380	9,547	9,184	9,032	8,645
Standard deviation	1,361	1,465	1,843	1,165	948	1,439	1,621	1,346
Survey Unit	**TS6-9**	**TS6-10**	**TS6-11**	**TS6-12**	**TS6-13**	**TS6-14**	**TS6-15**	**TS6-16**
Mean (cpm)	11,502	12,609	13,163	12,616	11885	14,045	14,094	14,054
Median (cpm)	11,399	12,533	13,054	12,643	11814	14,105	13,860	13,894
Number of measurements	2,865	4,370	3,777	3,358	4812	4,344	4,827	3,098
Maximum (cpm)	15,774	20,337	18,659	18,859	16538	19,888	19,983	21,309
Minimum (cpm)	7,700	0	9,720	8,823	8698	9,163	10,343	9,998
Standard deviation	1,236	1,724	1,125	1,333	965	1,894	1,457	1,614
Survey Unit	**TS6-17**	**TS6-18**	**TS6-19**	**TS6-20**	**TS6-21**	**TS6-22**	**TS6-23**	**TS6-24**
Mean (cpm)	13,158	14,809	15,107	15,183	13,552	14,245	14,770	15,618
Median (cpm)	13,027	14,698	14,944	15,149	13,413	14,141	14,631	15,583
Number of measurements	4,544	3,916	4,372	4,179	3,443	3,725	3,881	3,152
Maximum (cpm)	18,643	21,925	22,221	29,010	18,441	20,846	21,141	23,699
Minimum (cpm)	9,338	11,040	11,697	10,359	10,170	10,236	11,351	10,330
Standard deviation	1,181	1,408	1,268	1,578	1,241	1,355	1,225	1,473
Survey Unit	**TS6-25**	**TS6-26**	**TS6-27**	**TS6-28**	**TS6-29**	**TS6-30**	**TS6-31**	**TS6-32**
Mean (cpm)	13,801	14,165	14,896	14,128	13,239	14,343	14,560	12,817
Median (cpm)	13,578	14,040	14,695	13,920	13,046	14,325	14,430	12,483
Number of measurements	4,040	3,756	4,306	3,739	4,917	4,383	3,671	3,465
Maximum (cpm)	21,198	23,742	26,291	21,277	20,273	19,848	19,740	18,434
Minimum (cpm)	9,917	9,694	11,630	10,717	9,554	9,804	11,653	8,668
Standard deviation	1,673	1,622	1,464	1,316	1,534	1,514	1,201	1,733
Survey Unit	**TS6-33**	**TS6-34**	**TS6-35**					
Mean (cpm)	12,718	14,408	13,252					
Median (cpm)	12,441	14,228	13,141					
Number of measurements	4,379	3,674	3,595					
Maximum (cpm)	19,500	20,106	20,309					
Minimum (cpm)	8,937	10,287	9,402					
Standard deviation	1,574	1,553	1,096					

Notes:
cpm = counts per minute
TS = Training Site

Table 5-3. Gamma Scanning Data Summary Statistics for Class 1 Survey Units, Training Site 7, Environmental Restoration Program Site OT-10

Survey Unit	TS7-1	TS7-2	TS7-3	TS7-4	TS7-5
Mean (cpm)	12,958	13,603	13,076	14,078	12,903
Median (cpm)	12,700	13,394	12,965	13,956	12,734
Number of measurements	5,412	4,997	5,274	4,764	5,014
Maximum (cpm)	19,261	21,792	19,711	19,256	18,983
Minimum (cpm)	9,843	9,697	9,188	10,150	9,570
Standard deviation	1,459	1,618	1,478	1,263	1,349
Survey Unit	**TS7-6**	**TS7-7**	**TS7-8**	**TS7-9**	**TS7-10**
Mean (cpm)	12,226	12,489	12,171	13,245	12,821
Median (cpm)	12,072	12,333	12,077	13,030	12,570
Number of measurements	4,846	3,962	4,606	4,875	5,452
Maximum (cpm)	18,444	17,600	17,674	19,815	18,748
Minimum (cpm)	8,581	9,587	9,250	9,425	9,524
Standard deviation	1,211	981	1,020	1,670	1,459

Notes:
cpm = counts per minute
TS = Training Site

Table 5-4. Gamma Scanning Data Summary Statistics for Class 1 Survey Units, Training Site 8, Environmental Restoration Program Site OT-10

Survey Unit	TS8-1	TS8-2	TS8-3	TS8-4	TS8-5	TS8-6	TS8-7
Mean (cpm)	13,621	13,141	14,429	13,271	13,346	12,809	12,725
Median (cpm)	13,525	13,105	13,956	13,254	13,241	12,802	12,698
Number of measurements	5,852	3,338	3,619	4,892	4,263	4,585	5,397
Maximum (cpm)	18,853	19,696	36,685	17,789	18,541	16,931	19,417
Minimum (cpm)	10,274	7,191	10,660	10,627	8,452	9,902	7,954
Standard deviation	1,041	1,287	2,264	836	1,133	1,114	922

Notes:
cpm =counts per minute
TS = Training Site

Table 5-5. Gamma Scanning Data Summary Statistics for Class 2 Survey Units, Training Site 5, Environmental Restoration Program Site OT-10

Survey Unit	TS5-20	TS5-21	TS5-22
Mean (cpm)	13,387	13,430	12,956
Median (cpm)	13,252	13,433	12,960
Number of measurements	11,920	11,722	2,910
Maximum (cpm)	19,726	17,385	15,527
Minimum (cpm)	9,742	10,043	10,220
Standard deviation	1,124	894	661

Notes:
cpm = counts per minute
TS = Training Site

Table 5-6. Gamma Scanning Data Summary Statistics for Class 2 Survey Units, Training Site 6, Environmental Restoration Program Site OT-10

Survey Unit	TS6-36	TS6-37	TS6-38
Mean (cpm)	11,219	12,713	12,502
Median (cpm)	11,206	12,687	12,374
Number of measurements	17,485	16,136	12,413
Maximum (cpm)	16,388	18,660	21,144
Minimum (cpm)	7,391	8,126	7,745
Standard deviation	1,114	1,203	1,359

Notes:
cpm = counts per minute
TS = Training Site

Table 5-7. Gamma Scanning Data Summary Statistics for Class 2 Survey Units, Training Site 7, Environmental Restoration Program Site OT-10

Survey Unit	TS7-11
Mean (cpm)	13,008
Median (cpm)	12,870
Number of measurements	12,493
Maximum (cpm)	19,684
Minimum (cpm)	9113
Standard deviation	1,241

Notes:
cpm = counts per minute
TS = Training Site

Table 5-8. Gamma Scanning Data Summary Statistics for Class 2 Survey Units, Training Site 8, Environmental Restoration Program Site OT-10

Survey Unit	TS8-8	TS8-9
Mean (cpm)	12,749	12,668
Median (cpm)	12,728	12,647
Number of measurements	12,493	12,493
Maximum (cpm)	16,299	17,599
Minimum (cpm)	9,476	9,581
Standard deviation	943	939

Notes:
cpm = counts per minute
TS = Training Site

The number of final status survey soil samples required from each Class 1 survey unit was based on statistical analysis of the gamma scanning survey data. The method used for the calculations was discussed in Section 4.5 of this report. Tables 5-9 through 5-12 present the values used in the sample number calculation for each Class 1 survey unit. The pooled standard deviation for 70 of the 71 Class 1 survey units was below the thorium-232 background concentration of 0.91 pCi/g. This low standard deviation required that the shift (Δ) be adjusted downward to achieve a relative shift (Δ/σ) between 1 and 3. The relative shift values were rounded down to a value included in MARSSIM Table 5.1 (EPA, 1997).

5.1.2 Static Gamma Radiation Measurements

Static gamma radiation-measurements were taken at each soil sample location prior to sample collection. Seven hundred thirteen static radiation measurements were taken in Class 1 survey units: 190 at TS5, 350 at TS6, 100 at TS7, and 73 at TS8. Static gamma radiation measurements were also taken at 113 points in Class 2 survey units. The static gamma locations at each site and their respective measurements are presented on Figures 5-9 through 5-12. Tables 5-13 through 5-16 present the summary statistics for each survey unit. The static gamma measurements are presented in Appendix A.

Table 5-9. Sample Number Calculations for Training Site 5, Environmental Restoration Program Site OT-10

Training Site Number:	Training Site 5																	
MARSSIM Survey Unit	TS5-1		TS5-2		TS5-3		TS5-4		TS5-5		TS5-6		TS5-7		TS5-8		TS5-9	
		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$
α	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645
β	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645
Δ	1.84		1.84		2.28		1.84		1.84		1.84		1.84		1.84		1.84	
Number of Data Points <18750 (m)	3416		2867		3889		2762		3486		3043		2688		2321		2846	
Standard Deviation for Data <18750 (s_1)	0.588		0.555		0.805		0.525		0.563		0.532		0.564		0.563		0.532	
Number of Data Points > 18750 (n)	15		9		4		20		32		34		20		19		27	
Standard Deviation for Data > 18750 (s_2)	1.17		1.20		0.42		0.70		1.52		1.29		0.90		0.61		2.20	
Pooled Standard Deviation (σ)	0.59		0.56		0.80		0.53		0.58		0.55		0.57		0.56		0.57	
Δ/σ	3		3		2.75		3		3		3		3		3		3	
P_r	0.983039		0.983039		0.974067		0.983039		0.983039		0.983039		0.983039		0.983039		0.983039	
N		15.46344		15.46344		16.05429		15.46344		15.46344		15.46344		15.46344		15.46344		15.46344
N with 20% safety factor:		19		19		20		19		19		19		19		19		19
N/2		10		10		10		10		10		10		10		10		10

Training Site Number:	Training Site 5																	
MARSSIM Survey Unit	TS5-10		TS5-11		TS5-12		TS5-13		TS5-14		TS5-15		TS5-16		TS5-17		TS5-18		TS5-19	
		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$
α	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645
β	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645
Δ	1.84		1.84		1.43		1.43		1.84		1.84		1.84		1.84		1.14		0.95	
Number of Data Points <18750 (m)	3298		3136		2632		2388		2947		2793		2820		2982		2532		1914	
Standard Deviation for Data <18750 (s_1)	0.537		0.55		0.507		0.518		0.541		0.592		0.545		0.617		0.362		0.319	
Number of Data Points > 18750 (n)	20		48		3		16		19		14		2		12		0		0	
Standard Deviation for Data > 18750 (s_2)	0.94		0.95		0.23		0.55		0.98		0.95		0.33		0.46		0.46		0.46	
Pooled Standard Deviation (σ)	0.54		0.56		0.51		0.52		0.54		0.59		0.54		0.62		0.36		0.32	
Δ/σ	3		3		2.75		2.75		3		3		3		2.75		3		2.75	
P_r	0.983039		0.983039		0.974067		0.974067		0.983039		0.983039		0.983039		0.974067		0.983039		0.974067	
N		15.46344		15.46344		16.05429		16.05429		15.46344		15.46344		15.463441		16.05429		15.46344		16.05429
N with 20% safety factor:		19		19		20		20		19		19		19		20		20		19
N/2		10		10		10		10		10		10		10		10		10		10

Notes:
MARSSIM = Multi-Agency Radiation Survey and Site Investigation Manual (EPA 2000)

Table 5-10. Sample Number Calculations for Training Site 6, Environmental Restoration Program Site OT-10

Training Site Number:	Training Site 6																	
MARSSIM Survey Unit	TS6-1		TS6-2		TS6-3		TS6-4		TS6-5		TS6-6		TS6-7		TS6-8		TS6-9	
		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$
α	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645
β	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645
Δ	1.66		1.9		2.375		1.425		1.14		1.9		1.9		1.66		1.425	
Number of Data Points <18750 (m)	4411		3756		3948		3004		3904		4596		4352		3899		2865	
Standard Deviation for Data <18750 (s1)	0.536		0.568		0.73		0.468		0.381		0.559		0.633		0.538		0.497	
Number of Data Points > 18750 (n)	16		16		10		0		0		13		15		2		0	
Standard Deviation for Data > 18750 (s2)	0.55		1.14		0.92		0.46		0.46		1.83		1.01		0.04		0.46	
Pooled Standard Deviation (σ)	0.54		0.57		0.73		0.47		0.38		0.57		0.63		0.54		0.50	
Δ/σ	3		3		3		3		2.75		3		2.75		3		2.75	
P_r	0.983039		0.983039		0.983039		0.983039		0.974067		0.983039		0.974067		0.983039		0.974067	
N		15.46344		15.46344		15.46344		15.46344		16.05429		15.46344		16.05429		15.46344		16.05429
N with 20% safety factor:		19		19		19		19		20		19		20		19		20
N/2		10		10		10		10		10		10		10		10		10

Training Site Number:	Training Site 5																	
MARSSIM Survey Unit	TS6-10		TS6-11		TS6-12		TS6-13		TS6-14		TS6-15		TS6-16		TS6-17		TS6-18	
		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$
α	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645
β	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1 645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645
Δ	1.9		1.425		1.66		1.14		2.375		1.9		1.9		1.425		1.9	
Number of Data Points <18750 (m)	4355		3777		3357		4812		4320		4795		3065		4544		3884	
Standard Deviation for Data <18750 (s1)	0.643		0.452		0.534		0.388		0.748		0.564		0.612		0.475		0.541	
Number of Data Points > 18750 (n)	5		0		1		0		24		32		33		0		32	
Standard Deviation for Data > 18750 (s2)	0.81		0.46		0.46		0.46		0.52		0.57		0.93		0.46		1.47	
Pooled Standard Deviation (σ)	0.64		0.45		0.53		0.39		0.75		0.56		0.62		0.48		0.55	
Δ/σ	2.75		3		3		2.75		3		3		3		2.75		3	
P_r	0.974067		0.983039		0.983039		0.974067		0.983039		0.983039		0.983039		0.974067		0.983039	
N		16.05429		15.46344		15.46344		16.05429		15.46344		15.46344		15.46344		16.05429		15.46344
N with 20% safety factor:		20		19		19		20		19		19		19		20		19
N/2		10		10		10		10		10		10		10		10		10

Notes:
MARSSIM = Multi-Agency Radiation Survey and Site Investigation Manual (EPA 2000)

Table 5-10. Sample Number Calculations for Training Site 6, Environmental Restoration Program Site OT-10 (concluded)

Training Site Number:	Training Site 6																	
MARSSIM Survey Unit	TS6-19		TS6-20		TS6-21		TS6-22		TS6-23		TS6-24		TS6-25		TS6-26		TS6-27	
		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$
α	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645
β	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645
Δ	1.425		1.9		1.425		1.66		1.425		1.9		1.9		1.9		1.9	
Number of Data Points <18750 (m)	4336		4122		3443		3704		3857		3080		4010		3730		4229	
Standard Deviation for Data <18750 (s1)	0.486		0.599		0.499		0.524		0.47		0.552		0.646		0.616		0.526	
Number of Data Points > 18750 (n)	36		57		0		21		24		72		30		26		77	
Standard Deviation for Data > 18750 (s2)	1.21		2.42		0.46		0.86		1.10		1.27		1.03		2.57		1.84	
Pooled Standard Deviation (σ)	0.50		0.66		0.50		0.53		0.48		0.58		0.65		0.65		0.58	
Δ/σ	2.75		2.75		2.75		3		2.75		3		2.75		2.75		3	
P_r	0.974067		0.974067		0.974067		0.983039		0.974067		0.983039		0.974067		0.974067		0.983039	
N		16.05429		16.05429		16.05429		15.46344		16.05429		15.46344		16.05429		16.05429		15.46344
N with 20% safety factor:		20		20		20		19		20		19		20		20		19
N/2		10		10		10		10		10		10		10		10		10

Training Site Number:	Training Site 6															
MARSSIM Survey Unit	TS6-28		TS6-29		TS6-30		TS6-31		TS6-32		TS6-33		TS6-34		TS6-35	
		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$
α	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645
β	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645
Δ	1.425		1.9		1.9		1.425		2.375		1.9		1.9		1.425	
Number of Data Points <18750 (m)	3717		4905		4369		3653		3465		4376		3639		3592	
Standard Deviation for Data <18750 (s1)	0.505		0.605		0.6		0.466		0.697		0.63		0.598		0.435	
Number of Data Points > 18750 (n)	22		12		14		18		0		3		35		3	
Standard Deviation for Data > 18750 (s2)	1.01		0.75		0.55		0.61		0.46		0.64		0.59		1.04	
Pooled Standard Deviation (σ)	0.51		0.61		0.60		0.47		0.70		0.63		0.60		0.44	
Δ/σ	2.75		3		3		3		3		3		3		3	
P_r	0.974067		0.983039		0.983039		0.983039		0.983039		0.983039		0.983039		0.983039	
N		16.05429		15.46344		15.46344		15.46344		15.46344		15.46344		15.46344		15.46344
N with 20% safety factor:		20		19		19		19		19		19		19		19
N/2		10		10		10		10		10		10		10		10

Notes:
MARSSIM = Multi-Agency Radiation Survey and Site Investigation Manual (EPA 2000)

Table 5-11. Sample Number Calculations for Training Site 7, Environmental Restoration Program Site OT-10

Training Site Number:	Training Site 7																			
MARSSIM Survey Unit	TS7-1		TS7-2		TS7-3		TS7-4		TS7-5		TS7-6		TS7-7		TS7-8		TS7-9		TS7-10	
		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$
α	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645
β	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645
Δ	1.84		1.84		1.84		1.5		1.84		1.47		1.17		1.23		1.84		1.84	
Number of Data Points <18750 (m)	5410		4982		5271		4758		5012		4846		3962		4606		4869		4869	
Standard Deviation for Data <18750 (s1)	0.585		0.638		0.592		0.504		0.541		0.487		0.395		0.41		0.667		0.536	
Number of Data Points > 18750 (n)	2		15		3		6		2		0		0		0		6		0	
Standard Deviation for Data > 18750 (s2)	0.46		1.46		0.77		0.30		0.08		0.46		0.46		0.46		0.61		0.46	
Pooled Standard Deviation (σ)	0.58		0.64		0.59		0.50		0.54		0.49		0.39		0.41		0.67		0.54	
Δ/σ	3		2.75		3		3		3		3		3		3		2.75		3	
P_r	0.983039		0.974067		0.983039		0.983039		0.983039		0.983039		0.983039				0.974067		0.983039	
N		15.46344		16.05429		15.46344		15.46344		15.46344		15.46344		15.46344		15.46344		16.05429		15.46344
N with 20% safety factor:		19		20		19		19		19		19		19		19		20		19
N/2		10		10		10		10		10		10		10		10		10		10

Notes:
MARSSIM = Multi-Agency Radiation Survey and Site Investigation Manual (EPA 2000)

Table 5-12. Sample Number Calculations for TS8, Environmental Restoration Program Site OT-10

Training Site Number:	Training Site 8													
MARSSIM Survey Unit	TS8-1		TS8-2		TS8-3		TS8-4		TS8-5		TS8-6		TS8-7	
		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$		$Z_{1-\alpha/\beta}$
α	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645
β	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645	0.05	1.645
Δ	1.425		1.425		2.85		1.14		1.425		1.425		1.14	
Number of Data Points <18750 (m)	5851		3335		3466		4892		4263		4585		5396	
Standard Deviation for Data <18750 (s1)	0.418		0.513		0.492		0.336		0.456		0.448		0.369	
Number of Data Points > 18750 (n)	1		3		153		0		0		0		1	
Standard Deviation for Data > 18750 (s2)	0.46		0.76		6.78		0.46		0.46		0.46		0.46	
Pooled Standard Deviation (σ)	0.418		0.51		1.47		0.34		0.46		0.45		0.37	
Δ/σ	3		2.75		1.9		3		3		3		3	
P_r	0.983039		0.974067		0.910413		0.983039		0.983039		0.983039		0.983039	
N		15.46344		16.05429		21.42044		15.46344		15.46344		15.46344		15.46344
N with 20% safety factor:		19		20		26		19		19		19		19
N/2		10		10		13		10		10		10		10

Notes:
MARSSIM = Multi-Agency Radiation Survey and Site Investigation Manual (EPA 2000)

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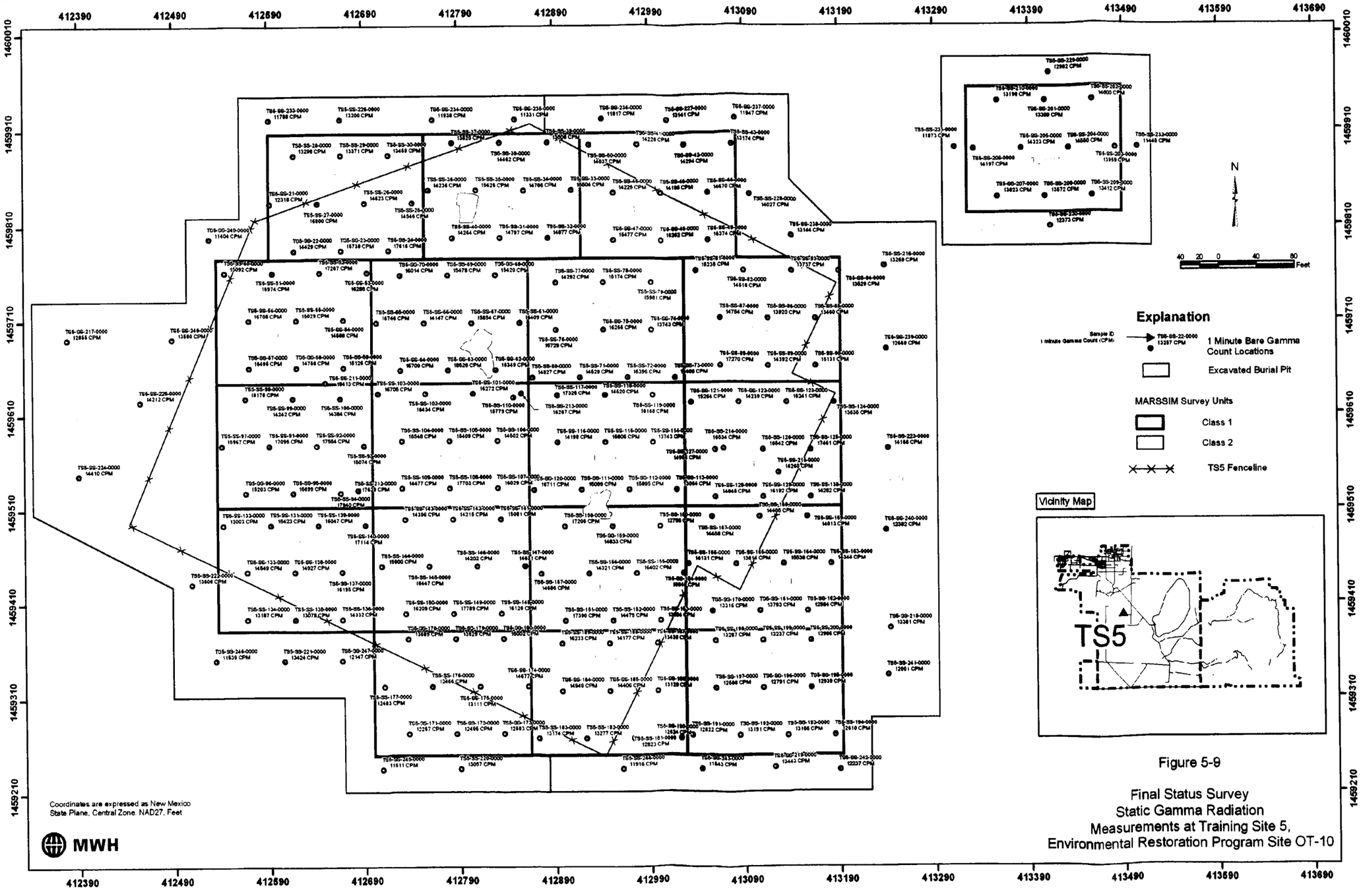

Figure 5-9

Final Status Survey
Static Gamma Radiation
Measurements at Training Site 5,
Environmental Restoration Program Site OT-10

Figure 5-9. Final Status Survey Static Gamma Radiation Measurements at Training Site 5, Environmental Restoration Program Site OT-10

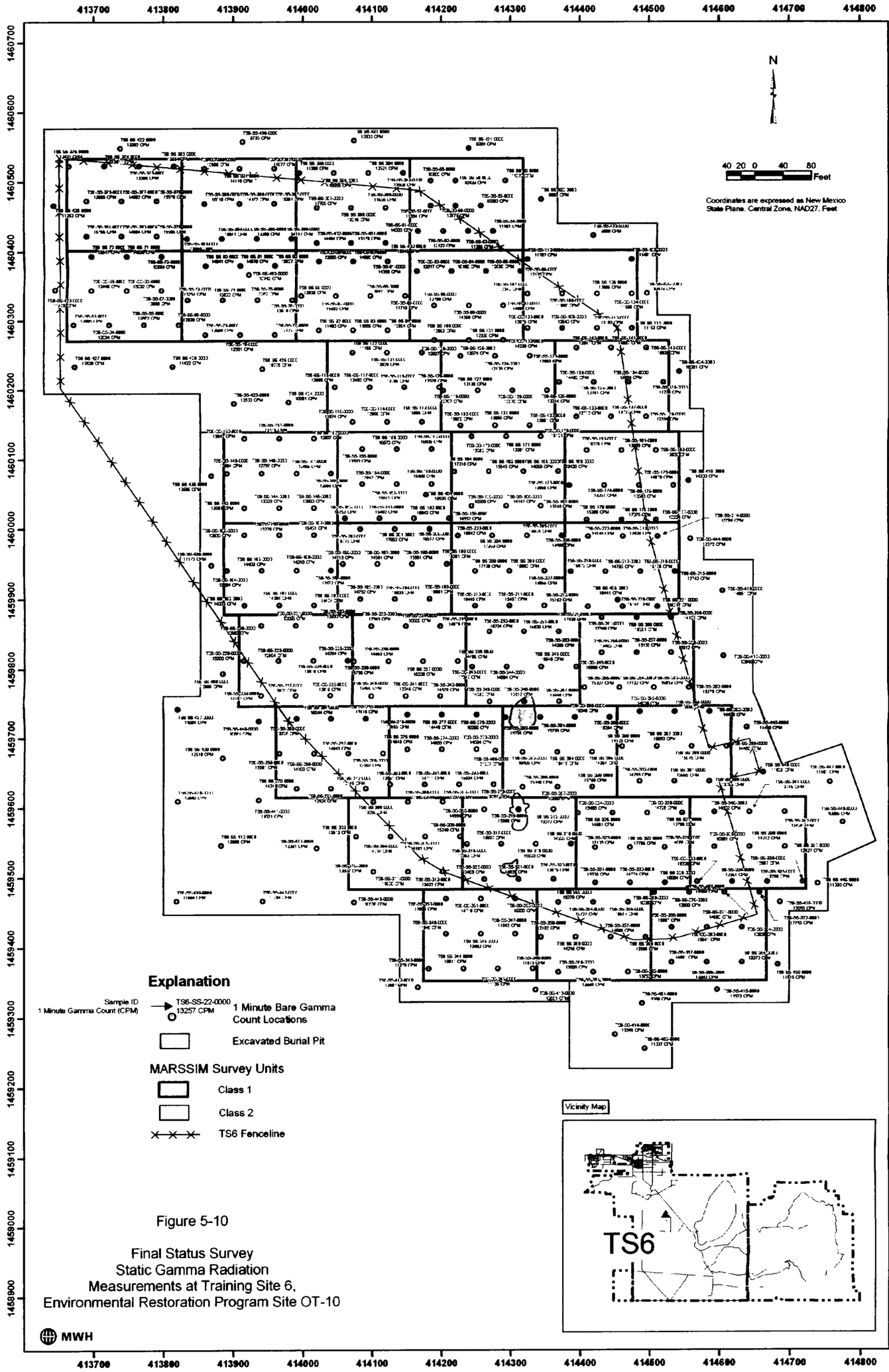

Figure 5-10. Final Status Survey Static Gamma Radiation Measurements at Training Site 6, Environmental Restoration Program Site OT-10

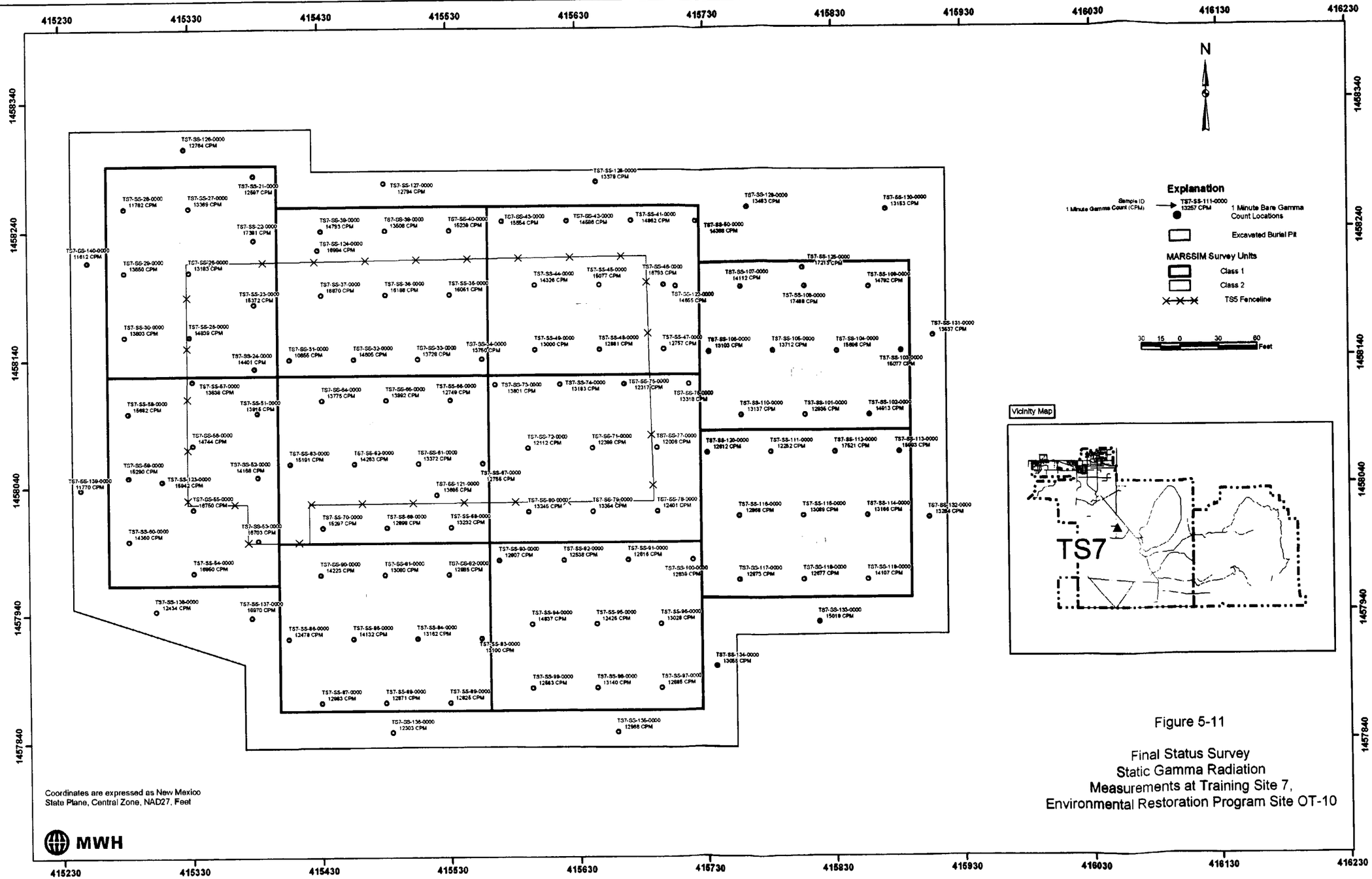

Figure 5-11

Final Status Survey
Static Gamma Radiation
Measurements at Training Site 7,
Environmental Restoration Program Site OT-10

Figure 5-11. Final Status Survey Static Gamma Radiation Measurements at Training Site 7, Environmental Restoration Program Site OT-10

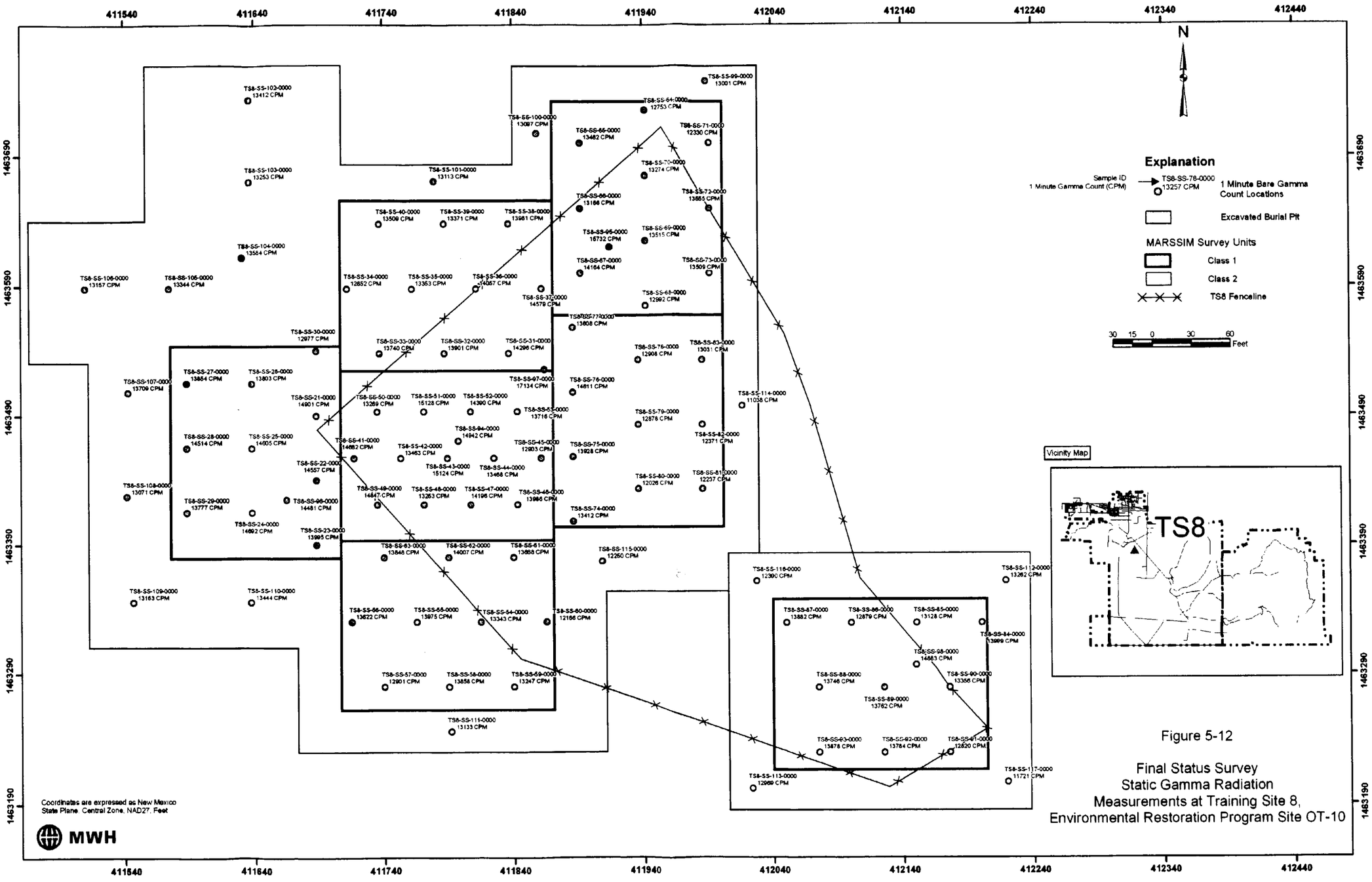

Figure 5-12

Final Status Survey
Static Gamma Radiation
Measurements at Training Site 8,
Environmental Restoration Program Site OT-10

Figure 5-12. Final Status Survey Static Gamma Radiation Measurements at Training Site 8, Environmental Restoration Program Site OT-10

Table 5-13. Static Gamma Measurement Summary Statistics for Training Site 5, Environmental Restoration Program Site OT-10.

Survey Unit	TS5-1	TS5-2	TS5-3	TS5-4	TS5-5	TS5-6
Mean (cpm)	14,620	14,596	14,593	15,732	16,065	15,139
Median (cpm)	14,488	14,614	14,261	15,550	15,934	15,001
Number of measurements	10	10	10	10	10	10
Maximum (cpm)	17,616	15,625	16,262	17,267	18,526	16,396
Minimum (cpm)	12,318	13,506	13,174	14,588	14,147	13,743
Standard deviation	1,666	679	884	930	1,122	911
Survey Unit	**TS5-7**	**TS5-8**	**TS5-9**	**TS5-10**	**TS5-11**	**TS5-12**
Mean (cpm)	14,594	16,133	15,986	15,252	15,186	14,786
Median (cpm)	14,454	15,833	16,151	15,447	15,099	14,738
Number of measurements	10	10	10	10	10	10
Maximum (cpm)	17,270	18,175	17,703	17,325	17,461	17,114
Minimum (cpm)	13,460	14,242	14,477	13,064	13,635	13,003
Standard deviation	1,132	1,461	996	1,363	1,225	1,427
Survey Unit	**TS5-13**	**TS5-14**	**TS5-15**	**TS5-16**	**TS5-17**	**TS5-18**
Mean (cpm)	15,500	15,152	14,219	13,239	13,823	12,962
Median (cpm)	15,491	14,760	14,179	12,847	13,358	12,963
Number of measurements	10	10	10	10	10	10
Maximum (cpm)	17,789	17,390	16,131	15,002	16,233	13,287
Minimum (cpm)	14,202	12,756	12,584	12,257	12,624	12,588
Standard deviation	1,187	1,523	1,032	981	1,122	256
Survey Unit	**TS5-19**	**TS5-20**	**TS5-21**	**TS5-22**		
Mean (cpm)	13,903	12,667	12,732	12,148		
Median (cpm)	13,891	12,855	12,559	12,123		
Number of measurements	10	15	15	4		
Maximum (cpm)	14,600	14,410	14,166	12,902		
Minimum (cpm)	13,198	11,331	11,543	11,445		
Standard deviation	503	1,061	835	630		

Notes:
cpm = counts per minute
TS = Training Site

Table 5-14. Static Gamma Measurement Summary Statistics for Training Site 6, Environmental Restoration Program Site OT-10.

Survey Unit	TS6-1	TS6-2	TS6-3	TS6-4	TS6-5	TS6-6
Mean (cpm)	14,242	14,051	13,603	11,456	13,153	13,356
Median (cpm)	13,998	14,114	12,527	11,263	12,947	13,268
Number of measurements	10	10	10	10	10	10
Maximum (cpm)	15,765	15,351	19,345	14,388	14,836	14,641
Minimum (cpm)	12,431	11,877	10,521	10,080	12,449	12,172
Standard deviation	1,118	954	3,030	1,200	751	827
Survey Unit	**TS6-7**	**TS6-8**	**TS6-9**	**TS6-10**	**TS6-11**	**TS6-12**
Mean (cpm)	13,496	13,369	11,906	13,065	13,458	12,728
Median (cpm)	13,270	12,732	11,777	12,918	13,325	12,727
Number of measurements	10	10	10	10	10	10
Maximum (cpm)	15,860	15,190	13,103	15,685	15,650	14,697
Minimum (cpm)	11,480	12,195	10,995	11,188	12,109	10,930
Standard deviation	1,718	1,161	727	1,206	963	1,282
Survey Unit	**TS6-13**	**TS6-14**	**TS6-15**	**TS6-16**	**TS6-17**	**TS6-18**
Mean (cpm)	12,894	15,380	14,649	14,638	14,527	16,032
Median (cpm)	12,823	15,434	14,103	14,033	14,359	15,847
Number of measurements	10	10	10	10	10	10
Maximum (cpm)	13,583	16,843	17,216	17,075	16,229	18,517
Minimum (cpm)	12,007	13,693	13,282	12,620	13,394	14,581
Standard deviation	487	1,092	1,402	1,489	820	1,359
Survey Unit	**TS6-19**	**TS6-20**	**TS6-21**	**TS6-22**	**TS6-23**	**TS6-24**
Mean (cpm)	16,134	15,484	13,745	14,718	16,005	16,266
Median (cpm)	15,852	15,181	13,786	14,666	16,077	16,083
Number of measurements	10	10	10	10	10	10
Maximum (cpm)	17,958	18,196	14,254	17,849	18,446	18,278
Minimum (cpm)	14,899	12,743	12,954	12,345	14,285	14,127
Standard deviation	1,123	1,730	394	1,433	1,347	1,269

Table 5-14. Static Gamma Measurement Summary Statistics for Training Site 6, Environmental Restoration Program Site OT-10 (concluded)

Survey Unit	TS6-25	TS6-26	TS6-27	TS6-28	TS6-29	TS6-30
Mean (cpm)	13,488	14,623	15,958	14,186	13,415	14,140
Median (cpm)	13,262	14,677	15,779	14,076	13,473	14,174
Number of measurements	10	10	10	10	10	10
Maximum (cpm)	15,044	16,285	18,415	15,075	15,248	15,523
Minimum (cpm)	12,148	12,653	14,364	13,783	11,839	12,393
Standard deviation	953	1,162	1,047	391	1,121	1,140

Survey Unit	TS6-31	TS6-32	TS6-33	TS6-34	TS6-35	TS6-36
Mean (cpm)	14,860	13,890	12,362	14,204	13,982	10,640
Median (cpm)	14,615	13,588	11,877	13,818	13,880	10,500
Number of measurements	10	10	10	10	10	15
Maximum (cpm)	17,765	16,230	15,235	18,957	15,383	13,302
Minimum (cpm)	13,305	12,351	10,811	12,192	12,763	8,364
Standard deviation	1,481	1,318	1,570	1,875	769	1,131

Survey Unit	TS6-37	TS6-38
Mean (cpm)	11,811	12,488
Median (cpm)	11,784	12,069
Number of measurements	15	15
Maximum (cpm)	13,606	14,209
Minimum (cpm)	10,539	10,995
Standard deviation	918	1,062

Notes:
cpm = counts per minute
TS = Training Site

Table 5-15. Static Gamma Measurement Summary Statistics for Training Site 7, Environmental Restoration Program Site OT-10.

Survey Unit	TS7-1	TS7-2	TS7-3	TS7-4	TS7-5	TS7-6
Mean (cpm)	14,036	14,559	14,420	15,220	13,752	12,814
Median (cpm)	13,727	14,699	14,477	15,017	13,574	12,792
Number of measurements	10	10	10	10	10	10
Maximum (cpm)	17,381	16,870	16,793	16,950	15,297	13,801
Minimum (cpm)	11,762	10,855	12,757	13,638	12,749	12,008
Standard deviation	1,577	1,729	1,279	1,249	938	630

Survey Unit	TS7-7	TS7-8	TS7-9	TS7-10	TS7-11
Mean (cpm)	13,174	12,968	14,497	13,714	13,235
Median (cpm)	13,032	12,823	14,452	12,971	13,055
Number of measurements	10	10	10	10	15
Maximum (cpm)	14,223	14,837	17,488	17,521	16,970
Minimum (cpm)	12,478	12,425	12,935	12,252	11,612
Standard deviation	563	695	1,413	1,713	1,313

Notes:
cpm = counts per minute
TS = Training Site

Table 5-16. Static Gamma Measurement Summary Statistics Training Site 8, Environmental Restoration Program Site OT-10

Survey Unit	TS8-1	TS8-2	TS8-3	TS8-4	TS8-5	TS8-6
Mean (cpm)	14,168	13,764	14,034	13,464	13,274	13,101
Median (cpm)	14,255	13,821	13,986	13,645	13,378	12,970
Number of measurements	10	10	13	10	10	10
Maximum (cpm)	14,901	14,579	15,128	14,007	14,164	14,611
Minimum (cpm)	12,977	12,852	12,903	12,166	12,330	12,026
Standard deviation	588	508	753	576	503	806

Survey Unit	TS8-7	TS8-8	TS8-9
Mean (cpm)	13523	13,061	12,551
Median (cpm)	13,574	13,157	12,610
Number of measurements	10	15	4
Maximum (cpm)	13,999	13,709	13,262
Minimum (cpm)	1,2820	11,038	11,721
Standard deviation	441	636	698

Notes:
cpm = counts per minute
TS = Training Site

The mean and median of the static gamma measurements for each survey unit were below the 20,000-cpm investigation level.

5.1.3 Soil Sample Results

Eight hundred fifty nine soil samples were collected during the final status surveys, including 713 randomly located final status survey samples, 71 replicate samples, and 75 samples collected from excavation pit areas on TS5 and TS6. The numbers of soil samples collected in Class 1 survey units by site were 256 samples from TS5, 413 samples from TS6, 110 samples from TS7, and 80 samples from TS8. No soil samples were collected at the 113 static gamma radiation measurement locations in Class 2 survey units.

The soil sample locations at each site and their respective thorium-232 concentrations are shown on Figures 5-13 through 5-16. Summary statistics of the training site-sample results are presented in Tables 5-17 through 5-20. Histograms for thorium-232 soil concentration data at each site are presented in Figures 5-17 through 5-20.

The complete soil sample analytical results are presented in Appendix B. The data validation report for the analytical data is presented in Appendix C.

The mean and median thorium-232 soil concentrations in all survey units are below the $DCGL_w$ plus background of 6.61 pCi/g. Only 1 out of the 859 soil samples, TS6-SS-379-0000, had a thorium-232 concentration above the $DCGL_w$ plus background. The release criteria for this location was satisfied by using the EMC and unity rule analyses as presented in sections 5.3.2 and 5.3.3.

Out of 859 soil samples, three sample analyses (TS6-SS-379, TS6-SS-383, and TS6-SS-97) reported thorium-234 concentrations significantly higher than expected. Severn Trent Laboratories reevaluated the spectra from the three samples and determined that interference from the thorium-232 decay series introduced these anomalies.

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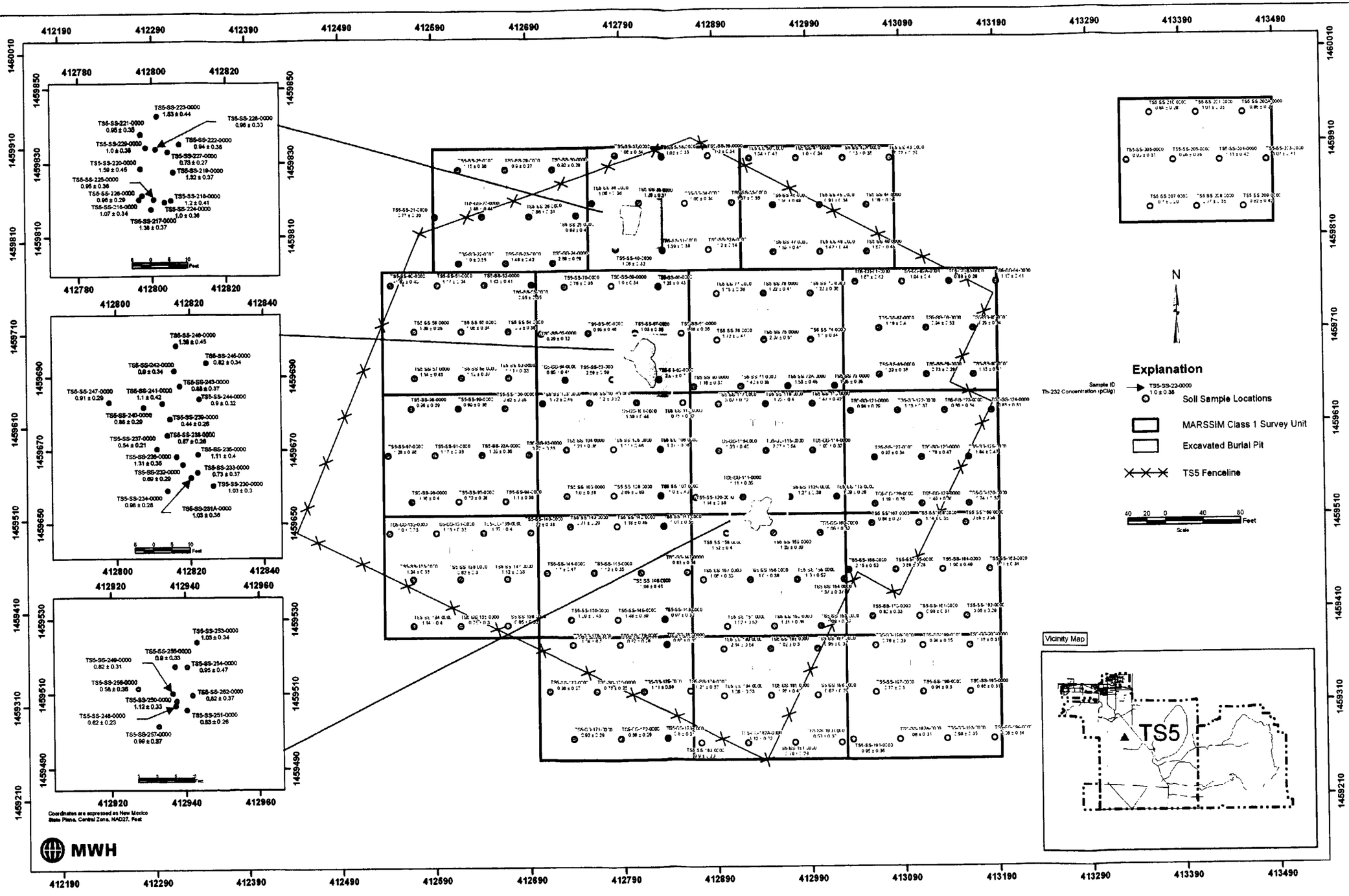

Figure 5-13. Final Status Survey Soil Sample Results for Training Site 5, Environmental Restoration Program Site OT-10

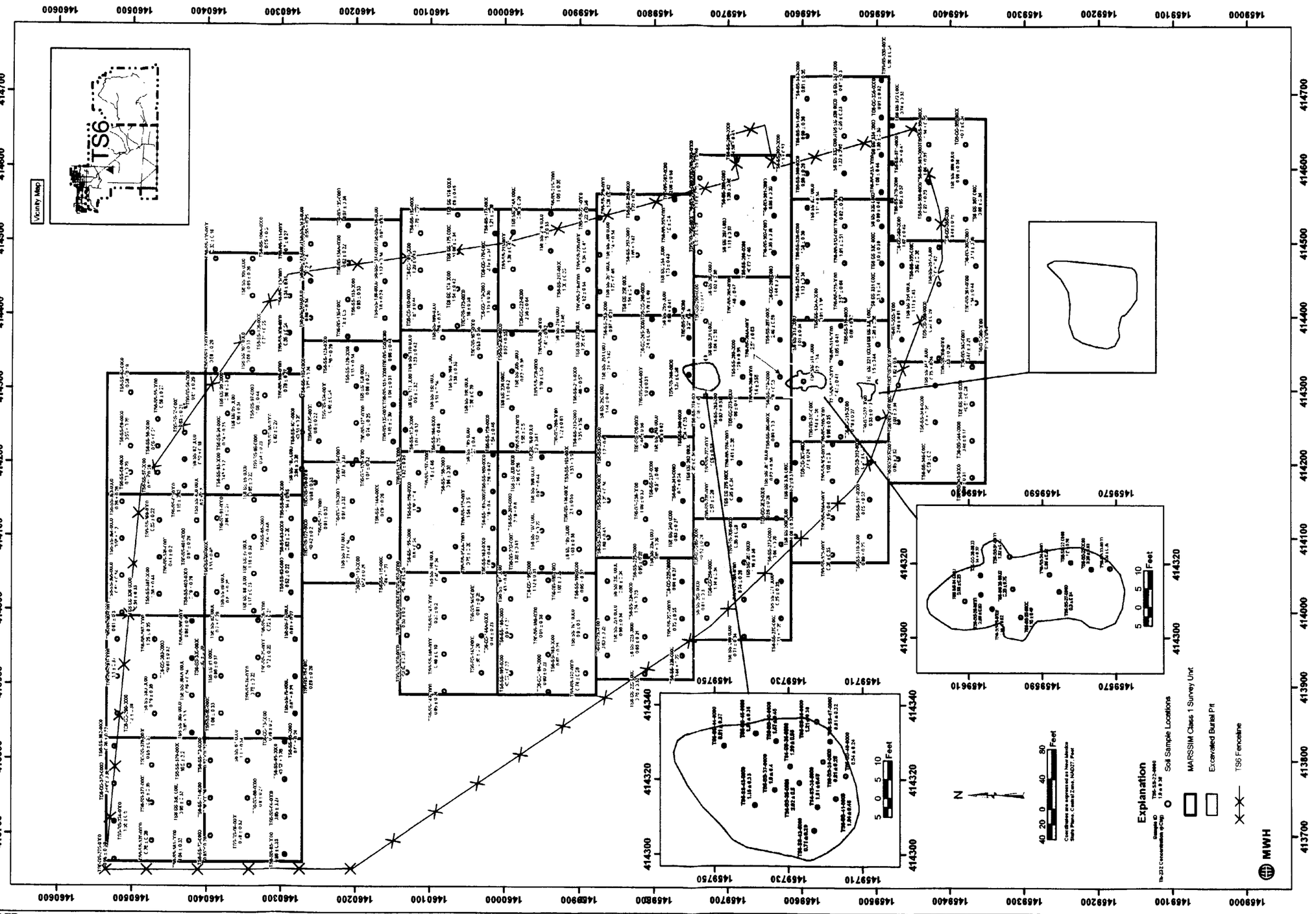

Figure 5-14. Final Status Survey Soil Sample Results for Training Site 6, Environmental Restoration Program Site OT-10

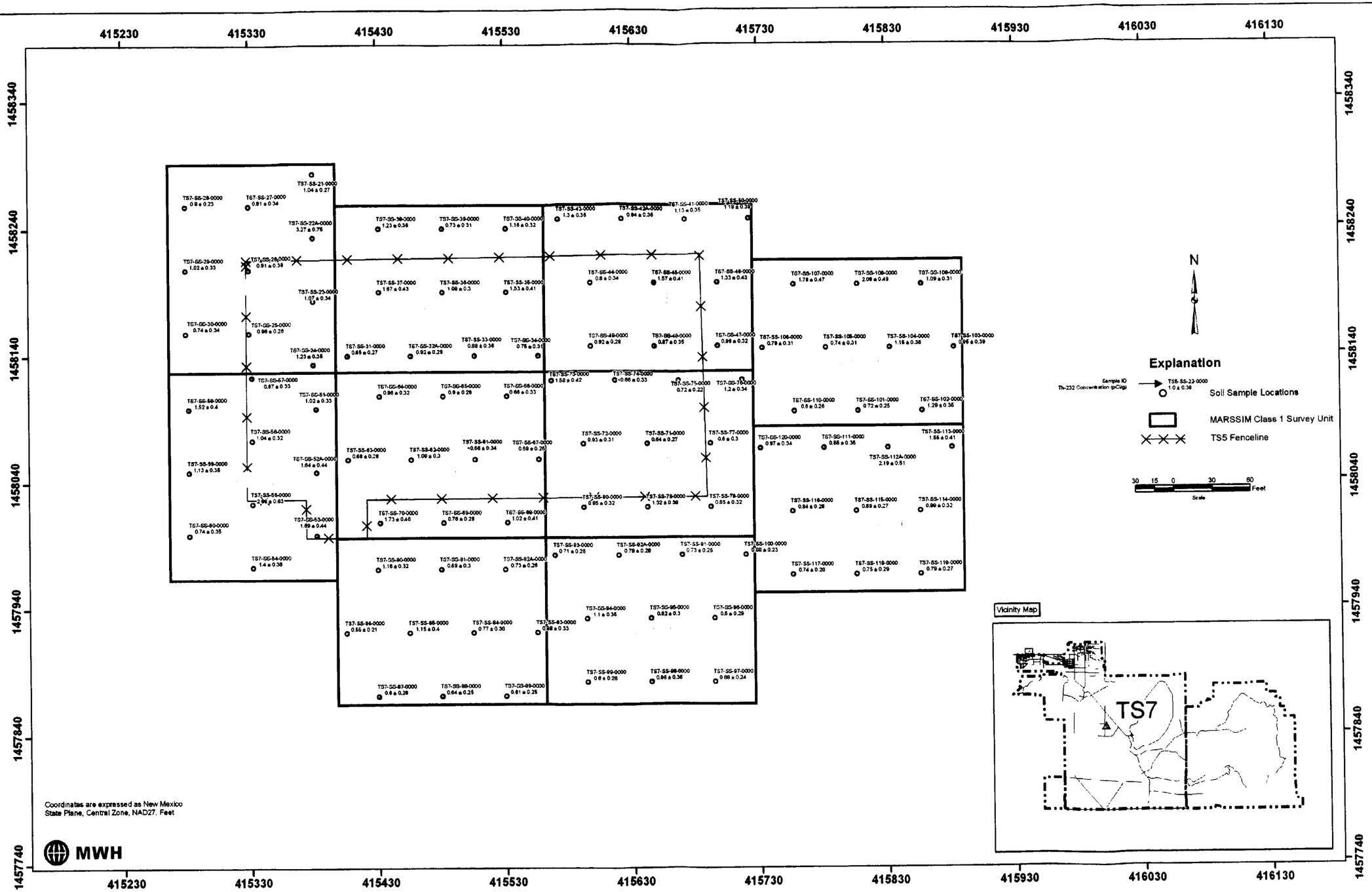

Figure 5-15. Final Status Survey Soil Sample Results for Training Site 7, Environmental Restoration Program Site OT-10

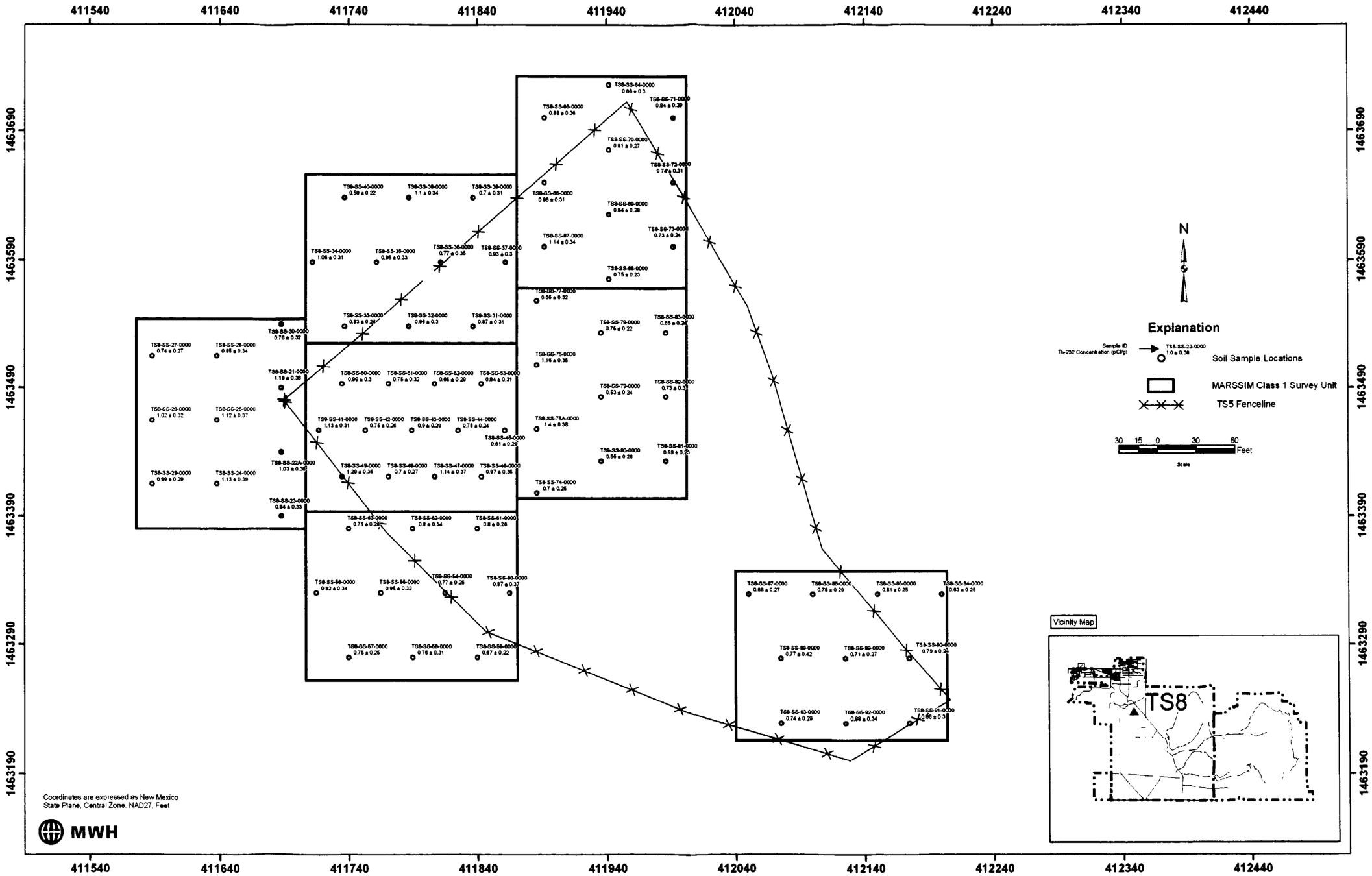

Figure 5-16. Final Status Survey Soil Sample Results for Training Site 8, Environmental Restoration Program Site OT-10

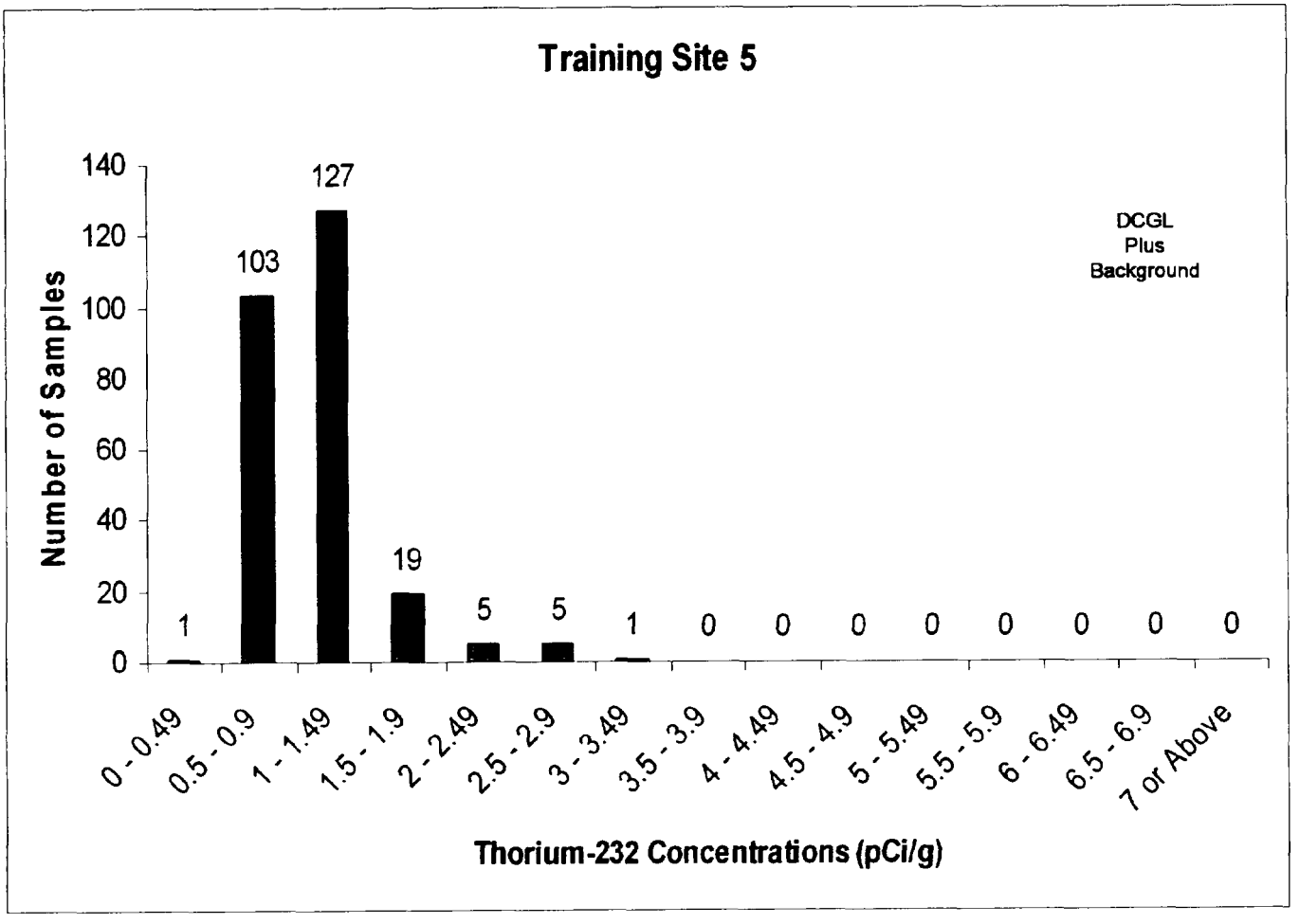

Figure 5-17. Histogram of the Final Status Survey Throrium-232 Soil Concentrations at Training Site 5, Environmental Restoration Program Site OT-10

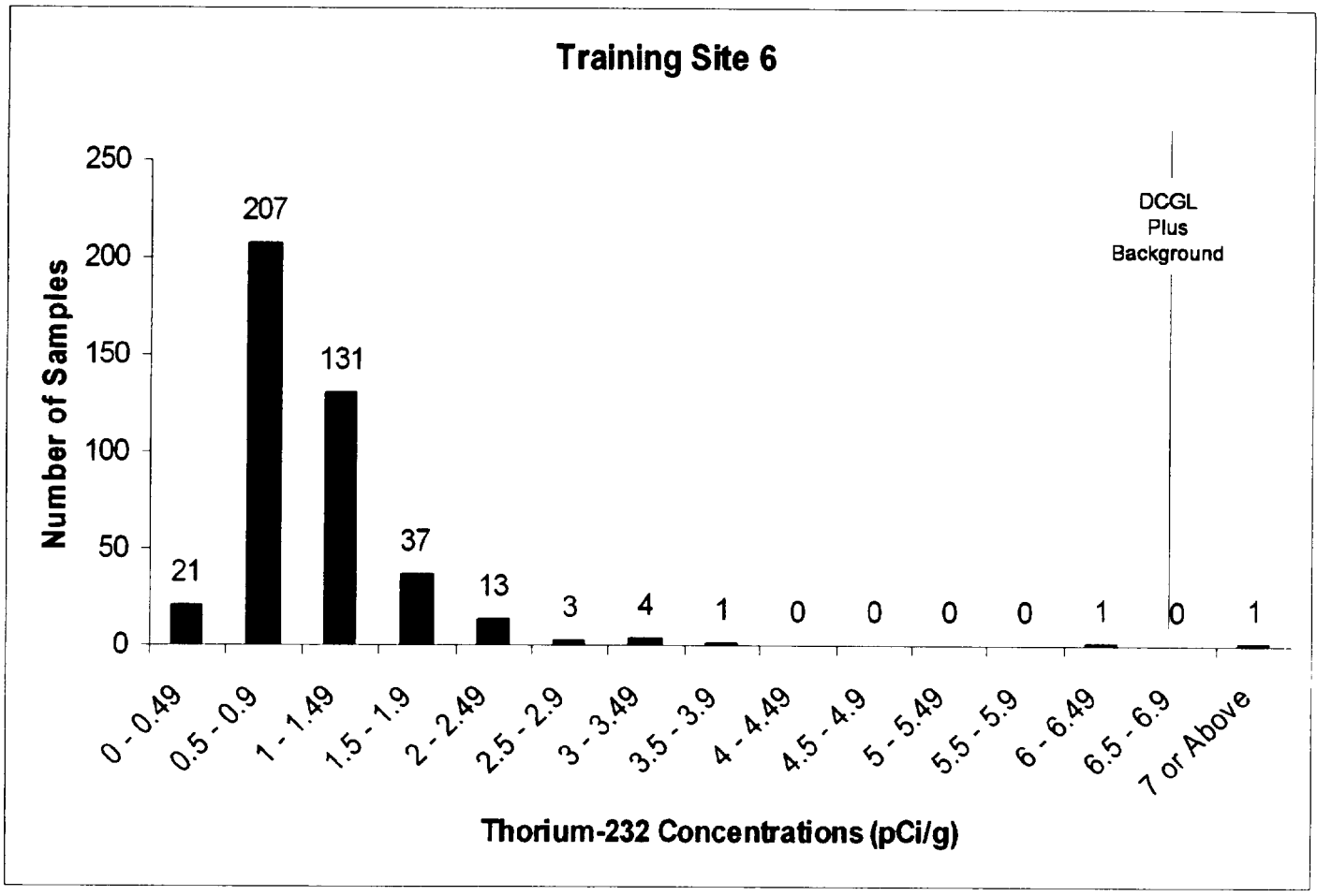

Figure 5-18. Histogram of the Final Status Survey Thorium-232 Soil Concentrations at Training Site 6, Environmental Restoration Program Site OT-10

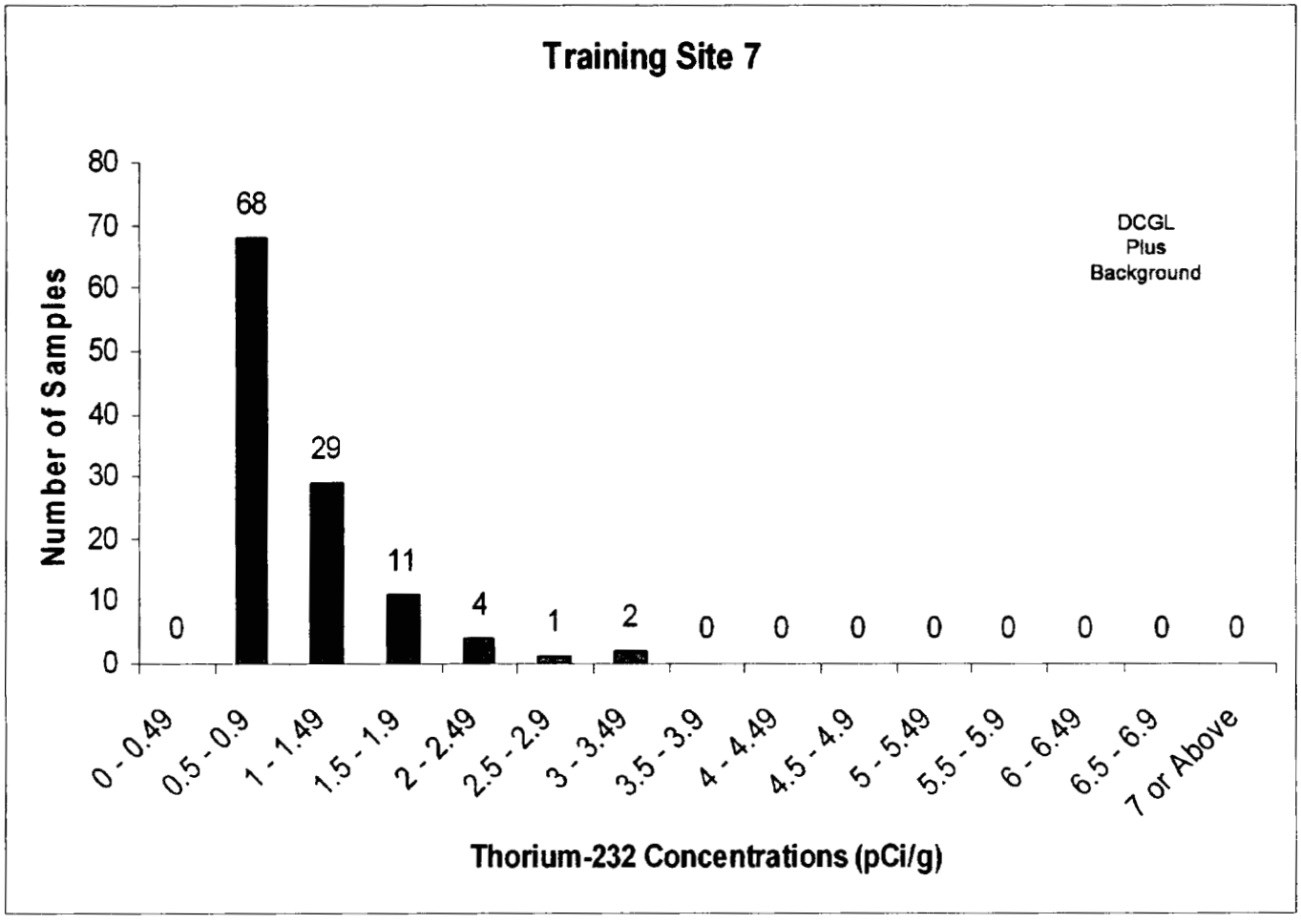

Figure 5-19. Histogram of the Final Status Survey Thorium-232 Soil Concentrations at Training Site 7, Environmental Restoration Program Site OT-10

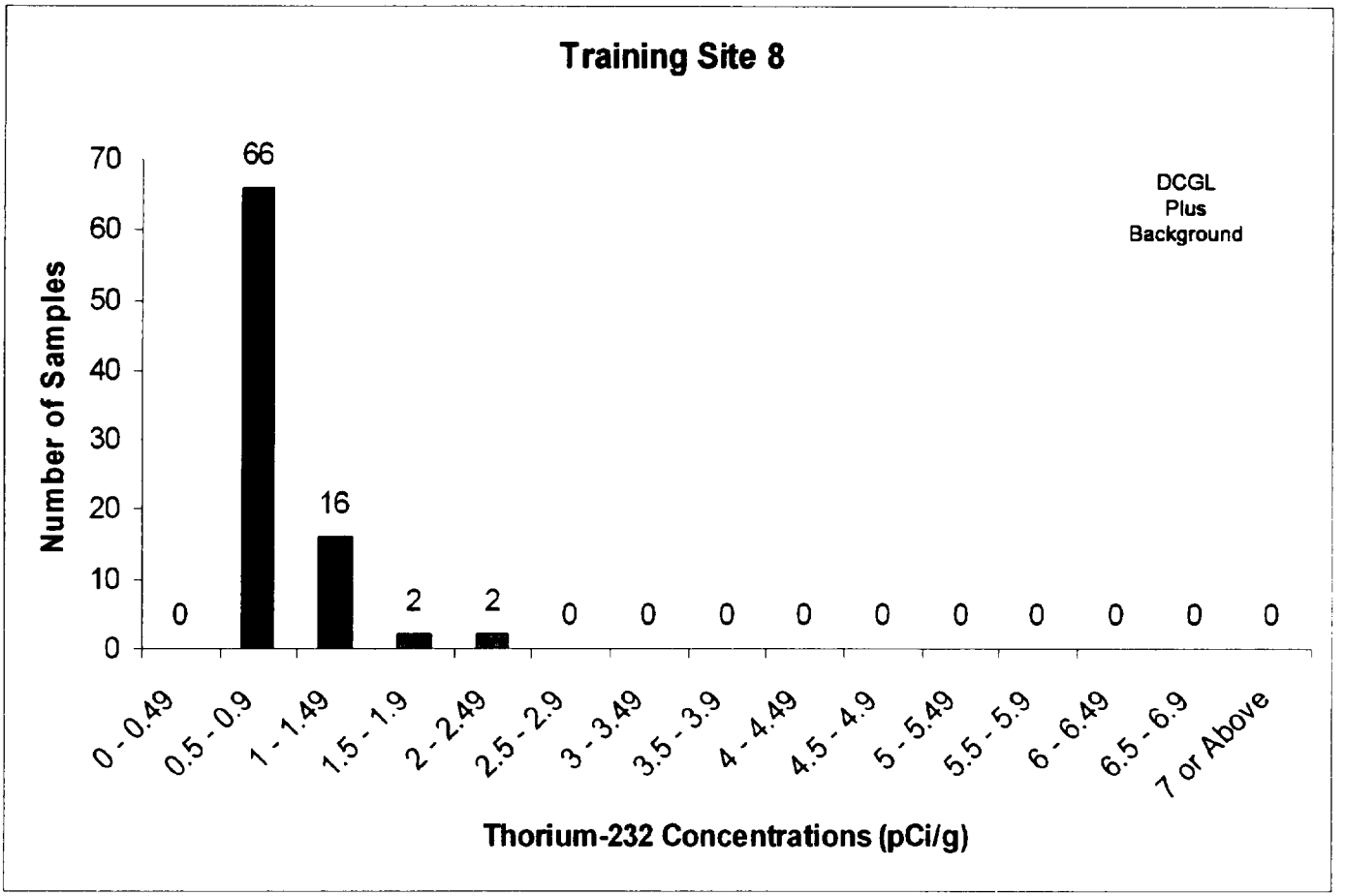

Figure 5-20. Histogram of the Final Status Survey Thorium-232 Soil Concentrations at Training Site 8, Environmental Restoration Program Site OT-10

Table 5-17. Summary Statistics for Final Status Survey Soil Samples at TS5, Environmental Restoration Program Site OT-10

Survey Unit	TS5-1	TS5-2	TS5-3	TS5-4	TS5-5	TS5-6	TS5-7	TS5-8	TS5-9	TS5-10
Number of samples	11	27	11	11	31	11	11	11	11	14
Minimum Thorium-232 (pCi/g)	0.77	0.68	0.77	0.9	0.44	1.1	0.73	0.72	0.75	0.9
Maximum Thorium-232 (pCi/g)	2.89	1.59	1.67	1.63	2.93	2.07	1.67	1.29	2.65	3.02
Average Thorium-232 (pCi/g)	1.2	1.12	1.24	1.23	1.11	1.37	1.12	1.04	1.31	1.35
Median Thorium-232 (pCi/g)	0.92	1.07	1.13	1.17	0.98	1.23	1.13	1.02	1.2	1.15
Standard deviation	0.61	0.22	0.3	0.24	0.55	0.3	0.25	0.18	0.52	0.56

Survey Unit	TS5-11	TS5-12	TS5-13	TS5-14	TS5-15	TS5-16	TS5-17	TS5-18	TS5-19
Number of samples	11	11	11	19	11	11	11	11	11
Minimum Thorium-232 (pCi/g)	0.74	0.62	0.71	0.58	0.7	0.58	0.58	0.76	0.64
Maximum Thorium-232 (pCi/g)	1.84	1.27	1.7	1.82	2.15	1.21	2.14	1.13	1.11
Average Thorium-232 (pCi/g)	1.16	1.02	1.12	1.1	1.13	0.9	1.04	0.95	0.88
Median Thorium-232 (pCi/g)	0.97	1.12	1.04	1.06	0.95	0.88	1.02	0.95	0.86
Standard deviation	0.38	0.22	0.28	0.35	0.48	0.17	0.42	0.12	0.16

TS-5 Summary	
Number of samples	256
Minimum Thorium-232 (pCi/g)	0.44
Maximum Thorium-232 (pCi/g)	3.02
Average Thorium-232 (pCi/g)	1.13
Median Thorium-232 (pCi/g)	1.05
Standard deviation	0.39

Notes:
pCi/g = picocuries per gram

Table 5-18. Summary Statistics for Final Status Survey Soil Samples at TS6, Environmental Restoration Program Site OT-10

Survey Unit	TS6-1	TS6-2	TS6-3	TS6-4	TS6-5	TS6-6	TS6-7	TS6-8	TS6-9	TS6-10
Number of samples	11	11	11	11	11	11	11	11	11	11
Minimum Thorium-232 (pCi/g)	0.74	0.61	0.41	0.38	0.61	0.58	0.52	0.34	0.33	0.55
Maximum Thorium-232 (pCi/g)	16.5	1.3	6.2	1.18	1.1	1.08	1.64	1.68	1.34	1.32
Average Thorium-232 (pCi/g)	2.4	0.89	1.24	0.63	0.85	0.76	0.97	0.79	0.7	0.84
Median Thorium-232 (pCi/g)	0.96	0.85	0.76	0.61	0.85	0.72	0.84	0.745	0.655	0.805
Standard deviation	4.68	0.25	1.67	0.21	0.13	0.14	0.34	0.36	0.26	0.21

Survey Unit	TS6-11	TS6-12	TS6-13	TS6-14	TS6-15	TS6-16	TS6-17	TS6-18	TS6-19	TS6-20
Number of samples	11	11	11	11	11	11	11	11	11	11
Minimum Thorium-232 (pCi/g)	0.29	0.55	0.37	0.64	0.88	0.78	0.51	0.57	0.82	0.64
Maximum Thorium-232 (pCi/g)	1.45	1.8	0.86	1.6	1.75	2.19	1.43	2.19	2.35	2.36
Average Thorium-232 (pCi/g)	0.83	0.98	0.62	1.16	1.26	1.35	0.88	1.39	1.33	1.28
Median Thorium-232 (pCi/g)	0.86	0.95	0.65	1.16	1.33	1.21	0.9	1.2	1.19	1.22
Standard deviation	0.33	0.35	0.17	0.35	0.29	0.38	0.26	0.53	0.44	0.49

Survey Unit	TS6-21	TS6-22	TS6-23	TS6-24	TS6-25	TS6-26	TS6-27	TS6-28	TS6-29	TS6-30
Number of samples	11	11	11	11	11	11	26	11	11	24
Minimum Thorium-232 (pCi/g)	0.44	0.63	0.75	0.96	0.35	0.56	0.54	0.67	0.7	0.33
Maximum Thorium-232 (pCi/g)	1.24	1.69	3.91	2.08	1.16	1.8	2.51	1.55	1.50	3.36
Average Thorium-232 (pCi/g)	0.79	1.08	1.6	1.44	0.81	1.03	1.37	1.18	1.02	1.43
Median Thorium-232 (pCi/g)	0.73	1.14	1.37	1.54	0.775	0.98	1.25	1.155	0.96	1.14
Standard deviation	0.21	0.35	0.9	0.37	0.25	0.36	0.56	0.25	0.22	0.86

Survey Unit	TS6-31	TS6-32	TS6-33	TS6-34	TS6-35
Number of samples	11	11	11	11	11
Minimum Thorium-232 (pCi/g)	0.75	0.66	0.47	0.63	0.74
Maximum Thorium-232 (pCi/g)	2.57	1.38	1.92	3.48	1.67
Average Thorium-232 (pCi/g)	1.24	0.99	0.86	1.31	1.06
Median Thorium-232 (pCi/g)	1.1	0.98	0.765	1.0	0.985
Standard deviation	0.55	0.23	0.46	0.87	0.25

TS-6 Summary	
Number of samples	413
Minimum Thorium-232 (pCi/g)	0.29
Maximum Thorium-232 (pCi/g)	16.5
Average Thorium-232 (pCi/g)	1.13
Median Thorium-232 (pCi/g)	0.97
Standard deviation	0.96

Notes:
pCi/g = picocuries per gram

Table 5-19. Summary Statistics for Final Status Survey Soil Samples at TS7, Environmental Restoration Program Site OT-10

Survey Unit	TS7-1	TS7-2	TS7-3	TS7-4	TS7-5	TS7-6	TS7-7	TS7-8	TS7-9	TS7-10
Number of samples	11	11	11	11	11	11	11	11	11	11
Minimum Thorium-232 (pCi/g)	0.74	0.65	0.8	0.74	0.66	0.6	0.55	0.5	0.6	0.69
Maximum Thorium-232 (pCi/g)	3.27	1.67	1.57	2.66	1.73	1.58	1.16	1.1	2.09	2.19
Average Thorium-232 (pCi/g)	1.38	1.04	1.08	1.37	0.94	0.94	0.77	0.77	1.11	1.13
Median Thorium-232 (pCi/g)	1.02	0.92	0.99	1.4	0.895	0.87	0.72	0.73	1.06	0.85
Standard deviation	0.92	0.33	0.24	0.53	0.32	0.33	0.21	0.16	0.46	0.55

TS-7 Summary	
Number of samples	110
Minimum Thorium-232 (pCi/g)	0.5
Maximum Thorium-232 (pCi/g)	3.27
Average Thorium-232 (pCi/g)	1.06
Median Thorium-232 (pCi/g)	0.915
Standard Deviation	0.48

Notes:
pCi/g = picocuries per gram

Table 5-20. Summary Statistics for Final Status Survey Soil Samples at TS8, Environmental Restoration Program Site OT-10

Survey Unit	TS8-1	TS8-2	TS8-3	TS8-4	TS8-5	TS8-6	TS8-7
Number of samples	11	11	14	11	11	11	11
Minimum Thorium-232 (pCi/g)	0.74	0.59	0.54	0.67	0.62	0.53	0.63
Maximum Thorium-232 (pCi/g)	1.19	1.1	1.29	0.95	1.14	1.4	0.88
Average Thorium-232 (pCi/g)	0.96	0.88	0.86	0.8	0.82	0.82	0.76
Median Thorium-232 (pCi/g)	0.99	0.90	0.8	0.8	0.84	0.7	0.77
Standard deviation	0.16	0.15	0.22	0.08	0.14	0.31	0.07

TS-8 Summary	
Number of samples	80
Minimum Thorium-232 (pCi/g)	0.53
Maximum Thorium-232 (pCi/g)	1.4
Average Thorium-232 (pCi/g)	0.84
Median Thorium-232 (pCi/g)	0.805
Standard deviation	0.18

Notes:
pCi/g = picocuries per gram

5.1.4 Judgmental and Miscellaneous Sample Data Sets

Several data sets were collected as part of the NRC approval and inspection process. The data sets included analyses of reference area soil samples for uranium-238, as required in the NRC approval of the Decommissioning Plan (NRC, 2003a), and two sample groups collected as part of NRC inspection of the decommissioning activities.

The NRC approval of the Decommissioning Plan requested that the reference area soil concentrations of uranium-238 be reviewed as part of the final status survey report (NRC, 2003). Nine of the twenty reference area samples from the site characterization survey were archived and available for uranium analysis. These nine samples were analyzed for uranium isotopes using alpha spectroscopy by Method NAS/DOE 3050/RP (NAS/DOE, 1994).

The isotopic uranium analytical results from the reference area soil samples are presented in Table 5-21. The summary statistics for the uranium-238 sample results are presented in Table 5-22. The mean uranium-238 soil concentration in the reference area samples is 0.73 pCi/g.

The NRC collected soil samples during the May and November 2003 inspections of the decommissioning project. Soil samples were collected at biased locations in areas of highest residual gamma activity. The soil samples were split between the NRC and Kirtland AFB. Seven samples were collected during the May 2003 inspection: one from the reference area and six from TS7. All seven samples were submitted for analysis.

Forty-nine samples were collected during the November 2003 inspection: 15 at TS5, 16 at TS6, 7 at TS7, and 11 at TS8. Fifteen samples, approximately 30 percent of the total, were submitted for analysis by the Air Force.

The Kirtland AFB sample portions were analyzed by Severn Trent Laboratory for gamma-emitting radionuclides by Method 901.1 (EPA, 1980). The results of the Air Force sample portions are presented in Tables 5-23 and 5-24.

The results of the May 2003 NRC inspection samples were all below the $DCGL_w$ plus background of 6.61 pCi/g thorium-232. Several of the results from the November 2003 NRC inspection samples were above the $DCGL_w$. However, all samples from the November 2003 inspection were below the $DCGL_{EMC}$ of 20.8 pCi/g thorium-232 for a 1-m^2 area. The NRC inspection soil sample results that exceeded the $DCGL_w$ plus background of 6.61 pCi/g thorium-232 were located in the following survey units: TS5-2, TS5-11, TS6-18, and TS8-3.

Table 5-21. Reference Area Soil Sample Uranium Analytical Results

Field Sample Identification	RA-SS-01-0000	RA-SS-02-0000	RA-SS-04-0000	RA-SS-06-0000	RA-SS-08-0000
Date Collected	4/17/2001	4/17/2001	4/17/2001	4/17/2001	4/17/2001
Matrix	Soil	Soil	Soil	Soil	Soil
Analyte/Methods (Units)					
Isotopic Uranium/A711 (pCi/g)					
Uranium-233 and 234	0.59 ± 0.21	1.35 ± 0.35	0.68 ± 0.23	0.33 ± 0.16	0.48 ± 0.18
Uranium-235 and 236	0.095 ± 0.079	0.076 ± 0.064	<0.077 ± 0.0065	<0.12 ± 0.039	<0.042 ± 0.044
Uranium-238	0.48 ± 0.18	1.55 ± 0.39	0.52 ± 0.19	0.56 ± 0.22	0.67 ± 0.22

Field Sample Identification	RA-SS-09-0000	RA-SS-10-0000	RA-SS-12-0000	RA-SS-13-0000
Date Collected	4/17/2001	4/17/2001	4/17/2001	4/17/2001
Matrix	Soil	Soil	Soil	Soil
Analyte/Methods (Units)				
Isotopic Uranium/A711 (pCi/g)				
Uranium-233 and 234	0.73 ± 0.25	0.54 ± 0.2	0.96 ± 0.3	0.49 ± 0.17
Uranium-235 and 236	<0.045 ± 0.047	0.061 ± 0.062	0.36 ± 0.18	0.036 ± 0.043
Uranium-238	0.74 ± 0.25	0.55 ± 0.2	0.87 ± 0.29	0.65 ± 0.2

Notes:
NAS/DOE, 1994
pCi/g = picocuries per gram

Table 5-22. Summary Statistics for Reference Area Uranium-238 Analytical Results

Reference Area	Uranium-238
Number of samples	9
Minimum uranium-238 (pCi/g)	0.48
Maximum uranium-238 (pCi/g)	1.55
Average uranium-238 (pCi/g)	0.732
Standard deviation	0.330

Notes:
NAS/DOE, 1994
pCi/g = picocuries per gram

Table 5-23. Sample Data from May 2003 U.S. Nuclear Regulatory Commission Inspection Soil Samples, Environmental Restoration Program Site OT-10

Field Sample ID	REFERENCE AREA BACKGROUND	KAFB-TS7-NRC-001	KAFB-TS7-NRC-002	KAFB-TS7-NRC-003	KAFB-TS7-NRC-004	KAFB-TS7-NRC-004	KAFB-TS7-NRC-005
Date Collected	5/20/2003	5/20/2003	5/20/2003	5/20/2003	5/20/2003	5/20/2003	5/20/2003
Matrix	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Analyte/Methods (Units)	E901.1	E901.1	E901.1	E901.1	E901.1	E901.1	E901.1
Gamma Emitting Radionuclides/E901.1 (pCi/g)							
Actinium-228	1.38 ± 0.49	4.7 ± 1.5	4.2 ± 1.3	2.21 ± 0.73	3.5 ± 1.1	2.44 ± 0.84	2.45 ± 0.79
Bismuth-212	<0.8 ± 0.36	2.7 ± 1.5	1.75 ± 0.8	1.46 ± 0.66	<1.6 ± 1.5	1.99 ± 0.8	<1.3 ± 0.64
Bismuth-214	0.73 ± 0.23	0.72 ± 0.3	0.73 ± 0.27	0.45 ± 0.2	0.74 ± 0.31	0.87 ± 0.23	0.7 ± 0.23
Cesium-137	<0.12 ± 0.057	0.33 ± 0.21	0.17 ± 0.1	<0.099 ± 0.059	<0.15 ± 0.085	<0.11 ± 0.06	<0.13 ± 0.073
Cobalt-60	<0.061 ± 0.049	<0.17 ± 0.086	<0.12 ± 0.061	<0.076 ± 0.046	<0.15 ± 0.078	<0.12 ± 0.053	<0.11 ± 0.053
Lead-212	0.91 ± 0.16	5.14 ± 0.81	3.12 ± 0.45	1.62 ± 0.27	3.46 ± 0.56	2.49 ± 0.36	2.71 ± 0.4
Lead-214	0.73 ± 0.19	0.93 ± 0.29	0.77 ± 0.24	0.54 ± 0.16	0.47 ± 0.23	0.71 ± 0.18	0.57 ± 0.18
Potassium-40	15.3 ± 2.7	17.5 ± 3	15.9 ± 2.9	14.3 ± 2.7	15.8 ± 2.8	12.5 ± 2.5	15.8 ± 2.9
Radium-224	3.0 ± 1.9	49 ± 27	3.8 ± 2.2	6.1 ± 3.5	33 ± 18 J	2.7 ± 1.6	3.8 ± 2.4
Radium-226	0.73 ± 0.38	0.67 ± 0.24	0.61 ± 0.28	0.65 ± 0.17	<0.57 ± 0.21	0.5 ± 0.23	0.86 ± 0.33
Thallium-208	0.272 ± 0.088	1.54 ± 0.33	1.08 ± 0.22	0.59 ± 0.15	1.0 ± 0.23	0.91 ± 0.19	0.94 ± 0.2
Thorium-234	<1.1 ± 0.59	<2.2 ± 1.6	2.4 ± 1.2	<1.2 ± 0.65	3.32 ± 0.99 J	<1.3 ± 0.72	1.92 ± 0.58
Uranium-235 and -236	<0.81 ± 0.49	<2.0 ± 1.3	<1.4 ± 0.91	<0.94 ± 0.6	<1.8 ± 1.2	<1.2 ± 0.68	<1.2 ± 0.69

Notes:
EPA, 1980
ID = identifier
J = estimated value
KAFB = Kirtland Air Force Base
pCi/g = picocuries per gram

Table 5-24. November 2003 Nuclear Regulatory Commission Inspection Soil Samples, Environmental Restoration Program Site OT-10

Field Sample ID	KAFB-TS5-NRC-3	KAFB-TS5-NRC-7	KAFB-TS5-NRC-10	KAFB-TS5-NRC-11	KAFB-TS6-NRC-2
Date Collected	11/19/2003	11/19/2003	11/19/2003	11/19/2003	11/18/2003
Matrix	Soil	Soil	Soil	Soil	Soil
Analyte/Methods (Units)	E901.1	E901.1	E901.1	E901.1	E901.1
Gamma-Emitting Radionuclide/E901.1 (pCi/g)					
Actinium-228	8.9 ± 1.8	6.9 ± 1.4	4.17 ± 0.92	6.2 ± 1.3	4.22 ± 0.88
Bismuth-212	5.3 ± 1.4	5.2 ± 1.4	3.1 ± 01± 1	2.7 ± 1.4	2.62 ± 0.92
Bismuth-214	0.84 ± 0.28	1.02 ± 0.31	0.82 ± 0.28	0.96 ± 0.27	0.62 ± 0.24
Cesium-137	0.28 ± 0.12	<0.15 ± 0.085	<0.14 ± 0.073	<0.17 ± 0.089	<0.11 ± 0.064
Cobalt-60	<0.14 ± 0.072	<0.12 ± 0.064	<0.12 ± 0.061	<0.13 ± 0.059	<0.1 ± 0.058
Lead-212	9.3 ± 1.4	6.9 ± 1.1	3.79 ± 0.6	5.47 ± 0.89	3.9 ± 0.62
Lead-214	1.05 ± 0.25	1.03 ± 0.26	0.82 ± 0.17	0.61 ± 0.21	0.63 ± 0.16
Potassium-40	15.2 ± 2.9	16.6 ± 3.4	16.9 ± 3.4	15.6 ± 3.1	14.6 ± 3.1
Radium-224	10.4 ± 6.2	7.0 ± 4.3	5.5 ± 3.4	7.4 ± 4.4	4.9 ± 3
Radium-226	<2.4 ± 1.4	<2.4 ± 1.5	3.3 ± 1.9	<2.3 ± 1.3	<1.9 ± 01± 1
Thallium-208	3.13 ± 0.54	2.38 ± 0.41	1.51 ± 0.29	2.15 ± 0.39	1.49 ± 0.28
Thorium-234	7.6 ± 1.9	5.9 ± 1.5	3.14 ± 0.76	3.43 ± 0.87	3.42 ± 0.79
Uranium-235 and -236	<0.63 ± 0.36	<0.68 ± 0.4	<0.52 ± 0.3	<0.62 ± 0.36	<0.52 ± 0.3
Field Sample ID	KAFB-TS6-NRC-3	KAFB-TS6-NRC-8	KAFB-TS6-NRC-12	KAFB-TS6-NRC-14	KAFB-TS6-NRC-16
Date Collected	11/18/2003	11/18/2003	11/18/2003	11/18/2003	11/18/2003
Matrix	Soil	Soil	Soil	Soil	Soil
Analyte/Methods (Units)	E901.1	E901.1	E901.1	E901.1	E901.1
Gamma-Emitting Radionuclide/E901.1 (pCi/g)					
Actinium-228	2.65 ± 0.61	6.7 ± 1.4	2.68 ± 0.62	3.31 ± 0.77	3.34 ± 0.78
Bismuth-212	1.68 ± 0.66	4.5 ± 1.5	1.83 ± 0.73	1.9 ± 01± 1	2.18 ± 0.997
Bismuth-214	0.58 ± 0.2	1.03 ± 0.36	1.2 ± 0.31	1.11 ± 0.31	1.14 ± 0.3
Cesium-137	<0.096 ± 0.051	<0.2 ± 0.1	<0.11 ± 0.061	<0.15 ± 0.078	<0.11 ± 0.061
Cobalt-60	<0.1 ± 0.05	<0.17 ± 0.082	<0.13 ± 0.065	<0.17 ± 0.088	<0.14 ± 0.071
Lead-212	2.56 ± 0.43	6.9 ± 1.1	2.06 ± 0.35	3.03 ± 0.54	2.98 ± 0.51
Lead-214	0.65 ± 0.16	1.02 ± 0.26	0.97 ± 0.19	1.26 ± 0.29	1.11 ± 0.24
Potassium-40	15.7 ± 2.9	16.8 ± 3.6	18.5 ± 3.5	17.7 ± 3.6	16.4 ± 3.4
Radium-224	3.2 ± 2	7.4 ± 4.5	<1.6 ± 0.94	6.0 ± 3.8	5.7 ± 3.5
Radium-226	2.24 ± 0.93	<2.8 ± 1.5	2.1 ± 1.3	2.8 ± 1.4	<2.3 ± 1.2
Thallium-208	0.93 ± 0.19	2.57 ± 0.44	0.46 ± 0.15	0.94 ± 0.22	0.92 ± 0.22
Thorium-234	2.62 ± 0.77	5.8 ± 1.5	1.78 ± 0.53	2.87 ± 0.83	3.2 ± 01± 1
Uranium-235 and -236	<0.4 ± 0.22	<0.76 ± 0.44	<0.47 ± 0.27	<0.54 ± 0.31	<0.58 ± 0.33

Table 5-24. November 2003 Nuclear Regulatory Commission Inspection Soil Samples Environmental Restoration Program Site OT-10 (Concluded)

Field Sample ID	KAFB-TS7-NRC-1	KAFB-TS7-NRC-6	KAFB-TS8-NRC-3	KAFB-TS8-NRC-4	KAFB-TS8-NRC-9
Date Collected	11/18/2003	11/18/2003	11/19/2003	11/19/2003	11/19/2003
Matrix	Soil	Soil	Soil	Soil	Soil
Analyte/Methods (Units)	E901.1	E901.1	E901.1	E901.1	E901.1
Gamma-Emitting Radionuclides/E901.1 (pCi/g)					
Actinium-228	2.62 ± 0.59	3.94 ± 0.85	8.0 ± 1.6	12.8 ± 2.5	6.3 ± 1.3
Bismuth-212	1.83 ± 0.63	1.92 ± 0.75	5.3 ± 1.4	7.9 ± 2	3.3 ± 1.1
Bismuth-214	0.71 ± 0.19	0.71 ± 0.25	0.57 ± 0.27	0.81 ± 0.29	0.95 ± 0.25
Cesium-137	0.161 ± 0.08	<0.12 ± 0.079	<0.12 ± 0.079	<0.17 ± 0.094	<0.14 ± 0.079
Cobalt-60	<0.11 ± 0.053	<0.11 ± 0.057	<0.12 ± 0.067	<0.12 ± 0.068	<0.11 ± 0.067
Lead-212	2.58 ± 0.44	3.3 ± 0.56	8.3 ± 1.3	12.7 ± 1.9	5.8 ± 0.88
Lead-214	0.72 ± 0.16	0.78 ± 0.18	0.72 ± 0.2	0.71 ± 0.23	0.76 ± 0.16
Potassium-40	14.2 ± 2.7	15.7 ± 3.2	13.4 ± 2.7	16.3 ± 3.4	20.8 ± 3.9
Radium-224	1.36 ± 0.79	5.5 ± 3.5	8.3 ± 5	14.3 ± 8.5	7.5 ± 4.5
Radium-226	<1.6 ± 0.85	<2.0 ± 1.1	2.9 ± 2.2	<3.0 ± 1.7	<2.1 ± 1.2
Thallium-208	0.94 ± 0.2	1.2 ± 0.25	2.82 ± 0.48	4.24 ± 0.67	1.99 ± 0.36
Thorium-234	1.6 ± 0.94	2.12 ± 0.63	5.9 ± 1.6	9.8 ± 2.1	4.8 ± 01± 1
Uranium-235 and -236	<0.39 ± 0.22	<0.48 ± 0.3	<0.64 ± 0.36	<0.84 ± 0.5	<0.57 ± 0.33

Notes:
EPA, 1980
ID = identifier
KAFB = Kirtland Air Force Base
pCi/g = picocuries per gram

5.1.5 Exposure Rate Results

Exposure rate measurements were taken at 53 locations during the final status surveys. Measurements were taken at both 18 inches (as was done during the site characterization survey) and 3 ft above ground surface. The exposure rate and the static gamma radiation measurements are presented in Table 5-25. Evaluation of the exposure rate measurements taken at 18 inches and 3 ft above ground surface shows that they are statistically the same.

The dynamic range of the exposure rate measurements taken during the final status survey was too small to develop a correlation between the gamma radiation count rate and the exposure rate. Therefore, the exposure rate measurements taken during the site characterization survey were merged with the final status survey data to develop the correlation. The site characterization survey exposure rate measurements are presented in Table 5-26.

Figure 5-21 presents the graph of the 72 measurements taken during the final status survey and site characterization survey. A strong linear correlation exists between the gamma radiation count rates and the exposure rates, with a Pearson's Correlation (r^2) of 0.99. The equation of the line is as follows, with gamma radiation measured in cpm and exposure rates in microRoentgens per hour (μR/hr):

$$\text{Exposure Rate} = (0.001 * \text{gamma count rate}) + 0.5035 \qquad \text{Eq. 5-1}$$

Equation 5-1 was used to convert the gamma count rates to exposure rates. Maps of site exposure rates are presented in Figures 5-22 through 5-25.

Table 5-25. Final Status Survey Static Gamma and Exposure Rate Measurements, Environmental Restoration Program Site OT-10

Location	Static Gamma Count (cpm)	Exposure rate at 18 inches (µR/hr)	Exposure Rate at 3 ft (µR/hr)
61	11,873	14	14
62	11,445	13	13
63	11,788	13	13
64	11,938	14	14
65	11,331	14	14
66	11,817	14	14
67	11,947	14	14
68	13,144	15	15
69	12,559	15	14
70	12,382	13	13
71	12,001	14	14
72	12,237	15	15
73	11,543	14	14
74	11,916	14	14
75	11,511	15	14
76	11,539	13	13
77	12,147	14	14
78	13,580	15	15
79	11,404	14	13
80	10,500	13	13
81	10,961	12	12
82	10,775	13	13
83	11,422	14	14
84	10,628	12	12
85	11,475	13	13
86	11,850	14	14
87	9,795	11	11
88	10,300	12	12
89	9,693	11	11
90	9,699	12	12
91	10,361	11	11
92	10,565	12	12
93	11,172	13	13
94	11,061	13	13
95	12,640	15	15
96	11,684	13	13
97	10,881	13	13
98	11,021	13	13
99	11,784	13	14
100	10,539	13	13
101	12,372	14	14
102	11,445	13	13
103	11,825	13	13
104	11,561	13	13
105	10,995	13	13
106	11,388	13	13
107	11,915	14	14
108	13,085	15	15
109	11,837	14	14
110	11,038	14	14
111	12,250	15	15
112	12,390	14	14
113	11,721	14	14
Average	11614.24	13.50000	13.44444

Notes:
cpm = counts per minute
µR/hr = microRoentgens per hour

Table 5-26. Site Characterization Survey Static Gamma and Exposure Rate Measurements, Environmental Restoration Program Site OT-10

Location	Static Gamma Count (cpm)	Exposure Rate at 18 inches (μR/hr)
TS-5	16,439	17
TS-5	28,825	26
TS-5	86,496	70
TS-5	131,962	140
TS-5	263,596	290
TS-5	16,400	16
TS-6	27,673	26
TS-6	33,014	32
TS-6	87,232	85
TS-6	42,865	42
TS-6	27,010	26
TS-7	13,257	14
TS-7	16,653	16
TS-7	23,654	24
TS-7	41,588	42
TS-7	143,565	140
TS-7	36,648	40
TS-7	20,352	19
TS-7	12,472	13

Notes:
cpm = counts per minute
μR/hr = microRoentgens per hour

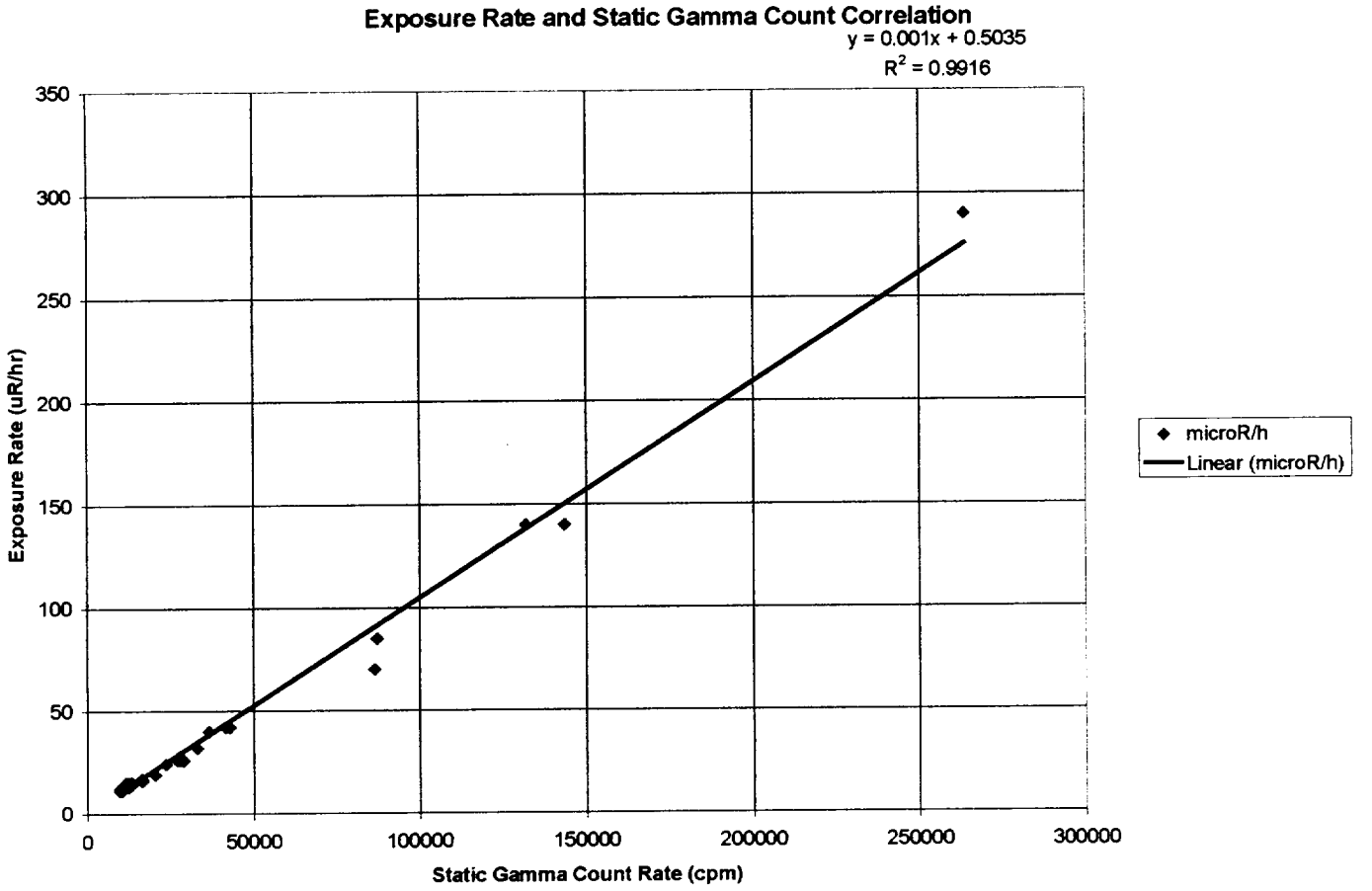

Figure 5-21. Correlation between Exposure Rates and Gamma Radiation Count Rates, Environmental Restoration Program Site OT-10

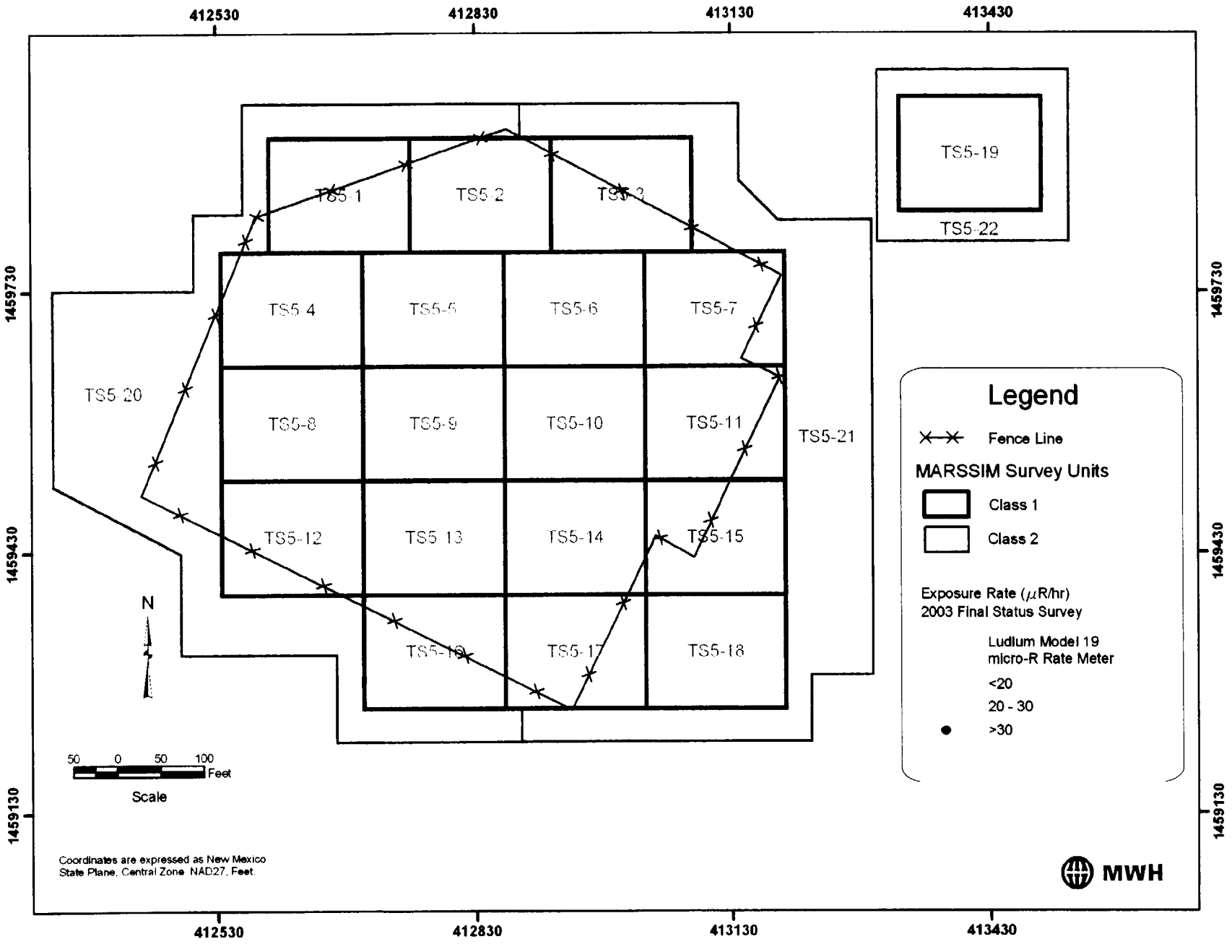

Figure 5-22. Exposure Rates at Training Site 5, Environmental Restoration Program Site OT-10

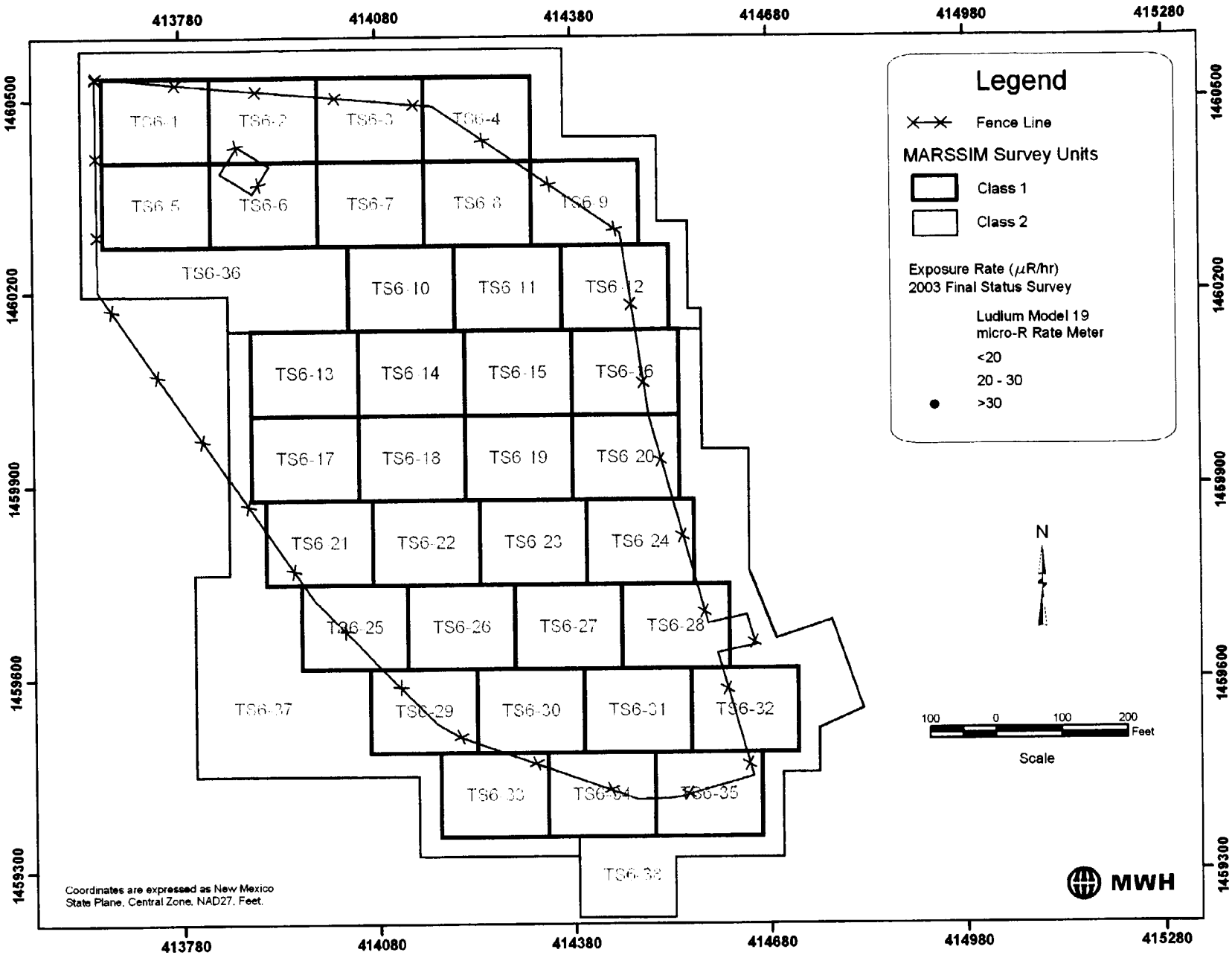

Figure 5-23. Exposure Rates at Training Site 6, Environmental Restoration Program Site OT-10

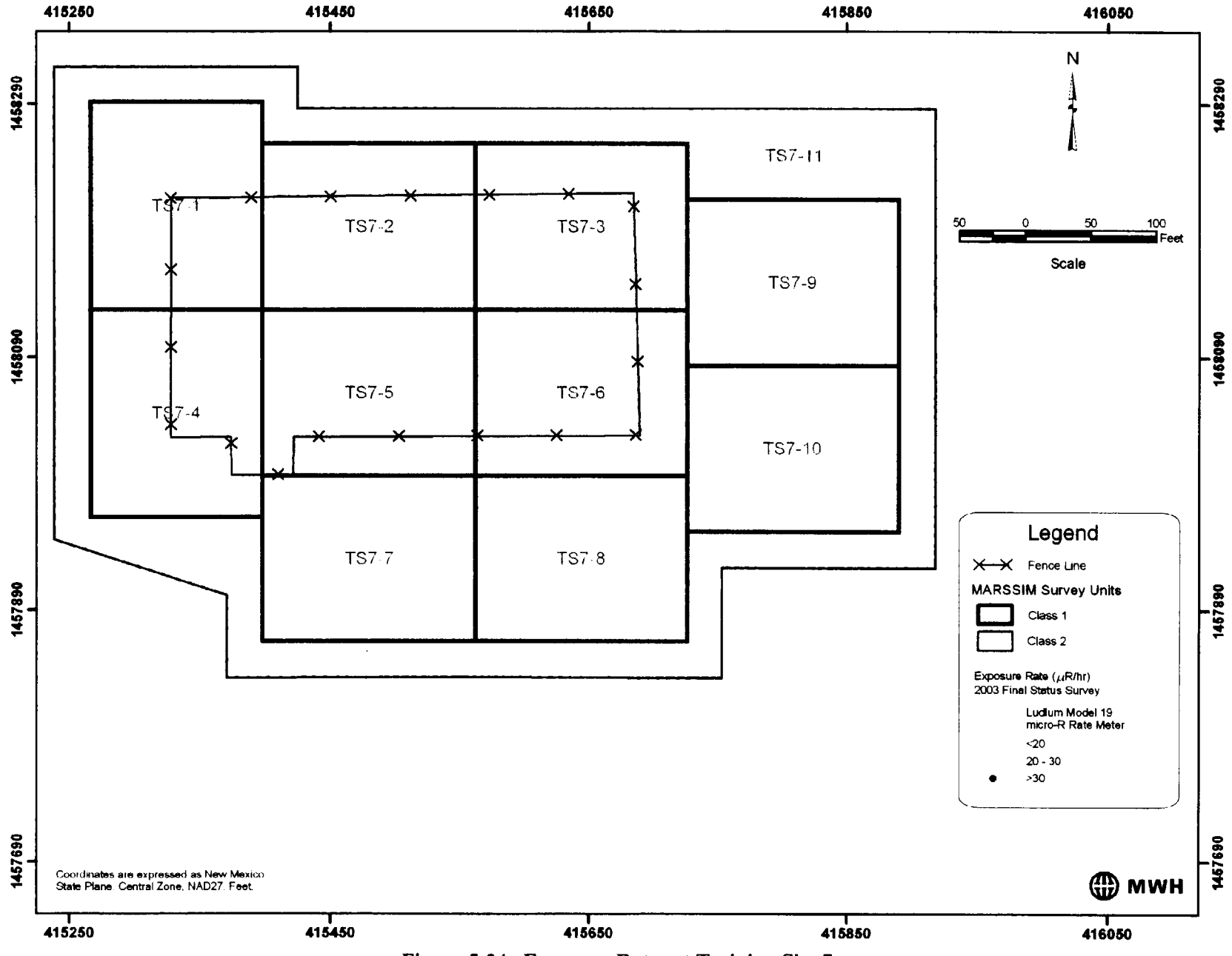

Figure 5-24. Exposure Rates at Training Site 7, Environmental Restoration Program Site OT-10

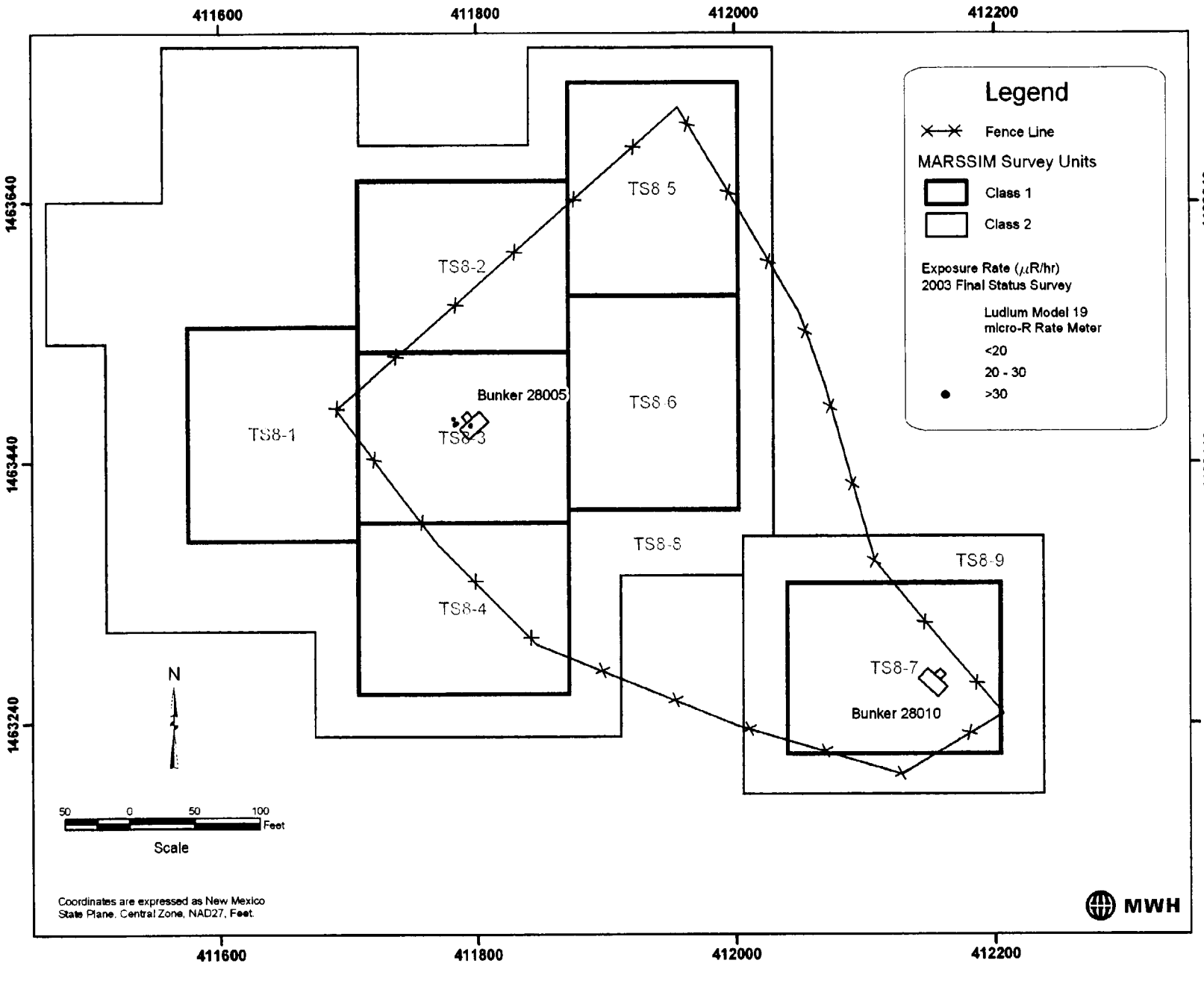

Figure 5-25. Exposure Rates at Training Site 8, Environmental Restoration Program Site OT-10

5.1.6 Calculation of Minimum Detectable Concentration

The MDCs for thorium-232 in soil were originally presented in the OT-10 Decommissioning Plan (USAF, 2002). However, MARSSIM guidance recommends that the MDCs be determined in the field using data collected during the decommissioning process.

Static MDCs can easily be determined in the field by determining the detector efficiency from integrated count times, the natural background count rate, and thorium-232 concentrations determined from soil sample analyses. It is more difficult to measure the scanning MDCs. Guidance on the empirical determination of the scanning MDCs is given in Section 9.3.6 of *Decommissioning Health Physics, A Handbook for MARSSIM Users* (Abelquist, 2001). Suggested methods include flagging gamma emission "hot spots" and taking soil samples. In this method, the lowest concentration is recommended as an indicator of the MDC.

Extensive effort was made during decommissioning to evaluate the ability to predict thorium-232 concentrations in surface soil. Static 1-minute gamma radiation counts were made above soil sampling locations to assess detector response per unit soil concentration. This resulted in a correlation between the gamma count rate (static) and the thorium-232 soil concentration. The static MDC can be determined using the correlation, the background count rate, and the detector efficiency.

During soil removal, technicians used gamma radiation detectors to scan land areas and identify soils that were believed to exceed the $DCGL_w$. Remedial action support surveys (RASS), using GPS-based survey equipment to scan the area, were performed to document the progress of soil removal. Gamma radiation maps produced by the RASS often showed areas requiring further cleanup that the technicians were unable to detect. Therefore, a combination of real-time excavation control monitoring by technicians and periodic RASS was used to complete the work. The scanning MDC in this report is based on the data from the RASS because these data were used to confirm that excavation was complete.

The sensitivity of the RASS is illustrated by the results of the first RASS at TS-5, as shown in Figures 5-26 and 5-27, where the data are displayed in color intervals of 1,000 cpm and 2,000 cpm, respectively. The plots clearly demonstrate that areas of elevated contamination exhibit increasing count rates toward the center of the elevated area. Areas exhibiting 1,000 to 2000 cpm above the contiguous areas can be identified in the gamma radiation maps.

The scanning data from the RASS are as sensitive in predicting soil concentrations as individual static gamma radiation count rate measurements. This allowed simple methods commonly employed for determining MDCs for static methods to be used to estimate the scanning MDC.

5.1.6.1 Comparison of Static and Scanning Measurements in Predicting Soil Concentrations

The final status survey data for TS5 have been selected to compare scanning data to 1-minute static counts. The final status survey consists of gamma scanning data over 100 percent of the training site area, static 1-minute integrated gamma radiation counts at each soil sample location, and soil sample analytical data. The final status survey gamma scanning data for TS5 are contoured in 1,000-cpm increments and presented in Figure 5-28.

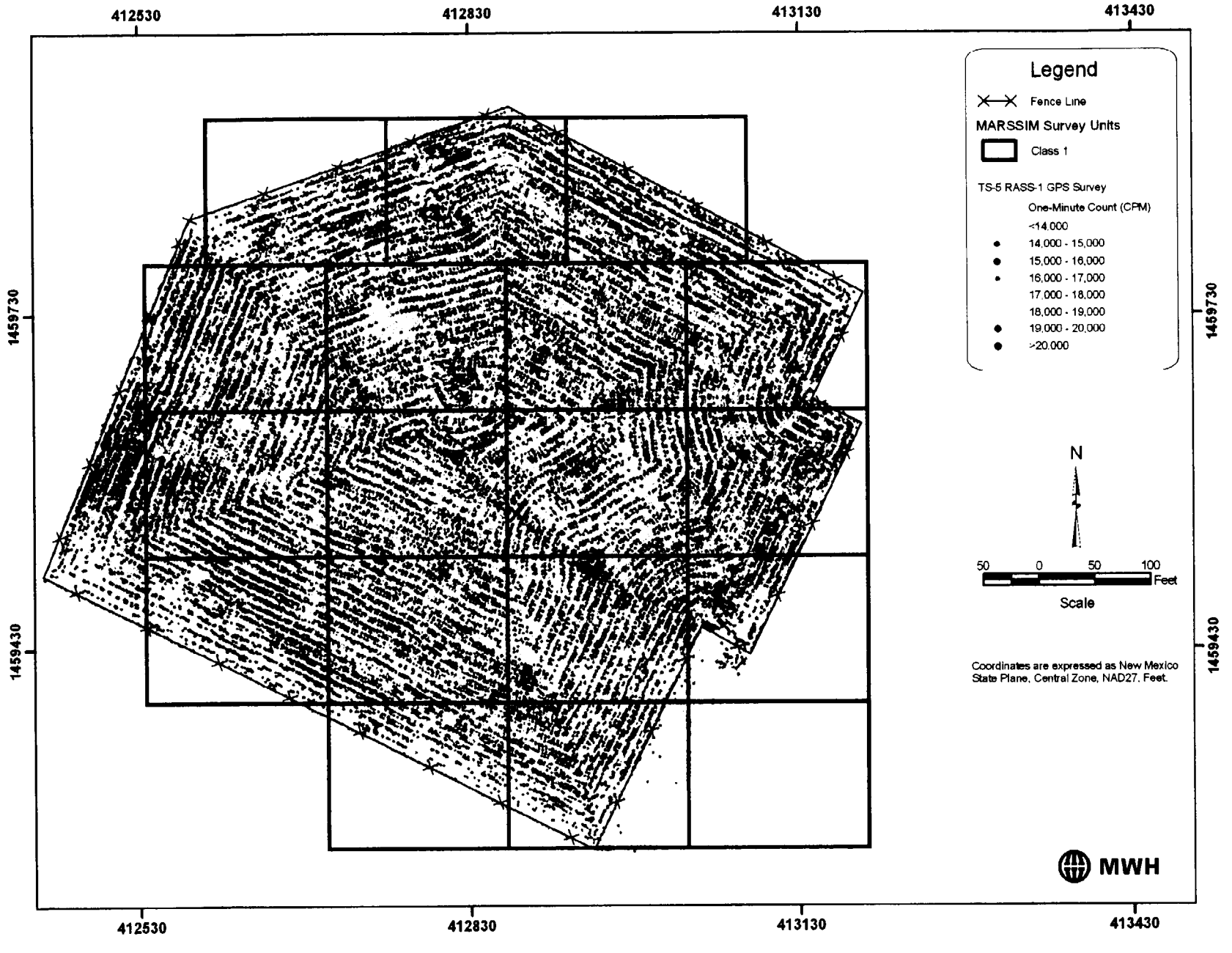

Figure 5-26. First Remedial Action Support Survey at Training Site 5, 1000 Count Per Minute Data Range, Environmental Restoration Program Site OT-10

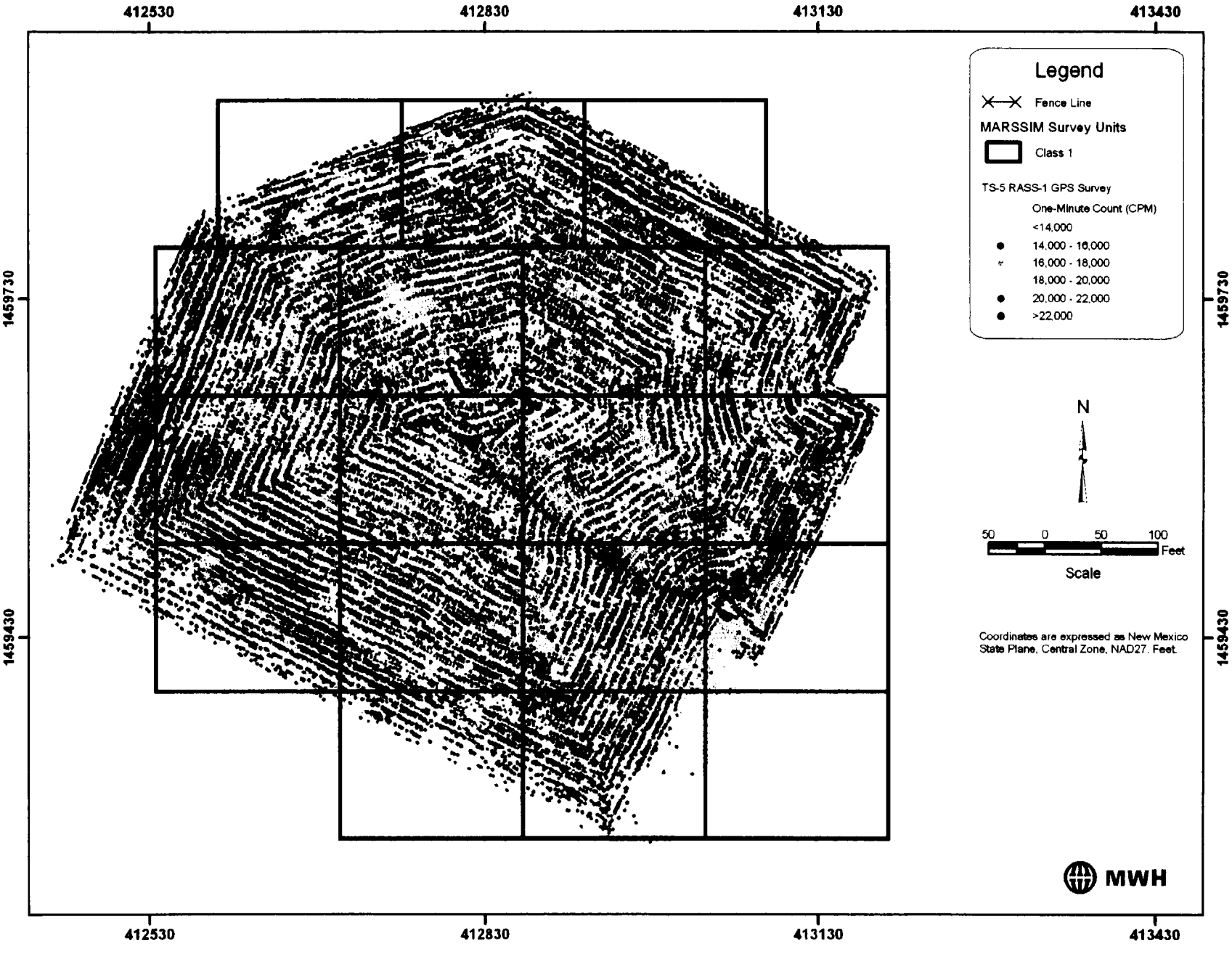

Figure 5-27. First Remedial Action Support Survey at Training Site 5, 2000 Count Per Minute Data Range, Environmental Restoration Program Site OT-10

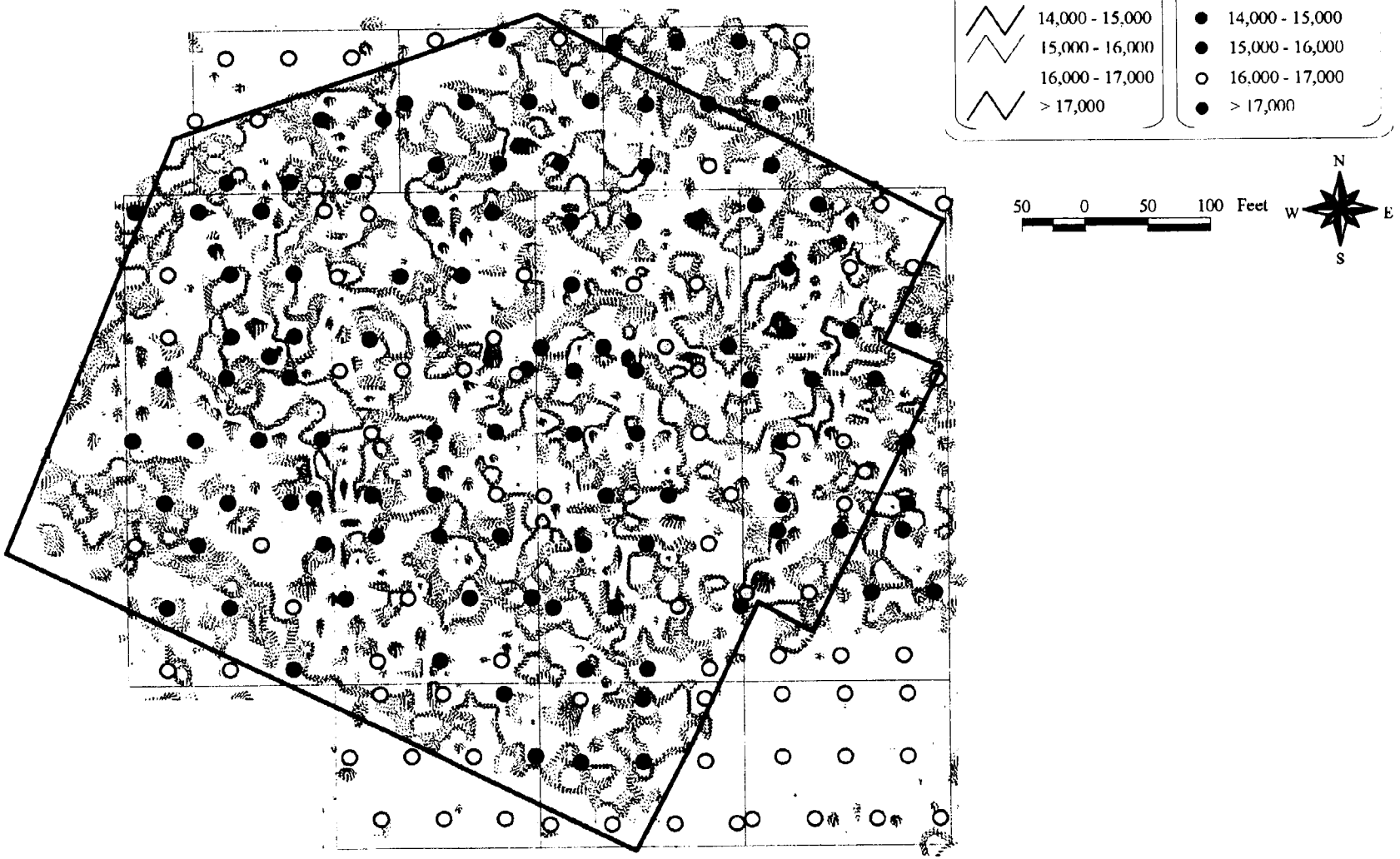

Figure 5-28. Training Site 5 Final Status Survey Gamma Scanning and Static Gamma Measurements, 1000 Count Per Minute Data Range, Environmental Restoration Program Site OT-10

For comparison, the 1-minute integrated gamma radiation measurements were classified and presented in Figure 5-28 as dots at the sampling locations using the same 1,000-cpm increment color scheme as the scanning data contours. Most of the colors representing the 1-minute counts in the figure fall within the contours of similar color, indicating that the two data sets agree. For most situations where the colors disagree, the sampling locations are near the edge of the contour. It should also be noted that the spatial locations are determined using GPS receivers with only sub-meter accuracy. This could also be responsible for some of the disagreement in the data ranges. Figure 5-28 shows that the two gamma-radiation data sets generally agree.

As an additional test, the average gamma count rates were calculated from the scanning data for the 26 soil sample locations with the highest thorium-232 concentrations. The averages were obtained by considering the gamma scanning data within a 3-ft radius of the soil sample location. The data were then compared to the 1-minute integrated count at the soil sample location. The ratios between the two were calculated and the mean and standard deviation of the ratios were determined to be 0.96 and 0.06, respectively, as shown in Table 5-27. This positive agreement indicates that any relationship developed for the 1-minute integrated counts should also apply to the mean count rate of the scanning data for the corresponding area. This confirms that the use of static data in calculating the scanning MDC is appropriate when using scanning data maps to display scanning data.

Table 5-27. Comparison of Average Count Rate from TS5 Final Status Survey Gamma Scanning and Integrated 1-Minute Counts, Environmental Restoration Program Site OT-10

Sample ID	Number of Readings in 6-foot Diameter	Average Gamma in 6-foot Diameter (cpm)	Integrated 1-minute Count (cpm)	6-foot GPS Survey Avg.: 1-minute Count
TS5-SS-24-0000	4	16,414	17,616	0.932
TS5-SS-46-0000	3	14,288	14,225	1.004
TS5-SS-47-0000	5	14,823	15,477	0.958
TS5-SS-49-0000	5	14,402	15,374	0.937
TS5-SS-52-0000	3	16,344	17,267	0.947
TS5-SS-60-0000	3	14,911	15,092	0.988
TS5-SS-62-0000	2	15,215	16,349	0.931
TS5-SS-63-0000	6	16,944	18,526	0.915
TS5-SS-75-0000	2	14,906	16,255	0.917
TS5-SS-76-0000	7	16,307	15,729	1.037
TS5-SS-81-0000	3	14,963	15,235	0.982
TS5-SS-103-0000	4	17,121	16,705	1.025
TS5-SS-108-0000	3	14,055	17,703	0.794
TS5-SS-115-0000	2	14,872	15,805	0.941
TS5-SS-117-0000	3	15,733	17,325	0.908
TS5-SS-125-0000	5	16,414	17,461	0.940
TS5-SS-126-0000	8	15,888	16,542	0.960
TS5-SS-144-0000	1	14,874	15,900	0.935
TS5-SS-151-0000	3	19,158	17,390	1.102
TS5-SS-155-0000	9	15,236	16,402	0.929
TS5-SS-158-0000	2	17,757	17,205	1.032
TS5-SS-164-0000	2	14,494	15,536	0.933
TS5-SS-166-0000	4	16,423	16,131	1.018
TS5-SS-189-0000	4	15,380	16,233	0.947
TS5-SS-211-0000	2	18,852	18,413	1.024
TS5-SS-214-0000	6	16,261	16,534	0.983

Mean:	0.962
Std. Dev.:	0.059

Notes:
cpm = counts per minute GPS = global positioning system
ID = identifier Std. Dev. = standard deviation

5.1.6.2 Minimum Detectable Concentration Calculation

The MDC is easiest to calculate for the case where the frequency distribution is normal for measurements made in an uncontaminated area (reference area) and where it is reasonable to assume that the variance is constant for the range between background levels and the level corresponding to the MDC. The frequency distributions of several TS5 gamma-scanning surveys are shown in Figure 5-29.

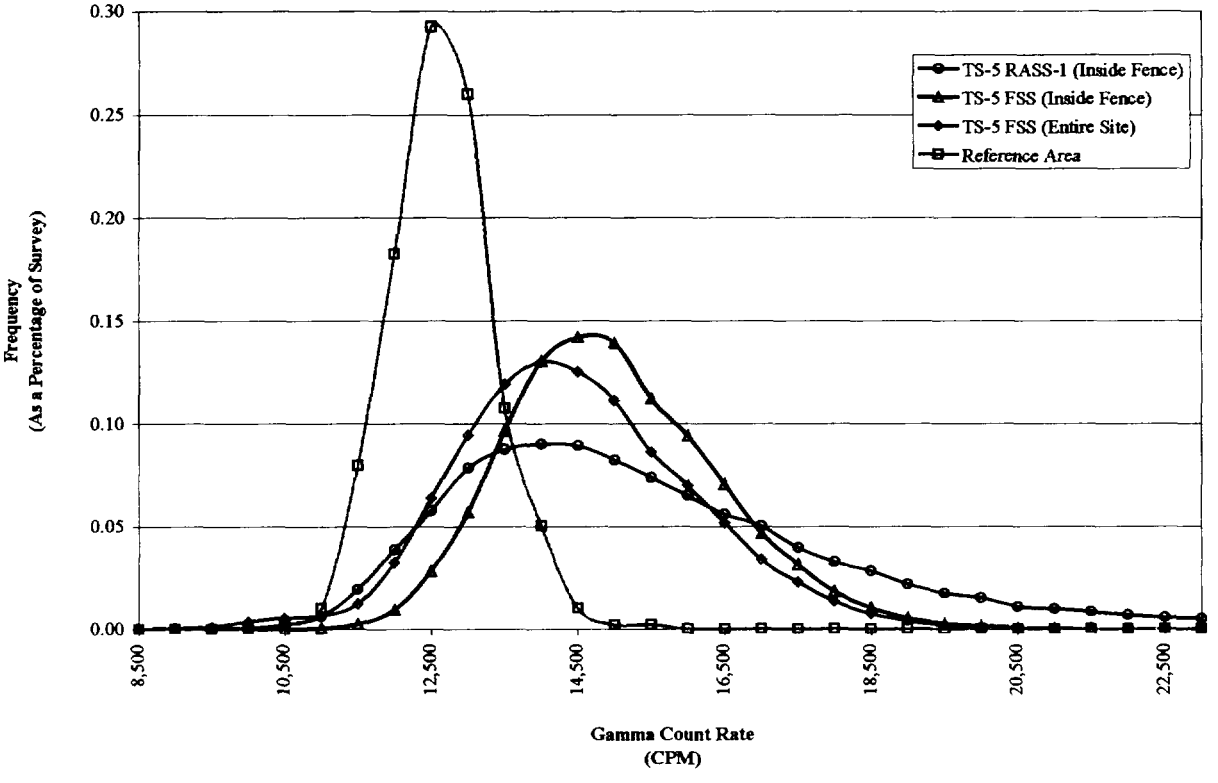

Figure 5-29. Frequency Distributions for Gamma Scanning Surveys, Environmental Restoration Program Site OT-10

The frequency distributions were developed by creating histograms of 500 cpm width and normalized so that the area beneath each curve is equal to 500. Distributions were plotted for the reference area, the first remedial action support survey at TS5 (TS5 RASS-1), and two data sets from the TS5 final status survey, (TS5 FSS Inside Fence and TS5 FSS Entire Site).

The frequency distribution for the scanning data from the reference area is shown in Figure 5-29. The mean and standard deviation for the 892 records are 12,400 cpm and 700 cpm, respectively. The coefficient of variation for the background gamma count rate records is 0.06. Histogram, Skewness and Kurtosis, and the Shapiro-Francia Tests for Normality were applied and failed to show that the data were not normally distributed. The 20 soil samples from the reference area averaged 0.91 pCi/g thorium-232 with a standard deviation of 0.15 pCi/g. This coefficient of variation of 0.16 is significantly larger than that for the gamma records (0.06) taken within the reference area.

The frequency distribution plot for the TS5 RASS-1 data shown in Figure 5-29 indicates the frequency distribution for TS5 after most of the contaminated material had been removed from the site. As anticipated, the distribution is skewed to the higher count rates because of the contaminated material still present at the site. The gamma radiation investigation level of 20,000 cpm was used as a threshold for removal of additional soil that could potentially exceed the thorium-232 $DCGL_w$. A final status survey within the fenced area resulted in the frequency distribution labeled TS5 FSS (Inside Fence). The curve labeled TS5 FSS (Entire Site) reflects all data in the Class 1 areas of TS5 and includes a large area outside the fence boundary that is near background levels.

A plot of the gamma radiation count rate and the corresponding thorium-232 concentration for the TS5 final status survey soil samples is presented in Figure 5-30 and shows a large scatter at near-background concentrations. A significant contribution to this scatter arises from the analytical error in the soil sample analysis at near-background levels. There is also a gamma shine influence on the gamma radiation count rates for soil samples taken in background areas adjacent to slightly contaminated areas. For the calculation of the scanning MDC, we considered all the data presented in Figure 5-30, and then considered only the data associated with soils contaminated with the thorium source material at concentrations of 1.5 pCi/g Thorium-232 or greater.

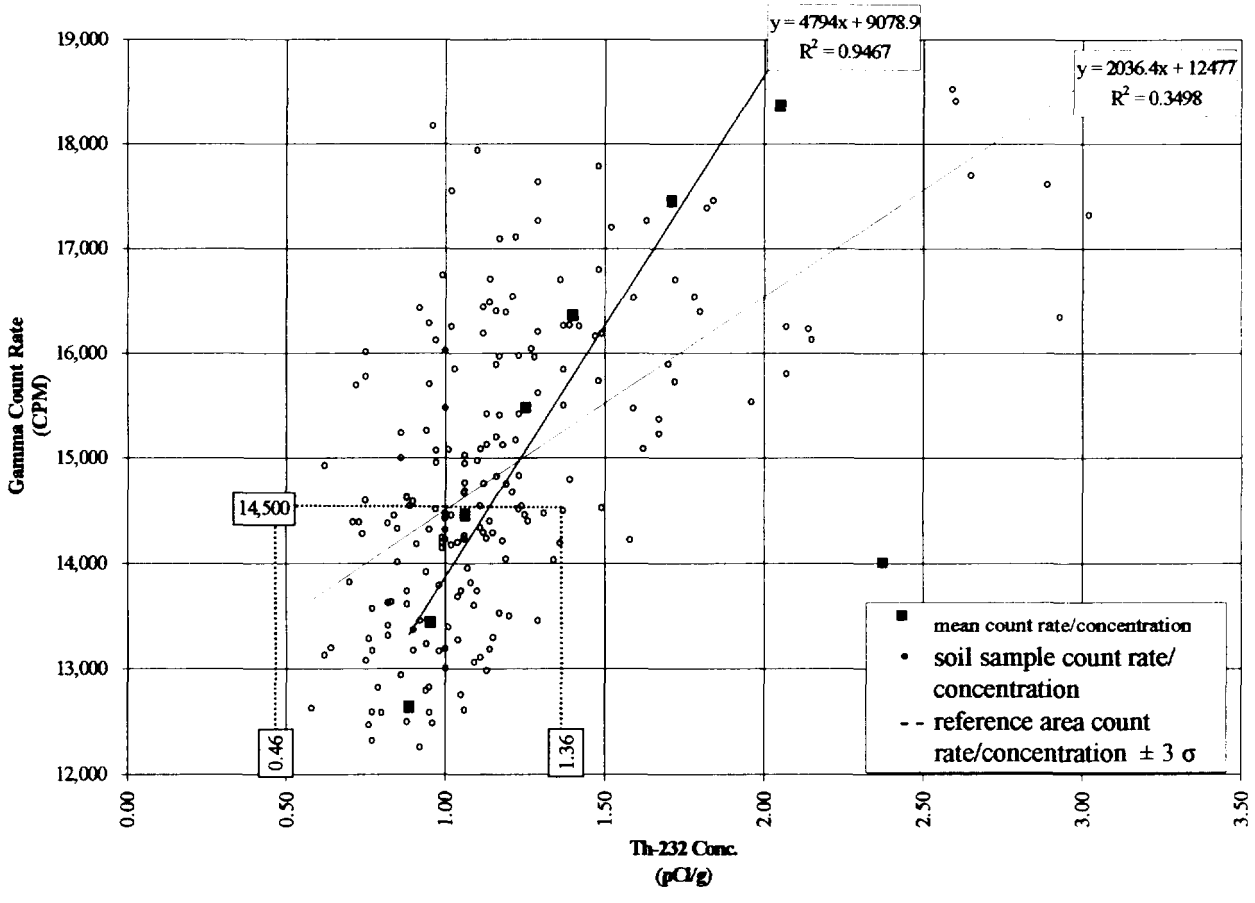

Figure 5-30. Training Site 5 Final Status Survey, Thorium-232 Soil Concentration and Static Gamma Count Rates, Environmental Restoration Program Site OT-10

MDCs using all data from Final Status Survey at TS5

The final status survey soil analytical data and the 1-minute integrated gamma radiation counts for TS5 are plotted in Figure 5-30. As expected, most of the thorium-232 concentration values are near natural background concentrations.

An area corresponding to the mean ± 3 standard deviations for the reference area is shown as a dotted rectangle in Figure 5-30, corresponding to the soil sample thorium-232 concentrations and the gamma radiation count rates from the scanning surveys. All data within the dotted lines are within the variations for the reference area and thus should be considered natural background levels. An explanation as to why there is a larger variation in the gamma count rates at these low thorium-232 values was given previously and was attributed to gamma shine from nearby contaminated areas. It is also known that the variation in the thorium-232 soil concentration includes the errors from the laboratory analysis. The reported laboratory standard deviation (counting error) is approximately 10 to 15 percent of the reported concentration at this concentration level. The 1-minute counts for the data shown in Figure 5-30 have less than 1 percent statistical uncertainty (1 standard deviation) and, therefore, the statistical error is negligible.

A least-squares-fit often places excessive weight on outlying data. To minimize this phenomenon, data pair values corresponding to the mean concentration and mean count rate were calculated for each datum falling between gamma radiation count-rate ranges of 1,000 cpm. The least-squares-fitted line was then calculated and plotted using the mean values as shown in Figure 5-30. The equation of the least-squares-fitted line of the mean values is given by

$$y = 4794x + 9079 \qquad \text{Eq. 5-2}$$

Where

y is the count rate in cpm, and

x is the thorium-232 concentration in pCi/g.

The y-intercept should be close to the mean background for the reference area. In this case, the value 13,440 cpm, calculated using the reference area mean thorium-232 concentration of 0.91 pCi/g, compares favorably to the mean count rate of 12,400 cpm for the reference area.

In the simplest form, where the distributions of the background concentrations and the measurement of the constituents are normally distributed, the MDC is expressed as the net level, L_D, such that the probability that an estimate of L is $\leq L_C$ is equal to β, or

$$L_D = L_C + z_{1-\beta}\,\sigma_o \qquad \text{Eq. 5-3}$$

Where

L_C is the critical level, defined as the level such that the probability of exceeding L_C is no greater than α if the constituent is absent, or $L_C = z_{1-\alpha}\sigma_o$.

In the preceding formula, σ_o is the variance of the net when the true value is zero. For the case where the variance is constant between L = 0 and L = L_D and $\alpha = \beta = 0.05$, then

$$L_D = 2z_{1-\alpha}\ \sigma_o = 3.29\ \sigma_o \qquad \text{Eq. 5-4}$$

The variance in the net count rate is equal to the sum of the variances of the background and the true value. For the situation where the variances are constant, adding the variances in quadrature results in $\sigma_o = \sqrt{2}\ \sigma_B$ or

$$L_D = 4.65\ \sigma_B \qquad \text{Eq. 5-5}$$

Where

σ_B^2 is the variance of the measurements.

Using the standard deviation for the reference area data, of 700-cpm, L_D equals 3,255 cpm. Dividing by the slope, 4,794 cpm/pCi/g, yields a net MDC of 0.7 pCi/g. This method ignores the variance in the slope of the fitted line, which appears (from the data scatter) to be large. However, when high density gamma survey contours are used to delineate areas of increased gamma emissions, areas averaging 1,000-cpm to 2,000-cpm above background are very evident from the survey maps. A measure of the possible error in determining the slope of the line is obtained by a least-squares-fitted line to the raw data. The least-squares-fitted line calculated from the raw data is given by

$$y = 2036.4x + 12{,}477 \qquad \text{Eq. 5-6}$$

Where

y is the gamma count rate in cpm, and

x is the thorium-232 concentration in pCi/g.

The least-squares-fitted line from the raw data is also shown on Figure 5-30.

Using equation 5-6 resulted in a slope of only 2,036 cpm/pCi/g. The calculated MDC for this calibration factor is 1.59 pCi/g. This is a reasonable best estimate of the upper limit of the net MDC for surveys conducted in areas having minimal contamination.

MDCs for More Highly Contaminated Areas

A more analytical approach to estimating the MDC from empirical data is suggested in the "Compendium of Analytical Nomenclature, Definitive Rules 1997" (International Union of Pure and Applied Chemistry, 1997). They develop a relationship of the MDC to the least-squares-fitted calibration data such as the gamma count rate and soil concentration data that exist for TS5 and other OT-10 training sites. They show that when the variance is constant, the MDC can be approximated by the equation

$$MDC \approx (2t_{p,v}\sigma_o/b)(K/I) \qquad \text{Eq. 5-7}$$

Where

$K = 1 + r(a,b)(\sigma_\alpha/\sigma_o)t_{p,v}(\sigma_\beta/b)$;

$I = 1 - t_{p,v}^2(\sigma_\beta/b)$;

$t_{p,v}$ is the critical value from the Student t distribution function corresponding to the confidence level, $1 - \alpha$ and degrees of freedom, v;

r(a,b) is the negative of the linear correlation coefficient for the best-fit line;

$y = bx + a$. $\sigma_{\alpha \text{ and}}\sigma_\beta$ are the variances of the intercept and slope, respectively; and

σ_o is the variance of the net count when the concentration is zero.

Again, because the variance is assumed constant over the low concentration range, the variance of the net count can be estimated as twice the variance of the background count or twice the square of the standard deviation ($2*700^2$ =9.8E5 cpm).

From the formulae that calculate the linear regression (Walpole and Myers, 1985) and associated confidence intervals, it can be shown that when x is the independent variable,

$$\sigma_\alpha^2 = \frac{\sum_{i=1}^{n} x_i^2}{n \times \sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2} \times \sigma^2 \qquad \text{Eq. 5-8}$$

$$\sigma_\beta^2 = \frac{\sigma^2}{n \times \sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2} \qquad \text{Eq. 5-9}$$

$$\sigma^2 = \frac{S_{yy} - b \times S_{xy}}{n-2} \qquad \text{Eq. 5-10}$$

Where

$$S_{xy}=\left(\sum_{i=1}^{n} x_i \times y_i\right)-\frac{\left(\sum_{i=1}^{n} x_i\right)\times\left(\sum_{i=1}^{n} y_i\right)}{n} \qquad \text{Eq. 5-11}$$

and

$$S_{yy}=\sum_{i=1}^{n} y_i^{\,2}-\frac{\left(\sum_{i=1}^{n} y_i\right)^2}{n} \qquad \text{Eq. 5-12}$$

The data for the 26 points in TS5 having the highest soil concentration were used to illustrate the method of calculating the net MDC, knowing only the calibration curve and the variance in the gamma count rate for the reference area. The plot of the data and least-squares-fit line is shown in Figure 5-31 where $R^2 = 0.303$, slope = 1,234 and y-intercept is 13,994. The data, formulae, and results for calculating the MDC and confidence limits for these 26 points are presented in Tables 5-28 and 5-29. For this example, the net MDC of 2.6 pCi/g above background was calculated using the above equations.

Table 5-28. Training Site 5 Final Status Survey Data for Calculating Confidence Limits

Sample	Unshielded Detector (cpm)	Thorium-232 (pCi/g)	Xi^2	Yi^2	Xi ´ Yi	Y'	Y"	$(X_i - X^-)^2$
TS5-SS-24-0000	17,616	2.89	8.4	310,323,456	50,910.2	15,906.1	19,216.6	0.77
TS5-SS-46-0000	14,225	1.58	2.5	202,350,625	22,475.5	14,365.3	17,523.7	0.19
TS5-SS-47-0000	15,477	1.59	2.5	239,537,529	24,608.4	14,378.8	17,534.9	0.18
TS5-SS-49-0000	15,374	1.67	2.8	236,359,876	25,674.6	14,485.7	17,625.4	0.12
TS5-SS-52-0000	17,267	1.63	2.7	298,149,289	28,145.2	14,432.5	17,579.9	0.15
TS5-SS-60-0000	15,092	1.62	2.6	227,768,464	24,449.0	14,419.1	17,568.6	0.15
TS5-SS-62-0000	16,349	2.93	8.6	267,289,801	47,902.6	15,946.3	19,275.1	0.84
TS5-SS-63-0000	18,526	2.59	6.7	343,212,676	47,982.3	15,592.4	18,789.8	0.33
TS5-SS-75-0000	16,255	2.07	4.3	264,225,025	33,647.9	14,994.8	18,103.7	0.00
TS5-SS-76-0000	15,729	1.72	3.0	247,401,441	27,053.9	14,551.7	17,682.9	0.09
TS5-SS-81-0000	15,235	1.67	2.8	232,105,225	25,442.5	14,485.7	17,625.4	0.12
TS5-SS-103-0000	16,705	1.72	3.0	279,057,025	28,732.6	14,551.7	17,682.9	0.09
TS5-SS-108-0000	17,703	2.65	7.0	313,396,209	46,913.0	15,656.9	18,873.4	0.41
TS5-SS-115-0000	15,805	2.07	4.3	249,798,025	32,716.4	14,994.8	18,103.7	0.00
TS5-SS-117-0000	17,325	3.02	9.1	300,155,625	52,321.5	16,035.6	19,408.0	1.02
TS5-SS-125-0000	17,461	1.84	3.4	304,886,521	32,128.2	14,707.4	17,823.4	0.03
TS5-SS-126-0000	16,542	1.78	3.2	273,637,764	29,444.8	14,630.0	17,752.7	0.05
TS5-SS-144-0000	15,900	1.7	2.9	252,810,000	27,030.0	14,525.4	17,659.8	0.10
TS5-SS-151-0000	17,390	1.82	3.3	302,412,100	31,649.8	14,681.7	17,799.7	0.04
TS5-SS-155-0000	16,402	1.8	3.2	269,025,604	29,523.6	14,655.9	17,776.2	0.05
TS5-SS-158-0000	17,205	1.52	2.3	296,012,025	26,151.6	14,283.9	17,457.0	0.24
TS5-SS-164-0000	15,536	1.96	3.8	241,367,296	30,450.6	14,859.1	17,967.9	0.00
TS5-SS-166-0000	16,131	2.15	4.6	260,209,161	34,681.7	15,091.4	18,204.6	0.02
TS5-SS-189-0000	16,233	2.14	4.6	263,510,289	34,738.6	15,079.5	18,191.9	0.02
TS5-SS-211-0000	18,413	2.6	6.8	339,038,569	47,873.8	15,603.2	18,803.6	0.35
TS5-SS-214-0000	16,534	1.59	2.5	273,373,156	26,289.1	14,378.8	17,534.9	0.18
	mean	2.01	4.26				Sum	5.512862

Notes:
cpm = counts per minute
pCi/g = picocuries per gram
TS = Training site

Table 5-29. Calculation of Confidence Limits and Minimum Detectable Concentration

Parameter	Result	
$S_{xx}=\sum_{i=1}^{n} x_i^{\,2}-\frac{\left(\sum_{i=1}^{n} x_i\right)^2}{n}$	6	
$S_{yy}=\sum_{i=1}^{n} y_i^{\,2}-\frac{\left(\sum_{i=1}^{n} y_i\right)^2}{n}$	27,710,280	
$S_{xy}=\left(\sum_{i=1}^{n} x_i \times y_i\right)-\frac{\left(\sum_{i=1}^{n} x_i\right)\times\left(\sum_{i=1}^{n} y_i\right)}{n}$	6,804	
$y'=(bx+a)-1.71\times S\times\sqrt{1+\frac{1}{n}+\frac{(x_i-\bar{x})^2}{S_{xx}}}$	See Table 5-28	
$y''=(bx+a)+1.71\times S\times\sqrt{1+\frac{1}{n}+\frac{(x_i-\bar{x})^2}{S_{xx}}}$	See Table 5-28	
$b=\frac{S_{xy}}{S_{xx}}$	1,234	
$\sigma^2=\frac{S_{yy}-b\times S_{xy}}{n-2}$	804,678	
$\sigma_\alpha^{\,2}=\frac{\sum_{i=1}^{n} x_i}{n\times\sum_{i=1}^{n}\left(x_i-\bar{x}\right)^2}\times\sigma^2$	622,012	
$\sigma_\beta^{\,2}=\frac{\sigma^2}{n\times\sum_{i=1}^{n}\left(x_i-\bar{x}\right)^2}$	5,614	
$\sigma_o^{\,2}$	980,000	
r $(a,b)^2$	0.303	
-r(a,b)	-0.55	
$t_{p,v}$ for n=26 and α=0.05	1.71	
MDC $\approx (2\, t_{p,v}\, \sigma_o/b)(K/I)$	2.6 pCi/g	(Eq. 5-6)

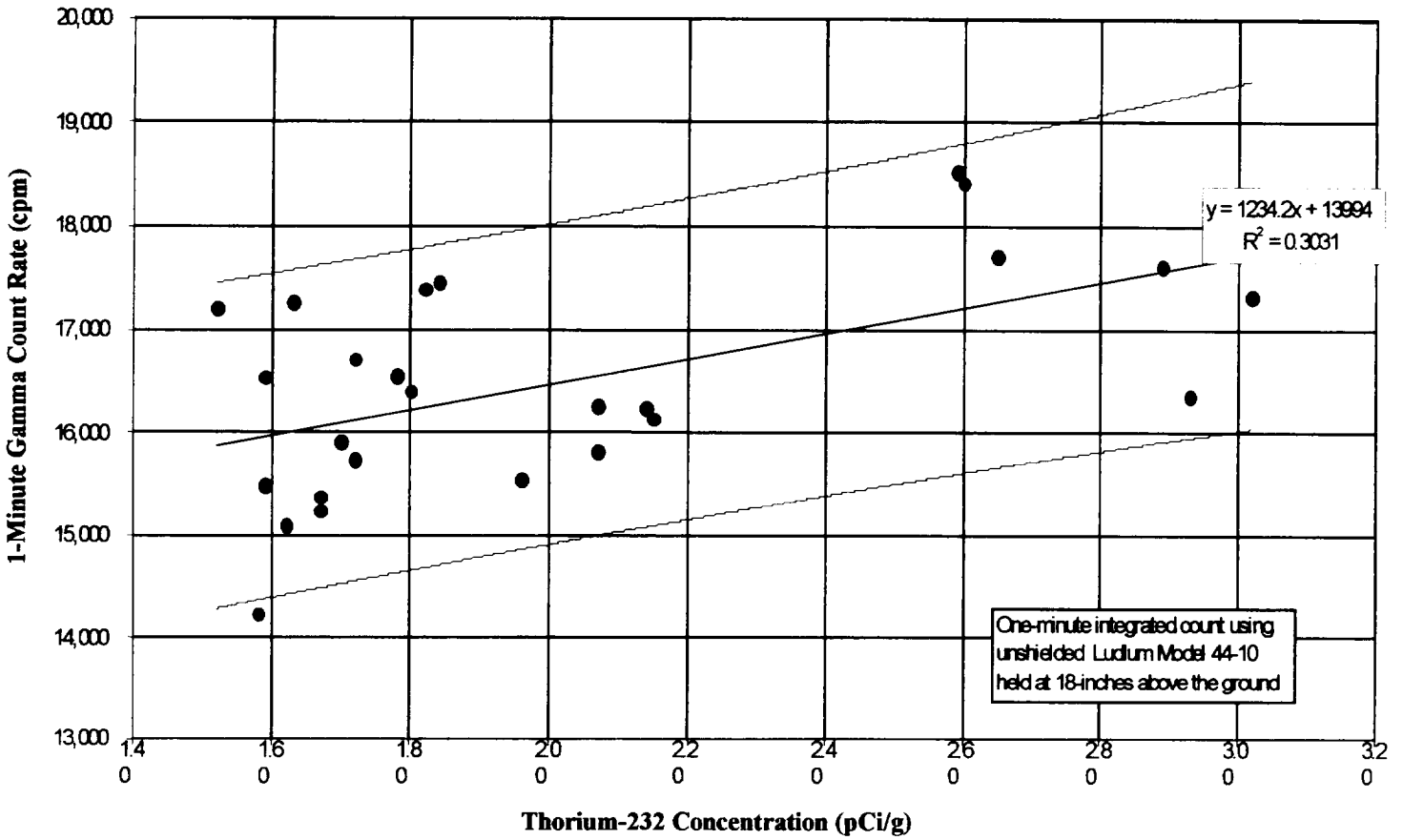

Figure 5-31. Gamma Count Rate vs. Concentration Correlation with Upper and Lower 95% Confidence Lines for Highest 26 Thorium-232 Concentration Values From Final Status Survey at Training Site 5, Environmental Restoration Program Site OT-10

5.1.6.3 Summary of Minimum Detectable Concentration Determinations

The use of high-density scanning data maps greatly improves the ability to identify slightly contaminated areas, and the scanning MDC obtained in this manner is approximately equal to the static MDC. Empirical estimates of the scanning MDC (and thus the static MDC) were 0.7 pCi/g, 1.6 pCi/g, and 2.6 pCi/g. These results compare favorably to the static and scanning MDCs of 0.4 pCi/g and 1.3 pCi/g, respectively, which were presented in the Decommissioning Plan (USAF, 2002).

5.2 Building Survey Results

This section describes the final status survey measurements from Building 28010 at TS8.

As described in the OT-10 Decommissioning Plan, the release criteria for structures are 170 dpm/100cm^2 total alpha activity and 34 dpm/100 cm^2 removable alpha activity (USAF, 2002). These criteria assume all alpha activity arises from thorium-232 and decay progeny, which is considered to be a conservative assumption since uranium, radium, and radon progeny are likely to be present in the building. While the decommissioning plan also presents criteria for beta activity from thorium-232, no beta activity measurements were collected during the final status surveys.

5.2.1 Survey Grid Areas

All interior and exterior surfaces of the building, including the double doors, were divided into grid blocks no larger than 1 m^2 each. The interior of the building was divided into a total of 121 grid blocks: 28 on the floor, 24 on the west wall, 25 on the east wall, and 44 on the ceiling. The exterior of the building was divided into 69 grid blocks: 34 on the exterior wall, 12 on the top ledge, 10 on the back side of the ledge, 10 on the concrete stoop, and 3 on the building vent. While most grid blocks were square and 1 m^2, some grid blocks were less than 1 m^2 and irregular.

5.2.2 Alpha Survey Measurements

5.2.2.1 Building Interior Survey

Total Alpha Measurements

All grid blocks were 100 percent surveyed for total alpha surface contamination using a 2-minute scanning time. The technician listened to the audio signal of the count rate to monitor for any areas of elevated activity. The results of the building interior scanning surveys are presented in Figures 5-32 through 5-35. The total gross alpha data from the interior survey are summarized in Table 5-30.

Table 5-30. Summary Statistics for Total Gross Alpha Measurements, Interior Survey of Building 28010, Environmental Restoration Program Site OT-10

Location	Number of Measurements	Lowest Activity (dpm/100 cm^2)	Highest Activity (dpm/100 cm^2)	Average +/- 1σ
Floor	28	0	72	16 +/- 13
West wall	24	0	39	13 +/- 14
East wall	25	0	72	30 +/- 24
Ceiling	44	0	81	19 +/-20

Notes:
cm^2 = square centimeters
dpm = disintegrations per minute

All total alpha measurements collected from the interior of Building 28010 were below the decommissioning criteria of 170 dpm/cm^2.

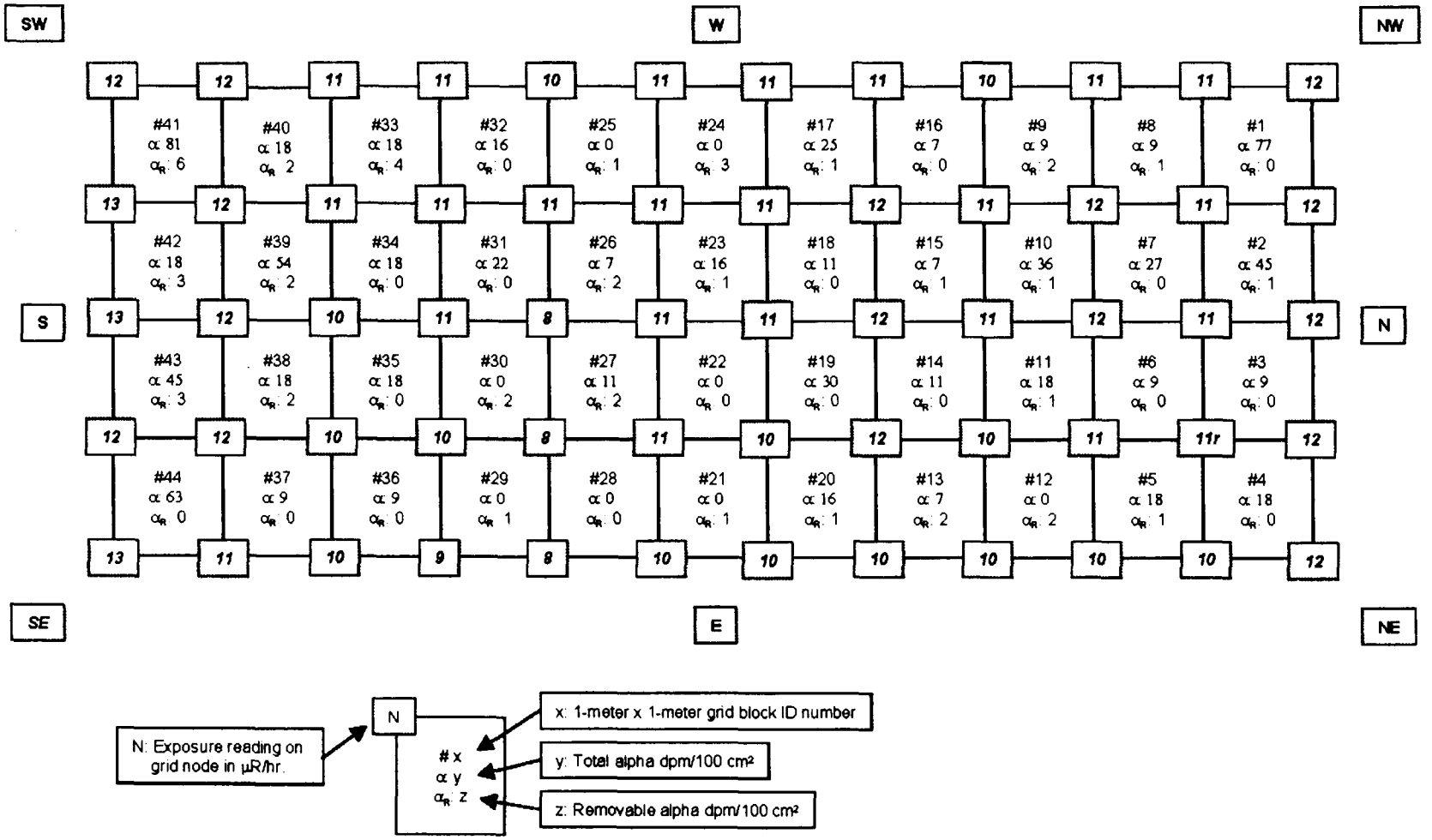

Figure 5-32. Final Status Survey, Interior of Building 28010, Ceiling, Environmental Restoration Program Site OT-10

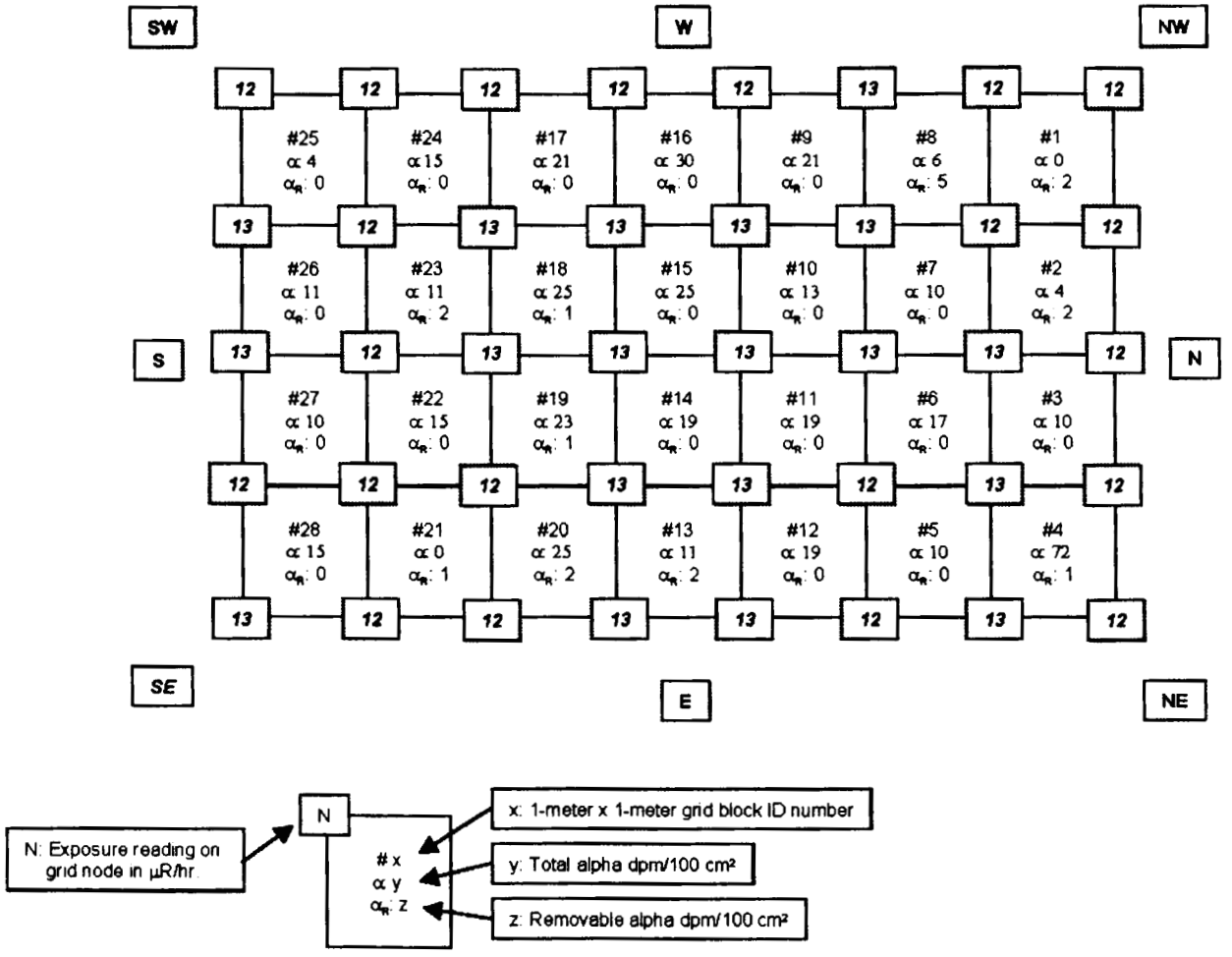

Figure 5-33. Final Status Survey, Interior of Building 28010, Floor, Environmental Restoration Program Site OT-10

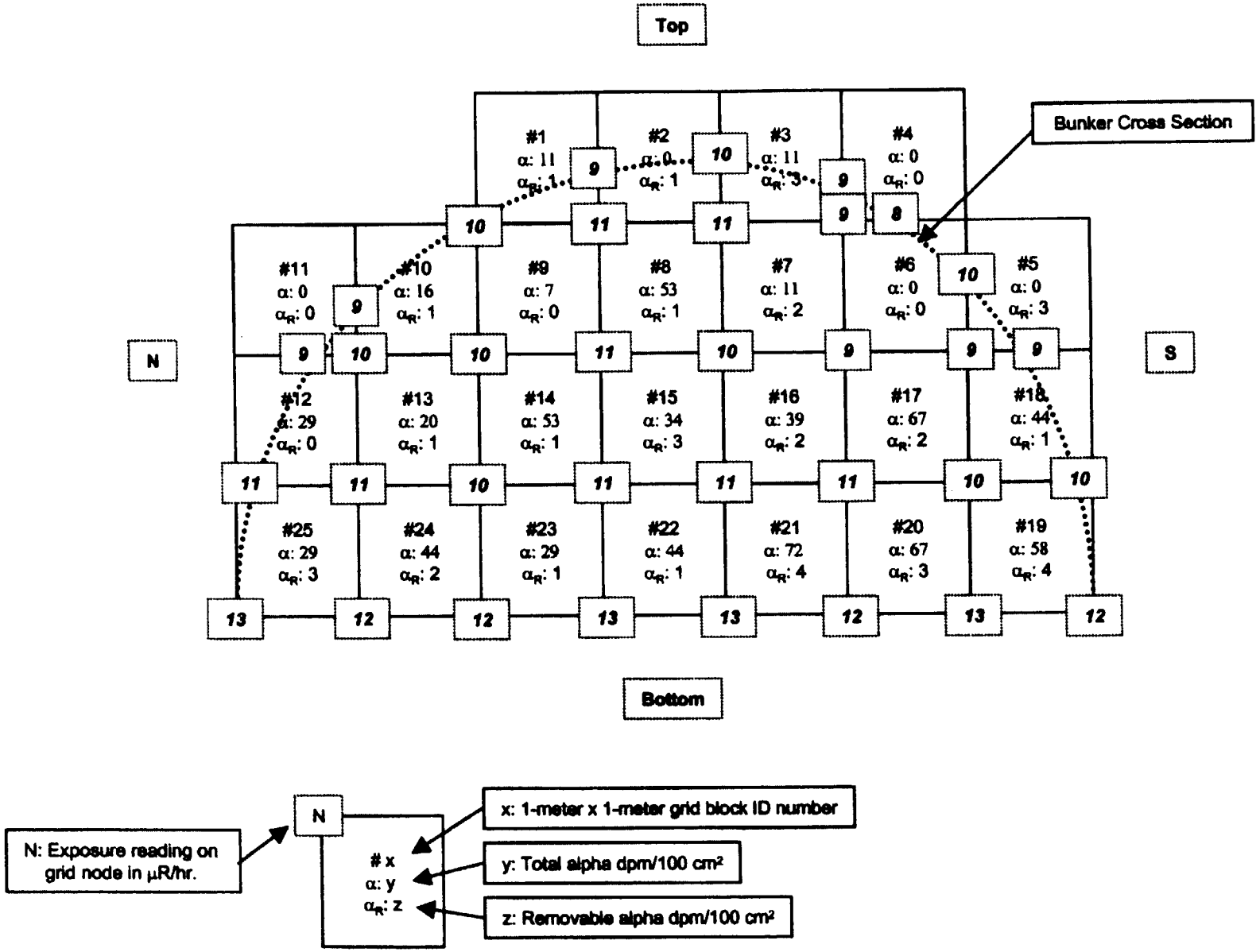

Figure 5-34. Final Status Survey, Interior of Building 28010, East Wall, Environmental Restoration Program Site OT-10

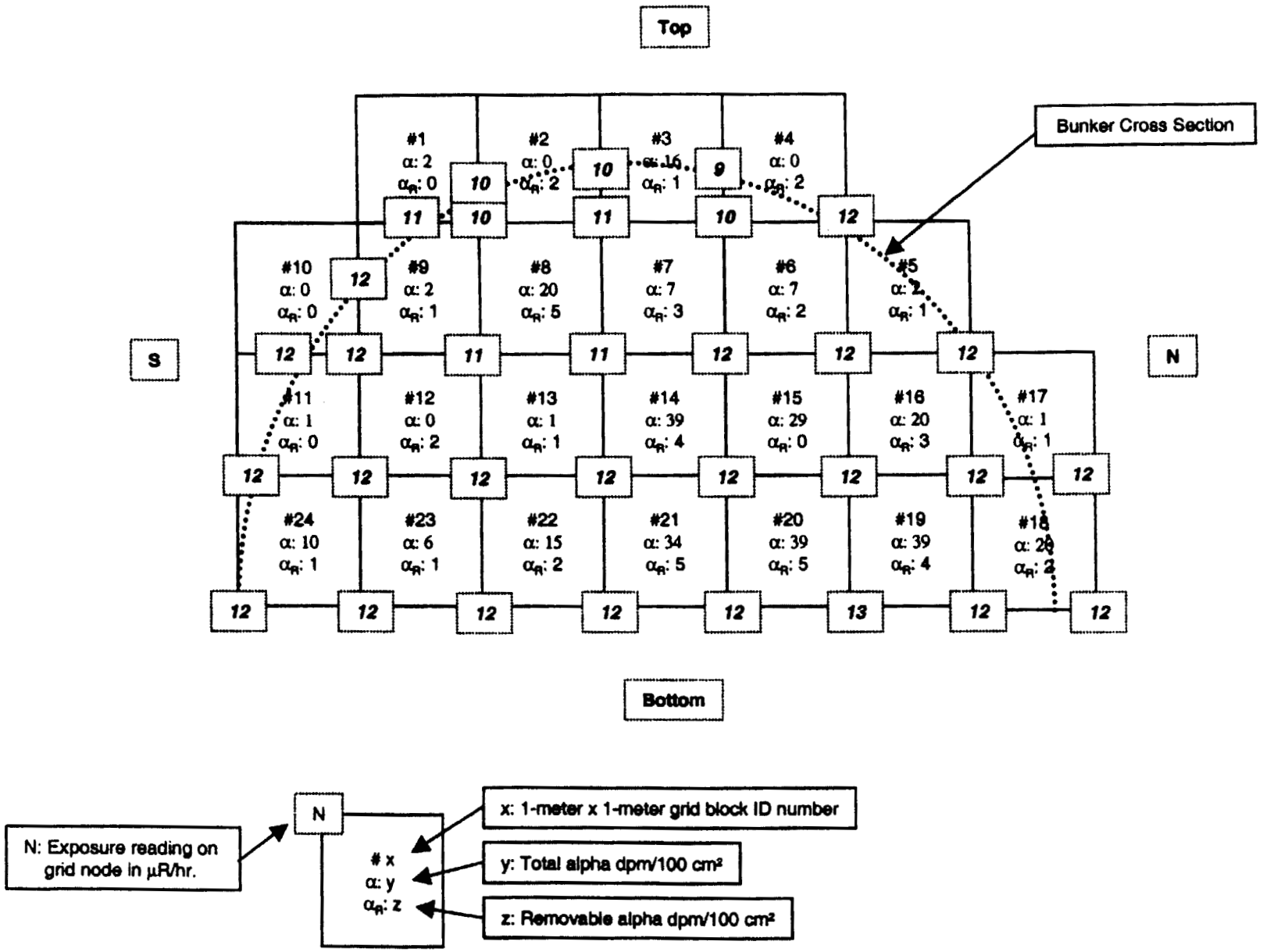

Figure 5-35. Final Status Survey, Interior of Building 28010, West Wall, Environmental Restoration Program Site OT-10

Removable Alpha Measurements

Removable activity was measured in the building interior by collecting swipe samples from each of the 121 grid blocks inside building 28010. Swipes were counted for 5 minutes on a Ludlum Model 2929 with a Ludlum Model 43-10-1 tray counter.

Figures 5-32 through 5-35 depict the removable surface activity in the interior of building 28010. The data from this survey are summarized in Table 5-31. All removable alpha swipe measurements were below the 34 dpm/100 cm^2 decommissioning criteria.

Table 5-31. Summary Statistics for Removable Gross Alpha Measurements, Interior Survey of Building 28010, Environmental Restoration Program site OT-10

Location	Number of Measurements	Lowest Activity (dpm/100 cm^2)	Highest Activity (dpm/100 cm^2)	Average +/- 1σ
Floor	28	0	5	1 +/- 1
West wall	24	0	5	2 +/- 2
East wall	25	0	4	2 +/- 1
Ceiling	44	0	6	1 +/- 1

Notes:
cm^2 = square centimeters
dpm = disintegrations per minute

5.2.2.2 Building Exterior Survey

Total Alpha Measurements

The exteriors of Building 28010 and the reference Building 28011 were not surveyed as part of the 2001 site characterization surveys. However, exterior surveys of both buildings were performed as part of the final status survey activities. The pre-remediation or site characterization survey results for the exterior of Building 28010 are presented in Figure 5-31. A summary of the site characterization data is presented in Table 5-32.

Table 5-32. Summary Statistics for Pre-Remediation Total Gross Alpha Measurements, Exterior of Building 28010, Environmental Restoration Program Site OT-10

Location	Number of Measurements	Lowest Activity (dpm/100 cm^2)	Highest Activity (dpm/100 cm^2)	Average +/- 1σ
Front	34	10	175	68 +/- 35
Ledge	22	18	277	120 +/- 86
Concrete stoop	10	18	131	64 +/- 35
Vent	3	62	305	159 +/- 129

Notes:
dpm = disintegrations per minute
cm^2 = square centimeters

Nine of the 69 grid blocks had activity above the 170 dpm/100 cm^2 decommissioning criteria for total alpha contamination. Decontamination of the ledge and vent areas was conducted using an acid wash and a wire brush. Following decontamination, the grid blocks were resurveyed and six of the grid blocks still exhibited total alpha contamination above the decommissioning criteria. The post-remediation survey results are presented in Figure 5-37.

A summary of the post-remediation survey results is presented in Table 5-33. Several of the Building 28010 exterior measurements did not comply with the release criteria due to elevated background activity. Therefore, the exterior of the reference building was surveyed to determine background activity.

Table 5-33. Summary Statistics for Post-Remediation Total Gross Alpha Measurements, Exterior of Building 28010, Environmental Restoration Program Site OT-10

Location	Number of Measurements	Lowest Activity (dpm/100 cm^2)	Highest Activity (dpm/100 cm^2)	Average +/- 1σ
Front	34	10	175	70 +/- 34
Ledge	22	18	215	104+/- 67
Concrete stoop	10	24	57	39 +/- 11
Vent	3	68	228	133 +/- 84

Notes:
cm^2 = square centimeters
dpm = disintegrations per minute

Measurements were taken from the exterior of the reference Building 28011 on the building front, top ledge, and concrete stoop. The data from the reference building are summarized in Table 5-34. The activity observed from these locations was consistent with the measurements taken from Building 28010.

Table 5-34. Summary Statistics for Total Gross Alpha Measurements, Exterior of Reference Building 28011, Environmental Restoration Program Site OT-10

Location	Number of Measurements	Lowest Activity (dpm/100 cm^2)	Highest Activity (dpm/100 cm^2)	Average +/- 1σ
Front	8	66	197	106 +/- 52
Ledge	7	84	320	174 +/- 90
Mean of metal surfaces	15	66	320	138 +/-
Concrete stoop	8	55	115	75 +/- 20

Notes:
cm^2 = square centimeters
dpm = disintegrations per minute

The elevated activity observed at reference Building 28011 supports the conclusion that elevated activity at building 28010 is due to radon daughters and not long-lived alpha contamination.

Average count rates were calculated for the metal and concrete surfaces at reference Building 28011. The front, ledge, and vent areas of the buildings are metal surfaces and the stoop is a concrete surface. The net activity at Building 28010 was calculated by subtracting the reference building mean activity from the post-remediation activity measurements. The calculated net activity values are presented in Figure 5-37. All net activity values are below the release criteria of 170 dpm/100 cm^2.

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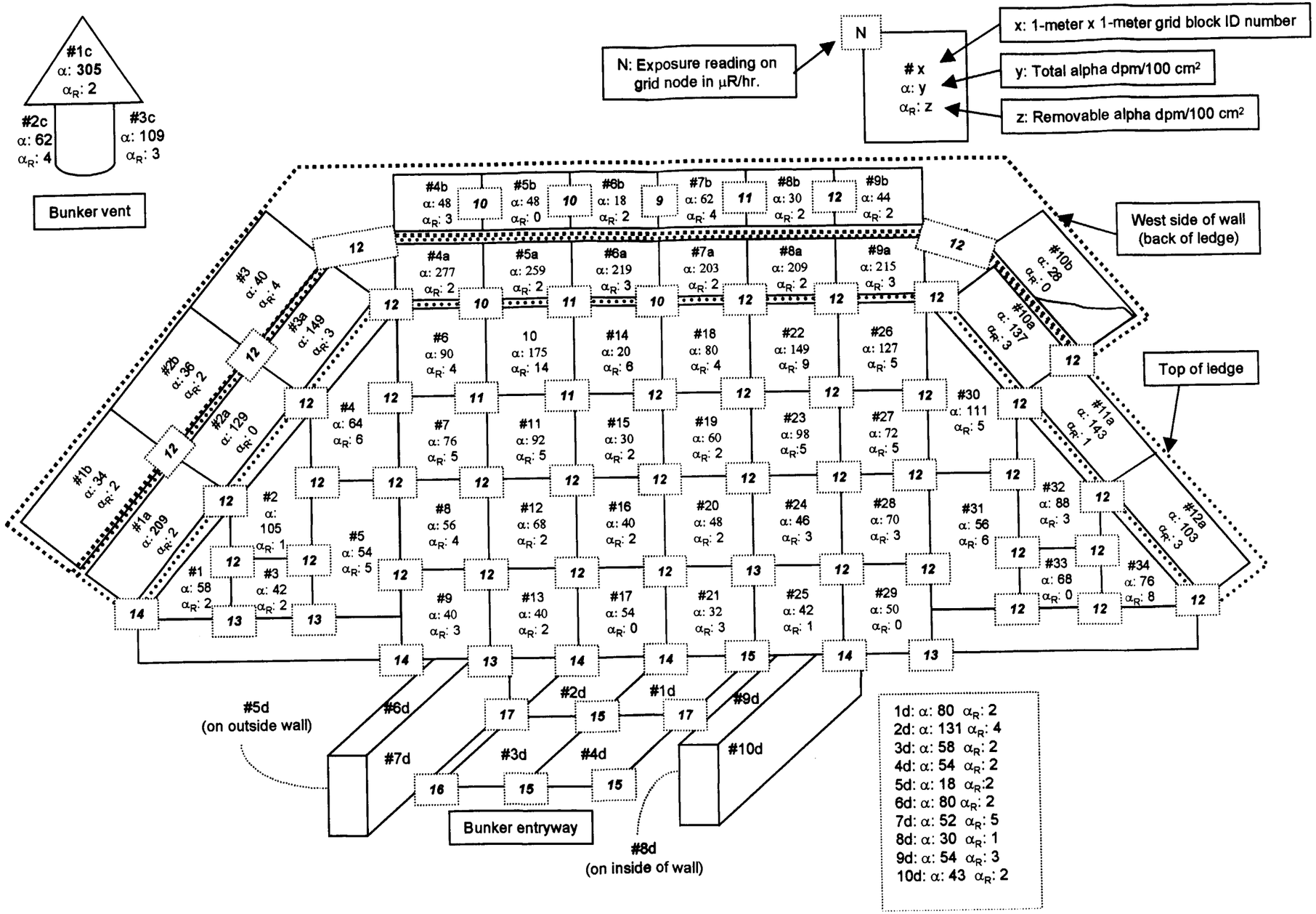

Figure 5-36. Final Status Survey, Exterior of Building 28010, Pre-Remediation, Environmental Restoration Program Site OT-10

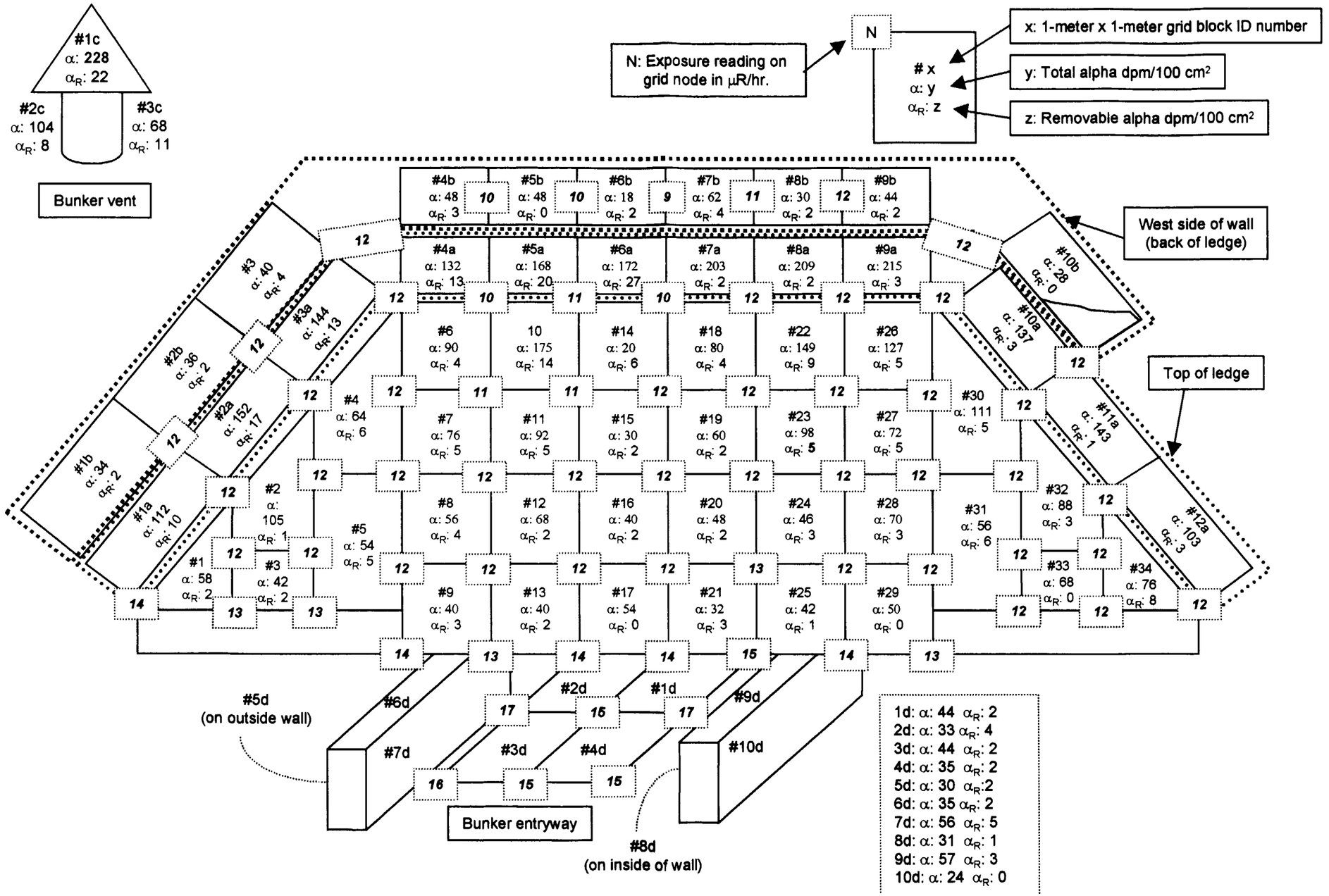

Figure 5-37. Final Status Survey, Exterior of Building 28010, Post-Remediation, Environmental Restoration Program Site OT-10

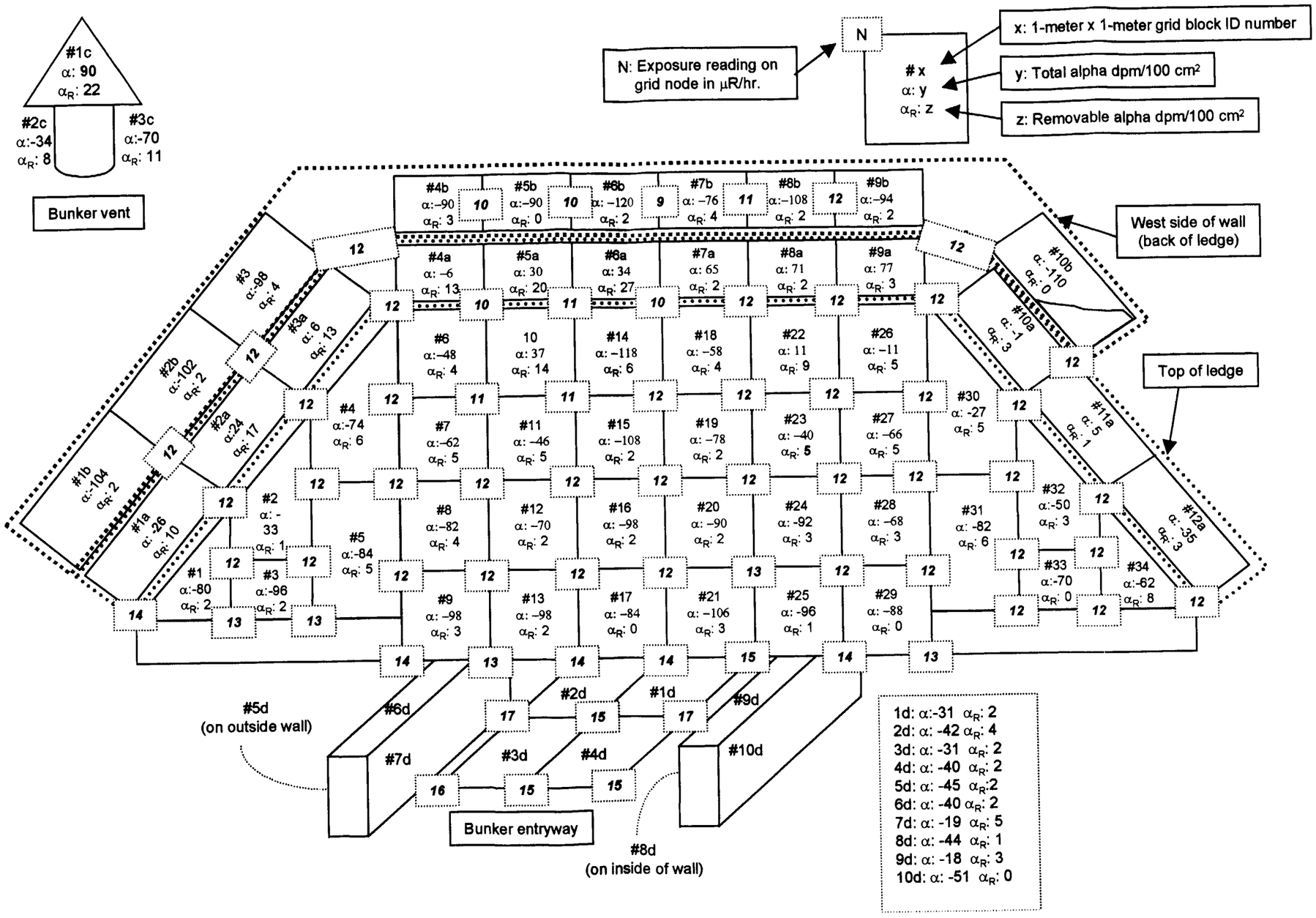

Figure 5-38. Final Status Survey, Exterior of Building 28010, Net Activity, Environmental Restoration Program Site OT-10

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Removable Alpha Measurements

Removable alpha activity on all of the 121 grid blocks was below the release criteria of 34 dpm/100 cm^2.

Removable activity was measured on the building exterior by collecting swipe samples from the 69 grid blocks outside the building. The post-remediation removable activity for each grid block is shown in Figure 5-36. The data from this survey are summarized in Table 5-35.

Table 5-35. Removable Gross Alpha Measurements, Exterior of Building 28010, Environmental Restoration Program Site OT-10

Location	Number of Measurements	Lowest Activity (dpm/100 cm^2)	Highest Activity (dpm/100 cm^2)	Average +/- 1σ
Front	34	0	14	4 +/- 3
Ledge	22	0	27	6 +/- 7
Concrete stoop	10	0	5	2 +/- 1
Vent	3	8	22	14 +/- 7

Notes:
cm^2 = square centimeters
dpm = disintegrations per minute

Removable alpha activity on all of the 69 grid blocks was below the release criteria of 34 dpm/100 cm^2.

5.2.3 Calculation of Minimum Detectable Concentration

Total alpha surface contamination within each grid block was measured with either a Ludlum Model 43-5 or Ludlum Model 43-90 alpha scintillation detector coupled to a Ludlum Model 2221 ratemeter/scaler. The Model 43-90 was used to collect measurements on the floor due to its superior efficiency and larger detection area. The Model 43-5 was used to collect measurements from the walls and ceiling because the geometry of the detector fit better into the corrugated shape of these areas. The MDC for each instrument was calculated from the following equation:

$$MDC = \frac{2.71+3.29\sqrt{[(R_b T_s)(1+T_s/T_b)]}}{\text{eff}^* \text{ area CF}^* T_s} \qquad \text{Eq. 5-13}$$

Where

R_b is the background count rate;

T_s and T_b are the count times of the sample and background, respectively;

eff is the efficiency; and

area CF is a conversion factor to convert detector area to an area of 100 cm^2.

On the first day the survey was conducted, the background on the Model 43-90 was 5 counts in 10 minutes and the efficiency was 0.21 cpm/dpm. Assuming a 2-minute count time for each grid block and the given instrument parameters, the MDC for this instrument on this day was 12 dpm/100 cm^2. The background on the Model 43-5 was 4 counts in 10 minutes, and the efficiency was 0.14 cpm/dpm. Again, given these parameters and a 2-minute count time of each wall and ceiling survey grid, the MDC for this instrument was 28 dpm/100 cm^2. The MARSSIM guidance recommends an MDC of less than 50 percent of the release criteria. Using the release criteria for total surface activity of 170 dpm/100 cm^2, it is evident that both instrument sets meet this guidance.

To calculate the MDC for the removable activity, equation 5-13 was modified by omitting the area conversion factor (CF). Using a 600-minute background, the MDCs for the Ludlum Model 2929s over the three days used to count the swipe samples ranged from 2.4 to 3.3 dpm/100 cm^2. These MDCs are below the MARSSIM guidance of less than 50 percent of 34 dpm/100 cm^2 release criteria.

5.2.4 Exposure Rate Measurements

Gamma-ray exposure rate readings were taken on contact at all grid intersection points on the inside of the building. One hundred sixty five exposure rate measurements were taken inside the building including 40 from the floor, 60 from the ceiling, 34 from the east wall, and 31 from the west wall. Exposure rate measurements ranged from 8 to 13 μR/hr, inclusive of background, which are similar to measurements collected in reference Building 28011.

The exposure rate measurements for the inside of building 28010 are presented on Figures 5-32 through 5-35.

Gamma-ray exposure rate readings were taken on contact at all grid intersection points on the building exterior. Sixty seven exposure rate readings were taken outside the building. All readings ranged between 9 and 17 μR/hr, inclusive of background, which are similar to readings observed in the reference building, building 28011. The exposure rate measurements for the outside of building 28010 are depicted on Figure 5-37.

5.3 Statistical Evaluation of Final Status Survey Results

The land area final status survey results were statistically evaluated to determine if the OT-10 sites meet the release criteria. The building survey results were not statistically evaluated because all measurements were below the release criteria after background was subtracted.

The statistical evaluation consists of three components:

- The first component is whether soil concentrations at each MARSSIM Class 1 survey unit are less than the $DCGL_w$. In other words, on average, are radionuclide concentrations at a Class 1 survey unit less than the release criterion? This is evaluated using the mean concentrations and the WRS Test.

- The second component is when individual samples exceed the $DCGL_w$, do they exceed the elevated measurement comparison $DCGL_{EMC}$? In other words, are there individual locations that have a high enough concentration to be of concern, even if they do not cause the average concentration at the survey unit to exceed the $DCGL_w$? This analysis was extended to both the final status survey soil samples and areas above the 23,000-cpm investigation level from the final status gamma scanning surveys.

- The third component of the statistical analysis is whether there are areas of contamination that are greater than typical for a specific Class 1 survey unit, which, while not a concern individually, causes a concern when considered together. This is based on a unity rule analysis. The following sections describe these analyses.

5.3.1 Mean and Wilcoxon Rank Sum Tests

Each MARSSIM Class 1 survey unit was evaluated using the mean and the WRS test. The $DCGL_w$ is intended for comparison to the mean. The WRS test is actually a test of the median. However, if a large portion of a Class 1 survey unit exceeds the $DCGL_w$ by a small amount, the median is also a sensitive indicator regarding whether the final status survey criteria have not been met.

The mean thorium-232 activity in each MARSSIM Class 1 survey unit is summarized in Tables 5-17 through 5-20. The mean of all of the units is less than the $DCGL_w$, and thus, all of the units meet this criterion.

Under the WRS test, the null hypothesis is that the Class 1 survey unit exceeds background by at least the $DCGL_w$. The WRS test is performed by adding the $DCGL_w$ to each of the background measurements to provide "adjusted reference area measurements." The adjusted reference area measurements are then pooled together with the Class 1 survey unit data and ordered from lowest to highest. The lowest result is given a rank of 1, the second lowest a rank of 2, etc. The ranks of the Class 1 survey unit data are summed and compared to those for the adjusted reference area data. In order to reject the null hypothesis, the sum of the adjusted reference area ranks must be above a critical value taken from MARSSIM Table I.4 (EPA, 1997).

The WRS test was performed using α and β of 0.05. The parameter α is the level of significance and is the maximum probability of rejecting the null hypothesis when it is, in fact, true. The parameter β is the probability that the null hypothesis will be accepted when it is, in fact, false; $1-\beta$ represents the power of the test to detect a false null hypothesis.

A requirement for using the WRS test under MARSSIM is that non-detects must not exceed 40 percent of either the reference area or site data. Additionally, in accordance with MARSSIM, all detections below the highest reporting limit are also assigned the same value, and these are treated as tied data. For example, if one result is <0.9 pCi/g and a second result is 0.7 pCi/g, these results are treated as ties.

Finally, if all of the Class 1 survey unit data are less than the $DCGL_w$, then all the Class 1 survey unit data are less than all adjusted reference area measurements. When this happens, the null hypothesis will always be rejected, and the Class 1 survey unit will pass the WRS test. For example, 10 samples were

collected at most Class 1 survey units, and there are 20 reference area samples. If all of the Class 1 survey unit data are less than the $DCGL_w$, they will have ranks 1 through 10, while the ranks of the adjusted reference area data will be 11 through 30. In this example, a critical value of 347 is obtained from MARSSIM Table I.4 and the sum of the ranks for the adjusted reference area data is 410. The sum of the ranks for the adjusted reference area data is above the critical value and therefore the null hypothesis for the survey unit is rejected. Thus, as long as the Class 1 survey unit data are less than the $DCGL_w$, it is known that the Class 1 survey unit passes, even without performing any calculations.

Each of the MARSSIM Class 1 survey units was evaluated using the WRS test. The evaluation used the analytical results from the randomly selected soil sample locations and those from burial pit sample locations. Survey units with burial pit samples include TS5 survey units 2, 5, 10, and 14 and TS6 survey units 23, 27, and 30. The summaries of the WRS test results for each site are presented in Tables 5-36 through 5-39.

The WRS evaluation for each Class 1 unit is presented in Appendix D. All of the Class 1 units passed the WRS test. There is a potential for failing the WRS test only when there is detection above the $DCGL_w$. There was only one soil sample result above the $DCGL_w$. This was at TS6 at unit TS6-1 with a thorium-232 concentration of 16.5 pCi/g. This unit passed the WRS test.

As previously discussed, the WRS test is not to be employed if there are more than 40 percent nondetects. For some survey units, for example TS7 survey units 5, 6, 7, 8, and 9, nondetects, in combination with detections less than the maximum reporting limit, exceed this limit. However, this did not generally invalidate the use of the WRS test when all data were less than the $DCGL_w$. When all samples are less than the $DCGL_w$, the site automatically passes the WRS test, and nondetects are not an issue.

Table 5-36. Summary of Wilcoxon Rank Sum Test Results for TS5, Multi-Agency Radiation Survey Site Investigation Manual (MARSSIM) Class 1 Survey Units, Environmental Restoration Program Site OT-10

TS5 MARSSIM Unit	1	2	3	4	5	6	7
Number of Reference Area Samples:	20	20	20	20	20	20	20
Number of Site Samples:	10	24	10	10	28	10	10
Total Number of Samples:	30	44	30	30	48	30	30
Sum of Ranks:	465	990	465	465	1176	465	465
Sum of Reference Area Ranks:	410	690	410	410	770	410	410
Critical Value (for alpha = 0.05)	347	520	347	347	569	347	347
IF "Sum of Reference Area Ranks" > "Critical Value" then Site Passes WRS Test", Where "Sum of Reference Area Ranks" < "Critical Value" then Site Fails WRS Test	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES
Number of Non-Detects:	5	5	5	5	5	5	5
Number of Non-Detects + Values < Max ND Reporting Limit:	10	11	10	9	14	9	10
40% of the data from either the reference area or the survey unit are "less than", the WRS Test *cannot* be used.	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
TS5 MARSSIM Unit	8	9	10	11	12	13	14
Number of Reference Area Samples:	20	20	20	20	20	20	20
Number of Site Samples:	10	10	13	10	10	10	17
Total Number of Samples:	30	30	33	30	30	30	37
Sum of Ranks:	465	465	561	465	465	465	703
Sum of Reference Area Ranks:	410	410	470	410	410	410	550
Critical Value (for alpha = 0.05)	347	347	385	347	347	347	434
IF "Sum of Reference Area Ranks" > "Critical Value" then Site Passes WRS Test", Where "Sum of Reference Area Ranks" < "Critical Value" then Site Fails WRS Test	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES
Number of Non-Detects:	5	5	5	5	5	5	5
Number of Non-Detects + Values < Max ND Reporting Limit:	10	10	9	10	11	10	12
40% of the data from either the reference area or the survey unit are "less than", the WRS Test *cannot* be used.	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
TS5 MARSSIM Unit	15	16	17	18	19		
Number of Reference Area Samples:	20	20	20	20	20		
Number of Site Samples:	10	10	10	10	10		
Total Number of Samples:	30	30	30	30	30		
Sum of Ranks:	465	465	465	465	465		
Sum of Reference Area Ranks:	410	410	410	410	410		
Critical Value (for alpha = 0.05)	347	347	347	347	347		
IF "Sum of Reference Area Ranks" > "Critical Value" then Site Passes WRS Test", Where "Sum of Reference Area Ranks" < "Critical Value" then Site Fails WRS Test	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES		
Number of Non-Detects:	5	5	5	5	5		
Number of Non-Detects + Values < Max ND Reporting Limit:	9	11	12	11	12		
40% of the data from either the reference area or the survey unit are "less than", the WRS Test *cannot* be used.	FALSE	FALSE	FALSE	FALSE	FALSE		

Notes:
MARSSSIM = Multi-Agency Radiation Survey and Site Investigation Manual (EPA, 1997)
ND = Non detects
TS = Training site
WRS = Wilcoxon Rank Sum

Table 5-37. Summary of Wilcoxon Rank Sum Test Results for TS6, Multi-Agency Radiation Survey Site Investigation Manual (MARSSIM) Class 1 Survey Units, Environmental Restoration Program Site OT-10

TS6 MARSSIM Unit	1	2	3	4	5	6	7
Number of Reference Area Samples:	20	20	20	20	20	20	20
Number of Site Samples:	10	10	10	10	10	10	10
Total Number of Samples:	30	30	30	30	30	30	30
Sum of Ranks:	465	465	465	465	465	465	465
Sum of Reference Area Ranks:	390	410	401	410	410	410	410
Critical Value (for alpha = 0.05)	347	347	347	347	347	347	347
IF "Sum of Reference Area Ranks" > "Critical Value" then Site Passes WRS Test", Where "Sum of Reference Area Ranks" < "Critical Value" then Site Fails WRS Test	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES
Number of Non-Detects:	5	6	5	5	6	5	5
Number of Non-Detects + Values < Max ND Reporting Limit:	11	14	14	18	13	16	12
40% of the data from either the reference area or the survey unit are "less than", the WRS Test *cannot* be used.	FALSE	TRUE	TRUE	TRUE	TRUE	TRUE	FALSE
TS6 MARSSIM Unit	8	9	10	11	12	13	14
Number of Reference Area Samples:	20	20	20	20	20	20	20
Number of Site Samples:	10	10	10	10	10	10	10
Total Number of Samples:	30	30	30	30	30	30	30
Sum of Ranks:	465	465	465	465	465	465	465
Sum of Reference Area Ranks:	410	410	410	410	410	410	410
Critical Value (for alpha = 0.05)	347	347	347	347	347	347	347
IF "Sum of Reference Area Ranks" > "Critical Value" then Site Passes WRS Test", Where "Sum of Reference Area Ranks" < "Critical Value" then Site Fails WRS Test	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES
Number of Non-Detects:	6	5	6	5	5	7	5
Number of Non-Detects + Values < Max ND Reporting Limit:	15	18	14	13	11	17	10
40% of the data from either the reference area or the survey unit are "less than", the WRS Test *cannot* be used.	TRUE	TRUE	TRUE	TRUE	FALSE	TRUE	FALSE
TS6 MARSSIM Unit	15	16	17	18	19	20	21
Number of Reference Area Samples:	20	20	20	20	20	20	20
Number of Site Samples:	10	10	10	10	10	10	10
Total Number of Samples:	30	30	30	30	30	30	30
Sum of Ranks:	465	465	465	465	465	465	465
Sum of Reference Area Ranks:	410	410	410	410	410	410	410
Critical Value (for alpha = 0.05)	347	347	347	347	347	347	347
IF "Sum of Reference Area Ranks" > "Critical Value" then Site Passes WRS Test", Where "Sum of Reference Area Ranks" < "Critical Value" then Site Fails WRS Test	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES
Number of Non-Detects:	5	5	6	5	5	5	5
Number of Non-Detects + Values < Max ND Reporting Limit:	9	10	13	10	9	10	16
40% of the data from either the reference area or the survey unit are "less than", the WRS Test *cannot* be used.	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	TRUE

Table 5-37. Summary of Wilcoxon Rank Sum Test Results for TS6, Multi-Agency Radiation Survey Site Investigation Manual (MARSSIM) Class 1 Survey Units, Environmental Restoration Program Site OT-10 (concluded)

TS6 MARSSIM Unit	22	23	24	25	26	27	28
Number of Reference Area Samples:	20	20	20	20	20	20	20
Number of Site Samples:	10	11	10	10	10	23	10
Total Number of Samples:	30	31	30	30	30	43	30
Sum of Ranks:	465	496	465	465	465	946	465
Sum of Reference Area Ranks:	410	430	410	410	410	670	410
Critical Value (for alpha = 0.05)	347	367	347	347	347	508	347
IF "Sum of Reference Area Ranks" > "Critical Value" then Site Passes WRS Test", Where "Sum of Reference Area Ranks" < "Critical Value" then Site Fails WRS Test	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES
Number of Non-Detects:	6	5	5	6	5	6	6
Number of Non-Detects + Values < Max ND Reporting Limit:	13	9	9	15	11	13	11
40% of the data from either the reference area or the survey unit are "less than", the WRS Test *cannot* be used.	TRUE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE
TS6 MARSSIM Unit	29	30	31	32	33	34	35
Number of Reference Area Samples:	20	20	20	20	20	20	20
Number of Site Samples:	10	22	10	10	10	10	10
Total Number of Samples:	30	42	30	30	30	30	30
Sum of Ranks:	465	903	465	465	465	465	465
Sum of Reference Area Ranks:	410	650	410	410	410	410	410
Critical Value (for alpha = 0.05)	347	495	347	347	347	347	347
IF "Sum of Reference Area Ranks" > "Critical Value" then Site Passes WRS Test", Where "Sum of Reference Area Ranks" < "Critical Value" then Site Fails WRS Test	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES
Number of Non-Detects:	5	7	5	5	7	5	6
Number of Non-Detects + Values < Max ND Reporting Limit:	10	14	9	11	15	11	11
40% of the data from either the reference area or the survey unit are "less than", the WRS Test *cannot* be used.	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE

Notes:
MARSSSIM = Multi-Agency Radiation Survey and Site Investigation Manual (EPA, 1997)
ND = Non detects
TS = Training site
WRS = Wilcoxon Rank Sum

Table 5-38. Summary of Wilcoxon Rank Sum Test Results for TS7, Multi-Agency Radiation Survey Site Investigation Manual (MARSSIM) Class 1 Survey Units, Environmental Restoration Program Site OT-10

TS7 MARSSIM Unit	1	2	3	4	5	6	7
Number of Reference Area Samples:	20	20	20	20	20	20	20
Number of Site Samples:	10	10	10	10	10	10	10
Total Number of Samples:	30	30	30	30	30	30	30
Sum of Ranks:	465	465	465	465	465	465	465
Sum of Reference Area Ranks:	410	410	410	410	410	410	410
Critical Value (for alpha = 0.05)	347	347	347	347	347	347	347
IF "Sum of Reference Area Ranks" > "Critical Value" then Site Passes WRS Test", Where "Sum of Reference Area Ranks" < "Critical Value" then Site Fails WRS Test	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES
Number of Non-Detects:	5	5	5	5	6	6	5
Number of Non-Detects + Values < Max ND Reporting Limit:	10	12	9	10	14	14	16
40% of the data from either the reference area or the survey unit are "less than", the WRS Test *cannot* be used.	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE

TS7 MARSSIM Unit	8	9	10
Number of Reference Area Samples:	20	20	20
Number of Site Samples:	10	10	10
Total Number of Samples:	30	30	30
Sum of Ranks:	465	465	465
Sum of Reference Area Ranks:	410	410	410
Critical Value (for alpha = 0.05)	347	347	347
IF "Sum of Reference Area Ranks" > "Critical Value" then Site Passes WRS Test", Where "Sum of Reference Area Ranks" < "Critical Value" then Site Fails WRS Test	SITE PASSES	SITE PASSES	SITE PASSES
Number of Non-Detects:	5	5	5
Number of Non-Detects + Values < Max ND Reporting Limit:	15	13	13
40% of the data from either the reference area or the survey unit are "less than", the WRS Test *cannot* be used.	TRUE	TRUE	TRUE

Notes:
MARSSSIM = Multi-Agency Radiation Survey and Site Investigation Manual (EPA, 1997)
ND = Non detects
TS = Training site
WRS = Wilcoxon Rank Sum

Table 5-39. Summary of Wilcoxon Rank Sum Test Results for TS8, Multi-Agency Radiation Survey Site Investigation Manual (MARSSIM) Class 1 Survey Units, Environmental Restoration Program Site OT-10

TS8 MARSSIM Unit	1	2	3	4	5	6	7
Number of Reference Area Samples:	20	20	20	20	20	20	20
Number of Site Samples:	10	10	13	10	10	10	10
Total Number of Samples:	30	30	33	30	30	30	30
Sum of Ranks:	465	465	561	465	465	465	465
Sum of Reference Area Ranks:	410	410	470	410	410	410	410
Critical Value (for alpha = 0.05)	347	347	385	347	347	347	347
IF "Sum of Reference Area Ranks" > "Critical Value" then Site Passes WRS Test", Where "Sum of Reference Area Ranks" < "Critical Value" then Site Fails WRS Test	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES	SITE PASSES
Number of Non-Detects:	5	5	5	5	5	5	5
Number of Non-Detects + Values < Max ND Reporting Limit:	11	12	13	14	14	17	17
40% of the data from either the reference area or the survey unit are "less than", the WRS Test *cannot* be used.	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE	TRUE

Notes:
MARSSSIM = Multi-Agency Radiation Survey and Site Investigation Manual (EPA, 1997)
ND = Non detects
TS = Training site
WRS = Wilcoxon Rank Sum

5.3.2 Elevated Measurement Comparison

Elevated measurement comparisons are made to ensure that, even if a Class 1 survey unit may have average activity less than the $DCGL_w$, there are no localized areas of contamination that remain a concern. In general, the elevated measurement comparison takes the form of

$$DCGL_{EMC} = DCGL_w \times F \qquad \text{Eq. 5-14}$$

Where

F is a factor dependent upon the size of the elevated area.

The values of F were calculated in the OT-10 Decommissioning Plan (USAF, 2002) and are presented in Table 3-2 of this report.

As required by MARSSIM, the elevated measurement comparison was performed on the systematic-sampling grid, and locations were identified by the gamma scanning surveys (EPA, 1997). For the soil samples collected during the final status survey, the typical Class 1 unit has 10 samples from a 2,000-m^2 area. Therefore, each measurement represents approximately 200 m^2. The value of F for a 200-m^2 area is 1.13, resulting in a $DCGL_{EMC}$ of 6.4 pCi/g.

Only one final status survey soil sample, TS6-SS-379, exceeded the $DCGL_w$ and was evaluated using the elevated measurement comparison. The analytical result of 16.1 pCi/g also exceeds the $DCGL_{EMC}$ of 6.4pCi/g for a 200-m^2 area. Further evaluation of the area surrounding the sample location failed to identify any elevated gamma activity. All gamma radiation measurements in the vicinity were below the 20,000-cpm investigation level. The elevated soil concentration appears to be limited to the sample location. Therefore, assuming an elevated measurement area of 200-m^2 is believed to be overly conservative; all final status survey samples were 5-point composites collected within a 3-ft-diameter circle. The area factor of 3.65 for a 1-m^2 area is closest to the sample area. The $DCGL_{EMC}$ of 20.8 pCi/g for the 1-m^2 area is greater than the TS-SS-379 sample result of 16.1 pCi/g. Using an area factor of 3.65, the TS6-SS-379 soil sample result passes the elevated measurement comparison test.

The gamma scanning surveys identified numerous areas above the 20,000-cpm investigation level at all training sites. At TS8, the area of elevated activity is associated with the contaminated building 28005 and, therefore, was not evaluated. Areas at TS5, TS6, and TS7 above 6.61 pCi/g thorium-232 or approximately 23,000 cpm, were evaluated using the elevated measurement comparison.

The gamma scanning surveys collected over 2,000 measurements in each MARSSIM Class 1 survey unit, so that each measurement represents 1-m^2 or less. In applying the elevated measurement comparison to the gamma scanning survey data, it was noted that no area factors (F) were derived for areas smaller than 1-m^2. Consequently, around each elevated measurement, a 1-m^2 polygon was constructed with the elevated measurement at the center. The elevated measurements above 23,000 cpm identified at TS5 and TS6 are shown in Figures 5-39 and 5-40. No gamma radiation measurements above 23,000 cpm were identified at TS7. All gamma measurements within the polygon were converted to net thorium-232 soil concentrations using the linear regression equations for the two data distributions. Gamma count rates greater than 18,750 were converted to thorium-232 concentrations using the Equation 5-15.

$$y = 652.1x + 18{,}642 \qquad \text{Eq. 5-15}$$

Where

y is the gamma count rate, and

x is thorium-232 concentration in pCi/g.

Gamma count rates less than 18,750 were converted to thorium-232 concentrations using Equation 5-16.

$$y = 3{,}177.8x + 10{,}979 \qquad \text{Eq. 5-16}$$

The thorium-232 concentrations were then averaged together to estimate the soil concentration in the polygon. The net mean thorium-232 concentration (concentration minus background) was then compared to the $DCGL_{EMC}$ of 20.8 pCi/g for a 1-m^2 area.

If the net mean thorium-232 concentration is less than 20.8 pCi/g, then the area passes the elevated measurement comparison test. Table 5-40 summarizes the results of the elevated measurement comparison for the gamma scanning survey data. All elevated areas identified from the gamma scanning surveys pass the elevated measurement comparison test.

Table 5-40. Elevated Measurement Comparison using the Final Status Survey Gamma Scanning Data, Environmental Restoration Program Site OT-10

Training Site	Polygon ID	N	Gamma Count Rate (cpm)	Net Thorium-232 Concentration (pCi/g)	Net Mean Thorium-232 in the Elevated Area (pCi/g)	$DCGL_{EMC}$ (pCi/g)	PASS/FAIL
TS-5	9-C	3	23,543	6.61	4.07	20.8	PASS
			16,747	0.91			
			22,293	4.69			
TS-6	20-A	2	29,010	14.99	7.57	20.8	PASS
			19,328	0.14			
	24-D	6	23,699	6.84	1.70	20.8	PASS
			16,619	0.86			
			19,261	0.04			
			16,003	0.67			
			16,772	0.91			
			16,548	0.84			
	26-E	3	23,551	6.62	6.02	20.8	PASS
			23,742	6.91			
			22,194	4.54			
	27-M	3	21,630	3.67	5.31	20.8	PASS
			18,400	1.43			
			26,291	10.82			

Notes:
All area comparisons are based upon a 1-m^2 area.
Converted calculations are the average of each individual value converted to concentration less background. For values greater than 18,750 the equation: $y = 652.1x + 18{,}642$ and for values less than 18,750: $y = 3{,}177.8 x + 10{,}979$.
cpm = counts per minute
$DCGL_{EMC}$ = derived-concentration guideline limit for elevated measurement comparison
ID = identifier
N = number of gamma radiation measurements in the 1-m^2 area.
PCi/g = picocuries per gram

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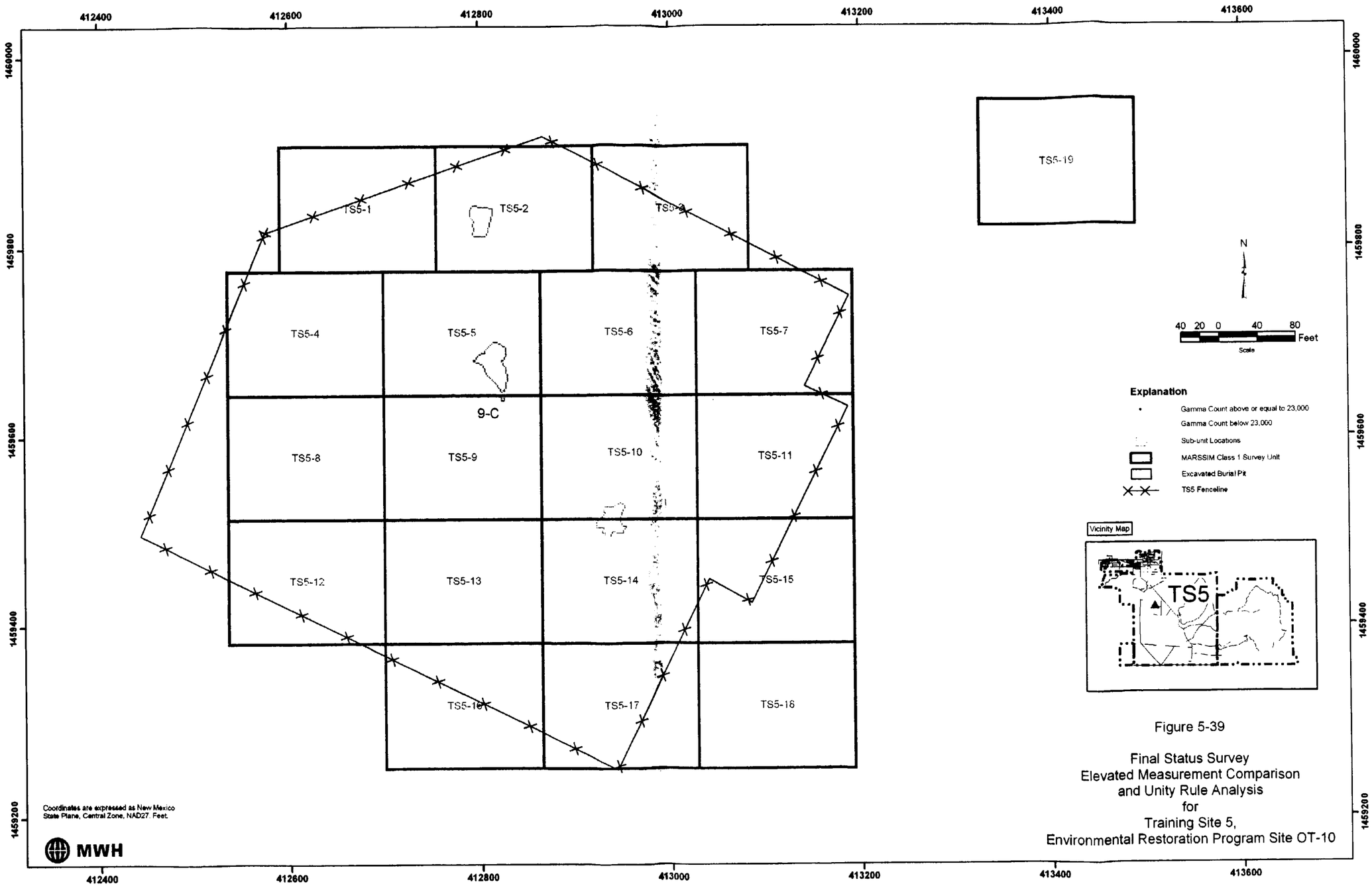

Figure 5-39

Final Status Survey
Elevated Measurement Comparison
and Unity Rule Analysis
for
Training Site 5,
Environmental Restoration Program Site OT-10

Figure 5-39. Final Status Survey Elevated Measurement Comparison and Unity Rule Analysis for Training Site 5, Environmental Restoration Program Site OT-10

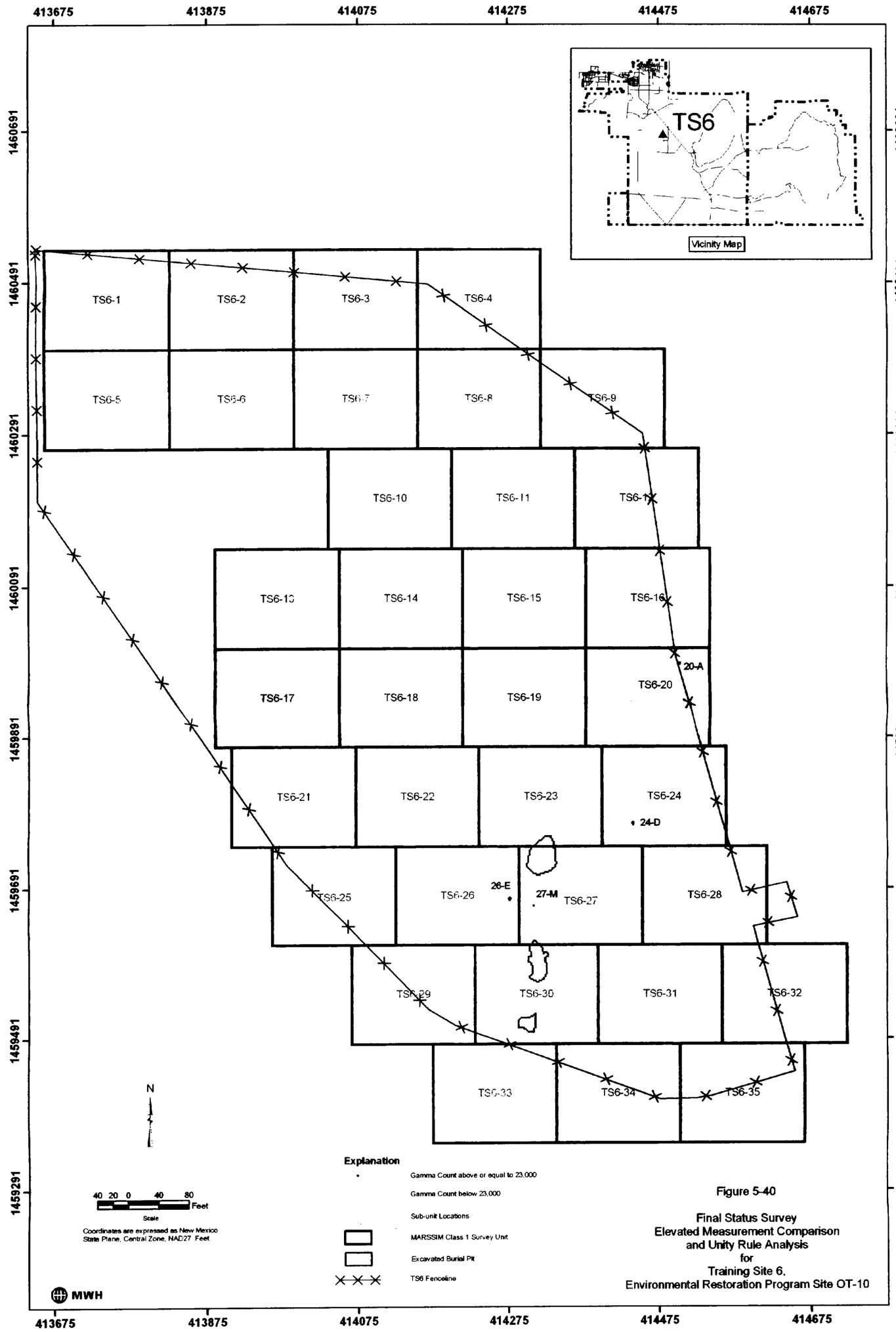

Figure 5-40. Final Status Survey Elevated Measurement Comparison and Unity Rule Analysis for Training Site 6, Environmental Restoration Program Site OT-10

5.3.3 Unity Rule Analysis

Survey units where isolated areas of elevated activity exist in addition to residual activity distributed relatively uniformly across the site have the potential to exceed the release criterion. The elevated measurement comparison was used to examine whether these elevated measurements, taken alone, posed a concern. The unity rule is used to evaluate the significance of elevated areas and the residual activity in a survey unit. For example, if there is a 1-m^2 area with an activity of 10 pCi/g, this concentration is below the elevated measurement comparison value of 20.8 pCi/g above background, and the area complies with the requirements of the Decommissioning Plan. However, if there are five elevated areas, it is possible that they would pose a risk in combination, although none of them pose a concern individually. The unity rule is used to examine this potential. Mathematically, the unity rule is expressed as:

$$\delta/DCGL_w + (\text{average concentration in elevated area} - \delta)/[F^*DCGL_w] < 1 \qquad \text{Eq. 5-17}$$

Where

> δ is a conservative estimate of the net mean concentration (concentration minus background) for the survey unit as a whole, assuming that the contamination is relatively evenly distributed. Where there are multiple areas of elevated activity, a separate term is included for each area.

Unity rule calculations were performed on only the gamma scanning survey data. There was no need to perform these calculations on the soil samples, as there was only one elevated measurement in all of these data. Because the purpose of the unity rule is to evaluate the combined effect of multiple elevated measurements, its application to the soil samples would have produced no new insights.

For the gamma scanning survey data, the unity rule analysis used the elevated measurements identified for the elevated measurements comparison. The elevated measurements identified at TS5 andTS6 are shown in Figures 5-39 and 5-40. Table 5-41 presents the values used for the unity rule analysis. The analysis uses the net mean thorium-232 concentrations (concentration minus background) for each elevated area developed during the elevated measurement comparison. These elevated area concentrations are divided by the $DCGL_{EMC}$ of 20.8 pCi/g to determine the elevated area fraction. The survey unit fraction is calculated by dividing the net mean survey unit concentration by the $DCGL_w$ of 5.7 pCi/g. For a given survey unit, the survey unit fraction and all the elevated area fractions are added to determine the sum of the fractions. If the sum of the fractions is less than 1, the survey unit passes the unity rule analysis. All the Class 1 survey units pass the unity rule analysis.

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Table 5-41. Unity Rule Analysis Using the Final Status Survey Gamma Scanning Data, Environmental Restoration Program Site OT-10

Training Site	Polygon ID	N	Gamma Count Rate (cpm)	Net Thorium-232 Concentration (pCi/g)	Net Mean Thorium-232 in the Elevated Area (pCi/g)	Area Factor	Elevated Area Fraction	Mean Gamma Count Rate in Survey Unit (cpm)	Net Mean Thorium-232 in Survey Unit (pCi/g)	Survey Unit Fraction	Sum of the Fractions
TS-5	9-C	3	23543	6.61	4.07	3.65	0.18	14938	0.34	0.06	0.24
			16747	0.91							
			22293	4.69							
TS-6	20-A	2	29010	14.99	7.57	3.65	0.34	15183	0.41	0.07	0.41
			19328	0.14							
	24-D	6	23699	6.84	1.70	3.65	0.06	15618	0.55	0.10	0.16
			16619	0.86							
			19261	0.04							
			16003	0.67							
			16772	0.91							
			16548	0.84							
	26-E	3	23551	6.62	6.02	3.65	0.28	14165	0.09	0.02	0.30
			23742	6.91							
			22194	4.54							
	27-M	3	21630	3.67	5.31	3.65	0.24	14896	0.32	0.06	0.30
			18400	1.43							
			26291	10.82							

Notes:
All area comparisons are based upon a 1 square meter area.
Converted calculations are the average of each individual value converted to concentration less background. For values greater than 18750 the equation: $y = 652.1x + 18642$ and for values less than 18750: $y = 3177.8x + 10979$.
cpm = counts per minute
$DCGL_{EMC}$ = Derived Concentration Guideline Limit for Elevated Measurement Comparison
ID = identifier
N = number of gamma radiation measurements in the one square meter area.
pCi/g = picocuries per gram

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5.4 Quality Assurance/Quality Control Process for Comparison of Severn Trent and Armstrong Laboratories Data

This section presents the results of comparison of analytical data for soil samples analyzed by Severn Trent Laboratories (STL) of Earth City, Missouri and Armstrong Laboratories of Brooks City Base, Texas. STL provided the primary analytical support and Armstrong Laboratories served as the quality assurance (QA) laboratory for this project. The QA samples are listed in Table 5-42 and represent 10 percent of the total number of final status survey samples. The samples were prepared and analyzed by both laboratories using their internal standard operating procedures (SOPs) for gamma emitting radionuclides using modified method EPA 901.1 (EPA, 1980).

After initial analysis of the soil samples was completed by STL, the samples scheduled for QA analysis were forwarded by STL to Armstrong Laboratories. Upon sample receipt, Armstrong Laboratories recombined the sample portions (the samples had been homogenized, dried, and split into different portions by STL for analysis), prepared, and analyzed the samples in accordance with their SOPs.

Activity concentrations were reported for the following gamma-emitting radionuclides:

- Actinium-228
- Bismuth-212
- Bismuth-214
- Cesium-137
- Cobalt-60
- Lead-212
- Lead-214
- Potassium-40
- Radium-224
- Radium-226 (Bismuth-214 to report Radium-226)
- Thallium-208
- Thorium-228 (Armstrong only)
- Thorium-234
- Uranium 235 and 236 (STL only)

Table 5-42. Quality Assurance Samples at Environmental Restoration Program Site OT-10

Training Site 5	Training Site 6	Training Site 7	Training Site 8
TS5-SS-31-0000	TS6-SS-73-0000	TS7-SS-41-0000	TS8-SS-21-0000
TS5-SS-41-0000	TS6-SS-113-0000	TS7-SS-51-0000	TS8-SS-31-0000
TS5-SS-71-0000	TS6-SS-83-0000	TS7-SS-61-0000	TS8-SS-41-0000
TS5-SS-91-0000	TS6-SS-93-0000	TS7-SS-71-0000	TS8-SS-54-0000
TS5-SS-131-0000	TS6-SS-63-0000	TS7-SS-101-0000	TS8-SS-64-0000
TS5-SS-141-0000	TS6-SS-373-0000	TS7-SS-111-0000	TS8-SS-74-0000
TS5-SS-181-0000	TS6-SS-383-0000	TS7-SS-21-0000	TS8-SS-84-0000
TS5-SS-191-0000	TS6-SS-133-0000	TS7-SS-31-0000	TS6-SS-223-0000
TS5-SS-201-0000	TS6-SS-273-0000	TS7-SS-81-0000	TS6-SS-253-0000
TS5-SS-161-0000	TS6-SS-293-0000	TS7-SS-91-0000	TS6-SS-263-0000
TS5-SS-171-0000	TS6-SS-173-0000		TS6-SS-283-0000
TS5-SS-121-0000	TS6-SS-363-0000		TS6-SS-303-0000
TS5-SS-81-0000	TS6-SS-333-0000		TS6-SS-343-0000
TS5-SS-51-0000	TS6-SS-53-0000		TS6-SS-353-0000
TS5-SS-21-0000	TS6-SS-393-0000		
TS5-SS-61-0000	TS6-SS-103-0000		
TS5-SS-101-0000	TS6-SS-123-0000		
TS5-SS-111-0000	TS6-SS-143-0000		
TS5-SS-151-0000	TS6-SS-213-0000		
TS5-SS-216-0000	TS6-SS-243-0000		
TS5-SS-226-0000	TS6-SS-153-0000		
TS5-SS-230-0000	TS6-SS-163-0000		
TS5-SS-240-0000	TS6-SS-183-0000		
TS5-SS-248-0000	TS6-SS-193-0000		
	TS6-SS-203-0000		
	TS6-SS-233-0000		
	TS6-SS-313-0000		
	TS6-SS-323-0000		

Notes:
TS = Training site

The STL and Armstrong Laboratories sample results are listed in Tables 5-43 through 5-46. The relative percent difference (RPD) and replicate error ratio (RER) were calculated between the STL and Armstrong Laboratories results for those analytes that were detected above the MDC in both samples.

If an analyte was detected in only one of the samples, the RPD was not calculated and the RER was calculated using the minimum detectable concentration (MDC) as the concentration (for the sample that was non-detect). It should be noted that Armstrong Laboratories does not have the software capability to determine the error for non-detect samples; therefore, the MDC was applied as the error (based on guidance provided by Armstrong Laboratories).

The equations that were used to calculate the RPDs and RERs are shown below:

Where

$$RPD = \left(\frac{|A - B|}{[A + B]/2} \right) \times 100 \qquad \text{Eq. 5-18}$$

A and B are the reported concentrations for sample duplicate analyses.

$$RER = \frac{(S - R)}{\left(\sqrt{(0.15 \times S)^2 + E_s^{\,2}}\right) + \left(\sqrt{(0.15 \times R)^2 + E_R^{\,2}}\right)} \qquad \text{Eq. 5-19}$$

Where

S = Sample value,

E_S = Sample counting error (at 2 sigma),

R = Replicate value, and

E_R = Replicate counting error (at 2 sigma).

The calculated RPDs and RERs were compared to the quality control limits used for data verification for field replicates. The criterion used for the RPD evaluation was 35 percent and the criterion used for RER evaluation was $\leq$ 1.0. In most cases, the RPDs were within the evaluation criterion of 35 percent. If the RPD was outside the evaluation criterion, the RER was then compared to the evaluation criterion of $\leq$ 1.0. In almost all cases, the RER was within the acceptance criterion. For those cases where the RER was outside the evaluation criterion, it was primarily because the sample concentrations were less than five times the MDC or because the uncertainty in the sample concentration was relatively high. Based on the results of this evaluation, the data between STL and Armstrong are comparable.

The next component of this evaluation was to assess whether both laboratories detected the same analytes in the same samples. The results of this evaluation indicate that both laboratories detected the same analytes at similar concentrations. In most cases where an analyte was detected by one laboratory and not the other the reported concentration was at or near the MDC.

The result of the QA evaluation between the STL and Armstrong Laboratories sample data indicates that the data for this project are precise and are comparable. This evaluation also indicates that the data are of sufficient quality to support the project-specific data quality objectives.

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Table 5-43. Quality Assurance Samples Comparison at Training Site 5, Environmental Restoration Program Site OT-10

Field Sample Identification	TS5-SS21-0000	TS5-SS21-0000			TS5-SS31-0000	TS5-SS31-0000			TS5-SS41-0000	TS5-SS41-0000			TS5-SS51-0000	TS5-SS51-0000		
Date Collected	10/3/2003	10/3/2003			10/1/2003	10/1/2003			10/3/2003	10/3/2003			10/1/2003	10/1/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil			Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1			E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)																
Gamma-Emitting Radionulices/E901.1 (pCi/g)																
Actinium-228	**0.77 ± 0.29**	**0.91 ± 0.12**	16.7	0.28	**1.39 ± 0.38**	**1.23 ± 0.11**	12.2	0.25	**1 ± 0.34**	**0.93 ± 0.09**	7.3	0.13	**1.17 ± 0.34**	**1.07 ± 0.13**	8.9	0.17
Bismuth-212	<1.1 ± 0.51	**0.71 ± 0.33**	NC	0.44	<1.1 ± 0.52	**0.87 ± 0.29**	NC	0.27	<0.92 ± 0.46	**0.68 ± 0.26**	NC	0.32	<0.96 ± 0.45	**0.99 ± 0.31**	NC	0.04
Bismuth-214	**0.88 ± 0.26**	**0.92 ± 0.12**	4.4	0.08	**0.92 ± 0.24**	**0.87 ± 0.1**	5.6	0.11	**0.69 ± 0.22**	**0.98 ± 0.1**	34.7	0.69	**0.66 ± 0.24**	**0.89 ± 0.11**	29.7	0.53
Cesium-137	<0.089 ± 0.05	<0.08 ± 0.08	NC	0.07	<0.11 ± 0.049	<0.06 ± 0.06	NC	0.44	**0.136 ± 0.07**	**0.14 ± 0.04**	2.9	0.03	**0.197 ± 0.092**	**0.1 ± 0.04**	***65.3***	0.70
Cobalt-60	<0.096 ± 0.045	<0.08 ± 0.08	NC	0.12	<0.11 ± 0.06	<0.07 ± 0.07	NC	0.30	<0.096 ± 0.051	<0.06 ± 0.06	NC	0.32	<0.085 ± 0.042	<0.07 ± 0.07	NC	0.13
Lead-212	**0.83 ± 0.21 B**	**0.86 ± 0.15**	3.6	0.07	**1.19 ± 0.25**	**1.35 ± 0.12**	12.6	0.29	**1.01 ± 0.19**	**0.9 ± 0.11**	11.5	0.26	**1.38 ± 0.26**	**1.18 ± 0.11**	15.6	0.37
Lead-214	**1.07 ± 0.21**	**0.8 ± 0.1**	28.9	0.64	**1.02 ± 0.21**	**0.79 ± 0.08**	25.4	0.57	**0.88 ± 0.17**	**0.84 ± 0.09**	4.7	0.11	**0.85 ± 0.2**	**0.79 ± 0.09**	7.3	0.16
Potassium-40	**14.6 ± 3.1**	**15.62 ± 1.98**	6.8	0.15	**15.8 ± 3.1**	**16.2 ± 1.97**	2.5	0.06	**19 ± 3.7**	**16.82 ± 2.03**	12.2	0.28	**15.7 ± 3.2**	**16.15 ± 2.02**	2.8	0.06
Radium-224	**2.1 ± 1.6**	**0.95 ± 0.75**	***75.4***	0.48	**3 ± 2.1**	**0.6 ± 0.41**	***133.3***	0.93	**2.1 ± 1.3**	**0.67 ± 0.52**	***103.2***	0.77	**2.3 ± 1.5**	**1.81 ± 0.6**	23.8	0.22
Radium-226	**2.3 ± 1.4**	**2.18 ± 0.89**	5.4	0.05	**2.07 ± 0.95**	**1.21 ± 0.61**	***52.4***	0.53	**1.36 ± 0.94**	**1.38 ± 0.57**	1.5	0.01	<1.9 ± 1.0	**1.78 ± 0.78**	NC	0.06
Thallium-208	**0.263 ± 0.099**	**0.27 ± 0.06**	2.6	0.04	**0.45 ± 0.13**	**0.47 ± 0.06**	4.3	0.08	**0.34 ± 0.11**	**0.41 ± 0.05**	18.7	0.35	**0.37 ± 0.13**	**0.44 ± 0.07**	17.3	0.29
Thorium-228	NA	**0.91 ± 0.12**	NC	NC	NA	**1.23 ± 0.11**	NC	NC	NA	**0.93 ± 0.09**	NC	NC	NA	**1.07 ± 0.13**	NC	NC
Thorium-234	<1.1 ± 0.97	**0.78 ± 0.37**	NC	0.23	<1.1 ± 0.68	<0.84 ± 0.84	NC	0.17	<0.99 ± 0.41	<0.75 ± 0.75	NC	0.20	<1.1 ± 0.72	**0.67 ± 0.27**	NC	0.42
Uranium 235 and 236	<0.38 ± 0.21	NA	NC	NC	<0.45 ± 0.25	NA	NC	NC	<0.4 ± 0.22	NA	NC	NC	<0.42 ± 0.24	NA	NC	NC

Field Sample Identification	TS5-SS61-0000	TS5-SS61-0000			TS5-SS71-0000	TS5-SS71-0000			TS5-SS81-0000	TS5-SS81-0000			TS5-SS91-0000	TS5-SS91-0000		
Date Collected	10/2/2003	10/2/2003			10/1/2003	10/1/2003			10/1/2003	10/1/2003			10/2/2003	10/2/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil			Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1			E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)																
Gamma-Emitting Radionulices/E901.1 (pCi/g)																
Actinium-228	**1.16 ± 0.36**	**1.25 ± 0.15**	7.5	0.14	**1.49 ± 0.38**	**1.25 ± 0.12**	17.5	0.36	**1.67 ± 0.42**	**1.2 ± 0.13**	32.8	0.66	**1.17 ± 0.38**	**1.42 ± 0.12**	19.3	0.38
Bismuth-212	<1.0 ± 0.52	**1.07 ± 0.33**	NC	0.08	<0.85 ± 0.41	**0.86 ± 0.28**	NC	0.01	**1.06 ± 0.58**	**0.8 ± 0.31**	28.0	0.28	<1.2 ± 0.55	**1.28 ± 0.35**	NC	0.08
Bismuth-214	**0.83 ± 0.27**	**0.89 ± 0.12**	7.0	0.13	**0.8 ± 0.22**	**0.97 ± 0.1**	19.2	0.40	**0.73 ± 0.2**	**0.75 ± 0.1**	2.7	0.05	**0.97 ± 0.24**	**0.9 ± 0.12**	7.5	0.15
Cesium-137	<0.1 ± 0.056	<0.09 ± 0.09	NC	0.07	<0.1 ± 0.06	<0.06 ± 0.06	NC	0.33	**0.178 ± 0.08**	**0.16 ± 0.05**	10.7	0.13	**0.33 ± 0.13**	**0.25 ± 0.06**	27.6	0.38
Cobalt-60	<0.094 ± 0.053	<0.08 ± 0.08	NC	0.10	<0.11 ± 0.055	<0.07 ± 0.07	NC	0.31	<0.093 ± 0.045	<0.08 ± 0.08	NC	0.10	<0.13 ± 0.064	<0.09 ± 0.09	NC	0.25
Lead-212	**1.33 ± 0.25 B**	**1.03 ± 0.12**	25.4	0.58	**1.39 ± 0.27**	**1.11 ± 0.11**	22.4	0.52	**1.45 ± 0.28**	**1.22 ± 0.13**	17.2	0.40	**1.24 ± 0.25**	**1.22 ± 0.16**	1.6	0.04
Lead-214	**0.95 ± 0.2**	**0.91 ± 0.12**	4.3	0.09	**0.93 ± 0.19**	**0.88 ± 0.08**	5.5	0.13	**0.84 ± 0.19**	**0.72 ± 0.09**	15.4	0.33	**1.06 ± 0.21**	**0.91 ± 0.12**	15.2	0.34
Potassium-40	**17.4 ± 3.3**	**15.46 ± 2**	11.8	0.27	**13.7 ± 3**	**15.81 ± 1.95**	14.3	0.31	**13.5 ± 2.7**	**16.88 ± 2.11**	22.3	0.51	**17.4 ± 3.6**	**17.65 ± 2.2**	1.4	0.03
Radium-224	<2.3 ± 1.3	<2.83 ± 2.83	NC	0.13	**2.7 ± 1.9**	<1.94 ± 1.94	NC	0.19	**3.8 ± 2.4**	**1.67 ± 0.66**	***77.9***	0.67	**2.3 ± 1.7**	**1.18 ± 0.69**	***64.4***	0.46
Radium-226	<2.0 ± 1.1	**1.89 ± 1**	NC	0.05	**1.43 ± 0.99**	**1.27 ± 0.61**	11.9	0.10	<1.5 ± 0.8	**1.87 ± 0.79**	NC	0.22	**2.1 ± 1.6**	**2.03 ± 0.81**	3.4	0.03
Thallium-208	**0.48 ± 0.14**	**0.44 ± 0.07**	8.7	0.16	**0.52 ± 0.14**	**0.47 ± 0.06**	10.1	0.20	**0.48 ± 0.14**	**0.46 ± 0.06**	4.3	0.08	**0.45 ± 0.14**	**0.48 ± 0.07**	6.5	0.12
Thorium-228	NA	**1.25 ± 0.15**	NC	NC	NA	**1.25 ± 0.12**	NC	NC	NA	**1.2 ± 0.13**	NC	NC	NA	**1.42 ± 0.12**	NC	NC
Thorium-234	<1.2 ± 0.49	**0.88 ± 0.36**	NC	0.35	<1.0 ± 0.55	<0.85 ± 0.85	NC	0.10	<0.98 ± 0.58	**0.44 ± 0.31**	NC	0.59	**1.51 ± 0.72**	**1 ± 0.28**	***40.6***	0.48
Uranium 235 and 236	<0.43 ± 0.26	NA	NC	NC	<0.37 ± 0.21	NA	NC	NC	<0.37 ± 0.2	NA	NC	NC	<0.44 ± 0.25	NA	NC	NC

Table 5-43. Quality Assurance Samples Comparison at Training Site 5, Environmental Restoration Program Site OT-10 (continued)

Field Sample Identification	TS5-SS101-0000	TS5-SS101-0000			TS5-SS111-0000	TS5-SS111-0000			TS5-SS121-0000	TS5-SS121-0000			TS5-SS131-0000	TS5-SS131-0000		
Date Collected	10/2/2003	10/2/2003			10/2/2003	10/2/2003			10/2/2003	10/2/2003			10/2/2003	10/2/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil			Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1			E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)																
Gamma-Emitting Radionulices/E901.1 (pCi/g)																
Actinium-228	1.39 ± 0.44	1.12 ± 0.13	21.5	0.39	1.11 ± 0.35	1.29 ± 0.14	15.0	0.29	0.94 ± 0.29	0.84 ± 0.11	11.2	0.20	1.13 ± 0.33	1.08 ± 0.09	4.5	0.09
Bismuth-212	<1.0 ± 0.49	0.8 ± 0.28	NC	0.24	<0.87 ± 0.54	0.57 ± 0.29	NC	0.35	1.16 ± 0.52	0.59 ± 0.26	*65.1*	0.69	<1.2 ± 0.53	0.71 ± 0.24	NC	0.60
Bismuth-214	1.01 ± 0.28	1.01 ± 0.12	0.0	0.00	0.82 ± 0.29	0.96 ± 0.12	15.7	0.28	0.74 ± 0.22	0.95 ± 0.11	24.9	0.49	0.96 ± 0.27	0.98 ± 0.11	2.1	0.04
Cesium-137	<0.09 ± 0.052	<0.07 ± 0.07	NC	0.16	<0.1 ± 0.058	<0.08 ± 0.08	NC	0.14	<0.084 ± 0.043	<0.07 ± 0.07	NC	0.12	0.142 ± 0.088	0.18 ± 0.04	23.6	0.27
Cobalt-60	<0.1 ± 0.059	<0.07 ± 0.07	NC	0.23	<0.072 ± 0.045	<0.08 ± 0.08	NC	0.06	<0.11 ± 0.053	<0.08 ± 0.08	NC	0.22	<0.11 ± 0.059	<0.06 ± 0.06	NC	0.41
Lead-212	1.19 ± 0.23	1.21 ± 0.12	1.7	0.04	1.07 ± 0.24	1.21 ± 0.14	12.3	0.27	0.85 ± 0.19	0.92 ± 0.09	7.9	0.18	0.98 ± 0.22	0.76 ± 0.09	25.3	0.54
Lead-214	0.96 ± 0.2	0.87 ± 0.09	9.8	0.22	1.03 ± 0.23	0.92 ± 0.1	11.3	0.25	0.81 ± 0.17	0.82 ± 0.11	1.2	0.03	0.95 ± 0.2	0.82 ± 0.08	14.7	0.33
Potassium-40	17 ± 3.4	16.05 ± 2.02	5.7	0.13	14.3 ± 3.2	14.72 ± 1.9	2.9	0.06	15.1 ± 2.9	16.21 ± 2.03	7.1	0.16	17.7 ± 3.5	17.76 ± 2.13	0.3	0.01
Radium-224	<1.4 ± 0.87	0.83 ± 0.6	NC	0.38	3 ± 2	1.05 ± 0.7	*96.3*	0.70	2.6 ± 1.8	0.58 ± 0.52	*127.0*	0.85	3.9 ± 2.5	<1.69 ± 1.69	NC	0.52
Radium-226	2.4 ± 1.2	1.52 ± 0.93	*44.9*	0.40	<1.9 ± 0.95	1.51 ± 0.91	NC	0.20	1.9 ± 1.2	1.64 ± 0.76	14.7	0.13	<1.8 ± 0.94	1.58 ± 0.55	NC	0.14
Thallium-208	0.45 ± 0.12	0.48 ± 0.07	6.5	0.13	0.42 ± 0.13	0.42 ± 0.07	0.0	0.00	0.31 ± 0.1	0.39 ± 0.06	22.9	0.41	0.38 ± 0.14	0.37 ± 0.05	2.7	0.04
Thorium-228	NA	1.12 ± 0.13	NC	NC	NA	1.29 ± 0.14	NC	NC	NA	0.84 ± 0.11	NC	NC	NA	1.08 ± 0.09	NC	NC
Thorium-234	1.58 ± 0.5	<0.77 ± 0.77	NC	0.61	<1.2 ± 0.69	<0.78 ± 0.78	NC	0.28	1.78 ± 0.6	0.66 ± 0.26	*91.8*	*120*	<1.2 ± 0.68	<0.73 ± 0.73	NC	0.33
Uranium 235 and 236	<0.44 ± 0.24	NA	NC	NC	<0.49 ± 0.26	NA	NC	NC	<0.36 ± 0.19	NA	NC	NC	<0.44 ± 0.26	NA	NC	NC

Field Sample Identification	TS5-SS141-0000	TS5-SS141-0000			TS5-SS151-0000	TS5-SS151-0000			TS5-SS161-0000	TS5-SS161-0000			TS5-SS171-0000	TS5-SS171-0000		
Date Collected	10/2/2003	10/2/2003			10/2/2003	10/2/2003			10/2/2003	10/2/2003			10/3/2003	10/3/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00	0.00			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil			Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1			E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)																
Gamma-Emitting Radionulices/E901.1 (pCi/g)																
Actinium-228	1.01 ± 0.36	0.94 ± 0.09	7.2	0.13	1.82 ± 0.52	1.78 ± 0.14	2.2	0.05	0.98 ± 0.31	1.13 ± 0.1	14.2	0.28	0.92 ± 0.29	1.15 ± 0.1	22.2	0.44
Bismuth-212	<0.91 ± 0.43	0.58 ± 0.24	NC	0.47	<1.2 ± 0.58	1.24 ± 0.37	NC	0.04	<0.61 ± 0.52	0.72 ± 0.28	NC	0.13	<0.85 ± 0.38	0.72 ± 0.28	NC	0.19
Bismuth-214	0.83 ± 0.27	0.82 ± 0.09	1.2	0.02	0.79 ± 0.28	0.92 ± 0.12	15.2	0.27	0.72 ± 0.24	0.83 ± 0.11	14.2	0.26	0.89 ± 0.25	0.81 ± 0.11	9.4	0.18
Cesium-137	<0.095 ± 0.045	<0.06 ± 0.06	NC	0.32	<0.14 ± 0.074	0.08 ± 0.05	NC	0.47	<0.14 ± 0.069	0.05 ± 0.03	NC	0.87	<0.14 ± 0.066	0.05 ± 0.03	NC	0.90
Cobalt-60	<0.1 ± 0.053	<0.06 ± 0.06	NC	0.35	<0.096 ± 0.044	<0.07 ± 0.07	NC	0.22	<0.096 ± 0.05	<0.07 ± 0.07	NC	0.21	<0.11 ± 0.059	<0.07 ± 0.07	NC	0.30
Lead-212	0.9 ± 0.18	0.86 ± 0.09	4.5	0.10	1.79 ± 0.36	1.78 ± 0.16	0.6	0.01	0.94 ± 0.21	0.86 ± 0.86	8.9	0.07	0.78 ± 0.19	0.93 ± 0.09	17.5	0.39
Lead-214	0.87 ± 0.18	0.78 ± 0.08	10.9	0.25	0.9 ± 0.2	0.92 ± 0.1	2.2	0.05	0.76 ± 0.17	0.88 ± 0.08	14.6	0.33	0.8 ± 0.17	0.82 ± 0.08	2.5	0.06
Potassium-40	14.8 ± 2.9	17.62 ± 2.11	17.4	0.40	16 ± 3.2	16.45 ± 2.05	2.8	0.06	19 ± 3.6	15.8 ± 1.97	18.4	0.42	16.4 ± 3.2	15.71 ± 1.96	4.3	0.10
Radium-224	2.3 ± 1.6	<0.65 ± 0.65	NC	0.72	2.8 ± 2	1.6 ± 0.75	*54.5*	0.42	2.4 ± 1.7	<2.2 ± 2.2	NC	0.05	2.3 ± 1.7	1.22 ± 0.63	*61.4*	0.45
Radium-226	<1.2 ± 0.87	1.65 ± 0.58	NC	0.30	<1.9 ± 0.97	2.05 ± 0.99	NC	0.07	<1.8 ± 0.95	2.22 ± 0.72	NC	0.24	1.4 ± 1.1	2.54 ± 0.74	*57.9*	0.58
Thallium-208	0.34 ± 0.1	0.34 ± 0.05	0.0	0.00	0.71 ± 0.16	0.69 ± 0.08	2.9	0.06	0.46 ± 0.12	0.36 ± 0.05	24.4	0.47	0.36 ± 0.11	0.36 ± 0.05	0.0	0.00
Thorium-228	NA	0.94 ± 0.09	NC	NC	NA	1.78 ± 0.14	NC	NC	NA	1.13 ± 0.1	NC	NC	NA	1.14 ± 0.1	NC	NC
Thorium-234	<0.9 ± 0.53	<0.75 ± 0.75	NC	0.11	<1.4 ± 0.74	0.75 ± 0.35	NC	0.57	<1.0 ± 0.56	0.68 ± 0.27	NC	0.37	1.35 ± 0.58	0.28 ± 0.25	*131.3*	*1.23*
Uranium 235 and 236	<0.36 ± 0.2	NA	NC	NC	<0.51 ± 0.29	NA	NC	NC	<0.35 ± 0.2	NA	NC	NC	<0.37 ± 0.22	NA	NC	NC

Table 5-43. Quality Assurance Samples Comparison at Training Site 5, Environmental Restoration Program Site OT-10 (continued)

Field Sample Identification	TS5-SS181-0000	TS5-SS181-0000			TS5-SS191-0000	TS5-SS191-0000			TS5-SS201-0000	TS5-SS201-0000			TS5-SS216-0000	TS5-SS216-0000		
Date Collected	10/6/2003	10/6/2003			10/6/2003	10/6/2003			10/6/2003	10/6/2003			9/9/2003	9/9/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil			Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1			E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)																
Gamma-Emitting Radionulices/E901.1 (pCi/g)																
Actinium-228	**0.79 ± 0.29**	**0.92 ± 0.11**	15.2	0.27	**0.95 ± 0.36**	**0.9 ± 0.09**	5.4	0.09	**1.01 ± 0.35**	**0.82 ± 0.11**	20.8	0.35	**1.07 ± 0.34**	**1.02 ± 0.13**	4.8	0.09
Bismuth-212	<0.84 ± 0.41	**0.64 ± 0.31**	NC	0.27	<0.92 ± 0.44	**0.73 ± 0.24**	NC	0.26	<1.1 ± 0.51	**0.75 ± 0.26**	NC	0.43	<0.85 ± 0.73	**0.87 ± 0.35**	NC	0.02
Bismuth-214	**0.75 ± 0.21**	**0.78 ± 0.1**	3.9	0.08	**0.96 ± 0.26**	**0.87 ± 0.1**	9.8	0.19	**0.82 ± 0.23**	**0.92 ± 0.1**	11.5	0.23	**0.95 ± 0.23**	**0.98 ± 0.12**	3.1	0.07
Cesium-137	<0.097 ± 0.051	**0.04 ± 0.03**	NC	0.68	<0.13 ± 0.061	**0.1 ± 0.03**	NC	0.31	**0.173 ± 0.094**	**0.15 ± 0.04**	14.2	0.16	<0.085 ± 0.047	<0.08 ± 0.08	NC	0.04
Cobalt-60	<0.097 ± 0.057	<0.07 ± 0.07	NC	0.21	<0.12 ± 0.058	<0.06 ± 0.06	NC	0.49	<0.1 ± 0.048	<0.07 ± 0.07	NC	0.25	<0.11 ± 0.06	<0.08 ± 0.08	NC	0.21
Lead-212	**0.8 ± 0.19**	**0.94 ± 0.08**	16.1	0.36	**0.7 ± 0.19**	**0.89 ± 0.13**	23.9	0.47	**0.84 ± 0.2**	**0.73 ± 0.09**	14.0	0.29	**1 ± 0.21**	**0.95 ± 0.14**	5.1	0.11
Lead-214	**0.95 ± 0.19**	**0.83 ± 0.07**	13.5	0.32	**0.82 ± 0.2**	**0.82 ± 0.08**	0.0	0.00	**0.85 ± 0.2**	**0.81 ± 0.07**	4.8	0.11	**0.78 ± 0.19**	**0.83 ± 0.11**	6.2	0.13
Potassium-40	**15.6 ± 3**	**16.62 ± 2.06**	6.3	0.14	**14.2 ± 2.8**	**17.03 ± 2.05**	18.1	0.42	**17.8 ± 3.6**	**16.88 ± 2.04**	5.3	0.12	**15.1 ± 3.1**	**14.78 ± 1.89**	2.1	0.05
Radium-224	<1.7 ± 1.4	<0.69 ± 0.69	NC	0.48	<1.9 ± 1.5	<0.64 ± 0.64	NC	0.58	**2 ± 1.6**	<0.65 ± 0.65	NC	0.59	**2.4 ± 1.7**	**1.25 ± 0.81**	***63.0***	0.45
Radium-226	**1.6 ± 1.1**	**1.96 ± 0.65**	20.2	0.20	**2.5 ± 1.2**	**1.42 ± 0.56**	***55.1***	0.58	<1.7 ± 0.9	**1.2 ± 0.56**	NC	0.33	<1.7 ± 0.93	**2.23 ± 0.95**	NC	0.27
Thallium-208	**0.24 ± 0.099**	**0.37 ± 0.06**	***42.6***	0.69	**0.232 ± 0.094**	**0.32 ± 0.05**	31.9	0.52	**0.31 ± 0.1**	**0.28 ± 0.05**	10.2	0.17	**0.4 ± 0.12**	**0.46 ± 0.07**	14.0	0.26
Thorium-228	NA	**0.92 ± 0.11**	NC	NC	NA	**0.9 ± 0.09**	NC	NC	NA	**0.82 ± 0.11**	NC	NC	NA	**1.02 ± 0.13**	NC	NC
Thorium-234	**1.34 ± 0.57**	**0.59 ± 0.52**	***77.7***	0.66	**1.04 ± 0.58**	<0.72 ± 0.72	NC	0.24	<0.98 ± 0.54	**0.5 ± 0.4**	NC	0.50	**1.45 ± 0.96**	**0.65 ± 0.33**	***76.2***	0.60
Uranium 235 and 236	<0.31 ± 0.18	NA	NC	NC	<0.4 ± 0.22	NA	NC	NC	<0.4 ± 0.22	NA	NC	NC	<0.42 ± 0.23	NA	NC	NC

Field Sample Identification	TS5-SS226-0000	TS5-SS226-0000			TS5-SS230-0000	TS5-SS230-0000			TS5-SS240-0000	TS5-SS240-0000			TS5-SS248-0000	TS5-SS248-0000		
Date Collected	9/11/2003	9/11/2003			9/16/2003	9/16/2003			9/16/2003	9/16/2003			9/18/2003	9/18/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil			Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1			E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)																
Gamma-Emitting Radionulices/E901.1 (pCi/g)																
Actinium-228	**0.96 ± 0.29**	**0.91 ± 0.11**	5.3	0.10	**1.03 ± 0.3**	**0.72 ± 0.11**	***35.4***	0.63	**0.88 ± 0.29**	**0.86 ± 0.11**	2.3	0.04	**0.62 ± 0.23**	**0.87 ± 0.1**	33.6	0.61
Bismuth-212	<0.93 ± 0.46	**0.53 ± 0.31**	NC	0.50	<0.86 ± 0.44	**0.63 ± 0.29**	NC	0.30	<0.44 ± 0.43	**0.81 ± 0.27**	NC	0.51	<0.7 ± 0.36	**0.49 ± 0.27**	NC	0.32
Bismuth-214	**1.06 ± 0.24**	**1.03 ± 0.12**	2.9	0.06	**1.04 ± 0.27**	**0.96 ± 0.11**	8.0	0.16	**0.66 ± 0.23**	**0.88 ± 0.1**	28.6	0.53	**0.57 ± 0.17**	**0.81 ± 0.12**	34.8	0.66
Cesium-137	<0.094 ± 0.05	<0.08 ± 0.08	NC	0.11	<0.082 ± 0.05	<0.07 ± 0.07	NC	0.10	<0.067 ± 0.038	<0.06 ± 0.06	NC	0.07	<0.085 ± 0.047	**40.14 ± 38.55**	NC	***1.03***
Cobalt-60	<0.11 ± 0.053	<0.08 ± 0.08	NC	0.22	<0.081 ± 0.053	<0.07 ± 0.07	NC	0.09	<0.074 ± 0.043	<0.07 ± 0.07	NC	0.03	<0.08 ± 0.032	<0.07 ± 0.07	NC	0.10
Lead-212	**0.79 ± 0.19**	**0.77 ± 0.13**	2.6	0.05	**0.9 ± 0.18**	**0.65 ± 0.13**	32.3	0.65	**0.98 ± 0.19**	**0.91 ± 0.09**	7.4	0.17	**0.59 ± 0.14**	**0.69 ± 0.13**	15.6	0.30
Lead-214	**1.05 ± 0.2**	**0.92 ± 0.1**	13.2	0.31	**0.9 ± 0.19**	**0.81 ± 0.1**	10.5	0.23	**0.72 ± 0.15**	**0.81 ± 0.09**	11.8	0.27	**0.7 ± 0.15**	**0.84 ± 0.1**	18.2	0.41
Potassium-40	**14.4 ± 3.1**	**14.11 ± 1.82**	2.0	0.04	**14.8 ± 3.2**	**16.57 ± 2.06**	11.3	0.25	**16.7 ± 3.2**	**17.14 ± 2.09**	2.6	0.06	**14.6 ± 2.8**	**13.9 ± 1.78**	4.9	0.11
Radium-224	**3.9 ± 2.5**	**1.04 ± 0.78**	***115.8***	0.85	<1.2 ± 0.8	**0.89 ± 0.82**	NC	0.19	<1.7 ± 1.3	**0.75 ± 0.49**	NC	0.52	**1.7 ± 1.3**	**0.6 ± 0.07**	***95.7***	0.76
Radium-226	**1.9 ± 1.0**	**1.56 ± 0.94**	19.7	0.17	<1.6 ± 0.83	**1.53 ± 0.87**	NC	0.04	**2.04 ± 0.82**	**1.61 ± 0.68**	23.6	0.27	**0.99 ± 0.9**	**2.59 ± 0.09**	***89.4***	***1.22***
Thallium-208	**0.38 ± 0.11**	**0.33 ± 0.06**	14.1	0.25	**0.3 ± 0.1**	**0.3 ± 0.06**	0.0	0.00	**0.36 ± 0.11**	**0.34 ± 0.05**	5.7	0.10	**0.19 ± 0.074**	**0.27 ± 0.06**	34.8	0.53
Thorium-228	NA	**0.91 ± 0.11**	NC	NC	NA	**0.72 ± 0.11**	NC	NC	NA	**0.86 ± 0.11**	NC	NC	NA	**0.87 ± 0.1**	NC	NC
Thorium-234	**1.19 ± 0.45**	<0.75 ± 0.75	NC	0.35	<0.97 ± 0.53	**0.38 ± 0.31**	NC	0.68	<0.97 ± 0.56	**0.64 ± 0.24**	NC	0.39	<0.82 ± 0.45	**0.4 ± 0.33**	NC	0.52
Uranium 235 and 236	<0.38 ± 0.21	NA	NC	NC	<0.39 ± 0.22	NA	NC	NC	<0.38 ± 0.21	NA	NC	NC	<0.3 ± 0.17	NA	NC	NC

Notes:
Bold indicates a positive result.
Bold italics indicates an RPD or RER greater than 35 or 1.0, respectively.
ft bgs = feet below ground surface
NA = not applicable
NC = not calculated
pCi/g = picocuries per gram
RER = replicate error ratio
RPD = relative percent difference

Table 5-44. Quality Assurance Samples Comparison at Training Site 6, Environmental Restoration Program Site OT-10

Field Sample Identification	TS6-SS-53-0000	TS6-SS-53-0000			TS6-SS-63-0000	TS6-SS-63-0000			TS6-SS-73-0000	TS6-SS-73-0000			TS6-SS-83-0000	TS6-SS-83-0000		
Date Collected	10/6/2003	10/6/2003			9/25/2003	9/25/2003			9/25/2003	9/25/2003			9/25/2003	9/25/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil			Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1			E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)																
Gamma-Emitting Radionuclides/E901.1 (pCi/g)																
Actinium-228	**0.63 ± 0.21**	**0.87 ± 0.1**	32.0	0.61	**0.86 ± 0.33**	**0.75 ± 0.12**	13.7	0.21	**0.76 ± 0.27**	**0.76 ± 0.11**	0.0	0.00	**0.63 ± 0.28**	**0.85 ± 0.12**	29.7	0.47
Bismuth-212	<0.62 ± 0.37	**0.38 ± 0.27**	NC	0.37	<0.97 ± 0.47	**0.54 ± 0.27**	NC	0.56	<0.65 ± 0.33	<0.53 ± 0.53	NC	0.14	<0.68 ± 0.35	**0.47 ± 0.27**	NC	0.33
Bismuth-214	**0.59 ± 0.18**	**0.93 ± 0.11**	***44.7***	0.90	**0.85 ± 0.2**	**0.92 ± 0.12**	7.9	0.17	**0.62 ± 0.19**	**0.76 ± 0.1**	20.3	0.39	**0.75 ± 0.21**	**0.84 ± 0.11**	11.3	0.22
Cesium-137	**0.1 ± 0.051**	**0.06 ± 0.03**	***50.0***	0.47	<0.096 ± 0.047	**0.11 ± 0.05**	NC	0.14	<0.094 ± 0.048	**0.05 ± 0.03**	NC	0.54	**0.117 ± 0.063**	**0.19 ± 0.05**	***47.6***	0.59
Cobalt-60	<0.078 ± 0.035	<0.08 ± 0.08	NC	0.02	<0.075 ± 0.044	<0.09 ± 0.09	NC	0.11	<0.11 ± 0.054	<0.07 ± 0.07	NC	0.31	<0.1 ± 0.048	<0.08 ± 0.08	NC	0.15
Lead-212	**0.65 ± 0.13**	**0.75 ± 0.11**	14.3	0.26	**0.69 ± 0.16**	**0.73 ± 0.1**	5.6	0.10	**0.69 ± 0.14**	**0.61 ± 0.08**	12.3	0.22	**0.46 ± 0.13**	**0.85 ± 0.11**	***59.5***	***1.00***
Lead-214	**0.61 ± 0.13**	**0.84 ± 0.11**	31.7	0.71	**0.81 ± 0.17**	**0.82 ± 0.09**	1.2	0.03	**0.75 ± 0.15**	**0.86 ± 0.09**	13.7	0.32	**0.76 ± 0.15**	**0.89 ± 0.09**	15.8	0.37
Potassium-40	**13.7 ± 2.5**	**14.86 ± 1.86**	8.1	0.19	**16.4 ± 3.2**	**14.53 ± 1.91**	12.1	0.27	**13.1 ± 2.8**	**14.17 ± 1.81**	7.8	0.17	**11.7 ± 2.5**	**16.8 ± 2.09**	***35.8***	0.81
Radium-224	<1.3 ± 1.0	**0.75 ± 0.6**	NC	0.34	<1.7 ± 1.2	**0.7 ± 0.66**	NC	0.53	**2.6 ± 1.7**	<2.2 ± 2.2	NC	0.10	**2.5 ± 1.7**	**0.62 ± 0.61**	***120.5***	0.80
Radium-226	**1.52 ± 0.8**	**2.47 ± 0.72**	***47.6***	0.58	**1.8 ± 1.1**	**1.67 ± 0.77**	7.5	0.07	<1.4 ± 0.75	**1.41 ± 0.82**	NC	0.01	<1.2 ± 0.88	**2.9 ± 0.8**	NC	0.94
Thallium-208	**0.213 ± 0.077**	**0.3 ± 0.05**	33.9	0.58	**0.283 ± 0.097**	**0.28 ± 0.06**	1.1	0.02	**0.224 ± 0.067**	**0.26 ± 0.05**	14.9	0.23	**0.221 ± 0.071**	**0.33 ± 0.06**	***39.6***	0.70
Thorium-228	NA	**0.87 ± 0.1**	NC	NC	NA	**0.75 ± 0.12**	NC	NC	NA	**0.76 ± 0.11**	NC	NC	NA	**0.85 ± 0.12**	NC	NC
Thorium-234	<0.84 ± 0.45	**1.03 ± 0.33**	NC	0.23	<0.92 ± 0.35	**0.43 ± 0.28**	NC	0.74	<0.88 ± 0.47	**0.64 ± 0.3**	NC	0.30	<0.83 ± 0.45	**0.61 ± 0.26**	NC	0.30
Uranium 235 and 236	<0.28 ± 0.16	NA	NC	NC	<0.34 ± 0.2	NA	NC	NC	<0.31 ± 0.19	NA	NC	NC	<0.33 ± 0.18	NA	NC	NC

Field Sample Identification	TS6-SS-93-0000	TS6-SS-93-0000			TS6-SS-103-0000	TS6-SS-103-0000			TS6-SS-113-0000	TS6-SS-113-0000			TS6-SS-123-0000	TS6-SS-123-0000		
Date Collected	9/25/2003	9/25/2003			10/6/2003	10/6/2003			9/25/2003	9/25/2003			9/25/2003	9/25/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil			Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1			E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)																
Gamma-Emitting Radionuclides/E901.1 (pCi/g)																
Actinium-228	**0.43 ± 0.2**	**0.64 ± 0.12**	***39.3***	0.58	**0.33 ± 0.18**	**0.84 ± 0.1**	***87.2***	***1.47***	**1.32 ± 0.36**	**1.17 ± 0.12**	12.0	0.24	**0.86 ± 0.29**	**0.75 ± 0.09**	13.7	0.24
Bismuth-212	<0.43 ± 0.27	<0.7 ± 0.7	NC	0.27	<0.59 ± 0.28	**0.49 ± 0.26**	NC	0.18	<1.0 ± 0.48	**0.93 ± 0.35**	NC	0.08	<1.0 ± 0.5	**0.63 ± 0.26**	NC	0.46
Bismuth-214	**0.4 ± 0.13**	**0.73 ± 0.11**	***58.4***	***1.11***	**0.2 ± 0.12**	**0.74 ± 0.09**	***114.9***	***2.03***	**0.99 ± 0.29**	**0.84 ± 0.12**	16.4	0.30	**1.09 ± 0.25**	**0.82 ± 0.1**	28.3	0.59
Cesium-137	<0.057 ± 0.028	<0.07 ± 0.07	NC	0.13	<0.057 ± 0.031	<0.07 ± 0.07	NC	0.13	<0.14 ± 0.068	**0.06 ± 0.05**	NC	0.49	<0.085 ± 0.043	<0.06 ± 0.06	NC	0.24
Cobalt-60	<0.082 ± 0.033	<0.09 ± 0.09	NC	0.06	<0.064 ± 0.033	<0.07 ± 0.07	NC	0.06	<0.1 ± 0.051	<0.09 ± 0.09	NC	0.07	<0.14 ± 0.062	<0.07 ± 0.07	NC	0.51
Lead-212	**0.43 ± 0.12**	**0.68 ± 0.13**	***45.0***	0.65	**0.376 ± 0.093**	**0.76 ± 0.11**	***67.6***	***1.02***	**1.3 ± 0.25**	**1.15 ± 0.11**	12.2	0.31	**0.68 ± 0.17**	**0.75 ± 0.08**	9.8	0.19
Lead-214	**0.52 ± 0.14**	**0.8 ± 0.1**	***42.4***	0.88	**0.342 ± 0.091**	**0.69 ± 0.09**	***67.4***	***1.44***	**0.98 ± 0.19**	**0.78 ± 0.11**	22.7	0.50	**0.91 ± 0.2**	**0.78 ± 0.1**	15.4	0.33
Potassium-40	**9.5 ± 2**	**14.3 ± 1.9**	***40.3***	0.90	**10.5 ± 2.1**	**17.47 ± 2.13**	***49.8***	***1.16***	**16.5 ± 3.3**	**15.06 ± 2**	9.1	0.20	**13.9 ± 3.2**	**13.77 ± 1.73**	0.9	0.02
Radium-224	<1.2 ± 0.84	<1.01 ± 1.01	NC	0.10	**1.4 ± 1.0**	**0.6 ± 0.58**	***80.0***	0.50	**2.9 ± 2**	**1.17 ± 0.61**	***85.0***	0.65	**2.8 ± 1.9**	<0.77 ± 0.77	NC	0.75
Radium-226	<1.1 ± 0.57	**1.49 ± 0.78**	NC	0.28	<0.94 ± 0.49	**1.16 ± 0.67**	NC	0.18	**1.5 ± 1.4**	**1.9 ± 0.91**	23.5	0.17	<1.8 ± 0.95	**1.96 ± 0.62**	NC	0.10
Thallium-208	**0.099 ± 0.064**	**0.21 ± 0.05**	***71.8***	0.89	**0.136 ± 0.052**	**0.28 ± 0.05**	***69.2***	***1.19***	**0.44 ± 0.13**	**0.34 ± 0.06**	25.6	0.45	**0.269 ± 0.094**	**0.28 ± 0.05**	4.0	0.07
Thorium-228	NA	**0.64 ± 0.12**	NC	NC	NA	**0.84 ± 0.1**	NC	NC	NA	**1.17 ± 0.12**	NC	NC	NA	**0.75 ± 0.09**	NC	NC
Thorium-234	<0.69 ± 0.37	<0.73 ± 0.73	NC	0.04	<0.61 ± 0.33	**0.58 ± 0.38**	NC	0.04	<1.2 ± 0.63	**0.55 ± 0.31**	NC	0.67	<1.2 ± 0.62	**0.54 ± 0.23**	NC	0.74
Uranium 235 and 236	<0.31 ± 0.17	NA	NC	NC	<0.22 ± 0.13	NA	NC	NC	<0.43 ± 0.24	NA	NC	NC	<0.44 ± 0.24	NA	NC	NC

Table 5-44. Quality Assurance Samples Comparison at Training Site 6, Environmental Restoration Program Site OT-10 (continued)

Field Sample Identification	TS6-SS-133-0000	TS6-SS-133-0000			TS6-SS-143-0000	TS6-SS-143-0000			TS6-SS-153-0000	TS6-SS-153-0000			TS6-SS-163-0000	TS6-SS-163-0000		
Date Collected	9/30/2003	9/30/2003			9/25/2003	9/25/2003			9/25/2003	9/25/2003			9/26/2003	9/26/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil			Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1			E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)																
Gamma-Emitting Radionuclides/E901.1 (pCi/g)																
Actinium-228	**0.93 ± 0.33**	**0.81 ± 0.13**	13.8	0.22	**0.86 ± 0.29**	**0.7 ± 0.1**	20.5	0.35	**1.54 ± 0.5**	**1.55 ± 0.1**	0.6	0.01	**1.51 ± 0.54**	**1.14 ± 0.12**	27.9	0.47
Bismuth-212	<1.0 ± 0.53	**0.44 ± 0.36**	NC	0.61	<0.77 ± 0.36	**0.33 ± 0.23**	NC	0.72	<1.4 ± 0.67	**0.98 ± 0.32**	NC	0.40	<1.1 ± 0.54	**0.9 ± 0.31**	NC	0.22
Bismuth-214	**1.11 ± 0.27**	**1.05 ± 0.13**	5.6	0.12	**0.65 ± 0.21**	**0.76 ± 0.1**	15.6	0.29	**1.37 ± 0.35**	**1.4 ± 0.15**	2.2	0.05	**1.22 ± 0.32**	**0.97 ± 0.12**	22.8	0.45
Cesium-137	<0.12 ± 0.064	<0.09 ± 0.09	NC	0.19	<0.13 ± 0.062	**0.1 ± 0.04**	NC	0.28	<0.13 ± 0.067	<0.08 ± 0.08	NC	0.33	<0.12 ± 0.069	<0.07 ± 0.07	NC	0.35
Cobalt-60	<0.11 ± 0.051	<0.1 ± 0.1	NC	0.06	<0.077 ± 0.037	<0.07 ± 0.07	NC	0.06	<0.086 ± 0.041	<0.09 ± 0.09	NC	0.03	<0.14 ± 0.074	<0.08 ± 0.08	NC	0.38
Lead-212	**0.97 ± 0.19**	**0.81 ± 0.1**	18.0	0.39	**0.71 ± 0.15**	**0.69 ± 0.07**	2.9	0.06	**1.4 ± 0.28**	**1.23 ± 0.12**	12.9	0.33	**1.44 ± 0.3**	**1.24 ± 0.13**	14.9	0.38
Lead-214	**1.02 ± 0.22**	**1 ± 0.12**	2.0	0.04	**0.74 ± 0.14**	**0.69 ± 0.08**	7.0	0.16	**1.38 ± 0.26**	**1.2 ± 0.14**	14.0	0.32	**1.22 ± 0.25**	**1.01 ± 0.11**	18.8	0.42
Potassium-40	**14.2 ± 3**	**14.16 ± 1.92**	0.3	0.01	**15.1 ± 3**	**15.99 ± 2**	5.7	0.13	**15.7 ± 3.3**	**17.9 ± 2.24**	13.1	0.29	**18.1 ± 3.5**	**14.73 ± 1.88**	20.5	0.46
Radium-224	<1.3 ± 0.92	**0.76 ± 0.64**	NC	0.34	**2 ± 1.4**	**0.47 ± 0.44**	***123.9***	0.81	**4.3 ± 2.8**	**1.21 ± 0.81**	***112.2***	0.83	**5.9 ± 3.7**	**1.24 ± 0.71**	***130.5***	***1.03***
Radium-226	**1.9 ± 1.2**	**1.47 ± 0.84**	25.5	0.20	**1.9 ± 1.1**	**2.02 ± 0.69**	6.1	0.06	<2.3 ± 1.2	**2.53 ± 0.86**	NC	0.11	**2.1 ± 1.2**	**2.25 ± 0.75**	6.9	0.07
Thallium-208	**0.31 ± 0.12**	**0.31 ± 0.06**	0.0	0.00	**0.209 ± 0.081**	**0.29 ± 0.05**	32.5	0.53	**0.44 ± 0.14**	**0.45 ± 0.07**	2.2	0.04	**0.46 ± 0.15**	**0.44 ± 0.06**	4.4	0.08
Thorium-228	NA	**0.81 ± 0.13**	NC	NC	NA	**0.7 ± 0.1**	NC	NC	NA	**1.55 ± 0.1**	NC	NC	NA	**1.14 ± 0.12**	NC	NC
Thorium-234	**1.65 ± 0.55**	**0.61 ± 0.32**	***92.0***	***1.11***	**1.14 ± 0.55**	**0.45 ± 0.24**	***86.8***	0.84	<1.5 ± 0.82	**0.7 ± 0.3**	NC	0.68	<1.3 ± 0.51	**0.78 ± 0.27**	NC	0.62
Uranium 235 and 236	<0.42 ± 0.23	NA	NC	NC	<0.33 ± 0.18	NA	NC	NC	<0.48 ± 0.27	NA	NC	NC	<0.47 ± 0.26	NA	NC	NC

Field Sample Identification	TS6-SS-173-0000	TS6-SS-173-0000			TS6-SS-183-0000	TS6-SS-183-0000			TS6-SS-193-0000	TS6-SS-193-0000			TS6-SS-203-0000	TS6-SS-203-0000		
Date Collected	9/30/2003	9/30/2003			9/26/2003	9/26/2003			9/26/2003	9/26/2003			9/26/2003	9/26/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil			Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1			E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)																
Gamma-Emitting Radionuclides/E901.1 (pCi/g)																
Actinium-228	**1.16 ± 0.38**	**1.02 ± 0.15**	12.8	0.22	**0.67 ± 0.28**	**1.06 ± 0.1**	***45.1***	0.80	**1.38 ± 0.6**	**1.13 ± 0.12**	19.9	0.30	**1.56 ± 0.5**	**1.66 ± 0.15**	6.2	0.12
Bismuth-212	<1.0 ± 0.51	**0.61 ± 0.38**	NC	0.42	<0.84 ± 0.42	**0.71 ± 0.28**	NC	0.18	<1.4 ± 0.68	**0.86 ± 0.36**	NC	0.49	<1.4 ± 0.63	**0.59 ± 0.32**	NC	0.81
Bismuth-214	**0.91 ± 0.25**	**1.03 ± 0.15**	12.4	0.24	**0.62 ± 0.2**	**0.82 ± 0.1**	27.8	0.53	**1.2 ± 0.39**	**1.37 ± 0.15**	13.2	0.25	**1.21 ± 0.33**	**1.16 ± 0.14**	4.2	0.08
Cesium-137	<0.094 ± 0.049	<0.1 ± 0.1	NC	0.04	**0.102 ± 0.069**	**0.1 ± 0.04**	2.0	0.02	<0.14 ± 0.081	<0.09 ± 0.09	NC	0.29	<0.14 ± 0.076	<0.09 ± 0.09	NC	0.29
Cobalt-60	<0.11 ± 0.061	<0.11 ± 0.11	NC	0.00	<0.096 ± 0.049	<0.07 ± 0.07	NC	0.21	<0.12 ± 0.063	<0.1 ± 0.1	NC	0.12	<0.17 ± 0.073	<0.09 ± 0.09	NC	0.48
Lead-212	**1.18 ± 0.22**	**1.1 ± 0.12**	7.0	0.17	**0.78 ± 0.17**	**1 ± 0.11**	24.7	0.52	**1.25 ± 0.31**	**1 ± 0.12**	22.2	0.53	**1.95 ± 0.36**	**1.72 ± 0.16**	12.5	0.35
Lead-214	**0.77 ± 0.18**	**1.2 ± 0.14**	***43.7***	0.97	**0.67 ± 0.16**	**0.82 ± 0.08**	20.1	0.45	**1.45 ± 0.32**	**1.18 ± 0.12**	20.5	0.45	**1.38 ± 0.28**	**1.18 ± 0.12**	15.6	0.36
Potassium-40	**14.6 ± 3.1**	**13.97 ± 1.98**	4.4	0.09	**17.6 ± 3.4**	**16.85 ± 2.06**	4.4	0.10	**20.3 ± 4.2**	**18.23 ± 2.31**	10.7	0.24	**19 ± 3.8**	**17.07 ± 2.17**	10.7	0.24
Radium-224	**1.23 ± 0.82**	<1.2 ± 1.2	NC	0.01	**3.6 ± 2.3**	**0.88 ± 0.58**	***121.4***	0.92	**4.6 ± 3.1**	**1.43 ± 0.68**	***105.1***	0.82	**4.2 ± 2.6**	**1.39 ± 0.87**	***100.5***	0.79
Radium-226	<1.6 ± 0.88	**2.02 ± 0.84**	NC	0.23	<1.1 ± 0.87	**1.66 ± 0.7**	NC	0.34	**3.5 ± 1.5**	**2.39 ± 0.93**	***37.7***	0.43	**2.5 ± 1.2**	**1.95 ± 0.83**	24.7	0.26
Thallium-208	**0.33 ± 0.12**	**0.32 ± 0.06**	3.1	0.05	**0.31 ± 0.11**	**0.37 ± 0.06**	17.6	0.30	**0.4 ± 0.15**	**0.4 ± 0.07**	0.0	0.00	**0.64 ± 0.18**	**0.64 ± 0.08**	0.0	0.00
Thorium-228	NA	**1.02 ± 0.15**	NC	NC	NA	**1.06 ± 0.1**	NC	NC	NA	**1.13 ± 0.12**	NC	NC	NA	**1.66 ± 0.15**	NC	NC
Thorium-234	**1.15 ± 0.65**	**0.98 ± 0.37**	16.0	0.16	<0.95 ± 0.52	**0.75 ± 0.25**	NC	0.25	<1.7 ± 0.9	**0.96 ± 0.33**	NC	0.57	**2 ± 0.91**	**0.89 ± 0.32**	***76.8***	0.85
Uranium 235 and 236	<0.42 ± 0.23	NA	NC	NC	<0.35 ± 0.2	NA	NC	NC	<0.49 ± 0.3	NA	NC	NC	<0.59 ± 0.32	NA	NC	NC

Table 5-44. Quality Assurance Samples Comparison at Training Site 6, Environmental Restoration Program Site OT-10 (continued)

Field Sample Identification	TS6-SS-213-0000	TS6-SS-213-0000			TS6-SS-223-0000	TS6-SS-223-0000			TS6-SS-233-0000	TS6-SS-233-0000			TS6-SS-243-0000	TS6-SS-243-0000		
Date Collected	9/30/2003	9/30/2003			9/26/2003	9/26/2003			9/26/2003	9/26/2003			9/26/2003	9/26/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil			Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1			E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)																
Gamma-Emitting Radionuclides/E901.1 (pCi/g)																
Actinium-228	1.38 ± 0.41	1.46 ± 0.16	5.6	0.11	0.66 ± 0.24	0.62 ± 0.11	6.3	0.10	1.69 ± 0.43	1.97 ± 0.12	15.3	0.34	1.68 ± 0.62	1.54 ± 0.13	8.7	0.15
Bismuth-212	1.14 ± 0.64	0.76 ± 0.33	*40.0*	0.38	<0.59 ± 0.39	<0.64 ± 0.64	NC	0.05	<0.66 ± 0.67	1.83 ± 0.34	NC	*1.05*	<1.4 ± 0.66	1.44 ± 0.37	NC	0.04
Bismuth-214	1.09 ± 0.3	1.14 ± 0.14	4.5	0.09	0.6 ± 0.18	0.8 ± 0.11	28.6	0.55	0.65 ± 0.2	0.89 ± 0.1	31.2	0.62	1.39 ± 0.34	1.24 ± 0.14	11.4	0.24
Cesium-137	<0.13 ± 0.065	<0.09 ± 0.09	NC	0.25	<0.094 ± 0.048	<0.07 ± 0.07	NC	0.20	<0.087 ± 0.047	<0.07 ± 0.07	NC	0.14	<0.13 ± 0.076	<0.09 ± 0.09	NC	0.24
Cobalt-60	<0.12 ± 0.069	<0.09 ± 0.09	NC	0.18	<0.095 ± 0.043	<0.09 ± 0.09	NC	0.04	<0.11 ± 0.056	<0.07 ± 0.07	NC	0.31	<0.12 ± 0.066	<0.09 ± 0.09	NC	0.19
Lead-212	1.53 ± 0.29	1.44 ± 0.13	6.1	0.16	0.45 ± 0.14	0.63 ± 0.07	33.3	0.53	1.32 ± 0.26	2.05 ± 0.15	*43.3*	*1.16*	1.96 ± 0.38	1.46 ± 0.17	29.2	0.78
Lead-214	1.33 ± 0.24	1.11 ± 0.11	18.0	0.43	0.76 ± 0.17	0.67 ± 0.09	12.6	0.27	0.7 ± 0.16	0.81 ± 0.08	14.6	0.33	1.24 ± 0.27	1.15 ± 0.11	7.5	0.17
Potassium-40	16.4 ± 3.4	16.27 ± 2.09	0.8	0.02	16.1 ± 3.1	15.37 ± 2.01	4.6	0.10	12.9 ± 2.8	16.46 ± 1.97	24.3	0.54	18.9 ± 3.9	17.28 ± 2.2	9.0	0.20
Radium-224	4.7 ± 3	1.21 ± 0.66	*118.1*	0.93	1.7 ± 1.4	0.61 ± 0.5	*94.4*	0.56	2.5 ± 1.8	1.2 ± 0.5	*70.3*	0.55	3.4 ± 2.6	1.43 ± 1	*81.6*	0.54
Radium-226	1.6 ± 1.1	2.5 ± 0.93	*43.9*	0.42	<1.5 ± 0.77	1.51 ± 0.81	NC	0.01	<1.6 ± 0.87	1.53 ± 0.61	NC	0.05	2.1 ± 1.4	2.63 ± 0.93	22.4	0.22
Thallium-208	0.49 ± 0.15	0.45 ± 0.06	8.5	0.16	0.261 ± 0.09	0.23 ± 0.05	12.6	0.20	0.58 ± 0.14	0.73 ± 0.08	22.9	0.50	0.54 ± 0.18	0.56 ± 0.08	3.6	0.06
Thorium-228	NA	1.46 ± 0.16	NC	NC	NA	0.62 ± 0.11	NC	NC	NA	1.97 ± 0.12	NC	NC	NA	1.54 ± 0.13	NC	NC
Thorium-234	<1.3 ± 0.72	1.28 ± 0.34	NC	0.02	<0.91 ± 0.48	0.5 ± 0.32	NC	0.50	1.34 ± 0.66	0.6 ± 0.36	*76.3*	0.70	2.09 ± 0.9	0.71 ± 0.32	*98.6*	*1.07*
Uranium 235 and 236	<0.44 ± 0.24	NA	NC	NC	<0.36 ± 0.2	NA	NC	NC	<0.4 ± 0.23	NA	NC	NC	<0.57 ± 0.31	NA	NC	NC

Field Sample Identification	TS6-SS-253-0000	TS6-SS-253-0000			TS6-SS-263-0000	TS6-SS-263-0000			TS6-SS-273-0000	TS6-SS-273-0000			TS6-SS-283-0000	TS6-SS-283-0000		
Date Collected	9/26/2003	9/26/2003			9/27/2003	9/27/2003			9/27/2003	9/27/2003			9/27/2003	9/27/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil			Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1			E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)																
Gamma-Emitting Radionuclides/E901.1 (pCi/g)																
Actinium-228	1 ± 0.4	0.97 ± 0.13	3.0	0.05	0.81 ± 0.3	0.76 ± 0.1	6.4	0.11	1.06 ± 0.41	0.98 ± 0.13	7.8	0.13	1.29 ± 0.38	1.04 ± 0.13	21.5	0.40
Bismuth-212	<0.95 ± 0.48	0.76 ± 0.29	NC	0.23	<0.92 ± 0.45	0.29 ± 0.22	NC	0.91	<0.88 ± 0.42	0.55 ± 0.41	NC	0.38	<1.1 ± 0.51	0.83 ± 0.3	NC	0.31
Bismuth-214	1.11 ± 0.27	0.99 ± 0.13	11.4	0.23	0.58 ± 0.21	0.77 ± 0.11	28.1	0.49	1.34 ± 0.32	1.05 ± 0.15	24.3	0.49	1.04 ± 0.27	1.05 ± 0.12	1.0	0.02
Cesium-137	<0.12 ± 0.058	<0.09 ± 0.09	NC	0.20	<0.08 ± 0.048	<0.07 ± 0.07	NC	0.08	<0.12 ± 0.063	<0.1 ± 0.1	NC	0.12	<0.11 ± 0.056	<0.07 ± 0.07	NC	0.31
Cobalt-60	<0.13 ± 0.062	<0.1 ± 0.1	NC	0.18	<0.078 ± 0.041	<0.08 ± 0.08	NC	0.02	<0.14 ± 0.058	<0.11 ± 0.11	NC	0.17	<0.12 ± 0.048	<0.09 ± 0.09	NC	0.21
Lead-212	1.19 ± 0.23	0.95 ± 0.1	22.4	0.53	0.68 ± 0.17	0.74 ± 0.1	8.5	0.16	1.16 ± 0.25	0.87 ± 0.09	28.6	0.67	1.31 ± 0.28	1.03 ± 0.12	23.9	0.58
Lead-214	1.19 ± 0.22	1.03 ± 0.1	14.4	0.34	0.69 ± 0.17	0.73 ± 0.09	5.6	0.12	1.21 ± 0.25	1.06 ± 0.11	13.2	0.30	1.08 ± 0.22	1 ± 0.13	7.7	0.17
Potassium-40	18.3 ± 3.8	14.69 ± 1.99	21.9	0.47	14 ± 2.8	14.47 ± 1.84	3.3	0.07	16 ± 3.5	15.61 ± 2.13	2.5	0.05	16.2 ± 3.2	15.79 ± 2	2.6	0.06
Radium-224	2.8 ± 1.8	<1.11 ± 1.11	NC	0.57	2.6 ± 1.8	0.94 ± 0.6	*93.8*	0.68	3.6 ± 2.5	0.83 ± 0.69	*125.1*	0.85	3.4 ± 2.3	1.01 ± 0.77	*108.4*	0.76
Radium-226	2.4 ± 1.1	1.48 ± 0.93	*47.4*	0.44	1.4 ± 1.1	1.94 ± 0.73	32.3	0.28	3.6 ± 1.3	2.27 ± 0.96	*45.3*	0.55	2.2 ± 1.5	2.38 ± 0.81	7.9	0.07
Thallium-208	0.32 ± 0.13	0.33 ± 0.06	3.1	0.05	0.2 ± 0.079	0.32 ± 0.05	*46.2*	0.78	0.35 ± 0.13	0.33 ± 0.07	5.9	0.09	0.43 ± 0.12	0.4 ± 0.06	7.2	0.14
Thorium-228	NA	0.97 ± 0.13	NC	NC	NA	0.76 ± 0.1	NC	NC	NA	0.98 ± 0.13	NC	NC	NA	1.04 ± 0.13	NC	NC
Thorium-234	1.8 ± 0.72	<0.78 ± 0.78	NC	0.65	<0.97 ± 0.52	0.51 ± 0.25	NC	0.57	<1.4 ± 0.74	0.91 ± 0.36	NC	0.42	<1.2 ± 0.66	1.06 ± 0.29	NC	0.14
Uranium 235 and 236	<0.47 ± 0.26	NA	NC	NC	<0.36 ± 0.2	NA	NC	NC	<0.45 ± 0.25	NA	NC	NC	<0.44 ± 0.24	NA	NC	NC

Table 5-44. Quality Assurance Samples Comparison at Training Site 6, Environmental Restoration Program Site OT-10(continued)

Field Sample Identification	TS6-SS-293-0000	TS6-SS-293-0000			TS6-SS-303-0000	TS6-SS-303-0000			TS6-SS-313-0000	TS6-SS-313-0000			TS6-SS-323-0000	TS6-SS-323-0000		
Date Collected	9/30/2003	9/30/2003			10/10/2003	10/10/2003			9/27/2003	9/27/2003			9/27/2003	9/27/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil			Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1			E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)																
Gamma-Emitting Radionuclides/E901.1 (pCi/g)																
Actinium-228	1.55 ± 0.46	1.13 ± 0.14	31.3	0.57	0.95 ± 0.33	0.88 ± 0.13	7.7	0.13	1.01 ± 0.34	0.81 ± 0.09	22.0	0.38	2.57 ± 0.64	2.09 ± 0.13	20.6	0.44
Bismuth-212	<1.2 ± 0.57	0.78 ± 0.39	NC	0.42	<0.78 ± 0.39	0.56 ± 0.26	NC	0.32	<0.91 ± 0.46	0.4 ± 0.24	NC	0.70	2.6 ± 1.0	1.52 ± 0.37	*52.4*	0.72
Bismuth-214	0.9 ± 0.33	1.03 ± 0.13	13.5	0.23	0.65 ± 0.21	0.74 ± 0.11	12.9	0.23	0.89 ± 0.24	1.03 ± 0.11	14.6	0.30	1.04 ± 0.31	1.16 ± 0.13	10.9	0.21
Cesium-137	<0.16 ± 0.08	0.14 ± 0.05	NC	0.15	<0.094 ± 0.049	<0.07 ± 0.07	NC	0.20	<0.092 ± 0.051	<0.05 ± 0.05	NC	0.41	<0.14 ± 0.07	<0.07 ± 0.07	NC	0.49
Cobalt-60	<0.097 ± 0.049	<0.1 ± 0.1	NC	0.02	<0.099 ± 0.053	<0.09 ± 0.09	NC	0.06	<0.089 ± 0.051	<0.06 ± 0.06	NC	0.26	<0.16 ± 0.075	<0.08 ± 0.08	NC	0.50
Lead-212	1.22 ± 0.27	1.2 ± 0.14	1.7	0.04	0.67 ± 0.17	0.99 ± 0.1	*38.6*	0.78	0.73 ± 0.18	0.66 ± 0.1	10.1	0.19	2.46 ± 0.46	2.24 ± 0.17	9.4	0.27
Lead-214	1.3 ± 0.25	1.01 ± 0.13	25.1	0.56	0.63 ± 0.14	0.78 ± 0.1	21.3	0.46	1.03 ± 0.2	0.88 ± 0.08	15.7	0.37	1.36 ± 0.28	1.07 ± 0.1	23.9	0.54
Potassium-40	17.7 ± 3.7	15.64 ± 2.08	12.4	0.27	14.4 ± 2.8	14.76 ± 1.93	2.5	0.06	15.9 ± 3.2	14.36 ± 1.78	10.2	0.23	17.9 ± 3.6	15.25 ± 1.9	16.0	0.36
Radium-224	3.3 ± 2.4	<1.13 ± 1.13	NC	0.60	2.9 ± 1.9	<0.91 ± 0.91	NC	0.69	4.5 ± 2.8	<0.66 ± 0.66	NC	*1.08*	5.3 ± 3.4	0.82 ± 0.56	*146.4*	*1.10*
Radium-226	1.7 ± 1.4	2.25 ± 0.98	27.8	0.22	<1.1 ± 0.9	1.77 ± 0.79	NC	0.38	1.7 ± 1.1	0.91 ± 0.56	*60.5*	0.46	<2.4 ± 1.3	2.1 ± 0.73	NC	0.14
Thallium-208	0.55 ± 0.16	0.44 ± 0.08	22.2	0.39	0.286 ± 0.092	0.35 ± 0.06	20.1	0.35	0.23 ± 0.11	0.3 ± 0.05	26.4	0.38	0.92 ± 0.21	0.74 ± 0.08	21.7	0.46
Thorium-228	NA	1.13 ± 0.14	NC	NC	NA	0.88 ± 0.13	NC	NC	NA	0.81 ± 0.09	NC	NC	NA	2.09 ± 0.13	NC	NC
Thorium-234	1.48 ± 0.82	0.52 ± 0.03	*96.0*	*1.03*	<0.86 ± 0.47	0.63 ± 0.29	NC	0.29	1.2 ± 0.58	<0.76 ± 0.76	NC	0.32	3.1 ± 1.1	1.15 ± 0.41	*91.8*	*1.19*
Uranium 235 and 236	<0.5 ± 0.26	NA	NC	NC	<0.33 ± 0.19	NA	NC	NC	<0.38 ± 0.22	NA	NC	NC	<0.57 ± 0.32	NA	NC	NC

Field Sample Identification	TS6-SS-333-0000	TS6-SS-333-0000			TS6-SS-343-0000	TS6-SS-343-0000			TS6-SS-353-0000	TS6-SS-353-0000			TS6-SS-363-0000	TS6-SS-363-0000		
Date Collected	9/30/2003	9/30/2003			9/27/2003	9/27/2003			9/29/2003	9/29/2003			9/29/2003	9/29/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil			Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1			E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)																
Gamma-Emitting Radionuclides/E901.1 (pCi/g)																
Actinium-228	1.08 ± 0.44	0.96 ± 0.14	11.8	0.18	0.88 ± 0.31	0.56 ± 0.12	*44.4*	0.66	2.46 ± 0.61	1.51 ± 0.16	*47.9*	0.96	1.04 ± 0.31	0.8 ± 0.13	26.1	0.46
Bismuth-212	<1.0 ± 0.52	0.51 ± 0.3	NC	0.58	<0.87 ± 0.39	<0.64 ± 0.64	NC	0.22	2.43 ± 0.89	1.12 ± 0.39	*73.8*	0.94	<0.92 ± 0.47	<0.68 ± 0.68	NC	0.20
Bismuth-214	0.98 ± 0.3	0.85 ± 0.12	14.2	0.26	0.75 ± 0.22	0.69 ± 0.11	8.3	0.15	1.09 ± 0.32	0.95 ± 0.13	13.7	0.25	1.08 ± 0.28	0.95 ± 0.13	12.8	0.25
Cesium-137	<0.1 ± 0.059	<0.08 ± 0.08	NC	0.14	<0.09 ± 0.047	<0.08 ± 0.08	NC	0.08	<0.13 ± 0.072	<0.1 ± 0.1	NC	0.17	<0.11 ± 0.056	<0.08 ± 0.08	NC	0.22
Cobalt-60	<0.11 ± 0.047	<0.1 ± 0.1	NC	0.07	<0.081 ± 0.037	<0.1 ± 0.1	NC	0.14	<0.15 ± 0.069	<0.11 ± 0.11	NC	0.22	<0.1 ± 0.043	<0.09 ± 0.09	NC	0.07
Lead-212	0.9 ± 0.23	0.94 ± 0.1	4.3	0.09	0.56 ± 0.13	0.59 ± 0.09	5.2	0.09	2.18 ± 0.44	1.6 ± 0.12	30.7	0.88	0.72 ± 0.18	0.85 ± 0.09	16.6	0.33
Lead-214	1.18 ± 0.26	0.85 ± 0.11	32.5	0.68	0.73 ± 0.16	0.7 ± 0.08	4.2	0.09	1.22 ± 0.29	0.96 ± 0.11	21.8	0.46	1.03 ± 0.24	0.95 ± 0.12	8.1	0.17
Potassium-40	14.5 ± 3.2	15.27 ± 2.01	5.2	0.11	12.8 ± 2.7	12.81 ± 1.75	0.1	0.00	15.8 ± 3.4	15.76 ± 2.13	0.3	0.01	15.1 ± 3.2	14.82 ± 1.98	1.9	0.04
Radium-224	2.8 ± 2.1	0.84 ± 0.59	*107.7*	0.71	<1.7 ± 1.2	<0.99 ± 0.99	NC	0.32	4.7 ± 3.1	<3.32 ± 3.32	NC	0.21	3.1 ± 2.1	0.85 ± 0.62	*113.9*	0.81
Radium-226	2.5 ± 1.5	2.9 ± 0.89	14.8	0.16	<1.5 ± 0.76	1.2 ± 0.73	NC	0.19	4.6 ± 2.7	2.55 ± 1.05	*57.3*	0.53	1.9 ± 1.2	2.28 ± 0.93	18.2	0.17
Thallium-208	0.31 ± 0.12	0.3 ± 0.06	3.3	0.05	0.287 ± 0.091	0.27 ± 0.08	6.1	0.09	0.74 ± 0.21	0.68 ± 0.09	8.5	0.16	0.27 ± 0.1	0.31 ± 0.06	13.8	0.22
Thorium-228	NA	0.96 ± 0.14	NC	NC	NA	0.56 ± 0.12	NC	NC	NA	1.51 ± 0.16	NC	NC	NA	0.8 ± 0.13	NC	NC
Thorium-234	5.1 ± 1.1	3.37 ± 0.41	*40.9*	0.87	<0.85 ± 0.45	0.57 ± 0.28	NC	0.37	2.5 ± 1.2	0.84 ± 0.37	*99.4*	*1.01*	<1.1 ± 0.61	0.94 ± 0.32	NC	0.16
Uranium 235 and 236	<0.49 ± 0.27	NA	NC	NC	<0.37 ± 0.2	NA	NC	NC	<0.6 ± 0.34	NA	NC	NC	<0.4 ± 0.22	NA	NC	NC

Table 5-44. Quality Assurance Samples Comparison at Training Site 6, Environmental Restoration Program Site OT-10 (concluded)

Field Sample Identification	TS6-SS-373-0000	TS6-SS-373-0000			TS6-SS-383-0000	TS6-SS-383-0000			TS6-SS-393-0000	TS6-SS-393-0000		
Date Collected	9/29/2003	9/29/2003			9/29/2003	9/29/2003			10/3/2003	10/3/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)												
Gamma-Emitting Radionuclides/E901.1 (pCi/g)												
Actinium-228	**0.74 ± 0.36**	**0.87 ± 0.12**	16.1	0.23	**0.65 ± 0.3**	**0.71 ± 0.11**	8.8	0.13	**0.76 ± 0.26**	**0.92 ± 0.11**	19.0	0.35
Bismuth-212	<1.2 ± 0.54	**0.61 ± 0.28**	NC	0.68	<0.98 ± 0.51	**0.45 ± 0.29**	NC	0.64	<0.79 ± 0.37	**0.61 ± 0.26**	NC	0.27
Bismuth-214	**0.91 ± 0.27**	**0.95 ± 0.12**	4.3	0.08	**1.13 ± 0.26**	**0.83 ± 0.12**	30.6	0.62	**0.79 ± 0.23**	**0.97 ± 0.11**	20.5	0.41
Cesium-137	<0.12 ± 0.062	<0.08 ± 0.08	NC	0.27	<0.11 ± 0.056	<0.09 ± 0.09	NC	0.13	**0.15 ± 0.075**	**0.17 ± 0.04**	12.5	0.16
Cobalt-60	<0.1 ± 0.056	<0.09 ± 0.09	NC	0.07	<0.13 ± 0.075	<0.09 ± 0.09	NC	0.24	<0.098 ± 0.052	<0.07 ± 0.07	NC	0.22
Lead-212	**0.84 ± 0.2**	**0.87 ± 0.11**	3.5	0.07	**0.87 ± 0.17**	**0.63 ± 0.09**	32.0	0.64	**0.69 ± 0.16**	**0.83 ± 0.09**	18.4	0.36
Lead-214	**0.87 ± 0.23**	**0.98 ± 0.1**	11.9	0.25	**0.93 ± 0.2**	**0.74 ± 0.08**	22.8	0.50	**0.66 ± 0.15**	**0.75 ± 0.09**	12.8	0.28
Potassium-40	**15.8 ± 3.4**	**15.9 ± 2.07**	0.6	0.01	**16.6 ± 3.2**	**15.92 ± 2.07**	4.2	0.09	**14.6 ± 2.9**	**15.44 ± 1.91**	5.6	0.13
Radium-224	**2.7 ± 1.9**	<1.04 ± 1.04	NC	0.55	<1.2 ± 0.85	**1.07 ± 0.71**	NC	0.08	**2 ± 1.4**	**1.12 ± 0.51**	***56.4***	0.45
Radium-226	<2.1 ± 1.1	<2.13 ± 2.13	NC	0.01	**4.4 ± 1.4**	**4.58 ± 1**	4.0	0.07	<1.6 ± 0.81	**3.17 ± 0.75**	NC	0.91
Thallium-208	**0.35 ± 0.12**	**0.34 ± 0.06**	2.9	0.05	**0.183 ± 0.095**	**0.3 ± 0.06**	***48.4***	0.67	**0.29 ± 0.1**	**0.32 ± 0.05**	9.8	0.17
Thorium-228	NA	**0.87 ± 0.12**	NC	NC	NA	**0.71 ± 0.11**	NC	NC	NA	**0.92 ± 0.11**	NC	NC
Thorium-234	<1.3 ± 0.69	**0.65 ± 0.34**	NC	0.61	**4.57 ± 0.92**	**4.36 ± 0.45**	4.7	0.11	<0.92 ± 0.5	**0.48 ± 0.25**	NC	0.56
Uranium 235 and 236	<0.47 ± 0.26	NA	NC	NC	<0.44 ± 0.24	NA	NC	NC	<0.33 ± 0.18	NA	NC	NC

Notes:
Bold indicates a positive result.
Bold italics indicates an RPD or RER greater than 35 or 1.0, respectively.
ft bgs = feet below ground surface
NA = not applicable
NC = not calculated
pCi/g = picocuries per gram
RER = replicate error ratio
RPD = relative percent difference

Table 5-45. Quality Assurance Samples Comparison at Training Site 7, Environmental Restoration Program Site OT-10

Field Sample Identification	TS7-SS-21-0000	TS7-SS-21-0000			TS7-SS-31-0000	TS7-SS-31-0000			TS7-SS-41-0000	TS7-SS-41-0000			TS7-SS-51-0000	TS7-SS-51-0000		
Date Collected	9/22/2003	9/22/2003			9/22/2003	9/22/2003			9/22/2003	9/22/2003			9/22/2003	9/22/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil			Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1			E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)																
Gamma-Emitting Radionuclides/E901.1 (pCi/g)																
Actinium-228	1.04 ± 0.27	1.33 ± 0.11	24.5	0.54	0.65 ± 0.27	0.93 ± 0.1	*35.4*	0.61	1.13 ± 0.35	1.07 ± 0.13	5.5	0.10	1.02 ± 0.33	0.84 ± 0.12	19.4	0.33
Bismuth-212	<0.59 ± 0.45	1.08 ± 0.31	NC	0.61	<0.66 ± 0.32	0.92 ± 0.32	NC	0.38	<1.1 ± 0.56	0.74 ± 0.32	NC	0.39	<1.1 ± 0.54	0.83 ± 0.26	NC	0.32
Bismuth-214	0.79 ± 0.23	0.77 ± 0.11	2.6	0.05	0.63 ± 0.19	0.72 ± 0.1	13.3	0.25	1.03 ± 0.26	0.89 ± 0.11	14.6	0.29	0.58 ± 0.25	0.82 ± 0.11	34.3	0.56
Cesium-137	<0.07 ± 0.06	0.12 ± 0.05	NC	0.44	<0.089 ± 0.048	<0.07 ± 0.07	NC	0.16	<0.13 ± 0.064	0.08 ± 0.04	NC	0.46	<0.12 ± 0.059	<0.08 ± 0.08	NC	0.28
Cobalt-60	<0.079 ± 0.043	<0.07 ± 0.07	NC	0.08	<0.078 ± 0.044	<0.07 ± 0.07	NC	0.07	<0.13 ± 0.059	<0.08 ± 0.08	NC	0.35	<0.081 ± 0.043	<0.07 ± 0.07	NC	0.10
Lead-212	0.85 ± 0.17	1.28 ± 0.11	*40.4*	0.92	0.68 ± 0.17	0.97 ± 0.1	*35.2*	0.71	1.03 ± 0.23	0.8 ± 0.14	25.1	0.52	0.79 ± 0.22	0.81 ± 0.08	2.5	0.05
Lead-214	0.68 ± 0.15	0.72 ± 0.08	5.7	0.13	0.65 ± 0.15	0.77 ± 0.11	16.9	0.35	0.93 ± 0.22	0.79 ± 0.09	16.3	0.34	0.9 ± 0.2	0.84 ± 0.09	6.9	0.15
Potassium-40	14.9 ± 2.9	14.37 ± 1.84	3.6	0.08	15.9 ± 3	14.45 ± 1.84	9.6	0.22	15.9 ± 3.3	14.99 ± 1.9	5.9	0.13	15.8 ± 3.2	14.92 ± 1.9	5.7	0.13
Radium-224	2.4 ± 1.7	0.94 ± 0.64	*87.4*	0.61	2.1 ± 1.5	0.99 ± 0.58	*71.8*	0.52	3.1 ± 2.1	0.87 ± 0.74	*112.3*	0.77	3.5 ± 2.3	<1.07 ± 1.07	NC	0.71
Radium-226	1.4 ± 1.0	2.45 ± 0.9	*54.5*	0.53	<1.5 ± 0.74	1.74 ± 0.87	NC	0.14	<1.8 ± 0.96	1.29 ± 0.85	NC	0.27	<1.9 ± 0.98	1.22 ± 0.84	NC	0.36
Thallium-208	0.337 ± 0.097	0.52 ± 0.07	*42.7*	0.85	0.306 ± 0.099	0.34 ± 0.07	10.5	0.17	0.36 ± 0.11	0.38 ± 0.06	5.4	0.10	0.24 ± 0.11	0.29 ± 0.06	18.9	0.26
Thorium-228	NA	1.33 ± 0.11	NC	NC	NA	0.93 ± 0.1	NC	NC	NA	1.07 ± 0.13	NC	NC	NA	0.84 ± 0.12	NC	NC
Thorium-234	<0.85 ± 0.5	0.62 ± 0.32	NC	0.27	<0.92 ± 0.5	<0.71 ± 0.71	NC	0.17	<1.0 ± 0.43	0.46 ± 0.33	NC	0.68	<1.2 ± 0.62	0.96 ± 0.32	NC	0.24
Uranium 235 and 236	<0.34 ± 0.19	NA	NC	NC	<0.36 ± 0.19	NA	NC	NC	<0.39 ± 0.23	NA	NC	NC	<0.43 ± 0.25	NA	NC	NC

Field Sample Identification	TS7-SS-61-0000	TS7-SS-61-0000			TS7-SS-71-0000	TS7-SS-71-0000			TS7-SS-81-0000	TS7-SS-81-0000			TS7-SS-91-0000	TS7-SS-91-0000		
Date Collected	9/22/2003	9/22/2003			9/22/2003	9/22/2003			9/23/2003	9/23/2003			9/23/2003	9/23/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil			Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1			E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)																
Gamma-Emitting Radionuclides/E901.1 (pCi/g)																
Actinium-228	<0.66 ± 0.34	0.92 ± 0.12	NC	0.48	0.64 ± 0.27	0.64 ± 0.1	0.0	0.00	0.69 ± 0.3	0.82 ± 0.12	17.2	0.27	0.73 ± 0.25	0.73 ± 0.11	0.0	0.00
Bismuth-212	<0.81 ± 0.38	0.53 ± 0.26	NC	0.42	<0.86 ± 0.41	<0.57 ± 0.57	NC	0.29	<0.81 ± 0.42	0.57 ± 0.28	NC	0.33	<0.95 ± 0.46	<0.56 ± 0.56	NC	0.37
Bismuth-214	0.8 ± 0.23	0.83 ± 0.11	3.7	0.07	0.88 ± 0.25	0.69 ± 0.1	24.2	0.45	0.72 ± 0.22	0.74 ± 0.11	2.7	0.05	0.84 ± 0.21	0.74 ± 0.1	12.7	0.25
Cesium-137	<0.094 ± 0.047	<0.07 ± 0.07	NC	0.20	<0.093 ± 0.049	<0.07 ± 0.07	NC	0.19	<0.099 ± 0.046	<0.07 ± 0.07	NC	0.24	<0.088 ± 0.041	0.04 ± 0.03	NC	0.65
Cobalt-60	<0.097 ± 0.051	<0.08 ± 0.08	NC	0.13	<0.12 ± 0.056	<0.07 ± 0.07	NC	0.39	<0.09 ± 0.054	<0.08 ± 0.08	NC	0.07	<0.096 ± 0.051	<0.08 ± 0.08	NC	0.12
Lead-212	0.95 ± 0.22	1 ± 0.1	5.1	0.12	0.67 ± 0.16	0.68 ± 0.07	1.5	0.03	0.61 ± 0.17	0.72 ± 0.12	16.5	0.28	0.75 ± 0.17	0.74 ± 0.1	1.3	0.03
Lead-214	0.81 ± 0.2	0.8 ± 0.11	1.2	0.03	0.82 ± 0.18	0.69 ± 0.09	17.2	0.37	0.97 ± 0.19	0.85 ± 0.09	13.2	0.30	0.87 ± 0.18	0.76 ± 0.1	13.5	0.29
Potassium-40	14.8 ± 3	14.45 ± 1.84	2.4	0.05	13.4 ± 3	14.89 ± 1.88	10.5	0.23	15.5 ± 3	15.14 ± 1.92	2.3	0.05	15.5 ± 3.1	14.01 ± 1.81	10.1	0.22
Radium-224	<1.9 ± 1.5	1.48 ± 0.64	NC	0.19	4 ± 2.5	<0.95 ± 0.95	NC	0.86	2.3 ± 1.6	<1.01 ± 1.01	NC	0.49	<1.8 ± 1.4	<0.94 ± 0.94	NC	0.36
Radium-226	<1.3 ± 1.0	1.13 ± 0.8	NC	0.09	<1.1 ± 0.84	1.58 ± 0.8	NC	0.28	<1.5 ± 0.76	1.84 ± 0.8	NC	0.21	<1.6 ± 0.81	1.1 ± 0.73	NC	0.31
Thallium-208	0.34 ± 0.11	0.39 ± 0.06	13.7	0.24	0.217 ± 0.093	0.26 ± 0.05	18.0	0.27	0.29 ± 0.12	0.25 ± 0.05	14.8	0.21	0.261 ± 0.095	0.29 ± 0.05	10.5	0.17
Thorium-228	NA	0.92 ± 0.12	NC	NC	NA	0.64 ± 0.1	NC	NC	NA	0.82 ± 0.12	NC	NC	NA	0.73 ± 0.11	NC	NC
Thorium-234	<0.98 ± 0.54	<0.73 ± 0.73	NC	0.19	<0.9 ± 0.5	0.53 ± 0.33	NC	0.43	<0.92 ± 0.51	<0.71 ± 0.71	NC	0.17	<0.87 ± 0.48	<0.72 ± 0.72	NC	0.12
Uranium 235 and 236	<0.38 ± 0.22	NA	NC	NC	<0.34 ± 0.19	NA	NC	NC	<0.39 ± 0.22	NA	NC	NC	<0.38 ± 0.22	NA	NC	NC

Table 5-45. Quality Assurance Samples Comparison at Training Site 7, Environmental Restoration Program Site OT-10 (concluded)

Field Sample Identification	TS7-SS-101-0000	TS7-SS-101-0000			TS7-SS-111-0000	TS7-SS-111-0000		
Date Collected	9/22/2003	9/22/2003			9/22/2003	9/22/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)								
Gamma-Emitting Radionuclides/E901.1 (pCi/g)								
Actinium-228	**0.72 ± 0.25**	**0.66 ± 0.1**	8.7	0.15	**0.85 ± 0.35**	**0.8 ± 0.12**	6.1	0.09
Bismuth-212	<0.79 ± 0.38	**0.79 ± 0.3**	NC	0.00	<0.71 ± 0.48	**0.85 ± 0.31**	NC	0.17
Bismuth-214	**0.71 ± 0.22**	**0.79 ± 0.11**	10.7	0.20	**0.66 ± 0.21**	**0.77 ± 0.1**	15.4	0.29
Cesium-137	<0.092 ± 0.053	**0.06 ± 0.03**	NC	0.37	<0.099 ± 0.053	<0.07 ± 0.07	NC	0.23
Cobalt-60	<0.097 ± 0.051	<0.08 ± 0.08	NC	0.13	<0.095 ± 0.047	<0.07 ± 0.07	NC	0.21
Lead-212	**0.8 ± 0.18**	**0.76 ± 0.1**	5.1	0.10	**0.86 ± 0.17**	**0.69 ± 0.1**	21.9	0.44
Lead-214	**0.73 ± 0.16**	**0.83 ± 0.09**	12.8	0.29	**0.75 ± 0.17**	**0.73 ± 0.1**	2.7	0.06
Potassium-40	**15.7 ± 3.1**	**15.58 ± 1.96**	0.8	0.02	**14.7 ± 2.9**	**15.33 ± 1.93**	4.2	0.09
Radium-224	**3.5 ± 2.2**	**0.93 ± 0.67**	***116.0***	0.87	<1.2 ± 0.74	<0.99 ± 0.99	NC	0.12
Radium-226	<1.4 ± 0.72	**1.41 ± 0.87**	NC	0.01	**1.11 ± 0.89**	**1.61 ± 0.86**	***36.8***	0.28
Thallium-208	**0.236 ± 0.079**	**0.32 ± 0.06**	30.2	0.51	**0.204 ± 0.088**	**0.29 ± 0.05**	34.8	0.54
Thorium-228	NA	**0.66 ± 0.1**	NC	NC	NA	**0.8 ± 0.12**	NC	NC
Thorium-234	**0.93 ± 0.52**	**0.63 ± 0.3**	***38.5***	0.35	<0.97 ± 0.52	**0.48 ± 0.33**	NC	0.56
Uranium 235 and 236	<0.33 ± 0.18	NA	NC	NC	<0.37 ± 0.2	NA	NC	NC

Notes:
Bold indicates a positive result.
Bold italics indicates an RPD or RER greater than 35 or 1.0, respectively.
ft bgs = feet below ground surface
NA = not applicable
NC = not calculated
pCi/g = picocuries per gram
RER = replicate error ratio
RPD = relative percent difference

Table 5-46. Quality Assurance Samples Comparison at Training Site 8, Environmental Restoration Program Site OT-10

Field Sample Identification	TS8-SS-21-0000	TS8-SS-21-0000			TS8-SS-31-0000	TS8-SS-31-0000			TS8-SS-41-0000	TS8-SS-41-0000			TS8-SS-54-0000	TS8-SS-54-0000		
Date Collected	9/30/2003	9/30/2003			9/30/2003	9/30/2003			9/30/2003	9/30/2003			10/1/2003	10/1/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil			Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1			E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)																
Gamma-Emitting Radionuclides/E901.1 (pCi/g)																
Actinium-228	**1.19 ± 0.38**	**1.09 ± 0.13**	8.8	0.16	**0.87 ± 0.31**	1.08 ± 0.12	21.5	0.39	**1.13 ± 0.31**	**1.25 ± 0.13**	10.1	0.21	**0.77 ± 0.25**	**0.95 ± 0.13**	20.9	0.38
Bismuth-212	<0.94 ± 0.46	**0.69 ± 0.3**	NC	0.31	**0.92 ± 0.45**	**0.81 ± 0.33**	12.7	0.13	**1.21 ± 0.49**	**0.79 ± 0.38**	***42.0***	0.46	<0.72 ± 0.35	**0.4 ± 0.29**	NC	0.48
Bismuth-214	**0.79 ± 0.22**	**0.79 ± 0.1**	0.0	0.00	**0.74 ± 0.19**	**0.93 ± 0.11**	22.8	0.48	**0.55 ± 0.2**	**0.81 ± 0.12**	***38.2***	0.67	**0.65 ± 0.2**	**0.98 ± 0.13**	***40.5***	0.79
Cesium-137	<0.11 ± 0.054	**0.07 ± 0.04**	NC	0.41	<0.073 ± 0.043	<0.05 ± 0.05	NC	0.24	<0.085 ± 0.045	<0.09 ± 0.09	NC	0.04	<0.11 ± 0.054	**0.15 ± 0.05**	NC	0.36
Cobalt-60	<0.085 ± 0.046	<0.08 ± 0.08	NC	0.04	<0.098 ± 0.05	<0.07 ± 0.07	NC	0.23	<0.093 ± 0.049	<0.09 ± 0.09	NC	0.02	<0.094 ± 0.046	<0.1 ± 0.1	NC	0.04
Lead-212	**1.05 ± 0.2**	**1.06 ± 0.1**	0.9	0.02	**0.96 ± 0.2**	**1.17 ± 0.12**	19.7	0.45	**0.99 ± 0.2**	**1.34 ± 0.12**	30.0	0.71	**0.68 ± 0.16**	**0.97 ± 0.1**	***35.2***	0.71
Lead-214	**0.81 ± 0.17**	**0.88 ± 0.11**	8.3	0.18	**0.74 ± 0.15**	**0.79 ± 0.1**	6.5	0.15	**0.63 ± 0.15**	**0.86 ± 0.1**	30.9	0.68	**0.7 ± 0.15**	**0.98 ± 0.13**	33.3	0.74
Potassium-40	**17.2 ± 3.2**	**14.72 ± 1.86**	15.5	0.35	**18.9 ± 3.4**	**15.76 ± 1.98**	18.1	0.42	**18.6 ± 3.3**	**15.11 ± 1.98**	20.7	0.48	**21.4 ± 3.7**	**16.05 ± 2.1**	28.6	0.66
Radium-224	**3 ± 2**	**0.73 ± 0.58**	***121.7***	0.86	**3.3 ± 2.1**	**1.21 ± 0.61**	***92.7***	0.75	**2.3 ± 1.6**	**0.89 ± 0.6**	***88.4***	0.63	**2.1 ± 1.5**	**1.1 ± 0.66**	***62.5***	0.45
Radium-226	<1.5 ± 0.78	**1.35 ± 0.84**	NC	0.09	**2 ± 1.0**	**1.72 ± 0.92**	15.1	0.14	<1.3 ± 0.7	**1.99 ± 0.75**	NC	0.45	**1.8 ± 1.1**	**1.76 ± 0.9**	2.2	0.02
Thallium-208	**0.288 ± 0.097**	**0.43 ± 0.06**	***39.6***	0.73	**0.37 ± 0.11**	**0.52 ± 0.07**	33.7	0.66	**0.44 ± 0.1**	**0.46 ± 0.07**	4.4	0.09	**0.258 ± 0.082**	**0.37 ± 0.06**	***35.7***	0.65
Thorium-228	NA	**1.09 ± 0.13**	NC	NC	NA	**1.08 ± 0.12**	NC	NC	NA	**1.25 ± 0.13**	NC	NC	NA	**0.95 ± 0.13**	NC	NC
Thorium-234	<0.98 ± 0.6	**0.69 ± 0.32**	NC	0.30	<0.91 ± 0.36	<0.75 ± 0.75	NC	0.14	<0.84 ± 0.5	**1.22 ± 0.33**	NC	0.43	<0.81 ± 0.44	**0.59 ± 0.31**	NC	0.28
Uranium 235 and 236	<0.35 ± 0.2	NA	NC	NC	<0.37 ± 0.21	NA	NC	NC	<0.37 ± 0.2	NA	NC	NC	<0.33 ± 0.18	NA	NC	NC

Field Sample Identification	TS8-SS-64-0000	TS8-SS-64-0000			TS8-SS-74-0000	TS8-SS-74-0000			TS8-SS-84-0000	TS8-SS-84-0000		
Date Collected	9/30/2003	9/30/2003			10/10/2003	10/10/2003			10/1/2003	10/1/2003		
Depth (ft)	0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50			0.00 - 0.50	0.00 - 0.50		
Matrix	Soil	Soil			Soil	Soil			Soil	Soil		
Analysis Code	E901.1	E901.1			E901.1	E901.1			E901.1	E901.1		
Laboratory	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER	STL-St. Louis	Armstrong Lab	RPD	RER
Analyte/Methods (Units)												
Gamma-Emitting Radionuclides/E901.1 (pCi/g)												
Actinium-228	**0.66 ± 0.3**	**0.77 ± 0.12**	15.4	0.23	**0.7 ± 0.25**	**0.8 ± 0.12**	13.3	0.23	**0.63 ± 0.25**	**0.82 ± 0.13**	26.2	0.43
Bismuth-212	**0.71 ± 0.42**	**0.72 ± 0.31**	1.4	0.01	<0.65 ± 0.33	**0.65 ± 0.27**	NC	0.00	<1.0 ± 0.5	**0.83 ± 0.32**	NC	0.20
Bismuth-214	**0.62 ± 0.19**	**0.8 ± 0.11**	25.4	0.48	**0.74 ± 0.2**	**0.95 ± 0.12**	24.9	0.51	**0.68 ± 0.21**	**0.87 ± 0.12**	24.5	0.46
Cesium-137	<0.11 ± 0.056	**0.09 ± 0.04**	NC	0.20	<0.083 ± 0.043	<0.08 ± 0.08	NC	0.02	**0.114 ± 0.063**	**0.2 ± 0.05**	***54.8***	0.70
Cobalt-60	<0.086 ± 0.043	<0.09 ± 0.09	NC	0.03	<0.11 ± 0.053	<0.09 ± 0.09	NC	0.14	<0.075 ± 0.042	<0.09 ± 0.09	NC	0.11
Lead-212	**0.79 ± 0.17**	**0.75 ± 0.09**	5.2	0.10	**0.6 ± 0.14**	**0.82 ± 0.12**	31.0	0.55	**0.68 ± 0.17**	**0.85 ± 0.09**	22.2	0.44
Lead-214	**0.58 ± 0.13**	**0.82 ± 0.09**	34.3	0.78	**0.67 ± 0.14**	**0.86 ± 0.1**	24.8	0.57	**0.76 ± 0.17**	**0.84 ± 0.1**	10.0	0.22
Potassium-40	**18.8 ± 3.4**	**14.61 ± 1.92**	25.1	0.57	**19.4 ± 3.5**	**13.77 ± 1.86**	33.9	0.77	**16 ± 3.2**	**15.54 ± 2.03**	2.9	0.06
Radium-224	**3.1 ± 2**	**0.79 ± 0.57**	***118.8***	0.88	**2.2 ± 1.5**	**1.13 ± 0.71**	***64.3***	0.47	**2 ± 1.5**	**0.89 ± 0.58**	***76.8***	0.52
Radium-226	**1.6 ± 1.1**	**1.84 ± 0.81**	14.0	0.12	**1.35 ± 0.65**	**2.1 ± 0.89**	***43.5***	0.46	<1.7 ± 0.86	**2.07 ± 0.87**	NC	0.20
Thallium-208	**0.292 ± 0.096**	**0.29 ± 0.06**	0.7	0.01	**0.268 ± 0.075**	**0.33 ± 0.06**	20.7	0.38	**0.292 ± 0.096**	**0.27 ± 0.06**	7.8	0.12
Thorium-228	NA	**0.77 ± 0.12**	NC	NC	NA	**0.8 ± 0.12**	NC	NC	NA	**0.82 ± 0.13**	NC	NC
Thorium-234	<0.85 ± 0.47	**0.46 ± 0.32**	NC	0.48	<0.77 ± 0.43	**0.74 ± 0.3**	NC	0.04	<0.97 ± 0.51	**1.01 ± 0.3**	NC	0.05
Uranium 235 and 236	<0.33 ± 0.18	NA	NC	NC	<0.29 ± 0.16	NA	NC	NC	<0.36 ± 0.21	NA	NC	NC

Notes:
Bold indicates a positive result.
Bold italics indicates an RPD or RER greater than 35 or 1.0, respectively.
ft bgs = feet below ground surface
NA = not applicable
NC = not calculated
pCi/g = picocuries per gram
RER = replicate error ratio
RPD = relative percent difference

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6.0 CONCLUSIONS AND RECOMMENDATIONS

Site conditions at TS5, TS6, TS7, Building 28010, and TS8 with the exception of Building 28005 meet the radiological criteria for unrestricted use. During the decommissioning, TS8 was transferred to DTRA for use as a training facility. The TS8 land areas and Building 28010 were decontaminated and meet the radiological release criteria. However, Building 28005 at TS8 remains contaminated above the radiological release criteria.

The final status survey soil sample data indicate that the radionuclide concentrations are near background levels and that all survey units pass the MARSSIM-recommended tests. The gamma scanning data indicate that no contaminated areas exist that would cause the survey units to fail the elevated measurement comparison and unity rule tests. Therefore, final site conditions may be described as having uniformly low concentrations of radionuclides in soil near background concentrations.

The regulations in 10 CFR Part 20, §1402, require that the concentrations of contaminants be reduced to as low as reasonably achievable (ALARA) levels. Since all areas that had significantly elevated gamma emission rates have been removed, we believe that further removal of soil would not result in a proportional reduction in the radiation dose to future occupants of the site. This condition clearly demonstrates compliance with the ALARA policy.

It is recommended that a petition be submitted to the NRC for unrestricted release of TS5, TS6, TS7, Building 28010, and TS8 with the exception of Building 28005. The petition should include a Certificate of Disposition of Materials (NRC Form 314) and a copy of the Final Status Survey Report.

Installation of a fence at TS8 to segregate Building 28005 and prevent recontamination of the site is planned for the summer of 2005. A copy of the Final Status Survey Report should be provided to DTRA as documentation of the existing TS8 radiological conditions.

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