

June 24, 2011

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Brookhaven Site Office
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DOE CONTRACT NO. DE-AC05-06OR23100
SUBJECT: FINAL REPORT- INDEPENDENT VERIFICATION SURVEY OF THE
HIGH FLUX BEAM REACTOR, BUILDING 802 FAN HOUSE
BROOKHAVEN NATIONAL LABORATORY, UPTON, NEW YORK
DCN: 5098-SR-06-0

Dear Ms. Kneitel:

The Oak Ridge Institute for Science and Education (ORISE), Independent Environmental Assessment and Verification (IEAV) Program has enclosed the final verification survey report for the Fan House Building 802 as part of the High Flux Beam Reactor decommissioning project at Brookhaven National Laboratory. You may contact me via my information provided below or Phyllis Weaver at 865.576.5321 should you have any questions or require additional information.

Sincerely,



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Assistant Project Manager/Health Physicist
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EMH:bf

Enclosure

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**FINAL REPORT –
INDEPENDENT VERIFICATION
SURVEY OF THE HIGH FLUX
BEAM REACTOR,
BUILDING 802 FAN HOUSE
BROOKHAVEN NATIONAL
LABORATORY,
UPTON, NEW YORK**

E. M. Harpenau

Prepared for the
U.S. Department of Energy

ORISE

Oak Ridge Institute for Science and Education

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OF THE HIGH FLUX BEAM REACTOR, BUILDING 802 FAN HOUSE
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK**

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U.S. Department of Energy

FINAL REPORT




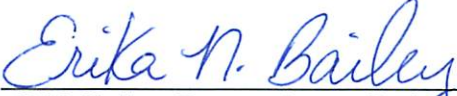
June 2011

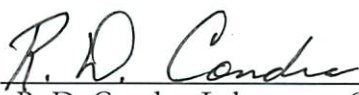
This report is based on work performed by the Oak Ridge Institute for Science and Education under contract number DE-AC05-06OR23100 with the U.S. Department of Energy

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 OF THE HIGH FLUX BEAM REACTOR, BUILDING 802 FAN HOUSE
 BROOKHAVEN NATIONAL LABORATORY
 UPTON, NEW YORK

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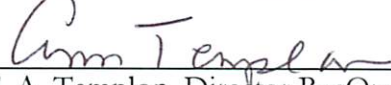
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ABBREVIATIONS AND ACRONYMS

AEC	Atomic Energy Commission
BAO	Brookhaven Area Office
BKG	background
BNL	Brookhaven National Laboratory
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CO	cleanup objective
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FIPS	Federal Information Processing Standard
FSS	final status survey
GPS	Global Positioning System
HFBR	High Flux Beam Reactor
IAG	Interagency Agreement
IEAV	Independent Environmental Assessment and Verification
ISM	Integrated Safety Management
ITP	Intercomparison Testing Program
IV	independent verification
JHA	Job Hazard Analyses
MAPEP	Mixed Analyte Performance Evaluation Program
MDC	minimum detectable concentration
MeV	million electron volts
NaI	sodium iodide
NIST	National Institute for Standards and Technology
NRIP	National Radiochemistry Intercomparison Program
NYSDEC	New York State Department of Environmental Conservation
ORAU	Oak Ridge Associated Universities
ORISE	Oak Ridge Institute for Science and Education
pCi/g	picocuries per gram
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
ROC	Radionuclide of Concern
ROD	Record of Decision
SOR	sum-of-ratio
SPCS	State Plane Coordinate System
TAP	total absorption peak

**INDEPENDENT VERIFICATION SURVEY
OF THE HIGH FLUX BEAM REACTOR, BUILDING 802 FAN HOUSE
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK**

1.0 INTRODUCTION AND SITE HISTORY

The Brookhaven National Laboratory (BNL) located in Upton, Suffolk County, New York, conducts research and development for the Department of Energy's (DOE) Office of Science (Figure A-1). BNL was originally occupied by the U.S. Army as Camp Upton during both World Wars, I and II. In 1947, the site was transferred to the former Atomic Energy Commission; the current DOE. DOE's Brookhaven Area Office (BAO) oversees activities at the site including environmental management programs that involve the cleanup and removal of contaminated facilities and soils.

Research operations and processes conducted at the site have produced a variety of radioactive and hazardous wastes that have had an impact on the local site environment. As a result, the BNL site was included on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priority List on December 21, 1989. In May 1992, DOE entered into an Interagency Agreement (IAG) with the Environmental Protection Agency (EPA) and New York State Department of Environmental Conservation (NYSDEC) under CERCLA, section 120. The IAG established the framework and schedule for characterizing, assessing, and remediating the site in accordance with requirements of CERCLA and the Resource Conservation and Recovery Act (RCRA) (EPA 1997). In April 2009, the Record of Decision (ROD) – Area of Concern 31 for the High Flux Beam Reactor (HFBR) was finalized. The HFBR ROD defined eight isolated areas of contamination that were present in 2005 and have since been remediated (BNL 2009). Per final status survey (FSS) requirements, BNL will assess the outside grounds around the HFBR to assure that the previous remediation activities remain successful and that no activity at BNL has since affected these areas.

Based on guidance in a DOE Environment Management Memorandum, independent verification (IV) shall be performed at all DOE cleanup sites (DOE 2011). At the request of the DOE-BAO, the Oak Ridge Institute for Science and Education's (ORISE) Independent Environmental Assessment and Verification (IEAV) program performed IV of FSS activities associated with the

HFBR decommissioning project. The purpose of IV is to confirm that remediation activities are effective in meeting established guidelines and that documentation accurately and adequately describes the final site conditions. By using an independent third party, DOE can provide a level of assurance to the stakeholders that the as-left radiological conditions meet the established cleanup goals and are accurately documented.

2.0 SITE DESCRIPTION

The HFBR Complex is centrally located within the BNL Site between Cornell Avenue, Renaissance Road, and Rutherford Drive. The HFBR Complex occupies approximately 13 acres that formerly housed multiple structures and systems, including the 802 Fan House. The HFBR 802 Fan House and associated piping once occupied the area located at the north base of the existing Stack (Figure A-2). The boundaries of the initial Survey Unit 6 were modified post remediation and before the FSS. The area delineated by the FSS boundary lines was approximately 1845 m² and included the soils and remaining clay off-gas piping associated with the 802 Fan House (BNL 2011).

3.0 OBJECTIVES

The objective of the verification survey was to obtain evidence by means of measurements and sampling to confirm that the final radiological conditions meet the established cleanup goals. This objective was achieved via multiple verification components, including document reviews, instrument scans, and sample analysis to determine the accuracy and adequacy of FSS documentation.

4.0 PROCEDURES

On May 9, 2011, ORISE performed visual inspections and independent measurements and sampling of remaining soils and the clay pipe associated with the 802 Fan House. Verification activities were conducted in accordance with an ORISE project-specific verification plan, and Survey Procedures and Quality Program Manuals (ORISE 2011a and 2008, and ORAU 2011). Survey activities included surface scans and direct measurements of the soil and structural process piping, and judgmental soil and smear sample collection.

4.1 REFERENCE SYSTEM

ORISE used a Global Positioning System (GPS) for documenting measurement and sampling locations, survey unit or area boundaries, and tracking scan data. The specific geographic coordinate system used was the State Plane Coordinate System (SPCS) New York Long Island Federal Information Processing Standard (FIPS) 3104. Coordinate measurements collected using the GPS were accurate to within one meter.

4.2 SURFACE SCANS

ORISE performed high density gamma scans of accessible soils at the 802 Fan House excavation area. High density alpha and beta scans were also performed at each opening of the remaining clay off-gas pipe that lay beneath an active high pressure steam line. Gamma scans were performed using an unshielded 2 in x 2 in NaI scintillation detector coupled to a ratemeter-scaler with an audible indicator. The detector was coupled to the GPS system that enabled real-time gamma count rate and position data capture (Figure A-3). Scans for alpha and beta residual surface contamination were performed using scintillation detectors coupled to ratemeter-scalers with audible indicators. Scan data were also recorded on the hard copy field survey map.

4.3 SURFACE MEASUREMENTS

Direct measurements were performed with a NaI scintillation detector at each soil sample location prior to and after each sample collection (Figure A-4). Exposed accessible surfaces of the remaining section of the 18 inch clay off-gas pipe were scanned for both alpha and beta contamination. Additionally, a direct measurement was collected at each opening using both alpha and beta detectors. In conjunction with the direct measurements, two smears were collected at each location to determine the presence of removable contamination (Figure A-5). Numbered filter paper disks, 47 mm in diameter were used for collecting removable contamination.

4.4 SOIL SAMPLING

The original soil sampling approach developed using Visual Sampling Plan software was modified as a result of a change in the survey units boundary prior to the FSS. ORISE had not been provided with the revised geospatially oriented maps prior to arriving on-site. Since gamma scans did not indicate the presence of contamination, the selection criteria for the judgmental soil sample

(0 to 0.15 m) locations were based on the deepest points of the excavation, the process connections, and locations with the potential for contamination to collect (Figure A-4).

5.0 SOIL CLEANUP OBJECTIVES

The cleanup objectives for the radionuclides of concern (ROCs) are provided in Table 1 as specified in the HFBR – ROD (BNL 2009). The primary ROCs are cesium-137 (Cs-137), strontium-90 (Sr-90), and radium-226 (Ra-226).

TABLE 1: RADIONUCLIDES OF CONCERN FOR THE 802 FAN HOUSE AT BNL UPTON, NEW YORK	
Radionuclide	Operable Unit I ROD (pCi/g)
Cs-137	23
Sr-90	15
Ra-226	5
<i>Estimated Cleanup Values (pCi/g)^a</i>	
H-3	Not Listed ^b
Co-60	1,260
Am-241	34
Pu-238	57
Pu-239/240	35
Eu-152	51
Eu-154	180
U-235	4.6 ^c
U-238	4.7 ^c

^aEach value listed in this section of the table is the estimated cleanup value if the individual radionuclide was the only radionuclide present (BNL 2010).

^bIf tritium is detected in soil samples, BNL plans to perform a Residual Radioactivity dose modeling software evaluation using the tritium soil concentration.

^cValues listed for uranium are based on 4 millirem per year from groundwater consumption.

6.0 SAMPLE ANALYSIS AND DATA INTERPRETATION

6.1 SOIL ANALYSIS

Soil samples were returned to the ORISE laboratory in Oak Ridge, TN for radiological analysis and interpretation. Sample analyses were performed in accordance with the ORISE Laboratory Procedures Manual (ORISE 2011). Soil samples were analyzed by gamma spectroscopy for Cs-137 and Ra-226. The spectra were also reviewed for other identifiable photopeaks. Sr-90 was quantified by radiochemical separation and counted on a low background proportional counter. Soil sample results are reported in units of picocuries per gram (pCi/g). Analytical results were compared to the cleanup objects provided in Table 1.

6.2 REMOVABLE ACTIVITY MEASUREMENTS

Two smear samples for removable contamination (one smear for gross alpha/beta and one smear for tritium analyses) were obtained from each measurement location inside the 18 inch clay off-gas pipe (Figure A-5). Moderate pressure was applied to a paper smear and approximately 100 cm² of the surface was wiped. Smears were placed in labeled envelopes with the location and other pertinent information recorded. A second smear was moistened with deionized water and an adjacent 100 cm² was wiped for tritium determination. The smear was then sealed in a labeled liquid scintillation vial with the location and pertinent information recorded. Smear results are presented in Table B-1.

7.0 FINDINGS AND RESULTS

The results of the verification surveys for the 802 Fan House and associated off-gas pipe are discussed below.

7.1 SURFACE SCANS

Gamma scan count rates ranged from approximately 5,200 to 13,357 gross counts per minute (cpm) with a mean of 8,311 cpm. The highest count rates were observed where soils were near ground level and in close proximity to ongoing remediation activities around the stack. The isolated count rate in excess of 11,200 cpm is the result of the gamma survey inside the clay off-gas pipe (Figure A-3). This type of ceramic construction material is known to consist of naturally occurring

radioactive material which is typically identified by the elevated count rates observed when compared to the count rates of the surrounding soil.

The orientation of the excavated soils at the east end of the pipe allowed the ORISE surveyor to scan to a depth of approximately one meter inside the pipe, while the excavated soil at the west pipe opening allowed the surveyor to reach an approximate depth of 0.6 meters. Alpha scans ranged from 0-15 cpm at the west opening and 0-10 cpm at the east opening. Beta scans for the west opening of the off-gas pipe ranged from 850-1050 cpm and 750-900 cpm at the east opening.

7.2 DIRECT MEASUREMENTS

Alpha and beta direct measurements were collected inside each opening of the off-gas pipe at the lowest point that could be reached without having to physically enter the pipe. A material specific background was not subtracted from the gross count rate. Moreover, the direct measurements were compared to the ceramic block background count rate for a beta detector with a similar efficiency as listed in Table 5.1 of NUREG-1507 (NRC 1998). This comparison supports the conclusion that the as-left radiological conditions meet the project cleanup goals. The direct measurement data are presented in Table B-1.

7.3 REMOVABLE ACTIVITY

Removable activity inside the clay off-gas pipe was determined through the collection of two smears at each direct measurement location. The removable activities for gross alpha/beta were collected on smears 5098R0041 and 5098R0042. A blank smear was included in the low background proportional analysis with resultant activities for gross alpha/beta of -0.43 and -3.64 dpm/100cm² respectively, which were consistent with the results for smear 5098R0041. H-3 concentrations were determined in smears 5098R0043 and 5098R0044 using a liquid scintillation counter. The resultant activities were 6.1 and 1.7 pCi/100cm² respectively.

7.4 SOIL ANALYSIS

Gamma spectroscopy sample results for the 802 Fan House are provided in Table B-2.

Concentrations of the primary ROCs, Cs-137 ranged from -0.01 to 0.07 pCi/g, Sr-90 ranged from -0.31 to 0.05 pCi/g, and Ra-226 ranged from 0.25 to 0.32 pCi/g. Gamma spectroscopy results were

reviewed to determine the need for additional alpha spectroscopy analysis. The low concentrations of the primary ROCs did not indicate the need for further evaluation.

8.0 COMPARISON OF RESULTS WITH GUIDELINES

The ROCs and the soil cleanup levels shown in Table 1 were compared to the analytical results from the soil samples and smears collected during the verification surveys to determine if the cleanup goals have been met. Since there are multiple ROCs, the unity rule sum-of-ratios (SOR) is applicable to soil samples using the following equation: where the sum of the ratio of individual radionuclide concentration divided by the radionuclide cleanup objective (CO) must be less than or equal to 1.

$$\frac{Conc_{Ra-226}}{CO_{Ra-226}} + \frac{Conc_{Cs-137}}{CO_{Cs-137}} + \frac{Conc_{Sr-90}}{CO_{Sr-90}} + \frac{Conc_n}{CO_n} \leq 1$$

9.0 CONCLUSION

On May 9, 2011, ORISE conducted verification survey activities including scans, sampling, and the collection of smears of the remaining soils and off-gas pipe associated with the 802 Fan House within the HFBR Complex at BNL. ORISE is of the opinion, based on independent scan and sample results obtained during verification activities at the HFBR 802 Fan House, that the FSS unit meets the applicable site cleanup objectives established for as left radiological conditions.

10.0 REFERENCES

Brookhaven National Laboratory (BNL). Bldg. 802 Demolition Highlights. Upton, NY; April 4, 2011.

Brookhaven National Laboratory. Final Record of Decision for AOC 31, High Flux Beam Reactor. Upton, NY; April, 2009.

Brookhaven National Laboratory. High Flux Beam Reactor Decommissioning Project Field Sampling Plan Building 705 (the Stack) and Remaining HFBR Outside Areas. Upton, New York; December, 2010.

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U.S. Department of Energy (DOE). DOE Order 458.1, Chg 1, Radiation Protection of the Public and the Environment. Washington, DC; March 8, 2011.

U.S. Environmental Protection Agency (EPA). Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination (OSWER Directive 9200.14-18), U.S. Environmental Protection Agency, August, 1997.

U.S. Environmental Protection Agency. Guidance on Choosing a Sampling Design for Environmental Data Collection. U.S. Environmental Protection Agency, December 2002.

U.S. Nuclear Regulatory Agency (NRC). Minimum Detectable Concentrations With Typical Radiation Survey Instruments for Various Contaminants and Field Conditions, NUREG 1507. Washington, DC. January 1998.

APPENDIX A
FIGURES



Figure A-1: Location of Brookhaven National Laboratory, Upton, New York



Figure A-2: Plot Plan of the 802 Fan House Survey Area at Brookhaven National Laboratory



Figure A-3: Gamma Scans of the 802 Fan House Survey Area

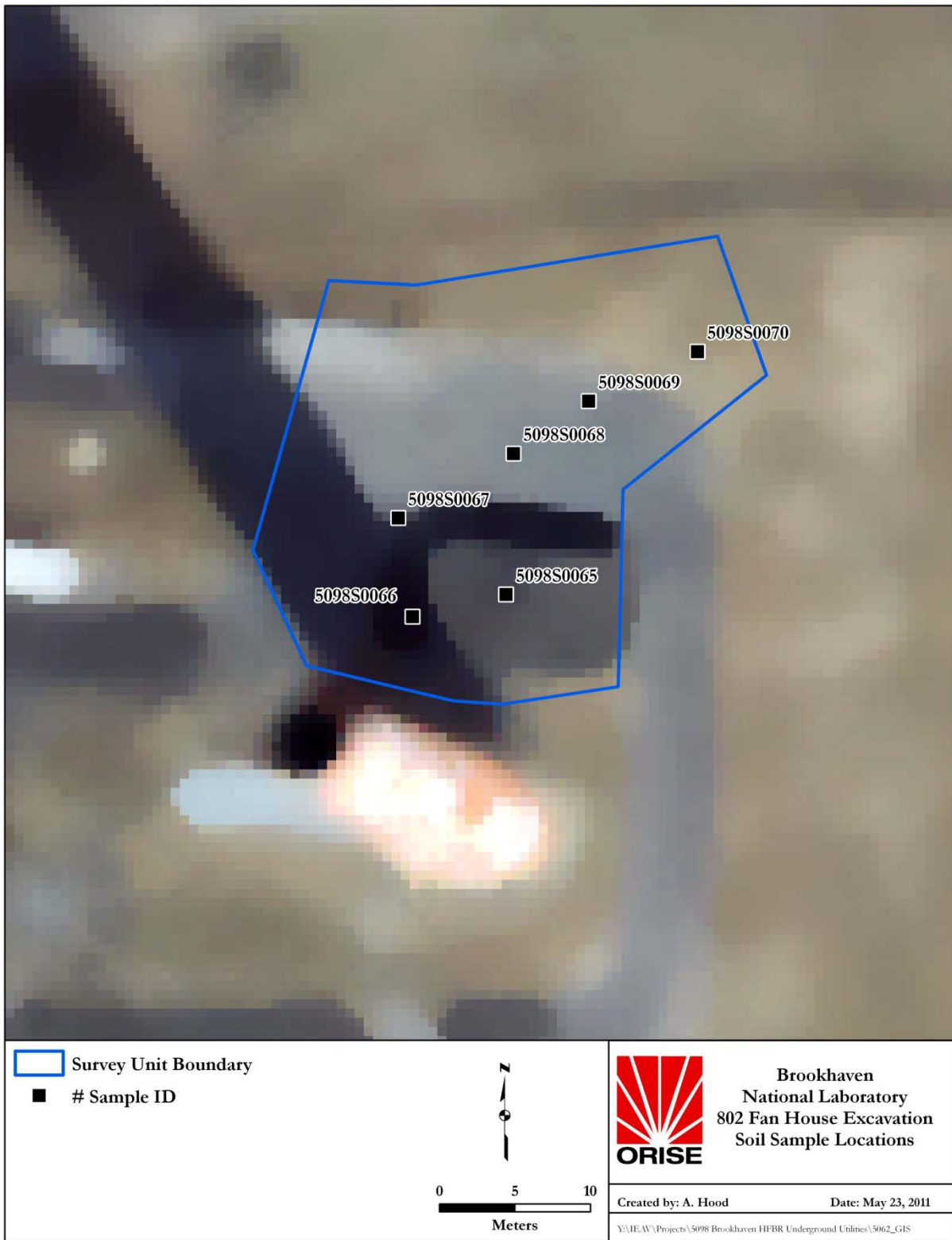


Figure A-4: 802 Fan House Judgmental Soil Sample Locations

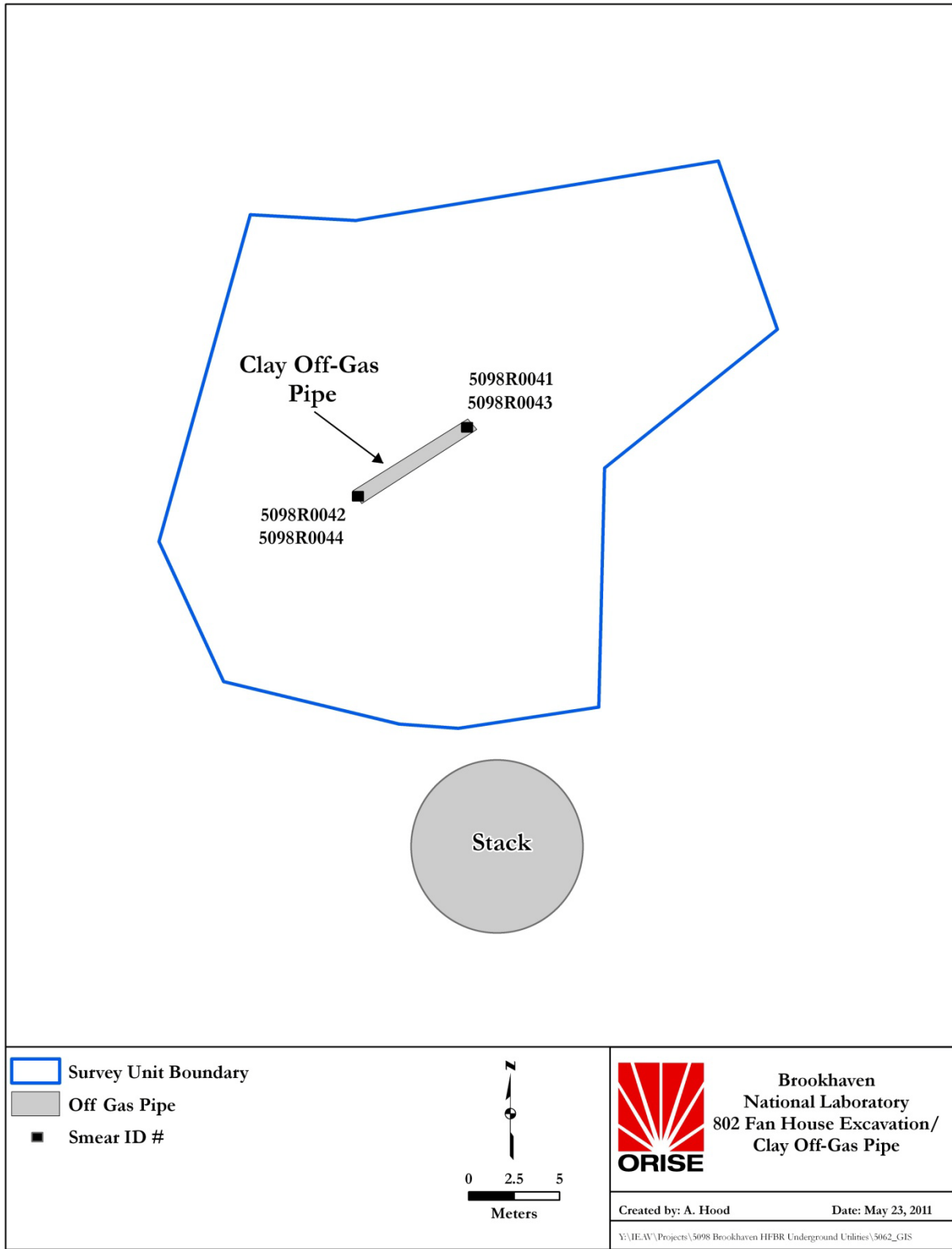


Figure A-5: Clay Off-Gas Pipe Direct Measurement and Smears Locations

**APPENDIX B
TABLES**

**TABLE B-1:
RADIONUCLIDE ACTIVITIES AND CONCENTRATIONS
FOR THE CLAY OFF-GAS PIPE 802 FAN HOUSE
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK**

Smear ID ^a	Direct Measurements				Removable Concentrations			
	Alpha		Beta		Tritium		Low Background Proportional	
	Gross cpm	Activity (dpm/100cm ²)	Gross cpm	Activity (dpm/100cm ²)	Gross cpm	Activity (pCi/g)	Gross Alpha (dpm/100cm ²)	Gross Beta (dpm/100cm ²)
5098R0041	7	64	804	2474	n/a ^b	n/a	-0.43	-3.64
5098R0042	4	36	832	2560	n/a	n/a	1.73	-2.60
5098R0043	7	64	804	2474	10.92	6.1	n/a	n/a
5098R0044	4	36	832	2560	8.79	1.7	n/a	n/a

^aRefer to Figure A-5

^bField is identified as not applicable because smears were individually collected for a specific analytical detection method.

**TABLE B-2:
RADIONUCLIDE CONCENTRATIONS IN SOIL
802 FAN HOUSE
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK**

Sample ID ^a	Radionuclide Concentration in Soil Samples (pCi/g)		
	Cs-137 ^b	Sr-90 ^c	Ra-226 ^{bd}
5098S0065	0.00 ± 0.02 ^e	0.01 ± 0.26	0.26 ± 0.04
5098S0066	0.04 ± 0.03	0.05 ± 0.24	0.25 ± 0.04
5098S0067	0.00 ± 0.02	-0.31 ± 0.22	0.26 ± 0.03
5098S0068	0.01 ± 0.02	-0.22 ± 0.22	0.27 ± 0.04
5098S0069	-0.01 ± 0.03	-0.05 ± 0.31	0.27 ± 0.04
5098S0070	0.07 ± 0.02	-0.05 ± 0.24	0.32 ± 0.04

^aRefer to Figure A-4

^bResults derived from gamma spectroscopy analysis.

^cResults derived from radiochemical separation and a low background proportional counter.

^dRadium-226 concentrations were derived from lead-214. Isotopes were considered to be in equilibrium.

^eUncertainties are at the 95% confidence level based on total propagated uncertainties.

APPENDIX C
MAJOR INSTRUMENTATION

The display of a specific product is not to be construed as an endorsement of the product or its manufacturer by the author or his employer.

C.1 SCANNING AND MEASUREMENT INSTRUMENT/DETECTOR COMBINATIONS

Ludlum Scintillation Detector Model 44-10, Crystal: 2-in. x 2-in. (Ludlum Measurements, Inc., Sweetwater, TX)

Coupled to:

Ludlum Ratemeter-Scaler Model 2221 (Ludlum Measurements, Inc., Sweetwater, TX)

Coupled to:

Trimble GeoXH Receiver and Data Logger (Trimble Navigation Limited, Sunnyvale, CA)

Ludlum Beta Scintillation Detector Model 44-142, 1.125-in. diameter magnetically shielded photomultiplier. (Ludlum Measurements, Inc., Sweetwater, TX)

Coupled to:

Ludlum Ratemeter-Scaler Model 2221 (Ludlum Measurements, Inc., Sweetwater, TX)

Ludlum Alpha Scintillation Detector Model 43-92, 1.125-in. diameter magnetically shielded photomultiplier. (Ludlum Measurements, Inc., Sweetwater, TX)

Coupled to:

Ludlum Ratemeter-Scaler Model 2221 (Ludlum Measurements, Inc., Sweetwater, TX)

C.2 LABORATORY ANALYTICAL INSTRUMENTATION

High-Purity Extended Range Intrinsic Detector CANBERRA/Tennelec Model No: ERVDS30-25195 (Canberra, Meriden, CT)

Used in conjunction with:

Lead Shield Model G-11 (Nuclear Lead, Oak Ridge, TN), Apex Gamma Software (Canberra, Meriden, CT) and Multichannel Analyzer with Dell Workstation

High-Purity Extended Range Intrinsic Detector Model No. GMX-45200-5 (AMETEK/ORTEC, Oak Ridge, TN)

Used in conjunction with:

Lead Shield Model SPG-16-K8 (Nuclear Data), Apex Gamma Software (Canberra, Meriden, CT) and Multichannel Analyzer with Dell Workstation

High-Purity Germanium Detector Model GMX-30-P4, 30% Eff. (AMETEK/ORTEC, Oak Ridge, TN)

Used in conjunction with:

Lead Shield Model G-16 (Gamma Products, Palos Hills, IL), Apex Gamma Software (Canberra, Meriden, CT) and Multichannel Analyzer with Dell Workstation

Low background alpha/beta counting system Canberra/Tennelec LB5100W (Canberra, Inc., Meriden, CT)

Liquid Scintillation Counter Model No. Tri-Carb 3100TR (PerkinElmer, Shelton, CT)

Liquid Scintillation Counter Model No. Tri-Carb 2500TR (Packard, Meriden, CT)

APPENDIX D
SURVEY AND ANALYTICAL PROCEDURES

D.1 PROJECT HEALTH AND SAFETY

The survey and sampling procedures were evaluated to ensure that any hazards inherent to the procedures themselves were addressed in current job hazard analyses (JHAs). All survey and laboratory activities were conducted in accordance with ORISE health and safety and radiation protection procedures.

Pre-survey activities included an overview of potential health and safety issues. BNL representatives provided site-specific safety awareness training for ORISE personnel involved with the survey effort. In-process and verification surveys were performed according to the ORISE generic health and safety plan, site-specific Integrated Safety Management (ISM) pre-job hazard checklist, and safety procedures discussed during the on-site training.

D.2 QUALITY ASSURANCE

Analytical and field survey activities were conducted in accordance with procedures from the following ORAU and ORISE documents:

- Survey Procedures Manual (ORISE 2008)
- Laboratory Procedures Manual (ORISE 2011b)
- Quality Program Manual (ORAU 2011)

The procedures contained in these manuals were developed to meet the requirements of 10 CFR 830 Subpart A, *Quality Assurance Requirements*, Department of Energy Order 414.1C, *Quality Assurance*, and the U.S. Nuclear Regulatory Commission, *Quality Assurance Manual for the Office of Nuclear Material Safety and Safeguards*, and contain measures to assess processes during their performance.

Quality control procedures include:

- Daily instrument background and check-source measurements to confirm that equipment operation is within acceptable statistical fluctuations.
- Participation in Mixed Analyte Performance Evaluation Program (MAPEP), National Institute for Standards and Technology (NIST) Radiochemistry Intercomparison Program (NRIP), and Intercomparison Testing Program (ITP) Laboratory Quality Assurance Programs.

- Training and certification of all individuals performing procedures.
- Periodic internal and external audits.

D.3 CALIBRATION

Calibration of all field and laboratory instrumentation was based on standards/sources, traceable to NIST, when such standards/sources were available. In cases where they were not available, standards of an industry-recognized organization were used.

D.4 SURVEY PROCEDURES

D.4.1 SURFACE SCANS

D.4.1.1 Gamma

Scans for elevated gamma radiation were performed by passing the detector slowly over the surface. The distance between the detector and surface was maintained as close to the surface as possible. NaI scintillation detectors were coupled to GPS units that enabled real-time recording of position in one-second intervals. Identification of elevated radiation levels was based on increases in the audible signal from the instrument. Positioning data files were downloaded from field data loggers for plotting using commercially available software (http://trl.trimble.com/docushare/dsweb/Get/Document-261826/GeoExpl2005_100A_GSG_ENG.pdf).

The scan minimum detectable concentrations (MDCs) for the NaI scintillation detector for the contaminants of concern in surface soil were obtained directly from NUREG-1507¹ when available or estimated using the calculation approach described in NUREG-1507. A typical NaI 2-in x 2-in detector MDC is 6.4 pCi/g for cesium-137. Audible increases in the activity rate are investigated by ORISE. It is standard procedure for ORISE staff to pause and investigate any locations where gamma radiation is distinguishable from background levels.

D.4.1.2 Beta

Surface scans were performed by passing the detectors slowly over the surface; the distance between the detector and the surface was maintained as close as reasonably possible. System surfaces were

¹NUREG-1507. Minimum Detectable Concentrations With Typical Radiation Survey Instruments for Various Contaminants and Field Conditions. U.S. Nuclear Regulatory Commission. Washington, DC; June 1998.

scanned for both alpha and beta radiation using hand-held scintillation detectors. Identification of elevated radiation levels was based on increases in the audible signal from the recording and/or indicating instrument.

Beta surface scan minimum detectable concentrations (MDCs) were estimated using the calculational approach described in NUREG-1507. The scan MDC is a function of many variables, including the background level. Additional parameters selected for the calculation of scan MDCs included a two-second observation interval, a specified level of performance at the first scanning stage of 95% true positive rate and 25% false positive rate, which yields a d' value of 2.32 (NUREG-1507, Table 6.1), and a surveyor efficiency of 0.5. The scanning instrument total efficiency (ϵ_{total}) for the hand-held scintillation detector was approximately 0.32.

The construction material-specific background levels ranged from 750 to 1050 cpm for the scintillation detector. To illustrate an example for a hand-held scintillation detector using a ceramic background of 1050 cpm, the minimum detectable count rate (MDCR) and scan MDC can be calculated using the following relationships:

$$\begin{aligned} s_i &= d'(b_i)^{1/2}; \\ \text{MDCR} &= s_i \times (60/i); \text{ and} \\ \text{MDCR}_{\text{surveyor}} &= \text{MDCR}/(p)^{1/2} \end{aligned}$$

Where:

s_i = the minimum detectable number of source counts

d' = the specified level of performance of 2.32

b_i = the number of background count in the observation interval

MDCR = minimum detectable count rate

i = observation interval

p = surveyor efficiency of 0.5

The equations are combined and the variables are then calculated as follows:

$$\begin{aligned} b_i &= (1050 \text{ cpm})(2 \text{ s})(1 \text{ min}/60 \text{ s}) = 35 \text{ counts}, \\ \text{MDCR} &= (2.32)(35 \text{ counts})^{1/2} [(60 \text{ s}/\text{min})/(2 \text{ s})] = 411.8 \text{ cpm}, \\ \text{MDCR}_{\text{surveyor}} &= 411.8/(0.5)^{1/2} = 292 \text{ cpm} \end{aligned}$$

The scan MDC is calculated assuming a total efficiency (ϵ_{total}) of 0.32:

$$\text{ScanMDC} = \frac{\text{MDCR}_{\text{surveyor}}}{(\epsilon_{total})} \text{dpm} / 100 \text{ cm}^2$$

For the given background, the estimated scan MDC was 913 dpm/100 cm² for the hand-held scintillation detector.

D.4.1.3 Alpha

Determination of the alpha scan sensitivity is a probability-based determination. That is, at a given scan speed and with the associated low alpha background count rates, what is the probability of the surveyor pausing to investigate. Based on the instrumentation and scan speeds, the alpha scan MDC was approximately 300 dpm/100 cm².

D.4.2 SURFACE ACTIVITY MEASUREMENTS

Measurements of total alpha and total beta surface activity levels were performed using hand-held scintillation detectors coupled to portable ratemeter-scalers. Count rates (cpm), which were integrated over one minute with the detector held in a static position, were converted to activity levels (dpm/100 cm²) by dividing the count rate by the total static efficiency ($\epsilon_i \times \epsilon_s$) and correcting for the physical area of the detector.

The *a priori* MDC for surface activity measurements was calculated using the following equation:

$$MDC = \frac{3 + (4.65\sqrt{B})}{Tx\epsilon_{Tot}xG}$$

Where:

B	=	background (total counts) in time interval, T
T	=	count time (min) used for field instruments
ϵ_{Tot}	=	total efficiency = $\epsilon_i \times \epsilon_s$
ϵ_i	=	instrument efficiency
ϵ_s	=	source efficiency
G	=	geometry (physical detector area cm ² /100)

The *a priori* alpha static MDC was approximately 87 dpm/100 cm² using the total efficiency of 0.11 and an instrument background of 2 cpm. The physical surface area assessed by the scintillation detector used was 100 cm². The *a priori* beta static MDC was approximately 300 dpm/100 cm² using the total efficiency of 0.32 and the nominal instrument background of 398 cpm. The physical surface area assessed by the detector used was 100 cm².

D.4.3 REMOVABLE ACTIVITY MEASUREMENTS

Smear samples for removable gross alpha and gross beta contamination were obtained from each measurement location. Removable activity samples were collected using numbered filter paper disks, 47 mm in diameter. Moderate pressure was applied to the smear and approximately 100 cm² of the surface was wiped. Smears were placed in labeled envelopes with the location and other pertinent information recorded. Wet smears were used for determining removable H-3 and C-14 activity and the smear placed into a liquid scintillation vial.

D.4.3 SOIL SAMPLING

Approximately 0.5 to 1 kilogram of soil was collected at each sample location. Collected samples were placed in plastic bags, sealed, and labeled in accordance with ORISE survey procedures.

D.5 RADIOLOGICAL ANALYSIS

D.5.1 GROSS ALPHA/BETA

Smears were counted on a low-background gas proportional system for gross alpha and beta activity. The MDCs of the procedure were 9 dpm/100 cm² and 15 dpm/100 cm² for a 2-minute count time for gross alpha and gross beta, respectively.

D.5.2 LIQUID SCINTILLATION

Smears were counted for five minutes in a liquid scintillation analyzer for low-energy betas to determine the H-3 and C-14 activity. The typical MDCs of the procedure were 34 dpm/100 cm² and 11 dpm/100 cm² for H-3 and C-14, respectively.

D.5.3 DETECTION LIMITS

Detection limits, referred to as MDC, were based on 3 plus 4.65 times the standard deviation of the background (BKG) count [$3 + (4.65 (\text{BKG})^{1/2})$]. Because of variations in background levels, measurement efficiencies, and contributions from other radionuclides in samples, the detection limits differ from sample to sample and instrument to instrument.

D.5.4 RADIOCHEMICAL SEPARATION

Soil samples were dissolved by a combination of potassium hydrogen fluoride and pyrosulfate fusions. The fusion cake was dissolved and strontium was coprecipitated on lead sulfate. The

strontium was separated from residual calcium and lead by precipitating strontium sulfate from ethylenediaminetetraacetic acid at a pH of 4.0. Strontium was separated from barium by complexing the strontium in diethylene triamine pentaacetic acid while precipitating barium as barium carbonate. The strontium was ultimately converted to strontium carbonate and counted on a low-background gas proportional counter. The typical MDC of the procedure is 0.4 pCi/g for a one hour count time.

D.5.5 GAMMA SPECTROSCOPY

Samples of soil were dried, mixed, crushed, and/or homogenized as necessary, and a portion sealed in a 0.5-liter Marinelli beaker or other appropriate container. The quantity placed in the beaker was chosen to reproduce the calibrated counting geometry. Net material weights were determined and the samples counted using intrinsic germanium detectors coupled to a pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. All total absorption peaks (TAPs) associated with the radionuclides of concern were reviewed for consistency of activity. Total absorption peaks used for determining the activities of radionuclides of concern and the typical associated MDCs for a one-hour count time were:

Radionuclide ^a	TAP (MeV)	MDC (pCi/g)
Cs-137	0.662	0.05
Ra-226 (from Pb-214)	0.351	0.08

^aSpectra were also reviewed for other identifiable TAPs.

D.5.6 UNCERTAINTIES

The uncertainties associated with the analytical data presented in the tables of this report represent the total propagated uncertainties for those data. These uncertainties were calculated based on both the gross sample count levels and the associated background count level.