Attachment Z

Final Status Survey Report #28 Documentation

(UNDER SEPARATE COVER)

FSSR # 28

FINAL

COLUMBUS CLOSURE PROJECT CHARACTERIZATION AND FINAL STATUS SURVEY REPORT FOR THE JN-1 A AND C FOUNDATION EXCAVATION

Revision 1
June 16, 2006

Prepared by

FSSR # 28

ECC & E2 Closure Services
1425 State Route 142 East
West Jefferson, OH 43162

Contract Number: DE-AC24-04OH20171

FINAL Characterization and Final Status Report for the JN-1 A and C Foundation Excavation

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1.0 Introduction

This report contains the final status surveys (FSS) for the JN-1 A and C foundation excavation, located at the Columbus Closure Project (CCP), 1425 State Route 142 East, West Jefferson, OH 43162. Final status surveys were conducted according to the guidance presented in the *Manual for Conducting Surveys in Support of License Termination*, NUREG/CR-5849 (NUREG/CR-5849) (ORAU, 1992) and the *Radiological Characterization and Final Status Plan for Battelle Columbus Laboratories Decommissioning Project, West Jefferson Site*, DD-97-02 (Final Status Plan) (Battelle, 2000). The final status surveys were conducted in December of 2005 and performed under Work Instruction 2806 (Closure Services, 2004).

The intent of this final status survey report is to provide a complete and unambiguous record of the radiological status of the JN-1 A and C foundation excavation. Sufficient information and data is provided to enable an independent re-creation and evaluation at some future date of both the survey activities and the reported results for the excavations. Information in this report is also available in referenced technical basis documents, final status survey plans and procedures, and the *Battelle Memorial Institute Columbus Operations, Decommissioning Plan*, DD-93-19 (BMI Decommissioning Plan), and reporting and quality assurance procedures.

To the extent practicable, this final status survey report is presented with minimal information incorporated by reference. This final status survey report has been generated following the comprehensive, annotated outline presented in Chapter 9 of NUREG-5849 (ORAU, 1992).

1.1 Background

On April 16, 1943, BMI, acting through what is now its Battelle Columbus Operations (BCO), entered into Contract No. W-7405-ENG-92 with the Manhattan Engineering District to perform atomic energy research and development (R&D) activities. BCO performed nuclear materials research and development at privately-owned facilities for the Manhattan Engineering District and its successor agencies – the Atomic Energy Commission (AEC), the Energy Research and Development Agency (ERDA), and the Department of Energy (DOE). Research and development continued until 1988 (Battelle, 2003a).

The BCO facilities at the King Avenue Site, Columbus, Ohio, and the West Jefferson North (WJN) and South (WJS) Sites, West Jefferson, Ohio, became partially radiologically contaminated as a result of the R&D activities. Decontamination of the King Avenue and WJS Sites has been completed and activities continue at the WJN site. The DOE, as the successor to the AEC and the Government's earlier work, is the agreed party with predominant liability and responsibility for decontamination and decommissioning (D&D) of the BCO facilities (Battelle, 2003a). The Assistant Secretary for Nuclear Energy of the DOE accepted the decontamination and decommissioning (D&D) of the WJN into the DOE's Surplus Facilities Management Program as a major project (DOE, 1986). The DOE is the agency funding and managing the cleanup of the WJN (Battelle, 2003a). However, the site is not a DOE-owned facility.

BMI holds U.S. Nuclear Regulatory Commission (NRC) license number SNM-7. BMI has continually operated and conducted D&D activities in full compliance with this NRC license. The BMI Decommissioning Plan for the WJN site does not serve as a declaration to terminate SNM-7, but establish the criteria for performing D&D activities. The end goal of the BMI Decommissioning Plan is to reach unrestricted use conditions for the site (Battelle, 2003a).

The DOE has contracted ECC&E2 Closure Services, LLC (Closure Services) to safely remove DOE radioactive materials and contamination from the WJN site. Removal of radioactive material will be to levels allowing future use of the site without radiological restrictions as described in the BMI Decommissioning Plan. Closure Services has conducted the characterization and the final status surveys of the JN-1 A and C foundation excavation, demonstrating that the area is available for unrestricted release.

2.0 Site Description

Created in 1984, the Battelle Columbus Decommissioning Project (BCLDP) is a remediation project that includes nine buildings at the King Avenue site and five at the WJN site. The CCP is the successor of the BCLDP. The WJN site has one permanent structure, the Well House. Three former research facilities, JN-1, JN-2, and JN-3 have been demolished as well as JN-6, the guard house. Several outfalls, filter beds, and wells are also located at the site. **Figure 1** presents a site map for the CCP.

2.1 Area Description

As shown in **Figure 1**, JN-1 lies on the eastern portion of the WJN site. Building JN-1 was the oldest and most contaminated building in the WJN site. Battelle initiated operation within the building in 1955 and continued its use until 1988. Operational activities focused on nuclear research studies. Work conducted included evaluations of both power and research reactor fuels; post-irradiation examination of fissile, control rod, source, and structural materials and components; and examination of irradiation surveillance capsules. In addition, the facility has been the site of radiation source encapsulation and physical and mechanical property studies of irradiated materials and structures (Battelle, 2003a). JN-1 A was the first JN-1 structure and housed two hot cells, the high level and low level hot cells. JN-1 C was the final addition to the JN-1 facility and was comprised of primarily office space. The concrete foundation and all piping has been removed and disposed of as low level waste as well as radiologically contaminated soils above the release criteria. **Figure 2** presents the area included in this report.

Two classifications of areas are used in NUREG-5849 and are termed **affected** or **unaffected.** These classifications are defined as (NRC, 1992):

> **Affected Areas:** Areas that have potential radioactive contamination (based on plant operating history) or known radioactive contamination (based on past or preliminary radiological surveillance). This would normally include areas where radioactive materials were used and stored, where records indicate spills or other unusual occurrences that could have resulted in spread of contamination, and where radioactive materials were buried. Areas immediately surrounding or adjacent to locations where radioactive materials were used, stored, or buried are included in this classification because of the potential for inadvertent spread of contamination.
>
> **Unaffected Areas:** All areas not classified as affected. These areas are not expected to contain residual radioactivity, based on knowledge of site history and previous information.

The JN-1 A and C foundation excavation is considered affected.

3.0 Decommissioning Activities

3.1 Decommissioning Objective

The objective of the final status survey performed on the JN-1 A and C foundation excavation is to statistically demonstrate that the remediation of the area was successful and that the excavation is free from residual radioactive contamination making it suitable for unrestricted release. The excavation is determined to be free of residual radioactive contamination when remaining soil contamination levels are below those presented in DD-93-03, Rev. 0, "Volumetric Release Criteria Technical Basis Document for Battelle Columbus Laboratory Decommissioning Project" (Battelle, 1993A). **Table 1** presents the volumetric release criteria as presented in DD-93-03, Rev. 0.

4.0 Final Status Survey Procedures

Planning and implementation of the final status survey of the excavations adhered to the requirements of the Final Status Plan (Battelle, 2000) and Work Instruction 2806 (CS, 2004).

4.1 Sampling Parameters

Final status samples of the JN-1 A and C foundation excavation were obtained from survey grids. Survey grids were each ten by ten meters, with each grid divided into equal sized quadrants. Final status soil samples were then obtained from each of the grid quadrants. Analyses of samples by gamma spectroscopy were performed by the on-site Radioanalytical Laboratory (RAL).

4.2 Major Contaminants Identified

The characterization of the JN-1 A and C foundation excavation soils identified Cesium-137 (Cs-137) as the contaminant of concern. Other radioisotopes present include Cobalt-60 (Co-6), Europium-152 (Eu-152) and Eu-154, Amercium-241 (Am-241), Srontium-90 (Sr-90), and Plutonium-238 (Pu-238 and 239. Cs-137 is used as a surrogate for the other radioisotopes present in the soils as the Cs-137 activity is predominant over the other radionuclides and Cs-137 possesses one of the lowest cleanup criterion of 15 pCi/g.

Closure Services has consistently utilized Cs-137 as an isotopic surrogate for determining relative concentrations for individual radionuclides contaminants of concern (RCOC). Relative isotopic concentrations for individual RCOC are determined using predetermined ratios of each isotope to Cs-137. Isotopic ratios have been developed for the Building JN-1 Mixture and for the Filter Bed Area. The Building JN-1 Mixture ratio was developed for waste shipping and was based primarily from samples collected within the JN-1 hot cells. The Filter Bed Area ratio was utilized for the final status survey of all areas not associated with JN-1 released as of December, 2005. Neither of these mixtures adequately reflects the conditions of this excavation. As such, a separate isotopic ratio has been developed for the remediation and final status surveys of the Building JN-1 foundation and backyard area.

Table 2 presents the isotopic activity concentrations of samples collected during the remediation of the Building JN-1 foundation, backyard, and the Bog Area. Remediation samples were collected between October and November of 2005. CS Characterization Technicians collected the samples according to Procedures SC-SP-004.2, "Mechanical Collection of Surface and Subsurface Soil Samples in Support of Site Characterization". Sample integrity protocol and data quality objectives were adhered to throughout the sampling effort. Samples were then screened and transferred to the Onsite Radioanalytical Laboratory (RAL) for analysis. Initially, analysis was for gamma emitting RCOC was performed according to procedure RL-TP-030, Rev. 5, "Gamma Spectrometric Analysis of Laboratory Samples Using Canberra Procount^{TM} Software". The RAL also performed analysis for Sr-90 according to procedure RL-TP-035, Rev. 4, "Strontium-90 Analysis by Extraction Chromatograph."

Table 3 lists the ratio of each RCOC to Cs-137. The average, or mathematical mean, and the 95 percent confidence interval were calculated for the ratio of each RCOC to Cs-137. Average values were calculated using the following mathematical equation (USDOC, 1966):

$$X = \frac{1}{n}\sum_{i=1}^{n} X_i$$

Where:

X	=	mathematical mean
n	=	number of samples
Xi	=	sample value (i.e. ratio)

The upper confidence interval of the sample mathematical mean was calculated using the following mathematical equation (USDOC, 1966):

$$X_U = X + t\frac{s}{\sqrt{n}}$$

Where:

X_U	=	upper confidence interval
X	=	mathematical mean
t	=	percentile of the t distribution, $\alpha = 0.05$, df = n-1
s	=	standard deviation
n	=	number of samples

The lower confidence interval of the sample mathematical mean was calculated using the following mathematical equation (USDOC, 1966):

$$X_L = X - t\frac{s}{\sqrt{n}}$$

Where:

X_L	=	lower confidence interval

The confidence interval reports a range of values on either side of the mathematical mean. A significance level of $\alpha = 0.05$ was used to set a confidence level. The confidence level equals $100*(1-\alpha)\%$, or indicating a 95 percent confidence level. This interval was set to contain the true average "95% of the time." The lower confidence interval value, X_L, has been selected as the isotopic ratio value for the Building JN-1 Foundation and Backyard area. The lower confidence level was selected as a lower radionuclide ratio is conservative.

Activity concentrations for final status survey samples collected for the Building JN-1 foundation and backyard have been calculated using the average isotopic ratios as presented in **Table 4**.

4.2.1 Guidelines Established

Table 1 presents the guidelines for residual radioactivity concentrations for soil and solid volumes as applied to the JN1 excavation. Criteria for residual radioactivity concentrations in soil are defined in "Volumetric Release Criteria Technical Basis Document for Battelle

Columbus Laboratories Decommissioning Project," DD-93-03, (Battelle, 1993). **Table 1** values have been generated primarily from various regulatory requirements, technical documents, and from soil guidelines generated by computer pathway analyses. Requirements such as those found in DOE Order 5400.5 have been incorporated into the volumetric release criteria. DOE Order 5400.5, Section IV.a.2, provides generic guidelines for residual concentrations of Ra-226, Ra-228, Th-230, and Th-232 that have been incorporated into the volumetric release criteria. Additionally, NRC Guidance has been received by the CCP establishing the soil radioactivity concentration guidelines for Co-60, Sr-90, Cs-137, Ra-226, and Ra-228, and for natural, enriched and depleted uranium.

Compliance to the cleanup criteria presented in **Table 1** is demonstrated through a "fraction of limit." The total quantity and activity concentration of each RCOC is calculated using the average isotopic ratio listed in **Table 4**, with the exception of the Cs-137 to Pu-241 ratio of 2.8. Calculated results for Co-60, Cs-137, Sr-90, Eu-152 and 154, Pu-239, 240 and 241, and Am-241 are then compared to the respective release criteria and a "fraction of the limit" is calculated. The "fraction of the limit" is determined by summing the ratios of each isotopic concentration to the respective release limit. Summed ratios must be less than one to meet sample release criteria. A modified screening criteria of 7.3 pCi/g for Cs-137 has been calculated using the "fraction of the limit" obtained from the JN1 foundation and backyard area surrogate ratio.

Exposure rates were compared to the 5 microRoentgen per hour (μR/hr) above mean background limit listed in DD-97-02, Rev. 0 (Battelle, 2000). Survey measurements are those 1-meter above the ground surface. The calculated mean background exposure rate and the 95 percent confidence intervals used for the CCP open area grounds is 8 ± 2 μR/hr. Compliance to the limit is met when the exposure rate survey is less then or equal to the limits of DD-97-02, Rev. 0 (Battelle, 2000). Initial compliance screening is met if individual exposure rates are less than or equal to 13 μR/hr. Further assessment of compliance allows for exposure rates to be averaged of a 100 m^2 gird area to meet the limit of less than or equal to 5 μR/hr above background at 1-meter above the ground surface. Additionally, exposure rates over any discreet area may not exceed 5 μR/hr above background.

Data collected from trench-like culverts located on Battelle property unassociated with site operations indicate a geometry effect, increasing the background exposure rates inside the trenches by 3 to 5 μR/hr. Trench exposure rate measurements must be less than or equal to 18 μR/hr. The same compliance assessment is applied to these measurements as stated above.

5.0 Equipment and Procedures

5.1 Equipment

Survey instruments sensitive to gamma radiation are used to monitor excavation surfaces for residual radioactive materials. Ludlum Model 44-10 two-inch by two-inch sodium iodide detectors with Eberline ESP-2 meters were used to scan the excavations. Ludlum Model 19 exposure rate meters were used to obtain microRoentgen per hour measurements.

Other instrumentation used in the Onsite Radioanalytical Laboratory (RAL) to support the final status survey includes:

- A VMS based Canberra Procount data acquisition system in conjunction with high purity germanium detectors for gamma spectroscopy of soil samples.
- A Tennelec Model LB5100 Simultaneous Alpha and Beta Gas Proportional Counter to count smear samples

5.2 Scanning Minimum Detectable Activities

Scanning minimum detectable concentrations (MDC_{scan}) is determined to demonstrate that the MDC_{scan} is less than the modified Cs-137 cleanup criteria. The MDC_{scan} is calculated utilizing the methodology described in NUREG-1507 and the background count rate and a default detector response to Cs-137 (NRC, 1998). The equation during the walkover surveys of the CCP incorporates a d' of 1.38 and a surveyor efficiency of 0.5. The ambient background in the area was 8,200 counts per minute (cpm). This background is determined using an un-shielded probe. The following is the calculation of the MDC_{scan} using an un-shielded probe:

$$b_i = (8{,}200\ \text{cpm}) \times (1\ \text{sec}) \times (1\ \text{min}/60\ \text{sec}) = 136\ \text{counts}$$

$$MDCR = (1.38) \times (\sqrt{136}\ counts) \times (60\ \text{sec}/1\text{min}) = 965\ \text{cpm}$$

$$MDCR_{surveyor} = 965\ \text{cpm}/\sqrt{0.5} = 1365\ \text{cpm}$$

$$MDER = 1365\ \text{cpm}/(900\ \text{cpm}/\mu\text{R/hr}) = 1.52\ \mu\text{R/hr}$$

$$MDC_{scan} = (5 pCi/g) * \frac{1.52 \mu R/hr}{1.307 \mu R/hr} = 5.81 pCi/g$$

5.3 Procedures

The Characterization Team was formally trained and qualified to applicable procedures prior to the initiation of the characterization and final status surveys. Documentation of training is maintained by CCP Project Records.

The following plans and procedures were utilized for the surveys:

DD-93-19, Rev. 5	Decommissioning Plan, Battelle Memorial Institute Columbus Operations
DD-97-02, Rev. 0	Radiological Characterization and Final Status Plan for BCLDP West Jefferson Site
SC-OP-002, Rev. 0	Facility Post-Decontamination Final Status Survey for Baseline Areas
SC-SP-004.2, Rev. 3	Manual and Mechanical Collection of Surface and Subsurface Soil Samples in Support of Site Characterization
HP-OP-100, Rev. 4	Operation and Calibration of the Eberline Model ESP-2 Survey Meter
WI-2806	Excavation and Trench Sampling and Surveys

6.0 Survey Findings

6.1 Exposure Rate Surveys

The calculated mean background exposure rate and the 95 percent confidence intervals used for the CCP grounds are 8 ± 2 μR/hr. The exposure rate readings for the excavation are presented in **Table 5**. A map of the of the survey locations is presented as **Figure 3**. The exposure rate readings were individually compared to the mean background value of 8 ± 2 μR/hr in demonstrate compliance with the 5 μR /hr above background release criterion (grounds exposure rate surveys must be less than 13 μR/hr to be compliant). The one meter measurements in the excavation indicated an average of 9.8 μR/hr. The minimum measurement in the excavation was 7 μR/hr and the maximum measurement was 12 μR/hr.

6.2 Scanning Measurements

Scanning of the JN-1 A and C foundation excavation was performed using a two inch by two inch sodium iodide detector. Scanning measurements did not exceed the Decision Level Value (DLV) of 18,374 cpm for soil walkover scans. Scanning results for these areas are presented in **Table 5**. A map of the of the survey locations is presented as **Figures 4 to 6**.

6.3 Excavation Sampling

Final status soil samples of the JN-1A and C foundation excavation were taken from each of the survey grids. Samples were obtained from each grid quadrant as required by Section 6.3.3 of DD-97-02, Rev. 0. Samples were also obtained from localized areas of elevated radiological concentrations.

Table 5 presents the reported analytical results for Cs-137 in each final status survey soil sample for the JN-1 A and C foundation excavation. **Figure 7** presents the sampling locations and the Cs-137 results for each location.

The following is a summary table of the Cs-137 results for the entire area:

Location	Number of Samples	Average (pCi/g)	Standard Deviation (pCi/g)	Range (pCi/g)	Modified Screening Criteria (pCi/g)
JN-1 A and C Foundation Excavation	95	0.57	0.73	-0.02 to 5.59	7.3

6.4 Radioanalytical Reporting Limits

Table 5 presents the reported analytical results for Cs-137 in each final status survey soil sample for the JN-1 A and C foundation excavation. All soil samples exhibited low concentrations Cs-137 activity. Utilizing the ratio of Cs-137 to other radionuclides, low concentrations of Cs-137 would indicate even lower concentrations of other gamma emitting radionuclides of concern. As such, gamma emitting radionuclides of concern other than Cs-137 would be less than corresponding Minimum Detectable Activity (MDA). **Table 6** presents the typical MDAs for the gamma-emitting radionuclides of concern.

Compliance to the cleanup criteria presented in **Table 1** is demonstrated through a "fraction of limit." The total quantity and activity concentrations are calculated using the average isotopic ratios of radionuclides to Cs-137. The Cs-137 ratios were obtained from characterization data obtained for JN1-A and C foundation area. **Table 4** summarizes the method of developing the Cs-137 ratios, with the exception of Plutonium (Pu)-241 (Battelle, 2003b). Pu-241 is calculated by applying a ratio to sum of Pu-238 and Pu-239 (obtained from ORIGEN 2.1 derived values, Battelle, 2003c), resulting in a Cs-137 to Pu-241 ratio of 2.8. Results for Co-60, Cs-137, Sr-90, Eu-152 and 154, Pu-239, 240 and 241, and Am-241 are then compared to the respective release criteria and a "fraction of limit" is calculated. The "fraction of limit" is determined by summing the ratios of each isotopic concentration to the respective release limit. The sum of ratios must be less than one to meet release criteria.

Cesium-137 has been established as the predominate radionuclide and has been historically used as a surrogate for other radionuclides of concern. As such, preliminary evaluation of radioanalytical results is performed by comparing Cs-137 to a modified screening criteria of 7.3 pCi/g. When soil sample results begin to approach detected Cs-137 levels above 4 pCi/g, CS applies a "fraction of limit" calculation to verify the original assumptions as previously discussed in section 4.2.1. Additionally, when Cs-137 levels begin to approach the modified clean-up criteria of 7.3 pCi/g, CS typically conducts further remediation as an administrative conservatism. One sample within the excavation area was above 4 pCi/g for Cs-137. This sample was obtained from the northeast quadrant of grid 115, and had a Cs-137 content of 5.59 pCi/g.

The following is the sum of ratio calculation for this sample.

RCOC	Ratio Cs-137 to RCOC	Cleanup Criteria (pCi/g)	RL05-4772-4332 Cs-137 & Ratio Results (pCi/g)	Fraction of Limit
Cs-137	1	15	5.59E+00	3.73E-01
Co-60	35	8	1.60E-01	2.00E-02
Eu-152	76.1	36	7.35E-02	2.04E-03
Eu-154	225	32	2.48E-02	7.76E-04
Am-241	78.9	30	7.08E-02	2.36E-03
Sr-90	4.1	5	1.36E+00	2.73E-01
Pu-238	57.5	25	9.72E-02	3.89E-03
Pu-239	83.1	25	6.73E-02	2.69E-03
Pu-241	2.8	25	2.00E+00	7.99E-02
			Summed Ratio	**7.57E-01**

7.0 Conclusions

The characterization and final status survey results demonstrate that the radiological endpoint criteria objectives of the NRC-approved Decommissioning Plan have been met for the excavation addressed by this effort. (Battelle, 2003) Reported analytical results for media samples obtained from the excavation are below the residual radioactivity concentrations for soil and solid volumes as presented in **Table 1**.

Remaining soil contamination levels are below those presented in DD-93-03, Rev. 0, "Volumetric Release Criteria Technical Basis Document for Battelle Columbus Laboratory Decommissioning Project" (Battelle, 1993). The decommissioning objective has been satisfied. The final status survey performed on the JN-1 A and C foundation excavation statistically demonstrates that the remediation of the area was successful and that the excavation is free from residual radioactive contamination making the area suitable for unrestricted release.

8.0 References

Battelle. 2003a. "Decommissioning Plan for the Battelle Memorial Institute Columbus Operations." DD-93-19.

Battelle, 2003b. Waste Characterization, Classification, and Shipping Support Technical Basis Document, Rev. 5 for BCLDP West Jefferson Facility, November 2003. Isotopic mixture for Pu-241 is calculated using the values obtained from the ORIGEN2.1-derived data values presented in the technical basis document.

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U.S. Nuclear Regulatory Commission (NRC), 1998. "Minimum Detectable Concentrations With Typical Radiation Survey Instruments for Various Contaminants and Field Conditions" NUREG-1507.

Oak Ridge Associated Universities (ORAU), 1992. "Manual for Conducting Radiological Surveys in Support of License Termination, Draft Report for Comment" NUREG/CR-5849, ORAU-92/C57, prepared for the Nuclear Regulatory Commission by the Environmental Survey and Assessment Program, Energy/Environmental Systems Division, ORAU, 1992.

Figures

Figure 1
Site Map

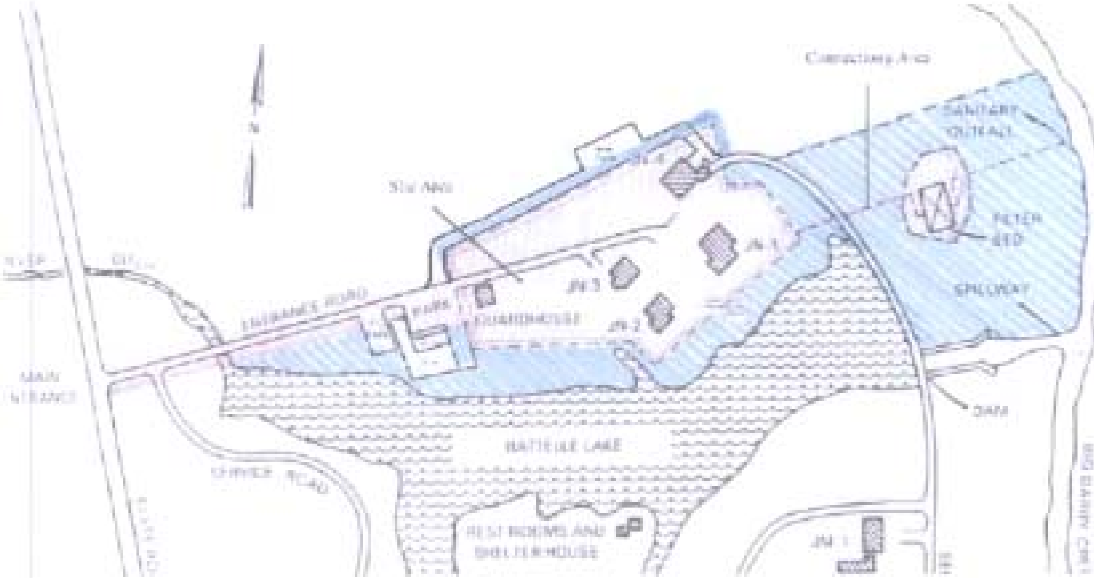


Figure 2
JN-1 A and C Foundation Excavation Location Map

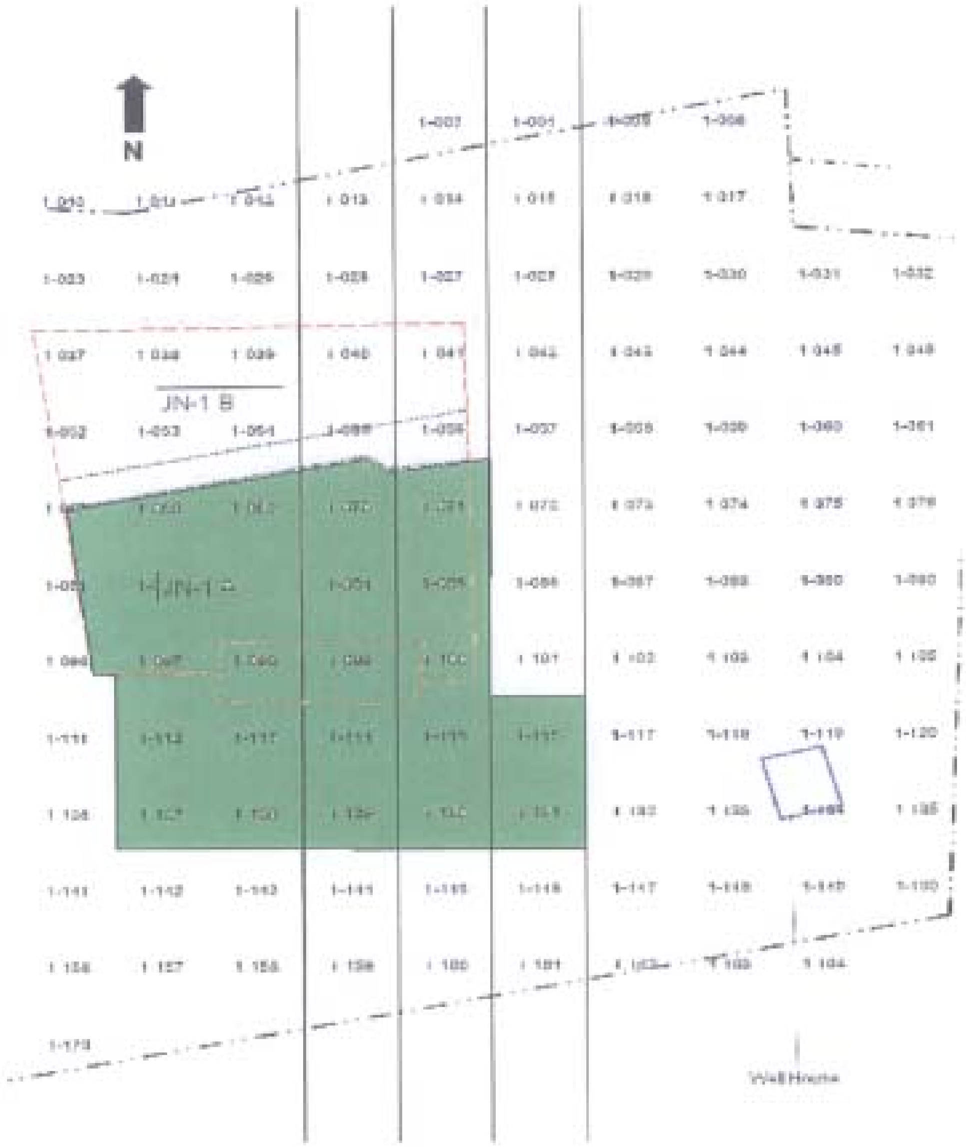


Figure 3
JN-1 A and C Foundation Exposure Rates (μR/hr)

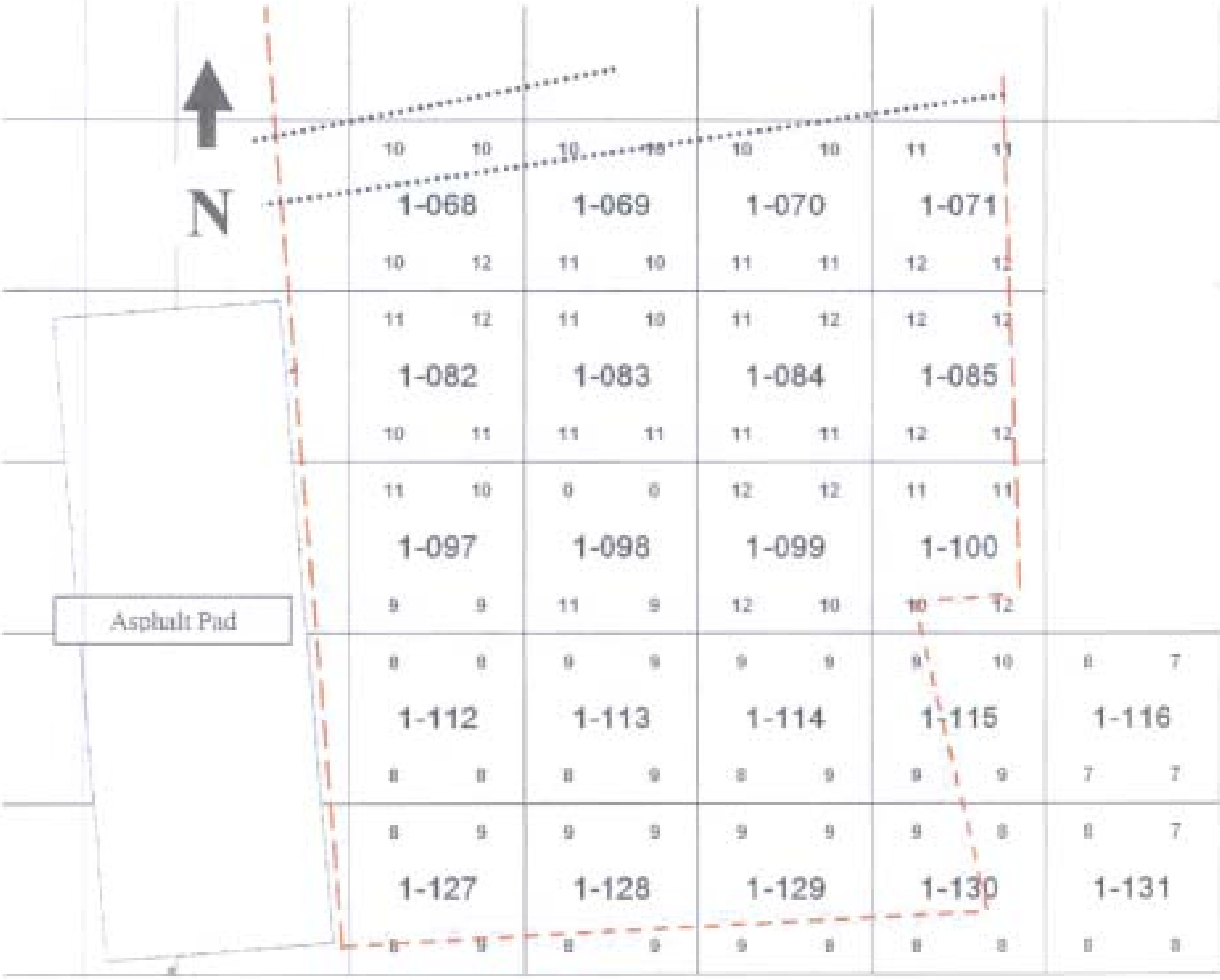


Figure 4
JN-1 A and C Foundation Walkover Scans (cpm)

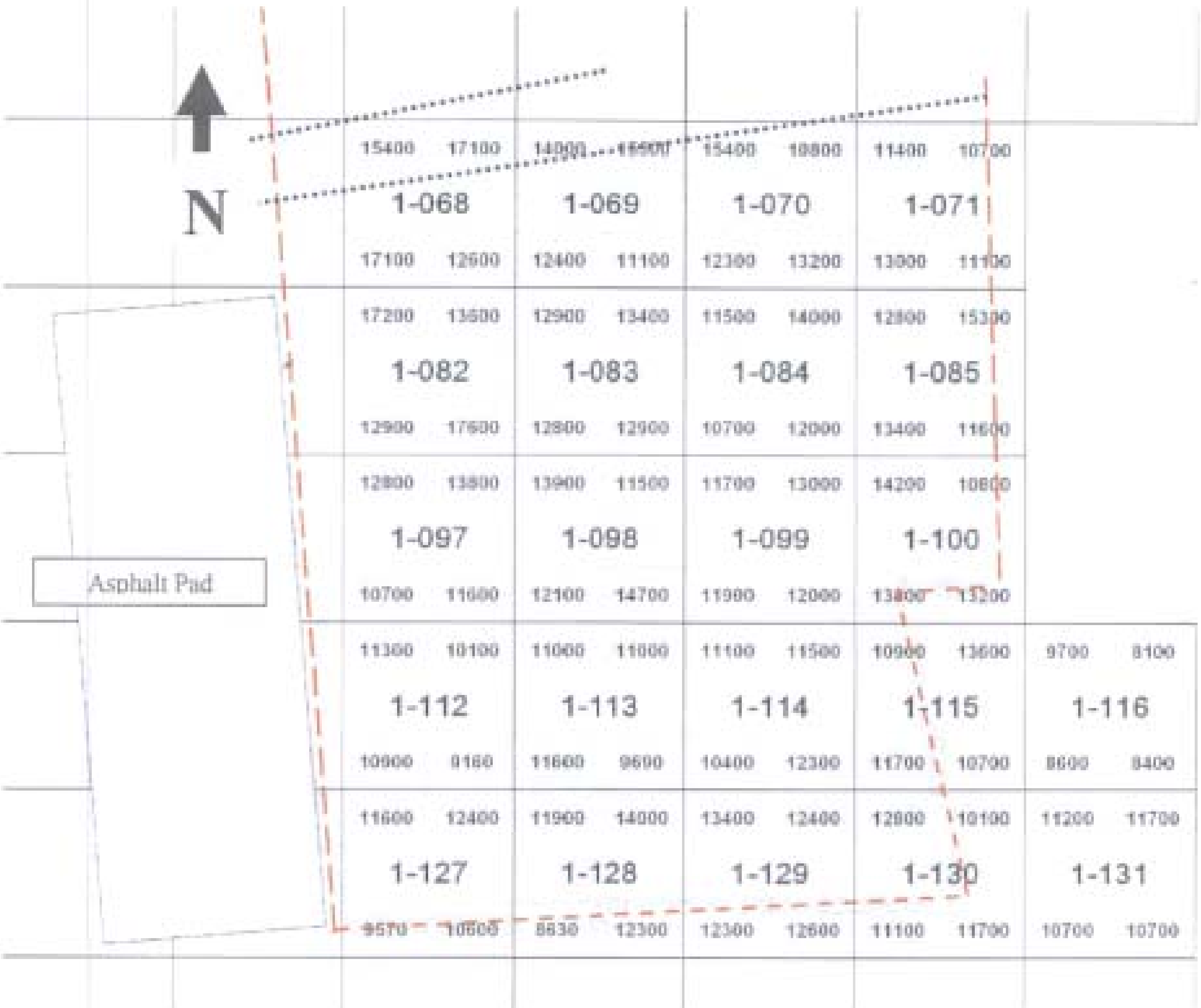


Figure 5
JN-1 A and C Foundation East Wall Scans (kcpm)

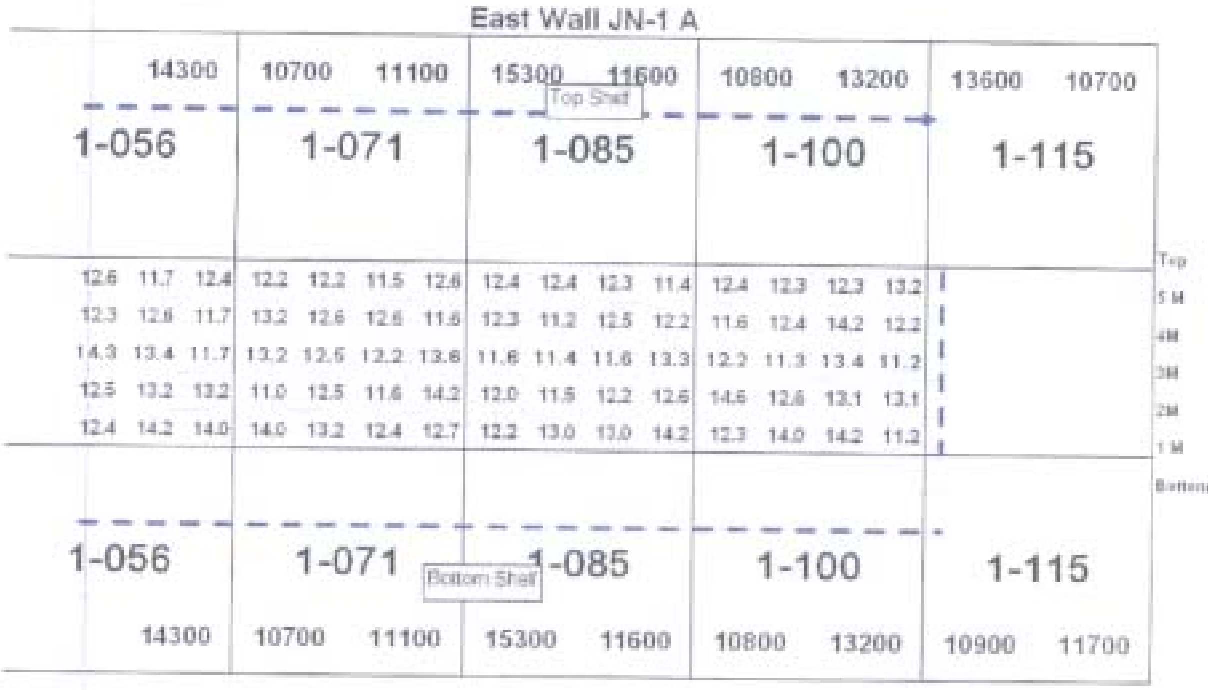


Figure 6
JN-1 A and C Foundation North Wall Scans (kcpm)

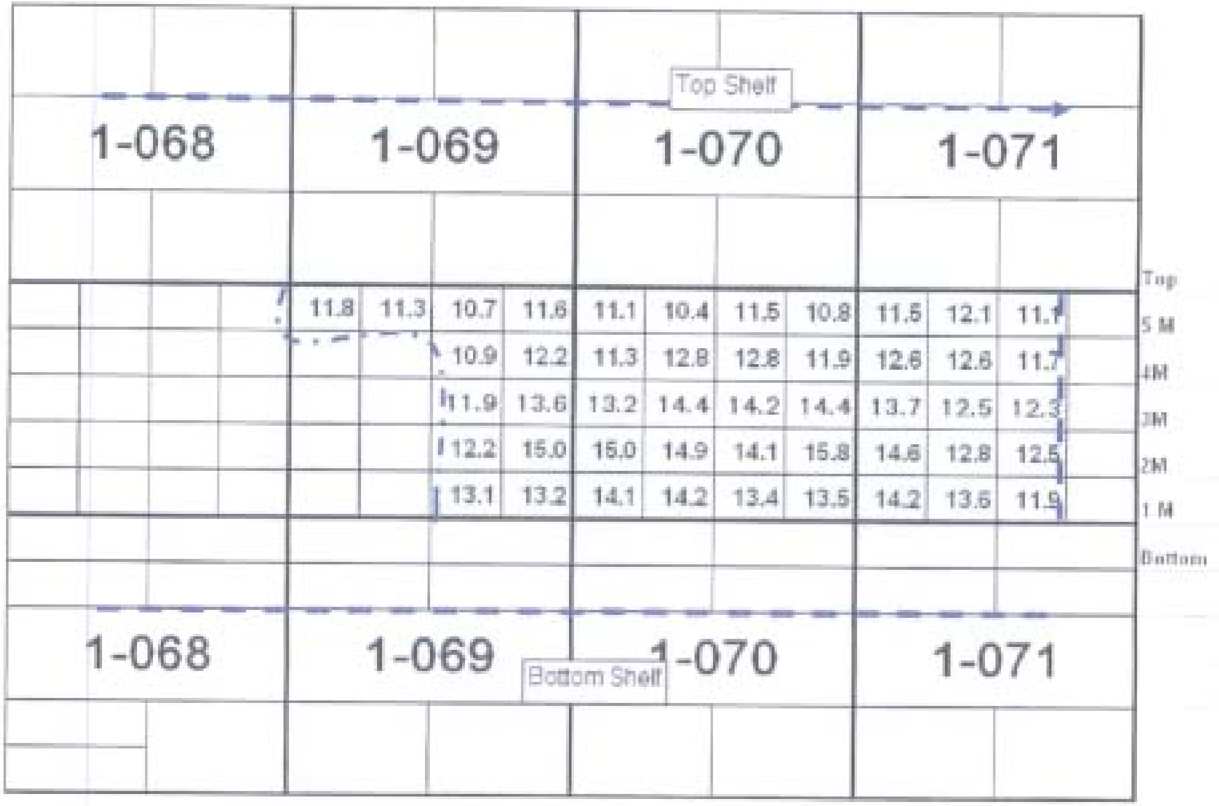
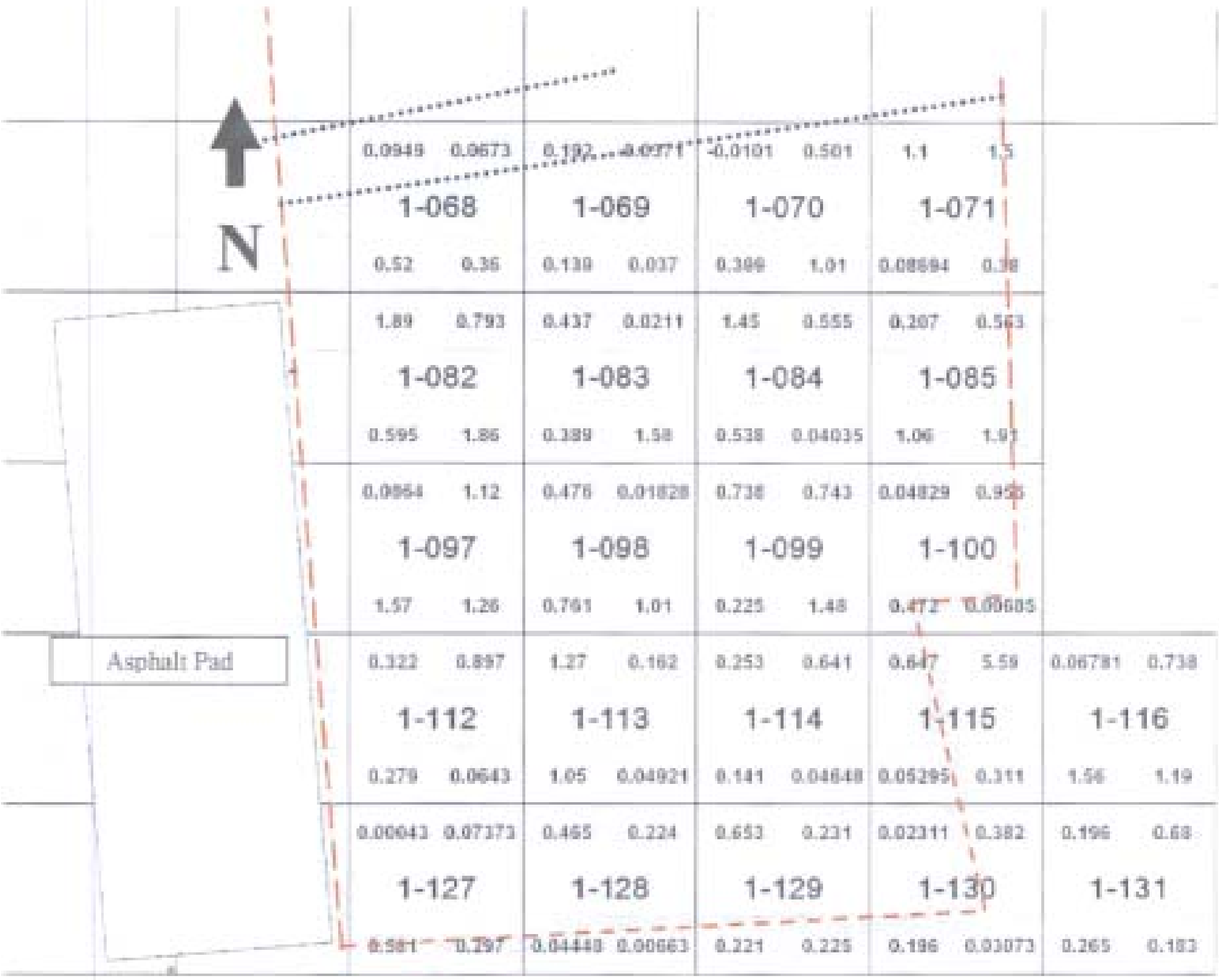


Figure 7

JN-1 A and C Foundation Sample Locations (Cs-137 pCi/g)



Tables

Table 1
BCLDP GUIDELINES FOR RESIDUAL
RADIOACTIVITY CONCENTRATIONS FOR SOIL AND SOLID VOLUMES

Radionuclide[a]	King Avenue Concentration (pCi/g)[b]	West Jefferson Concentration (pCi/g)[b]
Natural Uranium	10[1]	na[c]
Enriched Uranium	30[1]	30[1]
Depleted Uranium	35[1]	35[1]
Ac-227	19	19
Am-241	na[c]	30[4]
Am-243	na	30[4]
Ce-144	na	2,100
Cm-243	na	0.79
Cm-244	na	1.0
Co-60	8[2]	8[2]
Cs-134	na	33
Cs-137	15[2]	15[2]
C-14	940	940
Eu-152	na	36
Eu-154	na	32
Eu-155	na	1,800
Fe-55	na	2.7E+07
H-3[d]	41,000	38,000
I-129	na	13
Mn-54	na	61
Ni-59	na	1.3E+07
Ni-63	na	4.9E+06
Np-237	na	0.58
Pa-231	18	18
Pb-210	140	na
Pu-238	na	25[4]
Pu-239	na	25[4]
Pu-240	na	25[4]
Pu-241	na	25[4]
Pu-242	na	25[4]

Radionuclide[a]	King Avenue Concentration (pCi/g)[b]	West Jefferson Concentration (pCi/g)[b]
Ra-226 (0-15 cm of soil)	5[2,3]	na
Ra-226 (>15 cm of soil)	15[2,3]	na
Ra-228	5[2,3]	na
Ru-106	na	180
Sb-125	na	118
Sm-151	na	6,700
Sr-90	5[2]	5[2]
Th-228	29	na
Th-230	5[3]	na
Th-232	5[3]	na

Table 1 Notes and References

Notes:

a. Activity concentrations above natural background concentrations. Where more than one radionuclide is present, the sum of the ratios of the individual radionuclide concentrations to their respective concentration limits shall not exceed 1.

b. Concentrations for which no specific reference is cited have been derived from RESRAD calculations and are the more restrictive values calculated for soil deposition at a depth of 5 meters.

c. Indicates that this radionuclide is not expected to be found at the indicated site.

d. Difference in tritium activity concentrations are due to the difference in depths of the water tables at two sites. The water table depth at King Avenue is deeper than that at West Jefferson.

References:

1. Options 1 and 2 of the Branch Technical Position, "Disposal or Onsite Storage of Thorium or Uranium Wastes from Past Operations" (46 FR 52061, October 23, 1981).

2. NRC Memorandum, "Acceptable Cleanup Criteria and Practices for Decontamination and Decommissioning (License No. SNM-7)" dated April 17, 1992, to Harley L. Toy, License Coordinator and Manager, Nuclear Sciences, Battelle Memorial Institute from J.W.N. Hickey, Chief, Fuel Cycle Safety Branch, Division of Industrial and Medical Nuclear Safety, Office of Nuclear Material Safety and Safeguards.

3. DOE Order 5400.5, "Radiation Protection of the Public and the Environment".

4. NRC Policy and Guidance Directive FC83-23, "Termination of Byproduct, Source, and Special Nuclear Material Licenses".

Table 2

RAL Results of Building Foundation and Backyard Remediation

RAL Sample ID	Sample Location	Cs-137 (pCi/g)	Co-60 (pCi/g)	Eu-152 (pCi/g)	Eu-154 (pCi/g)	Am-241 (pCi/g)	Pu-238 (pCi/g)	Pu-239/240 (pCi/g)	Sr-90 (pCi/g)
RL05-2744	JN-1C	10.50	0.20	0.07	0.06	0.27	0.10	0.05	2.29
RL05-2745	JN-1C	16.30	0.46	0.07	0.09	-0.20	0.20	0.17	1.97
RL05-2746	JN-1C	5.52	0.19	0.05	0.03	0.30	0.12	0.05	0.83
RL05-2747	JN-1C	6.43	0.20	0.10	0.03	-0.08	0.05	0.01	1.11
RL05-2748	JN-1C	18.30	0.56	0.14	0.07	0.36	0.14	0.08	1.34
RL05-2750	JN-1C	18.40	1.30	0.11	0.10	0.09	0.80	0.38	10.90
RL05-2751	JN-1C	12.90	0.40	0.07	0.03	-0.10	0.14	0.09	1.73
RL05-3012	JN-1 A/B	16.10	0.19	0.15	0.09	-0.04	1.06	0.32	9.13
RL05-3014	JN-1 A/B	4.40	0.01	0.05	0.04	-0.19	0.05	0.01	0.91
RL05-3015	JN-1 A/B	25.60	0.70	0.22	0.17	0.42	0.77	0.32	13.30
RL05-3017	A/G Cell	15.70	0.38	0.04	0.02	-0.33	0.62	0.33	8.15
RL05-3294	Bog	15.80	0.45	0.02	0.04	0.28	0.05	0.08	2.34
RL05-3296	Bog	8.10	0.27	-0.04	0.01	-0.28	0.03	0.10	2.81
RL05-3297	Bog	43.20	0.75	-0.01	0.09	0.05	0.08	0.12	3.10
RL05-3300	Bog	19.50	0.49	0.03	0.04	-0.06	0.07	0.24	2.87
RL05-4049	JN-1 A	19.50	0.26	0.11	0.11	0.36	0.98	0.31	1.22
RL05-4084	JN-1 B	13.90	0.58	0.08	0.09	0.28	0.17	0.13	2.79
RL05-4085	JN-1 B	19.90	0.30	0.09	0.11	0.47	0.36	0.12	5.37
RL05-4100	JN-1 Bkyrd	7.47	0.15	0.05	0.10	0.38	0.22	0.52	1.44
RL05-4101	JN-1 Bkyrd	7.05	0.04	-0.10	0.04	-0.01	0.54	0.93	0.56
RL05-4153	JN-1 A	7.15	0.09	-0.02	-0.04	-0.03	0.13	0.53	2.24
RL05-4158	JN-1 A	12.80	0.45	0.08	0.02	0.17	0.55	0.28	10.50
RL05-4159	JN-1 A	7.56	0.24	0.02	-0.02	0.19	0.80	0.23	10.30
RL05-4161	JN-1 A	11.00	0.25	0.08	0.08	0.07	0.77	0.24	9.45
RL05-4162	JN-1 B	19.50	0.25	0.10	0.05	0.18	0.31	0.15	5.28

Table 3
Calculated Ratios of RCOC to Cs-137

RAL Sample ID	Sample Location	Ratio Cs-137 to Co-60	Ratio Cs-137 to Eu-152	Ratio Cs-137 to Eu-154	Ratio Cs-137 to Am-241	Ratio Cs-137 to Pu-238	Ratio Cs-137 to Pu-239/240	Ratio Cs-137 to Sr-90
RL05-2744	JN-1C	52.5	150.0	175.0	38.9	105.0	198.1	4.6
RL05-2745	JN-1C	35.4	232.9	181.1	81.5	81.5	95.9	8.3
RL05-2746	JN-1C	29.1	110.4	184.0	18.4	46.0	102.2	6.7
RL05-2747	JN-1C	32.2	64.3	214.3	80.4	139.8	584.5	5.8
RL05-2748	JN-1C	32.7	130.7	261.4	50.8	130.7	234.6	13.7
RL05-2750	JN-1C	14.2	167.3	184.0	204.4	23.0	48.4	1.7
RL05-2751	JN-1C	32.3	184.3	430.0	129.0	92.1	141.8	7.5
RL05-3012	JN-1 A/B	84.7	107.3	178.9	402.5	15.2	50.3	1.8
RL05-3014	JN-1 A/B	440.0	88.0	110.0	23.2	89.8	314.3	4.8
RL05-3015	JN-1 A/B	36.6	116.4	150.6	61.0	33.2	80.0	1.9
RL05-3017	A/G Cell	41.3	392.5	785.0	47.6	25.3	47.6	1.9
RL05-3294	Bog	35.1	790.0	395.0	56.4	316.0	197.5	6.8
RL05-3296	Bog	30.0	202.5	1620.0	28.9	270.0	81.0	2.9
RL05-3297	Bog	57.6	4800.0	480.0	960.0	540.0	360.0	13.9
RL05-3300	Bog	39.8	650.0	487.5	325.0	278.6	81.3	6.8
RL05-4049	JN-1 A	75.0	184.7	177.3	54.2	20.0	63.9	16.0
RL05-4084	JN-1 B	24.0	185.3	147.9	49.6	84.2	109.4	5.0
RL05-4085	JN-1 B	67.0	226.1	189.5	42.3	55.9	173.0	3.7
RL05-4100	JN-1 Bkyrd	49.8	140.9	74.7	19.7	34.6	14.3	5.2
RL05-4101	JN-1 Bkyrd	180.8	71.2	180.8	742.1	13.0	7.6	12.6
RL05-4153	JN-1 A	77.3	340.5	193.2	230.6	53.4	13.6	3.2
RL05-4158	JN-1 A	28.4	162.0	853.3	76.6	23.4	46.0	1.2
RL05-4159	JN-1 A	31.5	397.9	452.7	39.8	9.4	32.4	0.7
RL05-4161	JN-1 A	44.0	141.0	132.5	169.2	14.2	45.1	1.2
RL05-4162	JN-1 B	78.0	195.0	361.1	108.3	62.1	131.8	3.7
Mathematical Mean		66.0	333.1	344	161.6	102.3	130.2	5.7
Standard Deviation		84.6	931	332	231.1	125.1	131.5	4.31
X_U		96.3	742.4	426.9	244.3	147.0	171.2	7.2
X_L		35.7	76.1	225.1	78.9	57.5	83.1	4.1

Table 4
Isotopic Ratio for Building JN-1 Foundation and Backyard Area

Ratio Cs-137 to Co-60	Ratio Cs-137 to Eu-152	Ratio Cs-137 to Eu-154	Ratio Cs-137 to Am-241	Ratio Cs-137 to Pu-238	Ratio Cs-137 to Pu-239/240	Ratio Cs-137 to Sr-90
35.7	76.1	225	78.9	57.5	83.1	4.1

Table 5
JN-1 A and C Survey and Sampling Results

Grid Location	Sample ID	Collection Date	Walkover Scan (Results in cpm)	Exposure Rates (Results in μR/hr)	Cs-137 Content (Results in pCi/g)
1-068 NW	RL05-4879-4443	12/27/2005	15400	10	9.49E-02
1-068 NE	RL05-4880-4444	12/27/2005	17100	10	6.73E-02
1-068 SW	RL05-4881-4445	12/27/2005	17100	10	5.20E-01
1-068 SE	RL05-4882-4446	12/27/2005	12600	12	3.60E-01
1-069 NW	RL05-4883-4447	12/27/2005	14000	10	1.92E-01
1-069 NE	RL05-4884-4448	12/27/2005	15500	10	3.71E-02
1-069 SW	RL05-4885-4449	12/27/2005	12400	11	1.39E-01
1-069 SE	RL05-4886-4450	12/27/2005	11100	10	3.70E-02
1-070 NW	RL05-4830-4376	12/20/2005	15400	10	-1.00E-02
1-070 NE	RL05-4804-4359	12/19/2005	10800	10	5.01E-01
1-070 SW	RL05-4831-4377	12/20/2005	12300	11	3.99E-01
1-070 SE	RL05-4805-4360	12/19/2005	13200	11	1.01E+00
1-071 NW	RL05-4806-4361	12/19/2005	11400	11	1.10E+00
1-071 NE	RL05-4807-4362	12/19/2005	10700	11	1.50E+00
1-071 SW	RL05-4808-4363	12/19/2005	13000	12	8.69E-02
1-071 SE	RL05-4809-4364	12/19/2005	11100	12	3.80E-01
1-082 NW	RL05-4887-4451	12/27/2005	17200	11	1.89E+00
1-082 NE	RL05-4888-4452	12/27/2005	13600	12	7.93E-01
1-082 SW	RL05-4453-4889	12/27/2005	12900	10	5.95E-01
1-082 SE	RL05-4890-4454	12/27/2005	17600	11	1.86E+00
1-083 NW	RL05-4891-4455	12/27/2005	12900	11	4.37E-01
1-083 NE	RL05-4892-4456	12/27/2005	13400	10	2.11E-02
1-083 SW	RL05-4893-4557	12/27/2005	12800	11	3.89E-01
1-083 SE	RL05-4894-4458	12/27/2005	12900	11	1.58E+00
1-084 NW	RL05-4832-4378	12/20/2005	11500	11	1.45E+00
1-084 NE	RL05-4810-4365	12/19/2005	14000	12	5.55E-01
1-084 SW	RL05-4833-4379	12/20/2005	10700	11	5.38E-01
1-084 SE	RL05-4811-4366	12/19/2005	12000	11	4.03E-02
1-085 NW	RL05-4812-4367	12/19/2005	12800	12	2.07E-01
1-085 NE	RL05-4813-4368	12/19/2005	15300	12	5.63E-01
1-085 SW	RL05-4814-4369	12/19/2005	13400	12	1.06E+00

Grid Location	Sample ID	Collection Date	Walkover Scan (Results in cpm)	Exposure Rates (Results in µR/hr)	Cs-137 Content (Results in pCi/g)
1-085 SE	RL05-4796-4351	12/19/2005	11600	12	1.91E+00
1-097 NW	RL05-4895-4459	12/27/2005	12800	11	8.64E-02
1-097 NE	RL05-4896-4460	12/27/2005	13800	10	1.12E+00
1-097 SW	RL05-4834-4380	12/20/2005	10700	9	1.57E+00
1-097 SE	RL05-4835-4381	12/20/2005	11600	9	1.26E+00
1-098 NW	RL05-4836-4382	12/20/2005	13900	6	4.76E-01
1-098 NE	RL05-4837-4383	12/20/2005	11500	6	1.82E-02
1-098 SW	RL05-4838-4384	12/20/2005	12100	11	7.61E-01
1-098 SE	RL05-4797-4352	12/19/2005	14700	9	1.01E+00
1-099 NW	RL05-4839-4385	12/20/2005	11700	12	7.38E-01
1-099 NE	RL05-4798-4353	12/19/2005	13000	12	7.43E-01
1-099 SW	RL05-4800-4355	12/19/2005	11900	10	2.25E-01
1-099 SE	RL05-4799-4354	12/19/2005	12000	10	1.48E+00
1-100 NW	RL05-4801-4356	12/19/2005	14200	11	4.82E-02
1-100 NE	RL05-4815-4370	12/19/2005	10800	11	9.56E-01
1-100 SW	RL05-4802-4357	12/19/2005	13800	10	4.72E-01
1-100 SE	RL05-4803-4358	12/19/2005	13200	12	6.84E-03
1-112 NW	RL05-4759-4319	12/17/2005	11300	8	3.22E-01
1-112 NE	RL05-4760-4320	12/17/2005	10100	8	8.97E-01
1-112 SW	RL05-4761-4321	12/17/2005	10900	8	2.79E-01
1-112 SE	RL05-4762-4322	12/17/2005	9160	8	6.43E-02
1-113 NW	RL05-4763-4323	12/17/2005	11000	9	1.27E+00
1-113 NE	RL05-4764-4324	12/17/2005	11000	9	1.62E-01
1-113 SW	RL05-4765-4325	12/17/2005	11600	8	1.05E+00
1-113 SE	RL05-4766-4326	12/17/2005	9690	9	4.92E-02
1-114 NW	RL05-4767-4327	12/17/2005	11100	9	2.53E-01
1-114 NE	RL05-4768-4328	12/17/2005	11500	9	6.41E-01
1-114 SW	RL05-4769-4329	12/17/2005	10400	8	1.41E-01
1-114 SE	RL05-4770-4330	12/17/2005	12300	9	4.64E-02
1-115 NW	RL05-4771-4331	12/17/2005	10900	9	6.47E-01
1-115 NE	RL05-4772-4332	12/17/2005	13600	10	5.59E+00
1-115 SW	RL05-4773-4333	12/17/2005	11700	9	5.29E-02
1-115 SE	RL05-4774-4334	12/17/2005	10700	9	3.11E-01
1-116 NW	RL05-4511-4148	12/3/2005	9700	8	6.78E-02
1-116 NE	RL05-4512-4149	12/3/2005	8100	7	7.38E-01
1-116 SW	RL05-4513-4150	12/3/2005	8600	7	1.56E+00

Grid Location	Sample ID	Collection Date	Walkover Scan (Results in cpm)	Exposure Rates (Results in µR/hr)	Cs-137 Content (Results in pCi/g)
1-116 SE	RL05-4514-4151	12/3/2005	8400	7	1.19E+00
1-127 NW	RL05-4775-4335	12/17/2005	11600	8	4.33E-04
1-127 NE	RL05-4776-4336	12/17/2005	12400	9	7.37E-02
1-127 SW	RL05-4777-4337	12/17/2005	9570	8	5.81E-01
1-127 SE	RL05-4778-4338	12/17/2005	10600	9	2.97E-01
1-128 NW	RL05-4779-4339	12/17/2005	11900	9	4.65E-01
1-128 NE	RL05-4780-4340	12/17/2005	14000	9	2.24E-01
1-128 SW	RL05-4781-4341	12/17/2005	8630	8	4.44E-02
1-128 SE	RL05-4782-4342	12/17/2005	12300	9	6.62E-03
1-129 NW	RL05-4783-4343	12/17/2005	13400	9	6.53E-01
1-129 NE	RL05-4784-4344	12/17/2005	12400	9	2.31E-01
1-129 SW	RL05-4785-4345	12/17/2005	12300	9	2.21E-01
1-129 SE	RL05-4786-4346	12/17/2005	12600	8	2.25E-01
1-130 NW	RL05-4787-4347	12/17/2005	12800	9	2.31E-02
1-130 NE	RL05-4788-4348	12/17/2005	10100	8	3.82E-01
1-130 SW	RL05-4789-4349	12/17/2005	11100	8	1.96E-01
1-130 SE	RL05-4790-4350	12/17/2005	11700	8	3.07E-02
1-131 NW	RL05-4501-4140	12/3/2005	11200	8	1.96E-01
1-131 NE	RL05-4502-4141	12/3/2005	11700	7	6.80E-01
1-131 SW	RL05-4503-4142	12/3/2005	10700	8	2.65E-01
1-131 SE	RL05-4504-4143	12/3/2005	10700	8	1.83E-01
Grid 71 Wall	RL05-4492-4128	12/2/2005	11000 to 14200	12	-1.62E-02
Grid 85 Wall	RL05-4493-4129	12/2/2005	11200 to 14200	12	-1.19E-02
Grid 100 Wall	RL05-4494-4130	12/2/2005	11200 to 14600	12	-3.06E-03
Grid 56 Wall	RL05-4495-4131	12/2/2005	11700 to 14300	11	5.31E-01
Grid 68 Wall	RL05-4926-4461	12/29/2005	10700 to 15000	7	6.93E-01
Grid 69 Wall	RL05-4927-4462	12/29/2005	10400 to 15800	6	5.38E-02
Grid 70 Wall	RL05-4928-4463	12/29/2005	11100 to 14600	5	2.70E-02

Table 6
MDA of Gamma-Emitting Radionuclides of Concern

Cs-137 MDA (pCi/g)	Co-60 MDA (pCi/g)	Eu-152 MDA (pCi/g)	Eu-154 MDA (pCi/g)	Am-241 MDA (pCi/g)
0.024 +/- 0.013	0.022 +/- 0.012	0.067 +/- 0.030	0.055 +/- 0.039	0.451 +/- 0.30