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Further. Together.

August 5, 2016

Mr. John Hickman
U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
Division of Decommissioning, Uranium Recovery, and Waste Programs
Reactor Decommissioning Branch
Mail Stop: T8F5
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Rockville, MD 20852

SUBJECT: FINAL REPORT—INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE TURBINE BUILDING BASEMENT AND OPEN LAND AREAS AT THE ZION NUCLEAR POWER STATION, ZION, ILLINOIS (RFTA NO. 15-005); DCN 5271-SR-02-0

Dear Mr. Hickman:

ORAU is pleased to provide the enclosed final report detailing the independent confirmatory survey activities of the Turbine Building basement and the non-impacted open land areas at the Zion Nuclear Power Station in Zion, Illinois. This report provides the summary and results of activities performed by ORAU, under the Oak Ridge Institute for Science and Education (ORISE) contract, during the period of April 25–28, 2016.

You may contact me at 865.574.7008 or Nick Altic at 865.574.6273 if you have any questions.

Sincerely,

Kaitlin M. Engel
Health Physicist
ORAU

KME:lw

Enclosure

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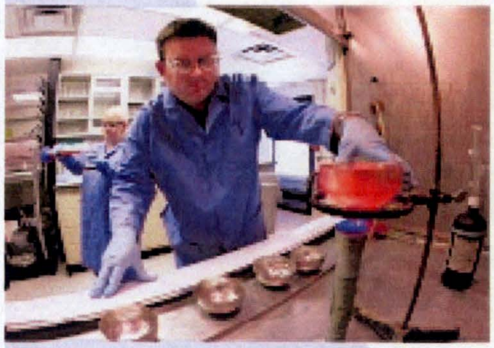

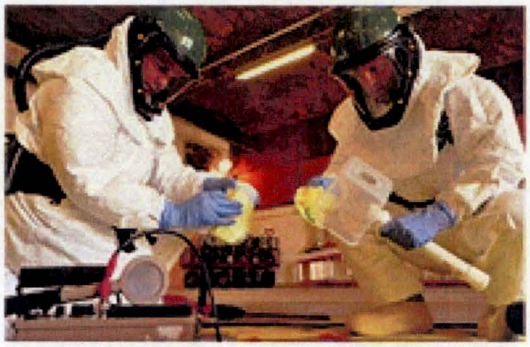

INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE TURBINE BUILDING BASEMENT AND OPEN LAND AREAS AT THE ZION NUCLEAR POWER STATION, ZION, ILLINOIS

K. M. Engel
and
N. A. Altic

Prepared for the U.S. Nuclear Regulatory Commission

August 2016

NOTICES

FINAL REPORT—INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE TURBINE BUILDING BASEMENT AND OPEN LANDS AREA AT THE ZION NUCLEAR POWER STATION, ZION, ILLINOIS

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Prepared by
K. M. Engel
and
N. A. Altic
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AUGUST 2016

FINAL REPORT

Prepared for the
U.S. Nuclear Regulatory Commission

Prepared by Oak Ridge Associated Universities under the Oak Ridge Institute for Science and Education contract, number DE-SC0014664, with the U.S. Department of Energy under interagency agreement (NRC FIN No. F-1244) between the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy.

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INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE TURBINE BUILDING BASEMENT AND OPEN LANDS AREA AT THE ZION NUCLEAR POWER STATION, ZION, ILLINOIS

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FINAL REPORT

AUGUST 2016

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CONTENTS

FIGURES

TABLES

ACRONYMS

BEGe	Broad Energy Germanium
CPM	counts per minute
DCGL	derived concentration guideline level
ISOCS	In Situ Object Counting System
MDC	minimum detectable concentration
NaI	sodium iodide
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
ORISE	Oak Ridge Institute for Science and Education
ROC	radionuclide of concern
RRA	Radiologically Restricted Area
SU	survey unit
TB	Turbine Building
ZNPS	Zion Nuclear Power Station
ZS	Zion*Solutions*, LLC

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INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE TURBINE BUILDING BASEMENT AND OPEN LANDS AREA AT THE ZION NUCLEAR POWER STATION, ZION, ILLINOIS

EXECUTIVE SUMMARY

The U.S. Nuclear Regulatory Commission (NRC) requested that ORAU, via the Oak Ridge Institute for Science and Education (ORISE) contract, perform confirmatory survey activities of the Zion Nuclear Power Station (ZNPS) in Zion, Illinois. Confirmatory activities are intended to ensure, if supported by the data, that ZNPS complies with the release criteria in 10 Code of Federal Regulations (CFR) 20.1402. The confirmatory survey, performed April 25-28, 2016, included gamma scans of the Turbine Building (TB) basement and land area Survey Unit (SU) 10213A, collection of judgmental volumetric sediment samples, and *in situ* gamma spectroscopy measurements of the TB basement. ORAU data supports the Class 3 designation applied by Zion to the TB basement and SU 10213A.

INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE TURBINE BUILDING BASEMENT AND OPEN LAND AREAS AT THE ZION NUCLEAR POWER STATION, ZION, ILLINOIS

1. INTRODUCTION

The Zion Nuclear Power Station (ZNPS) was operated by Exelon Generation Company (Exelon) and is currently being decommissioned by a division of Energy*Solutions* called Zion*Solutions*, LLC (ZS). The ZNPS operated commercially from 1973 to 1997. Cessation of nuclear operations was certified in 1998 after both reactor units had been defueled and the fuel assemblies had been placed in the spent fuel pools. Both units were then placed in a SAFSTOR condition until final decommissioning and dismantlement began in 2010. At that time, the U.S. Nuclear Regulatory Commission (NRC) operating license was transferred from Exelon to the decommissioning company, ZS. Decommissioning activities are expected to be completed by 2020. Upon successful completion of decommissioning activities, control and responsibility for the site will be transferred back to Exelon (EC 2015).

The NRC is responsible for oversight of permitted license activities that are currently being conducted at the ZNPS. The NRC requested that ORAU, under the Oak Ridge Institute for Science and Education (ORISE) contract, perform confirmatory surveys of the Turbine Building basement and assess the radiological status of the open land areas.

2. SITE DESCRIPTION

The ZNPS is located in Lake County, Illinois, on the easternmost portion of the city of Zion. It is approximately 40 miles north of Chicago, Illinois, and 42 miles south of Milwaukee, Wisconsin (Figure 2.1). The overall site is comprised of approximately 200 acres and is situated between the northern and southern parts of Illinois Beach State Park on the western shore of Lake Michigan (EC 2015 and ZS 2014). Figure 2.1 provides an aerial map of the site.

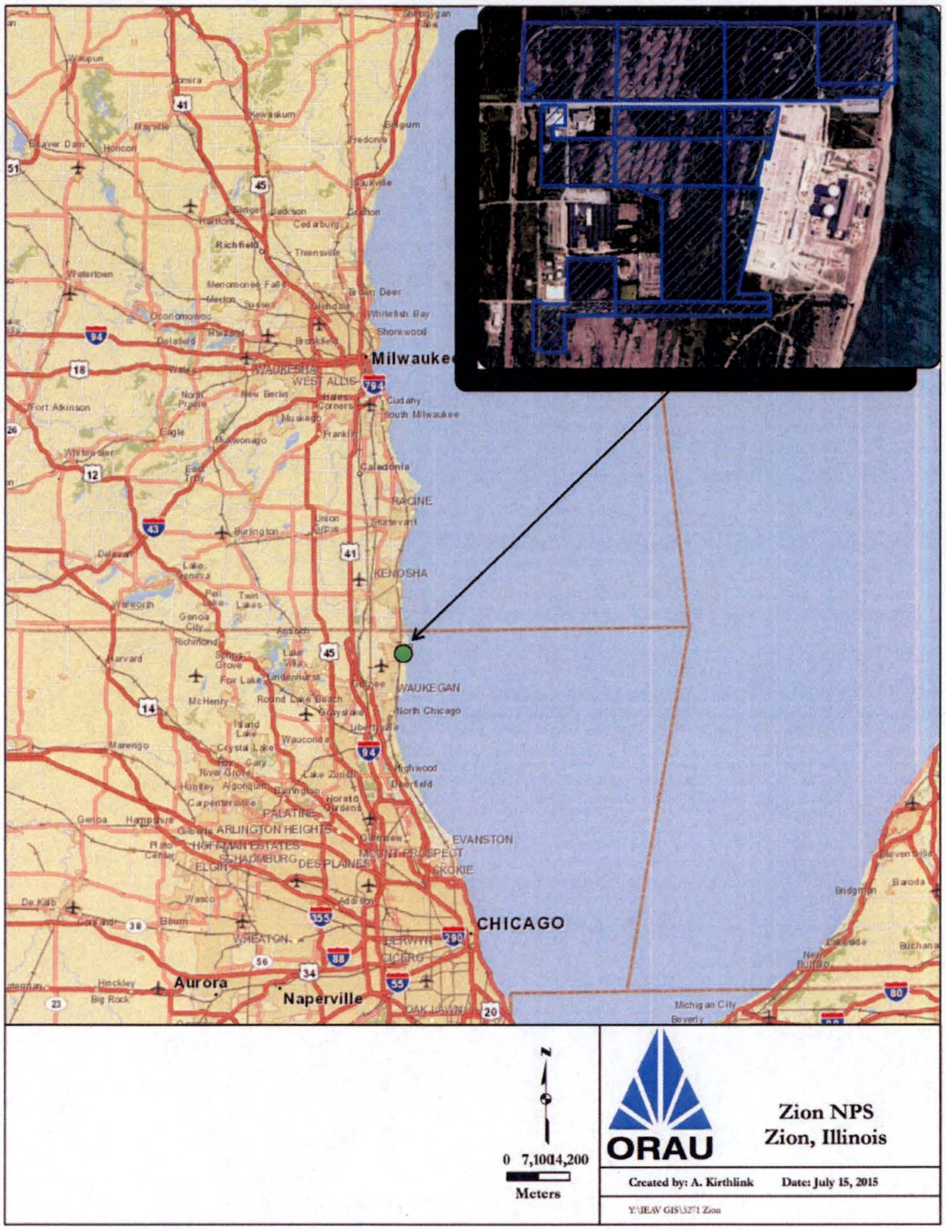

Figure 2.1. Location of the Zion Nuclear Power Station, Zion, Illinois

The Turbine Building (TB) basement has a surface area of approximately 14,679 m^2 and spans elevations from 560 feet (ft) to 588 ft above sea level. The 560 ft elevation includes four sumps, and elevator pit, and two electrical penetrations (ZS 2016). Access to the TB basement is limited to an earthen ramp from the 592 ft. elevation. The TB basement contains a fire sump, with access on the 560 ft. elevation. The fire sump has two elevations [depths], the bottom of the sump is approximately 20 feet below the basement floor and the upper elevation is approximately 10 feet below the basement floor.

A large majority of the site footprint is comprised of open land areas that have been classified as non-impacted. Most of the non-impacted land area survey units (SUs) are located to the west of Radiologically Restricted Area (RRA) fence, although there are small areas north and southwest of the fence. Lake Michigan forms the eastern boundary to the RRA fence. Figure 2.2 provides an overview of the land area SUs. The non-impacted land areas comprise the majority of the site footprint (areas shaded green in Figure 2.2).

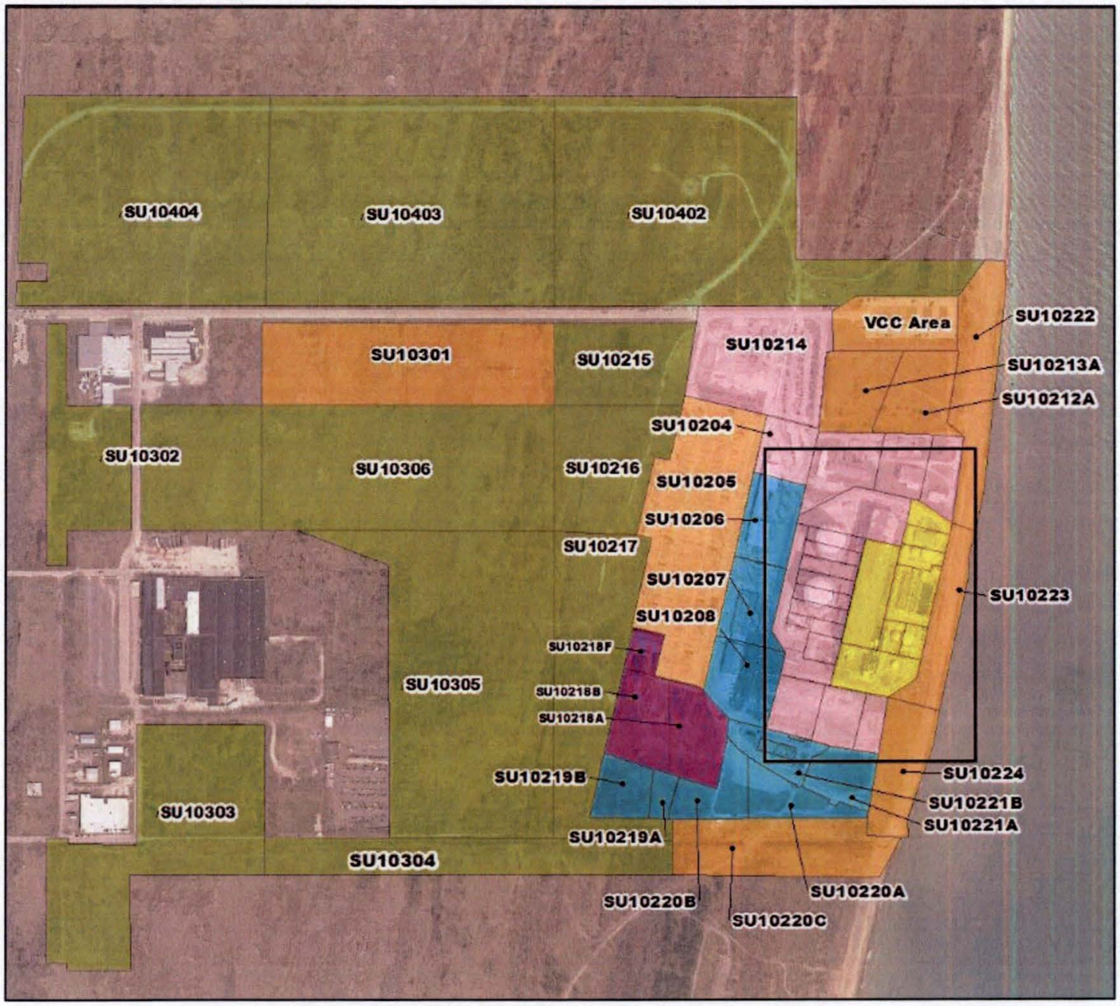

Figure 2.2. ZNPS Land Area Survey Units

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3. OBJECTIVES

The objectives of the confirmatory survey activities were to provide independent contractor field data reviews and to generate independent radiological data for use by the NRC in evaluating the accuracy and adequacy of the licensee's procedures and results.

4. APPLICABLE SITE GUIDELINES

The primary radionuclides of concern (ROCs) at the ZNPS are beta-gamma emitters—fission and activation products—resulting from reactor operation. Licensee documentation states that five specific ROCs accounted for 99.5% of the total activity at ZNPS (ZS 2015). Specific building surface activity guidelines are not applicable for the TB basement because the above-grade structure has been demolished and the debris will not remain on site. Instead, the remaining building surfaces were evaluated based on maximum source term inventory levels that corresponded to a total dose of 25 millirem per year (mrem/year). Table 4.1 provides the maximum inventories for each of the five ROCs divided by the total surface area of the TB basement.

Table 4.1. Turbine Building Basement Inventory Limits

ROC	Inventory Limit (pCi/m^2)
Co-60	1.35E+08
Cs-134	3.07E+07
Cs-137	4.05E+07
Ni-63	4.20E+09
Sr-90	1.50E+06

The volumetric soil—applicable to land area soil—and buried pipe derived concentration guideline levels ($DCGL_W$s) are listed in Table 4.2. Surface soil and subsurface soil $DCGL_W$s are defined for soil depths of 0.0 to 0.15 m and 0.15 to 1 m, respectively.

Table 4.2. Radionuclide Soil and Buried Pipe DCGLs[a]			
ROC	Surface Soil (pCi/g)	Subsurface Soil (pCi/g)	Buried Pipe (pCi/g)
Co-60	4.7	3.8	3.60E+04
Cs-134	7.5	4.9	6.33E+04
Cs-137	15.7	8.5	1.50E+05
Ni-63	3,988	847	1.31E+08
Sr-90	14.3	1.8	3.49E+05

[a]From Chapter 5 in the license termination plan (ZS 2014)

5. PROCEDURES

The confirmatory survey activities were conducted during the period of April 24–28, 2016, in accordance with the project-specific confirmatory survey plan, the *ORAU Radiological and Environmental Survey Procedure Manual* and the *ORAU Environmental Services and Radiation Training Quality Program Manual* (ORAU 2015a and 2015b).

5.1 SURFACE SCANS

ORAU performed low-density gamma radiation scans of the accessible lower surfaces (floors and lower walls) inside the TB basement. Gamma scans were performed using Ludlum Model 44-10 sodium iodide (NaI) detectors coupled to Ludlum Model 2221 ratemeter-scalers with audible indicators. In addition to the lower surfaces, gamma radiation surface scans were also performed in low-lying regions/accumulation points (i.e., sumps). Many of these areas were impacted by standing water (1 to 3 in.) during the time of the confirmatory survey.

Medium-density gamma walkover scans were also performed on the open land area survey unit, SU 10213A. The walkover scans were performed with the aforementioned detector/ratemeter pairs.

5.2 *IN SITU* ACTIVITY MEASUREMENTS

Quantitative gamma radiation measurements collected during the surface scans inside the TB basement were used to select 6 judgmental *in situ* gamma spectroscopy measurement locations in addition to 11 random locations. The *in situ* measurements were performed using a Broad Energy Germanium (BEGe) detector with a carbon composite window and a 90-degree lead collimator.

Efficiency calibrations for each collected spectrum were performed using the In Situ Object Counting System (ISOCS) calibration software. The source term was modeled as a disk source composed of concrete with a thickness of 0.5-inch, based on Zion's *in situ* technical basis document. A previous ORAU review of Zion's TBD found this modeling approach to be acceptable (ORAU 2015d). For the judgmental *in situ* measurements, the detector was mounted to a cart and suspended with a crane such that the field of view (FOV) was perpendicular to the measurement surface. Due to time constraints of using the crane, ORAU opted to collect the random *in situ* measurements using a floor-rolling cart. An example of the geometry of the wheeled cart measurements is presented in Figure 5.1 below. The source was modeled as a thin cylinder within the detector FOV. ORAU recognizes that this geometry may overestimate the activity per area as the FOV is larger than the modeled source. However, this calibration is still appropriate because the chance of a decision error from an over-estimation radioactivity is low due to the low-level (i.e. Class 3) residual radioactivity in the TB basement. Figures A-1 and A-2 depict the *in situ* gamma spectroscopy measurement locations. Due to time constraints and accessibility issues, measurement locations ISOCS-R-1, -4, -9, and -12 were not collected.

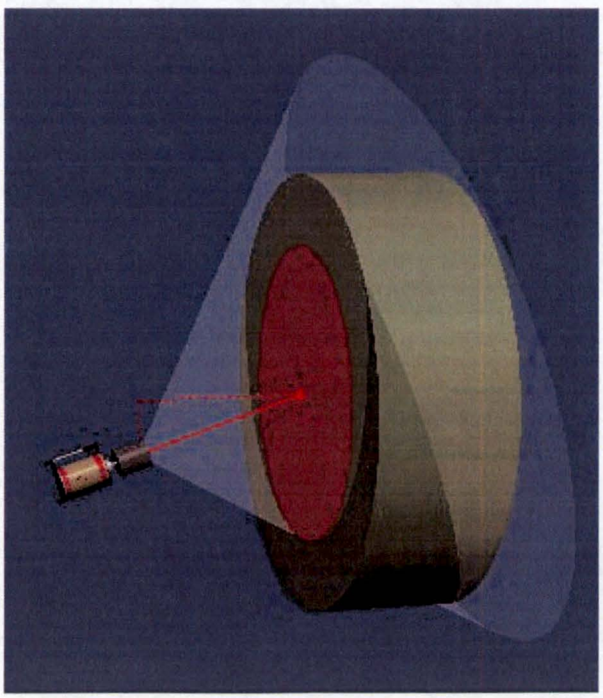

Figure 5.1. Example ISOCS wall geometry for the cart-mounted detector.

5.3 Soil, Sediment, and Water Sampling

A total of three soil samples were collected from SU 10213A. The soil samples were collected based on the highest detector response identified during the gamma walkover scans. Three sediment samples were collected from the fire sump in the Turbine Building Basement (one from the 20 foot elevation and two from the 10 foot elevation). The sediment samples were collected from locations exhibiting elevated detector response. Figure A-3 depicts the locations of the soil samples for SU. Per NRC's request, a water sample was collected near the corner of the west wall and a column below the Unit 1 steam tunnel. Water from the Unit 1 steam tunnel (not part of the SU) was running into the basement area that had elevated gamma radiation readings detected during the gamma scans.

6. SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and data collected on site were delivered to the ORAU/ORISE facility for analysis and interpretation. Sample custody was transferred to the Radiological and Environmental Analytical Laboratory (REAL) in Oak Ridge, Tennessee. Sample analyses were performed in accordance with the *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual* (ORAU 2015e). Samples were analyzed by gamma spectroscopy for gamma-emitting fission and activation products and results were reported in units of picocuries per gram (pCi/g). Soil/sediment samples were analyzed for Sr-90 via wet chemistry and low-background gas proportional counting and results were reported in pCi/g.

7. FINDINGS AND RESULTS

The results of the confirmatory survey are discussed in the subsections below.

7.1 Observations

Zion staff were not performing surveys during ORAU's visit; therefore, work practices were not observed. Zion staff were helpful in answering questions and were forthcoming with information.

7.2 SURFACE SCANS

The majority of the confirmatory gamma scan results of the TB basement exhibited radiation levels within the detector background range. However, there were some exceptions. Embedded piping located to the right of the earthen ramp if facing east (count rates up to 8,500 counts per minute (cpm)), the north end of wall 25 and the floor near that area (7,000 cpm and 7,600 cpm respectively), the 10 foot elevation of the fire sump (24,000 cpm), the corner of wall 1 near a column under the unit 1 steam tunnel (12,500 cpm), and a pipe in the condenser intake area (15,000 cpm) all had elevated readings above background, which was approximately 5,000 to 7,000 cpm.

The majority of the confirmatory gamma scan results of the SU 10213A exhibited radiation levels within the detector background range. However, elevated gamma radiation count rates were observed when approaching the southern edge of SU. From approximately 0 to 15 meters (m) from the south boundary, the detector response ranged from 5,500 to 11,000 cpm. From 15 m to the north boundary of the SU, the detector response ranged from 900 to 6,900 cpm. A Sea Land container storing radioactive material was located approximately 36 m to the south of the SU. These increased count rates as approaching the southern boundary are expected due to the presence of the container and volumetric soil samples were collected in the area to confirm this assumption.

7.3 *IN SITU* ACTIVITY MEASUREMENTS

Results from the *in situ* gamma spectroscopy measurements were preliminarily analyzed in the field and a peak for Cs-137 was observed in 3 locations, all of which were associated judgmental measurements. The results from the TB basement *in situ* measurements are reported in Table B-1. Table 7.1 below provides a mean inventory of the gamma-emitting ROCs for the TB Basement.

Only three random locations measured by Zion had activity concentration above the minimum detectable concentration (MDC). None of the random locations measured by ORAU identified any residual radioactivity above the MDC. Therefore, a comparison of the mean activity concentration of the ORAU and Zion random *in situ* measurement data set is unnecessary. All TB basement measurement MDCs for ORAU and Zion were below the inventory limit in table 4.1. MDCs reported by Zion were comparable to those reported by ORAU.

Table 7.1. Mean ROC Inventory in the Turbine Building Basement (pCi/m^2)		
Cs-137	Cs-134	Co-60
2.94E+03	1.32E+04	2.33E+03

Judgmental measurement location ISOCS-J-03 was located on the floor of the turbine building and Cs-137 was identified in the measurement spectrum. Further investigation with the NaI detector revealed that the source of the direct gamma radiation was originating from two embedded pipes in the floor. Judgmental measurement ISOCS-J-04 was collected from the floor of the 20' depth of the fire sump. Results for both measurements ISOCS-J-03 and ISOCS-J-04 were a small fraction of the inventory limit in Table 4.1. Judgmental measurement ISOCS-J-05 was taken in the TB basement of the 10 foot sump east wall based on elevated measurements from the gamma scan. The ISOCS spectrum showed the peak for Cs-137. This spectrum was not quantified due to poor geometry. The higher count rate was due to the sediment in the sump based on NaI scans; therefore, volumetric samples were collected in this area.

7.4 Radionuclide Concentrations in Soil, Sediment, and Water

Analytical results for the TB basement and open land area samples are provided in Tables B-2 through B-4. All three sediment samples from the TB basement sump exhibited ROC concentrations below the respective analytical MDCs for Cs-134 and Sr-90 (Table B-2). All three samples from the sump exhibited detectable concentrations of Co-60 and Cs-137. The maximum concentration in the sediment was 34.5 pCi/g for Cs-137 and 0.181 for Co-60. There are no applicable DCGLs for comparison to the TB sump sediment concentrations. Subsurface soil DCGL values are not appropriate for comparison as the depth of the sump will be greater than 1 meter once backfilled.

Cs-137 was the only ROC identified above the analytical MDC in the water sample collected from the TB basement. The Cs-137 concentration was 6.77 pCi/L.

For the soil samples collected from SU 10213A, only Cs-137 was present above the analytical MDC with a maximum concentration of 0.137 pCi/g, which is a small fraction of the surface soil DCGL.

8. SUMMARY

At the NRC's request, ORAU conducted confirmatory survey activities within the TB basement and the open land area, SU 10213A, at the ZNPS during the period of April 25–28, 2016. The survey activities included gamma radiation surface scans, *in situ* gamma spectroscopy measurements, and soil, sediment, and water sampling.

The majority of the TB basement gamma surface scans were not distinguishable from background. None of the randomly collected *in situ* measurements identified ROCs above the MDC. Two judgmental *in situ* measurements identified Cs-137 at concentrations which are a small fraction of the inventory limit. Moreover, the results of the confirmatory *in situ* measurements support the Class 3 designation applied by Zion.

Three sediment samples collected from the TB basement fire sump exhibited Cs-137 and Co-60 concentrations above the analytical MDC. Because there is not an applicable DCGL for direct comparison against the results of the sediment samples, ORAU recommends Zion evaluate the potential impact to the dose receptor.

Gamma surface scans of the land area exhibited increased detector response starting at approximately 15 m from the south boundary of SU 10213A. A Sea Land container storing radiological material was present approximately 36 m from the south boundary. The three judgmental soil samples collected from locations in SU 10213A contained Cs-137 concentrations above the analytical MDCs but were well below the Cs-137 DCGL. The Co-60 and Cs-134 concentrations were below the MDC. These results confirm that the elevated count rates were due to the material within Sea Land container. ORAU's soil sample results agree with the Class 3 classification of the land area SU 10213A.

9. REFERENCES

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APPENDIX A
FIGURES

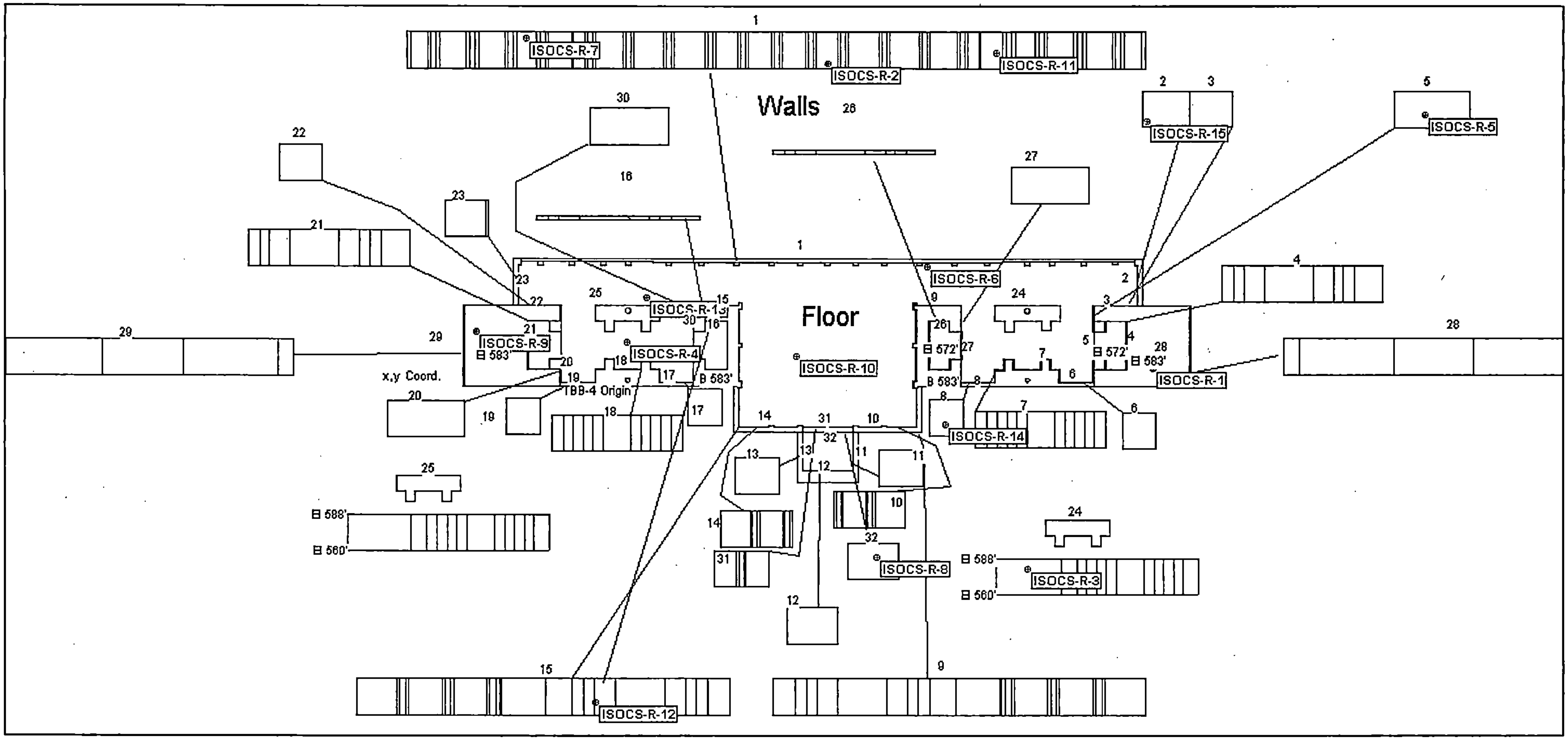

Figure A-1. Random *In Situ* Measurement Locations in the Turbine Building Basement

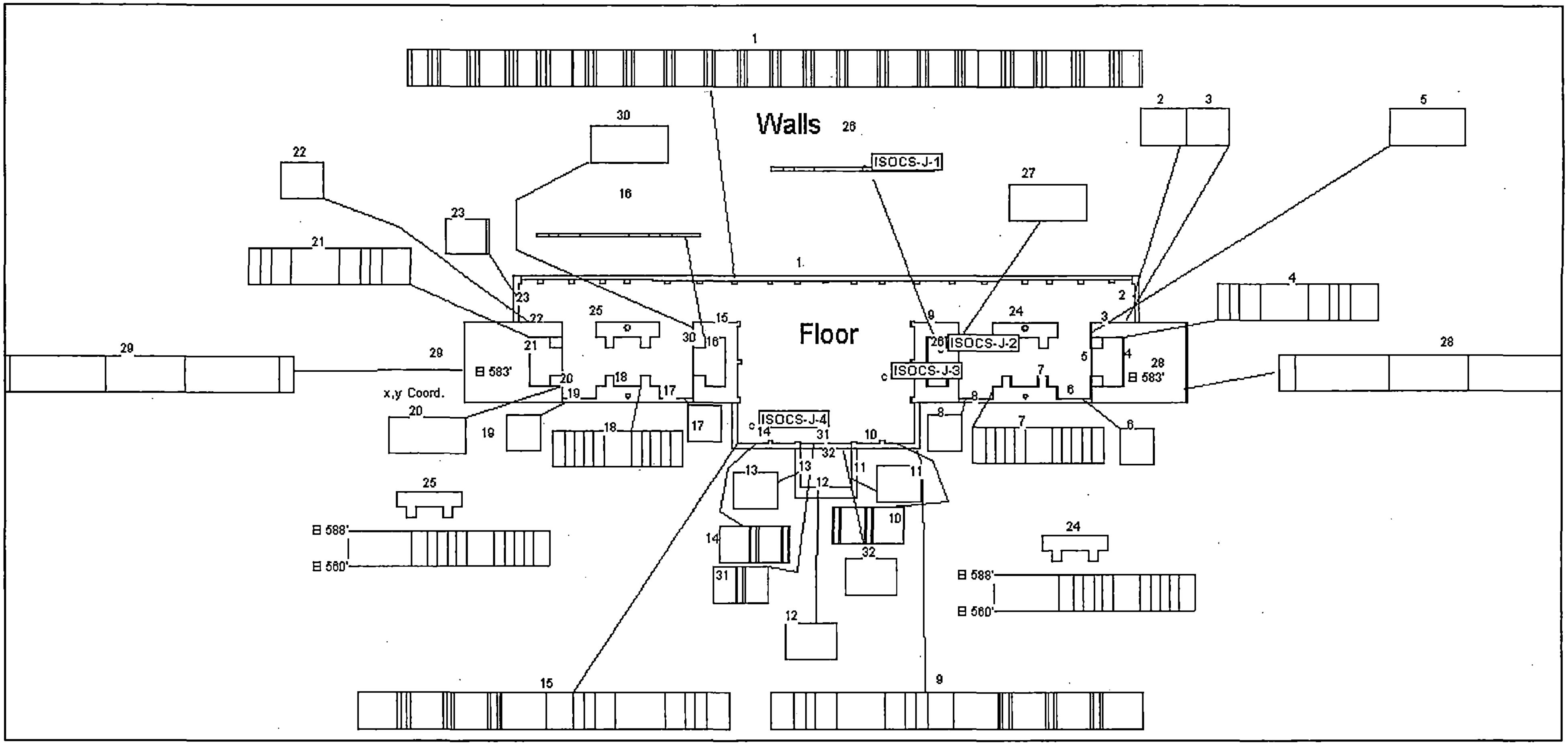

Figure A-2. Judgmental *In Situ* Measurement Locations in the Turbine Building Basement

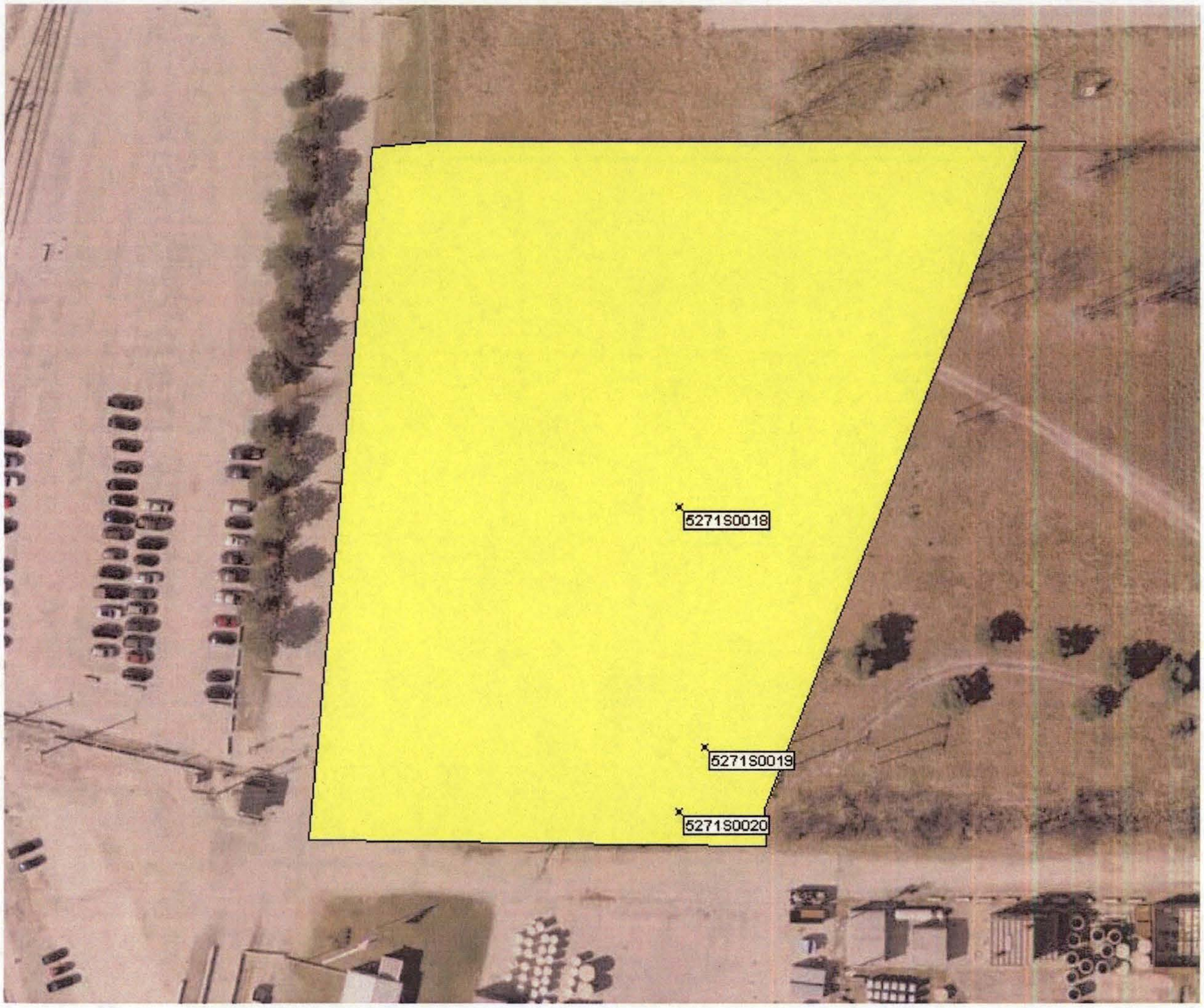

Figure A-3. Land Area, SU 10213A Soil Sample Locations

APPENDIX B
DATA TABLES

Table B.1. ORAU *In Situ* Measurement Activity Concentrations									
ORAU Location ID[a]	Co-60 (pCi/m²)			Cs-134 (pCi/m²)			Cs-137 (pCi/m²)		
	Activity	Uncertainty[b,c]	MDA[d]	Activity	Uncertainty	MDA	Activity	Uncertainty	MDA
ISOCS-R-02	2.70E+03	NA	3.60E+04	4.63E+04	NA	1.01E+05	1.64E+03	NA	2.49E+04
ISOCS-R-03	-1.02E+04	NA	4.10E+04	5.29E+04	NA	1.08E+05	-5.96E+03	NA	2.44E+04
ISOCS-R-05	1.42E+04	NA	3.95E+04	-2.84E+04	NA	8.65E+04	-1.95E+03	NA	2.14E+04
ISOCS-R-06	6.21E+03	NA	3.35E+04	1.47E+04	NA	8.60E+04	1.62E+03	NA	2.29E+04
ISOCS-R-07	2.12E+04	NA	4.31E+04	1.12E+04	NA	9.28E+04	1.08E+04	NA	2.64E+04
ISOCS-R-08	2.03E+04	NA	3.75E+04	8.03E+03	NA	1.15E+05	1.38E+04	NA	2.78E+04
ISOCS-R-10	2.67E+04	NA	3.83E+04	-3.13E+04	NA	8.42E+04	4.82E+03	NA	2.43E+04
ISOCS-R-11	-8.24E+03	NA	4.46E+04	2.76E+04	NA	9.72E+04	7.13E+03	NA	2.34E+04
ISOCS-R-13	-1.20E+04	NA	3.41E+04	1.64E+04	NA	9.17E+04	-1.41E+04	NA	2.18E+04
ISOCS-R-14	-1.81E+04	NA	3.28E+04	1.43E+04	NA	9.19E+04	1.78E+03	NA	2.12E+04
ISOCS-R-15	-1.71E+04	NA	2.61E+04	1.38E+04	NA	9.96E+04	1.28E+04	NA	2.36E+04
Mean	2.33E+03			1.32E+04			2.94E+03		
ISOCS-J-01	8.92E+03	NA	3.31E+04	-1.01E+04	NA	7.79E+04	1.10E+04	NA	2.03E+04
ISOCS-J-02	-1.25E+04	NA	3.69E+04	-1.88E+04	NA	6.87E+04	5.31E+03	NA	2.00E+04
ISOCS-J-03	1.39E+04	NA	3.60E+04	7.57E+04	NA	9.40E+04	8.80E+04	1.05E+04	2.55E+04
ISOCS-J-04	2.25E+04	NA	4.05E+04	1.77E+04	NA	7.86E+04	1.20E+05	1.24E+04	1.80E+04

[a] "R" denotes a randomly collected measurement; "J" denotes a judgmental measurement
[b] Uncertainty is not reported if radionuclide was not identified after running the analysis sequence
[c] Uncertainties represent the 95% confidence level, based on counting statistics.
[d] MDA = minimum detectable activity

Table B.2. Radionuclide Concentrations in the Turbine Building Basement[a, b]									
Sample ID	Location	Co-60 (pCi/g)		Cs-134 (pCi/g)		Cs-137 (pCi/g)		Sr-90 (pCi/g)	
		Concentration	MDC	Concentration	MDC	Concentration	MDC	Concentration	MDC
5271S0015	SE corner of 20' Elev.	0.181 ± 0.036	0.038	-0.022 ± 0.015	0.061	2.48 ± 0.17	0.05	-0.10 ± 0.21	0.39
5271S0016	NE corner of 10' Elev.	0.167 ± 0.025	0.030	0.014 ± 0.021	0.044	34.5 ± 2.0	0.1	0.02 ± 0.18	0.33
5271S0017	SE corner of 10' Elev.	0.172 ± 0.029	0.031	0.028 ± 0.017	0.045	31.2 ± 1.8	0.1	-0.11 ± 0.19	0.36

[a] Uncertainties represent the 95% confidence level, based on total propagated uncertainties
[b] MDC = Minimum Detectable Concentration

Table B.3. Radionuclide Concentrations in the Turbine Building Basement[a, b]									
Sample ID	Location	Co-60 (pCi/L)		Cs-134 (pCi/L)		Cs-137 (pCi/L)		Sr-90 (pCi/L)	
		Concentration	MDC	Concentration	MDC	Concentration	MDC	Concentration	MDC
5271W0001	Below Unit 1 Steam Tunnel	0.8 ± 1.1	2.2	1.1 ± 1.1	2.3	6.77 ± 0.96	1.68	--	--

[a] Uncertainties represent the 95% confidence level, based on total propagated uncertainties
[b] MDC = Minimum Detectable Concentration

Table B.4. Radionuclide Concentrations in the Open Land Area, SU 10213A[a, b]									
Sample ID	Coordinates	Co-60 (pCi/g)		Cs-134 (pCi/g)		Cs-137 (pCi/g)		Sr-90 (pCi/g)	
		Concentration	MDC	Concentration	MDC	Concentration	MDC	Concentration	MDC
5271S0018	642064N, 343689E	-0.001 ± 0.023	0.046	0.021 ± 0.025	0.053	0.137 ± 0.019	0.028	0.06 ± 0.18	0.33
5271S0019	642022N, 343694E	-0.014 ± 0.027	0.054	-0.025 ± 0.015	0.070	0.113 ± 0.024	0.035	0.05 ± 0.20	0.35
5271S0020	642010N, 343689E	-0.003 ± 0.027	0.054	-0.0054 ± 0.0096	0.0673	0.110 ± 0.022	0.033	0.06 ± 0.20	0.35

[a] Uncertainties represent the 95% confidence level, based on total propagated uncertainties
[b] MDC = Minimum Detectable Concentration

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

C.1.1 GAMMA

Ludlum NaI Scintillation Detector Model 44-10, Crystal: 5.1 cm × 5.1 cm
(Ludlum Measurements, Inc., Sweetwater, Texas)
coupled to:
Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, Texas)
coupled to:
Trimble Data Logger (Trimble Navigation Limited, Sunnyvale, California)

C.1.2 *IN SITU* GAMMA SPECTROSCOPY

High-Purity, Broad Energy Germanium Detector
CANBERRA Model No: BE3825
(Canberra, Meriden, Connecticut)
Used in conjunction with:
Preamplifier Model 2002C
(Canberra, Meriden, Connecticut)
Cryostat Model 7935-7-RDC-4
(Canberra, Meriden, Connecticut)
Multichannel Analyzer
Canberra's Gamma Software
Dell Laptop
(Canberra, Meriden, Connecticut)

C.2 LABORATORY ANALYTICAL INSTRUMENTATION

High-Purity, Extended Range Intrinsic Detector
CANBERRA/Tennelec Model No: ERVDS30-25195
(Canberra, Meriden, Connecticut)
Used in conjunction with:
Lead Shield Model G-11
(Nuclear Lead, Oak Ridge, Tennessee) and
Multichannel Analyzer
Canberra's Gamma Software
Dell Workstation
(Canberra, Meriden, Connecticut)

High-Purity, Intrinsic Detector
Model No. GMX-45200-5
CANBERRA Model No: GC4020
(Canberra, Meriden, Connecticut)
Used in conjunction with:
Lead Shield Model G-11
Lead Shield Model SPG-16-K8
(Nuclear Data)
Multichannel Analyzer
Canberra's Gamma Software
Dell Workstation
(Canberra, Meriden, Connecticut)

Tri-Carb Liquid Scintillation Analyzer
Packard Instrument Co. Model No. 3100
(Packard Instrument Co., Meriden, Connecticut)

APPENDIX D
SURVEY AND ANALYTICAL PROCEDURES

D.1 PROJECT HEALTH AND SAFETY

ORAU performed all survey activities in accordance with the *ORAU/ORISE Radiation Protection Manual*, the *ORAU Health and Safety Manual*, and the *ORAU Radiological and Environmental Survey Procedures Manual* (ORAU/ORISE 2014, ORAU 2015f, and ORAU 2015b). Prior to on-site activities, a work-specific hazard checklist was completed for the project and discussed with field personnel. The planned activities were thoroughly discussed with site personnel prior to implementation to identify hazards present. Additionally, prior to performing work, a pre-job briefing and walk down of the Turbine Building basement were completed with field personnel to identify hazards present and discuss safety concerns. Should ORAU have identified a hazard not covered in the *ORAU Radiological and Environmental Survey Procedures Manual* or the project's work-specific hazard checklist for the planned survey and sampling procedures, work would not have been initiated or continued until it was addressed by an appropriate job hazard analysis and hazard controls.

D.2 CALIBRATION AND QUALITY ASSURANCE

Calibration of all field instrumentation was based on standards/sources, traceable to National Institute of Standards and Technology (NIST).

Field survey activities were conducted in accordance with procedures from the following ORAU documents:

- *ORAU Radiological and Environmental Survey Procedures Manual* (ORAU 2015b)
- *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual* (ORAU 2015e)
- *ORAU Environmental Services and Radiation Training Quality Program Manual* (ORAU 2015d)

The procedures contained in these manuals were developed to meet the requirements of U.S. Department of Energy (DOE) Order 414.1D and the U.S. Nuclear Regulatory Commission (NRC) *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, NIST Radiochemistry Intercomparison Testing Program, and Intercomparison Testing Program Laboratory Quality Assurance Programs
- Training and certification of all individuals performing procedures
- Periodic internal and external audits

D.3 SURVEY PROCEDURES

D.3.1 SURFACE SCANS

Scans for elevated gamma radiation were performed by passing the detector slowly over the surface. The distance between the detector and surface was maintained at a minimum. Specific scan minimum detectable concentration (MDCs) for the sodium iodide scintillation detectors (NaI) were not determined as the instruments were used solely as a qualitative means to identify elevated gamma radiation levels in excess of background. Identifications of elevated radiation levels that could exceed the site criteria were determined based on an increase in the audible signal from the indicating instrument.

D.3.2 *IN SITU* GAMMA SPECTROSCOPY

The detector was positioned at the measurement location and left stationary for a count time of 15 minutes for each location. The collected spectrums were processed using an analysis sequence as follows:

1. Peak Search: Used to identify significant peaks within the spectrum.

2. Peak Area: Calculates the area under peaks identified in the Peak Search step.

3. Area Correction: For these spectra a background measurement was subtracted from each. In this step peak information from the background spectra is subtracted from the measurement spectra in order to compensate for building material background.

4. Efficiency Correction: To create an efficiency calibration for the detector, the ISOCS software is used to approximate the real world measurement geometry with templates provided in the software. The software then calculates the detector's efficiency at a range of energies based on the specific dimensions that the template was scaled to. For these spectra the Circular Plane geometry was used to approximate the detector's field of view (FOV) on a flat wall.

5. Nuclide Identification: The information from the previous analysis steps is matched against a library of isotopes and their associated energies and yields in order to identify the peaks found in the spectrum. Because of the efficiency calibration, the quantities of the identified isotopes are also calculated.

6. Detection Limits: An MDA is generated for each of the reported isotopes that reflect what the detection system's detection limits were based on the detector-source geometry, source matrix composition, and count time.

D. 3.3 MISCELLANEOUS MATERIAL AND SOIL SAMPLING

Soil and sediment samples (approximately 0.5 kilogram each) were collected using a clean garden trowel and then transferred into a new sample container by ORAU personnel.. One liter of water was collected into an clean HDPE container. ORAU personnel labeled each sample in accordance with ORAU survey procedures and completed the required chain-of-custody documentation.

D.4 RADIOLOGICAL ANALYSIS

D.4.1 GAMMA SPECTROSCOPY

Samples were analyzed as received, mixed, crushed, and/or homogenized as necessary, and a portion sealed in a 0.5-liter Marinelli beaker. 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, high purity, 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 ROCs were reviewed for consistency of activity. Spectra were also reviewed for other identifiable TAPs. TAPs used for determining the activities of ROCs and the typical associated MDCs for a one-hour count time were:

Table D.1. TAPs for Determining Activities		
Radionuclide[a]	TAP (MeV)	MDC (pCi/g)
Co-60	1.173	0.05
Cs-134	0.796	0.05
Cs-137	0.662	0.04

[a]Spectra were also reviewed for other identifiable TAPs.

D.5 DETECTION LIMITS

Detection limits, referred to as MDCs, were based on 95% confidence level. 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.