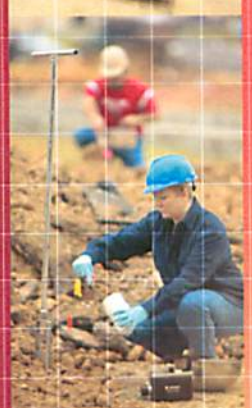

# INDEPENDENT VERIFICATION FINAL SUMMARY REPORT FOR THE DAVID WITHERSPOON, INC. 1630 SITE KNOXVILLE, TENNESSEE

Phyllis Weaver

Prepared for the
U.S. Department of Energy

ORISE
Oak Ridge Institute for Science and Education

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# INDEPENDENT VERIFICATION FINAL SUMMARY REPORT FOR THE DAVID WITHERSPOON, INC. 1630 SITE KNOXVILLE, TENNESSEE

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Prepared for the

U.S. Department of Energy

**FINAL REPORT**

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**INDEPENDENT VERIFICATION FINAL SUMMARY REPORT**
**FOR THE DAVID WITHERSPOON, INC. 1630 SITE**
**KNOXVILLE, TENNESSEE**

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## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| µg/kg | micrograms per kilogram |
| BJC | Bechtel Jacobs Company |
| Bkg | background |
| Cd | cadmium |
| cm | centimeter |
| COC | contaminants of concern |
| cpm | counts per minute |
| Cs-137 | cesium-137 |
| DOE | U.S. Department of Energy |
| D&D | decontamination and decommissioning |
| DWI | David Witherspoon, Inc. |
| EPA | Environmental Protection Agency |
| GPS | global positioning system |
| ITP | Intercomparison Testing Program |
| IV | independent verification |
| IVT | independent verification team |
| LVLI | Lionville Laboratory, Inc. |
| MAPEP | Mixed Analyte Performance Evaluation Program |
| MDC | minimum detectable concentration |
| MeV | million electron volts |
| mg/kg | milligrams per kilogram |
| MOU | Memorandum of Understanding |
| NaI | sodium iodide |
| NIST | National Institute of Standards and Technology |
| NRIP | NIST Radiochemistry Intercomparison Program |
| ORISE | Oak Ridge Institute for Science and Education |
| ORO | Oak Ridge Operations Office |
| Pb | lead |
| PCB | polychlorinated biphenyl |
| pCi/g | picocuries per gram |
| PSP | project-specific plan |
| Ra-226 | radium-226 |
| RL | remediation level |
| SMO | Sample Management Office |
| SU | survey unit |
| TAP | total absorption peak |
| TDEC | Tennessee Department of Environment and Conservation |
| Th-228 | thorium-228 |
| Th-232 | thorium-232 |
| U-234 | uranium-234 |
| U-235 | uranium-235 |
| U-238 | uranium-238 |
| VSP | Visual Sampling Plan |

# INDEPENDENT VERIFICATION FINAL SUMMARY REPORT FOR THE DAVID WITHERSPOON, INC. 1630 SITE KNOXVILLE, TENNESSEE

## INTRODUCTION AND SITE HISTORY

David Witherspoon Incorporated (DWI) operated three industrial sites in South Knoxville, Tennessee that accepted scrap metal and materials from facilities of the U.S. Department of Energy (DOE) and its predecessor agencies. All three of these sites are listed on the Tennessee Department of Environment and Conservation (TDEC) Superfund list due to radiological and chemical contamination. These sites are located at 901 Maryville Pike, also known as the Candora Site, the 1630 Maryville Pike Site, and the David Witherspoon Landfill that consists of 40 acres and is located to the rear of the 1630 Site. Cleanup at the DWI 901 Site was completed in 2006 and shortly thereafter, work began at the DWI 1630 Site (BJC 2006).

The DWI 1630 Site operated as an industrial landfill and metal recycling business permitted by the Tennessee Division of Radiological Health to accept low-level radiologically contaminated metal from many DOE Sites, including those in Oak Ridge, Tennessee; Paducah, Kentucky; and Portsmouth, Ohio. The site operated from the 1950s until its closure in 1974. The DWI 1630 Site is situated in an urban setting in the Vestal Community between the Kingsley Station and Mt. Olive communities in Knox County, Tennessee, just outside the city limits of Knoxville, approximately three miles south of downtown Knoxville.

DOE agreed to undertake remedial actions at the DWI 1630 Site as specified under a Consent Order with the State of Tennessee (Consent Order No. 90-3443, April 4, 1994) and as further delineated by a Memorandum of Understanding (MOU) between DOE and the State of Tennessee (BJC 2006). DOE contracted Bechtel Jacobs Company (BJC), LLC to remove radioactive materials and contamination from the DWI 1630 Site.

Past monitoring at the site indicated that improper handling of the waste had resulted in the contamination. Characterization surveys and analyses identified numerous radiological and chemical contaminants, including uranium, thorium, heavy metals, polychlorinated biphenyls (PCBs), asbestos, and organic compounds. The contaminants were noted in various media on the site, including debris, soil, sediment, groundwater, and surface water. There were no buildings located in

the subject areas during site operations. The DOE's decommissioning contractor, BJC performed characterization surveys, subsequent remediation, and final status surveys within the subject area. The DOE's Oak Ridge Operations Office (ORO) was responsible for oversight of decontamination and decommissioning (D&D) conducted at the DWI 1630 Site. Additional oversight was conducted by the TDEC.

BJC acquired the right to use a portion of some adjoining property as an access and support area for work at the DWI 1630 Site. The subject area has a temporary easement covering approximately 3.5 acres and is located on land owned by the Mayo Seed Company immediately southwest of the DWI 1630 Site at 2306 Maryville Pike. The Mayo tract is not associated with DWI 1630 past activities and is not known to be contaminated.

The purpose of independent verification activities was to confirm that remedial actions have been effective in meeting established and site-specific guidelines and that the documentation prepared by the contractor accurately and adequately describes the radiological conditions at the site. DOE has established a policy to perform independent (third party) verification surveys of remedial action activities at DOE Sites (DOE 2006). The Oak Ridge Institute for Science and Education (ORISE) was designated as the organization responsible for verifying the final status of the cleanup activities associated with the DWI 1630 Site.

## SITE DESCRIPTION

The DWI 1630 Site is located at 1630 Maryville Pike in Knoxville, Tennessee (Figure A-1). The site is situated between the CSX railroad on the west and by the Norfolk Southern railroad on the east. The 48 acre site consists of five separate tracts of land, including a tract located across the Norfolk Southern Railroad tracks (Figure A-2). A landfill capped with a low permeability clay cover occupies approximately five acres. Approximately 20 acres of the site contained superficial debris, including old vehicles, equipment, scrap metal, cable, wiring, piping, scaffolding, drums, cylinders, large containers, electric motors, transformers, many ferrous and nonferrous materials, soil-like debris, building materials, and miscellaneous trash associated with the DWI business operation (BJC 2006). The site terrain varied from densely wooded, steep hillsides to cleared level, and excavated areas at varying depths. In Figure A-2, grids evaluated by ORISE are outlined in red.

## OBJECTIVE

The primary objective of the independent verification was to determine if BJC performed the appropriate actions to meet the specified "hot spot" cleanup criteria of 500 picocuries per gram (pCi/g) uranium-238 (U-238) in surface soil. Specific tasks performed by the independent verification team (IVT) to satisfy this objective included: 1) performing radiological walkover surveys, and 2) collecting soil samples for independent analyses. The independent verification (IV) efforts were designed to evaluate radioactive contaminants (specifically U-238) in the exposed surfaces below one foot of the original site grade, given that the top one foot layer of soil on the site was removed in its entirety.

## DOCUMENT AND DATA REVIEW

The IVT reviewed the BJC Interim Action Work Plans, Sampling and Analysis Plan, and supporting data and documentation. The focus of the review included the survey methodology and instrumentation detection capabilities and calibration, in order to develop an applicable and appropriate project-specific plan (PSP) for radiological field surveys and sampling (ORISE 2007a). In addition, the IVT reviewed the BJC field screening and verification sampling data for comparison against the applicable soil release criteria.

## VERIFICATION SURVEY PROCEDURES

During the period of June 2008 to December 2008, ORISE performed radiological verification surveys of open land areas at the DWI 1630 Site. Site verification activities were performed in accordance with a PSP submitted to and approved by DOE (ORISE 2007a) and the ORISE Survey Procedures and the ORAU Quality Program Manuals (ORISE 2008a and ORAU 2007). The IV surveys were performed in several survey efforts, which are summarized in Table B-1. Land area surveys included gamma surface scans and soil sampling.

Prior to survey activities, a reference map was uploaded into Visual Sampling Plan (VSP) Version 5 software (PNNL 2007). The VSP software was used to determine the number of samples required to provide an adequate statistical representation of the area based on the assumed mean concentration and variability of the primary contaminant of concern, U-238, and to generate the random soil sampling locations.

## REFERENCE SYSTEM

ORISE used a global positioning system (GPS) for documenting survey area boundaries, sample locations, and referencing gamma scan data. The specific geographic reference system used was the Tennessee State Plane Coordinate System. A shape file for each set of grids or survey unit (SU) dimensions was created and then uploaded into a GPS for use by the IVT for tracking survey data and identifying measurement and sampling locations. Coordinate measurements collected using the GPS were accurate to within one meter.

## GAMMA SURFACE SCANS

ORISE performed medium to high density gamma scans over approximately 75% or greater of accessible surfaces in the subject grids (Figure A-3). Higher density scans were based on visual indications of areas with a higher potential for contamination (i.e., downstream of drains, and surface water collection points) and accessibility. Scans were performed using both 1.25 inch by 1.5 inch and 2 inch by 2 inch sodium iodide (NaI) scintillation detectors coupled to ratemeters with audible output. The *a priori* scan minimum detectable concentrations (MDC) were approximately 115 pCi/g for the smaller detector and 80 pCi/g for the larger NaI detector for the primary radionuclide of concern—U-238—as estimated from Table 6.4 of NUREG-1507(NRC 1997). The use of the GPS coupled to the detector/ratementer combination enabled real-time gamma count rate and position data capture.

## SOIL SAMPLING

Soil samples were collected for both radiological and chemical analyses (Figures A-4 and A-5). Samples were typically collected at a depth of 0 to 15 centimeters (cm) at the exposed surface (i.e., ground surface or the surface of an excavated area). Sample locations were either randomly selected to include a minimum of one sample per grid, or judgmentaly determined based on scan results. The initial verification effort did not include soil samples at a frequency of one per grid. The initial effort relied upon historical assessment and scan results of an area to make a judgment as to whether a sample would be collected. However, to better evaluate the contractor's efforts, ORISE adapted a statistically-based random sampling methodology for subsequent verification efforts to validate the remediation process and verify that site criteria had been met.

ORISE collected samples at judgmental locations based on the highest observed field scan results as well as randomly determined locations using VSP. ORISE collected a minimum of one IV soil sample in every grid, including partial grids, with the exception of three areas: CSX Railroad area (Grids R14, R15, and R16), Johnsons Junction (Grid N20), and (Grids P09, P10, and P11). These areas were surveyed prior to the change in verification approach (ORISE 2007c). ORISE collected 92 radiological soil samples, of which nine were from judgmental locations (ORISE 2007b and c, and 2008c, d, e, and f, 2009). Two samples were provided by the contractor. Thirty-seven soil samples for chemical analyses were collected. ORISE conducted chemical sampling only when BJC identified chemical issues in the area.

## SAMPLE ANALYSIS AND DATA INTERPRETATION

Radiological soil samples were returned to the ORISE laboratory in Oak Ridge, Tennessee for analysis and interpretation. Samples collected to determine PCB and metal concentrations were analyzed by Lionville Laboratory, Inc. (LVLI) in Exton, Pennsylvania, a DOE Oak Ridge Operations Sample Management Office (SMO)-approved facility.

Radiological analyses were performed in accordance with the ORISE Laboratory Procedures Manual (ORISE 2008b). The soil samples were analyzed by gamma spectroscopy for U-238 and reviewed for other gamma-emitting contaminants. Alpha spectroscopy analysis was conducted on samples S066 through S083 to quantify individual uranium and thorium isotopes. Radionuclide concentrations were reported in units of picocuries per gram (pCi/g). Additional information concerning major instrumentation, sampling equipment, calculation variables, and analytical procedures is provided in Appendices C and D.

LVLI performed PCB, lead (Pb), and cadmium (Cd) analyses in accordance with Environmental Protection Agency (EPA) approved Solid Waste-846 method 8000 series, method 8081A and 8082 for PCBs and methods 6000 and 7000 for the metals of concern (EPA 2007). The results were reported in units of micrograms per kilogram (µg/kg) and converted to units of milligrams per kilogram (mg/kg). The data qualifiers associated with the sample results are listed in Appendix E.

### SOIL RELEASE CRITERIA

Radiological sample data were compared to the "hot-spot" criterion of 500 pCi/g for U-238 as specified in the PSP (ORISE 2007a). PCB samples results were compared to the criterion of 10 mg/kg. Lead was compared with the acceptable range defined by the National Institute for Standards and Testing reported in the contractor's analytical results package. However, cadmium was not compared to any criterion.

## FINDINGS AND RESULTS

### DATA REVIEW

The BJC field screening and verification sample data indicated that results were generally comparable to the ORISE verification sample data. However, BJC did not sample from locations of elevated radiation; therefore, ORISE results, for cesium-137 (Cs-137) in Grid R15 and U-238 in Grid L12, are much higher than the BJC results. It should be noted that BJC typically did not collect verification samples for partial grids, although radiological walkover surveys and field screening were performed in these areas. Individual letter reports of independent verification were prepared for each of the verification survey efforts. These reports contain the results of the data reviews (ORISE 2007b and c, 2008c, d, e, f, and 2009).

### SURFACE SCANS

The gamma radiation levels reported are gross values that have not been corrected for the ambient background. Gamma radiation levels ranged from 6,000 to 70,000 cpm. The highest levels recorded were in the CSX Railroad area in Grids R15, and in Grid L12 just across the boundary from L13 (Figure A-3). The direct gamma scans in the CSX area identified several locations of higher radiation levels.

### RADIONUCLIDE CONCENTRATIONS IN SOIL

The U-238 activity concentration ranges from gamma spectroscopy are summarized inTable B-2. The data represent a compilation of all samples collected from surveyed grids during the period of June 2007 through December of 2008 (ORISE 2007b and c through 2008c, d, e, and f). The gamma

spectra were also reviewed for other identifiable radionuclide photopeaks. Radionuclide concentration range, mean, and median of identifiable gamma-emitting radionuclides have been included in Table B-3. U-238 concentrations determined by gamma spectroscopy ranged from 0.49 to 470 pCi/g. The highest U-238 concentration identified was located in Grid L12 soil sample S097 (Figure A-4). The direct static count rate measurement at this location was as high as 27,000 cpm. The U-238 mean activity concentration for verification samples was 8.32 pCi/g and the median was 1.52 pCi/g. The U-238 alpha spectroscopy results for soil samples S066 through S083 are provided in Table B-4 and ranged from 1.10 to 5.60 pCi/g.

PCB sample results are provided in Table B-5. Data were reviewed for the primary PCB isomer contaminant, Aroclor 1254. Measureable concentrations of the PCB isomers Aroclor 1248 and Aroclor 1260 were also reported. Total PCBs included the isomers Aroclor 1254 and 1260 unless the Aroclor 1248 isomer was reported as greater than the detection limit. Aroclor 1254 concentrations ranged from 0.0071 to 59 mg/kg. Samples S010 and S016 had the highest concentrations of Aroclor 1254 at 45 and 59 mg/kg, respectively.

Lead and cadmium results are reported in Table B-6. Lead concentrations ranged from 11.5 to 363 mg/kg. In most samples, cadmium results were below the minimum detection limit for the sample. Measurable cadmium ranged from 0.13 to 20.8 mg/kg.

## COMPARISON OF RESULTS WITH GUIDELINES

All IV soil samples collected at the DWI 1630 Site were less than the U-238 "hot-spot" limit of 500 pCi/g, as specified in the PSP (ORISE 2007a). The highest U-238 concentration was detected in sample S097 at 470 pCi/g and total U for sample S097 was 960 pCi/g, which includes both the uranium-234 (U-234) and U-235 isotopes.

Two samples contained Aroclor 1254 concentrations that exceeded the 10 mg/kg remediation levels (RLs) average. Aroclor 1254 concentrations for sample locations S010 and S016 were determined to be at 45 and 59 mg/kg, respectively. The results were reported to BJC and DOE in a letter report (ORISE 2008c). ORISE did not conduct followup sampling after the area was addressed by BJC.

Lead results were compared to the applicable site RL of 800 mg/kg. Lead concentrations were determined to be well below the RL. The highest concentration of lead was 363 mg/kg from sample location S023. An RL for cadmium has not been established for the site.

## CONCLUSION

During the period of July 2007 through December 2008, ORISE performed comprehensive independent verification surveys of surface soils at the DWI 1630 Site. The objective of the ORISE IV was to verify that post-excavation surface soil concentrations were less than the "hot-spot" criteria of 500 pCi/g U-238 (ORISE 2007a). Based on the results of the verification activities at the DWI 1630 Site, it is ORISE's position that the concentration of the radionuclides of concern for the subject grids, meet the release limits established for the DWI 1630 Site.

## REFERENCES


Bechtel Jacobs Company, LLC (BJC). Radiological Characterization Plan for the David Witherspoon 1630 Site Soil Remediation Project. Oak Ridge, Tennessee; SEC /RCSP-DWI1630-RCSP2006-01, October, 2006.

Oak Ridge Associated Universities (ORAU). Quality Program Manual for the Independent Environmental Assessment and Verification Program. Oak Ridge, Tennessee; November 1, 2007.

Oak Ridge Institute for Science and Education (ORISE). Project-Specific Plan for Conducting In-Process Reviews and Independent Verification Surveys of Remedial Action Activities at the David Witherspoon, Inc. 1630 Site, Knoxville, Tennessee. Oak Ridge, Tennessee; May 17, 2007a.

Oak Ridge Institute for Science and Education. Project-Specific In-Process Review of Remedial Action Activities at the David Witherspoon, Inc. 1630 Site, Knoxville, Tennessee. Oak Ridge, Tennessee; October 11, 2007b.

Oak Ridge Institute for Science and Education. Interim Letter Report—Verification Survey Of Johnson's Junction, CSX Area, and Moore's Ridge, David Witherspoon, Inc. 1630 Site, Knoxville, Tennessee. Oak Ridge, Tennessee; August 15, 2007c.

Oak Ridge Institute for Science and Education. Survey Procedures Manual for the Independent Environmental Assessment and Verification Program. Oak Ridge, Tennessee; May 1, 2008a.

Oak Ridge Institute for Science and Education. Laboratory Procedures Manual for the Independent Environmental Assessment and Verification Program. Oak Ridge, Tennessee; December 5, 2008b.

Oak Ridge Institute for Science and Education. Interim Letter Report–Verification Survey of 31 Grids, David Witherspoon, Inc. 1630 Site, Knoxville, Tennessee DCN 0465-LR-01-0. Oak Ridge, Tennessee; February 14, 2008c.

Oak Ridge Institute for Science and Education. Interim Letter Report–Verification Survey of Partial Grids H19, J21, J22, X20, and X21, David Witherspoon, Inc. 1630 Site, DCN 0465-SR-01-0; Knoxville, Tennessee. Oak Ridge, Tennessee; March 19, 2008d.

Oak Ridge Institute for Science and Education. Interim Letter Report–Verification Survey of Partial Grid E9, David Witherspoon, Inc. 1630 Site, DCN 0465-SR-02-0; Knoxville, Tennessee. Oak Ridge, Tennessee; June 12, 2008e.

Oak Ridge Institute for Science and Education. Interim Letter Report–Verification Survey of 19 Grids in the Lester Flat Area, David Witherspoon, Inc. 1630 Site, DCN 0465-SR-03-0; Knoxville, Tennessee; October 17, 2008f.

## REFERENCES (continued)

Oak Ridge Institute for Science and Education. Letter Report—Verification Survey of Final Grids at The David Witherspoon, Inc. 1630 Site, Knoxville, Tennessee - DCN 0465-SR-04-0. Oak Ridge, Tennessee; February 17, 2009.

Pacific Northwest National Laboratory (PNNL). Visual Sample Plan Version 5.0 User's Guide. Richland, Washington, September 2007.

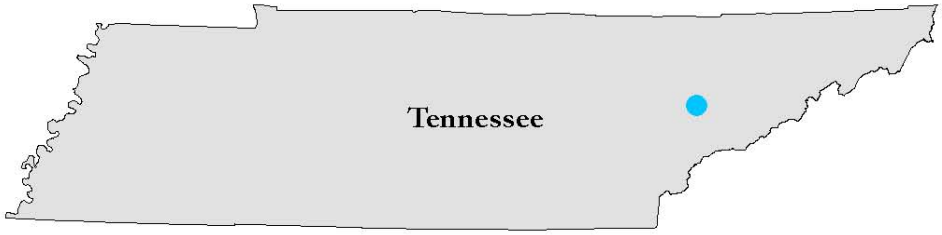
U.S. Department of Energy (DOE). Environment, Safety and Health Bulletin: A Guide to Good Practices for the Control and Release of Property. DOE/EH-0697. Washington, DC. July 2006.

U.S. Environmental Protection Agency (EPA). Data Quality Assessment: Statistical Methods for Practitioners. EPA QA/G-9S 59; Washington, DC. February 2006.

U.S. Environmental Protection Agency. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, 3rd Edition, Revision 6. Washington, DC. February 2007.

U.S. Nuclear Regulatory Commission (NRC). Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions NUREG/CR-1507 Washington DC. 1997.

# APPENDIX A
# FIGURES




David Witherspoon, Inc.

Survey Grids

N

**Figure A - 1: 1630 David Witherspoon Site**

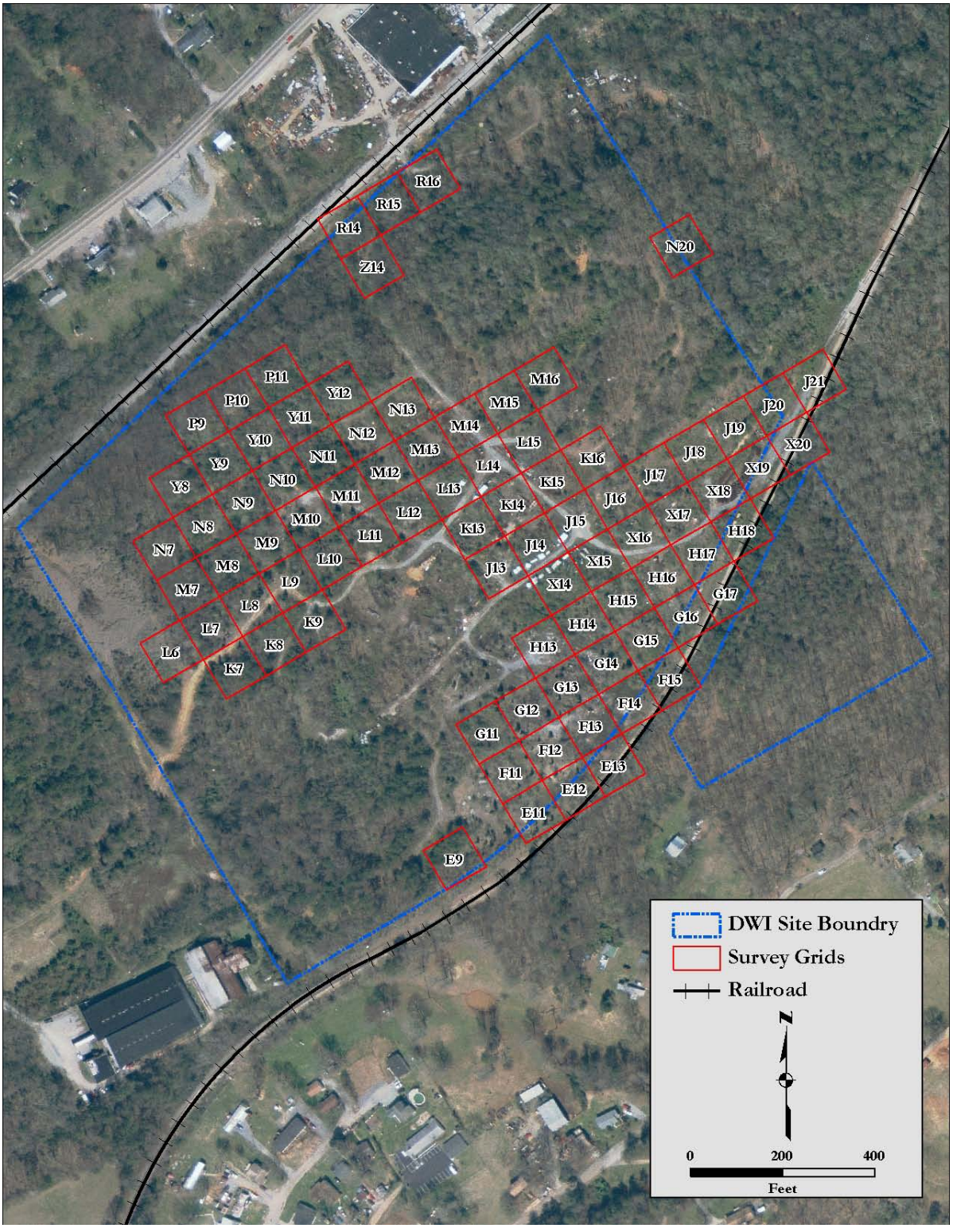



**Figure A - 2: 1630 David Witherspoon Site Plot Plan**

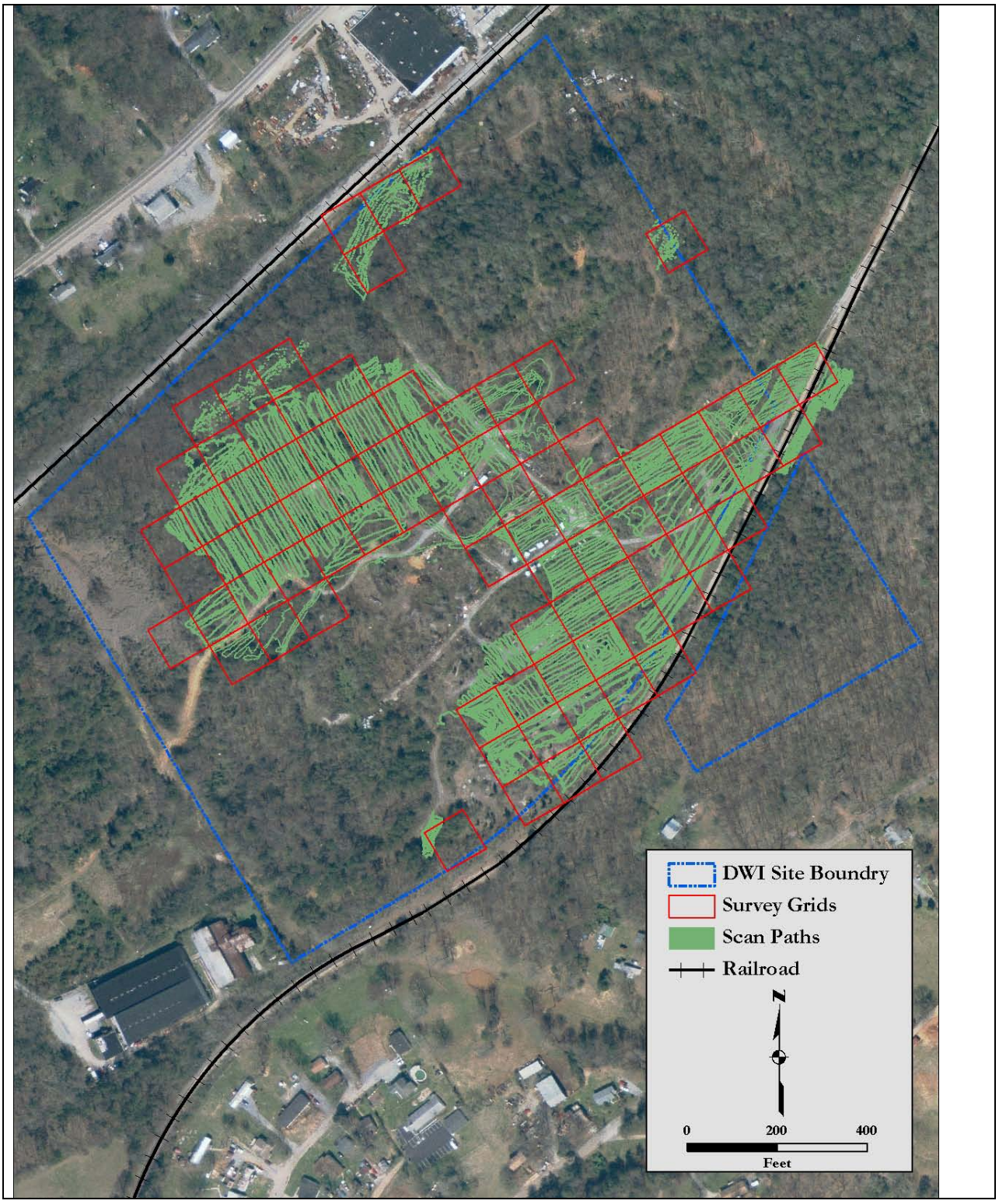



**Figure A - 3: 1630 David Witherspoon Site Gamma Walkover Scans**

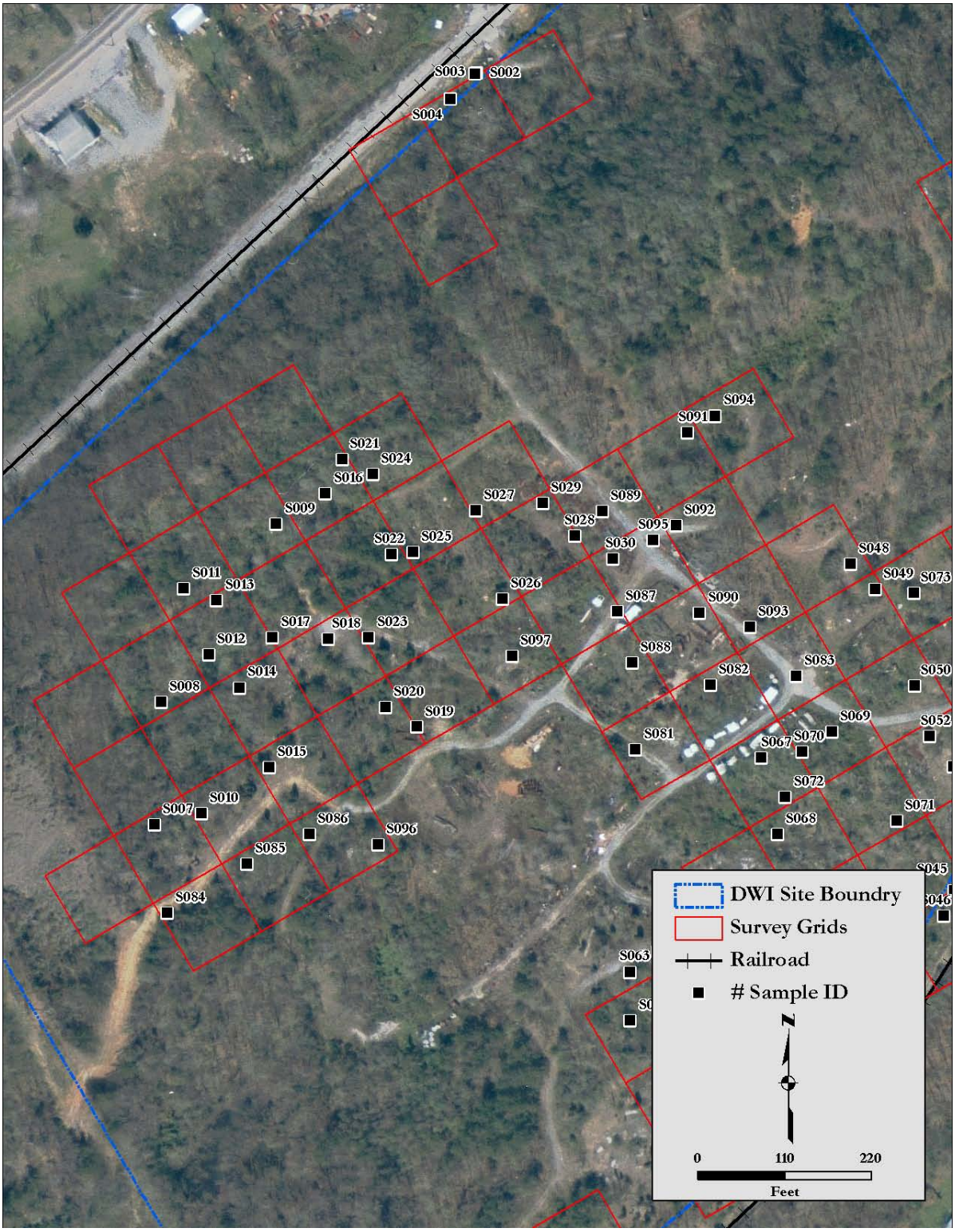



**Figure A - 4: 1630 David Witherspoon Site Sampling Locations–West Portion**

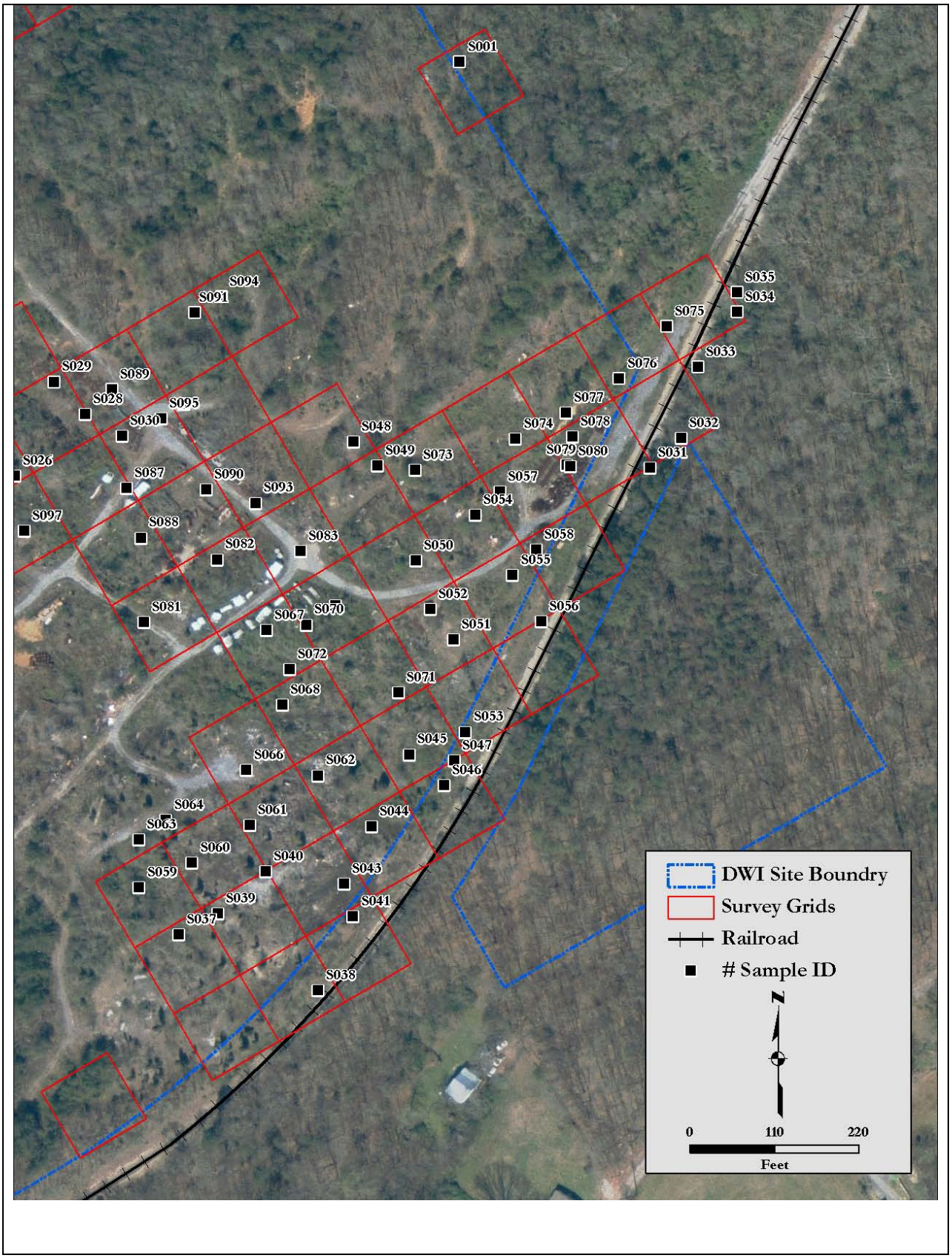



**Figure A - 5: David Witherspoon 1630 Site Sampling Location−East Portion**

# APPENDIX B
# TABLES

| TABLE B - 1:<br>SUMMARY OF VERIFICATION ACTIVITIES<br>DAVID WITHERSPOON, INC. 1630 SITE<br>KNOXVILLE, TENNESSEE | | |
|---|---|---|
| **Surveys** | **Grids** | **Date of Survey** |
| 1, 2 | N20, R14, R15, R16, P09, P10, P11 | July 10 and 12, 2007 |
| 3, 4, 5 | Y8 - Y13, N7 - N14, M7 - M14, and L6 - L14 | November 28, 30, and December 7, 2007 |
| 6 | H19, J21, J22, X20, and X21 | March 6, 2008 |
| 7 | E8, E9, F8, F9 | May 30, 2008 |
| 8 | E11 –E13, F11- F15, G15 – G17, H16 – H18, X16 – X18, K16, and J16 | September 8-11, 2008 |
| 9 | G11, 12, 13; E11, 12 | September 29-30, 2008 |
| 10, 11 | H13, 14, 15; X14, X15; J17, 18,J19, 20, 21 X19 | October 14, 15, 30 2008 |
| 12 | J13, J14, J15 | November 12, 2008 |
| 13 | K7,K8, K9, K13, 14,15; L12 L13, 14, 15; M14, 15,16 | December 15, 17, and 22, 2008 |

| TABLE B - 2<br>URANIUM-238 CONCENTRATIONS IN SOIL BY GAMMA SPECTROSCOPY<br>DAVID WITHERSPOON, INC 1630 SITE<br>KNOXVILLE, TENNESSEE | | | | |
|---|---|---|---|---|
| Location[a] (Grid #) | Coordinates | | Sample ID | U-238 Concentration (pCi/g) |
| | Northing | Easting | | |
| N20 | 582611 | 2581765 | S001 | 17.5 ± 1.3[b] |
| R14 | 582742 | 2581153 | S002 | 3.13 ± 0.94 |
| R15 | 582741 | 2584451 | S003 | 5.1 ± 2.9 |
| R16 | 582708 | 2581119 | S004 | 3.5 ± 1.1 |
| D1630VSP09-3[c] | ---[d] | --- | S005 | 4.92 ± 0.80 |
| D1630VSP10-3[c] | --- | --- | S006 | 27.5 ± 1.6 |
| L7 | 581786 | 2580745 | S007 | 2.04 ± 0.77 |
| N8 | 581941 | 2580753 | S008 | 1.34 ± 0.73 |
| Y10 | 582168 | 2580899 | S009 | 5.59 ± 0.65 |
| L8 | 581799 | 2580804 | S010 | 1.58 ± 0.69 |
| Y9 | 582085 | 2580782 | S011 | 2.34 ± 0.71 |
| N9 | 582002 | 2580813 | S012 | 0.49 ± 0.70 |
| N9 | 582070 | 2580824 | S013 | 1.03 ± 0.50 |
| M9 | 581960 | 2580852 | S014 | 1.41 ± 0.70 |
| L9 | 581615 | 2581650 | S015 | 1.10 ± 0.46 |
| Y11 | 582207 | 2580961 | S016 | 4.17 ± 0.80 |
| N10 | 582024 | 2580894 | S017 | 0.84 ± 0.68 |
| M10 | 582022 | 2580965 | S018 | 1.50 ± 0.61 |
| L10 | 581910 | 2581077 | S019 | 2.17 ± 0.57 |
| L10 | 581935 | 2581037 | S020 | 1.57 ± 0.49 |
| Y11 | 582250 | 2580983 | S021 | 1.18 ± 0.65 |
| N11 | 582129 | 2581045 | S022 | 1.18 ± 0.56 |
| M11 | 582023 | 2581016 | S023 | 2.44 ± 0.70 |
| Y12 | 582231 | 2581021 | S024 | 0.86 ± 0.53 |
| N12 | 582132 | 2581072 | S025 | 0.90 ± 0.51 |
| M12 | 582072 | 2581186 | S026 | 1.38 ± 0.49 |
| N13 | 582184 | 2581151 | S027 | 1.47 ± 0.63 |
| M13 | 582153 | 2581277 | S028 | 2.38 ± 0.51 |
| M13 | 582194 | 2581237 | S029 | 1.24 ± 0.70 |
| L14 | 582124 | 2581326 | S030 | 1.47 ± 0.63 |
| H19 | 582076 | 2582016 | S031 | 2.94 ± 0.89 |
| X20 | 582130 | 2582049 | S032 | 2.42 ± 0.65 |
| X21 | 582217 | 2582071 | S033 | 34.6 ± 2.0 |
| J21 | 582271 | 2582127 | S034 | 215 ± 11 |
| J22 | 582258 | 2582131 | S035 | 34.3 ± 2.4 |

| TABLE B - 2: (continued)<br>URANIUM-238 CONCENTRATIONS IN SOIL BY GAMMA SPECTROSCOPY<br>DAVID WITHERSPOON, INC. 1630 SITE<br>KNOXVILLE, TENNESSEE | | | | |
|---|---|---|---|---|
| Location[a] (Grid #) | Coordinates | | Sample ID | U-238 Concentration (pCi/g) |
| | Northing | Easting | | |
| F11 | 581474 | 2581400 | S037 | 1.39 ± 0.33 |
| E12 | 581402 | 2581581 | S038 | 1.18 ± 0.46 |
| F12 | 581502 | 2581450 | S039 | 1.13 ± 0.24 |
| F12 | 581556 | 2581512 | S040 | 1.17 ± 0.74 |
| E13 | 581497 | 2581626 | S041 | 0.77 ± 0.25 |
| F13 | 581540 | 2581615 | S043 | 1.36 ± 0.31 |
| F14 | 581615 | 2581650 | S044 | 1.08 ± 0.42 |
| G15 | 581709 | 2581700 | S045 | 0.97 ± 0.26 |
| F15 | 581669 | 2581745 | S046 | 1.39 ± 0.37 |
| F15 | 581701 | 2581758 | S047 | 1.60 ± 0.41 |
| K16 | 582117 | 2581627 | S048 | 1.22 ± 0.32 |
| J16 | 582085 | 2581658 | S049 | 1.17 ± 0.32 |
| X16 | 581962 | 2581708 | S050 | 0.93 ± 0.39 |
| H16 | 581859 | 2581757 | S051 | 2.19 ± 0.48 |
| H16 | 581898 | 2581727 | S052 | 1.92 ± 0.46 |
| G16 | 581738 | 2581773 | S053 | 1.62 ± 0.38 |
| X17 | 582021 | 2581785 | S054 | 1.64 ± 0.38 |
| H17 | 581943 | 2581834 | S055 | 3.47 ± 0.49 |
| G17 | 581882 | 2581872 | S056 | 8.49 ± 0.82 |
| X18 | 582061 | 2581818 | S057 | 2.30 ± 0.36 |
| H18 | 581976 | 2581865 | S058 | 2.00 ± 0.38 |
| G11 | 581536 | 2581348 | S059 | 1.02 ± 0.31 |
| G12 | 581567 | 2581417 | S060 | 1.39 ± 0.40 |
| G13 | 581617 | 2581491 | S061 | 1.53 ± 0.29 |
| G14 | 581682 | 2581581 | S062 | 1.45 ± 0.25 |
| E11 | 581598 | 2581347 | S063 | 1.46 ± 0.34 |
| E12 | 581684 | 2581383 | S064 | 1.05 ± 0.33 |
| H13 | 581689 | 2581487 | S066 | 7.88 ± 0.79 |
| X14 | 581871 | 2581514 | S067 | 1.72 ± 0.45 |
| H14 | 581773 | 2581534 | S068 | 1.52 ± 0.35 |
| X15 | 581903 | 2581603 | S069 | 4.91 ± 0.60 |
| X15 | 581878 | 2581565 | S070 | 1.74 ± 0.34 |
| H15 | 581790 | 2581685 | S071 | 1.31 ± 0.35 |
| H15 | 581820 | 2581594 | S072 | 1.93 ± 0.43 |
| J17 | 582080 | 2581707 | S073 | 1.95 ± 0.49 |

| TABLE B - 2: (continued)<br>URANIUM-238 CONCENTRATIONS IN SOIL BY GAMMA SPECTROSCOPY<br>DAVID WITHERSPOON, INC 1630 SITE<br>KNOXVILLE, TENNESSEE | | | | |
|---|---|---|---|---|
| Location[a] (Grid #) | Coordinates | | Sample ID | U-238 Concentration (pCi/g) |
| | Northing | Easting | | |
| J18 | 582120 | 2581838 | S074 | 1.55 ± 0.32 |
| J21 | 582267 | 2582035 | S075 | 2.31 ± 0.46 |
| J20 | 582199 | 2581973 | S076 | 2.92 ± 0.55 |
| J19 | 582164 | 2581904 | S077 | 1.49 ± 0.39 |
| X19 | 582123 | 2581612 | S078 | 1.23 ± 0.35 |
| X19 | 582086 | 2581905 | S079 | 1.48 ± 0.44 |
| X19 | 582084 | 2581909 | S080 | 1.38 ± 0.31 |
| J13 | 581881 | 2581354 | S081 | 2.06 ± 0.45 |
| J14 | 581963 | 2581449 | S082 | 2.92 ± 0.55 |
| J15 | 581974 | 2581558 | S083 | 1.70 ± 0.43 |
| K7 | 581673 | 2580760 | S084 | 1.53 ± 0.45 |
| K8 | 581736 | 2580862 | S085 | 1.23 ± 0.25 |
| K9 | 581773 | 2580941 | S086 | 0.91 ± 0.28 |
| L13 | 582056 | 2581331 | S087 | 1.01 ± 0.42 |
| K13 | 581991 | 2581350 | S088 | 8.06 ± 0.73 |
| M14 | 582184 | 2581312 | S089 | 1.37 ± 0.39 |
| K14 | 582054 | 2581435 | S090 | 6.05 ± 0.65 |
| M15 | 582284 | 2581420 | S091 | 50.3 ± 3.8 |
| L15 | 582166 | 2581406 | S092 | 1.29 ± 0.25 |
| K15 | 582037 | 2581499 | S093 | 2.39 ± 0.27 |
| M16 | 582305 | 2581455 | S094 | 1.10 ± 0.34 |
| L14 | 582147 | 2581376 | S095 | 1.55 ± 0.43 |
| K9 | 581760 | 2581028 | S096 | 1.10 ± 0.25 |
| L12 | 582000 | 2581198 | S097 | 470 ± 30 |

[a]Refer to Figures 4 and 5.
[b]Uncertainties represent the 95% confidence level based on total propagated uncertainties.
[c]Sample provided by BJC.
[d]---No data provided.

**TABLE B - 3:**
**STATISTICAL SUMMARY OF RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES BY GAMMA SPECTROSCOPY**
**DAVID WITHERSPOON, INC. 1630 SITE**
**KNOXVILLE, TENNESSEE**

| *DWI Survey Results* | *Radionuclide Concentration (pCi/g)* | | | | | | |
|---|---|---|---|---|---|---|---|
| | *Th-228* | *Th-232* | *Total Th* | *U-238* | *U-235* | *Total U* | *Cs-137* |
| *Concentration Range* | *-2.02 to 1.66* | *0.32 to 1.89* | *-1.7 to 3.36* | *0.49 to 470* | *-0.14 to 22.7* | *1.1 to 960* | *-0.28 to 663* |
| *Mean Concentration* | *1.22* | *1.33* | *2.55* | *8.32* | *0.44* | *17.0* | *8.69* |
| *Median Concentration* | *1.30* | *1.36* | *2.71* | *1.52* | *0.12* | *3.1* | *0.02* |

## TABLE B - 4:
## RADIONUCLIDE CONCENTRATIONS IN SOIL
## BY ALPHA SPECTROSCOPY
## DAVID WITHERSPOON, INC. 1630 SITE
## KNOXVILLE, TENNESSEE

| Sample ID/Location[a] | Radionuclide Concentration in Soil Samples (pCi/g) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Th-228 | Th-232 | Total Th[b] | U-234 | U-235 | U-238 | Total U[c] |
| S066 | 1.27 ± 0.19[d] | 1.27 ± 0.19 | 2.54 ± 0.26 | 5.43 ± 0.44 | 0.27 ± 0.05 | 5.36 ± 0.43 | 11.05 ± 0.61 |
| S067 | 1.48 ± 0.23 | 1.34 ± 0.21 | 2.82 ± 0.32 | 1.57 ± 0.16 | 0.11 ± 0.03 | 1.60 ± 0.16 | 3.28 ± 0.23 |
| S068 | 1.47 ± 0.22 | 1.40 ± 0.21 | 2.87 ± 0.30 | 1.18 ± 0.13 | 0.06 ± 0.02 | 1.38 ± 0.14 | 2.62 ± 0.19 |
| S069 | 1.32 ± 0.19 | 1.20 ± 0.18 | 2.52 ± 0.26 | 5.30 ± 0.43 | 0.31 ± 0.06 | 5.60 ± 0.45 | 11.22 ± 0.62 |
| S070 | 1.46 ± 0.22 | 1.39 ± 0.21 | 2.86 ± 0.30 | 1.83 ± 0.17 | 0.07 ± 0.03 | 1.68 ± 0.16 | 3.58 ± 0.24 |
| S071 | 1.23 ± 0.21 | 1.11 ± 0.19 | 2.35 ± 0.28 | 1.28 ± 0.14 | 0.07 ± 0.03 | 1.31 ± 0.15 | 2.65 ± 0.21 |
| S072 | 1.43 ± 0.22 | 1.25 ± 0.19 | 2.68 ± 0.29 | 1.38 ± 0.14 | 0.08 ± 0.03 | 1.46 ± 0.15 | 2.92 ± 0.21 |
| S073 | 1.30 ± 0.19 | 1.31 ± 0.19 | 2.61 ± 0.27 | 2.16 ± 0.20 | 0.13 ± 0.04 | 2.00 ± 0.19 | 4.29 ± 0.28 |
| S074 | 1.19 ± 0.18 | 1.22 ± 0.18 | 2.41 ± 0.26 | 1.27 ± 0.13 | 0.08 ± 0.03 | 1.39 ± 0.14 | 2.74 ± 0.19 |
| S075 | 1.47 ± 0.21 | 1.41 ± 0.20 | 2.87 ± 0.28 | 2.05 ±0.19 | 0.12 ± 0.03 | 2.20 ± 0.20 | 4.37 ± 0.27 |
| S076 | 1.33 ± 0.19 | 1.29 ± 0.18 | 2.62 ± 0.26 | 2.35 ± 0.21 | 0.13 ± 0.04 | 2.45 ± 0.22 | 4.93 ± 0.31 |
| S077 | 1.43 ± 0.20 | 1.40 ± 0.20 | 2.83 ± 0.28 | 1.61 ± 0.16 | 0.08 ± 0.03 | 1.73 ± 0.17 | 3.42 ± 0.23 |
| S078 | 1.55 ± 0.22 | 1.53 ± 0.21 | 3.07 ± 0.30 | 1.09 ± 0.12 | 0.06 ± 0.02 | 1.20 ± 0.13 | 2.34 ± 0.17 |
| S079 | 1.55 ± 0.22 | 1.39 ± 0.20 | 2.94 ± 0.29 | 1.43 ± 0.15 | 0.05 ± 0.02 | 1.68 ± 0.16 | 3.16 ± 0.22 |
| S080 | 1.55 ± 0.22 | 1.63 ± 0.23 | 3.17 ± 0.32 | 1.19 ± 0.13 | 0.09 ± 0.03 | 1.30 ± 0.13 | 2.58 ± 0.19 |
| S081 | 1.40 ± 0.20 | 1.25 ± 0.18 | 2.65 ± 0.28 | 1.08 ± 0.10 | 0.07 ± 0.03 | 1.54 ± 0.13 | 2.69 ± 0.17 |
| S082 | 1.25 ± 0.18 | 1.43 ± 0.21 | 2.68 ± 0.28 | 1.60 ± 0.13 | 0.07 ± 0.03 | 2.21 ± 0.15 | 3.88 ± 0.20 |
| S083 | 1.54 ± 0.22 | 1.61 ± 0.23 | 3.15 ± 0.32 | 1.06 ±0.10 | 0.06 ± 0.03 | 1.10 ± 0.10 | 2.22 ± 0.14 |

[a]Refer to Figure 5.
[b]Total thorium concentrations determined as follows: (Th-228 + Th-232).
[c]Total uranium concentrations determined as follows: (U-234 + U-235 + U238).
[d]Uncertainties represent the 95% confidence level based on total propagated uncertainties.

| TABLE B - 5:<br>PCB CONCENTRATIONS IN SOIL<br>1630 DAVID WITHERSPOON, INC. SITE<br>KNOXVILLE, TENNESSEE | | | | |
|---|---|---|---|---|
| **Sample ID/ Location[a]** | **Aroclor 1254 (mg/kg)** | **Aroclor 1260 (mg/kg)** | **Aroclor 1248 (mg/kg)** | **Total (mg/kg)** |
| S007 | 0.0071 J[b] | 0.0049 J | 0.018 U[c] | 0.0120 J |
| S008 | 0.0084 J | 0.016 UJ | 0.016 UJ | 0.0084 J |
| S009 | 6.2 | 1.2 | 3.4 | 10.8 |
| S010 | 45 J | 5.8 UJ | 5.8 UJ | 45 J |
| S011 | 1.1 | 0.240 | 0.180 U | 1.34 |
| S012 | 0.037 | 0.007 J | 0.018 U | 0.044 |
| S013 | 0.031 | 0.0084 J | 0.056 | 0.095 J |
| S014 | 0.100 | 0.061 | 0.090 | 0.251 |
| S015 | 0.040 | 0.023 | 0.097 | 0.16 |
| S016 | 59 J | 4.6 UJ | 4.6 UJ | 59 J |
| S017 | 0.019 U | 0.019 UJ | 0.019 U | 57 U |
| S018 | 0.290 | 0.210 | 0.017 U | 0.500 |
| S019 | 0.280 | 0.250 | 0.018 U | 0.530 |
| S020 | 0.080 | 0.016 U | 0.042 | 0.122 |
| S021 | 0.016 UJ | 0.016 UJ | 0.016 UJ | 48 U |
| S022 | 0.450 | 1.4 | 0.170 U | 1.85 |
| S023 | 3.4 J | 0.920 J | 0.390 UJ | 4.32 |
| S024 | 0.016 UJ | 0.016 UJ | 0.016 UJ | 48 U |
| S025 | 0.510 | 0.500 | 0.080 U | 1.01 |
| S026 | 0.240 | 0.330 | 0.093 | 0.663 |
| S027 | 0.170 | 0.210 J | 0.017 U | 0.380 |
| S028 | 9.1 J | 7.0 J | 0.780 U | 16.1 J |
| S029 | 0.230 | 0.240 | 0.016 U | 0.470 |
| S030 | 0.380 | 0.670 | 0.063 U | 1.05 |
| S059 | 0.015 U[b] | 0.015 U | 0.015 U | ND[d] |
| S060 | 0.015 U | 0.015 U | 0.015 U | ND |
| S061 | 0.027 | 0.011 J[c] | 0.015 U | 0.037 J |
| S062 | 0.051 | 0.013 J | 0.055 | 0.120 J |
| S063 | 0.051 J | 0.017 J | 0.077 J | 0.140 J |
| S064 | 0.030 | 0.033 | 0.059 | 0.120 |
| S066 | 0.240 J | 0.170 J | 0.230 J | 0.810 J |
| S067 | 0.190 | 0.088 | 0.330 | 0.610 |
| S068 | 0.620 | 0.420 | 1.300 | 2.300 |
| S069 | 0.720 | 0.230 | 0.750 | 1.700 |
| S071 | 0.130 | 0.075 | 0.220 | 0.430 |
| S073 | 0.033 | 0.160 | 0.009 J | 0.200 |
| S074 | 0.081 | 0.099 | 0.015 U | 0.200 |

[a]Refer to Figures 4 and 5.
[b]Present below detection limit. Refer to Appendix E for additional detail.
[c]Compound was analyzed for but not detected. Refer to Appendix E for additional detail.
[d]Sample analyzed but isomers were below the detection limits and non-detectable.

| TABLE B - 6:<br>LEAD AND CADMIUM CONCENTRATIONS IN SOIL<br>1630 DAVID WITHERSPOON, INC. SITE<br>KNOXVILLE, TENNESSEE | | |
|---|---|---|
| **Sample ID/ Location[a]** | **Lead (mg/kg)** | **Cadmium (mg/kg)** |
| S007 | 11.5 J | 0.66 U[b] J |
| S008 | 21.4 | 0.65 U |
| S009 | 157 J | 20.8 J |
| S010 | 118 J | 5.3 J |
| S011 | 56.1 J | 9.2 J |
| S012 | 22.4 | 0.71 UJ |
| S013 | 169 J | 4.1 J |
| S014 | 57 J | 3.8 J |
| S015 | 119 J | 4.3 J |
| S016 | 86.4 J | 5.1 J |
| S017 | 21.6 | 0.79 U |
| S018 | 285 J | 8.1 J |
| S019 | 61.5 J | 1.5 J |
| S020 | 28.0 J | 0.59 UJ |
| S021 | 26.1 J | 0.68 UJ |
| S022 | 95.3 | 2.5 |
| S023 | 363 J | 10 J |
| S024 | 18.1 J | 0.64 J |
| S025 | 71.6 | 1.7 |
| S026 | 50.0 | 1.0 |
| S027 | 33.8 J | 1.9 UJ |
| S028 | 71.1 J | 1.6 UJ |
| S029 | 23.8 J | 0.67 UJ |
| S030 | 24.0 J | 0.63 UJ |
| S059 | 22.8 | 0.15 J |
| S060 | 25.6 | 0.16 J |
| S061 | 22.7 | 0.15 J |
| S062 | 40.9 | 0.46 J |
| S063 | 35.3 | 0.70 J |
| S064 | 19.2 | 0.21 J |
| S066 | 57.2 | 0.43 J |
| S067 | 25.7 | 0.13 J |
| S068 | 108 | 0.65 J |
| S069 | 33.1 | 0.83 J |
| S071 | 28.6 | 0.17 J |
| S073 | 33.0 | 0.13 UJ |
| S074 | 75.8 | 0.62 J |

[a]Refer to Figure 5.
[b]Indicates that the isomer was analyzed but not detected. Refer to Appendix E for additional detail.

# APPENDIX C

# MAJOR INSTRUMENTATION

# 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 her employer.

## SCANNING INSTRUMENT/DETECTOR COMBINATIONS

### Gamma

Ludlum Ratemeter-Scaler Model 2221
coupled to
Ludlum NaI Scintillation Detector Model SPA-3, Crystal: 2 inch x 2 inch
(Ludlum Measurements, Inc., Sweetwater, TX)
coupled to
Trimble GeoXH Receiver and Data Logger (Trimble Navigation Limited, Sunnyvale, CA)

Ludlum Ratemeter-Scaler Model 2221
coupled to
Fluke NaI Scintillation Detector, Crystal: 1.25 inch x 1.5 inch
(Fluke Biomedical,)
coupled to
Trimble GeoXH Receiver and Data Logger (Trimble Navigation Limited, Sunnyvale, CA)

## LABORATORY ANALYTICAL INSTRUMENTATION

Alpha Spectrometry System
Tennelec Model 256
(Canberra, Meriden, CT)
Used in conjunction with:
Ion Implanted Detectors and
Multichannel Analyzer
Canberra Apex Alpha Software
Dell Workstation
(Canberra, Meriden, CT)

Alpha Spectrometry System
Canberra Model 7401VR
(Canberra, Meriden, CT)
Used in conjunction with:
Ion Implanted Detectors and
Multichannel Analyzer
Canberra Apex Alpha Software
Dell Workstation
(Canberra, Meriden, CT)

**LABORATORY ANALYTICAL INSTRUMENTATION (continued)**

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) and
Multichannel Analyzer
Canberra Apex Gamma Software
Dell Workstation
(Canberra, Meriden, CT)

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)
Multichannel Analyzer
Canberra Apex Gamma Software
Dell Workstation
(Canberra, Meriden, CT)

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) and
Multichannel Analyzer
Canberra Apex Gamma Software
Dell Workstation
(Canberra, Meriden, CT)

# APPENDIX D

# SURVEY AND ANALYTICAL PROCEDURES

# APPENDIX D

# SURVEY AND RADIOLOGICAL ANALYTICAL PROCEDURES

## 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. 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. Representatives with BJC provided site-specific safety awareness for each individual ORISE survey effort. In-process and verification surveys were performed according to the ORISE generic health and safety plan, site-specific integrated safety management pre-job hazard checklist, and safety procedures discussed during the on-site training.

## QUALITY ASSURANCE

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

- Survey Procedures Manual
- Laboratory Procedures Manual
- Quality Program Manual

The procedures contained in these manuals were developed to meet the requirements of DOE Order 414.1C 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 the Mixed-Analyte Performance Evaluation Program (MAPEP), National Institute of Standards and Technology (NIST), and Radiochemistry Intercomparison Testing Program (ITP).
- Training and certification of all individuals performing procedures.
- Periodic internal and external audits.

## 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.

## SURVEY PROCEDURES

### 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 nominal distance of about 1 to 5 cm. 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 MDCs for the NaI scintillation detector for the contaminants of concern in surface soil were obtained directly from NUREG-1507 when available or estimated using the approach described in NUREG-1507[1]. Typical NaI detector MDCs for both detector types are provided in the following table:

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

| NAI SCINTILLATION DETECTOR SCAN MDCS FOR COMMON RADIOLOGICAL CONTAMINANTS | | |
|---|---|---|
| **Radionuclide** | **1.25" x 1.5"NaI Detector** | **2" x 2" Nai Detector** |
| Cs-137 | 10.4 pCi/g | 6.4 pCi/g |
| Th-232 | 2.8 pCi/g | 1.8 pCi/g |
| U-238 (processed natural uranium) | 115 pCi/g | 80.0 pCi/g |

An audible increase in the activity rate was investigated by ORISE. It is standard procedure for the ORISE staff to pause and investigate any locations where gamma radiation is distinguishable from background levels.

**Soil Sampling**

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

## RADIOLOGICAL ANALYSIS

### DETECTION LIMITS

Detection limits, referred to as MDC, were based on 3 plus 4.65 times the standard deviation of the background count [$3 + (4.65\ (BKG)^{1/2})$]. 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.

**Alpha Spectroscopy**

Soil samples were homogenized then dissolved by a combination of potassium hydrogen fluoride and pyrosulfate fusions. The fusion cakes were dissolved and all alpha emitters were co-precipitated on barium sulfate. The barium sulfate was re-dissolved and the contaminants of concern (COC) were separated from the other actinides by extraction chromatography using Eichrom resins, co-precipitated with a cerium fluoride carrier, and analyzed using ion implanted detectors, alpha spectrometers, and multichannel analyzer.

An alpha spectroscopy detector system calculates an MDC for each individual isotope per sample based on the detector background, counting efficiency, yield, and quantity. An MDC is printed out with each sample result. The typical MDC for a 1,000-minute count time was 0.02 pCi/g.

**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 (TAP) 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 *a priori* MDCs for a one-hour count time have been provided in the following table:

| Radionuclide | TAP (MeV) | MDC (pCi/g) |
|---|---|---|
| U-238 (from Th-234) | 0.063 | 0.21 |
| U-235 | 0.143 | 0.06 |
| Ra-226 (from Pb-214) | 0.351 | 0.19 |
| Th-228 (from PB 212) | 0.239 | 0.02 |
| Th-232 (from Ac-228) | 0.911 | 0.05 |
| Cs-137 | 0.662 | 0.05 |

The *a priori* MDCs are based on background concentrations of radionuclides in soil for the purpose of estimating the capability of the measuring system to detect an activity concentration. Spectra were also reviewed for other identifiable TAPs.

**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 levels.

# APPENDIX E

# DATA QUALIFIERS FOR CHEMICAL RESULTS

# APPENDIX E

# DATA QUALIFIERS FOR CHEMICAL RESULTS

## DATA QUALIFIERS*

**U** = Compound was analyzed for but not detected. The associated numerical value is the estimated sample quantitation limit which is included and corrected for dilution and percent moisture.

**J** = Indicates an estimated value. This flag is used under the following circumstances 1) when estimating a concentration for tentatively identified compounds where a 1:1 response is assumed; or 2) when the mass spectral data indicate the presence of a compound that meets the identification criteria but the result is less than the specified detection limit but greater than zero. For example, if the limit of detection is 10 μg/L and a concentration of 3 μg/L is calculated, it is reported as 3J.