Pacific Northwest NATIONAL LABORATORY

S740277-RPT-05
PNNL-28626

Research Technology Laboratory (RTL) Disposition Program Final Status Survey Report

S740277-RPT-05

April 2019

EC Golovich
AL Bunn
FH Biebesheimer
JK Snelling

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor Battelle Memorial Institute, nor any of their employees, **makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights**. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or Battelle Memorial Institute. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from
the Office of Scientific and Technical
Information,
P.O. Box 62, Oak Ridge, TN 37831-0062
www.osti.gov
ph: (865) 576-8401
fox: (865) 576-5728
email: reports@osti.gov

Available to the public from the National Technical Information Service
5301 Shawnee Rd., Alexandria, VA 22312
ph: (800) 553-NTIS (6847)
or (703) 605-6000
email: info@ntis.gov
Online ordering: http://www.ntis.gov

S740277-RPT-05
PNNL-28626

Research Technology Laboratory (RTL) Disposition Program Final Status Survey Report

S740277-RPT-05

April 2019

EC Golovich
AL Bunn
FH Biebesheimer
JK Snelling

Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99354

Approvals

Prepared By:

4/17/19

Elizabeth C. Golovich
Project Manager for Release

Date

Concurred By:

4/17/19

H. F. Kerschner
RTL Disposition Program Manager

Date

4/18/19

William L. Duffy
Radiation Services Manager

Date

4/18/19

Steven D. Cooke
Assistant General Counsel

Date

Approved By:

4/19/19

Paul J. Crane
Director, Facilities and Infrastructure Operations

Date

Revision Table

Revision Number	Date	Changes	Author(s)
0	4/22/2019	Original Issuance	E.C. Golovich, A.L. Bunn, F.H. Biebesheimer, J.K. Snelling

Executive Summary

As part of the Battelle Facility Restoration Program (Smoter and Biebesheimer 2017), the Research Technology Laboratory (RTL) Complex was remediated through demolition and surveyed to show it meets the radiological release criteria for unrestricted use under the clearance process[1] (DOE 2011). The restoration program has directed the implementation of the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) methodology (NRC 2011) to verify the suitability of the site to be released for unrestricted use under the clearance process in U.S. Department of Energy (DOE) Order 458.1 (Biebesheimer 2018a; DOE 2011). The use of MARSSIM is accepted by federal and state agencies, including DOE. This report documents how the MARSSIM process was used to assure any residual radioactivity is within acceptable levels and as low as reasonably achievable.

Past land use for the RTL Complex property included agricultural, residential, and industrial activity. The historical site assessment (HSA) (Lindenmeier et al. 2015; Biebesheimer 2018b) identified use of radionuclides in past RTL Complex research and development activities from commissioning in 1966 until it was vacated in 2017. Based on the information provided in the HSA, the RTL Complex was delineated into six survey units. The 520 building footprint, tank vault and 530 building footprint, other building footprints, and pipeline survey units included excavated areas. The paved areas and open areas survey units were unexcavated areas. Survey units were all determined to be Class 3, with low probability of containing residual radioactivity, after demolition of the structures within the RTL Complex.

Authorized radiological release limits were developed and approved by the DOE Office of Science in December 2016 (DOE 2017). Table ES.1 lists the authorized release limits for the RTL Complex. Action levels were established at 75% of the authorized limits and are also given in Table ES.1.

Table ES.1. Release limits and action levels for radiological contaminant of potential concern

Radionuclide	Release Limit[(a)] (pCi/g)	Action Level (pCi/g)
Plutonium-238	800	600
Plutonium-239/240	740	555
Plutonium-241	30,000	22,500
Uranium-234	700	525
Uranium-235	60	45
Uranium-238	280	210
Cobalt-60	3.7	2.8

(a) Release limit is synonymous with authorized limit and derived concentration guideline levels associated with 25 mrem/yr; sum of fraction applies (Ikenberry 2016).

[1] *Clearance* is the removal of property that contains residual radioactive material from DOE radiological control under 10 CFR 835 and DOE O 458.1.

The *Research Technology Laboratory (RTL) Disposition Program: Final Status Survey Plan* (Bunn et al. 2018) was designed and conducted to provide quantitative data regarding the residual radioactivity present in each survey unit. Fourteen random sample locations were identified within each survey unit. Forty-four specific judgmental sample locations were selected across the site based on information in the HSA. The number of sample locations within a survey unit ranged from 15 to 28 (given in Table ES.2), for a total of 127 random and judgmental sample locations identified across the RTL Complex. Sampling for the final status survey occurred over 12 days between November 11 and December 7, 2018. Laboratory results were independently validated by Analytical Quality Associates prior to evaluation.

All of the over 880 residual radioactivity measurements were less than the release limits and action levels established through the RTL Disposition Program. A sum of fractions calculation for each survey unit resulted in values that were less than unity, this is indicated in Table ES.2 by a *Pass* designation. Based on the results presented in this report, the restoration program recommends that the RTL Complex be released for unrestricted use.

Table ES.2. Summary of RTL Complex Final Status Survey Results

Survey Unit	MARSSIM Class	Number Locations Sampled	Number of Results Less than Action Level[(a)]	Pass/Fail
520 Building Footprint	3	28	196	Pass
Tank Vault and 530 Building Footprint	3	17	119	Pass
Other Buildings Footprint	3	21	147	Pass
Pipelines	3	23	161	Pass
Paved Areas	3	23	161	Pass
Open Areas	3	15	105	Pass
Total	-	127	889	-

(a) All radiological contaminants of potential concern were measured at each sampled location, providing seven results for one location.

References

Biebesheimer FH. 2018a. *Battelle Facilities Restoration Program Management Plan, Volume II – RTL Complex Disposition Program*. S740277-PLAN-12, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

Biebesheimer FH. 2018b. *Research Technology Laboratory Complex Disposition Program – Final Historical Site Assessment Report*. S740277-RPT-02, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

Bunn AL, JK Snelling, and AM Gorton. 2018. *Research Technology Laboratory (RTL) Disposition Program: Final Status Survey Plan*. S740277-PLAN-14, Pacific Northwest National Laboratory, Richland, Washington.

DOE. 2011. *Radiation Protection of the Public and the Environment.* DOE O 458.1, U.S. Department of Energy. Washington, D.C. https://www.directives.doe.gov/directives/0458.1-BOrder/view.

DOE. 2017. Letter from Roger E. Snyder, Manager, U.S. Department of Energy, Pacific Northwest Site Office, to Dr. Seven Ashby, Director, Pacific Northwest National Laboratory, Battelle Memorial Institute, Pacific Northwest Division, Richland, Washington. "Contract No. DE-AC05-76RL01830, Approval of Authorized Limits for Radiological Clearance of the Research Technology Laboratory (RTL) Site." January 12, 2017. 17-PNS0-0087, U.S. Department of Energy, Pacific Northwest Site Office, Richland, Washington.

Ikenberry TA. 2016. *Authorized Limits for Radiological Clearance of the Research Technology Laboratory (RTL) Site*. DMA-TR-063, Dade Moeller, Richland, Washington.

Lindenmeier C, K Wagner, R Cameron, and F Biebesheimer. 2015. *Battelle Facilities Restoration Program – Preliminary Historical Site Assessment Report for the Research Technology Laboratory (RTL).* S697201-TECH-PM-007, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

NRC. 2000. *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM).* NUREG-1575, Rev. 1, U.S. Nuclear Regulatory Commission. Washington, D.C. http://www.epa.gov/radiation/marssim/.

Smoter RL and FH Biebesheimer. 2017. *Battelle Facilities Restoration Program Management Plan Volume I*. S697201-PLAN-PM-003, Rev. 2, Pacific Northwest National Laboratory, Richland, Washington.

Acronyms and Abbreviations

AEC	Atomic Energy Commission
BMI	Battelle Memorial Institute
COPC	contaminant of potential concern
DAC	Douglass Aircraft Company
DCGL	derived concentration guideline level
DOE	U.S. Department of Energy
DQI	data quality indicator
DQO	data quality objectives
ENC	Exxon Nuclear Company
EPA	Environmental Protection Agency
FSS	final status survey
HSA	historical site assessment
LCS	laboratory control sample
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	minimum detectable concentration
NAD	North American Datum
NRC	Nuclear Regulatory Commission
PNNL	Pacific Northwest National Laboratory
RPD	relative percent difference
RTL	Research Technology Laboratory
VSP	Visual Sample Plan

Contents

Figures

Tables

1.0 Introduction

The decisions and results documented throughout this report are based on use of the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM; NRC 2000) process as directed by the U.S. Department of Energy (DOE) Pacific Northwest Site Office and implemented by Pacific Northwest National Laboratory (PNNL) to demonstrate that residual radioactivity is within acceptable levels and as low as reasonably achievable at the site that once was the Research Technology Laboratory (RTL) Complex.

As part of the Battelle Facility Restoration Program (Smoter and Biebesheimer 2017), the RTL Complex was remediated through demolition and surveyed to show it meets the radiological release criteria in accordance with DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE 2011). The restoration program has directed the implementation of the MARSSIM methodology to verify the suitability of the site to be released for unrestricted use under the clearance process[1] in DOE Order 458.1 (Biebesheimer 2018a). The use of MARSSIM is accepted by federal and state agencies, including DOE.

As described in the *Battelle Facilities Restoration Program Management Plan Volume I* (Smoter and Biebesheimer 2017), the programs objectives are:

- “Unrestricted use” status for the real property asset. That is, the assets (including all building structures, components, and/or associated land) will be available for any use or disposition (e.g., sale, transfer, demolition, waste disposal) without regulatory restriction, permits, or licenses that are associated with potential radiological contamination of the facility.
- Acceptably low residual financial and regulatory risk to Battelle or DOE under applicable environmental, safety, and health regulations that are associated with legacy radiological contamination.

The *Battelle Facilities Restoration Program Management Plan, Volume II – RTL Complex Disposition* (Biebesheimer 2018a) describes the methods used to develop the basis for release of the RTL Complex for unrestricted use. Historical records were evaluated and documented as part of the historical site assessment (HSA; Lindenmeier et al. 2015; Biebesheimer 2018b) and are summarized in Section 2.0. Information gathered during the HSA development was used to design the Final Status Survey (FSS) described in the *Research Technology Laboratory (RTL) Disposition Program: Final Status Survey Plan* (FSS plan; Bunn et al. 2018).

The intentions of this report are to:

1. Summarize the evaluation to review the acceptability and suitability of survey data for decision-making purposes. This assessment was conducted by evaluating the survey data in respect to the data quality objectives (DQOs; Section 3.0), the FSS design and performance (Section 4.0), and the results of a data quality assessment (Section 5.0).

2. Describe the results of the FSS performed to characterize any potential residual radioactivity at the RTL Complex (Section 6.0) and conclude, by rejecting the null hypothesis, that the RTL Complex is ready to undergo release for unrestricted use following the clearance of property requirements described in DOE Order 458.1.

---

[1] *Clearance* is the removal of property that contains residual radioactive material from DOE radiological control under 10 CFR 835 and DOE O 458.1.

2.0 RTL Facility and Operations

2.1 Historical Land Use

Past land use for the RTL Complex site included agricultural, residential, and industrial activity. Former land use is important to consider when evaluating the types of contamination potentially present in the soil (Snelling and Bunn 2018).

Review of historical maps and aerial imagery dating to 1930 revealed agricultural land near the RTL Complex (Figure 1). Agricultural fields were likely associated with the farmhouse adjacent to the northeast corner of what is now the RTL Complex. The 1930 aerial imagery shows a portion of the agriculturally developed land, including an orchard (to the southwest of the farmhouse); however, the 1943 aerial imagery shows the land consisting predominantly of plowed fields or pasture (Snelling and Bunn 2018).

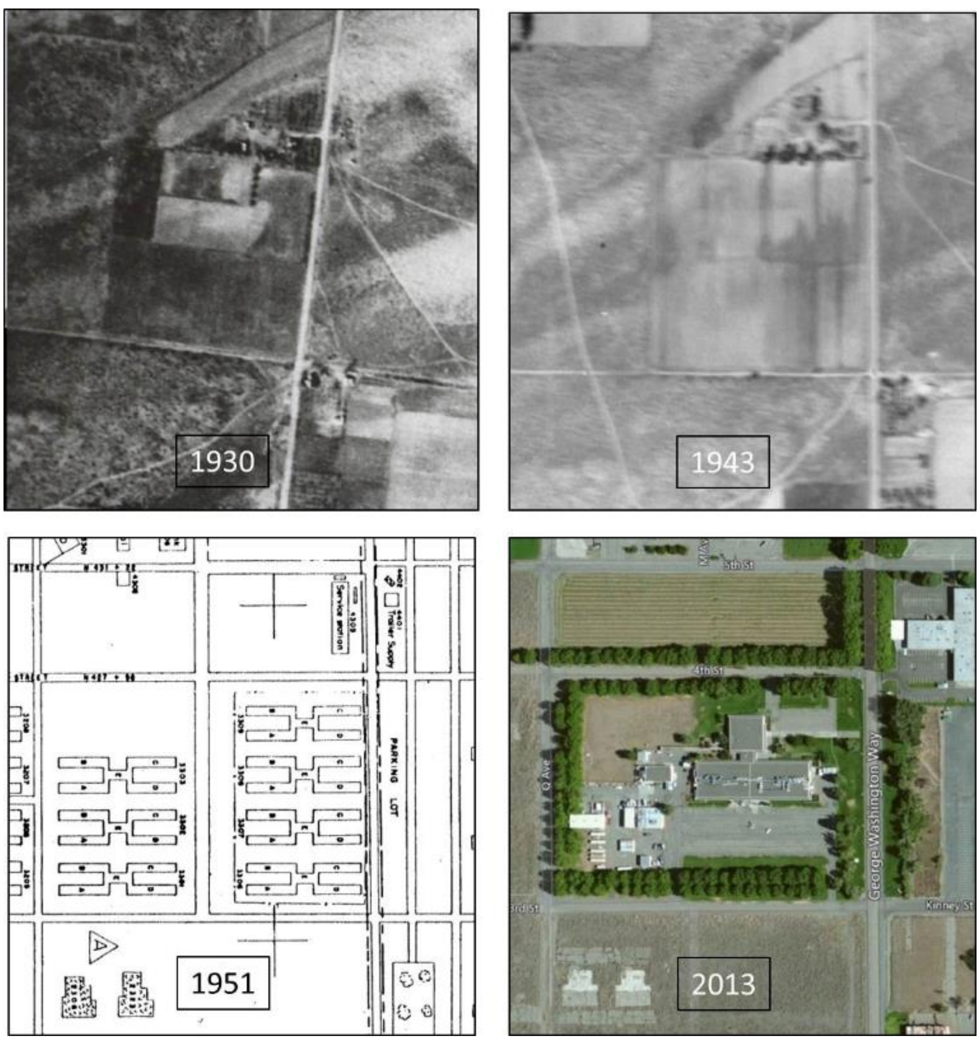

Figure 1. Former land use of the RTL Complex property included agricultural, residential, and industrial activity

After World War II, North Richland (including the area where the RTL Complex is located) became the site of the North Richland Construction Camp. From 1947 until its demolition prior to 1955, the barracks located on the site of the RTL Complex were used to house construction workers for the North Richland Construction Camp and then housed unmarried enlisted men at the U.S. Army's Camp Hanford (Figure 1). At its largest, the Construction Camp was home to as many as 13,750 people. Construction Camp facilities included over 200 prefabricated houses, 80 barracks, 2,200 trailer sites, bathhouses, a mess hall, a hospital, a school, a post office, a fire station, a patrol station, and numerous commercial and recreational establishments. When the Hanford Site expansion was completed, the surplus land and facilities were transferred to the U.S. Army to house personnel brought in to operate anti-aircraft artillery defenses for Hanford (Harvey 2000).

After decommissioning Camp Hanford in 1961, the U.S. Army demolished most of the buildings and transferred the land back to the Atomic Energy Commission (AEC), which then transferred the property to the City of Richland for economic development. The barracks buildings located at the site were demolished by 1955, and underground utilities were abandoned in place. In 1964, Douglas United Nuclear won the contract to build a high-technology product development business on 117 acres of the former Camp Hanford, which became the Donald W. Douglas Laboratories (Harvey et al. 2017). This facility was called the RTL Complex.

The Donald W. Douglas Laboratories was one of four economic diversification projects undertaken by the AEC in 1965. Completed in 1966, Building 520, the Energy and Waste Cleanup Research Facility, was one of the first two buildings (along with Building 560) constructed in the complex. The remainder of the buildings in the RTL Complex were secondary support facilities that consisted of warehouses, storage, utilities, and craft shops added over the next 10 to 15 years (Harvey et al. 2017). Douglas Laboratories used the facilities for the fabrication of prototype reactor fuels and for the development of small batteries for potential use in health care (Lindenmeier et al. 2015; Biebesheimer 2018b).

Douglas United Nuclear operated the facility until 1975, when it passed custodianship of the complex to Exxon Nuclear Company (ENC; Lindenmeier et al. 2015). ENC used the RTL Complex for the development of processes and techniques aimed at the fabrication of Sphere-PAC nuclear fuels, as well as various other nuclear fuel development research projects (Biebesheimer 2017, 2018b; Lindenmeier et al. 2015).

In 1981, Battelle Memorial Institute (BMI) purchased the RTL Complex from ENC and used the facility for numerous research and development purposes in the areas of material science, engineering, and management of natural resources for solving environmental problems. These activities were monitored to provide indications of radiological releases in accordance with applicable permits, which are summarized annually (Duncan et al. 2017).

2.2 RTL Complex Site Description

The RTL Complex is located within the Richland, Washington city limits and within the urban expansion area identified by Benton County, Washington (Benton County 2011; City of Richland 2014). This parcel is currently identified as *Business Research Park* and *General Commercial* by the City of Richland and Benton County, respectively. The RTL Complex is bounded to the south by properties owned by the City of Richland, Washington State University, and other commercial and private entities.

The BMI-owned RTL Complex property and the facility's spatial relationship to the rest of the PNNL campus are outlined in pink in Figure 2. Prior to demolition, the RTL Complex was composed of 10 buildings (510, 520, 524, 530, 540, 550, 560, 570, 580, and 590) on the 15.2-acre property. In addition to buildings, there was a tank vault (along the northwest wing of RTL 520), underground piping (asbestos pipe, hot/chilled water pipeline chase way, and sewer line), parking lots, and open areas. Figure 3 shows the locations of the buildings in the RTL complex prior to demolition.

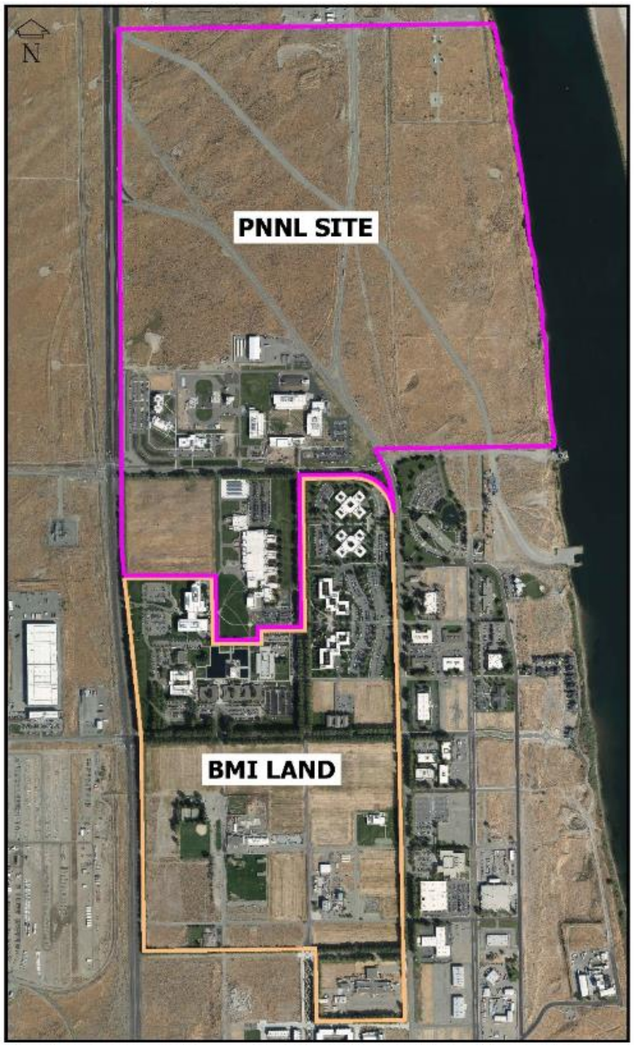

Figure 2. PNNL site and the location of the RTL Complex

Figure 3. Layout of the RTL Complex prior to demolition

2.3 Past Research Activities

The RTL520 Building was the primary facility of the RTL Complex. The Complex was built in 1966 by the Douglas Aircraft Company (as described in DAC 1967) as the company's diversification commitment to the Richland Operations Office of the AEC (Moore 1964). The RTL Complex was a branch of the research and development section of the Missile and Space Systems Division of Douglas Laboratories. Information derived from Douglas Laboratories' special nuclear material license application to the AEC (DAC 1967) indicated that its operations involved the use of hundreds of grams of plutonium-238 and plutonium-239, and kilograms of uranium-235 and uranium-233 for fabrication of prototype reactor fuels. Douglas Laboratories also was involved in the development of Betacel® batteries using promethium-147 as the most promising power source for use in cardiac pacemakers. These batteries were tested in clinical studies in both Europe and the United States during the early 1970s (Smith et al. 1975). The promethium-147 was obtained during isotopic separations associated with Hanford plutonium production during the 1960s, when operations at Hanford and Oak Ridge developed the necessary technologies for large-scale production at Hanford (Moore 1964).

Douglas Laboratories operated the facility until 1975, when it passed custodianship of the complex to ENC. No documentation describing this transition was identified during the preliminary HSA. An internal ENC document (ENC 1980) noted that significant surface decontamination was performed in hot labs 134 and 136, and some residual, non-smearable promethium-147 and plutonium-238 contamination remained in the duct work prior to building acquisition in 1975.

ENC used the facility as described in ENC 1982 for development of processes and techniques for the fabrication of Sphere-PAC nuclear fuels. The Sphere-PAC technology, used to create spherical particles of uranium oxide fuel as opposed to conventional pellet fuel, was developed at Oak Ridge National Laboratory and transitioned to RTL for pilot-scale production. Information from Exxon's application for radioactive material license (ENC 1982) after it acquired the building allowed for significant quantities—in the thousands of kilograms—of depleted and natural uranium to be used as well as hundreds of grams of uranium-234 in its Sphere-PAC process development.

After spheres were produced in the pilot operation, they were transferred to the Sphere-PAC Auxiliary Building (RTL 570) for drying, calcining, and sintering. At the time of this operation, the building was equipped with a pusher sintering furnace and three bench hoods for drying, calcining, inspection, and material transfers (Felt 1980). All previously installed Sphere-PAC equipment was dismantled and removed from the building prior to 1984 (PNL 1984).

BMI purchased the facility in 1981 and allowed ENC to operate under a lease agreement until it vacated the facility in 1983 (Woods 1983).

2.4 Deactivation, Decommission, Decontamination, and Demolition

In September 2017, the RTL Complex was transitioned to CH2M Hill Plateau Remediation Company for internal decontamination in accordance with the *Statement of Work CHPRC IWO for RTL Complex D4 Mobilization, Isolation, and Internal Remediation* (PNNL 2017a). All buildings on the site were demolished to grade in July 2018 (see Figure 4), and work commenced on subsurface demolition as described in the *Statement of Work CHPRC IWO for RTL Complex D4 Demolition & Subsurface Soil Remediation* (PNNL 2017b, 2018a). As shown in Figure 5, subsurface demolition was completed in September 2018 (PNNL 2018b). After demolition was complete, sampling was conducted in accordance with the FSS plan (Bunn et al. 2018). In January 2019, the RTL Complex was transitioned back to PNNL to be released for unrestricted use in accordance with the process described in the *Battelle Facilities Restoration Program Management Plan, Volume II – RTL Complex Disposition Program* (Biebesheimer 2018a).

Figure 4. Above-grade demolition of RTL Complex structures was completed in July 2018

Figure 5. Subsurface remediation was completed in October 2018

3.0 Data Quality Objectives

Data quality objectives for the RTL Complex are documented in *Research Technology Laboratory (RTL) Disposition Program: Data Quality Objectives (DQOs)* (Snelling and Bunn 2018) using the systematic seven-step process outlined in Appendix D of MARSSIM, *The Planning Phase of the Data Life Cycle* (NRC 2000). The DQOs are qualitative and quantitative statements developed to establish the type, quantity, and quality of data required support the radiological release decision for the RTL Complex.

3.1 State the Problem

The problem statement for release of the RTL Complex is as follows:

PNNL must collect a sufficient quantity and quality of radiological data to demonstrate the RTL Complex can be released for unrestricted use after demolition and excavation activities are complete.

3.2 Identify the Decision

Table 1 reflects the principal study questions, alternative actions, and decision statements for this project.

Table 1. Principal study questions, alternative actions, and decision statements

Principal Study Question	Alternative Actions
Does residual radiological contamination observed in the survey unit(s) meet the RTL Disposition Program objectives for the RTL Complex to be released for unrestricted use and not pose a potential impact to human health or the environment?	**Yes**: If it is determined that there is no radiological contamination that exceeds release limits, then the RTL Disposition Program will recommend that the RTL Complex be released for unrestricted use. **No**: Additional actions will be required prior to release of the RTL Complex.
Decision Statements	
Decision I: Determine that radiological contamination does not exist at a level that could impact release of the RTL Complex for unrestricted use and pose a potential impact to human health or the environment.	
Decision II: Determine whether the project has demonstrated the RTL Disposition Program meets release limits (DOE 2011, 2017) requirements for radiological contamination.	

3.3 Identify Inputs to the Decision

The following data were identified as required to resolve the decision statements described in Table 1:

1. Established release limits for the radiological COPCs for making the release decisions for RTL Complex survey units.

2. Designation of survey units as Class 3, under MARSSIM (NRC 2000).

3. Collection of simple random samples throughout each survey unit to satisfy the statistical tests required to evaluate the potential risk to human health or the environment.

4. Collection of specific judgmental samples in areas based on past information and professional judgement.

5. Identification of analytical testing methods capable of detecting and quantifying the COPCs in site media at required levels.

6. Assurance that collected data are usable for making the release decisions for RTL Complex survey units.

The MARSSIM process often includes developing an exposure scenario and dose model to derive these levels [authorized limits or derived concentration guideline levels (DCGLs)]. The release limits for the radiological COPCs in soil samples listed in Table 2 are conveyed in the *Authorized Limits for Radiological Clearance of the Research Technology Laboratory (RTL) Site, Pacific Northwest National Laboratory* (Ikenberry 2016). These authorized release limits were approved by the DOE Office of Science in December 2016 (DOE 2017). Action levels for radiological COPCs are set at 75% of the release limit and are also listed in Table 2. As described in Section 1.2 of *Research Technology Laboratory (RTL) Disposition Program: Data Quality Objectives (DQOs)* (Snelling and Bunn 2018), the term action level is a concentration in the soil that requires further investigation before the land can be released for unrestricted use. In addition to the action levels and release limits, the unity rule for the sum of fractions also applies.

Additional details regarding the inputs 2 through 6 are discussed as part of the survey design in Section 4.0.

Table 2. Release limits and action levels for radiological COPCs

Radionuclide	Release Limit [(a)] (pCi/g)	Action Level [(b)] (pCi/g)
Plutonium-238	800	600
Plutonium-239/240	740	555
Plutonium-241	30,000	22,500
Uranium-234	700	525
Uranium-235	60	45
Uranium-238	280	210
Cobalt-60	3.7	2.8

(a) Release limit is synonymous with authorized limit and DCGL associated with 25 mrem/yr; sum of fractions applies (Ikenberry 2016).
(b) The administrative constraint set to 75% of the release limit; sum of fractions applies.

3.4 Define the Study Boundaries

Spatial boundaries for survey and release of the RTL Complex include the survey units and the maximum lateral and vertical extent of each COPC for making the release decisions for RTL Complex survey units. The legal boundary of the RTL Complex is the horizontal extent. Vertical extent depends on the footprint of excavation.

The temporal boundaries are dictated by the program schedule.

3.5 Develop a Decision Rule

The scale of decision making in Decision I (Table 1) is defined as the RTL Complex. Any contaminant determined to exceed the release limit at any location within the RTL Complex will cause the determination that the RTL Complex is contaminated and needs further evaluation. The scale of decision making for Decision II (Table 1) is defined as each survey unit within the RTL Complex.

The decision rule associated with Decision I is as follows:

- **IF** it is determined that contamination exceeds the release limit within the spatial boundaries of the RTL Complex, **THEN** the following shall be investigated to determine whether further remedial action is needed to meet the release objectives:
  - Is the contamination representative of environmental conditions at the RTL Complex or within the region?
  - Is there a flaw in the conceptual site model?

The decision rules associated with Decision II are:

- **IF** a survey unit COPC concentration does not exceed the action level, **THEN** the survey unit will have met release objectives.
- **IF** a survey unit COPC concentration at a sample location exceeds the action level, but not the release limit, **THEN** other investigations may be necessary to determine if the results are an indication that the area within the survey unit may not meet release objectives.
  - The investigations include, but are not limited to, evaluating the results from the analytical laboratory to confirm that the measurement meets quality control criteria; performing additional statistical analyses of the results to understand the concentrations across the survey unit; or conducting more excavation or sampling. For the radiological COPC, the statistical analyses would determine if the mean concentration for the survey unit (NRC 2000) exceeds the action level.
- **IF** the survey unit COPC concentration exceeds the release limit, **THEN** the area will be evaluated to determine if the statistical results (as described above) exceed the release limit.
  - Further actions could include excavation and/or resampling (judgmental sampling in accordance with a Class 1 survey unit for radiological COPCs). The follow-up sample results will be statistically evaluated as described above and compared to the release limit.

Action levels were established to make certain the release limits were not exceeded. The release plan set the action levels at 75% of the release limits. Any sampling result greater than the action level would require further characterization to verify the measurement and determine if additional action, such as remediation, was necessary.

3.6 Specify Limits on Decision Errors

The null hypothesis statement for the RTL Complex is *the survey unit has concentrations of a COPC greater than the release limit for the COPC*. A decision error occurs when the decision maker rejects the null hypothesis when it is true (Type I, or alpha error), or accepts the null hypothesis when it is false (Type II, or beta error). Tolerable probabilities for falsely rejecting positive and negative values were both set to 0.05 (5%) for this study and are consistent with standard radiological COPC guidance (DOE 2011). These values were used to determine the required number of samples in the FSS plan (Bunn et al. 2018).

3.7 Optimize the Design for Obtaining Data

The DQOs were used to establish a resource-effective survey design. The survey units were designed to address the heterogeneity of the environment and reflect the past uses of the land. The desktop software package Visual Sample Plan (VSP; https://vsp.pnnl.gov/, Version 7.9; Matzke et al. 2014) was used to determine the number of random samples to collect for each survey unit and to generate a set of random sampling locations for each survey unit. A minimum of 14 samples were calculated for each survey unit as shown in the Section 3.2 and Appendix A of the FSS plan (Bunn et al. 2018).

In addition to the random samples, specific judgmental samples were identified due to operational knowledge of the RTL Complex as described in the *Final Historical Site Assessment Report* (Biebesheimer 2018b). The total number of samples in each survey unit ranged from 15 to 28, including random and specific judgmental samples. Additional discussion of sample locations is found in Section 4.2 and Appendix A.

4.0 Survey Design

Based on the information documented in the *Final Historical Site Assessment Report* (Biebesheimer 2018b), the FSS plan (Bunn et al. 2018) was designed and conducted to provide quantitative data on the presence of residual radioactivity.

4.1 Survey Units

The RTL Complex was delineated into six survey units based on MARSSIM (NRC 2000) recommendations for site classification. Each of these survey units describes an area with an equivalent likelihood of having certain contaminants present due to the processes that occurred at that location. Another reason for defining survey units is to assure that the probability for detecting potential contaminants throughout the area is equivalent (NRC 2000). The survey units for the RTL Complex are Class 3, following demolition of buildings of the RTL Complex. As described in MARSSIM, Class 3 areas are impacted areas that have a low probability of containing residual radioactivity (NRC 2000).

The six survey units within the RTL Complex can be classified as either excavated areas or unexcavated areas. Excavated areas include the following:

- RTL 520 building footprint (Figure 6A)
- RTL tank vault and RTL 530 building footprints (Figure 6B)
- RTL 510, 524, 540, 550, 560, 570, 580, and 590 building footprints (Figure 6C)
- Pipelines (Figure 6D)

Based on reviews of available information (Lindenmeier et al. 2015; Biebesheimer 2018b), the unexcavated areas are not likely to be contaminated. Unexcavated areas include the following:

- Paved areas (Figure 6E)
- Open areas (Figure 6F)

4.2 Sample Locations

Random and specific judgmental sample locations for the RTL Complex are shown in Figure 7. Sampling locations for random sample locations and specific judgmental sample locations are presented by survey unit in Appendix A.

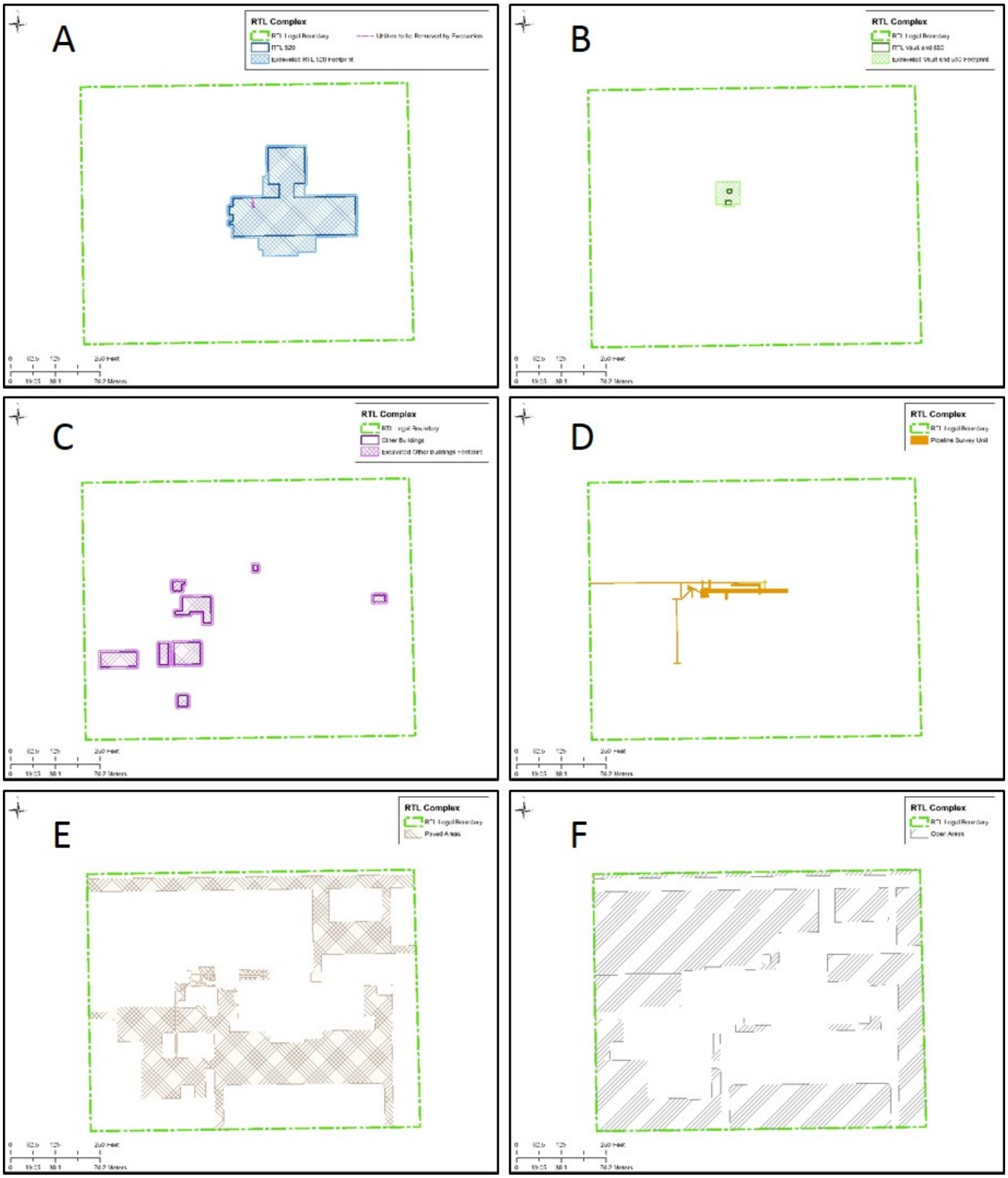

Figure 6. Survey units for RTL Complex: RTL 520 building footprint (A); RTL tank vault and RTL 530 building footprints (B), RTL 510, 524, 540, 550, 560, 570, 580, and 590 building footprints (C); pipelines (D); paved areas (E); and open areas (F)

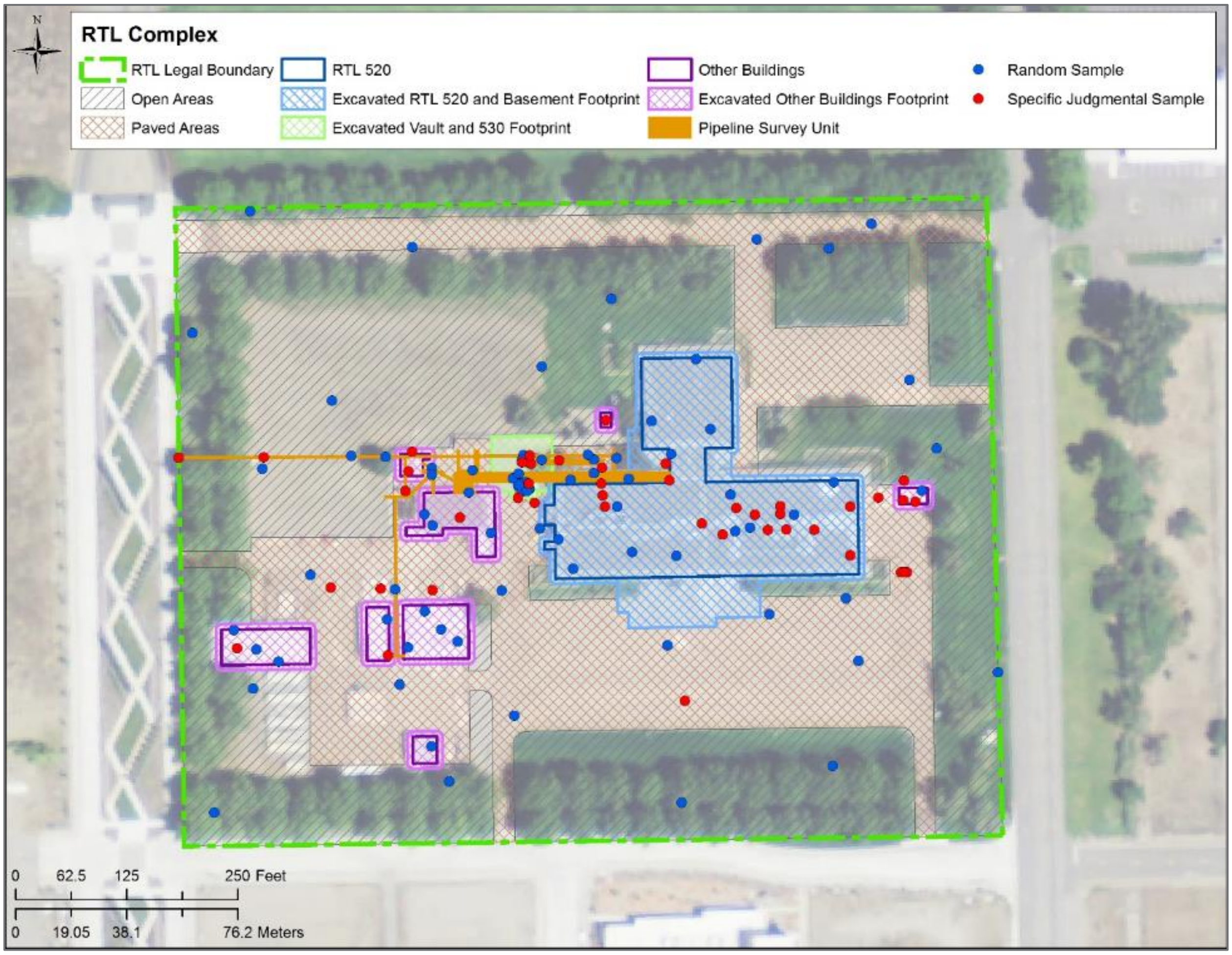

Figure 7. Summary of all random and specific judgmental samples for the RTL Complex

4.3 Analysis Methodology

Table 3 presents the radiological COPCs, the analytical technology used by TestAmerica, Inc. at their Richland, WA, location, and the required quantification limit as stated within the DQOs (Snelling and Bunn 2018). TestAmerica Inc. is accredited by the Washington State Department of Ecology and the ANSI National Accreditation Board (ISO/IEC 17025:2005 and DOECAP/DoD) in the field of testing for the radiological tests performed. The required quantification limits are 10% of the release limits for radiological COPCs in soil. Discussion of actual minimum detectable concentrations reported by the laboratory are discussed in Section 5.1.6.

Table 3. Analytical technology and required quantification limits for radiological COPCs

Analytical Technology	COPC	Required Quantification Limit [(a)] (pCi/g)
Alpha Spectroscopy	Plutonium-238	80
	Plutonium-239/240	74
Liquid Scintillation Counting	Plutonium-241	3000
Alpha Spectroscopy	Uranium-234	70
	Uranium-235	6
	Uranium-238	28
Gamma Spectroscopy	Cobalt-60	0.37

(a) 10% of the release limits. This is the most conservative approach based on MARSSIM (NRC 2000).

4.4 Layback Scoping Study

This section describes the sampling and analysis of layback soil as part of a scoping study for the RTL Complex (Bunn 2018). The scoping study was designed to meet the requirements of the FSS plan (Bunn et al. 2018). Layback is defined as “clean” material resulting from excavation (DOE/RL-96-22). For the RTL Complex, layback soil was removed as part of the excavation of the RTL 520 building to create a slope upon which the soil will not fall back or collapse into the excavation pit. The objective of the scoping study was to verify that the layback soil does not contain COPCs that are above the action levels and release limits for the disposition of the RTL Complex, meet the sum of fraction requirements, and can be used to backfill the excavated areas that meet the criteria for unrestricted use in accordance with the *Battelle Facilities Restoration Program Management Plan Volume I* and the *Battelle Facilities Restoration Program Management Plan, Volume II – RTL Complex Disposition Program* (Smoter and Biebesheimer 2017; Biebesheimer 2018a).

4.4.1 Layback Soil Piles

The layback soil consists of soil removed from the RTL 520 survey unit. The soil was removed from excavation area around the RTL 520 basement. The layback did not include soil from around the RTL 520 tank vault and excavated pipelines survey units, or from any other areas of known potential contamination sources.

The layback soil was estimated to be 4,000 cubic yards of soil. The soil volume exceeded the area available between predetermined sampling locations for staging the soil in one pile, so two layback staging areas within the open and paved areas survey units were used for piling the layback soil.

The process of removing the soil from the excavation area within the RTL 520 survey unit mixed the soil into heterogeneous piles. Heavy equipment was used to remove the soil and place it in a pile close to the excavation area, and then to move and consolidate the soil into two piles in the open areas and paved areas survey units. The layback piles did not cover any of the sampling locations identified in the FSS plan.

4.4.2 Layback Sample Locations

The minimum number of random samples calculated for the layback soil was 14, the same as in the FSS survey units. The assumptions for calculating the number of random samples for the layback scoping study were the same as stated in the FSS plan (Bunn et al. 2018).

The random sampling approach to select sample locations and meet the criteria for statistical evaluation was based on the use of a random number table. The piles were of an irregular configuration. Location of sampling was divided based on the side of the pile (north, south, east, west) and the vertical height of the pile (top, middle, bottom). Exact locations were selected by the sampling team in order to meet the sample requirements of Table 4 in a safe manner. Samples were collected using Table 4, as follows:

- Sample numbers 1 – 9 were collected from the pile located in the north staging area on the RTL Complex.
- Sample numbers 10 – 14 were collected from the pile located in the south staging area on the RTL Complex.

Table 4. General locations on layback piles for random samples

Sample Number	Side of the Pile	Depth of the Pile
1	West side	Bottom
2	West side	Top
3	South side	Middle
4	North side	Bottom
5	South side	Top
6	West side	Middle
Duplicate	West side	Middle
7	East side	Top
8	South side	Bottom
9	North side	Top
10	East side	Bottom
11	North side	Middle
12	East side	Middle
13	West side	Middle
14	North side	Top

4.4.3 Data Quality Objectives

All of the DQOs for the RTL Complex, as stated in Snelling and Bunn (2018), apply to the layback sampling and analyses. The DQOs establish the type, quantity, and quality of data required to make statistically valid and resource-efficient decisions in support of the RTL Disposition Program.

4.4.4 Analysis of Layback Soil Samples

The layback sampling and analyses met the quality assurance project plan for the layback soil piles as stated for radionuclides in the FSS plan (Bunn et al. 2018). The analytical results for the layback soil piles were evaluated using the same procedures and processes as the results for other RTL Complex survey units, as described in the DQO (Snelling and Bunn 2018) and the FSS plan (Bunn et al. 2018).

Figure 8 presents the reported values for each radionuclide on a lognormal scale to show the range of concentrations from layback samples. All COPC results were less than the action levels and release limits. Results confirmed assumptions that the layback piles do not contain COPCs above the release limits, action levels, or sum of fraction requirements for the disposition of the RTL Complex and can be used to backfill the excavated areas that meet the criteria for unrestricted use in accordance with the *Battelle Facilities Restoration Program Management Plan Volume I* and the *Battelle Facilities Restoration Program Management Plan, Volume II – RTL Complex Disposition Program* (Smoter and Biebesheimer 2017; Biebesheimer 2018a). Additional discussion of results can be found in Appendix B.

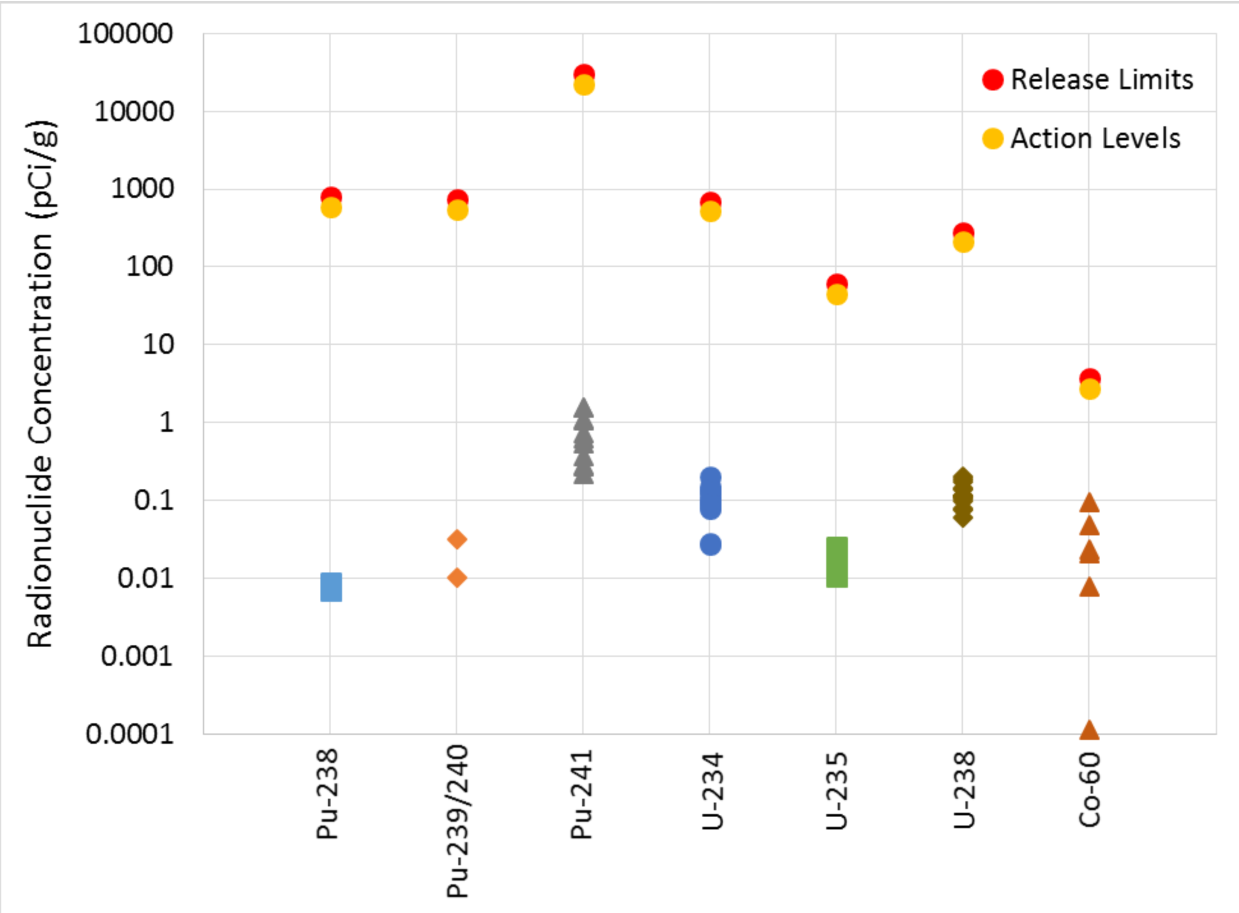

Figure 8. Lognormal plot indicating that radionuclide concentrations are below the action levels and release limits for the layback samples

5.0 Data Quality Assessment

Data quality assessment is an important part of the MARSSIM process. FSS data need to be both reliable and credible. This section describes the results of the quality control measures implemented during the FSS and deviations to the FSS plan (Bunn et al. 2018)

5.1 Data Quality Indicators

In addition to DQOs, data quality indicators (DQIs) that quantify the amount of error in the data collection process and the analytical measurement system are necessary to optimize survey design (NRC 2000). The principal DQIs are precision, accuracy, representativeness, comparability, completeness, and sensitivity. Of these DQIs, precision is a quantitative measure, accuracy is a combination of precision and bias, representativeness and comparability are qualitative, and completeness is a combination of both qualitative and quantitative measures (NRC 2000).

5.1.1 Precision

Precision is the measure of agreement among repeated measurements of the same property under identical or substantially similar conditions. As specified in the FSS plan (Bunn et al. 2018), field duplicate samples were collected from one sample location each sampling day to provide information on the consistency of sampling activities. Additionally, laboratory duplicates were evaluated to provide information on laboratory reproducibility.

The required laboratory analytical precision was ≤30% for replicate sample relative percent differences (RPDs). Sample and duplicate results (field and laboratory) were reviewed. RPD was only calculated where results for a given COPC were greater than or equal to five times (5x) the minimum detectable concentration (MDC). This approach is based on similar guidance from the U.S. Environmental Protection Agency for inorganic data review from multiple analytical methods (EPA 2010). No COPC values were reported that exceeded 5x MDC, so no RPD evaluations were completed. Precision is summarized with other DQIs in Table 6.

5.1.2 Accuracy

Accuracy is a measure of the overall agreement of a measurement to a known value that includes a combination of random error (precision) and systematic error (bias) components of sampling and analytical operations. Accuracy is determined by analyzing a reference material of known contaminant concentration or by reanalyzing material to which a known concentration of contaminant has been added. To be accurate, data must be both precise and unbiased.

Laboratory accuracy determination is based on laboratory control sample (LCS) results and tracer recovery factors. The required laboratory analytical accuracy is 70% to 130% for batch LCS percent recoveries and tracer recovery factors. Exceptions were identified for three samples, but the results were not found to impact the overall quality of the data. The plutonium-242 tracer recovery factor for sample B3KFC9 in the 520 building footprint survey unit was above the upper acceptance limit. The plutonium-238 result was greater than the MDC and was flagged as an estimate. The plutonium-239/240 result for the same sample was less than the MDC. The LCS recovery for plutonium-239/240 for 4 of the 17 samples in the tank vault and 530 building footprint survey unit was above the acceptance limit, but associated sample results were less than the MDC. The LCS recovery for plutonium-241 for 17 of the 21 samples in the other buildings footprint survey unit was above the upper acceptance limit, but associated sample results were less than the MDC. Accuracy is summarized with other DQIs in Table 6.

5.1.3 Representativeness

Representativeness is a qualitative term expressing "the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition" (ANSI/ASQ 1995). Representativeness is a qualitative attribute that is evaluated to determine whether measurements are made and collected in such a manner that the resulting data appropriately reflect the media and residual radioactivity measured.

The key to having representative samples is in the selection of sample locations. Because of the way that the survey units were defined, it was possible to assume that any area within a given survey unit had an equal probability of having residual radioactivity present. Random sample locations were chosen in accordance with guidance in MARSSIM.

All data generated in the RTL Complex were reviewed. The results showed that location coverage was consistent and supported the assumptions made in designing the surveys. As a measure of added conservativism, specific judgmental sampling was performed near areas with a higher potential for contamination based on information provided in the HSA (Lindenmeier et al. 2015; Biebesheimer 2018b). No issues were identified with the representativeness of sample locations. Representativeness is summarized with other DQIs in Table 6.

5.1.4 Comparability

Comparability is a qualitative term expressing the measure of confidence that one data set can be compared to another and can be combined for decision making. Use of the same sampling protocols for all samples and analysis completed by the same laboratories with the same methods for a given COPC provides confidence in the comparability of results. Comparability is summarized with other DQIs in Table 6.

5.1.5 Completeness

Completeness is a measure of the amount of valid data obtained from a measurement system, expressed as a percentage of the number of valid measurements that should have been collected. A percent completeness of 80% was stated as the required minimum for COPCs in the FSS plan. No issues were identified with the completeness of the data set, as each survey unit had 100% valid measurements for each COPC. Completeness is summarized with other DQIs in Table 6.

5.1.6 Sensitivity

Sensitivity is the capability of a method or instrument to discriminate among measurement responses representing different levels of the variable of interest. This indicator is measured by comparison of method detection limits to the required quantification limits (10% of the release limits).

No issues were identified in the sensitivity evaluation. The MDCs reported by the laboratory were lower than the required quantification limit (10% of release limits listed in Table 5) for each

COPC. Table 5 gives the minimum and maximum MDCs reported by the laboratory for each COPC. Sensitivity is summarized with other DQIs in Table 6.

Table 5. Actual quantification limits reported for radiological COPCs

	Release Limit (pCi/g)	Maximum Allowable MDC (pCi/g)	Minimum MDC Reported (pCi/g)	Maximum MDC Reported (pCi/g)
Plutonium-238	800	80	0.0344	0.146
Plutonium-239/240	740	74	0.0245	0.125
Plutonium-241	30,000	3,000	1.36	6.34
Uranium-234	700	70	0.0286	0.177
Uranium-235	60	6	0.0286	0.192
Uranium-238	280	28	0.0286	0.325
Cobalt-60	3.7	0.37	0.062	0.122

Table 6. Summary of evaluation of data quality indicators by RTL Complex survey unit

Data Quality Indicator	Evaluation Summary
Precision	Acceptable: Reported concentrations for primary and/or duplicate sample were <5x MDC, so no RPD calculated.
Accuracy	Acceptable: All LCS recoveries and carrier/tracer recovery factors were acceptable with exceptions for the 520 building,[(a)] tank vault and 530 building,[(b)] and other buildings'[(c)] survey units. Exceptions were not found to be quality affecting.
Representativeness	Acceptable: Samples were taken as outlined in the sampling and analysis plan, including random and judgmental samples.
Comparability	Acceptable: The same protocols were used to collect all samples. One laboratory completed the analysis for samples throughout all survey units using a single method for a given COPC.
Completeness	Acceptable: Completeness was calculated to be 100% for all COPCs in each survey unit.
Sensitivity	Acceptable: Minimum detection limits are less than the required quantification limit (10% of release limits) for each COPC in all survey units.

(a) The plutonium-242 tracer recovery factor for sample B3KFC9 at the 520-12 location was above the upper acceptance limit. The plutonium-238 sample result was greater than the MDC and was flagged as an estimate. The plutonium-239/240 result was less than the MDC and needed no additional flags.
(b) The LCS recovery for plutonium-239/240 was above the acceptance limit, but associated sample results for 4 locations were less than the MDC.
(c) The LCS recovery for plutonium-241 was above the upper acceptance limit, but associated sample results for 17 locations were less than the MDC.

5.2 Deviations from the Final Status Survey Plan

5.2.1 Removal of Sample Location J-32

A decision was made to remove sample J-32 from the list of samples identified in the FSS plan (Bunn et al. 2018). The J-32 sample location was a specific judgmental sample located at the sewer isolation point at the connection with the City of Richland municipal line along Innovation Blvd. It was recognized during the removal of the main east-west sewer line that removal of the sewer line to this sample location would be problematic with respect to its proximity to Innovation Blvd. There was another specific judgmental location (J-31) along the sewer line just east of the J-32 location that was collected. The J-31 location was at the access point for industrial wastewater discharge sampling for the City of Richland Industrial Wastewater Discharge Permit CR-IU001 Outfall 003. A decision was made to terminate sewer line removal activities at judgmental sample J-31. The sewer line was plugged with grout at this termination point and the sewer line between the two sample locations remains intact.

To support the decision to terminate sewer line removal activities, an in-process sample was collected at this location. Soil was collected as near as possible to the grout plug using a back-hoe bucket, and the in-process sample was collected from the bucket. The sample was analyzed for all radiological analytes specified in the FSS plan (Bunn et al. 2018). The sample numbers were B3J5X2, B3J5X3, and B3J5X4. All results were below the release limits identified in the FSS plan (Bunn et al. 2018).

Upon review of the analytical results, a layer of straw was placed in the trench created by the excavation of the sewer line to demarcate the excavation depth prior to backfill of the trench for safety and operational purposes. The trench was re-excavated to expose at-depth sample locations where the sewer line was removed for the FSS sampling event.

The removal of sample J-32 does not impact the quality and/or quantity of data used to make decisions on the release of the RTL Complex. The statistical evaluation of the random samples within the pipelines survey unit is not affected by the removal of the judgmental sample at location J-32. Any concern of COPCs along the sewer line would be identified through the analysis of samples from the J-31 location due east of the J-32 location.

5.2.2 Methods Report Multiple Radionuclides

TestAmerica, Inc., in Richland, WA, used alpha spectroscopy to evaluate concentrations of uranium-234 and uranium-235 in the samples taken from the RTL Complex. Results were reported as uranium-233/234 and uranium-235/236, giving concentrations as combined totals of the isotope pairs. Most of the uranium-233 and uranium-236 isotopes are at trace levels in comparison to the uranium-234 and uranium-235 isotopes. Given that the results are reported as a combination of two isotopes, the results could be biased high for individual uranium-234 and uranium-235 values. Across the RTL Complex, the highest reported value for uranium-233/234 is 0.451 pCi/g, which is approximately three orders of magnitude below the uranium-234 release limit of 700 pCi/g. The highest value reported for uranium-235/236 across the RTL Complex is 0.0522 pCi/g, which is also over three orders of magnitude below the uranium-235 release limit of 60 pCi/g. Any measurement uncertainty associated with reporting of the combined isotopes will not impact the quality of data used for decision making because all reported values are three orders of magnitude below the release limits.

5.3 Summary of Data Quality Assessment Results

The data obtained as part of the FSS are of acceptable quality for use in making decisions regarding the release of the RTL Complex. This determination that the results are usable is based on the analysis described in this section and those presented in Section 6.0.

6.0 Survey Results

The sampling campaign for the FSS of the RTL Complex was conducted over the course of 12 days between November 11 and December 7, 2018, collecting soil samples from 127 locations across the six survey units. Samples were analyzed using the technologies described in Section 4.3. Laboratory results were independently validated (Level C) by Analytical Quality Associates prior to evaluation.

Table 7 summarizes the results indicating that measured concentrations for all radiological COPCs were below the action levels and the release limits for all samples within the six survey units. Sum of fractions calculated for each of the survey units using maximum values are shown in Table 7. All values were approximately 3% of unity or less indicating that the sum of fractions requirement was also met for each survey unit.

Results for each radiological COPC from both random and specific judgmental locations were plotted by survey unit to illustrate the range of concentrations observed relative to the release limits and action levels. A lognormal axis was used to show the range of concentrations that were orders of magnitude (10 to 1000 times) lower than the release limits and action levels. Due to the use of the lognormal scale, only the positive non-zero values are presented in Figure 9 through Figure 15. These figures indicate that the reported concentrations are orders of magnitude below the release limits and similar concentrations are observed across each of the survey units.

Field and laboratory precision and bias results provided no evidence that measurement precision and bias uncertainty would impact evaluation of results compared to the release limits. Appendix C contains figures with the individual measurements plotted spatially by survey unit. Appendix D contains the analysis reports from the laboratory. Data validation reports from Analytical Quality Associated, Inc. are found by survey unit in Appendix E.

Table 7. Summary of sample results from the RTL Complex final status survey

COPC	Release Limit (pCi/g)	Action Level (pCi/g)		520 Building Footprint	Pipeline	Tank Vault & 530 Building Footprint	Other Buildings Footprint	Open Areas	Paved Areas
Pu-238	800	600	Detects	12	0	0	0	0	0
			Non-Detects	16	23	17	21	15	23
			Minimum	-0.012	-0.009	-0.009	-0.014	-0.010	-0.012
			Mean	0.062	-0.002	0.002	-0.003	0.002	-0.001
			Median	0.028	-0.004	-0.001	-0.004	-0.002	-0.003
			Maximum	0.238	0.010	0.023	0.008	0.034	0.013
			Standard Deviation	0.073	0.007	0.010	0.005	0.013	0.007
Pu-239/240	740	555	Detects	0	0	0	0	0	0
			Non-Detects	28	23	17	21	15	23
			Minimum	-0.009	-0.010	-0.012	-0.005	-0.003	-0.011
			Mean	0.000	0.001	-0.002	0.001	0.001	0.001
			Median	-0.001	-0.001	-0.002	-0.001	-0.001	-0.001
			Maximum	0.012	0.031	0.015	0.025	0.013	0.016
			Standard Deviation	0.005	0.008	0.007	0.007	0.006	0.007
Pu-241	30000	22500	Detects	0	0	0	0	0	0
			Non-Detects	28	23	17	21	15	23
			Minimum	-2.400	-1.000	-1.500	-0.760	-0.930	-0.570
			Mean	-0.389	-0.026	-0.487	0.314	0.149	0.618
			Median	-0.200	-0.160	-0.540	0.238	0.248	0.384
			Maximum	1.440	1.810	1.430	1.660	1.210	4.050
			Standard Deviation	1.096	0.763	0.749	0.726	0.630	1.028
U-234 [(a)]	700	525	Detects	24	18	15	17	13	20
			Non-Detects	4	5	2	4	2	3
			Minimum	0.016	0.023	0.042	0.046	0.024	0.032
			Mean	0.121	0.107	0.129	0.117	0.213	0.106
			Median	0.106	0.108	0.116	0.108	0.181	0.101
			Maximum	0.274	0.226	0.251	0.214	0.451	0.196
			Standard Deviation	0.062	0.058	0.054	0.051	0.131	0.040

COPC	Release Limit (pCi/g)	Action Level (pCi/g)		520 Building Footprint	Pipeline	Tank Vault & 530 Building Footprint	Other Buildings Footprint	Open Areas	Paved Areas
U-235 [(b)]	60	45	Detects	0	1	0	0	1	0
			Non-Detects	28	22	17	21	14	23
			Minimum	-0.013	-0.004	-0.006	-0.003	-0.003	-0.002
			Mean	0.005	0.010	0.002	0.003	0.008	0.006
			Median	0.000	0.012	0.000	-0.001	0.008	0.000
			Maximum	0.043	0.046	0.018	0.018	0.052	0.022
			Standard Deviation	0.011	0.013	0.007	0.007	0.014	0.007
U-238	280	210	Detects	26	19	11	19	13	19
			Non-Detects	2	4	6	2	2	4
			Minimum	0.020	0.034	0.012	0.055	0.024	0.012
			Mean	0.132	0.104	0.113	0.117	0.192	0.110
			Median	0.130	0.094	0.099	0.107	0.156	0.104
			Maximum	0.306	0.217	0.259	0.278	0.337	0.200
			Standard Deviation	0.054	0.046	0.062	0.053	0.103	0.048
Co-60	3.7	2.8	Detects	0	0	0	0	0	0
			Non-Detects	28	23	17	21	15	23
			Minimum	-0.110	-0.060	-0.120	-0.150	-0.140	-0.150
			Mean	-0.009	0.009	-0.016	0.011	-0.004	0.003
			Median	0.002	0.008	-0.017	0.019	0.007	0.013
			Maximum	0.079	0.071	0.066	0.109	0.072	0.074
			Standard Deviation	0.049	0.031	0.046	0.061	0.059	0.051
Sum of Fractions (using maximum values)				0.0240	0.0212	0.0195	0.0311	0.0223	0.0216

(a) Uranium-234 concentrations reported by the laboratory as uranium-233/234.
(b) Uranium-235 concentrations reported by the laboratory as uranium-235/236.

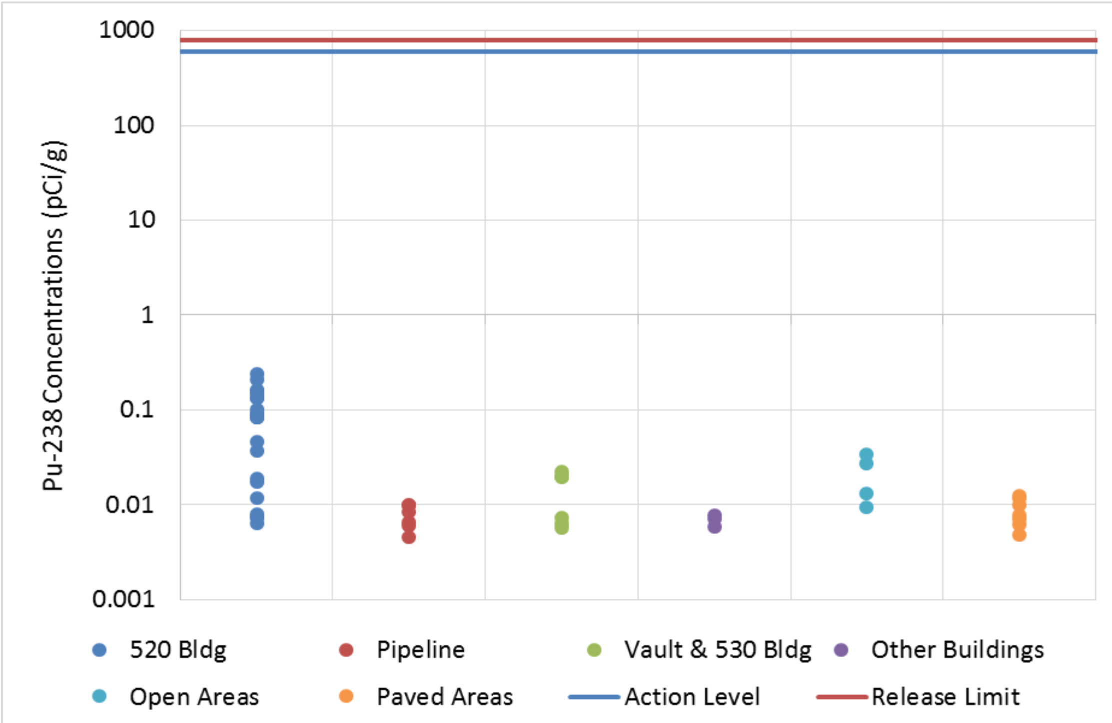

Figure 9. Lognormal plot of plutonium-238 concentrations by survey unit shown in relation to the action level (600 pCi/g) and release limit (800 pCi/g)

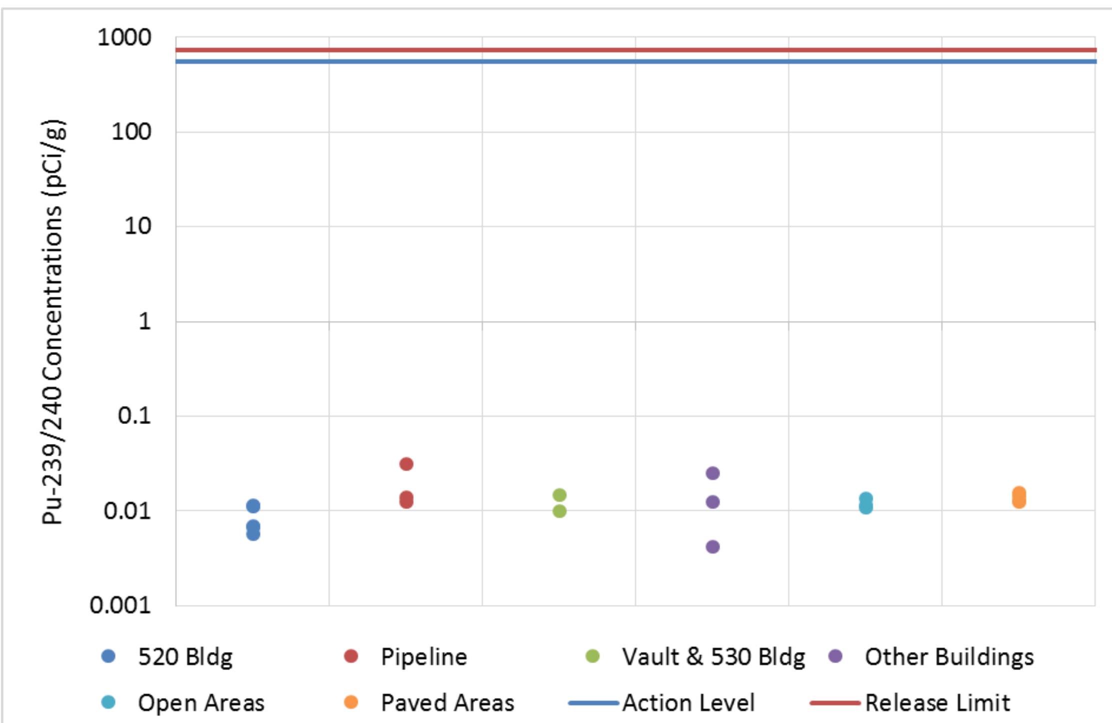

Figure 10. Lognormal plot of plutonium-239/240 concentrations by survey unit shown in relation to the action level (555 pCi/g) and release limit (740 pCi/g)

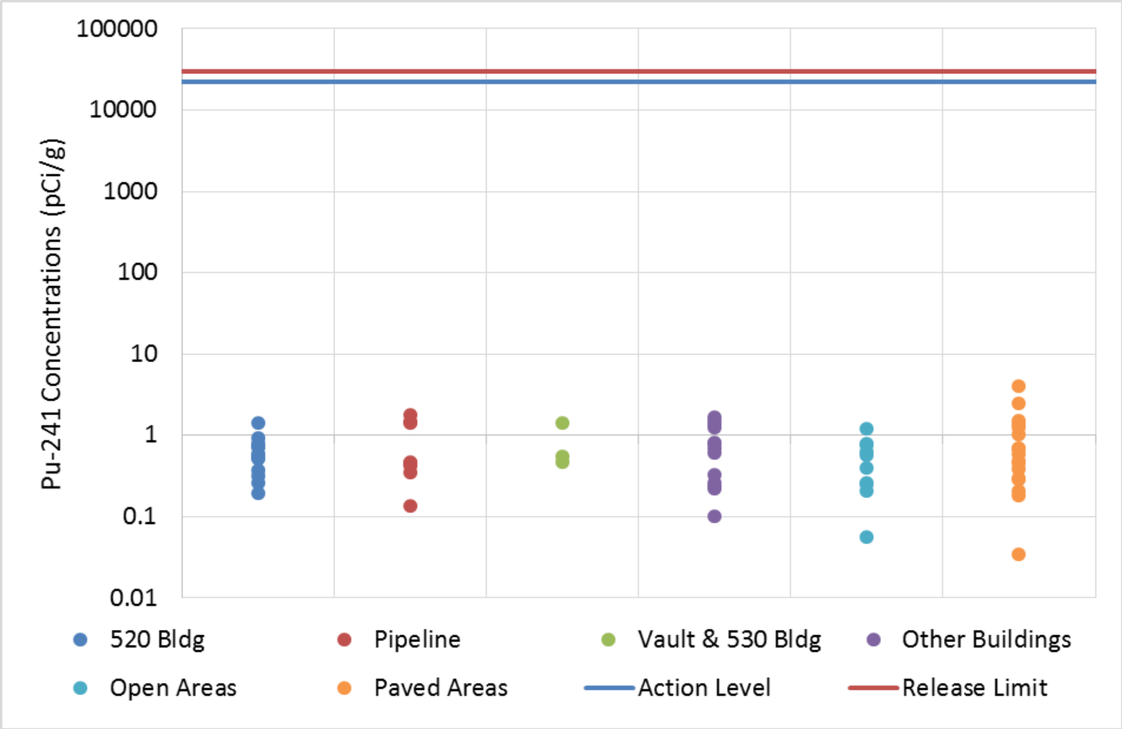

Figure 11. Lognormal plot of plutonium-241 concentrations by survey unit shown in relation to the action level (22,500 pCi/g) and release limit (30,000 pCi/g)

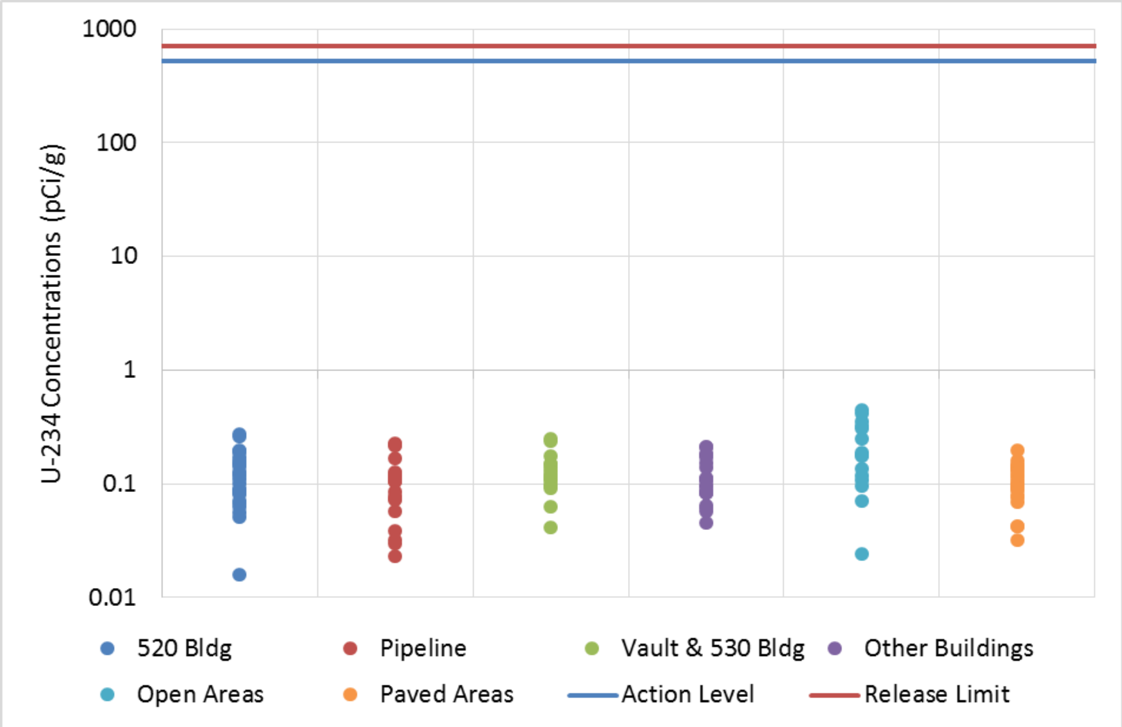

Figure 12. Lognormal plot of uranium-234 concentrations (reported as uranium-233/234) by survey unit shown in relation to the action level (525 pCi/g) and release limit (700 pCi/g)

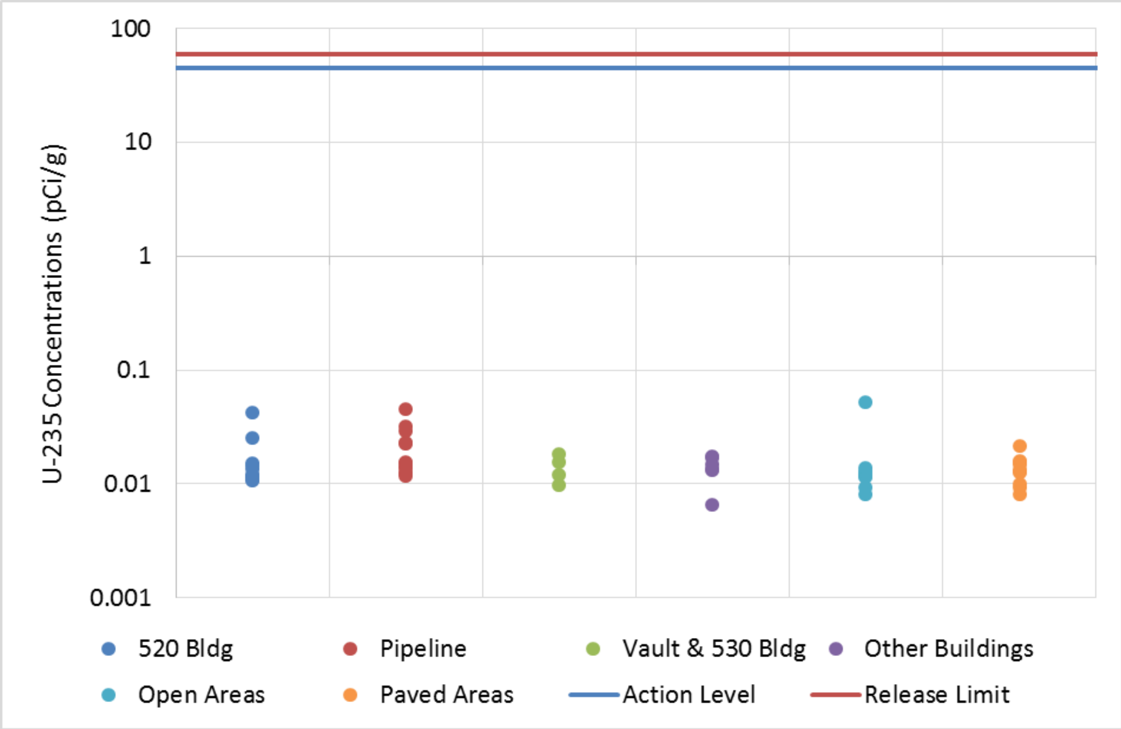

Figure 13. Lognormal plot of uranium-235 (reported as uranium-235/236) concentrations by survey unit shown in relation to the action level (45 pCi/g) and release limit (60 pCi/g)

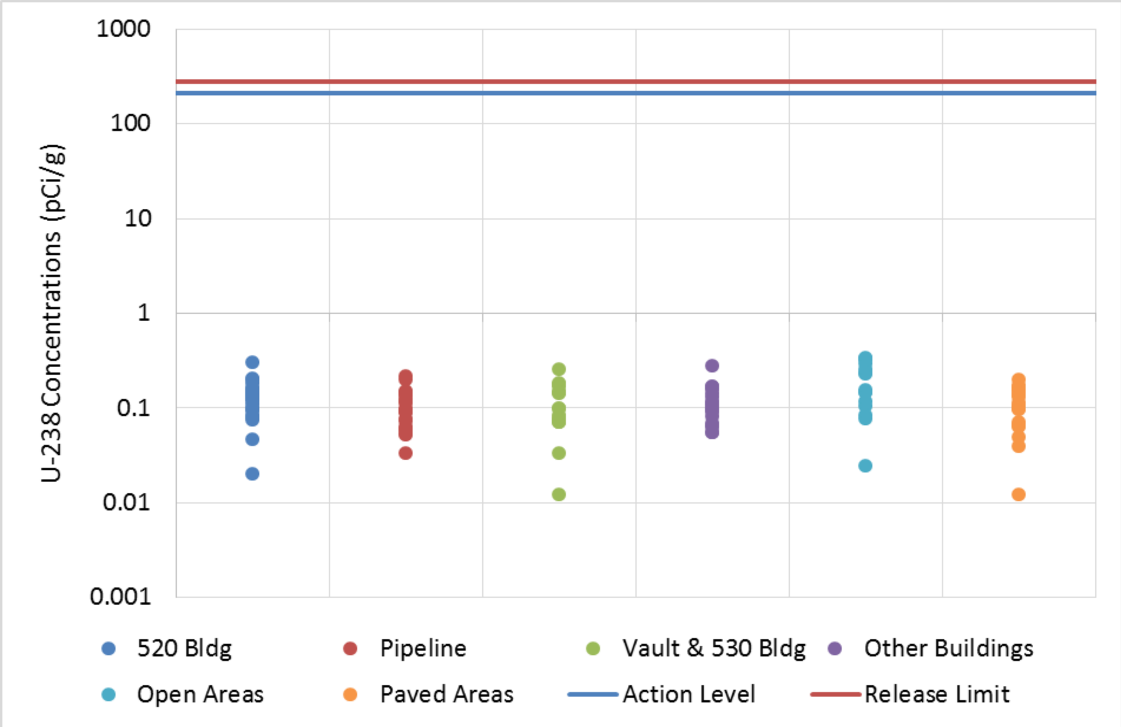

Figure 14. Lognormal plot of uranium-238 concentrations by survey unit shown in relation to the action level (210 pCi/g) and release limit (280 pCi/g)

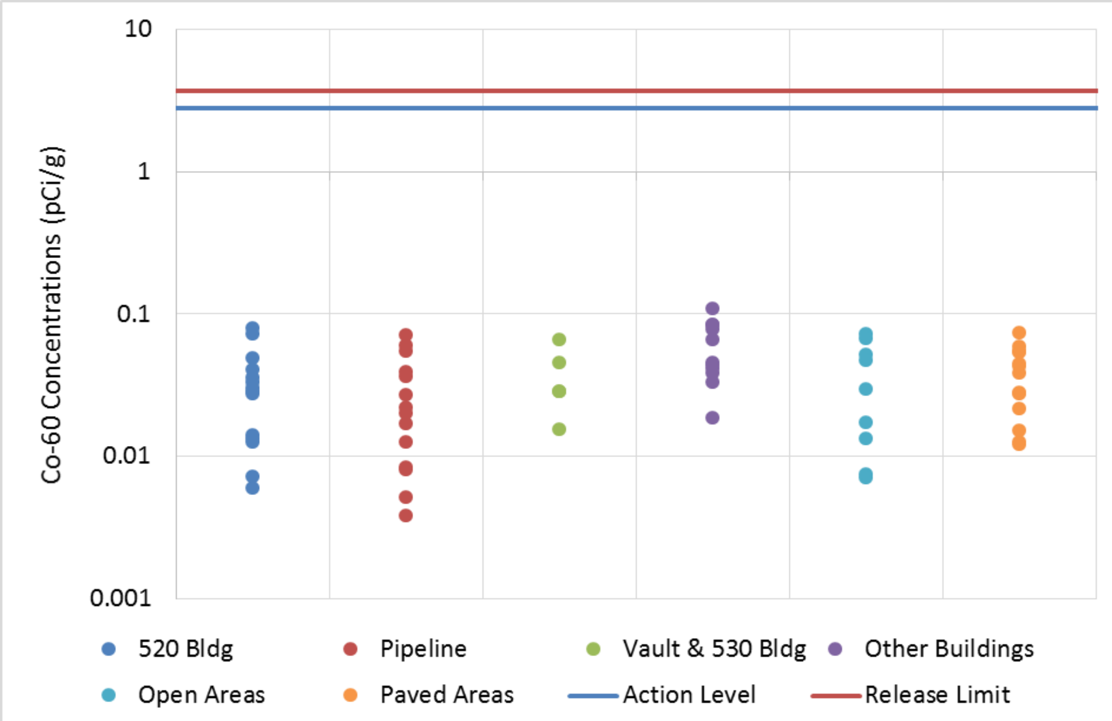

Figure 15. Lognormal plot of cobalt-60 concentrations by survey unit shown in relation to the action level (2.8 pCi/g) and release limit (3.7 pCi/g)

6.1 Final Status Survey Conclusions

All of the residual radioactivity measurements (>880 results) were less than the release limits and action levels established through the RTL Disposition Program. The FSS plan (Bunn et al. 2018) identified the Sign test as a statistical approach defined within MARSSIM to demonstrate compliance with the release criterion when the COPC of interest is not present in background or is present in such a small fraction of the DCGL (or release limit) as to be considered insignificant (NRC 2000). MARSSIM also states that if the largest measurement is below the DCGL, the Sign test will always show that the survey unit meets the release criterion. As shown in Table 7, the maximum values obtained for each COPC were orders of magnitude below the release limits across all six survey units meeting release criterion for the Sign test. The application of the sum of fractions using the maximum value reported for each radionuclide within a survey unit resulted in values ~3% or less of unity, indicated in Table 8 by a *Pass* designation. Therefore, the null hypothesis is rejected and the RTL Complex is recommended for release to unrestricted use in accordance with the clearance requirements of DOE Order 458.1.

Table 8. Summary of RTL Complex final status survey results

Survey Unit	MARSSIM Class	Number Locations Sampled	Number of Results Less than Action Level[(a)]	Pass/Fail
520 Building Footprint	3	28	196	Pass
Tank Vault and 530 Building Footprint	3	17	119	Pass
Other Buildings Footprint	3	21	147	Pass
Pipelines	3	23	161	Pass
Paved Areas	3	23	161	Pass
Open Areas	3	15	105	Pass
Total	-	127	889	-

(a) All radiological COPCs are measured at each sampled location, providing seven results for one location.

7.0 References

ANSI/ASQ. 1995. *Introduction to Attribute Sampling*. American National Standards Institute, Washington, D.C., American Society for Quality, Milwaukee, Wisconsin.

Biebesheimer FH. 2017. Memorandum from Fred Biebesheimer to "Skip" Kerschner. "Analysis of the RTL Complex East Tank Spill." November 17, 2017. S740277-17-01, Pacific Northwest National Laboratory, Richland, Washington.

Biebesheimer FH. 2018a. *Battelle Facilities Restoration Program Management Plan, Volume II – RTL Complex Disposition Program*. S740277-PLAN-12, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

Biebesheimer FH. 2018b. *Research Technology Laboratory Complex Disposition Program – Final Historical Site Assessment Report*. S740277-RPT-02, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

Benton County. 2011. Benton County State of Washington Zoning Map: Richland-West Richland Planning Area. Benton County, Prosser, Washington.

Bunn AL. 2018. Memorandum from Amoret Bunn to Harrison Kerschner and Elizabeth Golovich. "Scoping Study of the Layback Piles at the RTL Complex." October 31, 2018. S740277-18-04, Pacific Northwest National Laboratory, Richland, Washington.

Bunn AL, JK Snelling, and AM Gorton. 2018. *Research Technology Laboratory (RTL) Disposition Program: Final Status Survey Plan*. S740277-PLAN-14, Pacific Northwest National Laboratory, Richland, Washington.

City of Richland. 2014. *City of Richland Zoning GIS Map.* Richland, Washington.

DAC. 1967. *Application for a Special Nuclear Material License from the AEC*. Edited by Douglas Aircraft Company. Douglas Aircraft Company, Richland, Washington.

DOE. 2011. *Radiation Protection of the Public and the Environment.* DOE O 458.1, U.S. Department of Energy. Washington, D.C. https://www.directives.doe.gov/directives/0458.1-BOrder/view.

DOE. 2017. Letter from Roger E. Snyder, Manager, U.S. Department of Energy, Pacific Northwest Site Office, to Dr. Seven Ashby, Director, Pacific Northwest National Laboratory, Battelle Memorial Institute, Pacific Northwest Division, Richland, Washington. "Contract No. DE-AC05-76RL01830, Approval of Authorized Limits for Radiological Clearance of the Research Technology Laboratory (RTL) Site." January 12, 2017. 17-PNS0-0087.

Duncan JP, MR Sackschewsky, HT Tilden, JM Becker, JM Barnett, TW Moon, JL Mendez, J Su-Coker, MY Ballinger, JA Stephens, KD Hand, CP Beus, and EA Raney. 2017. *Pacific Northwest National Laboratory Annual Site Environmental Report for Calendar Year 2016.* PNNL-26735, Pacific Northwest National Laboratory, Richland, Washington.

ENC. 1980. *Decontamination of R&TC Hot Labs*. Exxon Nuclear Company, Richland, Washington.

ENC. 1982. *License Renewal Application for WN-I-062-2*. Exxon Nuclear Company, Richland, Washington.

EPA. 2010. *National Functional Guidelines for Inorganic Superfund Data Review*. USEPA-540-R-10-011, U.S. Environmental Protection Agency, Office of Environmental Information, Washington, D.C.

Felt RE 1980. *Sphere-Pac Fuel Development Program: First Semi-Annual Progress Report for the Period October, 1979-March 1980*. DOE/ET/34026-1, Exxon Nuclear Company, Richland, Washington.

Harvey D, DP McFarland, and J Ferry. 2017. *Cultural Resources Review of the Remediation of Radiological Contamination at the Research Technology Laboratory (RTL) Complex at the Pacific Northwest National Laboratory (PNNL) Benton County, Washington (HCRC#2015-PNSO-003) (Redacted)*. CH2M Hill, Richland, Washington.

Harvey DW. 2000. *History of the Hanford Site: 1943-1990.* Pacific Northwest National Laboratory, Richland, Washington. https://www.osti.gov/servlets/purl/887452.

Ikenberry TA. 2016. *Authorized Limits for Radiological Clearance of the Research Technology Laboratory (RTL) Site*. DMA-TR-063, Dade Moeller, Richland, Washington.

Lindenmeier C, K Wagner, R Cameron, and F Biebesheimer. 2015. *Battelle Facilities Restoration Program – Preliminary Historical Site Assessment Report for the Research Technology Laboratory (RTL).* S697201-TECH-PM-007, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

Matzke BD, JE Wilson, LL Newburn, ST Dowson, JE Hathaway, LH Sego, LM Bramer, and BA Pulsipher. 2014. *Visual Sample Plan Version 7.0 User's Guide*. PNNL-23211, Pacific Northwest National Laboratory, Richland, Washington. Available at https://vsp.pnnl.gov/.

Moore RL. 1964. *Promethium as an Isotopic Fuel.* HW-82215, General Electric, Richland, WA.

NRC. 2000. *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM).* NUREG-1575, Rev. 1, U.S. Nuclear Regulatory Commission. Washington, D.C. http://www.epa.gov/radiation/marssim/.

PNL. 1984. *RTL Information from 1984 Facilities Catalog.* Pacific Northwest Laboratories, Richland, WA.

PNNL. 2017a. *Statement of Work CHPRC IWO for RTL Complex D4 Mobilization, Isolation, and Internal Remediation*. S740277-SOW-04, Pacific Northwest National Laboratory, Richland, Washington.

PNNL. 2017b. *Statement of Work CHPRC IWO for RTL Complex D4 Demolition & Subsurface Soil Remediation.* S740277-SOW-05, Pacific Northwest National Laboratory, Richland, Washington.

PNNL. 2018a. *Facilities & Infrastructure Portfolio Project Review for July 2018.* Pacific Northwest National Laboratory, Richland, Washington.

PNNL. 2018b. *Facilities & Infrastructure Portfolio Project Review for September 2018.* Pacific Northwest National Laboratory, Richland, Washington.

Smith TH, J Greenborg, and WE Matheson. 1975. “Benefit/Risk Analysis of Cardiac Pacemakers Powered by Betacel Promethium-147 Batteries.” *Nuclear Technology* 26:54-64.

Smoter RL and FH Biebesheimer. 2017. *Battelle Facilities Restoration Program Management Plan Volume I*. S697201-PLAN-PM-003, Rev. 2, Pacific Northwest National Laboratory, Richland, Washington.

Snelling JK and AL Bunn. 2018. *Research Technology Laboratory (RTL) Disposition: Data Quality Objectives (DQOs).* S740277-PLAN-13, Rev. 1, Pacific Northwest National Laboratory. Richland, Washington.

Woods KN. 1983. *Exxon Nuclear RTL Vacate Letter*. Exxon Nuclear Company, Inc., Richland, Washington.

Appendix A – Survey Sample Locations

A.1 Sample Locations per Survey Unit as Generated in VSP

The Research Technology Laboratory (RTL) Complex survey units are considered Class 3 under the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM; NRC 2000); therefore, simple random sampling was used to generate 14 random sample locations within each survey unit using the Visual Sample Plan (VSP) software. The following sections present the sampling locations for random sample locations and specific judgmental sample locations within each survey unit.

Random sample locations and specific judgmental sample locations are presented as easting (X)/northing (Y) in North American Datum (NAD) 1983 Washington State Plane South (4602) in feet (EPSG 2286). Table A.1 presents the descriptions and coordinates of the 44 specific judgmental samples. No field judgmental samples were selected. Figure A.1 presents a summary of all random and specific judgmental sample locations for the RTL Complex.

Table A.1. Specific judgmental sample descriptions and coordinates

Sample No.	Description	Survey Unit	Easting (X), Northing (Y) [(a)]
J-1	RTL 520: Soil below slab of Laser Dye Processing Lab 248 (Exxon era), where large dye stains exist on concrete underneath sheet flooring that was removed.	RTL 520	1950236.5863, 368388.1079
J-2	RTL 520: Soil below slab of Laser Dye Processing Lab 448 (Exxon era), where large dye stains exist on concrete underneath sheet flooring that was removed.	RTL 520	1950236.9335, 368333.1600
J-3	RTL 520: East service corridor, located east of three FCAs in corridor.	RTL 520	1950196.3461, 368361.7787
J-4	RTL 520: East service corridor, located between three FCAs in corridor.	RTL 520	1950164.8318, 368362.0585
J-5	RTL 520: Soil below slab of Uranium Processing Lab 228 (Exxon era), where documented process upsets occurred and where PNNL documented the highest FCAs (1–6 million dpm/100 cm^2) on concrete underneath sheet flooring that was removed.	RTL 520	1950157.9923, 368388.5747
J-6	RTL 520: Soil below slab of Uranium Processing Lab 228 (Exxon era), where documented process upsets occurred and where PNNL documented the highest FCAs (1–6 million dpm/100 cm^2) on concrete underneath sheet flooring that was removed.	RTL 520	1950157.9302, 368379.5159
J-7	RTL 520: East service corridor, located west of three FCAs in corridor.	RTL 520	1950143.7070, 368361.6906
J-8	RTL 520: Soil below slab of Lab 218, where PNNL documented the second highest FCAs (1–2 million dpm/100 cm^2) on concrete underneath sheet flooring that was removed.	RTL 520	1950129.3329, 368379.0126

Sample No.	Description	Survey Unit	Easting (X), Northing (Y) [(a)]
J-9	RTL 520: Soil below slab of Lab 218, where PNNL documented the second highest FCAs (1–2 million dpm/100 cm^2) on concrete underneath sheet flooring that was removed.	RTL 520	1950108.6267, 368386.3803
J-10	6-foot-deep steel sewage sump in basement of RTL 520.	RTL 520	1950093.1940, 368356.1770
J-11	Condensate return unit in basement of RTL.	RTL 520	1950069.7560, 368368.9430
J-12	4-foot-deep steel sewage sump in basement of RTL. Note that while the sample appears to be outside of the RTL 520 building footprint, it falls within the footprint of the RTL 520 basement.	RTL 520	1950028.8250, 368436.2630
J-13	Align sample location along pipeline at mid-point between drains in Laboratory 132 and junction with foundation of RTL 520.	RTL 520	1949958.1960, 368400.3308
J-14	Align location to sample region where drains were located inside Laboratory 132.	RTL 520	1949960.4182, 368388.0231
J-15	Soil below northeast corner of radiological waste tank vault. This area is not covered by the randomly selected sample points for this survey unit.	RTL Tank Vault and 530	1949876.1409, 368445.4311
J-16	Soil below southwest corner of radiological waste tank vault. This area is not well covered by the randomly selected sample points.	RTL Tank Vault and 530	1949867.3543, 368437.7122
J-17	RTL 530: Small pit in the northeast corner of RTL 530 used as shielded storage of radioactive sources by Donald Douglas/Exxon prior to Battelle ownership. Battelle also used this area to store sources.	RTL Tank Vault and 530	1949874.5934, 368413.8384
J-18	RTL 510: Soil below slab in southwest corner of east room (solvent storage building – Exxon era) to provide more robust coverage beyond the random sample point already established in northeast corner.	Other Buildings	1950310.0238, 368393.4899
J-19	RTL 510: Soil below “pit” in southwest corner of west room.	Other Buildings	1950296.2217, 368394.9656
J-20	Sampling location for RTL 524.	Other Buildings	1949961.5963, 368485.1348
J-21	Additional sampling location for RTL 560.	Other Buildings	1949797.2575, 368375.3586
J-22	RTL 570: Soil below ventilation exhauster concrete pad footprint.	Other Buildings	1949743.5298, 368449.4808
J-23	RTL 570: Soil below pit, location below injection point of two French drains. Note, only physical evidence of southeast drain is apparent in pit. Sample point should be located approximately 18 in. northwest of southeast pit location.	Other Buildings	1949739.3641, 368427.6913
J-24	RTL 590: Soil below slab, west third of building. Under 90-day hazardous waste accumulation area. Located midway between existing randomly selected sample location and west wall.	Other Buildings	1949546.2651, 368228.2555

Sample No.	Description	Survey Unit	Easting (X), Northing (Y) [(a)]
J-25	Pipeline junction with RTL 520.	Pipeline Survey Unit	1950033.2369, 368417.7360
J-26	Pipeline junction with RTL 520 and Laboratory 132.	Pipeline Survey Unit	1949956.2418, 368413.7748
J-27	Pipeline junction with RTL tank vault.	Pipeline Survey Unit	1949877.2660, 368436.1802
J-28	Pipeline junction with RTL 530.	Pipeline Survey Unit	1949862.6350, 368397.7417
J-29	Multiple pipeline union.	Pipeline Survey Unit	1949736.1473, 368405.5786
J-30	Sewer drain from RTL 580.	Pipeline Survey Unit	1949716.2560, 368220.5096
J-31	Location of access point for industrial wastewater discharge sampling for the City of Richland Industrial Wastewater Discharge Permit CR-IU001 Outfall 003.	Pipeline Survey Unit	1949576.3076, 368443.4969
J-32	Soil below sewer isolation point at connection with City of Richland municipal line along Innovation Blvd. *Sample was not collected. See Section 5.2.1 for discussion.*	Pipeline Survey Unit	1949480.6835, 368442.9691
J-43	Soil at the same depth of the RTL tank vault (6 to 8 ft below grade) near the junction of the removed waste transfer pipeline with the RTL tank vault, which was removed in 1998 (Biebesheimer et al. 2016, Section 4.5.3; McCoy 1999).	Pipeline Survey Unit	1949908.8670, 368440.1503
J-44	Soil at the same depth of the RTL tank vault (6 to 8 ft below grade) along the removed waste transfer pipeline between RTL tank vault and RTL 520 building, which was removed in 1998 (Biebesheimer et al. 2016, Section 4.5.3; McCoy 1999).	Pipeline Survey Unit	1949957.3739, 368431.7475
J-33	Gravel area in southeast corner of RTL 520 associated with historical Exxon tank (Biebesheimer 2017). Note, this is a subsurface sample.	Paved Areas	1950300.7070, 368313.6670
J-34	Gravel area in southeast corner of RTL 520 associated with historical Exxon tank (Biebesheimer 2017). Note, this is a subsurface sample.	Paved Areas	1950297.7070, 368313.6670
J-35	Gravel area in southeast corner of RTL 520 associated with historical Exxon tank (Biebesheimer 2017). Note, this is a subsurface sample.	Paved Areas	1950293.7070, 368313.6670
J-36	Northeast loading dock for RTL 520.	Paved Areas	1950268.3621, 368398.1147
J-37	Soil below discharge/injection point for UIC RTL-02. (Biebesheimer et al. 2016.).	Paved Areas	1950050.3790, 368169.1470
J-38	Northwest loading dock for RTL 520.	Paved Areas	1949881.2957, 368392.1820
J-39	Catch basin 2 connected to UIC RTL-03 (sample J-41) (Biebesheimer et al. 2016).	Paved Areas	1949766.4159, 368293.8199
J-40	Catch basin 1 connected to UIC RTL-03 (sample J-41) (Biebesheimer et al. 2016).	Paved Areas	1949708.0444, 368295.3765

Sample No.	Description	Survey Unit	Easting (X), Northing (Y) [(a)]
J-41	Soil below discharge/injection point for UIC RTL-03 (Biebesheimer et al. 2016).	Paved Areas	1949651.9787, 368296.7477
J-42	Soil below discharge/injection point for UIC RTL-01 (Biebesheimer et al. 2016).	Open Areas	1950297.3909, 368417.2828

FCA = fixed contamination area; Other Buildings = RTL 510, 524, 540, 550, 560, and 590 buildings; PNNL = Pacific Northwest National Laboratory; UIC = underground injection control.
(a) Presented as easting (X)/northing (Y) in NAD 1983 Washington State Plane South (4602) in feet (EPSG 2286).

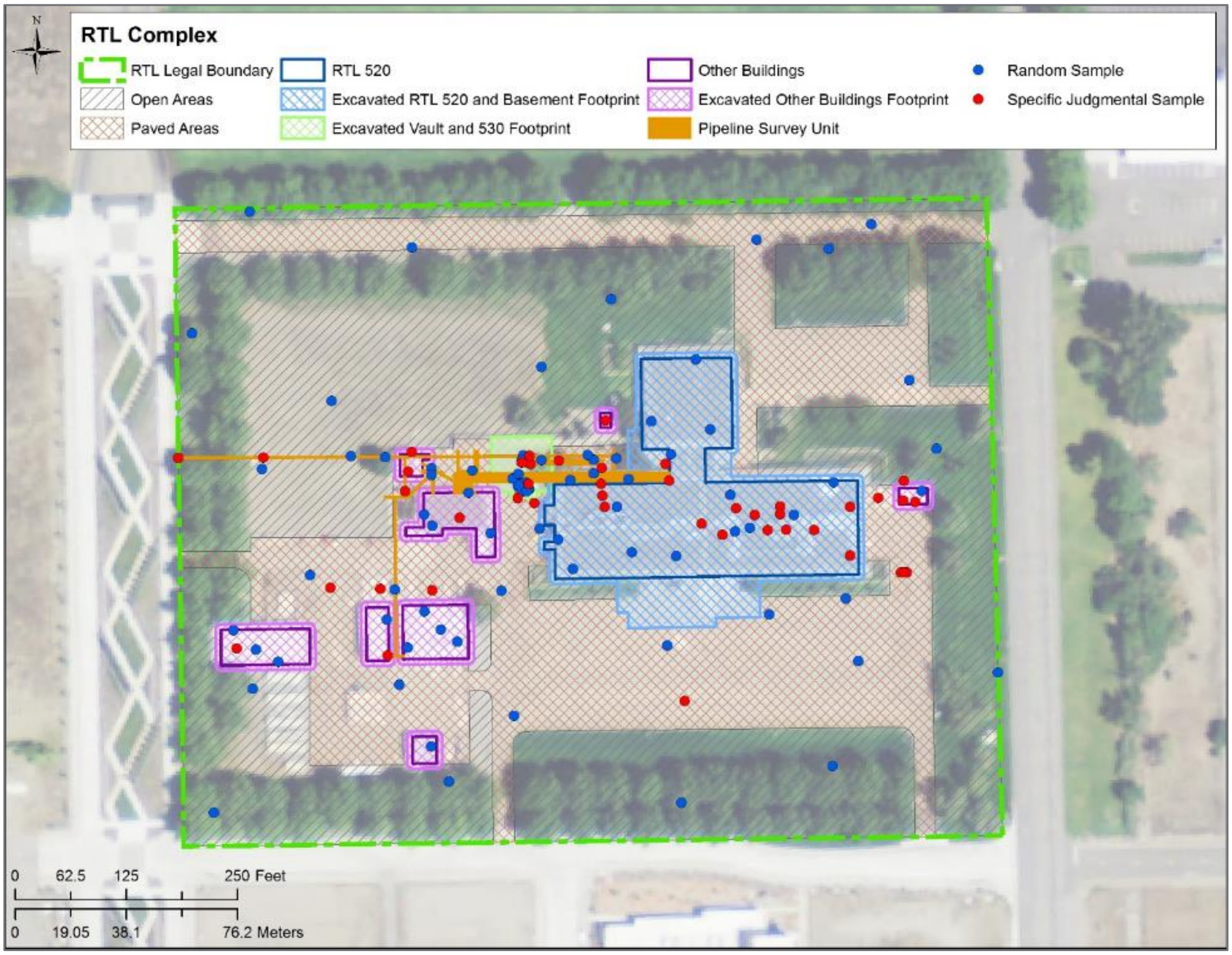

Figure A.1. Summary of all random and specific judgmental samples for the RTL Complex

A.2 RTL 520 Building Footprint

Table A.2 presents the 14 random sample locations for the RTL 520 building footprint (520) survey unit. Figure A.2 and Figure A.3 show the locations of the random samples and the specific judgmental samples.

Table A.2. Random sample locations for the RTL 520 building footprint survey unit

Sample No.	Easting (X)	Northing (Y)	Sample No.	Easting (X)	Northing (Y)
520-1	1949907.9353	368350.9599	520-8	1950079.5028	368475.0072
520-2	1950173.5882	368378.6399	520-9	1949990.9518	368336.6074
520-3	1950040.7618	368332.5066	520-10	1950123.7783	368364.2873
520-4	1950217.8637	368415.5465	520-11	1950035.2273	368447.3272
520-5	1950107.1750	368360.1866	520-12	1949924.5386	368318.1540
520-6	1949974.3485	368387.8666	520-13	1950101.6406	368401.1940
520-7	1950062.8995	368553.9464	520-14	1950013.0896	368484.2339

Easting (X) and northing (Y) coordinates presented in NAD 1983 Washington State Plane South (4602) in feet (EPSG 2286).

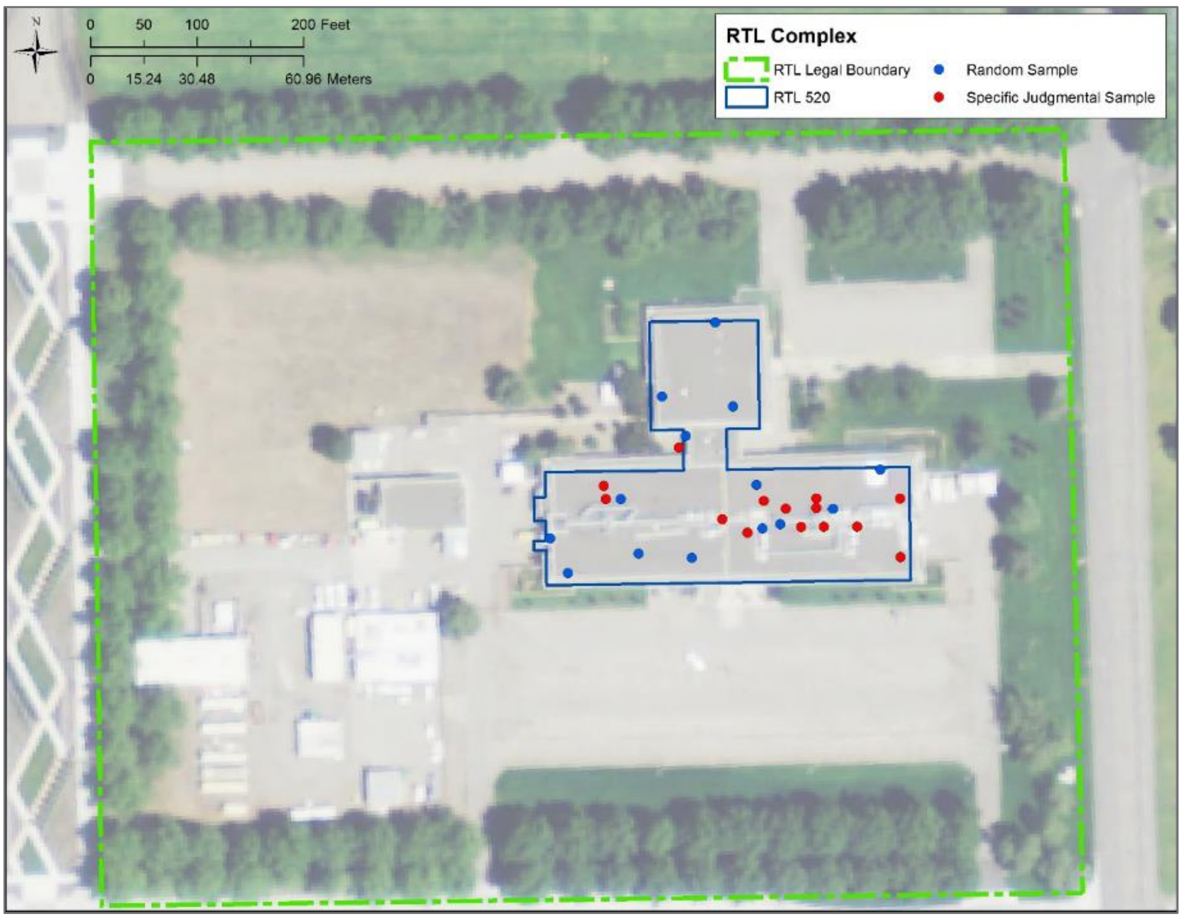

Figure A.2. RTL 520 footprint with random and specific judgmental sample locations

Figure A.3. RTL 520 footprint with random and specific judgmental sample locations (zoomed in)

A.3 RTL Tank Vault and RTL 530 Building Footprints

Table A.3 presents the 14 random sample locations for the RTL tank vault and RTL 530 building footprints (vault) survey unit. Figure A.4 shows RTL tank vault and RTL 530 building footprint within the complex. Figure A.5 is a close-up of the survey unit, showing the locations of the random samples and the specific judgmental samples.

Table A.3. Random sample locations for the RTL tank vault and RTL 530 building footprints survey unit

Sample No.	Easting (X)	Northing (Y)	Sample No.	Easting (X)	Northing (Y)
Vault-1	1949871.5252	368410.2322	Vault-8	1949864.4490	368412.1825
Vault-2	1949867.4817	368414.2828	Vault-9	1949872.5361	368405.4316
Vault-3	1949875.5688	368407.5319	Vault-10	1949871.6443	368441.2240
Vault-4	1949862.4273	368411.5824	Vault-11	1949871.7154	368442.3547
Vault-5	1949870.5144	368415.6329	Vault-12	1949868.6789	368445.7467
Vault-6	1949866.4708	368404.0814	Vault-13	1949874.7520	368437.0782
Vault-7	1949874.5579	368408.1319	Vault-14	1949867.1606	368440.4702

Easting (X) and northing (Y) coordinates presented in NAD 1983 Washington State Plane South (4602) in feet (EPSG 2286).

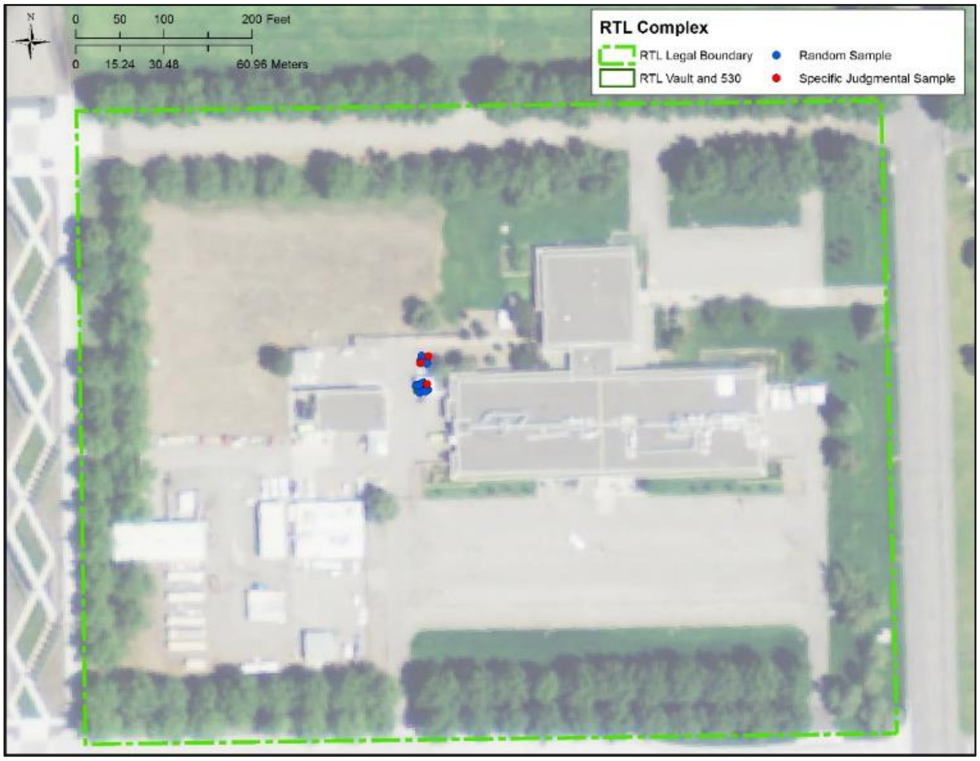

Figure A.4. The RTL Complex, showing the RTL tank vault and 530 footprint with random and specific judgmental sample locations

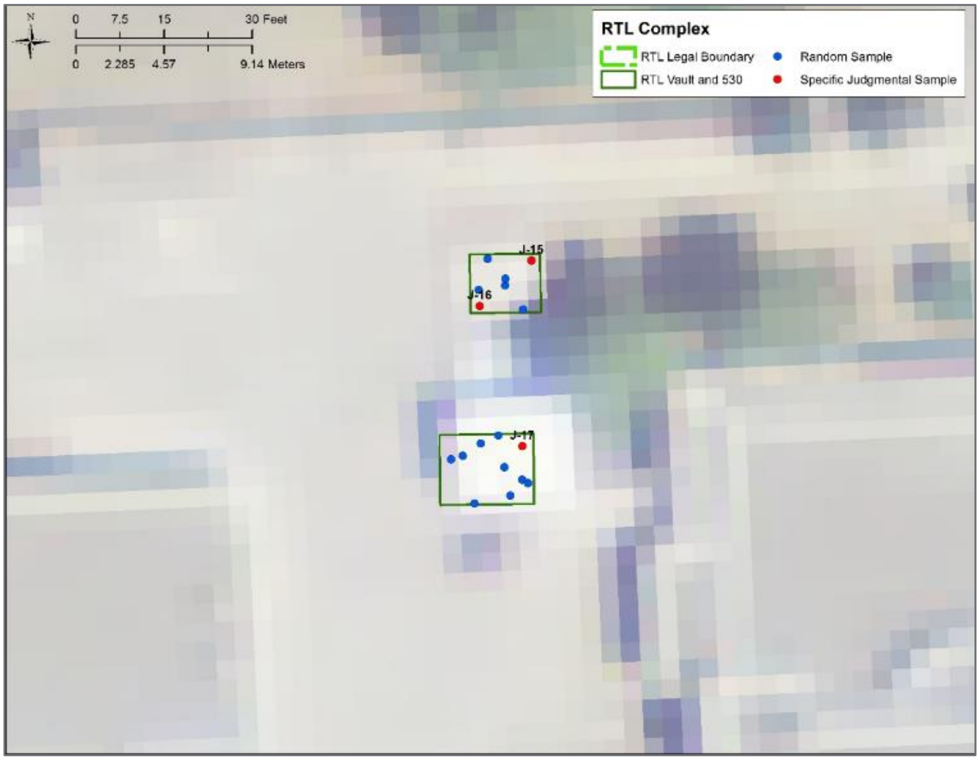

Figure A.5. RTL tank vault and 530 footprint with random and specific judgmental sample locations

A.4 RTL 510, 524, 540, 550, 560, 570, 580, and 590 Building Footprints

Table A.4 presents the 14 random sample locations for the RTL 510, 524, 540, 550, 560, 570, 580, and 590 building footprints (OB) survey unit. Figure A.6 shows the locations of the random samples and the specific judgmental samples.

Table A.4. Random sample locations for RTL 510, 524, 540, 550, 560, 570, 580, and 590 survey unit

Sample No.	Easting (X)	Northing (Y)	Sample No.	Easting (X)	Northing (Y)
OB-1	1949765.0400	368117.9036	OB-8	1949757.4508	368270.1985
OB-2	1949542.7348	368248.8214	OB-9	1949794.6441	368235.9419
OB-3	1949593.0247	368213.4933	OB-10	1949757.0279	368379.2574
OB-4	1949567.8798	368227.3174	OB-11	1949807.2775	368403.6350
OB-5	1949714.9347	368260.9722	OB-12	1949832.4022	368358.4913
OB-6	1949738.8542	368229.0905	OB-13	1949766.4497	368366.6172
OB-7	1949776.0474	368249.6445	OB-14	1950317.0872	368405.8925

Easting (X) and northing (Y) coordinates presented in NAD 1983 Washington State Plane South (4602) in feet (EPSG 2286).

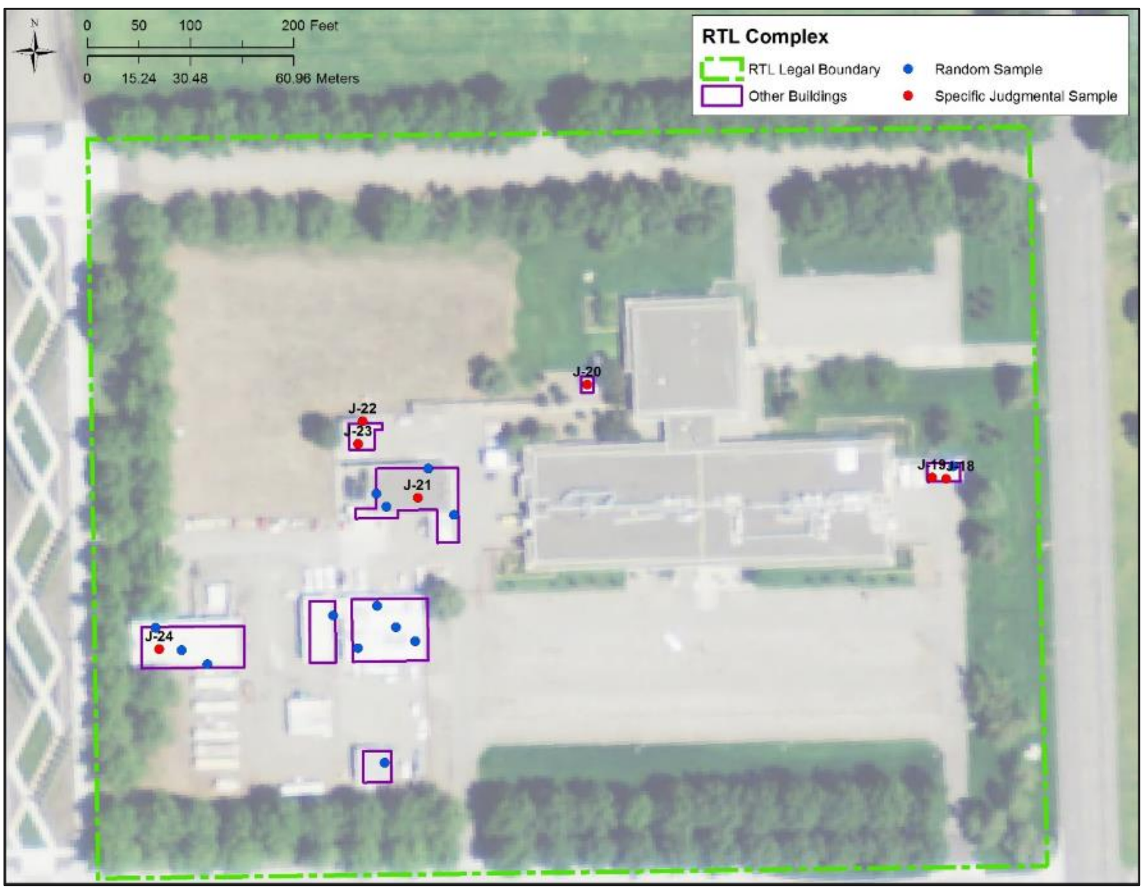

Figure A.6. RTL 510, 524, 540, 550, 560, 570, 580, and 590 building footprint with random and specific judgmental sample locations

A.5 Pipelines

Table A.5 presents the 14 random sample locations for the pipelines (PL) survey unit. Figure A.7 shows the locations of the random samples and the specific judgmental samples.

Table A.5. Random sample locations for the pipelines survey unit

Sample No.	Easting (X)	Northing (Y)	Sample No.	Easting (X)	Northing (Y)
PL-1	1949856.8567	368419.8214	PL-8	1949987.0934	368419.1778
PL-2	1949765.7089	368431.4069	PL-9	1949674.5864	368445.2450
PL-3	1949948.0046	368425.6142	PL-10	1949863.3927	368424.9705
PL-4	1949948.0300	368441.0614	PL-11	1949724.5007	368294.6343
PL-5	1949765.7343	368423.6832	PL-12	1949811.3082	368428.8323
PL-6	1949921.9878	368417.8905	PL-13	1949941.5194	368446.2105
PL-7	1949713.6498	368443.9578	PL-14	1949889.4350	368440.4178

Easting (X) and northing (Y) coordinates presented in NAD 1983 Washington State Plane South (4602) in feet (EPSG 2286).

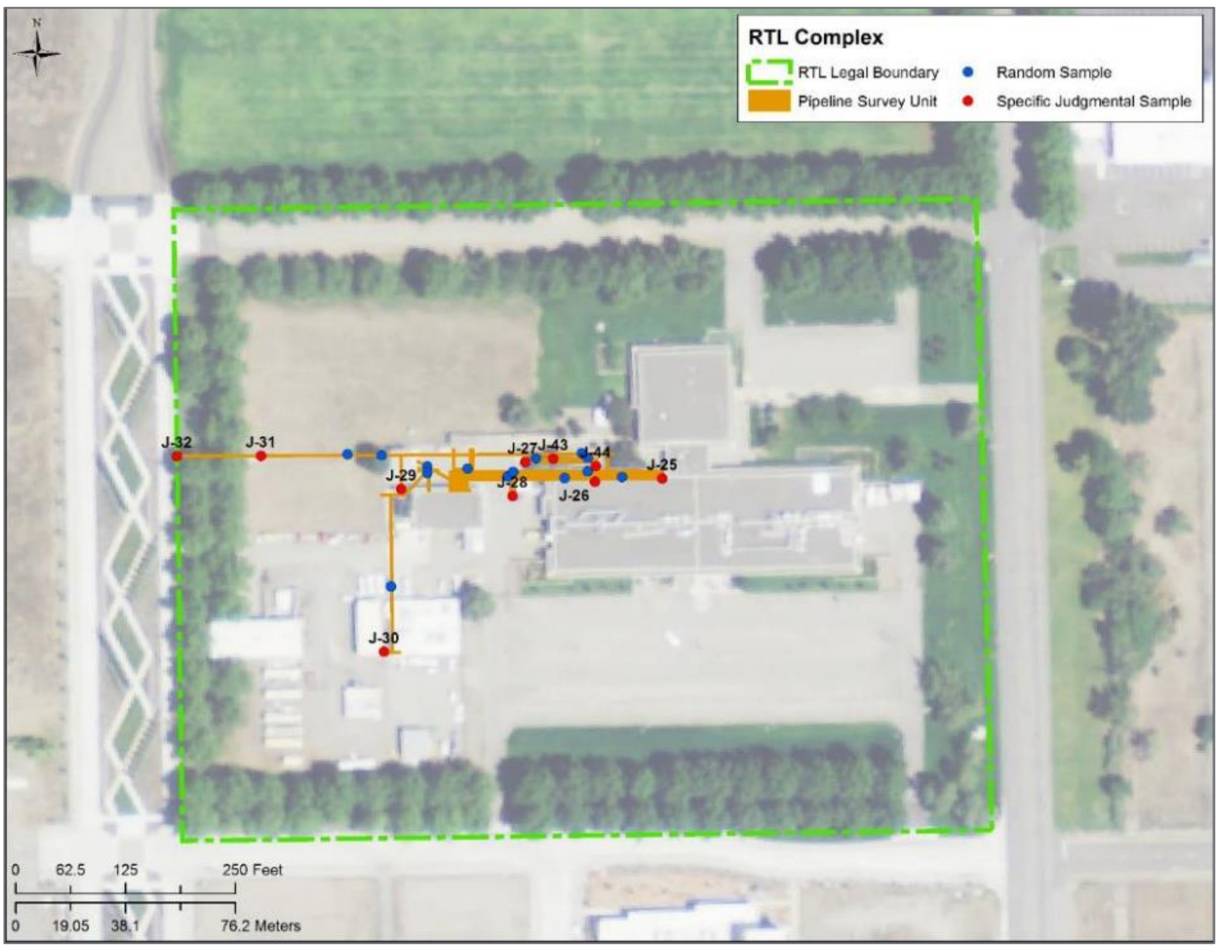

Figure A.7. Pipelines survey unit with random and specific judgmental sample locations

A.6 Paved Areas

Table A.6 presents the 14 random sample locations for the paved areas (PA) survey unit. Figure A.8 shows the locations of the random samples and the specific judgmental samples.

Table A.6. Random sample locations for the paved areas survey unit

Sample No.	Easting (X)	Northing (Y)	Sample No.	Easting (X)	Northing (Y)
PA-1	1950231.7815	368284.4718	PA-8	1950260.4979	368706.3693
PA-2	1949887.1852	368363.5776	PA-9	1950145.6324	368266.8927
PA-3	1949973.3343	368442.6833	PA-10	1949729.2453	368187.7869
PA-4	1949743.6034	368680.0007	PA-11	1949844.1107	368293.2613
PA-5	1949628.7380	368310.8404	PA-12	1950303.5724	368530.5786
PA-6	1949858.4689	368152.6288	PA-13	1950246.1397	368214.1555
PA-7	1950030.7670	368231.7346	PA-14	1950131.2742	368688.7902

Easting (X) and northing (Y) coordinates presented in NAD 1983 Washington State Plane South (4602) in feet (EPSG 2286).

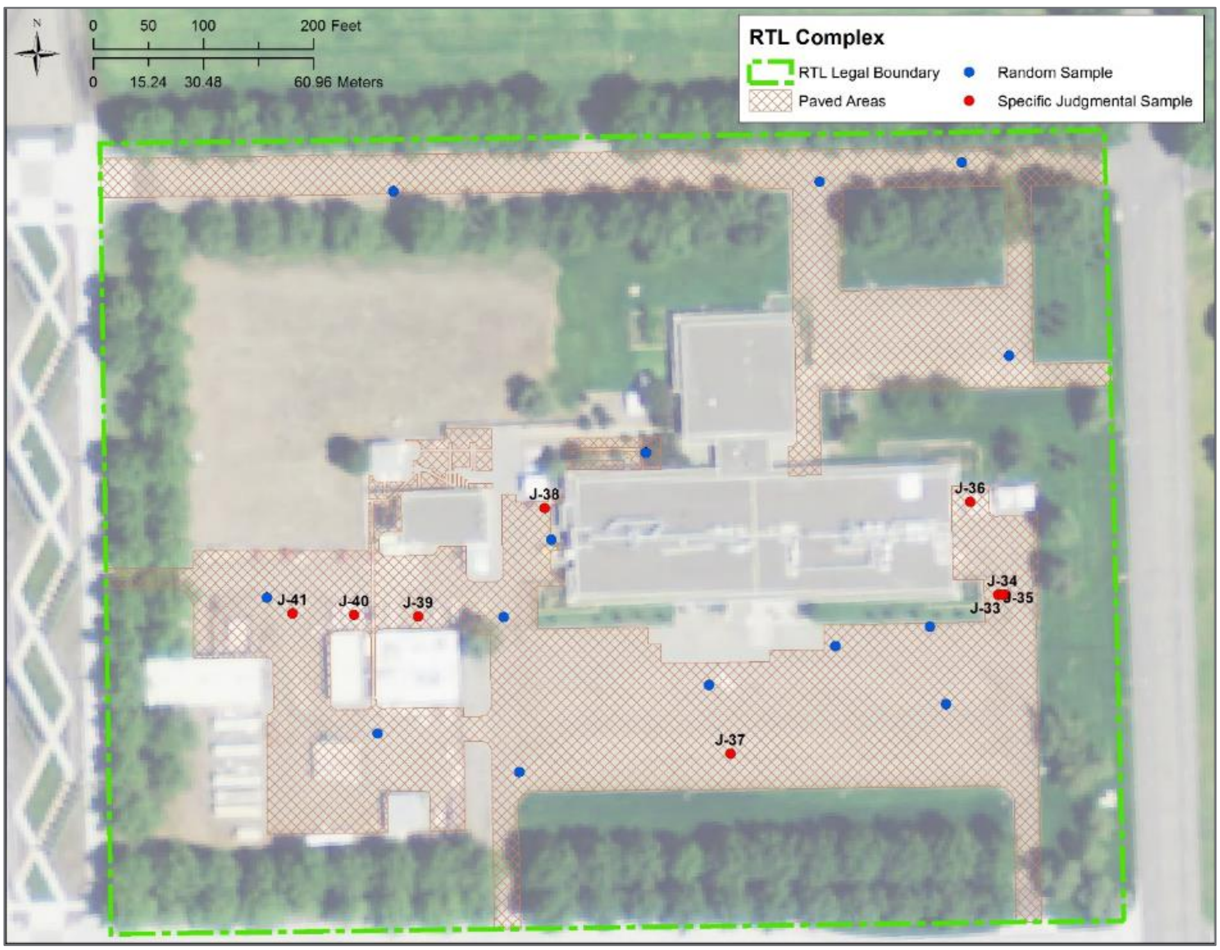

Figure A.8. Paved areas with random and specific judgmental sample locations

A.7 Open Areas

Table A.7 presents the 14 random sample locations for the open areas (OA) survey unit. Figure A.9 shows the locations of the random samples and the specific judgmental samples.

Table A.7. Random sample locations for the open areas survey unit

Sample No.	Easting (X)	Northing (Y)	Sample No.	Easting (X)	Northing (Y)
OA-1	1950216.7023	368095.7960	OA-8	1949495.9811	368583.5734
OA-2	1950046.8813	368054.7988	OA-9	1949653.2461	368507.0816
OA-3	1949520.3809	368043.5373	OA-10	1949967.7761	368621.8193
OA-4	1949784.9541	368078.4155	OA-11	1949574.6136	368430.5898
OA-5	1949564.4764	368183.0502	OA-12	1949889.1436	368545.3275
OA-6	1950333.9806	368453.5404	OA-13	1950212.6965	368678.7106
OA-7	1950403.1745	368201.4085	OA-14	1949560.7599	368720.6433

Easting (X) and northing (Y) coordinates presented in NAD 1983 Washington State Plane South (4602) in feet (EPSG 2286).

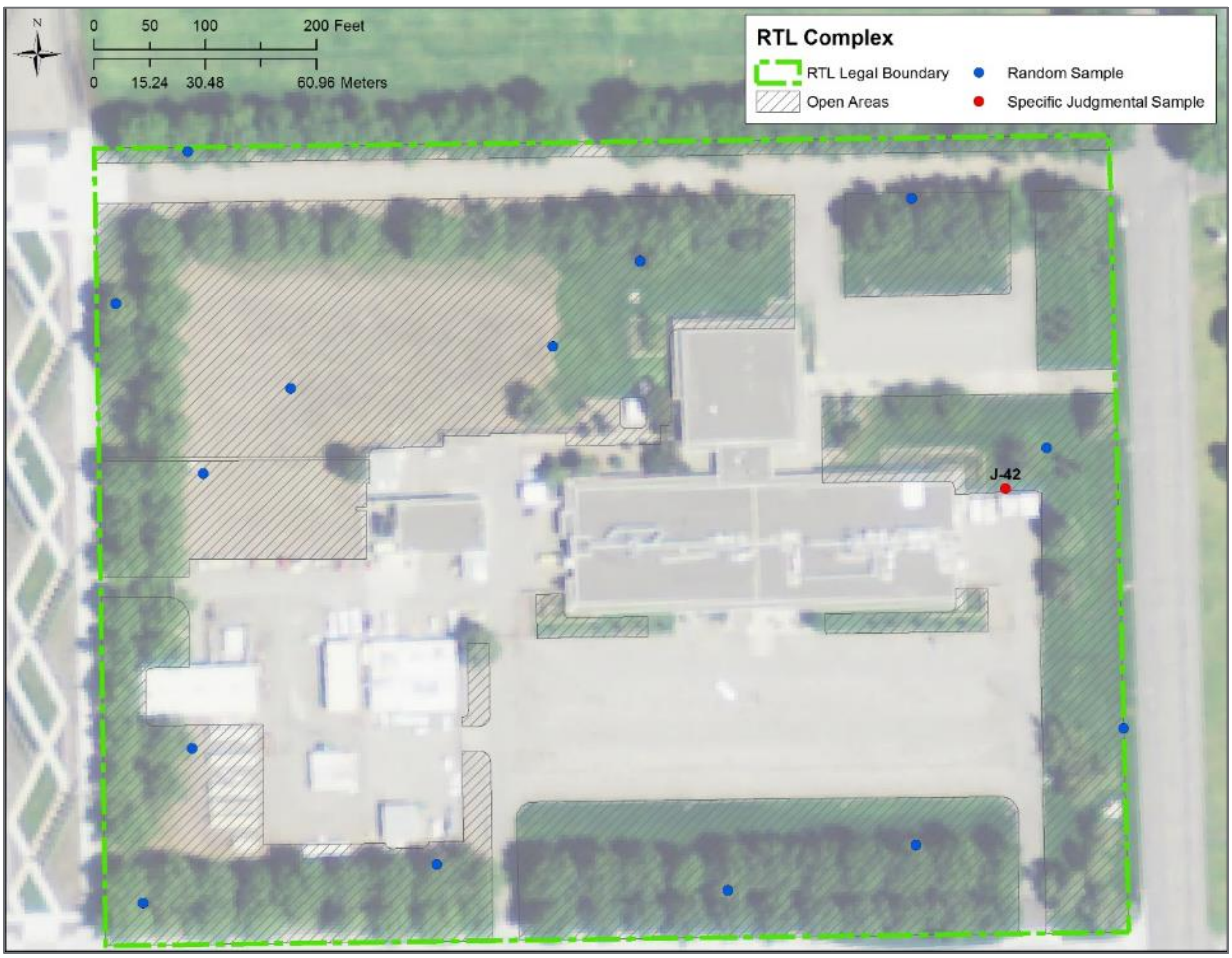

Figure A.9. Open areas with random and specific judgmental sample locations

A.8 References

Biebesheimer FH, HF Kerschner, LJ Oukrop, and MJ Minette. 2016. *Research Technology Laboratory Complex Deactivation, Decontamination, Decommissioning, & Demolition Project Transition Plan*. S740277-PLAN-09, Rev., Pacific Northwest National Laboratory, Richland, Washington.

Biebesheimer FH. 2017. Memorandum from Fred Biebesheimer to “Skip” Kerschner. “Analysis of the RTL Complex East Tank Spill.” November 17, 2017. S740277-17-01, Pacific Northwest National Laboratory, Richland, Washington.

EPSG 2286. North American Datum (NAD) 1983 State Plane Washington South FIPS 4602 (US Feet).

McCoy MW. 1999. *Final Report on the Removal of Radioactive Liquid Waste Tanks from RTL*. Pacific Northwest Laboratory, Richland, Washington.

Matzke BD, Wilson JE, Newburn LL, Dowson ST, Hathaway JE, Sego LH, Bramer LM, and Pulsipher BA. 2014. *Visual Sample Plan Version 7.0 User's Guide*. PNNL-23211, Pacific Northwest National Laboratory, Richland, Washington. Available at https://vsp.pnnl.gov/.

NRC. 2000. *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM). NUREG-1575, Rev. 1; EPA 402-R-97-016, Rev. 1; DOE/EH-0624, Rev.1, U.S. Nuclear Regulatory Commission, Washington, D.C.

Appendix B – Layback Scoping Study Results

This appendix briefly summarizes the results from the layback scoping study to confirm the assumption that the soil piles created from the excavation of the Research Technology Laboratory (RTL) 520 building were non-impacted. Layback is the soil removed during excavation to create a slope upon which the soil will not fall back or collapse into the excavation area. The layback did not include soil from around the RTL 520 tank vault and excavated pipelines survey units, or from any other areas of known potential contamination sources.

Samples were collected and analyzed as described in the *Research Technology Laboratory (RTL) Disposition Program: Final Status Survey Plan* (FSS plan; Bunn et al. 2018) and the project memo "Scoping Study of the Layback Piles at the RTL Complex" (Bunn 2018). Laboratory results were independently validated (Level C) by Analytical Quality Associates. The maximum reported result for each of the radiological contaminant of potential concern (COPCs) are given in Table B.1.

In all cases, the maximum reported values are well below (by 30x or more) the action levels and release limits defined in the FSS plan (Bunn et al. 2018). Many of the maximums are associated with a quality flag (U flag) in Table B.1 to identify results that were less than method detection limits. Figure B.1 presents reported values for each radionuclide on a lognormal scale to show the range of concentrations relative to the associated action levels and release limits. Results were below both release limits and action levels. These results confirm assumptions that the layback piles do not contain COPCs above the release limits for the disposition of the RTL Complex, and can be used to backfill the excavated areas that are cleared for unrestricted use in accordance with the *Battelle Facilities Restoration Program Management Plan Volume I* and the *Battelle Facilities Restoration Program Management Plan, Volume II – RTL Complex Disposition Program* (Smoter and Biebesheimer 2017; Biebesheimer 2018).

Table B.1. Maximum concentrations reported from layback scoping study

Radiological COPC (pCi/g)	Release Limit	Action Level	Maximum Concentration for All Layback Pile Samples	Quality Flag
Plutonium-238	800	600	0.00889	U
Plutonium-239/240	740	555	0.032	U
Plutonium-241	30,000	22,500	1.55	U
Uranium-234[(a)]	700	525	0.206	-
Uranium-235[(b)]	60	45	0.0251	U
Uranium-238	280	210	0.201	-
Cobalt-60	3.7	2.8	0.0932	U
Sum of Fractions			0.0267	

U = less than detection limit.
(a) Analytical result reported as uranium-233/234.
(b) Analytical result reported as uranium-235/236.

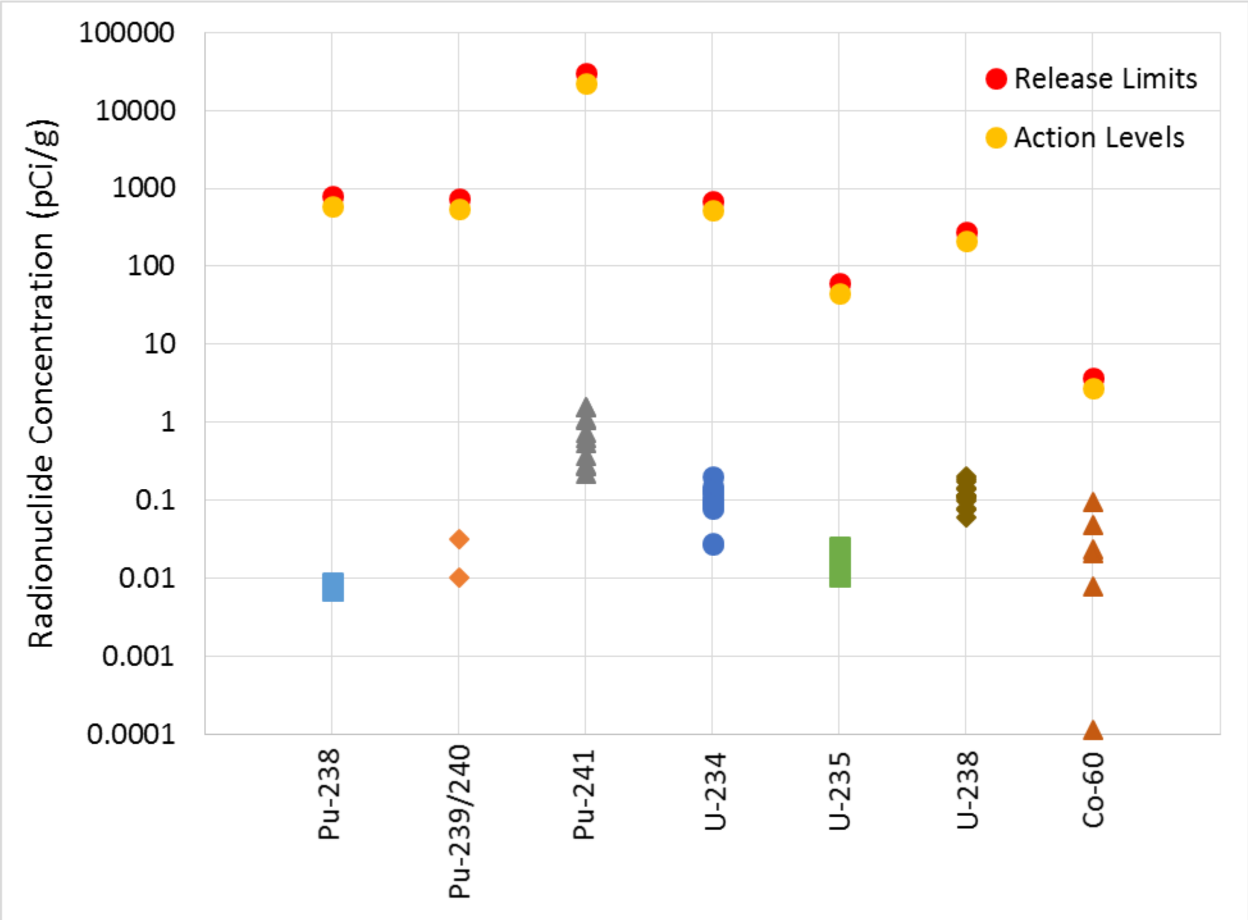

Figure B.1. Lognormal plot indicating that radionuclide concentrations are below the action levels and release limits for the layback samples

References

Biebesheimer FH. 2018. *Battelle Facilities Restoration Program Management Plan, Volume II – RTL Complex Disposition Program*. S740277-PLAN-12, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

Bunn AL. 2018. Memorandum from Amoret Bunn to Harrison Kerschner and Elizabeth Golovich. “Scoping Study of the Layback Piles at the RTL Complex.” October 31, 2018. S740277-18-04, Pacific Northwest National Laboratory, Richland, Washington.

Bunn AL, JK Snelling, and AM Gorton. 2018. *RTL Disposition Program Final Status Survey Plan.* S740277-PLAN-14. Pacific Northwest National Laboratory. Richland, Washington.

Smoter RL and FH Biebesheimer. 2017. *Battelle Facilities Restoration Program Management Plan Volume I*. S697201-PLAN-PM-003, Rev. 2, Pacific Northwest National Laboratory, Richland, Washington.

Appendix C – Survey Results by Survey Unit

This appendix presents results from the final status survey by location on an image of the Research Technology Laboratory (RTL) Complex. The seven radiological contaminant of potential concern (COPCs) are depicted individually by survey unit in the sections below. Random sample locations are identified by round markers and judgmental sample locations are identified by triangle markers. Sample location coordinates are given in Appendix A. The figures in the sections below show that there are no observable trends in the concentrations across the survey unit (i.e., no increase in concentration toward a location).

C.1 520 Building Footprint Survey Unit

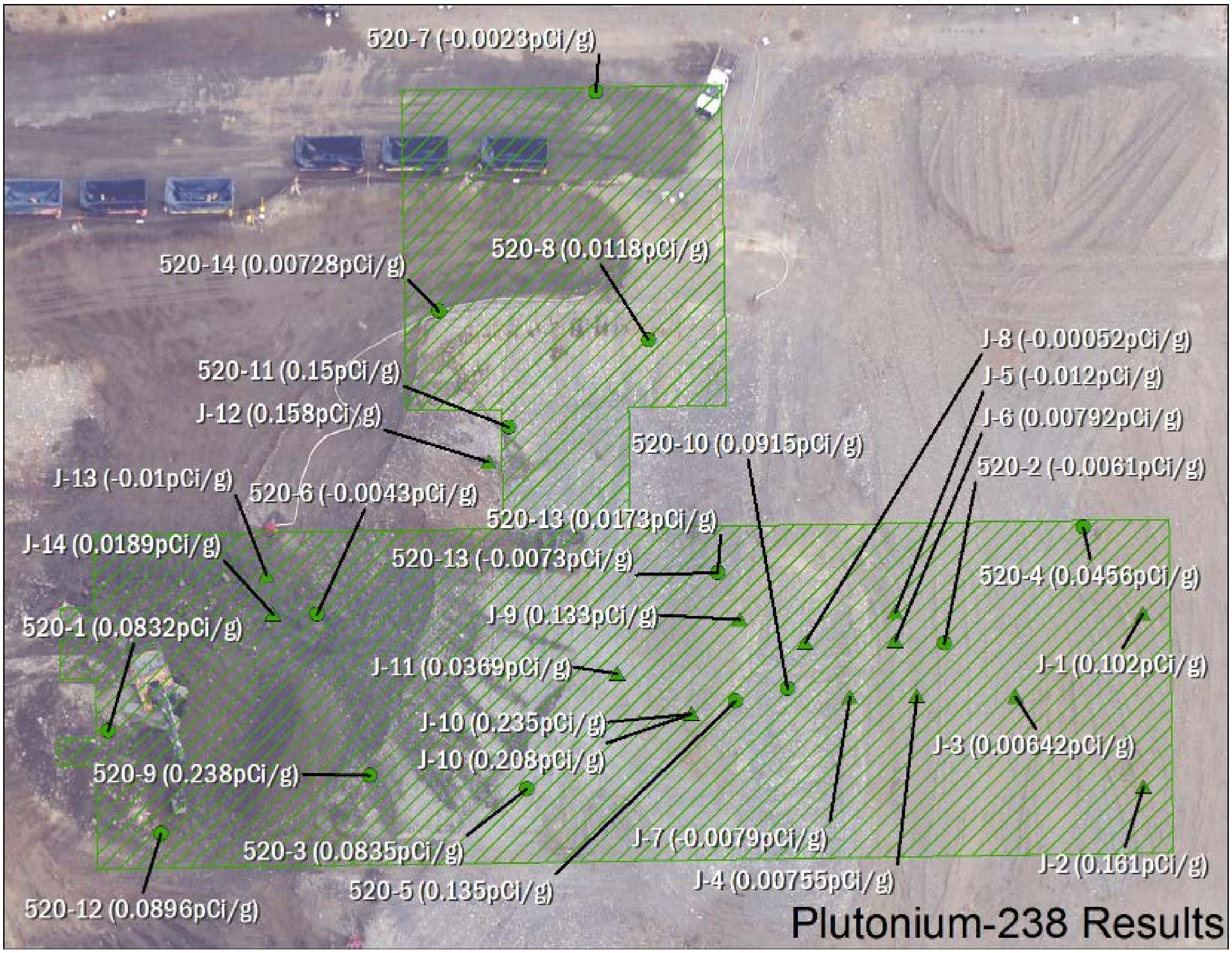

Figure C.1. Plutonium-238 results from sample locations within the 520 building footprint survey unit

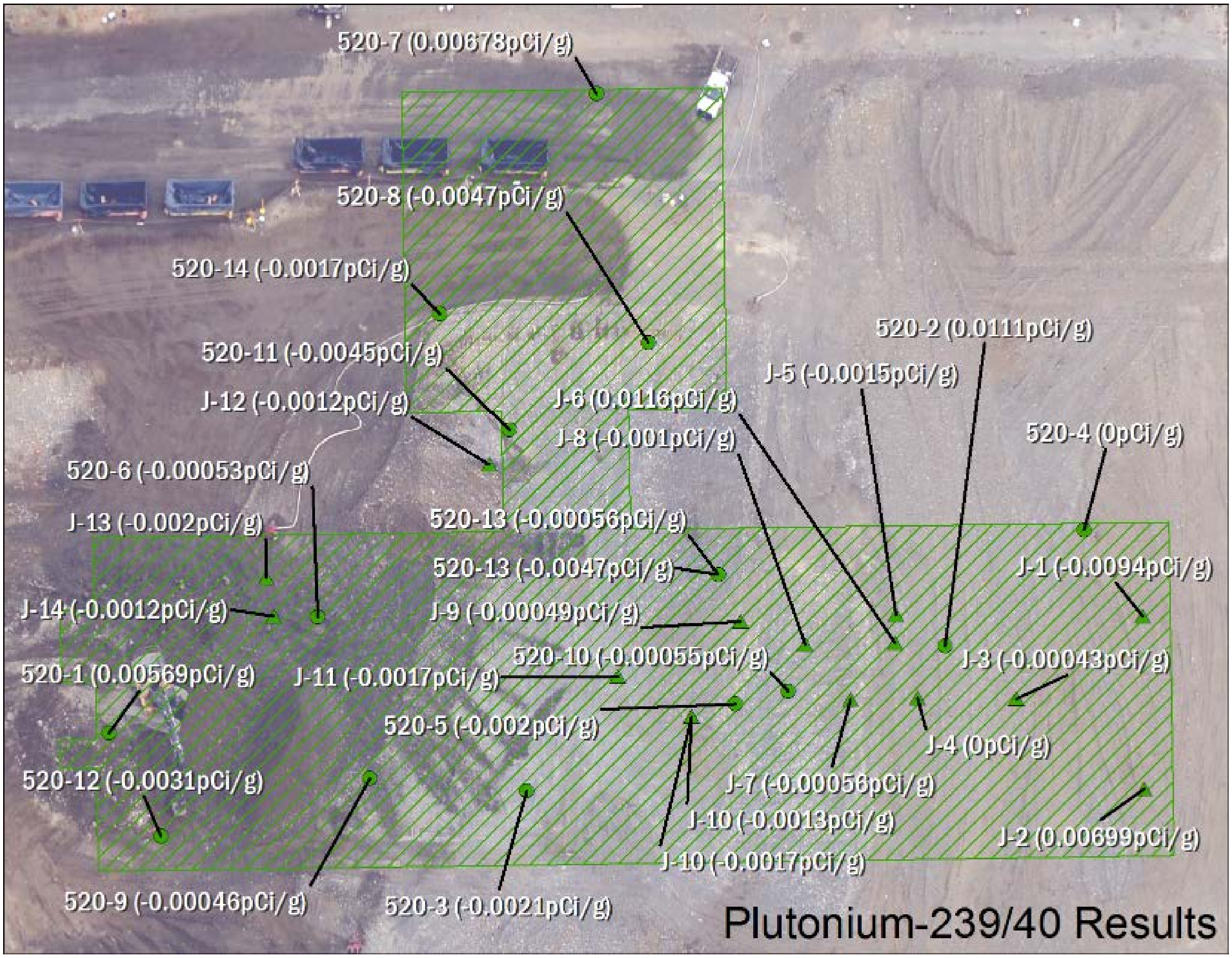

Figure C.2. Plutonium-239/240 results from sample locations within the 520 building footprint survey unit

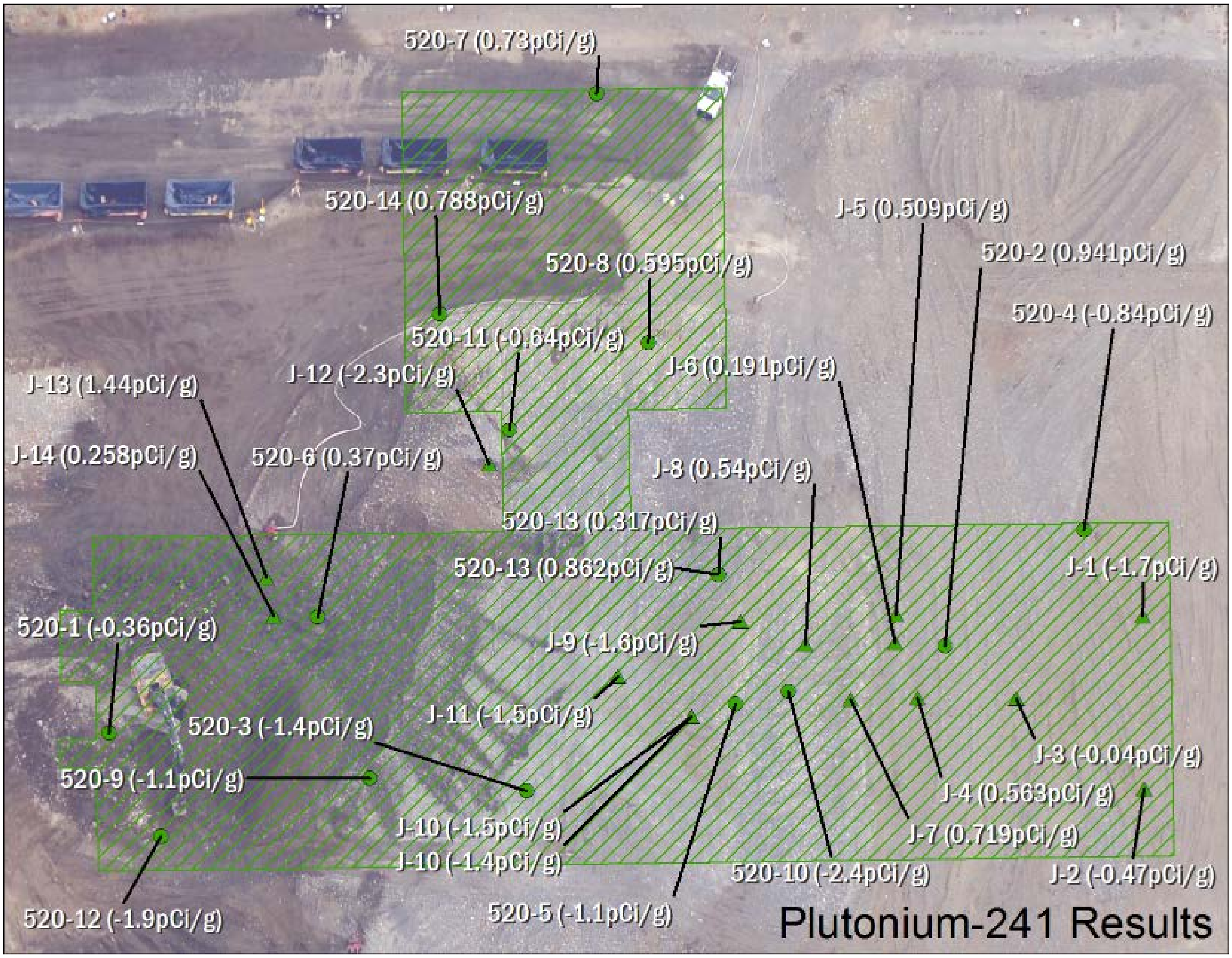

Figure C.3. Plutonium-241 results from sample locations within the 520 building footprint survey unit

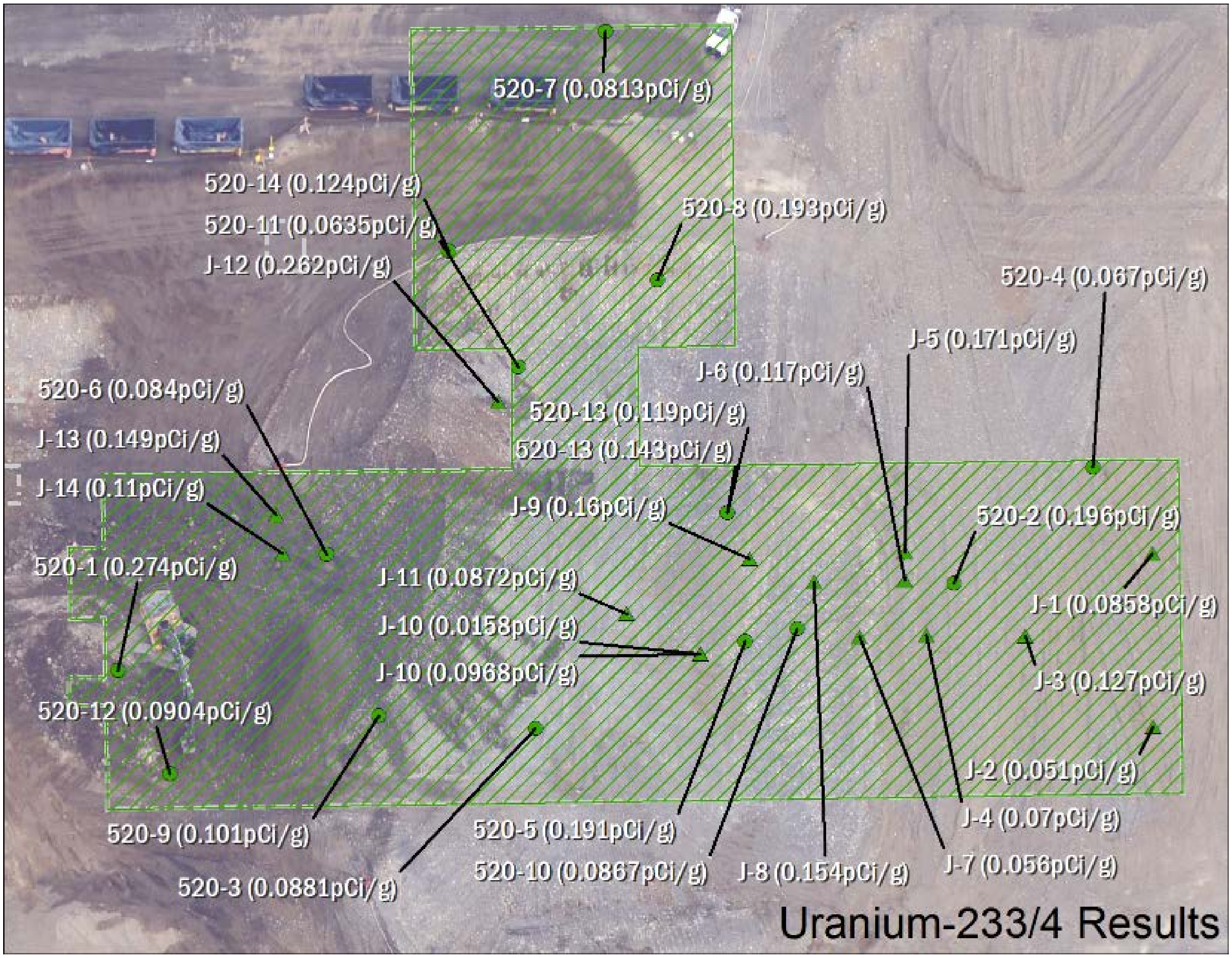

Figure C.4. Uranium-233/234 results from sample locations within the 520 building footprint survey unit

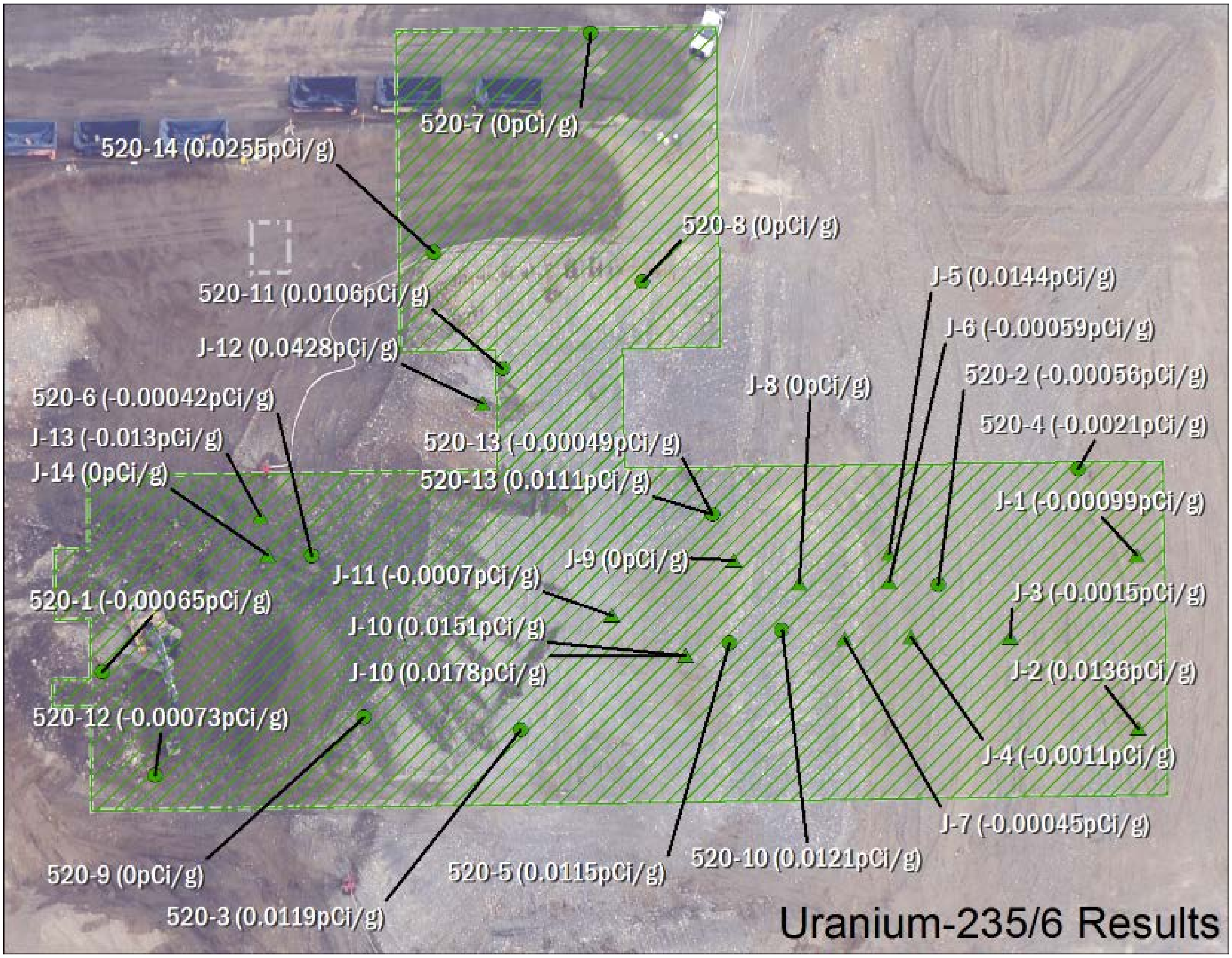

Figure C.5. Uranium-235/236 results from sample locations within the 520 building footprint survey unit

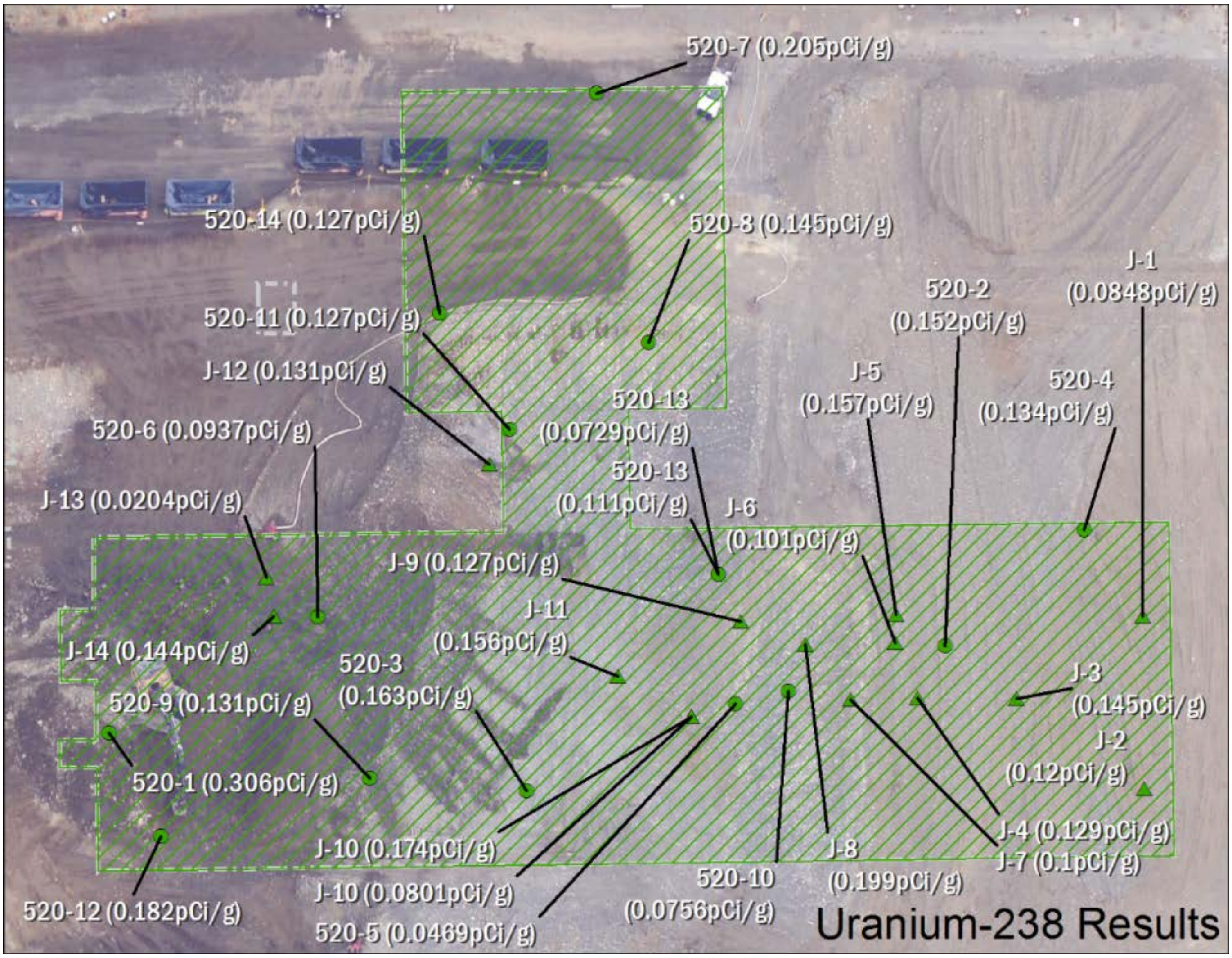

Figure C.6. Uranium-238 results from sample locations within the 520 building footprint survey unit

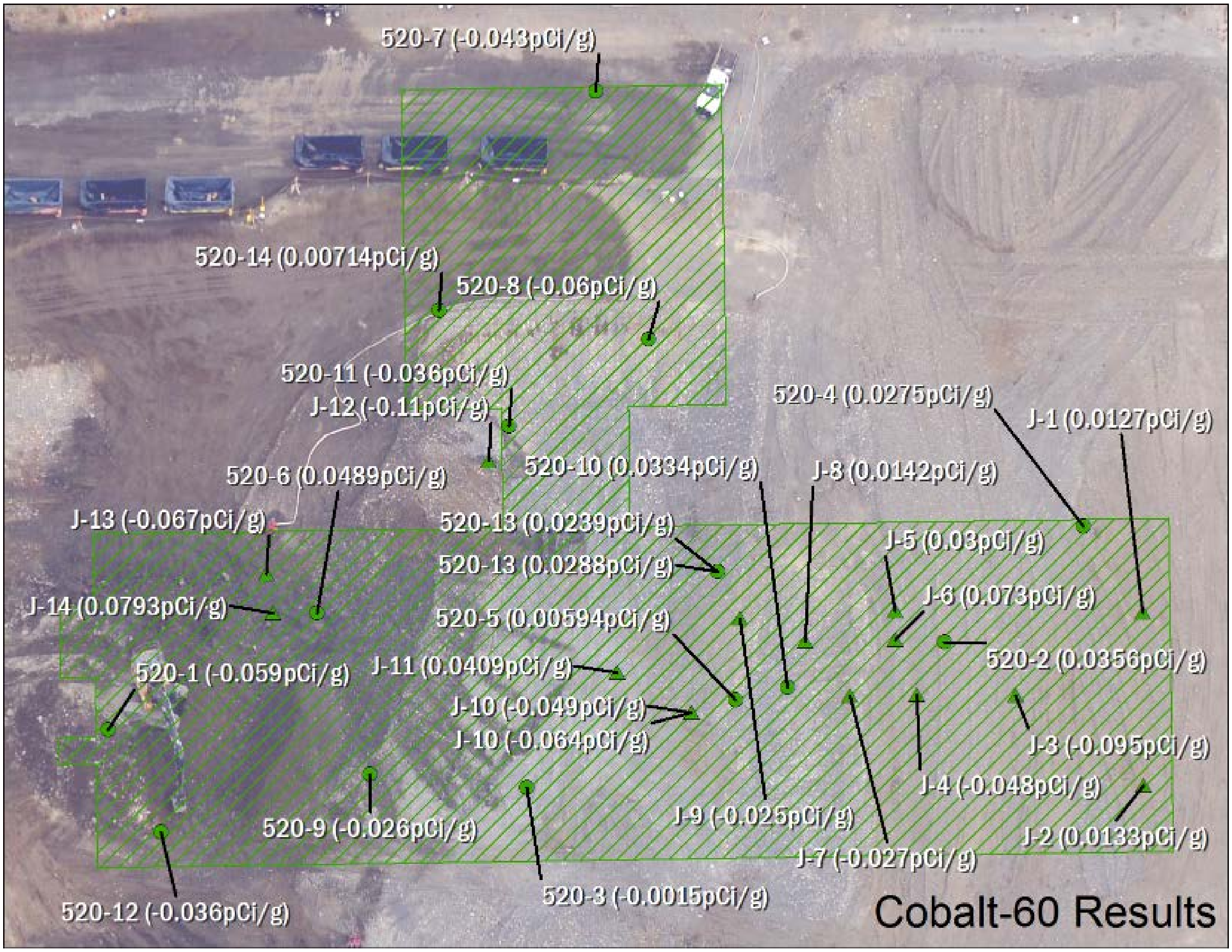

Figure C.7. Cobalt-60 results from sample locations within the 520 building footprint survey unit

C.2 Tank Vault and 530 Building Footprint Survey Unit

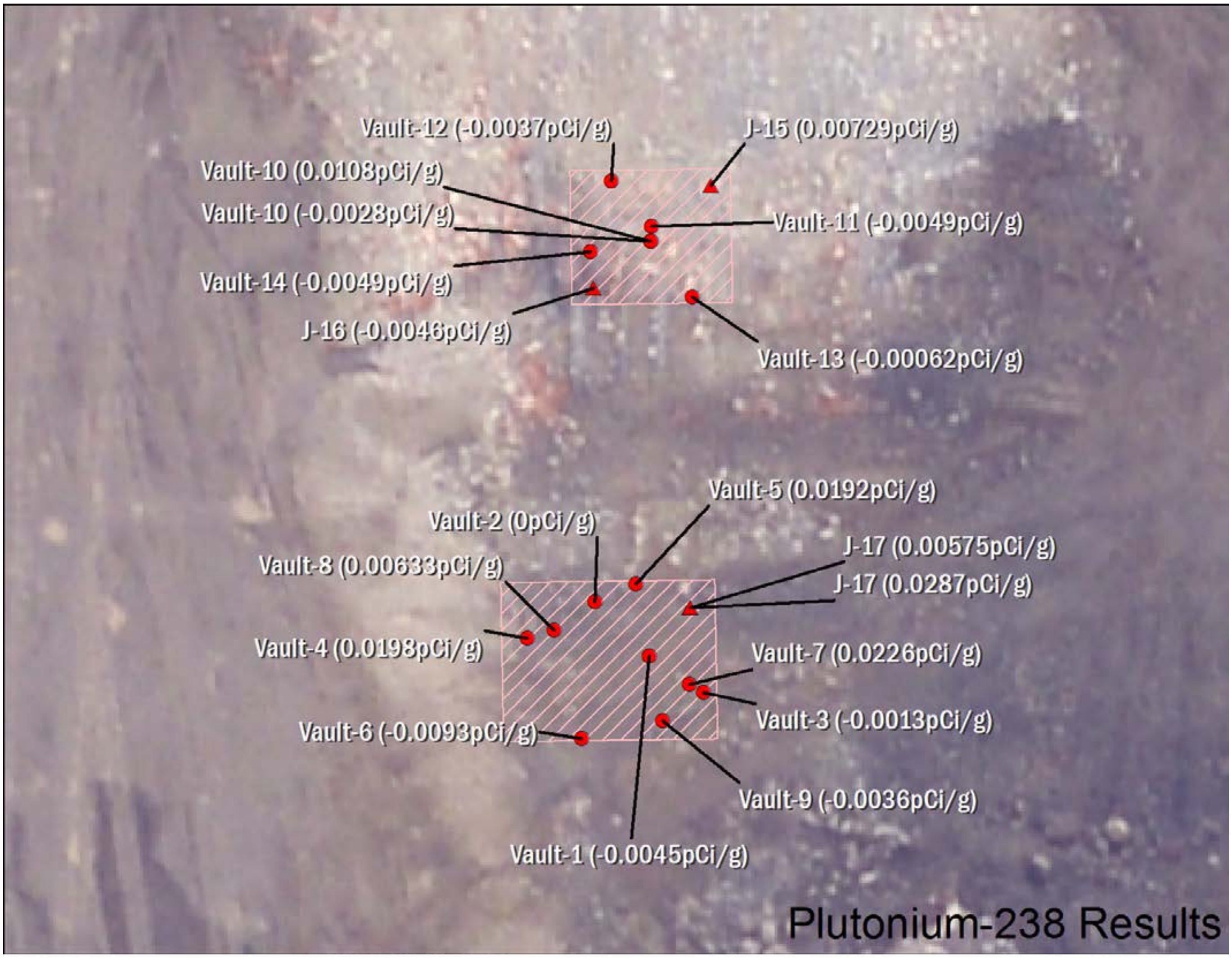

Figure C.8. Plutonium-238 results from sample locations within the tank vault and 530 building footprint survey unit

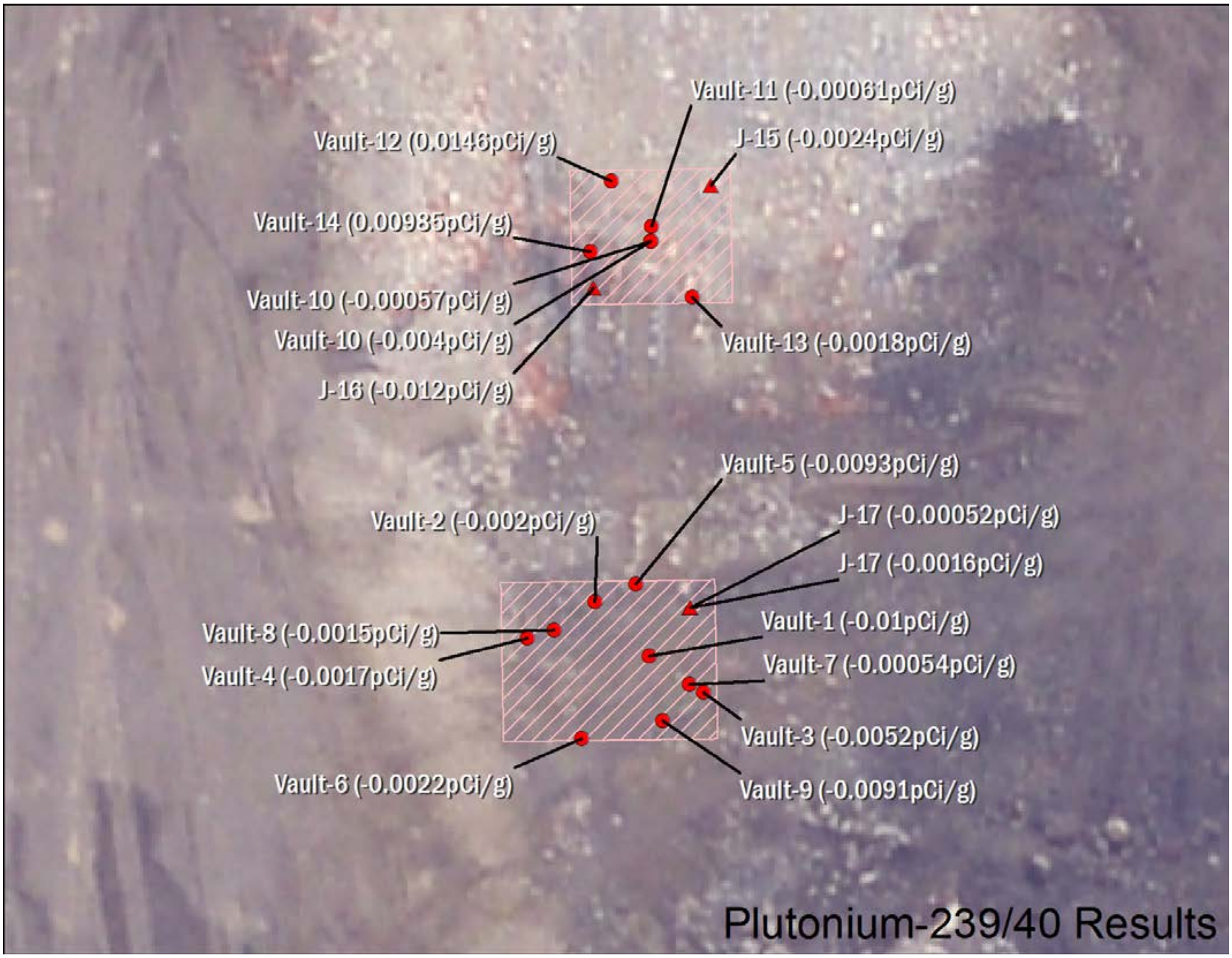

Figure C.9. Plutonium-239/240 results from sample locations within the tank vault and 530 building footprint survey unit

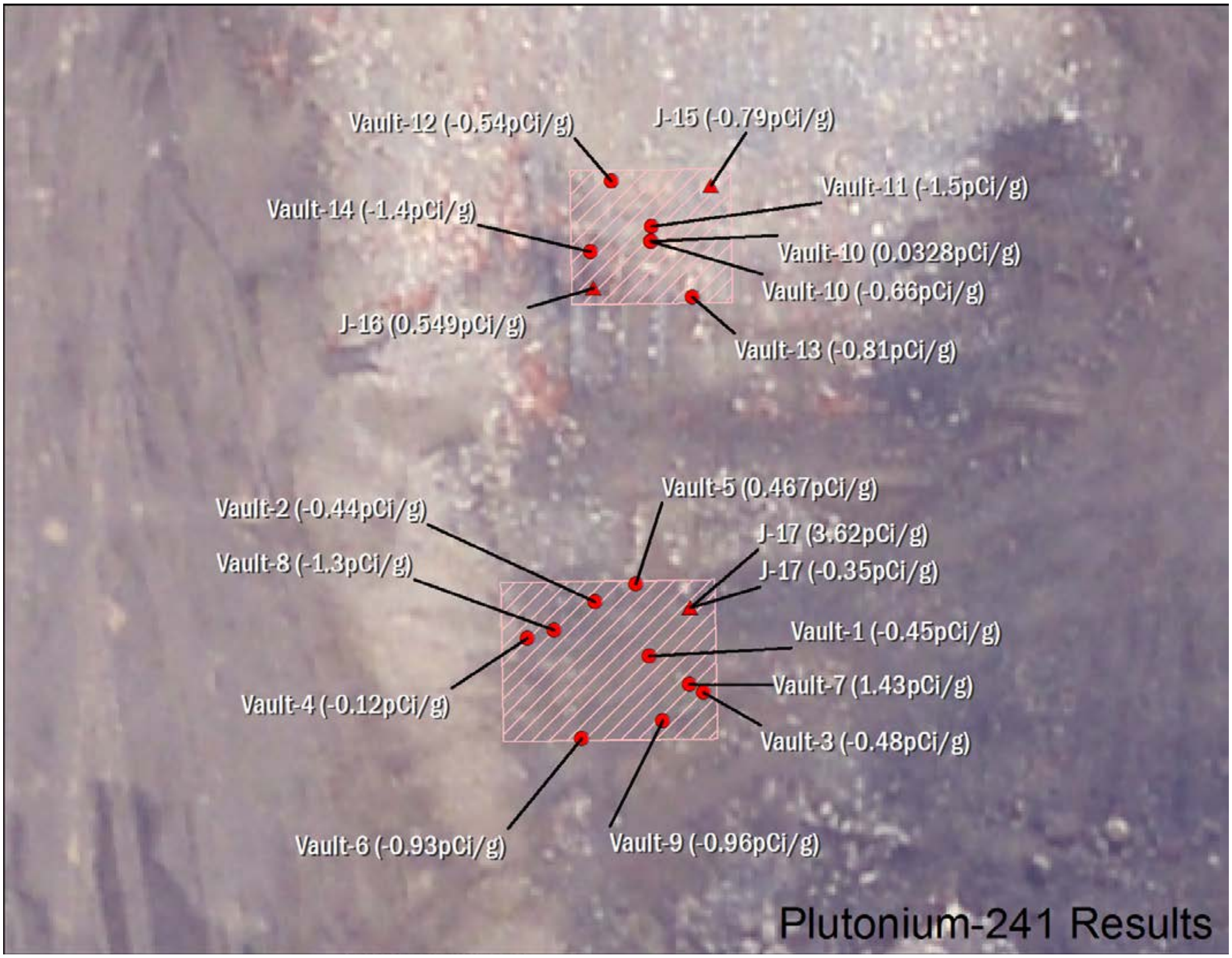

Figure C.10. Plutonium-241 results from sample locations within the tank vault and 530 building footprint survey unit

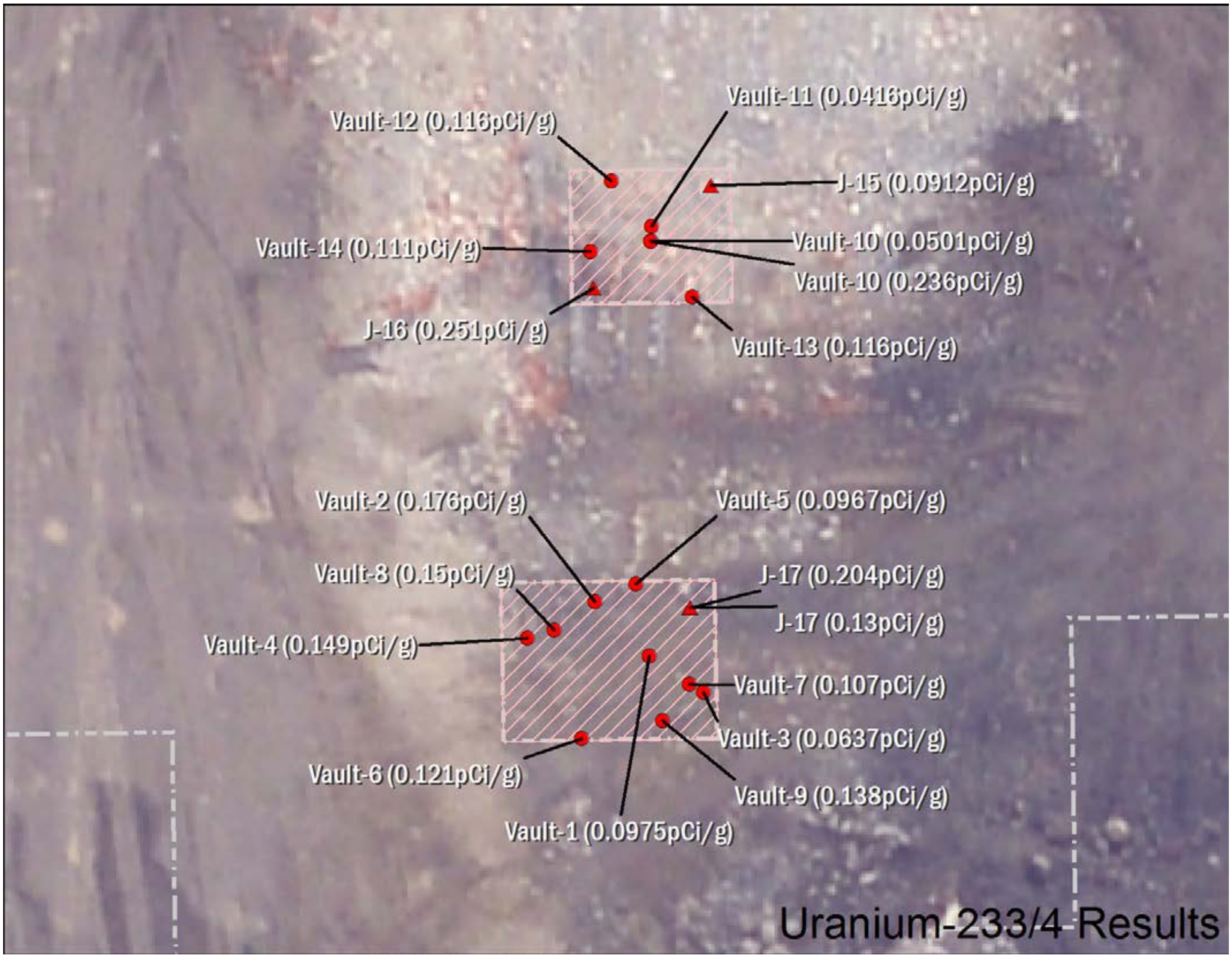

Figure C.11. Uranium-233/234 results from sample locations within the tank vault and 530 building footprint survey unit

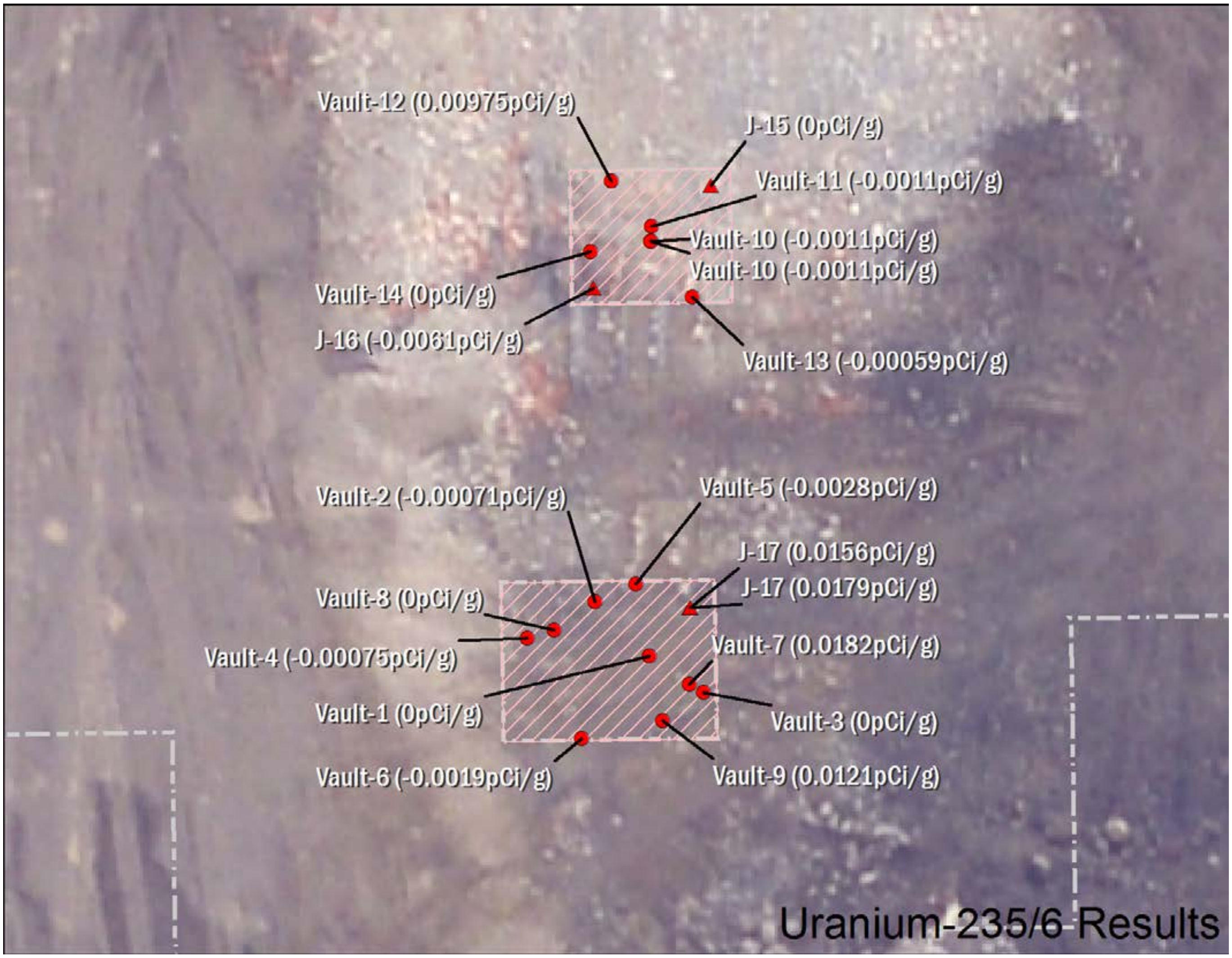

Figure C.12. Uranium-235/236 results from sample locations within the tank vault and 530 building footprint survey unit

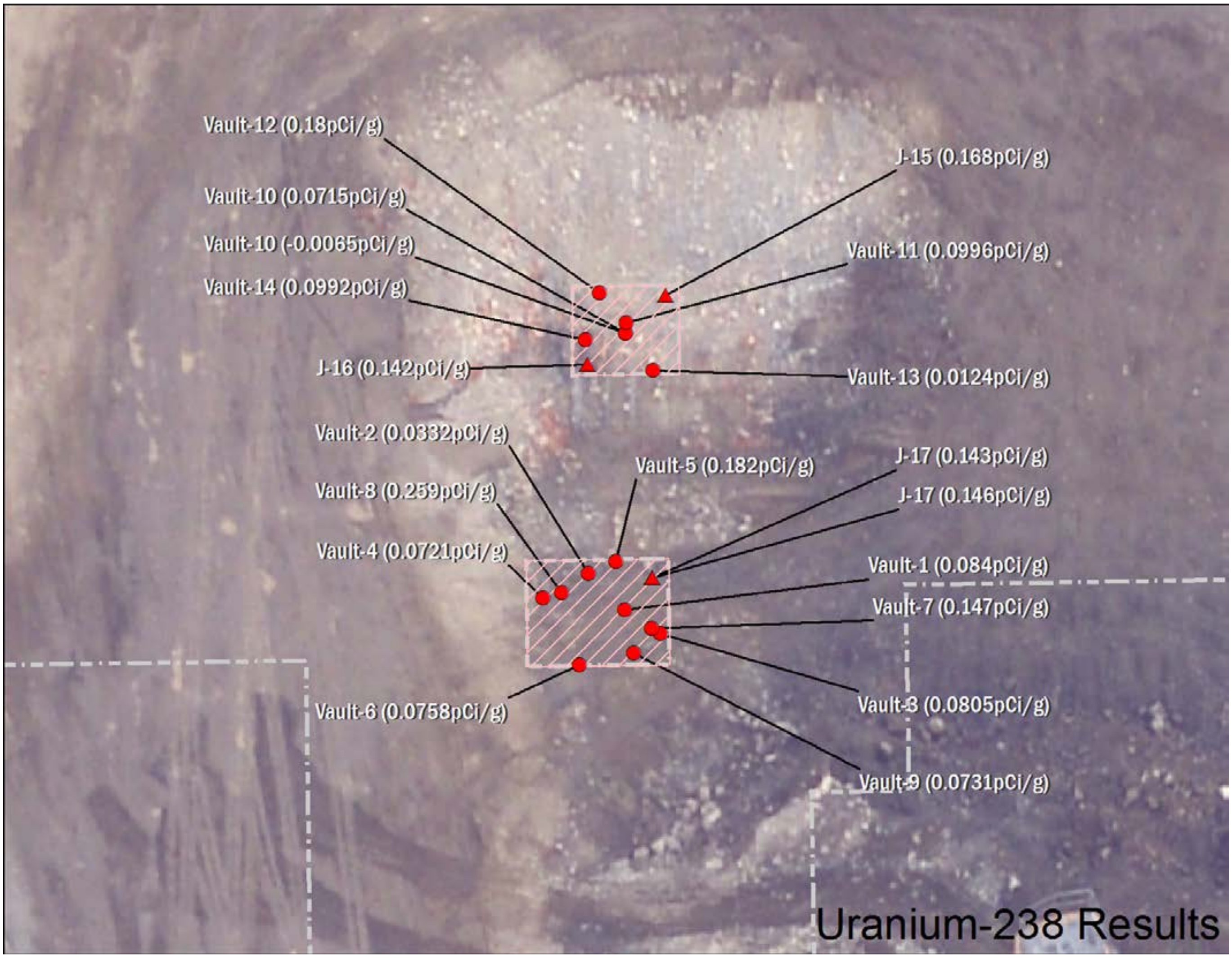

Figure C.13. Uranium-238 results from sample locations within the tank vault and 530 building footprint survey unit

Figure C.14. Cobalt-60 results from sample locations within the tank vault and 530 building footprint survey unit

C.3 Other Buildings Footprint Survey Unit

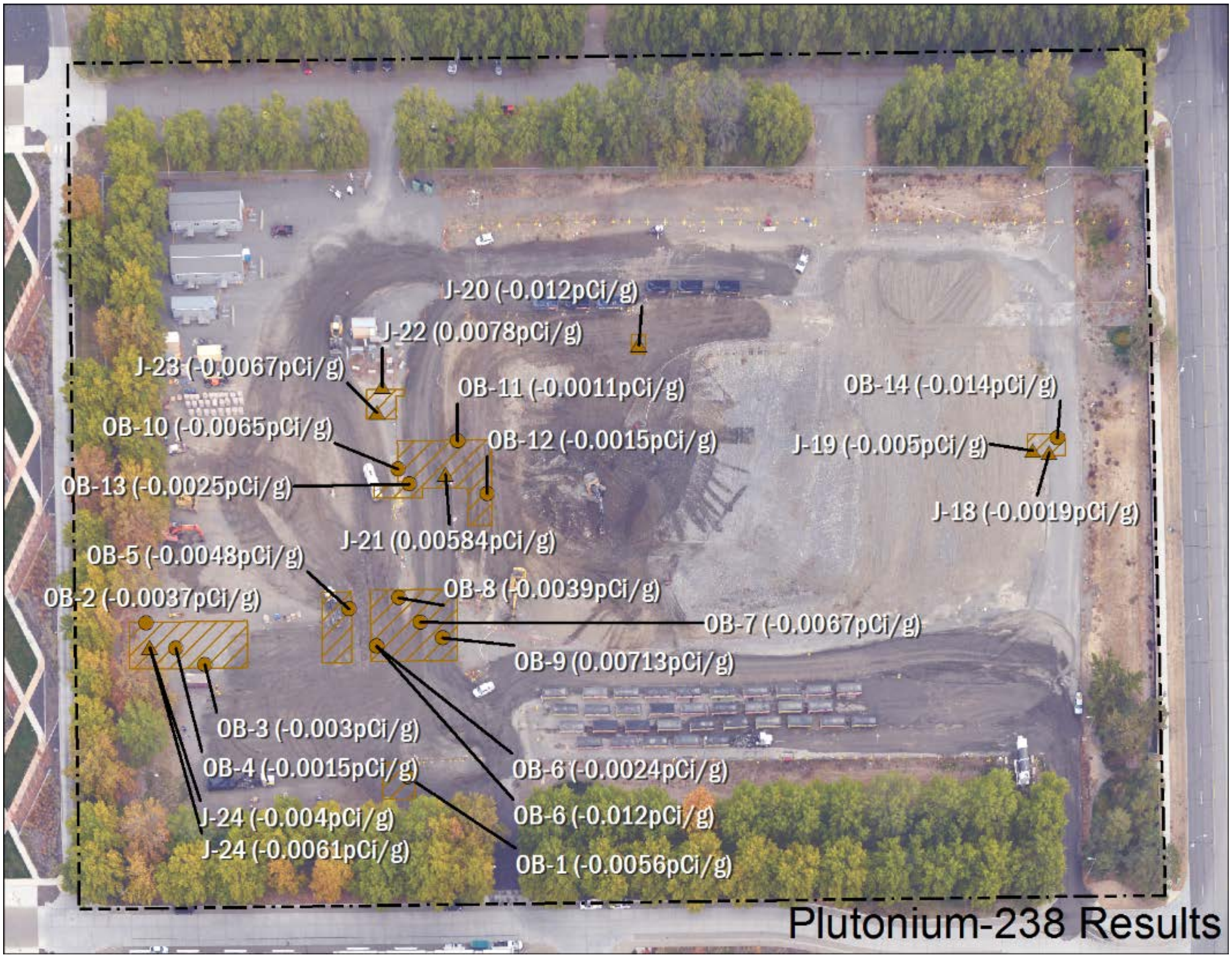

Figure C.15. Plutonium-238 results from sample locations within the other buildings footprint survey unit

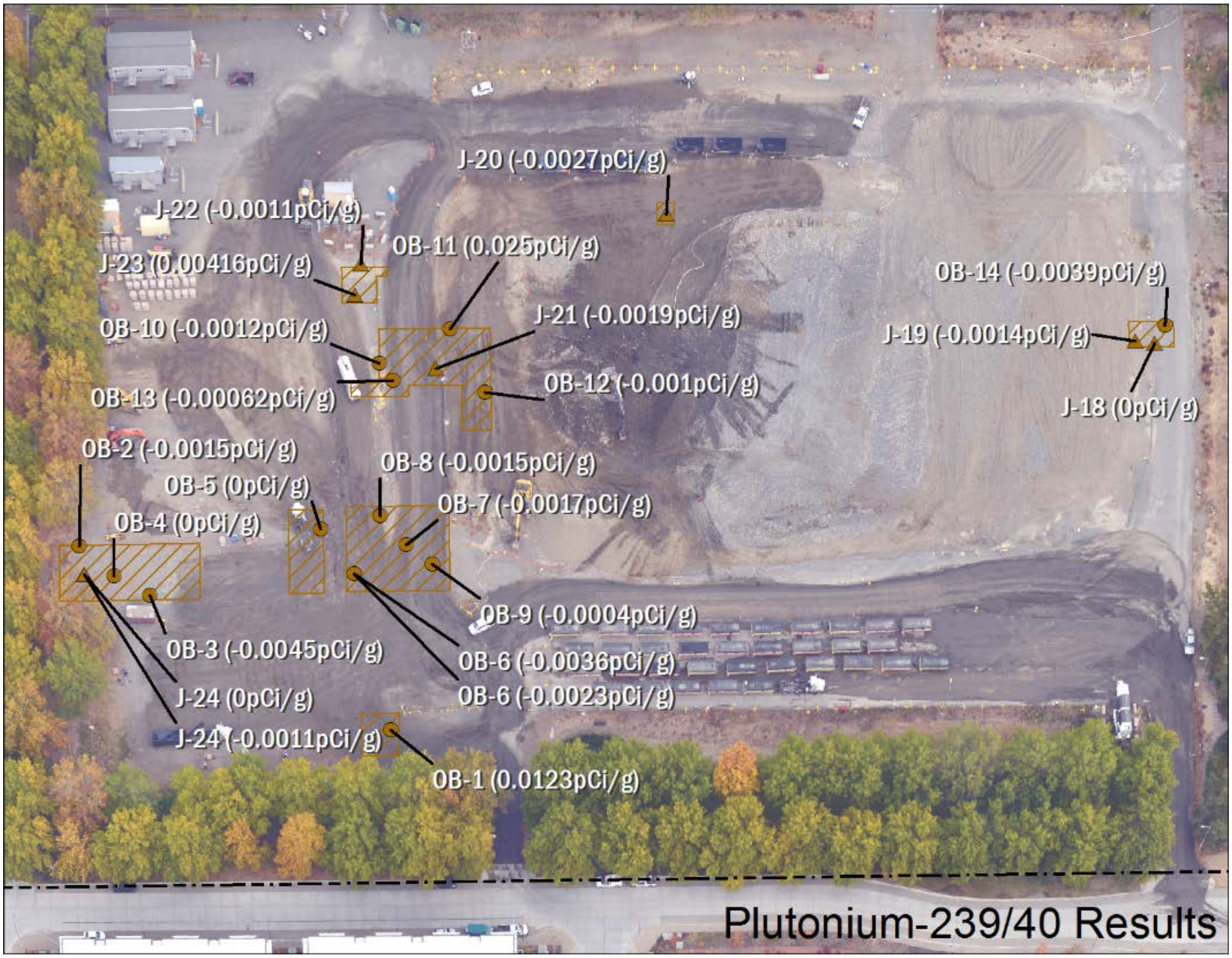

Figure C.16. Plutonium-239/240 results from sample locations within the other buildings footprint survey unit

Figure C.17. Plutonium-241 results from sample locations within the other buildings footprint survey unit

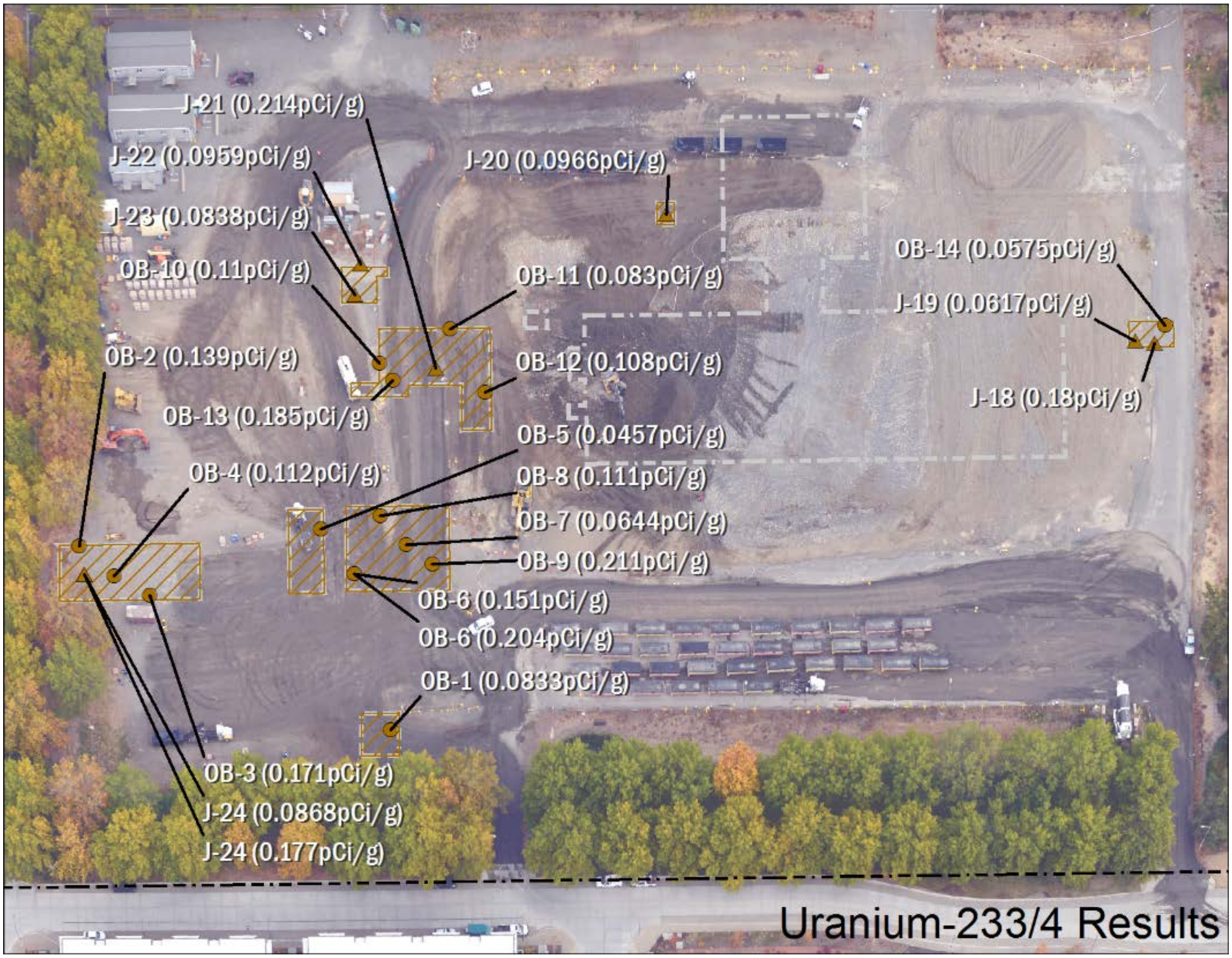

Figure C.18. Uranium-233/234 results from sample locations within the other buildings footprint survey unit

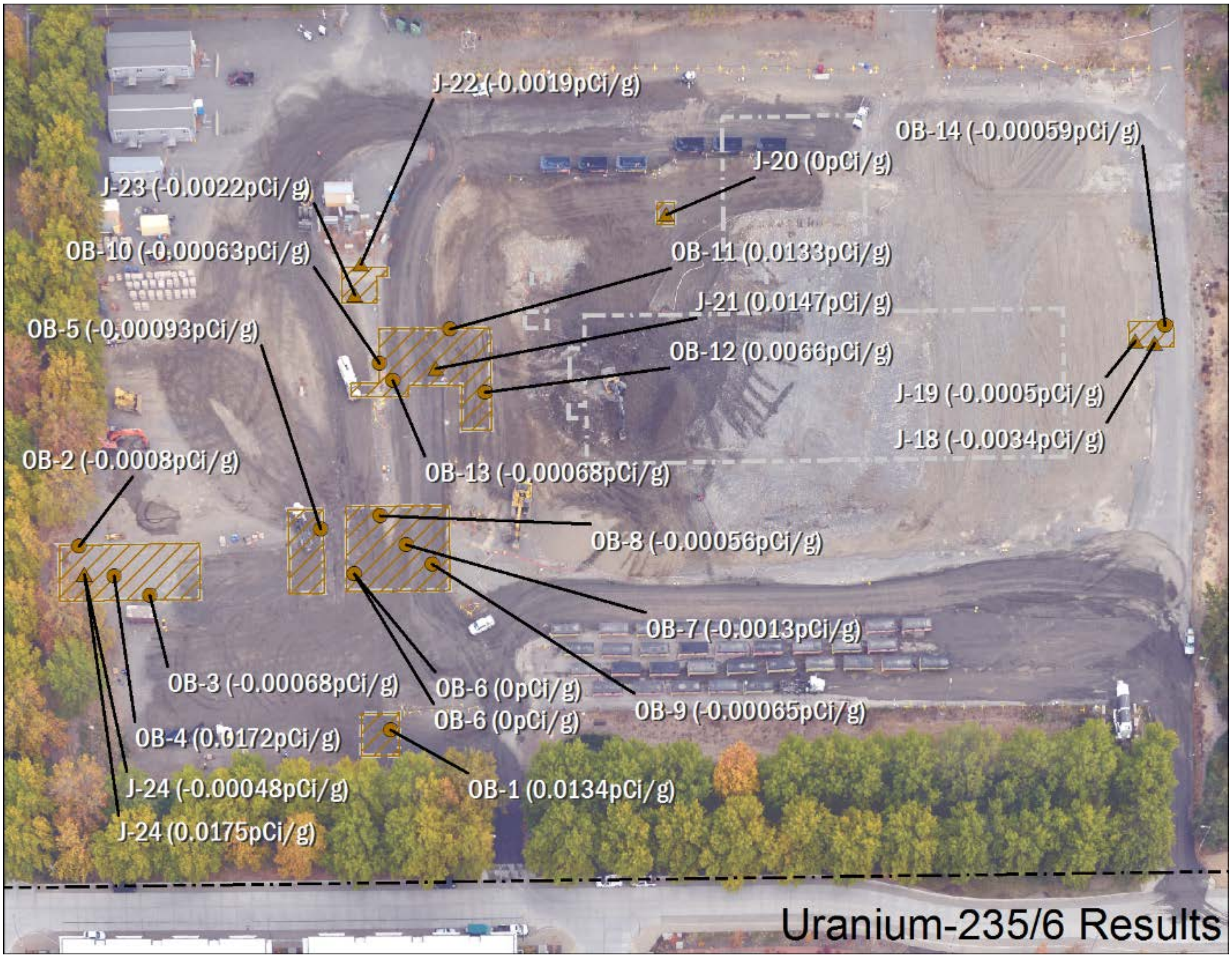

Figure C.19. Uranium-235/236 results from sample locations within the other buildings footprint survey unit

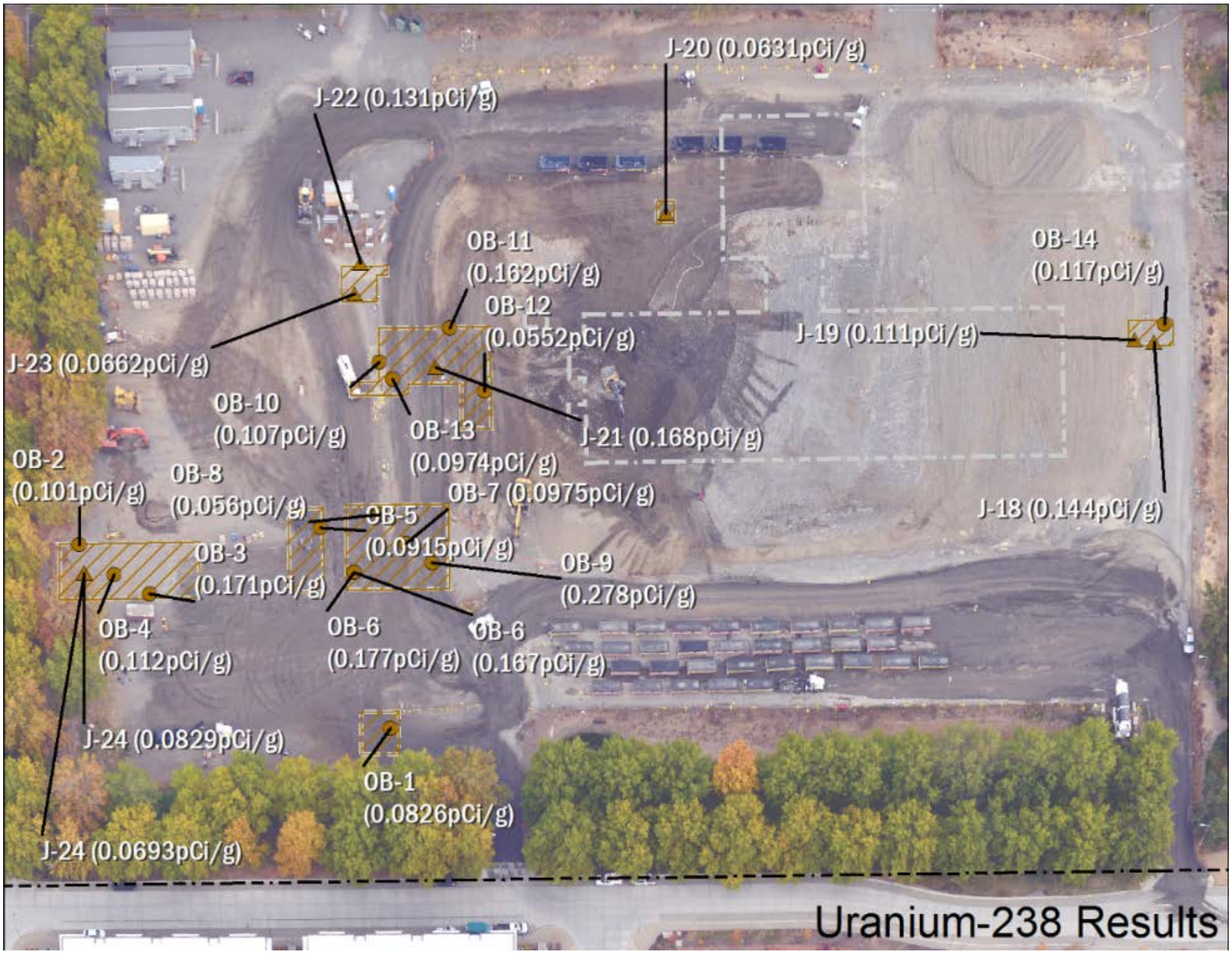

Figure C.20. Uranium-238 results from sample locations within the other buildings footprint survey unit

Figure C.21. Cobalt-60 results from sample locations within the other buildings footprint survey unit

C.4 Pipelines Survey Unit

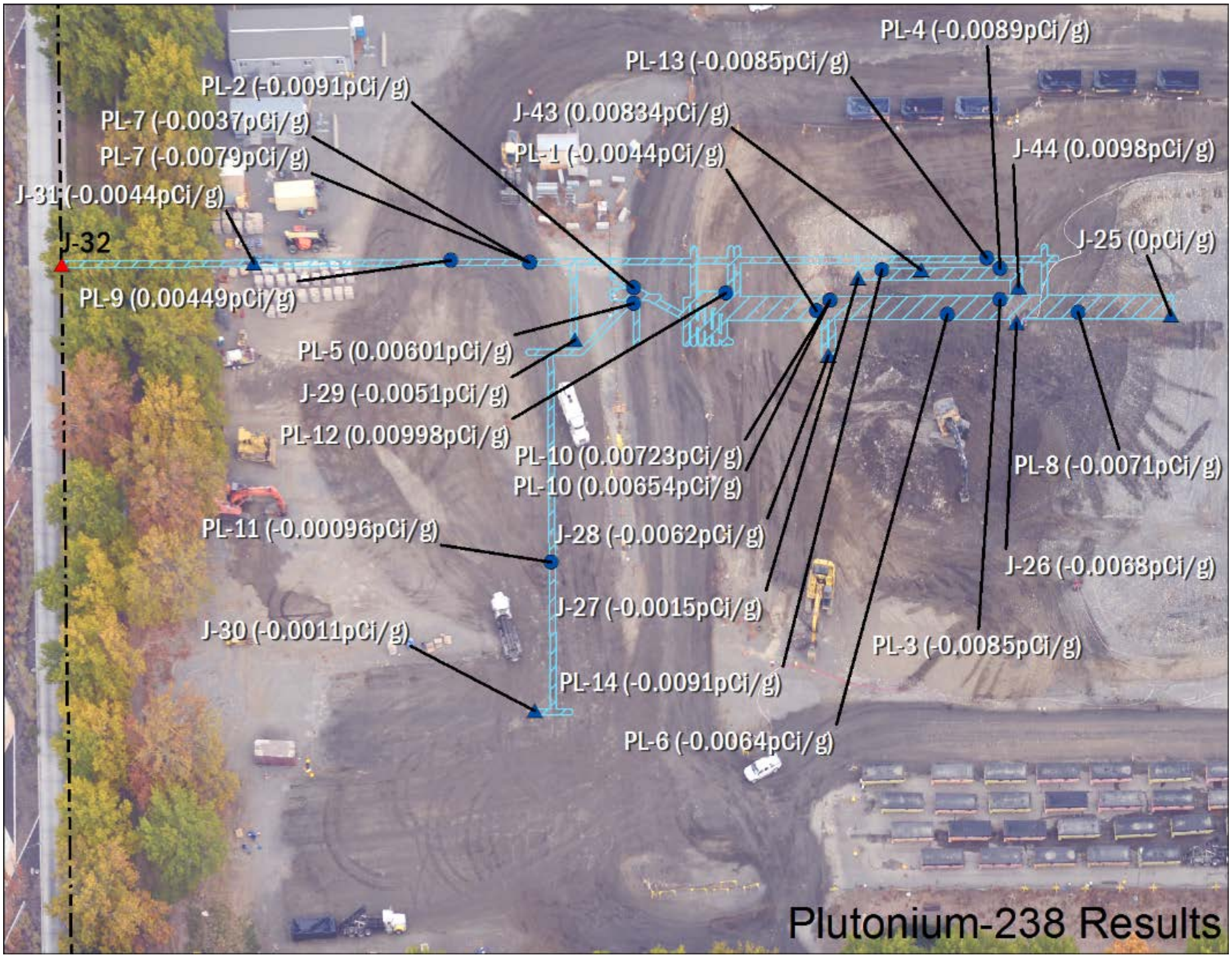

Figure C.22. Plutonium-238 results from sample locations within the pipelines survey unit

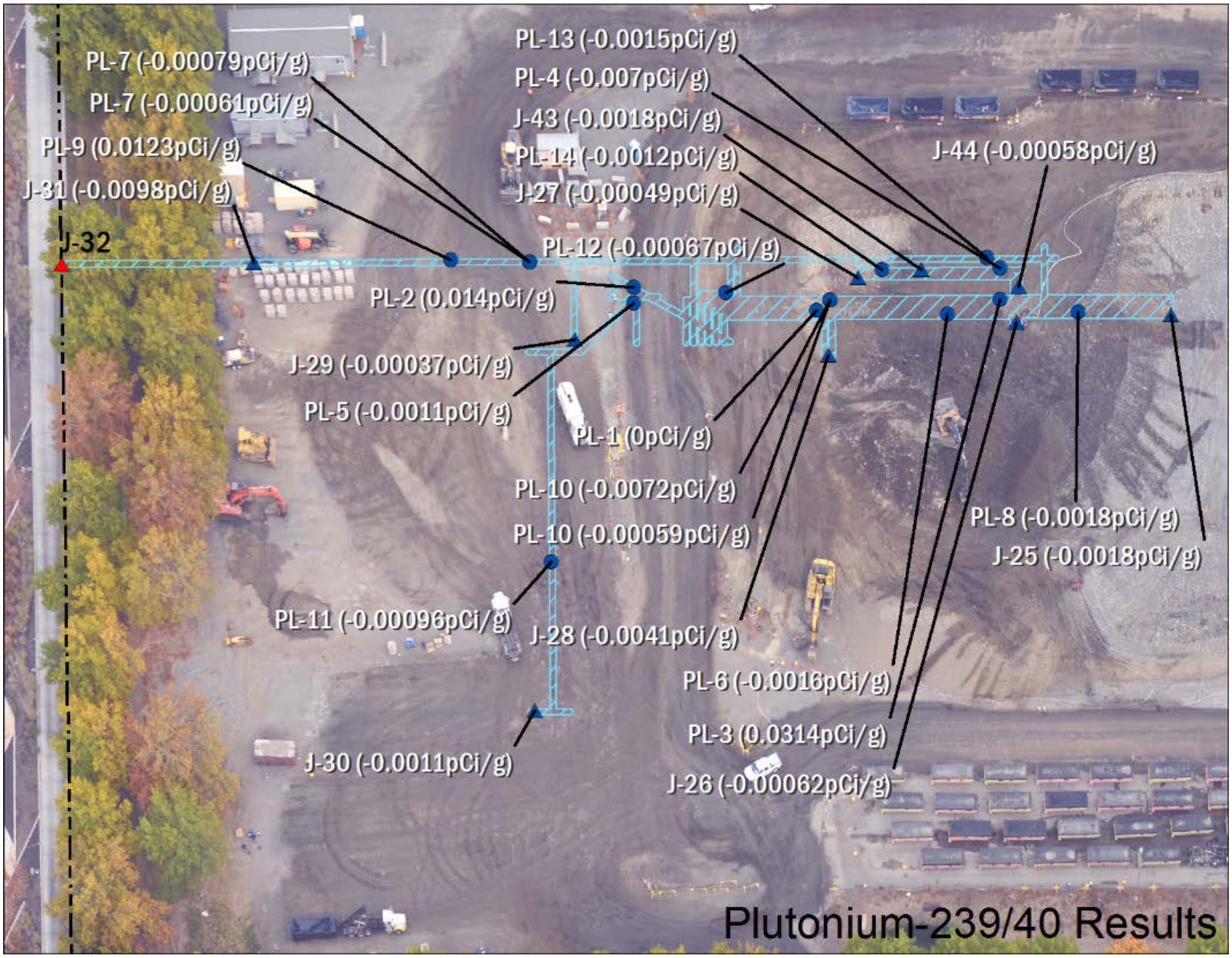

Figure C.23. Plutonium-239/240 results from sample locations within the pipelines survey unit

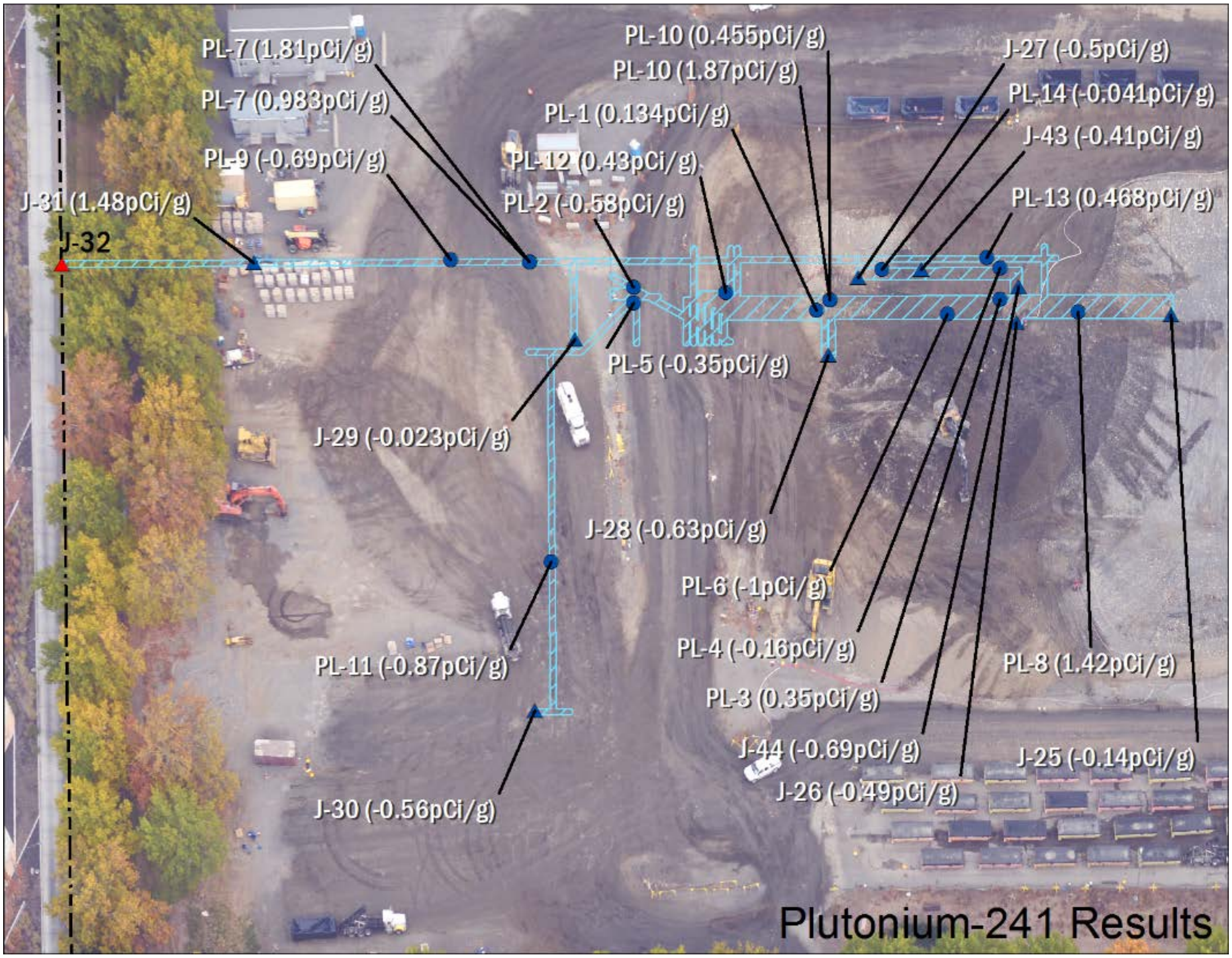

Figure C.24. Plutonium-241 results from sample locations within the pipelines survey unit

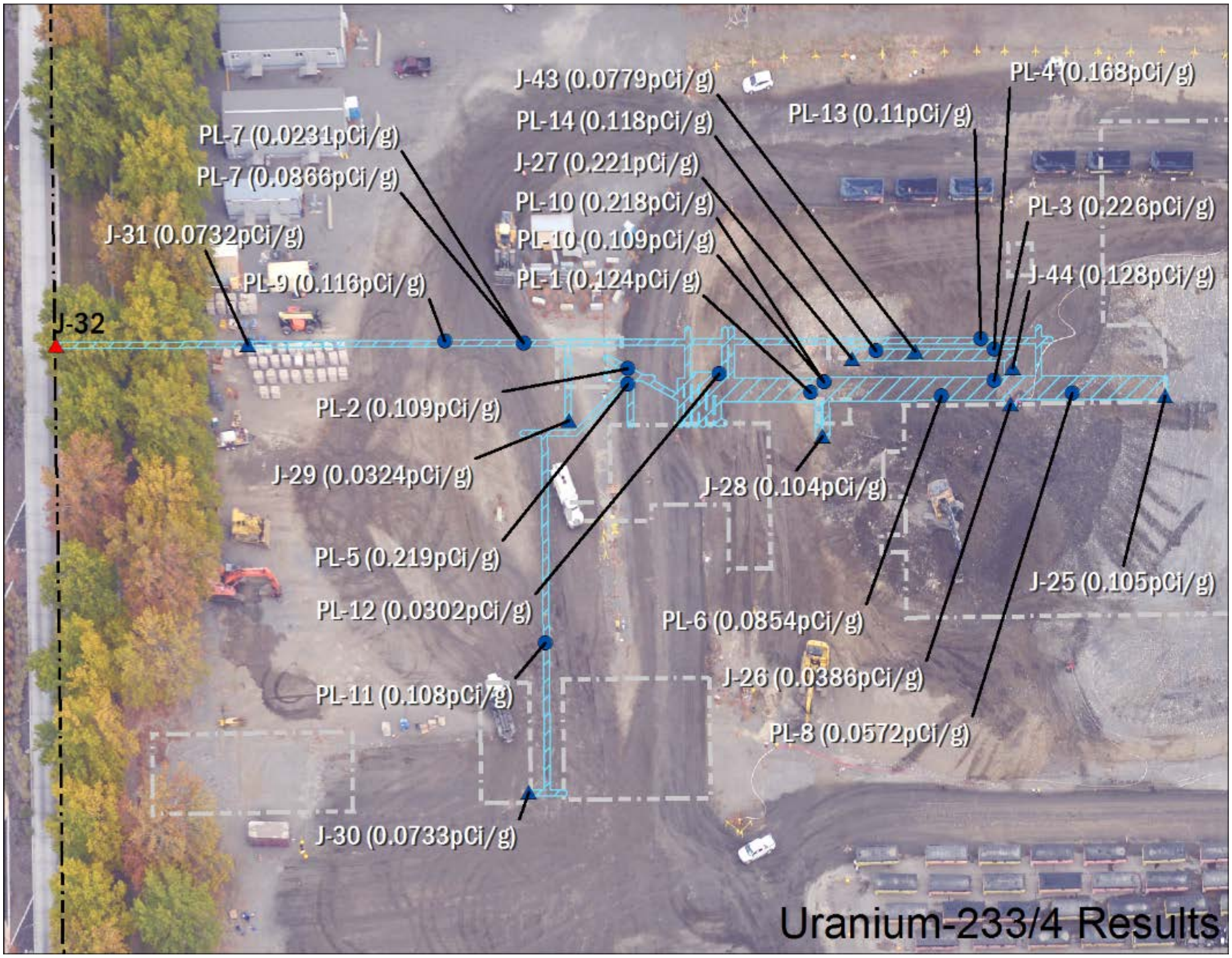

Figure C.25. Uranium-233/234 results from sample locations within the pipelines survey unit

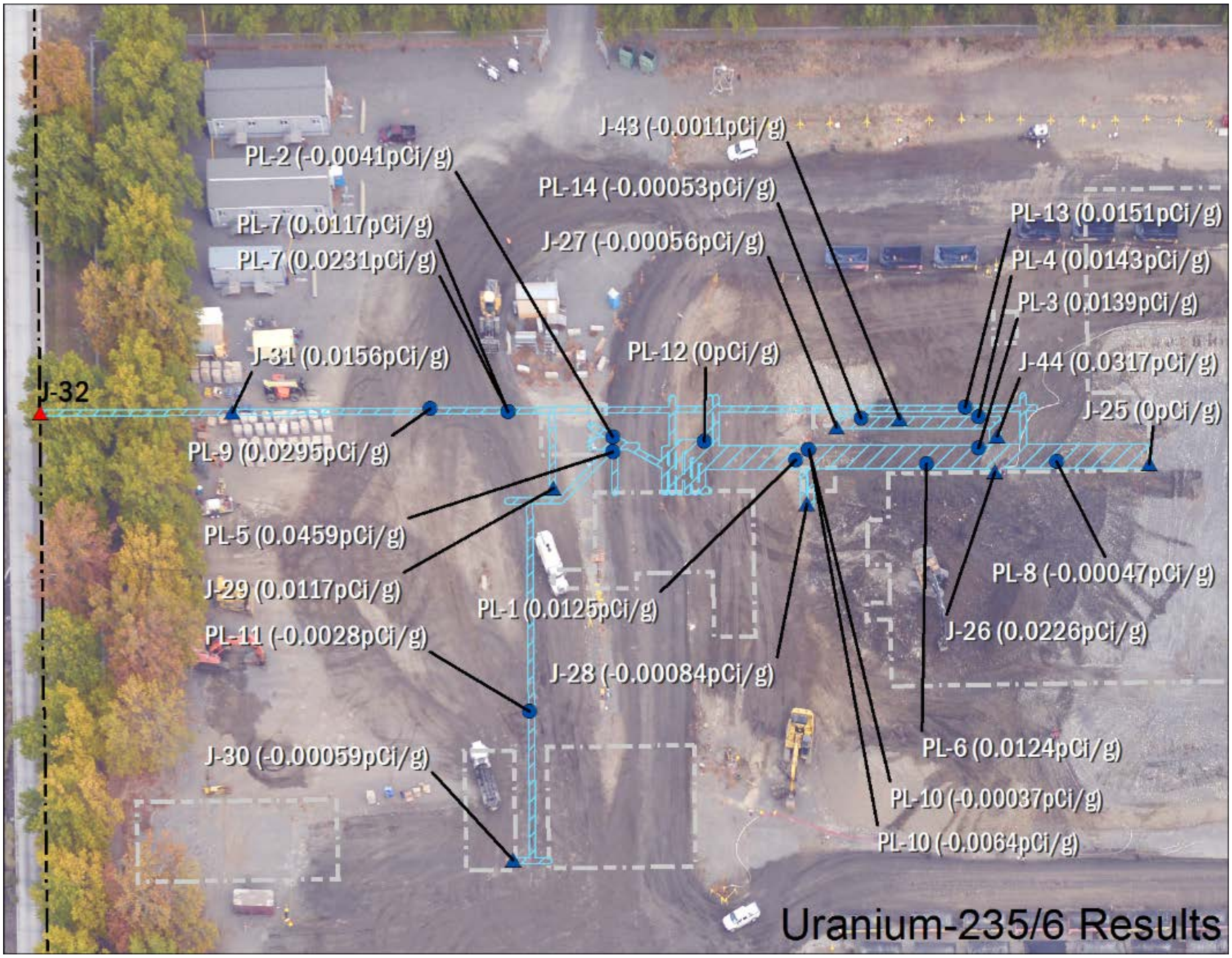

Figure C.26. Uranium-235/236 results from sample locations within the pipelines survey unit

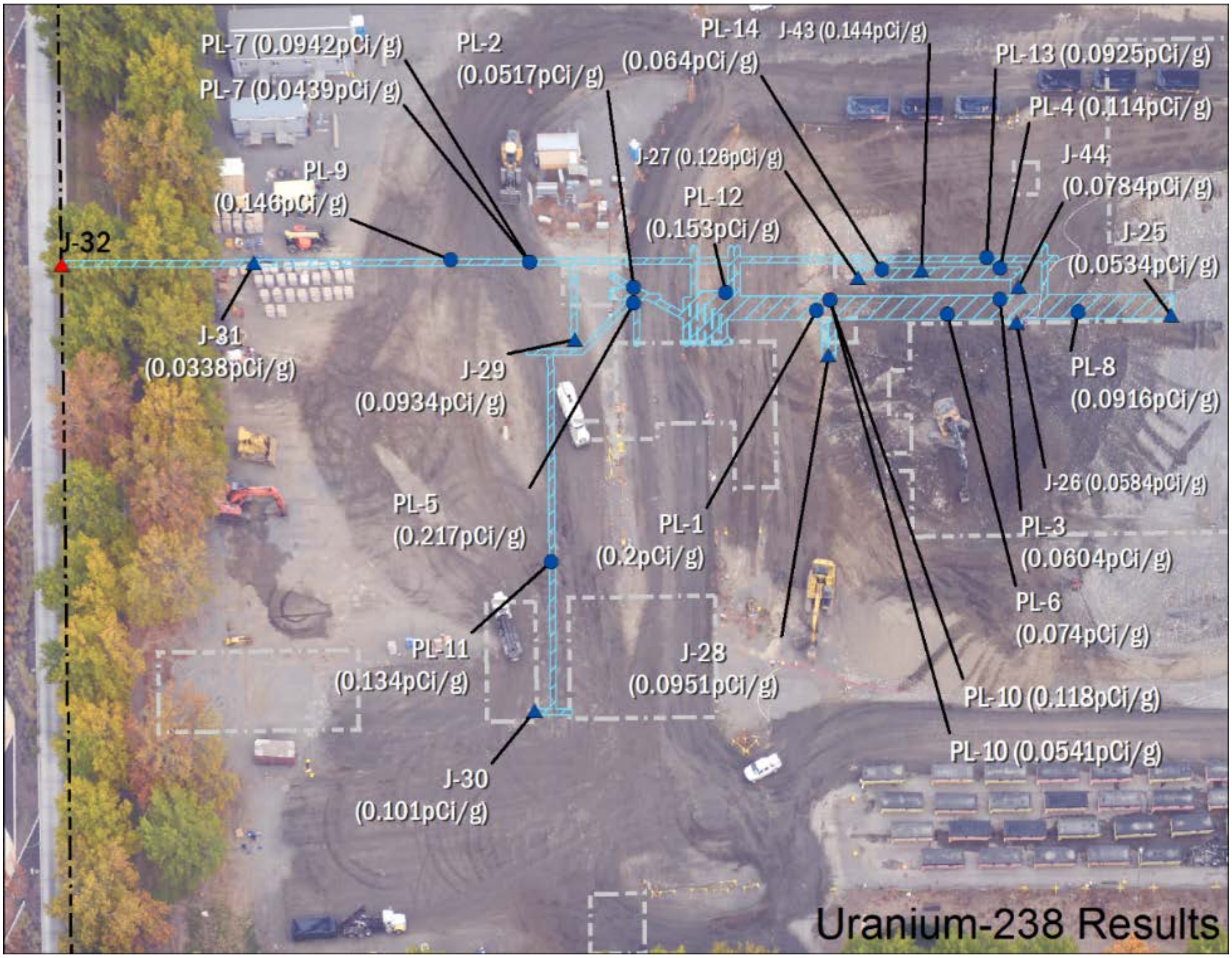

Figure C.27. Uranium-238 results from sample locations within the pipelines survey unit

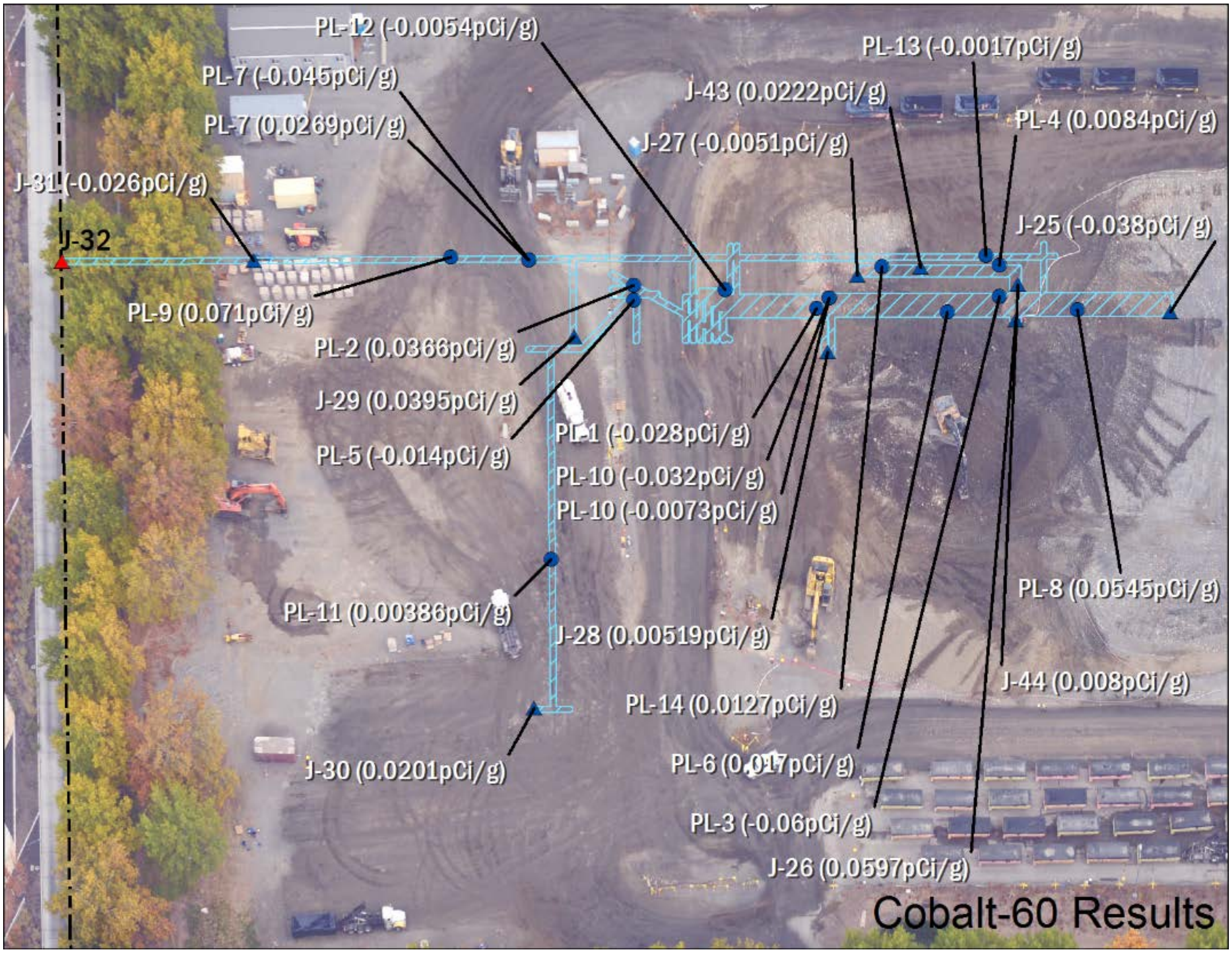

Figure C.28. Cobalt-60 results from sample locations within the pipelines survey unit

C.5 Paved Areas Survey Unit

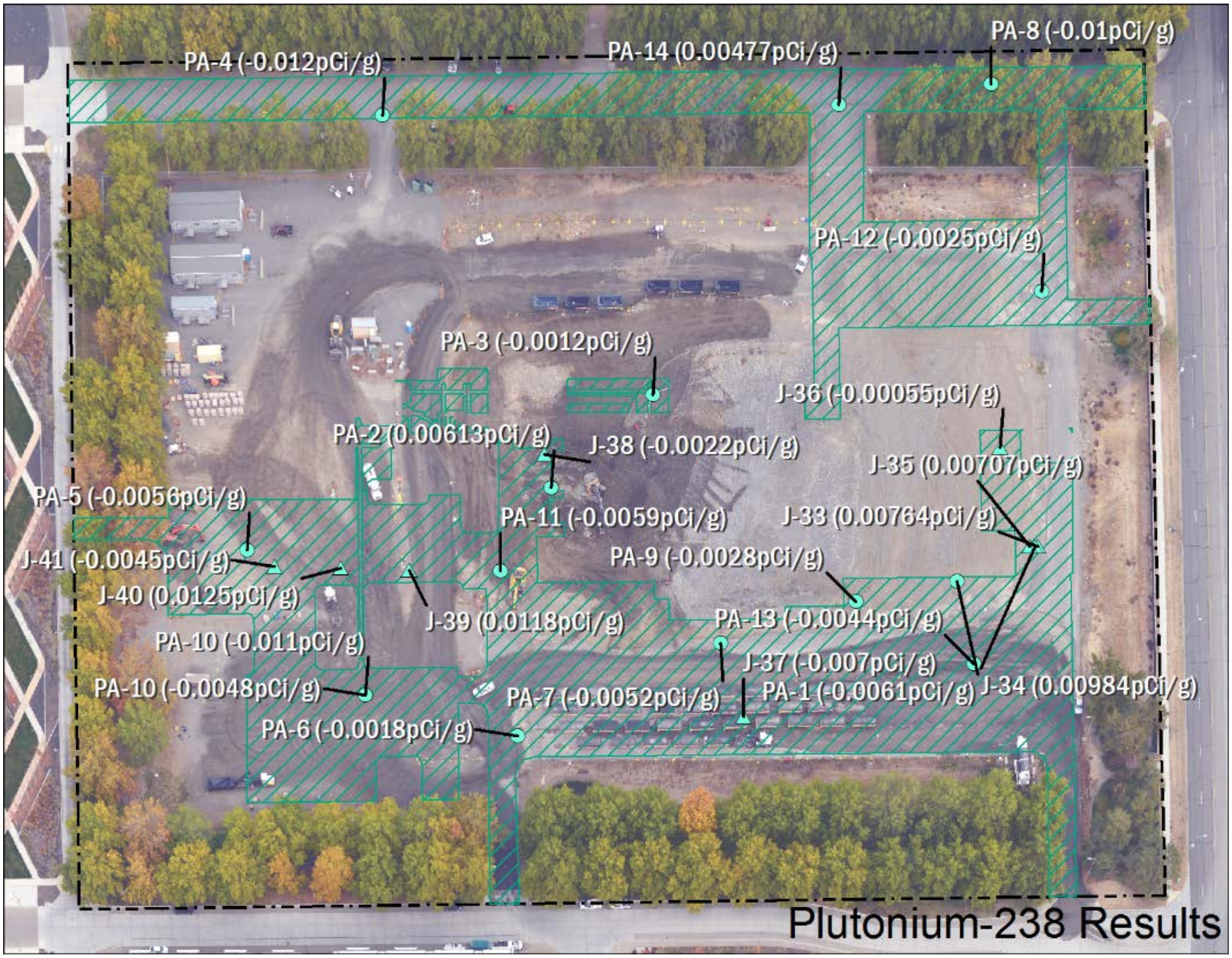

Figure C.29. Plutonium-238 results from sample locations within the paved area survey unit

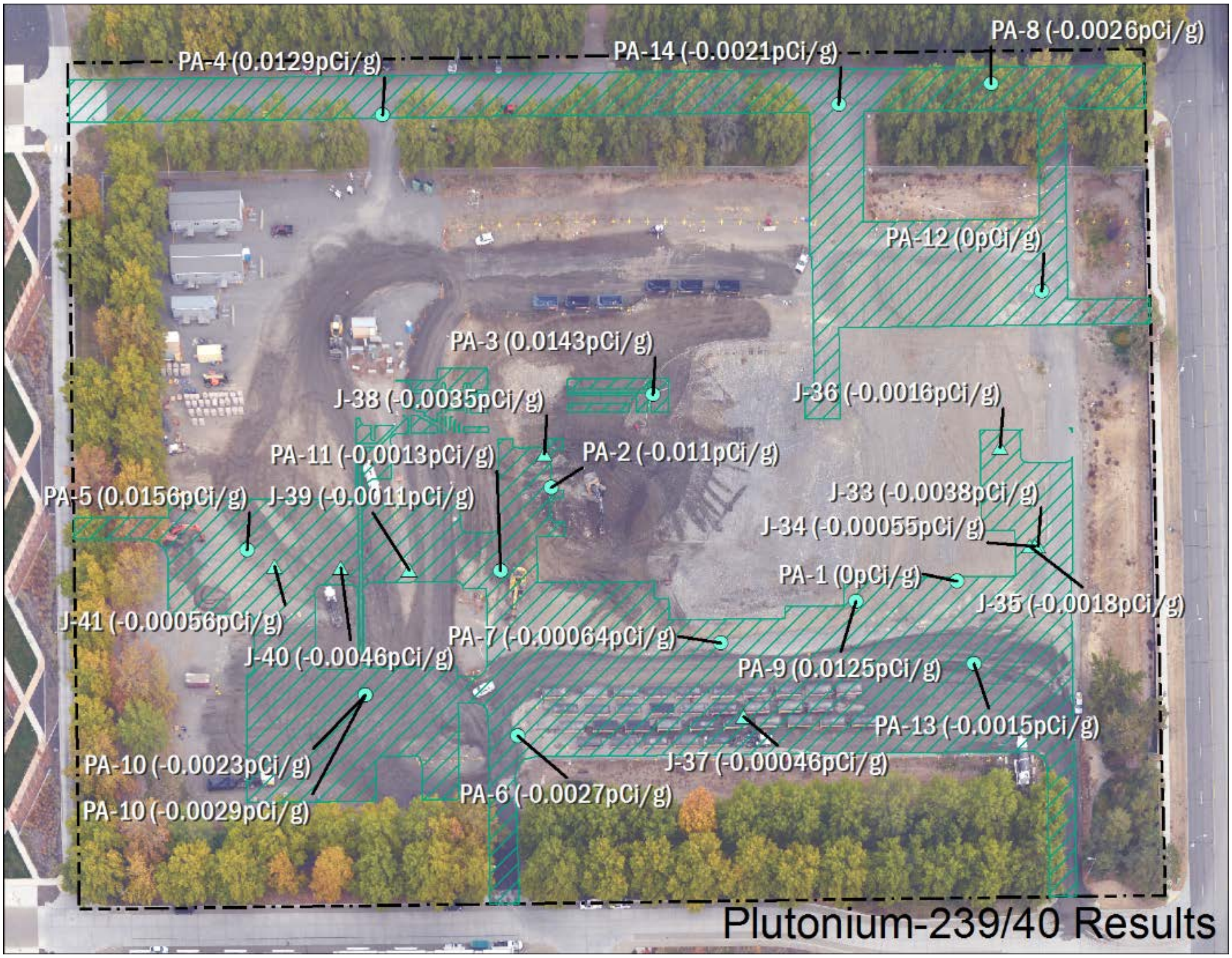

Figure C.30. Plutonium-239/240 results from sample locations within the paved area survey unit

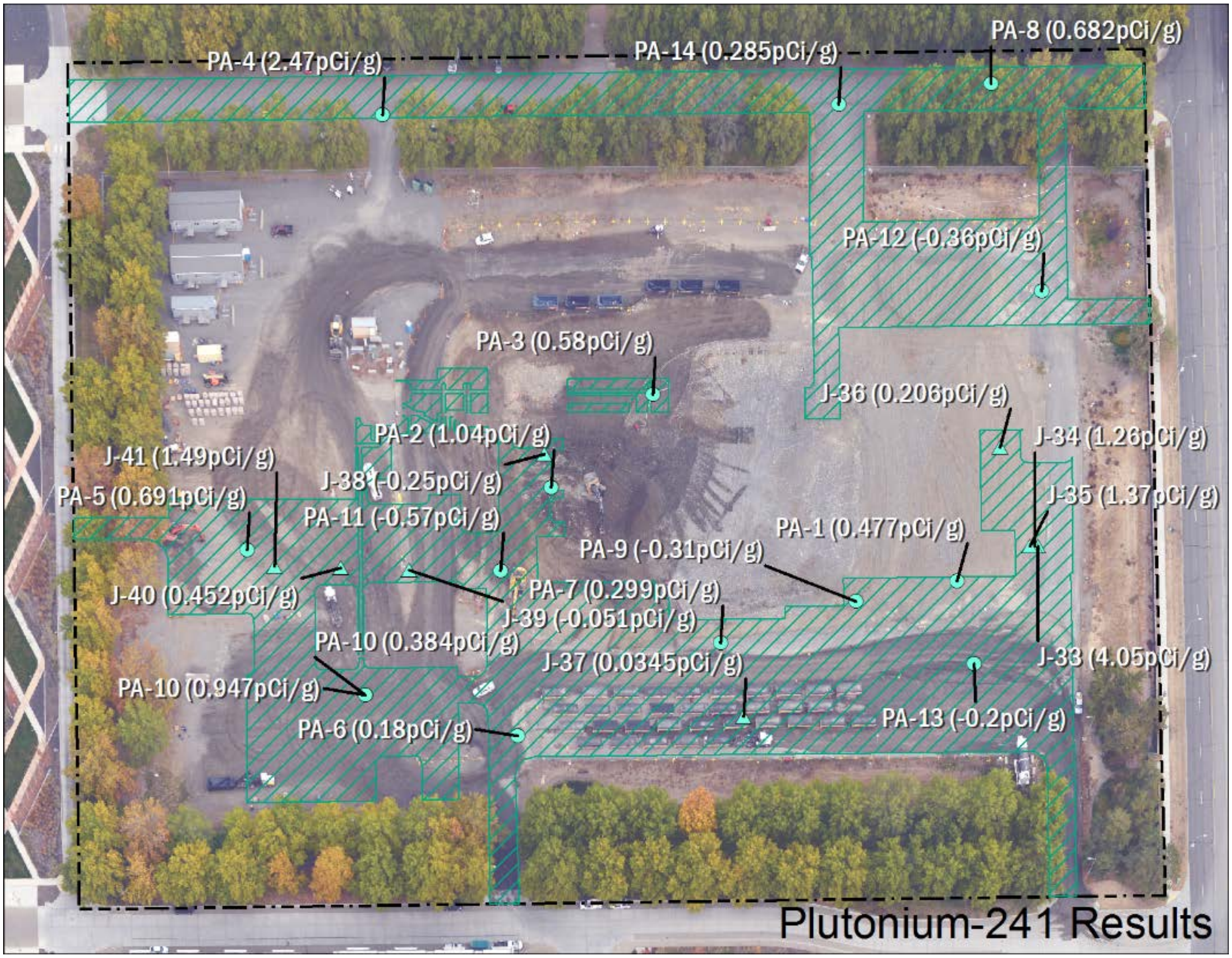

Figure C.31. Plutonium-241 results from sample locations within the paved area survey unit

Figure C.32. Uranium-233/234 results from sample locations within the paved area survey unit

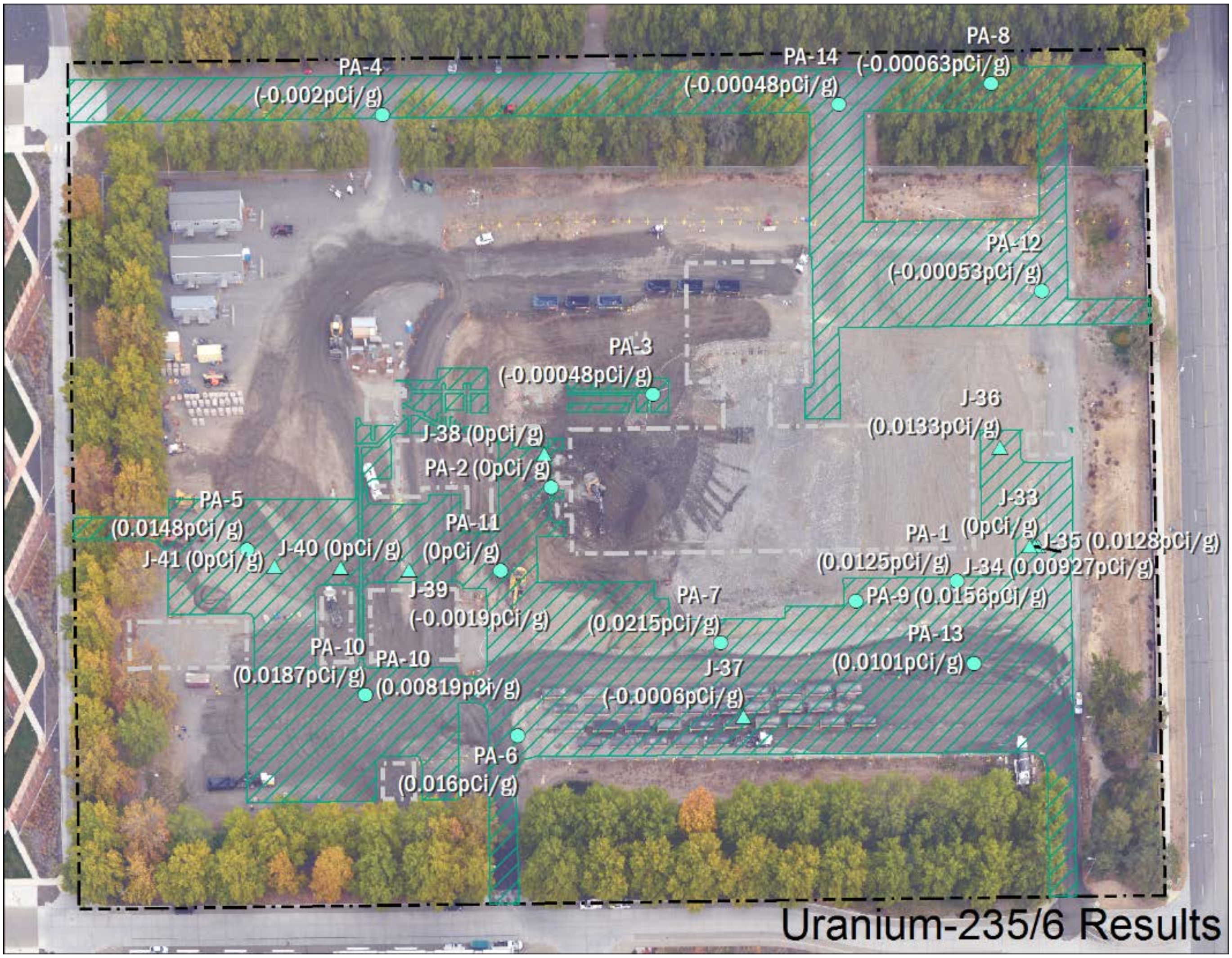

Figure C.33. Uranium-235/236 results from sample locations within the paved area survey unit

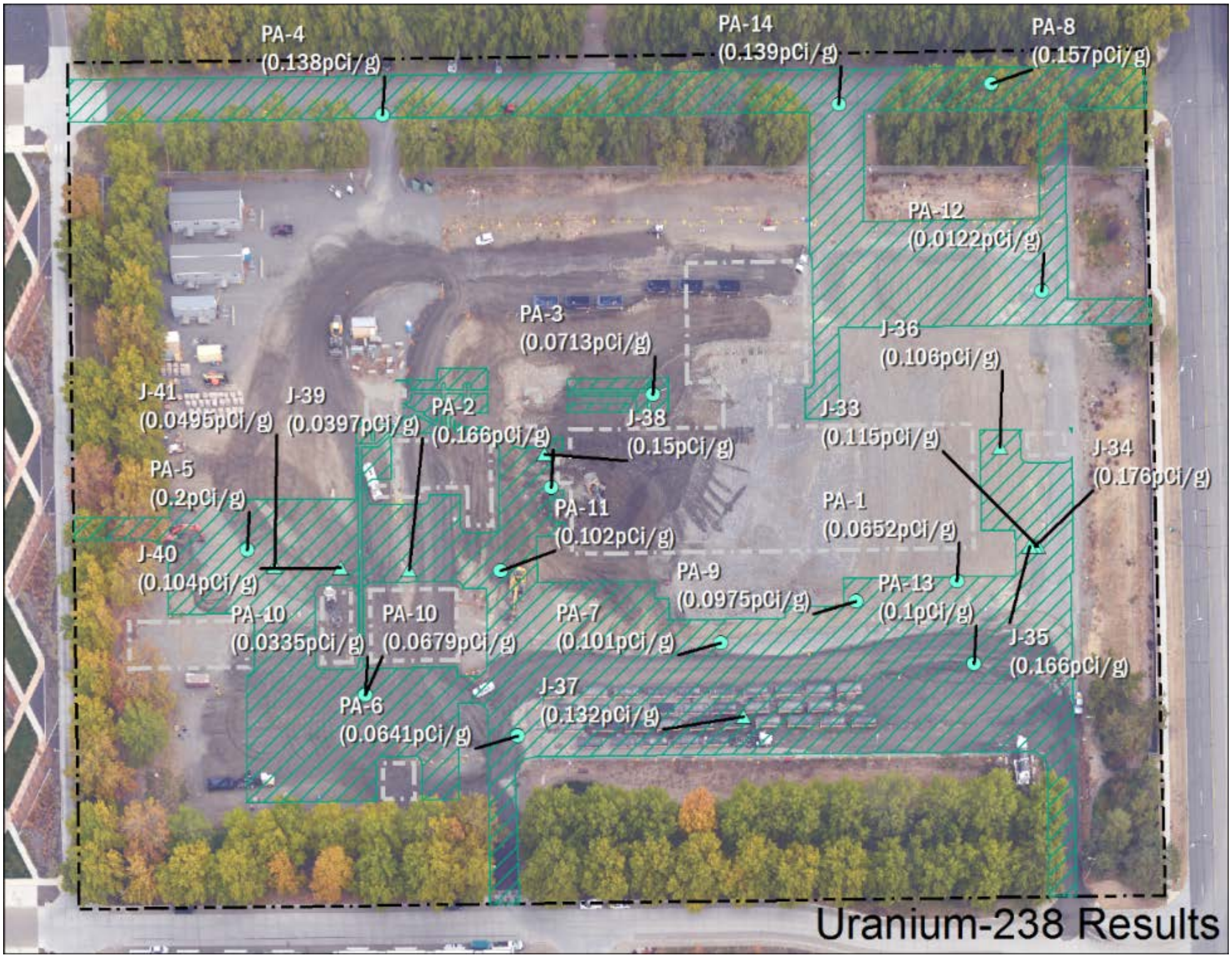

Figure C.34. Uranium-238 results from sample locations within the paved area survey unit

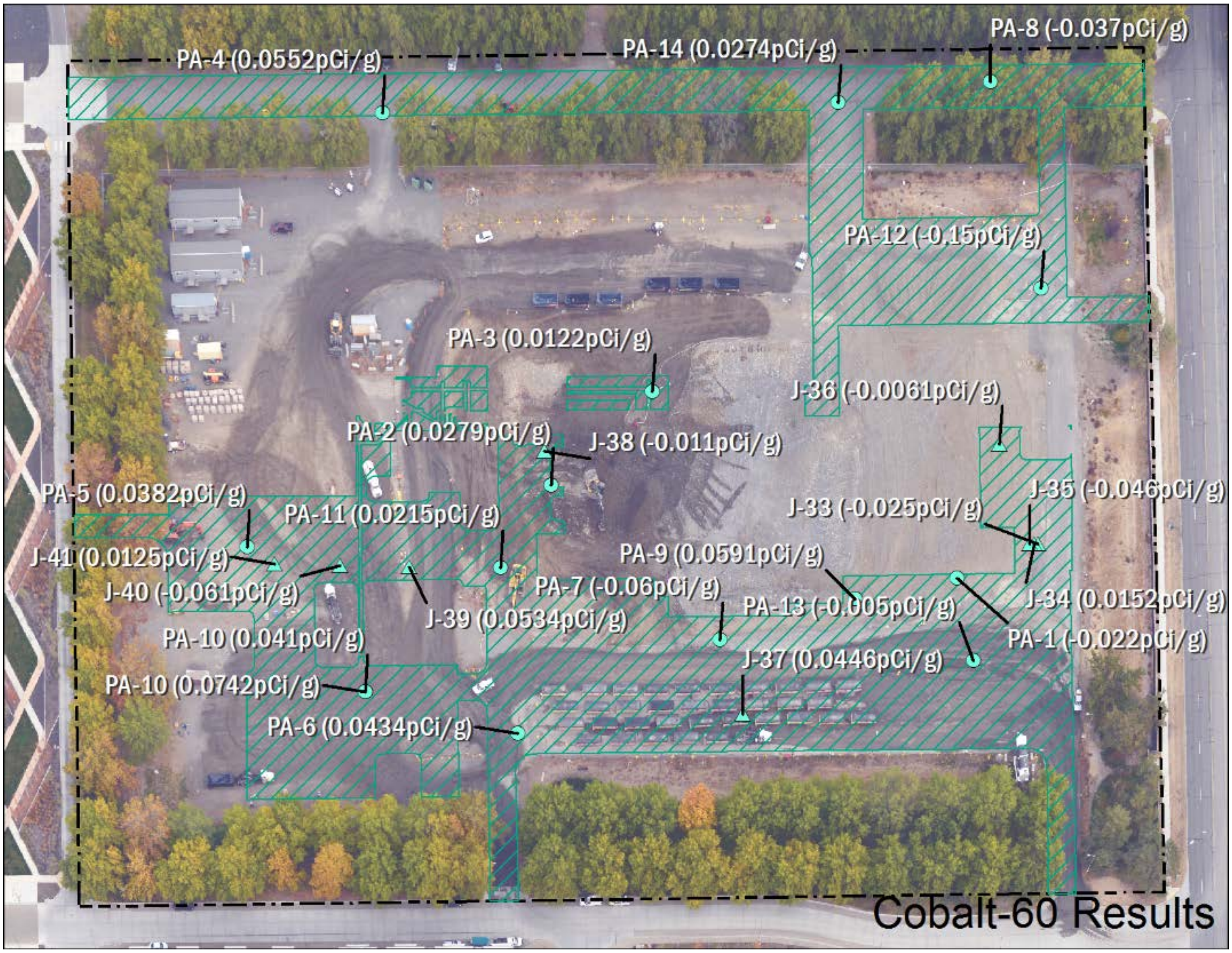

Figure C.35. Cobalt-60 results from sample locations within the paved area survey unit

C.6 Open Areas Survey Unit

Figure C.36. Plutonium-238 results from sample locations within the open areas survey unit

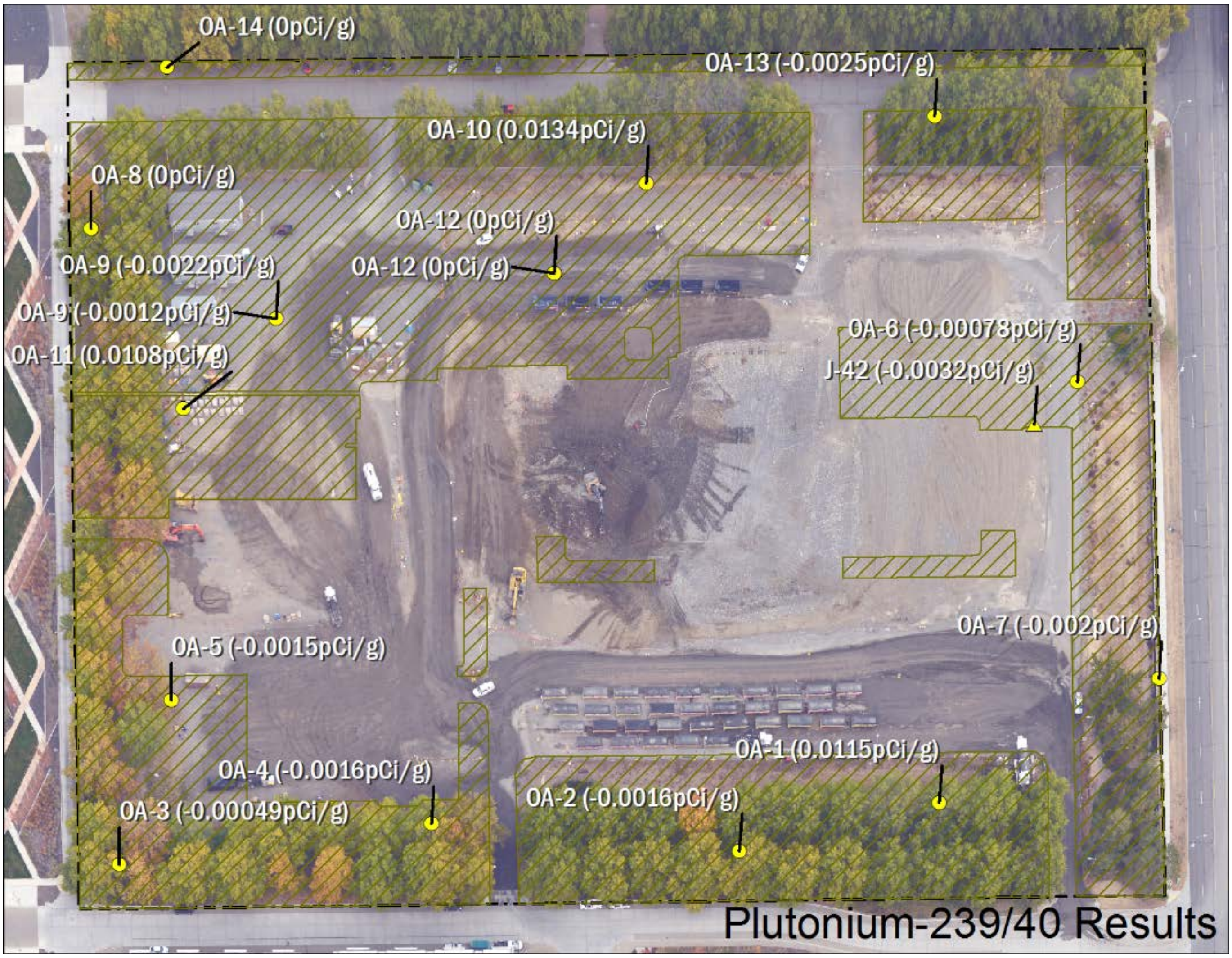

Figure C.37. Plutonium-239/240 results from sample locations within the open areas survey unit

Figure C.38. Plutonium-241 results from sample locations within the open areas survey unit

Figure C.39. Uranium-233/234 results from sample locations within the open areas survey unit

Figure C.40. Uranium-235/236 results from sample locations within the open areas survey unit

Figure C.41. Uranium-238 results from sample locations within the open areas survey unit

Figure C.42. Cobalt-60 results from sample locations within the open areas survey unit

Appendix D – Laboratory Reports

Table D.1 through Table D.6 list the unique identifiers for samples collected at each location within a survey unit. The reports from TestAmerica, Inc. (Richland, WA location) documenting the radiological analyses performance on these samples are also included within this appendix.

Table D.1. 520 building footprint survey unit sample locations and associated sample identification

Random		Specific Judgmental	
Sample Location	Sample ID	Sample Location	Sample ID
RTL 520-1	B3KF97	RTL 520 J-1	B3KF69
RTL 520-2	B3KF99	RTL 520 J-2	B3KF71
RTL 520-3	B3KFB1	RTL 520 J-3	B3KF73
RTL 520-4	B3KFB3	RTL 520 J-4	B3KF75
RTL 520-5	B3KFB5	RTL 520 J-5	B3KF77
RTL 520-6	B3KFB7	RTL 520 J-6	B3KF79
RTL 520-7	B3KFB9	RTL 520 J-7	B3KF81
RTL 520-8	B3KFC1	RTL 520 J-8	B3KF83
RTL 520-9	B3KFC3	RTL 520 J-9	B3KF85
RTL 520-10	B3KFC5	RTL 520 J-10	B3KF87
RTL 520-11	B3KFC7	RTL 520 J-11	B3KF89
RTL 520-12	B3KFC9	RTL 520 J-12	B3KF91
RTL 520-13	B3KFD1	RTL 520 J-13	B3KF93
RTL 520-14	B3KFD3	RTL 520 J-14	B3KF95

Table D.2. Pipeline survey unit sample locations and associated sample identification

Random		Specific Judgmental	
Sample Location	Sample ID	Sample Location	Sample ID
RTL PL-1	B3L1C3	RTL PL J-25	B3L1D7
RTL PL-2	B3L1C4	RTL PL J-26	B3L1D8
RTL PL-3	B3L1C5	RTL PL J-27	B3L1D9
RTL PL-4	B3L1C6	RTL PL J-28	B3L1F0
RTL PL-5	B3L1C7	RTL PL J-29	B3L1F1
RTL PL-6	B3L1C8	RTL PL J-30	B3L1F2
RTL PL-7	B3L1C9	RTL PL J-31	B3L1F3
RTL PL-8	B3L1D0	RTL PL J-43	B3L1F5
RTL PL-9	B3L1D1	RTL PL J-44	B3L1F6
RTL PL-10	B3L1D2	-	-
RTL PL-11	B3L1D3	-	-
RTL PL-12	B3L1D4	-	-
RTL PL-13	B3L1D5	-	-
RTL PL-14	B3L1D6	-	-

Table D.3. Tank vault and 530 building footprint survey unit sample locations and associated sample identification

Random		Specific Judgmental	
Sample Location	Sample ID	Sample Location	Sample ID
RTL Vault-1	B3KL23	RTL Tank Vault and 530 J-15	B3KL20
RTL Vault-2	B3KL24	RTL Tank Vault and 530 J-16	B3KL21
RTL Vault-3	B3KL25	RTL Tank Vault and 530 J-17	B3KL22
RTL Vault-4	B3KL26	-	-
RTL Vault-5	B3KL27	-	-
RTL Vault-6	B3KL28	-	-
RTL Vault-7	B3KL29	-	-
RTL Vault-8	B3KL30	-	-
RTL Vault-9	B3KL31	-	-
RTL Vault-10	B3KL32	-	-
RTL Vault-11	B3KL33	-	-
RTL Vault-12	B3KL34	-	-
RTL Vault-13	B3KL35	-	-
RTL Vault-14	B3KL36	-	-

Table D.4. Other buildings footprint survey unit sample locations and associated sample identification

Random		Specific Judgmental	
Sample Location	Sample ID	Sample Location	Sample ID
RTL OB-1	B3L265	RTL OB J-18	B3L258
RTL OB-2	B3L266	RTL OB J-19	B3L259
RTL OB-3	B3L267	RTL OB J-20	B3L260
RTL OB-4	B3L268	RTL OB J-21	B3L261
RTL OB-5	B3L269	RTL OB J-22	B3L262
RTL OB-6	B3L270	RTL OB J-23	B3L263
RTL OB-7	B3L271	RTL OB J-24	B3L264
RTL OB-8	B3L272	-	-
RTL OB-9	B3L273	-	-
RTL OB-10	B3L274	-	-
RTL OB-11	B3L275	-	-
RTL OB-12	B3L276	-	-
RTL OB-13	B3L277	-	-
RTL OB-14	B3L278	-	-

Table D.5. Paved areas survey unit sample locations and associated sample identification

Random		Specific Judgmental	
Sample Location	Sample ID	Sample Location	Sample ID
RTL PA-1	B3L2D4	RTL PA J-33	B3L2F8
RTL PA-2	B3L2D5	RTL PA J-34	B3L2F9
RTL PA-3	B3L2D6	RTL PA J-35	B3L2H0
RTL PA-4	B3L2D7	RTL PA J-36	B3L2H1
RTL PA-5	B3L2D8	RTL PA J-37	B3L2H2
RTL PA-6	B3L2D9	RTL PA J-38	B3L2H3
RTL PA-7	B3L2F0	RTL PA J-39	B3L2H4
RTL PA-8	B3L2F1	RTL PA J-40	B3L2H5
RTL PA-9	B3L2F2	RTL PA J-41	B3L2H6
RTL PA-10	B3L2F3	-	-
RTL PA-11	B3L2F4	-	-
RTL PA-12	B3L2F5	-	-
RTL PA-13	B3L2F6	-	-
RTL PA-14	B3L2F7	-	-

Table D.6. Open areas survey unit sample locations and associated sample identification

Random		Specific Judgmental	
Sample Location	Sample ID	Sample Location	Sample ID
RTL OA-1	B3L2V9	RTL OA J-42	B3L2X3
RTL OA-2	B3L2W0	-	-
RTL OA-3	B3L2W1	-	-
RTL OA-4	B3L2W2	-	-
RTL OA-5	B3L2W3	-	-
RTL OA-6	B3L2W4	-	-
RTL OA-7	B3L2W5	-	-
RTL OA-8	B3L2W6	-	-
RTL OA-9	B3L2W7	-	-
RTL OA-10	B3L2W8	-	-
RTL OA-11	B3L2W9	-	-
RTL OA-12	B3L2X0	-	-
RTL OA-13	B3L2X1	-	-
RTL OA-14	B3L2X2	-	-

Appendix E – Data Validation Reports

This appendix contains the data validation reports documenting the Level C validation of data collected within the six survey units as identified in the *RTL Disposition Program Final Status Survey Plan* (Bunn et al. 2018). The reports also contain validation of the non-radiological analyses which are discussed in the *Research Technology Laboratory (RTL) Disposition Program Final Verification Sampling Report for Non-radiological Analytes* (Golovich et al. 2019).

References

Bunn AL, JK Snelling, and AM Gorton. 2018. *RTL Disposition Program Final Status Survey Plan.* S740277-PLAN-14, Pacific Northwest National Laboratory. Richland, Washington.

Golovich EC, AL Bunn, FH Biebesheimer, and JK Snelling. 2019. *Research Technology Laboratory (RTL) Disposition Program Final Verification Sampling Report for Non-Radiological Analytes*. S740277-RPT-06, Pacific Northwest National Laboratory, Richland, Washington.

S740277-RPT-05
PNNL-28626

Pacific Northwest National Laboratory

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99354
1-888-375-PNNL (7665)

www.pnnl.gov