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**SUBJECT: DOE CONTRACT NO. DE-SC0014664  
INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND  
RESULTS FOR THE AMERICAN CENTRIFUGE LEAD CASCADE  
FACILITY IN PIKETON, OHIO  
RFTA NO. 18-006; DCN 5326-SR-01-0**

Dear Mr. Smith:

The Oak Ridge Institute for Science and Education (ORISE) is pleased to provide the enclosed report, which describes the procedures and results of the independent confirmatory survey that ORISE performed during the period of May 21-25, 2018 at the American Centrifuge Lead Cascade Facility in Piketon, Ohio. NRC's comments on the draft report have been incorporated into this report.

You may contact me at 865.576.6659 or Kaitlin Engel at 865.574.7008 if you have any questions or require additional information.

Sincerely,



Erika N. Bailey  
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# **INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE AMERICAN CENTRIFUGE LEAD CASCADE FACILITY IN PIKETON, OHIO**

**K. M. Engel  
ORISE**

**FINAL REPORT**

**Prepared for the  
U.S. Nuclear Regulatory Commission**

**AUGUST 2018**

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INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS  
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PIKETON, OHIO

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## ACRONYMS

AA	alternative action
ACO	American Centrifuge Operating, LLC
ACP	American Centrifuge Plant
ALARA	as low as reasonably achievable
cpm	counts per minute
CTTF	Centrifuge Training and Test Facility
DCGL	derived concentration guideline levels
dpm/100 cm <sup>2</sup>	disintegration per minute per 100 square centimeters
DOE	U.S. Department of Energy
DQOs	data quality objectives
DSs	decision statements
FSS	final status survey
GCEP	Gas Centrifuge Enrichment Plant
GM	Geiger-Muller
Lead Cascade	The American Centrifuge Lead Cascade Facility
MARSSIM	<i>Multi-Agency Radiation Survey and Site Investigation Manual</i>
MDC	minimum detectable concentration
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
ORISE	Oak Ridge Institute for Science and Education
PSQs	principal study questions
QQ	quantile-quantile
ROC	radionuclide of concern
SU	survey unit
VSP	Visual Sample Plan



**INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS  
FOR THE AMERICAN CENTRIFUGE LEAD CASCADE FACILITY IN  
PIKETON, OHIO**

**EXECUTIVE SUMMARY**

The U.S. Nuclear Regulatory Commission requested that the Oak Ridge Institute for Science and Education (ORISE) perform an independent confirmatory survey at the American Centrifuge Lead Cascade Facility in Piketon, Ohio. In March 2016, American Centrifuge Operating, LLC notified the U.S. Nuclear Regulatory Commission of Centrus Energy Corporation's decision to cease operations at the Lead Cascade and to terminate the Lead Cascade's Materials license (SNM-7003).

ORISE performed independent assessment activities during the period of May 21-25, 2018.

Confirmatory survey activities included alpha-plus-beta radiation floor scans, beta radiation drain scans, alpha radiation scans and direct measurements, and smear sampling, as applicable, in the X-3001 Train 2 North Utility Bay, X-3001 Train 3 North Utility Bay, X-3001 Trains 2 and 3 North Utility Bay Drains, X-3001 Train 1 Mezzanine, X-3001 Train 3 Mezzanine, X-3001 Train 3, X-3001 Train 3 Centrifuge Drains, X-3001 Train 6, X-7726 Centrifuge Training and Testing Facility, X-7726 Second Floor Utility Room, X-3012 Hot Shop, and X-7725 Loading/Storage Area. ORISE's survey results, combined with laboratory analytical results from the smear samples, did not identify anomalous results or other conditions that preclude the FSS data from demonstrating compliance with the release criteria.



## **INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE AMERICAN CENTRIFUGE LEAD CASCADE FACILITY IN PIKETON, OHIO**

### **1. INTRODUCTION**

The American Centrifuge Lead Cascade Facility (Lead Cascade) was a test loop of the American Centrifuge Plant (ACP) located in Piketon, Ohio. The Lead Cascade demonstrated the effectiveness of the centrifuge design and equipment by processing uranium hexafluoride ( $UF_6$ ) gas in a closed loop. After the demonstration was completed, the facility made a financial decision to cease uranium enrichment operations in February 2016, followed by removal of uranium gas from the centrifuges and process piping, dismantling of process equipment, and other actions needed to ultimately decommission the facility.

In March 2016, American Centrifuge Operating, LLC (ACO) notified the U.S. Nuclear Regulatory Commission (NRC) of Centrus Energy Corporation's decision to cease operations at the Lead Cascade and to terminate the Lead Cascade's Materials license (SNM-7003). In May 2016, ACO submitted a proposed amendment to the license to downgrade licensed activities at the Lead Cascade to "limited operations" and to remove the regulatory permission to enrich uranium. NRC issued an approval to the license amendment in December 2016 (NRC 2017).

The NRC requested that the Oak Ridge Institute for Science and Education (ORISE) perform confirmatory surveys in the X-3001 Train 2 North Utility Bay, X-3001 Train 3 North Utility Bay, X-3001 Trains 2 and 3 North Utility Bay Drains, X-3001 Train 1 Mezzanine, X-3001 Train 3 Mezzanine, X-3001 Train 3, X-3001 Train 3 Centrifuge Drains, X-3001 Train 6, X-7726 Centrifuge Training and Testing Facility, X-7726 Second Floor Utility Room, X-3012 Hot Shop, and X-7725 Loading/Storage Area. ORISE performed the confirmatory surveys on May 21-25, 2018.

### **2. SITE DESCRIPTION**

The footprint of the Lead Cascade is located within the U.S. Department of Energy's (DOE's) 1,528-hectare (3,777-acre) federal reservation in a rural area of Pike County, Ohio, approximately 32 kilometers (20 miles) north of Portsmouth, Ohio. Figure 2.1 depicts the portion of the reservation associated with the American Centrifuge Plant. The Lead Cascade facilities were leased from the DOE and are being prepared for return to DOE to meet unrestricted use per lease requirements (ACO 2018a).



**Figure 2.1. DOE Reservation and Footprint of the Lead Cascade (circled in red)  
(ACO 2018a)**

### 3. OBJECTIVE

The data quality objectives (DQOs) described herein are consistent with the Guidance on Systematic Planning Using the Data Quality Objectives Process (EPA 2006) and provided a formalized method for planning radiation surveys, improving survey efficiency and effectiveness, and ensuring that the type, quality, and quantity of data collected were adequate for the intended decision applications.

The seven steps in the DQO process are as follows:

1. State the problem
2. Identify the decision/objective
3. Identify inputs to the decision/objective
4. Define the study boundaries
5. Develop a decision rule



6. Specify limits on decision errors
7. Optimize the design for obtaining data

### **3.1 STATE THE PROBLEM**

The first step in the DQO process defined the problem that necessitated the study, identified the planning team, and examined the project budget and schedule. The Gas Centrifuge Enrichment Plant (GCEP) lease agreement between DOE and the United States Enrichment Corporation stated in part that prior to returning GCEP Leased Facilities, residual radiological contamination levels shall comply with the NRC's radiological criteria for unrestricted use, as specified in Title 10 of the Code of Federal Regulators 20.1402 (ACO 2018a), which states:

“A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a total effective dose equivalent to an average member of the critical group that does not exceed 25 mrem per year, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA).”

NRC requested that ORISE perform confirmatory surveys of the Lead Cascade to provide independent documentation and field reviews and generate independent radiological data to assist the NRC in evaluating the adequacy and accuracy of ACO's final status survey (FSS) results.

Therefore, the problem statement was as follows:

Independent confirmatory surveys are necessary to assist the NRC in their assessment and determination of the adequacy of the FSS design, implementation, and results for demonstrating compliance with the release criteria.

### **3.2 IDENTIFY THE DECISION**

The second step in the DQO process identified the principal study questions (PSQs) and alternative actions (AAs); developed decision statements; and organized multiple decisions, as appropriate. This was done by specifying AAs that could result from a “yes” response to the PSQs and combining the PSQs and AAs into decision statements (DSs). PSQs, AAs, and combined DSs are organized based on the survey unit (SU) type (i.e., the associated FSS methodology) and presented in Table 3.1.



**Table 3.1. Lead Cascade Confirmatory Survey Decision Process**

Principal Study Question	Alternative Actions
PSQ: Do confirmatory survey results agree with the final radiological survey data for the Lead Cascade?	<p>Yes: Compile confirmatory data and report results to the NRC for their decision making. Provide independent interpretation that confirmatory field surveys did not identify anomalous areas of residual radioactivity, quantitative field and laboratory data satisfied the NRC-approved decommissioning criteria, and/or that statistical sample population examination/assessment conditions were met.</p> <p>No: Compile confirmatory data and report results to the NRC for their decision making. Provide independent interpretation of confirmatory survey results identifying any anomalous field or laboratory data and/or when statistical sample population examination/assessment conditions were not satisfied for the NRC's determination of the adequacy of the FSS data.</p>
Decision Statement	
Confirmatory survey results did/did not identify anomalous results or other conditions that preclude the FSS data from demonstrating compliance with the release criteria.	

### 3.3 IDENTIFY INPUTS TO THE DECISION

The third step in the DQO process identified both the information needed and the sources of this information; determined the basis for action levels; and identified sampling and analytical methods to meet data requirements. For this effort, information inputs included the following:

- Applicable instrumentation and survey and sampling procedures, method procedures, and data management procedures (ORAU 2016a)
- The *ORAU Environmental Services and Radiation Training Quality Program Manual* (ORAU 2016b)
- Applicable laboratory equipment and procedures (ORAU 2017)
- Final status survey report and associated data (ACO 2018a)
- ORISE confirmatory survey results including: surface radiation scans, direct surface activity measurements, and removable gross alpha/beta activity





### **3.4 DEFINE THE STUDY BOUNDARIES**

The fourth step in the DQO process defined target populations and spatial boundaries; determined the timeframe for collecting data and making decisions; addressed practical constraints; and determined the smallest subpopulations, area, volume, and time for which separate decisions must be made.

Figure 2.1 presents the area of the site associated with the Lead Cascade. The FSS report presented data from five buildings including: X-3001, X-3012, X-7725, X-7726, and X-7727H. At NRC's direction based on the site's prior operations, confirmatory survey activities were performed in buildings X-3001, X-3012, X-7725, and X-7726 during the five days onsite.

### **3.5 DEVELOP A DECISION RULE**

The fifth step in the DQO process specified appropriate parameters (e.g., mean, median); confirmed action levels were above detection limits; and developed an if...then...decision rule statement. For this survey effort, the one parameter of interest was the mean uranium surface activity in an individual SU. For assessing the SU means, the project-specific plan included comparing the confirmatory mean surface activity levels for each SU to the mean surface activity reported in the FSS reports, if available, via a two-sample hypothesis test. A preliminary data assessment was performed that consisted of box plots of the SUs. Based on the preliminary assessment and because hypothesis tests of data populations with most results near or below the minimum detectable concentrations (MDCs) can be inconclusive and generally lack sufficient power to detect what would be a small and therefore inconsequential difference, further hypothesis testing was unnecessary. See Section 6 for further details.

Individual sample results were also evaluated against a single pass/fail criterion. The criterion used for individual data points was three times the total surface activity limit—specified in the footnote of Table 4.1, which is 15,000 disintegrations per minute per one hundred square centimeters (dpm/100 cm<sup>2</sup>) total activity.



The modified decision rule was stated as:

If surface activity, averages, maximums, and removable are less than the release limits, then conclude that confirmatory survey data agrees with the FSS data. Otherwise, perform further evaluation(s) and provide technical comments and recommendations to NRC.

### **3.6 SPECIFY LIMITS ON DECISION ERRORS**

The sixth step in the DQO process specified the decision maker's limits on decision errors, which were then used to establish performance goals for the survey. One order of control was to optimize the confirmatory field measurement detection sensitivities and ensure that laboratory analytical MDCs are sufficient for decision making. The nominal analytical MDCs were less than 10 percent of the contamination limits. Field instrumentation MDCs were optimized by following survey procedures.

### **3.7 OPTIMIZE THE DESIGN FOR OBTAINING DATA**

The seventh step in the DQO process was used to review the DQO outputs; develop data collection design alternatives; formulate mathematical expressions for each design; select the sample size to satisfy DQOs; decide on the most resource-effective design of agreed alternatives; and document requisite details. Survey design and laboratory analyses were optimized by implementing the procedures presented in Sections 5 and 6, respectively.

## **4. APPLICABLE SITE GUIDELINES**

The primary radionuclides of concern (ROCs) are uranium isotopes U-234, U-235, and U-238 from the  $\text{UF}_6$  feed. In order to demonstrate compliance with the 25 mrem/yr release criterion, a site-specific derived concentration guideline level ( $\text{DCGL}_w$ ) was developed and presented in the site's Decommissioning Plan, DP-2605-0001. Using RESRAD-Build, the  $\text{DCGL}_w$  was determined to be 39,200 dpm/100  $\text{cm}^2$  total uranium activity. However, ACO noted in their FSS report that the Lead Cascade license application limits are more restrictive and limit total contamination levels for unrestricted release and ALARA purposes. The more restrictive surface contamination limits are presented in the licensee's decommissioning plan and are reproduced in Table 4.1 (ACO 2018b). This lower value will be applied by ACO to demonstrate compliance with NRC's dose criterion and also for ALARA purposes.





Additionally, the FSS report noted that the contaminant (uranyl fluoride) sample analysis indicated that other radionuclides would be insignificant as nearly 100 percent of the projected dose is due to the uranium isotopes. Therefore, the final status survey's acceptance was based on the residual alpha activity (although some beta data were collected and presented in the FSS report) (ACO 2018a).

**Table 4.1. Lead Cascade License Application Contamination Levels<sup>a</sup>**

<b>Radionuclide</b>	<b>Removable (dpm/100 cm<sup>2</sup>)</b>	<b>Total (dpm/100 cm<sup>2</sup>)<sup>b</sup></b>
U-natural, U-235, U-238, and associated decay products. Transuranics $\leq 2$ percent by alpha activity, Tc-99 and beta-gamma emitters.	1,000	5,000

<sup>a</sup> Table source: ACO 2018b

<sup>b</sup> The levels may be averaged over one square meter provided the maximum surface activity in any area of 100 cm<sup>2</sup> is less than three times the total value. For the purposes of averaging, any square meter of the surface is considered to be above the total limit if: 1) the average of measurements from a representative number of n sections are above the total limits; or 2) it is determined that the sum of the activity of all isolated spots or particles in any 100 cm<sup>2</sup> exceeds three times the total limit.

## 5. PROCEDURES

The confirmatory survey activities, conducted during the period of May 21-25, 2018, were in accordance with the project-specific confirmatory survey plan, the *ORAU Radiological and Environmental Survey Procedure Manual*, and the *ORAU Environmental Services and Radiation Training Quality Program Manual* (ORISE 2018, ORAU 2016a and 2016b). Appendices B and C provide additional information regarding survey instrumentation and related processes discussed within this section.

### 5.1 SURVEY UNIT SELECTION

ORISE imported ACO's FSS summary data into a spreadsheet and ranked the site's SUs by highest alpha fraction values; the average and maximum alpha value(s) observed for an SU were divided by the total surface activity limit 5,000 dpm/100cm<sup>2</sup>. The four SUs with the highest alpha fraction, two of which also had the highest beta fractions, were: X-7726 Second Floor Utility Room, X-3001 Train 3-1, X-3001 Train 1 Mezzanine Floor, and X-3001 Train 3 Utility Bay 3 Discretionary. Additional SUs were selected at NRC's discretion based on facility knowledge and the potential for material accumulation, material pathways, and/or other indications of residual contamination. Table 5.1 lists the SUs selected for confirmatory surveys.



## **5.2 SURFACE SCANS**

SUs that were specifically selected for confirmatory survey based on the site's results received high-density scan coverage (up to 100 percent), while other SUs received low- to medium-density scan coverage (10-50 percent).

ORISE performed alpha-plus-beta radiation scans of the accessible floor space in the confirmatory SUs. Scans were performed using Ludlum Model 43-37 gas-flow proportional floor monitors coupled to Ludlum Model 2221 ratemeter scalars. Ratemeter scalars were coupled to hand-held data loggers for electronically recording the count-rate data.

ORISE performed alpha radiation scans of X-3001 Train 3, X-3001 Train 6, and X-7226 Centrifuge Training and Test Facility (CTTF) Centrifuge Drains that were in use during operations, including the water collection area of each drain. Alpha radiation scans were also performed on the X-7226 CTTF floor mounts and machine stands, X-7725 floor mounts, and X-3001 Trains 2 and 3 North Utility Bay machine mount pads. Scans were performed using Ludlum Model 43-68 gas-flow proportional detectors coupled to Ludlum Model 2221 ratemeter scalars.

ORISE performed beta radiation scans of the accessible portions of the drains in the North Utility Bays using Ludlum Model 44-9 Geiger-Mueller (GM) detectors coupled to Ludlum Model 2221 ratemeter scalars with audible indicators. The use of GM detectors in the North Utility Bay drains was necessary due to the size of the drains. The centrifuge drain piping in Train 3 was too small in diameter to survey the interior surfaces with the GM detector.

All scan surveys were qualitative, and performed to detect elevated direct radiation counts, indicative of residual contamination that would require quantitative investigations using other hand-held instruments. Scan MDCs were not specifically calculated for the GM or floor monitor detectors; see Appendix B for MDC calculations of the hand-held gas proportional detectors.

The scan densities performed within each SU are provided in Table 5.1.

## **5.3 NUMBER AND LOCATION OF CONFIRMATORY DIRECT MEASUREMENTS**

The confirmatory measurement locations to determine the average concentration for a SU were randomly selected. The number of measurements was determined using Visual Sample Plan (VSP),



version 7.9. The FSS data were used as VSP inputs to generate the confirmatory surface activity measurement sample population size—with the exception of the CTTF. CTTF FSS data were not readily available; therefore, the parameters required for sample size determination were estimated.

The measurement data were used to independently estimate the mean surface activity for each confirmatory SU and then compare the means with FSS results. The comparisons were performed as an unbiased evaluation to assess whether the confirmatory survey surface activity levels were significantly greater than or less than or equal to the FSS results at the 95% confidence level. Additional judgmental measurements were collected from locations where surface scans identified elevated direct radiation levels that were potentially in excess of the release limits.

**Table 5.1. Survey Units Evaluated**

<b>Survey Unit</b>	<b>Type of Direct Measurements / Smears <sup>a</sup></b>	<b>Number of Random Measurements</b>	<b>Number of Judgmental Measurements</b>	<b>Scans</b>
X-3001 Train 2 North Utility Bay	Random/Judgmental	45	4	High-density scans of floor
X-3001 Train 3 North Utility Bay	Random/Judgmental	37	6	High-density scans of floor
X-3001 Trains 2 and 3 North Utility Bay Drains	Judgmental	NA	18	Low-density scan of drains
X-3001 Train 1 Mezzanine	NA	NA	NA	Medium-density scans of floor
X-3001 Train 3 Mezzanine	NA	NA	NA	Medium-density scans of floor
X-3001 Train 3	Random/Judgmental	22	2	High-density scans of floor and gamma spec area
X-3001 Train 3 Centrifuge Drains	Random/Judgmental	55	8	High-density scans of drains including water collection areas
X-3001 Train 6	Judgmental	0	4	Medium-density scans of floor
X-7226 CTTF	Random/Judgmental	20	10	High-density scans of floor and centrifuge stand
X-7726 2 <sup>nd</sup> Floor Utility Room	Judgmental	0	6	High-density scans of floor
X-3012 Hot Shop	NA	NA	NA	High-density scans of floor; part of floor covered by plastic tarp (not scanned)

**Table 5.1. Survey Units Evaluated**

Survey Unit	Type of Direct Measurements / Smears <sup>a</sup>	Number of Random Measurements	Number of Judgmental Measurements	Scans
X-7725 Loading/Storage Area	NA	NA	NA	High-density scans near rollup door, medium-density scans in rest of area

<sup>a</sup> Judgmental direct measurements were performed based on scan results.

NA= Not applicable

Direct surface activity measurements were made using Ludlum Model 2221 ratemeter scalers coupled to Ludlum Model 43-68 gas proportional detectors with a 0.8 mg/cm<sup>2</sup>-thick Mylar window for alpha-only direct measurements. In narrow spaces, beta scans were also conducted using a hand-held Geiger-Mueller (GM) detector with a 1.7 mg/cm<sup>2</sup> window. A weighted efficiency was established assuming natural isotopic abundances to quantify total uranium surface activity. Weighted efficiency determinations were in accordance with NUREG-1507 (NRC 1998), the *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)* (NRC 2000), ORAU Survey Protocol C.21 (“Scan MDC Determination for Surface Activity”) (ORAU 2016a).

Dry smear samples, for determining removable gross alpha/beta activity levels, were collected from each direct measurement location. Smears covered 100 cm<sup>2</sup> and were collected post direct measurement.

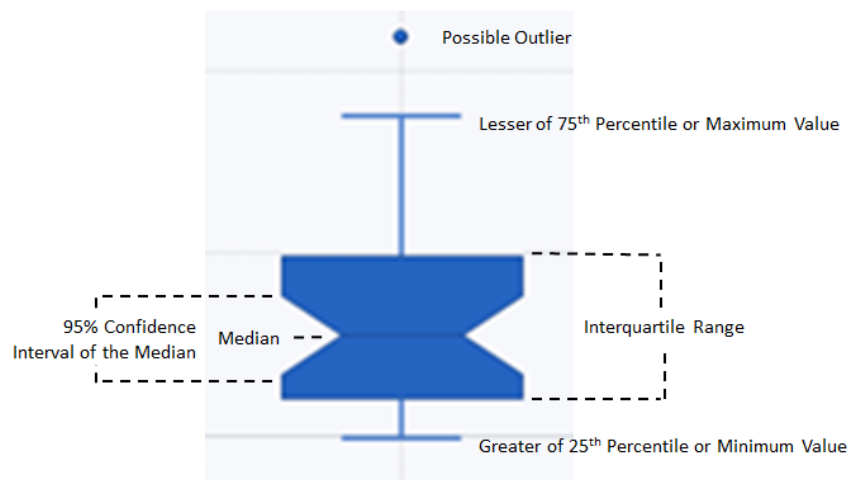
Material-specific background measurements were collected in building X-3002, within the site’s designated non-impacted background area that was, to the extent possible, of similar construction to the target materials. These background measurements were used to correct gross measurement counts for the conversion to surface activity levels in units of dpm/100 cm<sup>2</sup>.

## 6. SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and data collected on site were returned to the ORISE facility for analysis and interpretation. Sample custody was transferred to the Radiological and Environmental Analytical Laboratory in Oak Ridge, Tennessee. Sample analyses were performed in accordance with the *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual* (ORAU 2017). Smears were analyzed for removable gross alpha/beta activity using a low-background gas proportional

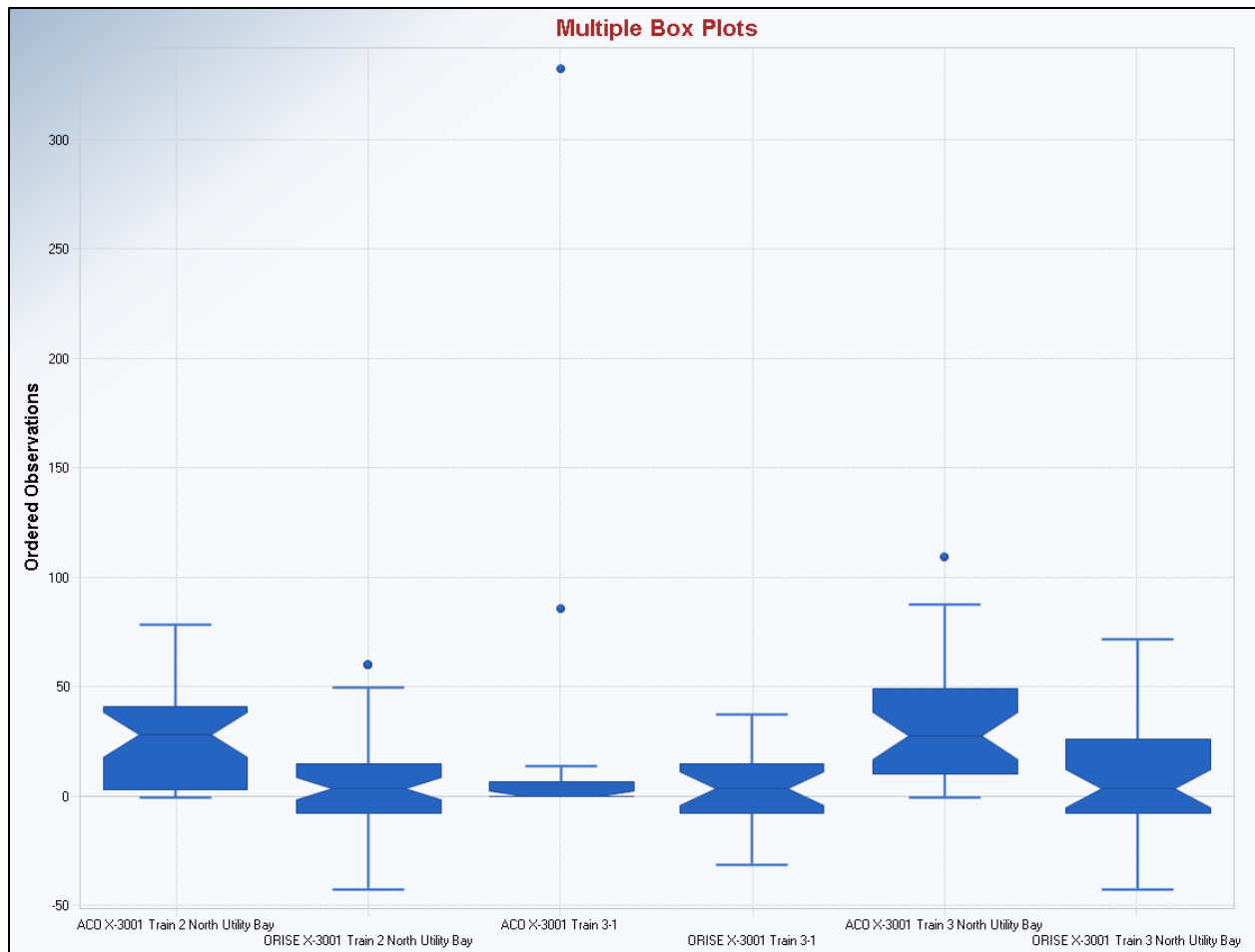
counter. Smear data and direct measurements for surface activity were converted to units of dpm/100 cm<sup>2</sup>. Additional laboratory instrumentation and processes are provided in Appendices B and C.

FSS data for three of the confirmatory SUs were available for mean uranium surface activity level comparison as follows: 1) X-3001 Train 2 North Utility Bay; 2) X-3001 Train 3 North Utility Bay; and 3) X-3001 Train 3-1. A preliminary data assessment was performed that consisted of box plots of these three SUs. Figure 6.1 shows descriptive statistic information that box plots provide.



**Figure 6.1. Box Plot Descriptive Statistics**

The plots shown in Figure 6.2 illustrate that all of the ORISE population data parameters are less than the FSS data, including the maximum observed values, meaning the FSS data are conservatively biased high. Additionally, the FSS population statistics include a systematic bias as only positive data are reported (i.e., negative results were reported as 0 dpm/100 cm<sup>2</sup>). A background population would be expected to contain an approximately equal number of positive and negative results with a mean of zero. This bias can be seen in the box plots for the ACO FSS results where all minimum values are zero. Additionally, the random location surface activity levels for these SUs are well below the calculated MDC (see Appendix B for ORISE MDC calculations). Based on this preliminary assessment and because hypothesis tests of data populations with most results near or below the MDCs can be inconclusive and generally lack sufficient power to detect what would be a small and therefore inconsequential difference, further hypothesis testing is unnecessary.



**Figure 6.2. Box Plots for Surface Activity Comparisons**

Individual sample results were also evaluated against the contamination levels listed in Table 4.1. As specified in the footnote, the criterion used for individual data points was three times the total surface activity limit, which is 15,000 dpm/100 cm<sup>2</sup>.

Scan data sets were graphed in a quantile-quantile (Q-Q) plot for assessment. The Q-Q plot is a graphical tool for assessing the distribution of a data set. The Y-axis represents gross alpha-plus-beta surface activity in units of counts per minute (cpm). The X-axis represents the data quantiles about the median value. Values less than the median are represented in the negative quantiles, and the values greater than the median are represented in the positive quantiles. A normal distribution that is not skewed by outliers—i.e., a background population—will appear as a straight line, with the slope of the line subject to the degree of variability among the data population. More than one distribution, such as background plus contamination or other outliers, will appear as a step function.



## **7. FINDINGS AND RESULTS**

The results of the confirmatory survey are discussed in the following subsections. Appendix A provides the tabulated survey data for all SUs investigated.

### **7.1 X-3001 TRAIN 2 AND TRAIN 3 NORTH UTILITY BAYS AND DRAINS**

Approximately 100 percent of the accessible floor area was scanned in X-3001 Trains 2 and 3 North Utility Bays. Areas previously remediated by ACO prior to the confirmatory survey were located within both North Utility Bays; these two areas still exhibited elevated radiation levels above background and were therefore selected for judgmental direct measurements. The Q-Q plot shown in Figure 7.1 for X-3001 Train 2 North Utility Bay alpha-plus-beta scan data appears normal with the data indicative of background levels. No direct measurements exceeded the contamination level and all removable activity was less than the MDC of 11 dpm/100 cm<sup>2</sup> for alpha and 14 dpm/100 cm<sup>2</sup> for beta. Figure 7.2 provides the Q-Q plot for X-3001 Train 3 North Utility Bay data set shows a step function indicating more than one data population due to contamination. No direct measurements exceeded the contamination level and all removable activity was less than the respective MDCs. All removable activity from the drains was less than the respective MDCs. Table 7.1 provides a summary of the survey data for these areas.

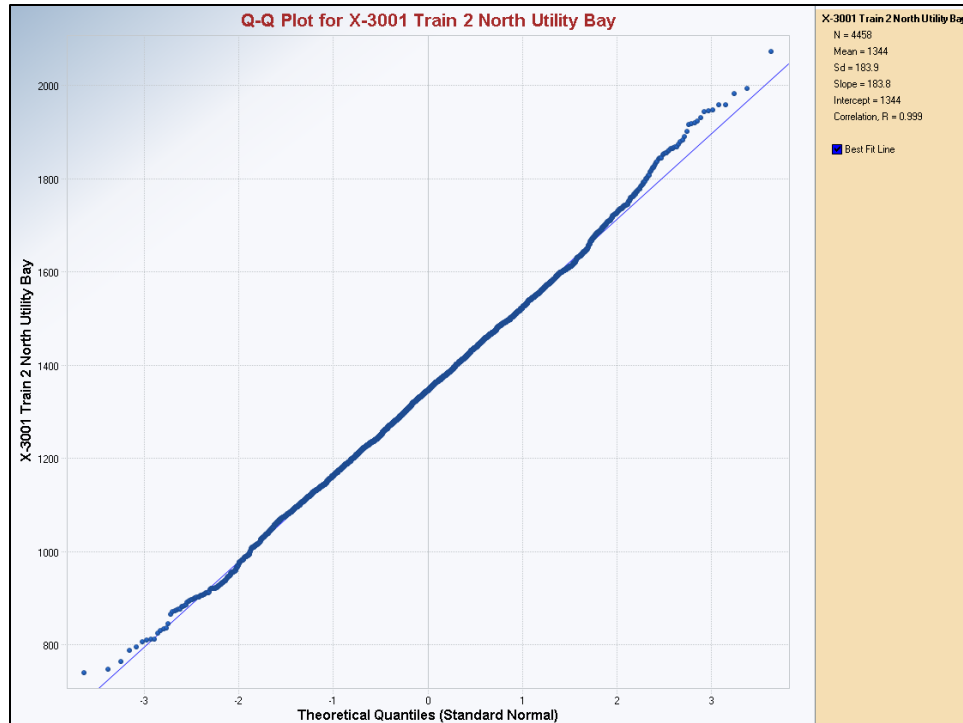


Figure 7.1. Q-Q Plot for X-3001 Train 2 North Utility Bay

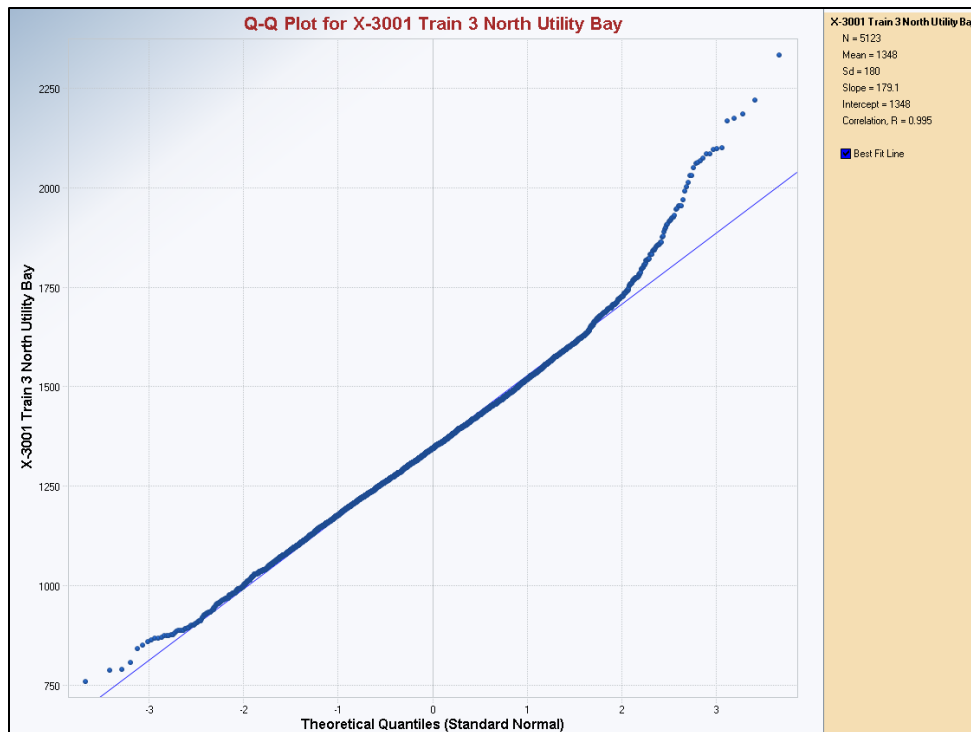


Figure 7.2. Q-Q Plot for X-3001 Train 3 North Utility Bay





**Table 7.1. Summary Data for X-3001 Train 2 and Train 3 North Utility Bays and Drains**

Survey Unit	Alpha-plus-Beta Scan Range (cpm)	ORISE Mean Alpha Activity	ACO Mean Alpha Activity	ORISE Maximum Total Alpha Activity	Maximum Removable Activity	
		dpm/100 cm <sup>2</sup>	dpm/100 cm <sup>2</sup>	dpm/100 cm <sup>2</sup>	Alpha	Beta
X-3001 Train 2 North Utility Bay	740 to 2,072	4.9	26.3	760	4.21	5.20
X-3001 Train 3 North Utility Bay	758 to 2,333	9.9	30.9	2,200	4.21	7.65
X-3001 Trains 2 and 3 North Utility Bay Drains	19 to 38	NA	NA	NA	1.92	6.42

NA= Not applicable

## 7.2 X-3001 TRAIN 1 AND TRAIN 3 MEZZANINES

Approximately 50 percent of the accessible floor area was scanned in Trains 1 and 3 upper level mezzanines in building X-3001. No areas of elevated radiation levels distinguishable from background were identified; therefore, no direct judgmental measurements or smear samples were collected from these areas. The Q-Q plot for X-3001 Train 1 and 3 Mezzanine data sets appears normal with no outliers. See Figure 7.3. Table 7.2 provides a summary of the survey data for these areas.

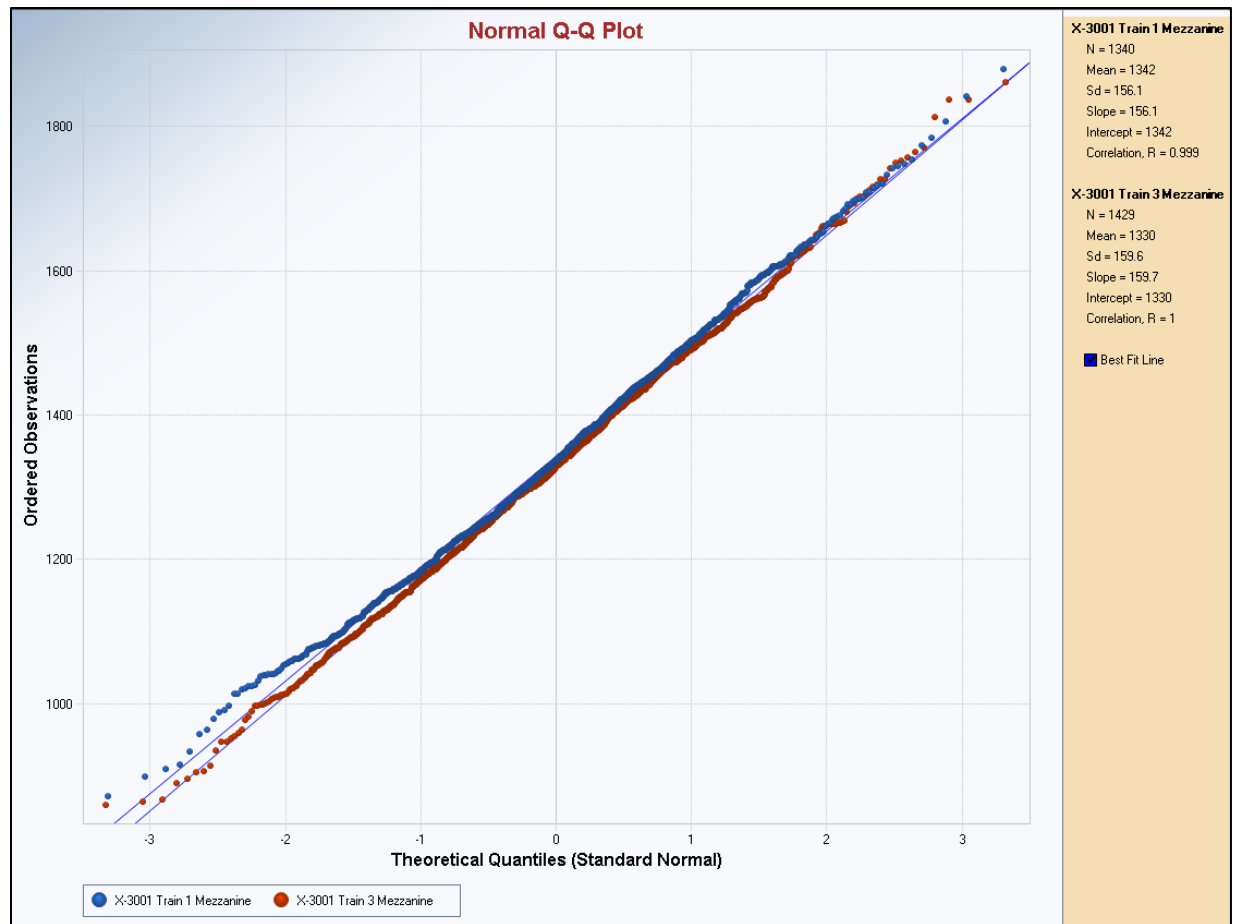


Figure 7.3. Q-Q Plot for X-3001 Train 1 and Train 3 Mezzanines

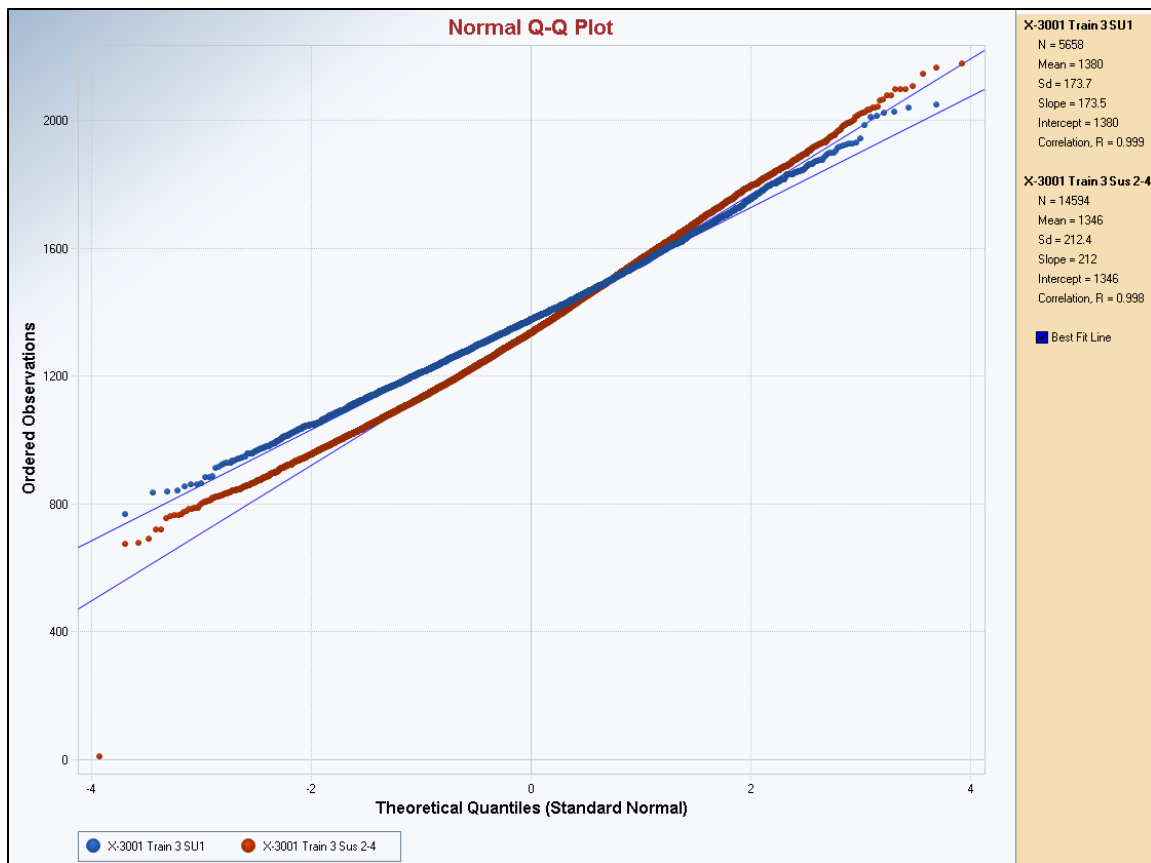
Table 7.2. Summary Data for X-3001 Train 1 and Train 3 Mezzanine

Survey Unit	Alpha-plus-Beta Scan Range (cpm)	ORISE Mean Alpha Activity	ACO Mean Alpha Activity	ORISE Maximum Total Alpha Activity	Maximum Removable Activity	
					Alpha	Beta
		dpm/100 cm <sup>2</sup>		dpm/100 cm <sup>2</sup>		
X-3001 Train 1 Mezzanine	871 to 1,879	NA	NA	NA	NA	NA
X-3001 Train 3 Mezzanine	859 to 1,861	NA	NA	NA	NA	NA

NA= Not applicable

### 7.3 X-3001 TRAIN 3

Approximately 100 percent of the floors in all four SUs in this area were scanned, including the wings containing the gamma spectroscopy area. One area in SU1 exhibited elevated alpha-plus-beta radiation levels (approximately 700 cpm) above background and was selected for two judgmental direct measurements and smear sampling. This area was the same area ACO had identified as containing elevated alpha radiation levels (though below the contamination level). The Q-Q plot appears normal for all SUs. See Figure 7.4. No direct measurements exceeded the contamination level and all removable activity levels were less than the respective MDCs. Table 7.3 provides a summary of the survey data for this area.



**Figure 7.4. Q-Q Plot for X-3001 Train 3**



**Table 7.3. Summary Data for X-3001 Train 3**

Survey Unit	Alpha-plus-Beta Scan Range (cpm)	ORISE Mean Alpha Activity	ACO Mean Alpha Activity	ORISE Maximum Total Alpha Activity	Maximum Removable Activity	
					Alpha	Beta
		dpm/100 cm <sup>2</sup>		dpm/100 cm <sup>2</sup>		
X-3001 Train 3	8 to 2,178	6.0	NA	720	1.92	5.20

NA= Not applicable

#### 7.4 X-3001 TRAIN 3 CENTRIFUGE DRAINS

The Centrifuge Drains investigated were from the drains located along the western-most edge of Train 3, where centrifuges were in operation. Approximately 100 percent of the 55 Centrifuge Drains were scanned. During the survey of the randomly selected Centrifuge Drains, elevated radiation levels were noted in the water collection area of the drains. Therefore, all water collection areas of the western-most 180 Centrifuge Drains were scanned. No direct measurements exceeded the Table 4.1 contamination levels and all removable activity was less than the respective MDCs. Table 7.4 provides a summary of the survey data for these areas.

**Table 7.4. Summary Data for X-3001 Train 3 Centrifuge Drains**

Survey Unit	Alpha-plus-Beta Scan Range (cpm)	ORISE Mean Alpha Activity	ACO Mean Alpha Activity	ORISE Maximum Total Alpha Activity	Maximum Removable Activity	
					Alpha	Beta
		dpm/100 cm <sup>2</sup>		dpm/100 cm <sup>2</sup>		
X-3001 Train 3 Centrifuge Drains	0 to 182	-15.0	NA	2,000	8.79	7.65

NA= Not applicable

#### 7.5 X-3001 TRAIN 6

Approximately 50 percent of the floor area was scanned in Train 6 in building X-3001. Scans were conducted in all four of ACO's SUs for Train 6. One area exhibited elevated radiation levels above background. This area was near and in a water collection area of a Centrifuge Drain; therefore, all water collection areas of the previously in use Centrifuge Drains were scanned. The Q-Q plot for X-3001 Train 6 data set shows a step function indicating more than one data population due to contamination. See Figure 7.5. No direct measurements exceeded the Table 4.1 contamination level,

and all removable activity levels were less than the respective MDCs. Table 7.5 provides a summary of the survey data for this area.

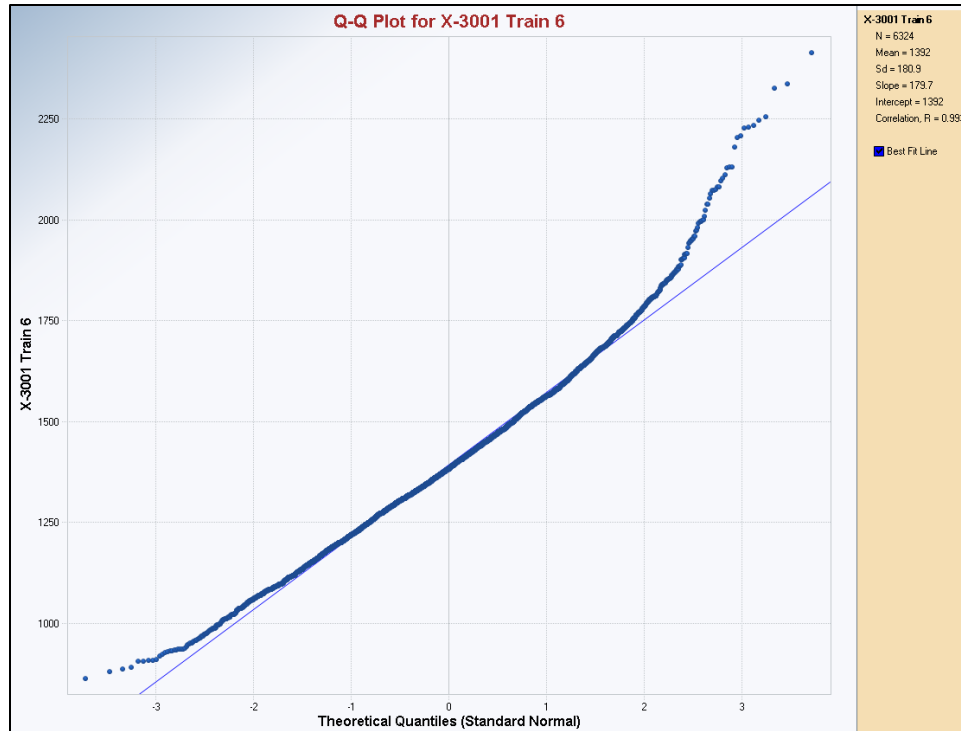


Figure 7.5. Q-Q Plot for X-3001 Train 6

Table 7.5. Summary Data for X-3001 Train 6						
Survey Unit	Alpha-plus-Beta Scan Range (cpm)	ORISE Mean Alpha Activity	ACO Mean Alpha Activity	ORISE Maximum Total Alpha Activity	Maximum Removable Activity	
					Alpha	Beta
		dpm/100 cm <sup>2</sup>		dpm/100 cm <sup>2</sup>		
X-3001 Train 6	862 to 2,414	NA	NA	2,100	1.92	5.20

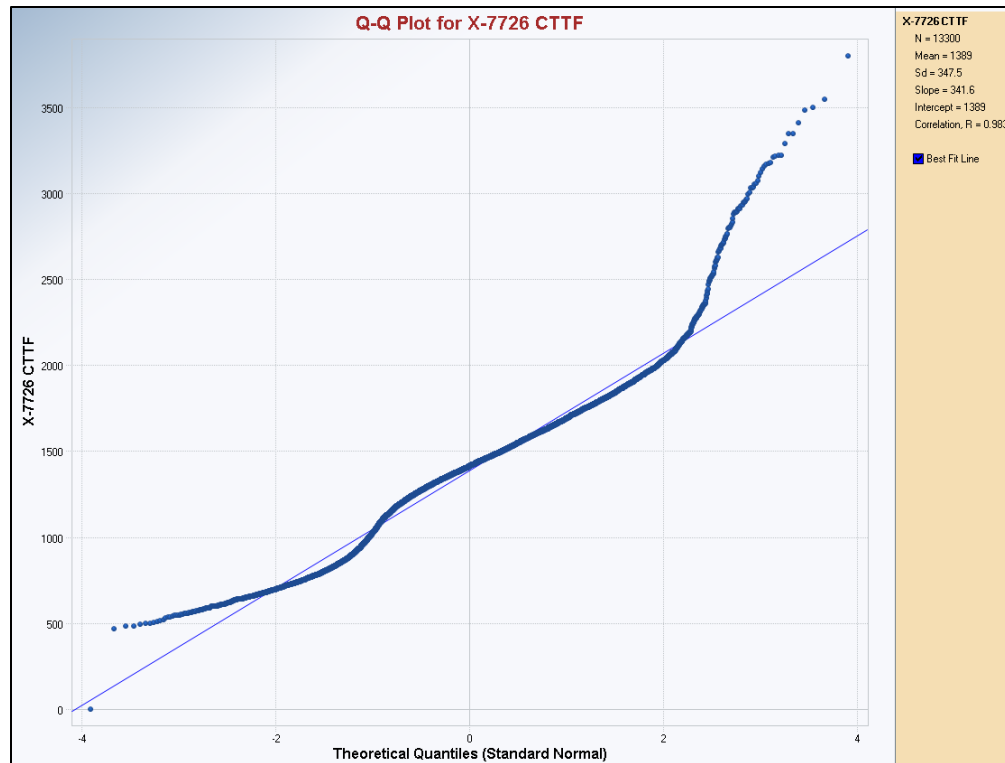
NA= Not applicable

## 7.6 X-7726 CTTF

Approximately 100 percent of the floor area was scanned in CTTF in building X-7726. Scans were conducted in the Material Storage Area, the Mezzanine, Assembly Stand, the Control Room, and all corridors. Ten areas exhibited elevated radiation levels above background. The Q-Q plot for X-7726 CTTF data set shows a step function indicating more than one data population due to



contamination (see Figure 7.6). No direct measurements exceeded the Table 4.1 contamination level and all removable activity was less than the respective MDCs. Table 7.6 provides a summary of the survey data for this area.



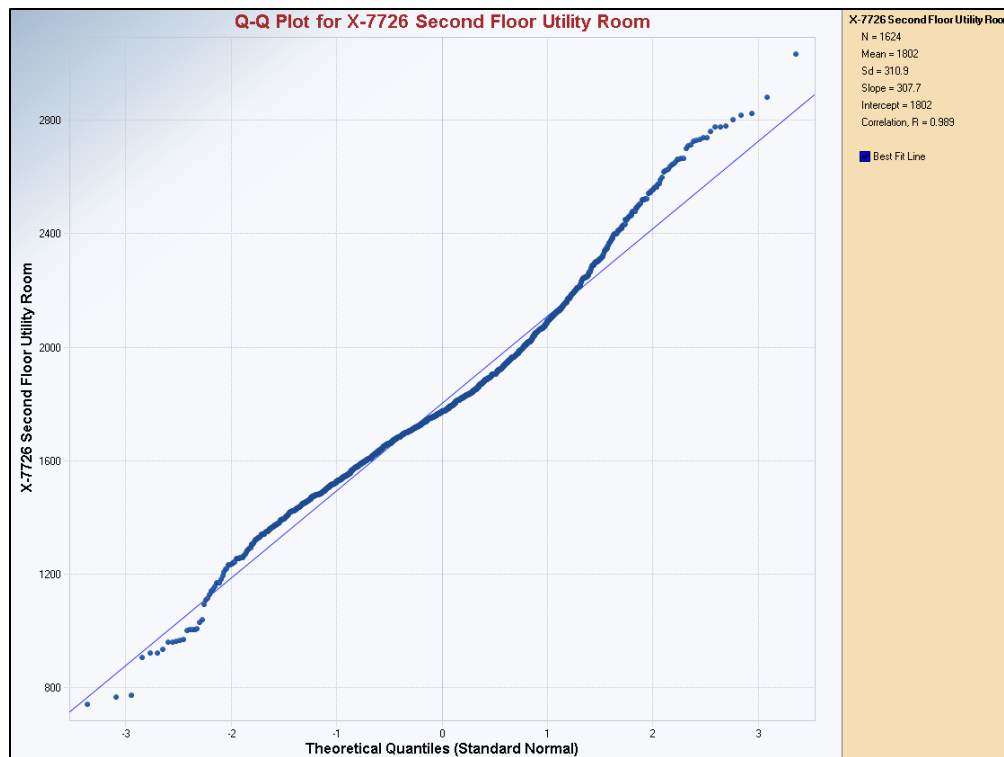
**Figure 7.6. Q-Q Plot for X-7726 CTTF**

Table 7.6. Summary Data for X-7726 CTTF						
Survey Unit	Alpha-plus-Beta Scan Range (cpm)	ORISE Mean Alpha Activity	ACO Mean Alpha Activity	ORISE Maximum Total Alpha Activity	Maximum Removable Activity	
					Alpha	Beta
		dpm/100 cm <sup>2</sup>		dpm/100 cm <sup>2</sup>		
X-7726 CTTF	0 to 3,798	9.1	NA	740	1.92	6.42

NA= Not applicable

## 7.7 X-7726 SECOND FLOOR UTILITY ROOM

Approximately 100 percent of the floor area was scanned in the X-7726 Second Floor Utility Room. Six areas exhibited elevated radiation levels above background. These areas were known to ACO and are believed to be due to operations prior to the Lead Cascade operations. The Q-Q plot for X-7726 Second Floor Utility Room data set shows a step function indicating more than one data population due to contamination (see Figure 7.7). No direct measurement exceeded the contamination level, and all removable activity was less than the respective MDCs. Table 7.7 provides a summary of the survey data for this area.



**Figure 7.7. Q-Q Plot for X-7726 Second Floor Utility Room**



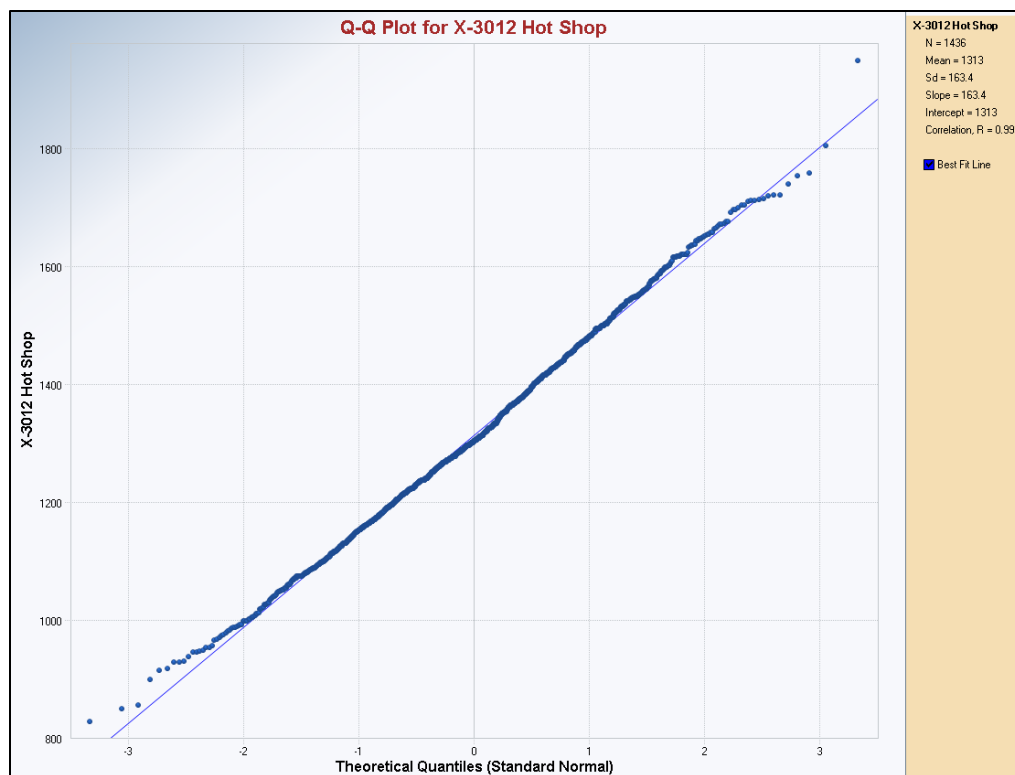
**Table 7.7. Summary Data for X-7726 Second Floor Utility Room**

Survey Unit	Alpha-plus-Beta Scan Range (cpm)	ORISE Mean Alpha Activity	ACO Mean Alpha Activity	ORISE Maximum Total Alpha Activity	Maximum Removable Activity	
		dpm/100 cm <sup>2</sup>	dpm/100 cm <sup>2</sup>	dpm/100 cm <sup>2</sup>	Alpha	Beta
X-7726 2nd Floor Utility Room	741 to 3,031	NA	NA	3,400	-0.37	3.97

NA= Not applicable

## 7.8 X-3012 HOT SHOP

Approximately 100 percent of the accessible floor area was scanned in the X-3012 Hot Shop; however, a portion of the area was covered with a plastic tarp that was not moved for surveys. No areas of elevated radiation levels above background were identified; therefore, no direct judgmental measurements or smear samples were collected from these areas. The Q-Q plot for X-3012 Hot Shop data set appears normal, with the exception of a possible background distribution outlier. See Figure 7.8. Table 7.8 provides a summary of the survey data for this area.



**Figure 7.8. Q-Q Plot for X-3012 Hot Shop**





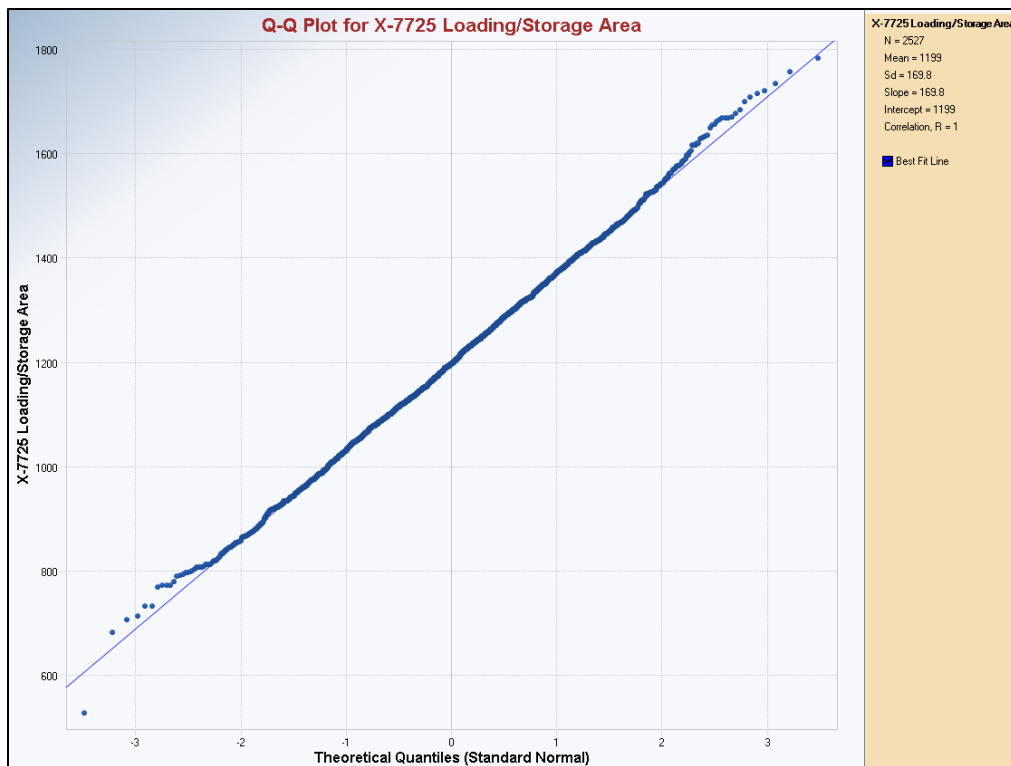
**Table 7.8. Summary Data for X-3012 Hot Shop**

Survey Unit	Alpha-plus-Beta Scan Range (cpm)	ORISE Mean Alpha Activity	ACO Mean Alpha Activity	ORISE Maximum Total Alpha Activity	Maximum Removable Activity	
		dpm/100 cm <sup>2</sup>	dpm/100 cm <sup>2</sup>	dpm/100 cm <sup>2</sup>	Alpha	Beta
X-3012 Hot Shop	828 to 1,949	NA	NA	NA	NA	NA

NA= Not applicable

## 7.9 X-7725 LOADING/STORAGE AREA

Approximately 100 percent of the accessible floor area was scanned near the rollup door and static centrifuge stands and approximately 50 percent of the accessible floor space was scanned in the rest of the X-7725 Loading/Storage Area. No elevated radiation levels above background were identified; therefore, no direct judgmental measurements or smear samples were collected from these areas. The Q-Q plot data set for X-7726 Loading/Storage Area appears normal (see Figure 7.9). Table 7.9 provides a summary of the survey data for this area.



**Figure 7.9. Q-Q Plot for X-7725 Loading/Storage Area**



**Table 7.9. Summary Data for X-7725 Loading/Storage Area**

Survey Unit	Alpha-plus-Beta Scan Range (cpm)	ORISE Mean Alpha Activity	ACO Mean Alpha Activity	ORISE Maximum Total Alpha Activity	Maximum Removable Activity	
					Alpha	Beta
		dpm/100 cm <sup>2</sup>		dpm/100 cm <sup>2</sup>		
X-7725 Loading/Storage Area	528 to 1,782	NA	NA	NA	NA	NA

NA= Not applicable

## 8. SUMMARY

At the NRC's request, ORISE conducted confirmatory survey activities in the X-3001 Train 2 North Utility Bay, X-3001 Train 3 North Utility Bay, X-3001 Trains 2 and 3 North Utility Bay Drains, X-3001 Train 1 Mezzanine, X-3001 Train 3 Mezzanine, X-3001 Train 3, X-3001 Train 3 Centrifuge Drains, X-3001 Train 6, X-7726 Centrifuge Training and Testing Facility, X-7726 Second Floor Utility Room, X-3012 Hot Shop, and X-7725 Loading/Storage Area at the American Centrifuge Lead Cascade Facility during the period of May 21-25, 2018. The survey activities included alpha-plus-beta radiation floor scans, beta radiation drain scans, alpha radiation scans, alpha direct measurements, and smear sampling, as applicable.

The scans of X-3001 Train 2 North Utility Bay Drains, X-3001 Train 3 North Utility Bay Drains, X-3001 Train 1 Mezzanine, X-3001 Train 3 Mezzanine, X-3012 Hot Shop, and X-7725 Loading/Storage Area were comparable to background. The alpha-plus-beta floor scans identified multiple areas with elevated radiation levels above background in the following areas: X-3001 Train 2 North Utility Bay, X-3001 Train 3 North Utility Bay, X-3001 Train 3, X-3001 Train 3 water collection areas of the Centrifuge Drains, X-3001 Train 6 and in the water collection area of a Centrifuge Drain, X-7726 CTTF, and X-7726 Second Floor Utility Room. Direct measurements and/or smears were judgmentally collected from 58 locations, based on the results of the scanning. Random direct measurements and smears were collected from a total of 179 locations throughout SUs X-3001 Train 2 North Utility Bay, X-3001 Train 3 North Utility Bay, X-3001 Train 3, X-3001 Train 3 Centrifuge Drains, and X-7726 CTTF. All direct measurements collected were below the Table 4.1 contamination level with a maximum value of 3,400 dpm/100 cm<sup>2</sup> and all smears were below the MDC of the analytical equipment, which were 11 and 14 dpm/100 cm<sup>2</sup> for alpha and beta removable activity, respectively. The confirmatory survey results did not identify residual



contamination that exceeded the Table 4.1 license application contamination limits, and confirmatory survey measurement population statistics were comparable with the reported FSS data for the respective Lead Cascade survey units investigated.



## 9. REFERENCES

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- ORAU 2016c. *ORAU Health and Safety Manual*. Oak Ridge Associated Universities. Oak Ridge, Tennessee. January.
- ORAU 2017. *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual*. Oak Ridge Associated Universities. Oak Ridge, Tennessee. August 24.
- ORISE 2018. *Project-Specific Plan for the Confirmatory Survey Activities at the American Centrifuge Lead Cascade Facility, Piketon, Ohio*. Oak Ridge Institute for Science and Education. Oak Ridge, Tennessee. May 18.

## **APPENDIX A: DATA TABLES AND FIGURES**

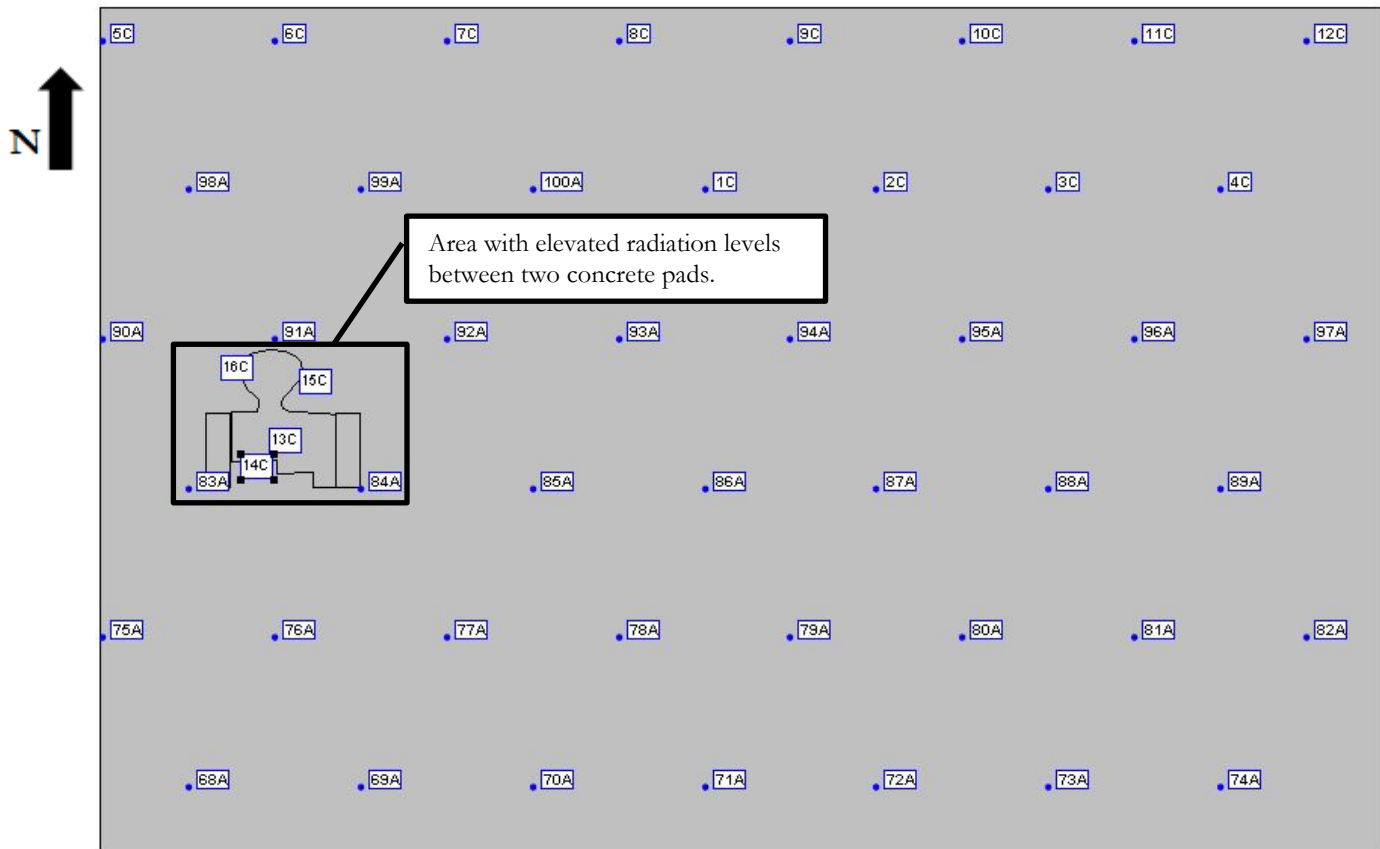


Figure A-1. X-3001 Train 2 North Utility Bay Measurement Locations

Table A.1. X-3001, Train 2 North Utility Bay Survey Data

Table A.1. X-3001, Train 2 North Utility Bay Survey Data									
Random/ Judgmental	Smear ID	Coordinates (m)		Surface	Material	Total Activity		Removable Activity	
		X	Y			Alpha		Alpha	Beta
						cpm	dpm/100 cm <sup>2</sup>	dpm/100 cm <sup>2</sup>	
Random	5326R0068A	2.2	1.5	Floor	Concrete	2	-19	-0.37	0.29
Random	5326R0069A	6.5	1.5	Floor	Concrete	5	15	-0.37	5.20
Random	5326R0070A	10.8	1.5	Floor	Concrete	4	3.4	-0.37	-3.38
Random	5326R0071A	15.1	1.5	Floor	Concrete	5	15	-0.37	1.52
Random	5326R0072A	19.4	1.5	Floor	Concrete	1	-31	-0.37	2.75
Random	5326R0073A	23.7	1.5	Floor	Concrete	0	-42	-0.37	3.97
Random	5326R0074A	28.0	1.5	Floor	Concrete	5	15	1.92	0.29
Random	5326R0075A	0.1	5.3	Floor	Concrete	4	3.4	-0.37	0.29
Random	5326R0076A	4.4	5.3	Floor	Concrete	7	37	-0.37	-3.38
Random	5326R0077A	8.7	5.3	Floor	Concrete	4	3.4	-0.37	2.75
Random	5326R0078A	13.0	5.3	Floor	Concrete	7	37	-0.37	1.52
Random	5326R0079A	17.3	5.3	Floor	Concrete	4	3.4	-0.37	-0.93

**Table A.1. X-3001, Train 2 North Utility Bay Survey Data**

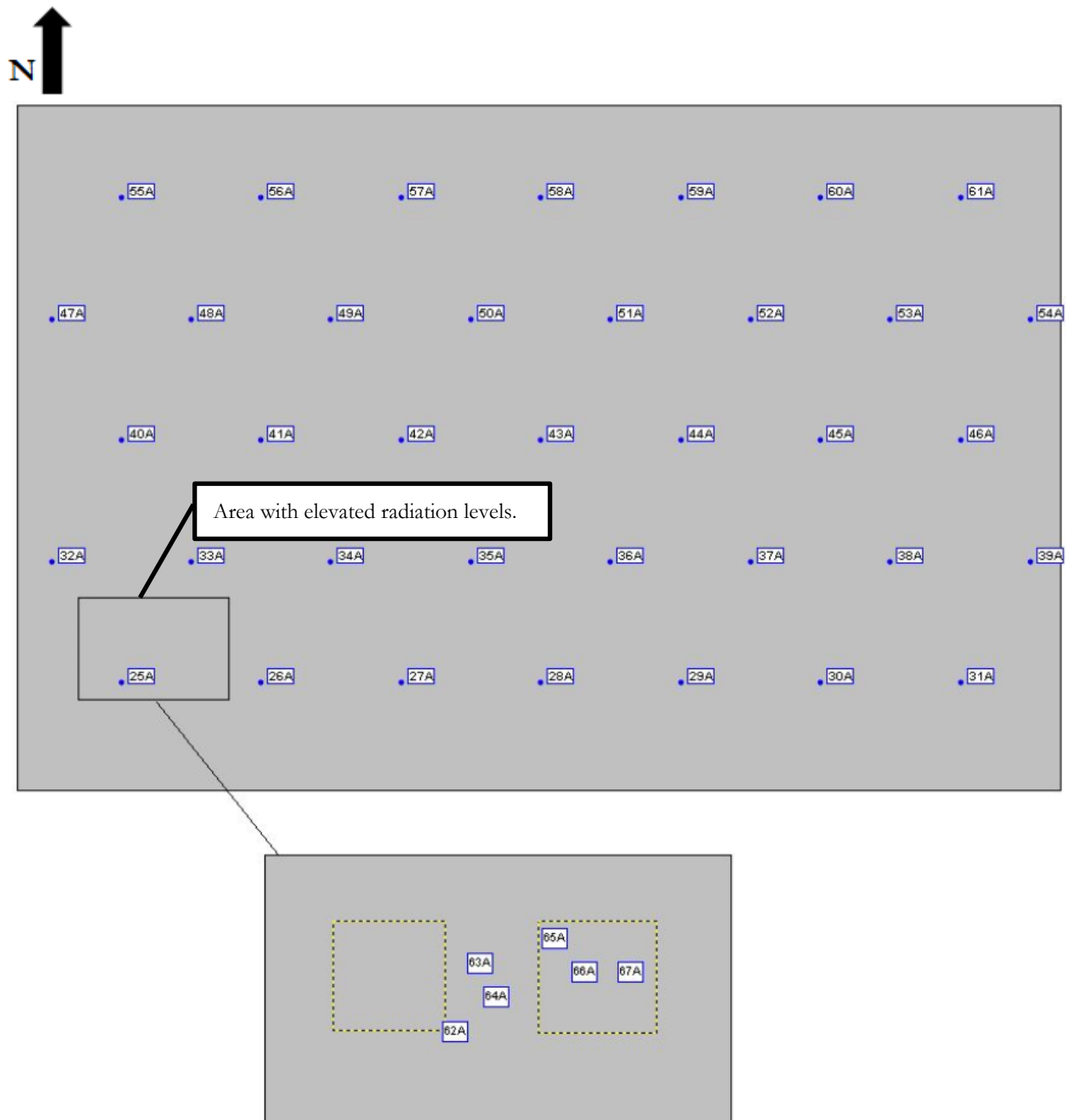
Random/ Judgmental	Smear ID	Coordinates (m)		Surface	Material	Total Activity		Removable Activity	
		X	Y			Alpha		Alpha	Beta
						cpm	dpm/100 cm²	dpm/100 cm²	
Random	5326R0080A	21.6	5.3	Floor	Concrete	3	-7.9	-0.37	-2.16
Random	5326R0081A	25.9	5.3	Floor	Concrete	5	15	-0.37	-0.93
Random	5326R0082A	30.2	5.3	Floor	Concrete	4	3.4	-0.37	3.97
Random	5326R0083A	2.2	9.0	Floor	Concrete	9	60	-0.37	-0.93
Random	5326R0084A	6.5	9.0	Floor	Concrete	8	49	-0.37	1.52
Random	5326R0085A	10.8	9.0	Floor	Concrete	6	26	1.92	-0.93
Random	5326R0086A	15.1	9.0	Floor	Concrete	1	-31	-0.37	2.75
Random	5326R0087A	19.4	9.0	Floor	Concrete	6	26	4.21	5.20
Random	5326R0088A	23.7	9.0	Floor	Concrete	4	3.4	-0.37	1.52
Random	5326R0089A	28.0	9.0	Floor	Concrete	2	-19	1.92	-0.93
Random	5326R0090A	0.1	12.7	Floor	Concrete	9	60	-0.37	1.52
Random	5326R0091A	4.4	12.7	Floor	Concrete	7	37	-0.37	2.75
Random	5326R0092A	8.7	12.7	Floor	Concrete	3	-7.9	-0.37	3.97
Random	5326R0093A	13.0	12.7	Floor	Concrete	3	-7.9	-0.37	0.29
Random	5326R0094A	17.3	12.7	Floor	Concrete	5	15	-0.37	-2.16
Random	5326R0095A	21.6	12.7	Floor	Concrete	4	3.4	1.92	-2.16
Random	5326R0096A	25.9	12.7	Floor	Concrete	3	-7.9	-0.37	-0.93
Random	5326R0097A	30.2	11.8	Floor	Concrete	2	-19	-0.37	0.29
Random	5326R0098A	2.2	16.4	Floor	Concrete	2	-19	-0.37	-2.16
Random	5326R0099A	6.5	16.4	Floor	Concrete	3	-7.9	-0.37	-2.16
Random	5326R0100A	10.8	16.4	Floor	Concrete	1	-31	-0.37	-2.16
Random	5326R0001C	15.1	16.4	Floor	Concrete	3	-7.9	-0.37	2.75
Random	5326R0002C	19.4	16.4	Floor	Concrete	4	3.4	-0.37	2.75
Random	5326R0003C	23.7	16.4	Floor	Concrete	3	-7.9	-0.37	-3.38
Random	5326R0004C	28.0	16.4	Floor	Concrete	3	-7.9	-0.37	0.29
Random	5326R0005C	0.1	20.1	Floor	Concrete	5	15	-0.37	-3.38
Random	5326R0006C	4.4	20.1	Floor	Concrete	9	60	1.92	5.20
Random	5326R0007C	8.7	20.1	Floor	Concrete	4	3.4	1.92	1.52
Random	5326R0008C	13.0	20.1	Floor	Concrete	5	15	-0.37	2.75
Random	5326R0009C	17.3	20.1	Floor	Concrete	4	3.4	-0.37	1.52
Random	5326R0010C	21.6	20.1	Floor	Concrete	3	-7.9	-0.37	2.75
Random	5326R0011C	25.9	20.1	Floor	Concrete	3	-7.9	-0.37	-3.38
Random	5326R0012C	30.2	20.1	Floor	Concrete	2	-19	-0.37	-2.16
Mean						4.1	4.9		

**Table A.1. X-3001, Train 2 North Utility Bay Survey Data**

Random/ Judgmental	Smear ID	Coordinates (m)		Surface	Material	Total Activity		Removable Activity	
		X	Y			Alpha		Alpha	Beta
						cpm	dpm/100 cm²	dpm/100 cm²	
Judgmental	5326R0013C	NA	NA	Floor	Concrete	30	300	4.21	0.29
Judgmental	5326R0014C	NA	NA	Floor	Concrete	61	650	-0.37	-0.93
Judgmental	5326R0015C	NA	NA	Floor	Concrete	71	760	-0.37	2.75
Judgmental	5326R0016C	NA	NA	Floor	Concrete	69	740	-0.37	-0.93

NA= Not applicable





**Figure A-2. X-3001 Train 3 North Utility Bay Measurement Locations**

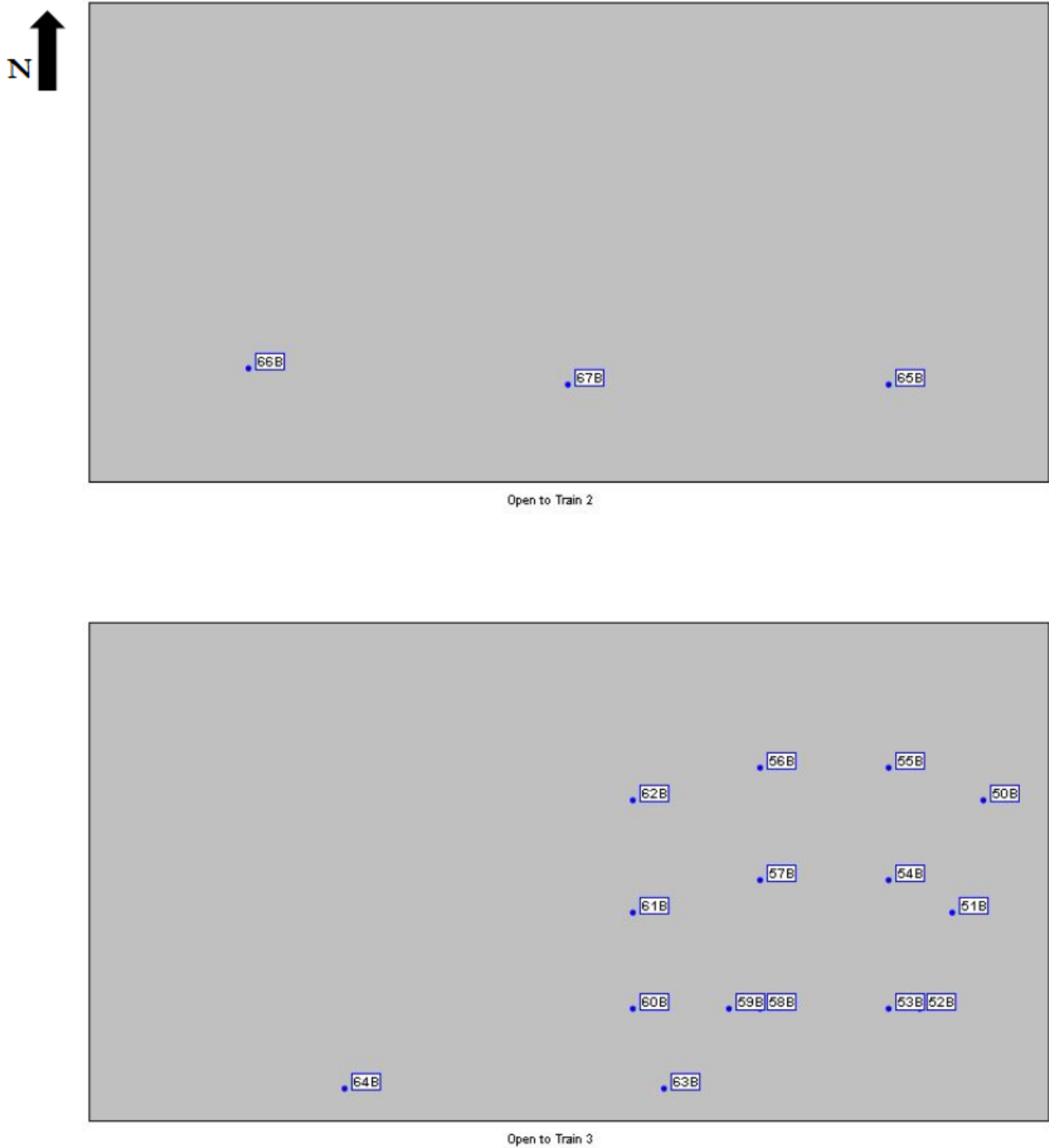
**Table A.2. X-3001, Train 3 North Utility Bay Survey Data**

Random/ Judgmental	Smear ID	Coordinates (m)		Surface	Material	Total Activity		Removable Activity	
		X	Y			Alpha		Alpha	Beta
						cpm	dpm/100 cm²	dpm/100 cm²	
Random	5326R0025A	3.2	3.3	Floor	Concrete	10	71	-0.37	0.29
Random	5326R0026A	7.5	3.3	Floor	Concrete	4	3.4	-0.37	-2.16
Random	5326R0027A	11.8	3.3	Floor	Concrete	2	-19	-0.37	-2.16
Random	5326R0028A	16.1	3.3	Floor	Concrete	6	26	-0.37	-0.93
Random	5326R0029A	20.4	3.3	Floor	Concrete	3	-7.9	-0.37	3.97
Random	5326R0030A	24.7	3.3	Floor	Concrete	8	49	-0.37	-0.93
Random	5326R0031A	28.9	3.3	Floor	Concrete	0	-42	-0.37	-2.16
Random	5326R0032A	1.1	7.0	Floor	Concrete	2	-19	-0.37	-3.38
Random	5326R0033A	5.4	7.0	Floor	Concrete	3	-7.9	-0.37	0.29
Random	5326R0034A	9.6	7.0	Floor	Concrete	5	15	-0.37	0.29
Random	5326R0035A	13.9	7.0	Floor	Concrete	4	3.4	-0.37	1.52
Random	5326R0036A	18.2	7.0	Floor	Concrete	6	26	-0.37	0.29
Random	5326R0037A	22.5	7.0	Floor	Concrete	6	26	-0.37	1.52
Random	5326R0038A	26.8	7.0	Floor	Concrete	8	49	-0.37	-0.93
Random	5326R0039A	31.1	7.0	Floor	Concrete	6	26	-0.37	1.52
Random	5326R0040A	3.2	8.6	Floor	Concrete	7	37	-0.37	-2.16
Random	5326R0041A	7.5	8.6	Floor	Concrete	4	3.4	1.92	3.97
Random	5326R0042A	11.8	10.7	Floor	Concrete	3	-7.9	-0.37	1.52
Random	5326R0043A	16.1	10.7	Floor	Concrete	4	3.4	-0.37	0.29
Random	5326R0044A	20.4	10.7	Floor	Concrete	8	49	-0.37	0.29
Random	5326R0045A	24.7	10.7	Floor	Concrete	3	-7.9	-0.37	3.97
Random	5326R0046A	28.9	10.7	Floor	Concrete	2	-19	1.92	1.52
Random	5326R0047A	1.1	14.4	Floor	Concrete	2	-19	-0.37	-3.38
Random	5326R0048A	5.4	14.4	Floor	Concrete	2	-19	-0.37	2.75
Random	5326R0049A	9.6	14.4	Floor	Concrete	3	-7.9	-0.37	2.75
Random	5326R0050A	13.9	14.4	Floor	Concrete	3	-7.9	-0.37	5.20
Random	5326R0051A	18.2	14.4	Floor	Concrete	7	37	4.21	-2.16
Random	5326R0052A	22.5	14.4	Floor	Concrete	4	3.4	-0.37	2.75
Random	5326R0053A	26.8	14.4	Floor	Concrete	7	37	-0.37	-2.16
Random	5326R0054A	31.1	14.4	Floor	Concrete	3	-7.9	-0.37	0.29
Random	5326R0055A	3.2	18.1	Floor	Concrete	8	49	-0.37	-0.93
Random	5326R0056A	7.5	18.1	Floor	Concrete	6	26	-0.37	3.97
Random	5326R0057A	11.8	18.1	Floor	Concrete	5	15	1.92	-3.38
Random	5326R0058A	16.1	18.1	Floor	Concrete	3	-7.9	-0.37	-2.16

**Table A.2. X-3001, Train 3 North Utility Bay Survey Data**

Random/ Judgmental	Smear ID	Coordinates (m)		Surface	Material	Total Activity		Removable Activity	
		X	Y			Alpha		Alpha	Beta
						cpm	dpm/100 cm²	dpm/100 cm²	
Random	5326R0059A	20.4	18.1	Floor	Concrete	5	15	-0.37	0.29
Random	5326R0060A	24.7	18.1	Floor	Concrete	4	3.4	-0.37	-3.38
Random	5326R0061A	28.9	18.1	Floor	Concrete	3	-7.9	-0.37	-0.93
Mean						4.6	10		
Judgmental	5326R0062A	NA	NA	Floor	Concrete	112	1,200	-0.37	-0.93
Judgmental	5326R0063A	NA	NA	Floor	Concrete	127	1,400	-0.37	-0.93
Judgmental	5326R0064A	NA	NA	Floor	Concrete	104	1,100	-0.37	7.65
Judgmental	5326R0065A	NA	NA	Floor	Concrete	137	1,500	-0.37	1.52
Judgmental	5326R0066A	NA	NA	Floor	Concrete	130	1,400	-0.37	-2.16
Judgmental	5326R0067A	NA	NA	Floor	Concrete	199	2,200	-0.37	2.75

NA= Not applicable

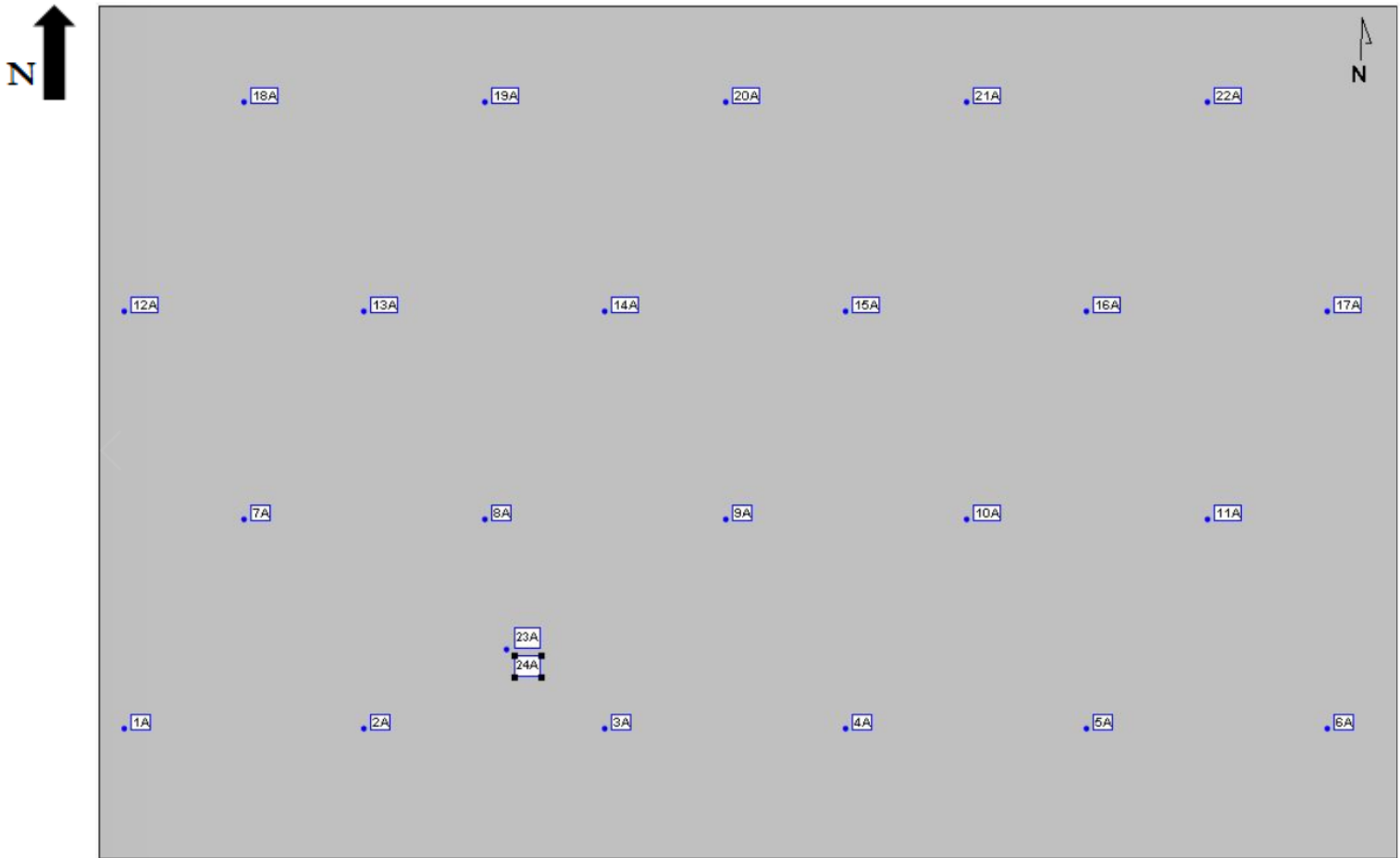


**Figure A-3. X-3001 Trains 2 and 3 North Utility Bay Drains Measurement Locations**

**Table A.3. X-3001, Trains 2 and 3 North Utility Bay Drains Survey Data**

Random/ Judgmental	Smear ID	Coordinates (m)		Surface	Material	Total Activity		Removable Activity	
		X	Y			Alpha		Alpha	Beta
						cpm	dpm/100 cm <sup>2</sup>	dpm/100 cm <sup>2</sup>	
Train 2									
Judgmental	5326R0065B	NA	NA	Drain	Rusted Metal	NA	NA	1.92	-2.16
Judgmental	5326R0066B	NA	NA	Drain	Rusted Metal	NA	NA	-0.37	0.29
Judgmental	5326R0067B	NA	NA	Drain	Rusted Metal	NA	NA	-0.37	-0.93
Train 3									
Judgmental	5326R0050B	NA	NA	Drain	Rusted Metal	NA	NA	-0.37	3.97
Judgmental	5326R0051B	NA	NA	Drain	Rusted Metal	NA	NA	1.92	6.42
Judgmental	5326R0052B	NA	NA	Drain	Rusted Metal	NA	NA	-0.37	1.52
Judgmental	5326R0053B	NA	NA	Drain	Rusted Metal	NA	NA	-0.37	0.29
Judgmental	5326R0054B	NA	NA	Drain	Rusted Metal	NA	NA	1.92	-0.93
Judgmental	5326R0055B	NA	NA	Drain	Rusted Metal	NA	NA	1.92	2.75
Judgmental	5326R0056B	NA	NA	Drain	Rusted Metal	NA	NA	-0.37	-2.16
Judgmental	5326R0057B	NA	NA	Drain	Rusted Metal	NA	NA	-0.37	-0.93
Judgmental	5326R0058B	NA	NA	Drain	Rusted Metal	NA	NA	-0.37	1.52
Judgmental	5326R0059B	NA	NA	Drain	Rusted Metal	NA	NA	-0.37	1.52
Judgmental	5326R0060B	NA	NA	Drain	Rusted Metal	NA	NA	-0.37	1.52
Judgmental	5326R0061B	NA	NA	Drain	Rusted Metal	NA	NA	-0.37	3.97
Judgmental	5326R0062B	NA	NA	Drain	Rusted Metal	NA	NA	-0.37	0.29
Judgmental	5326R0063B	NA	NA	Drain	Rusted Metal	NA	NA	-0.37	-0.93
Judgmental	5326R0064B	NA	NA	Drain	Rusted Metal	NA	NA	-0.37	2.75

NA= Not applicable



**Figure A-4. X-3001 Train 3 Measurement Locations**

**Table A.4. X-3001, Train 3 Survey Data**

Random/ Judgmental	Smear ID	Coordinates (m)		Surface	Material	Total Activity		Removable Activity	
		X	Y			Alpha		Alpha	Beta
						cpm	dpm/100 cm²	dpm/100 cm²	
Random	5326R0001A	0.6	3.2	Floor	Concrete	4	3.4	-0.37	5.20
Random	5326R0002A	6.5	3.2	Drain Floor	Metal	4	3.4	-0.37	-3.38
Random	5326R0003A	12.5	3.2	Floor	Concrete	7	37	-0.37	2.75
Random	5326R0004A	18.4	3.2	Drain Floor	Metal	3	-7.9	-0.37	2.75
Random	5326R0005A	24.4	3.2	Floor	Metal	3	-7.9	-0.37	2.75
Random	5326R0006A	30.3	3.2	Floor	Concrete	5	15	-0.37	0.29
Random	5326R0007A	3.6	8.3	Floor	Concrete	5	15	-0.37	2.75
Random	5326R0008A	9.5	8.3	Floor	Concrete	5	15	1.92	-3.38
Random	5326R0009A	15.5	8.3	Floor	Concrete	1	-31	-0.37	0.29
Random	5326R0010A	21.4	8.3	Floor	Concrete	7	37	-0.37	-2.16
Random	5326R0011A	27.3	8.3	Floor	Concrete	5	15	-0.37	-0.93
Random	5326R0012A	0.6	13.5	Floor	Concrete	5	15	-0.37	2.75
Random	5326R0013A	6.5	13.5	Floor	Concrete	6	26	-0.37	1.52
Random	5326R0014A	12.5	13.5	Floor	Concrete	6	26	1.92	0.29
Random	5326R0015A	18.4	13.5	Floor	Concrete	4	3.4	-0.37	1.52
Random	5326R0016A	24.4	13.5	Floor	Concrete	4	3.4	-0.37	-2.16
Random	5326R0017A	30.3	13.5	Floor	Concrete	2	-19	-0.37	-0.93
Random	5326R0018A	3.6	18.6	Floor	Concrete	3	-7.9	-0.37	0.29
Random	5326R0019A	9.5	18.6	Floor	Concrete	3	-7.9	1.92	2.75
Random	5326R0020A	15.5	18.6	Floor	Concrete	2	-19	-0.37	2.75
Random	5326R0021A	21.4	18.6	Floor	Concrete	4	3.4	-0.37	-0.93
Random	5326R0022A	27.3	18.6	Floor	Concrete	5	15	1.92	1.52
Mean						4.2	6.0		
Judgmental	5326R0023A	Near Southwest Corner of Centrifuge Drain 4-12		Floor	Concrete	56	590	-0.37	-0.93
Judgmental	5326R0024A			Floor	Metal/ Concrete	67	720	1.92	3.97

NA= Not applicable

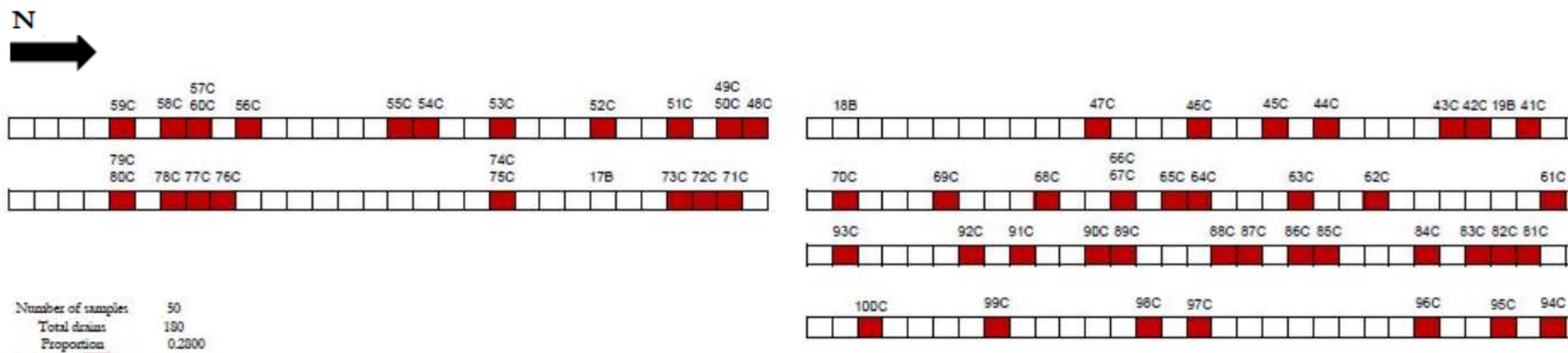


Figure A-5. X-3001 Train 3 Centrifuge Drains Measurement Locations



**Table A.5. X-3001, Train 3 Centrifuge Drains Survey Data**

Random/ Judgmental	Smear ID	Coordinates (m)		Surface	Material	Total Activity		Removable Activity	
		X	Y			Alpha		Alpha	Beta
						cpm	dpm/100 cm <sup>2</sup>	dpm/100 cm <sup>2</sup>	
Random	5326R0041C	NA	NA	Over Drain	Metal/PVC	0	-42	-0.37	-0.93
Random	5326R0042C	NA	NA	Over Drain	Metal/PVC	4	3.4	-0.37	-2.16
Random	5326R0043C	NA	NA	Over Drain	Metal/PVC	1	-31	-0.37	1.52
Random	5326R0044C	NA	NA	Over Drain	Metal/PVC	1	-31	-0.37	-2.16
Random	5326R0045C	NA	NA	Over Drain	Metal/PVC	2	-19	-0.37	-0.93
Random	5326R0046C	NA	NA	Over Drain	Metal/PVC	1	-31	-0.37	-2.16
Random	5326R0047C	NA	NA	Over Drain	Metal/PVC	3	-7.9	-0.37	0.93
Random	5326R0048C	NA	NA	Over Drain	Metal/PVC	3	-7.9	-0.37	6.42
Random	5326R0049C	NA	NA	Over Drain	Metal/PVC	0	-42	1.92	1.52
Random	5326R0051C	NA	NA	Over Drain	Metal/PVC	1	-31	-0.37	0.29
Random	5326R0052C	NA	NA	Over Drain	Metal/PVC	0	-42	-0.37	1.52
Random	5326R0053C	NA	NA	Over Drain	Metal/PVC	2	-19	1.92	-0.93
Random	5326R0054C	NA	NA	Over Drain	Metal/PVC	1	-31	-0.37	1.52
Random	5326R0055C	NA	NA	Over Drain	Metal/PVC	3	-7.9	-0.37	5.20
Random	5326R0056C	NA	NA	Over Drain	Metal/PVC	3	-7.9	-0.37	-0.93
Random	5326R0057C	NA	NA	Over Drain	Metal/PVC	0	-42	1.92	7.65
Random	5326R0058C	NA	NA	Over Drain	Metal/PVC	4	3.4	1.92	0.29
Random	5326R0059C	NA	NA	Over Drain	Metal/PVC	1	-31	-0.37	0.29
Random	5326R0061C	NA	NA	Over Drain	Metal/PVC	3	-7.9	-0.37	1.52
Random	5326R0062C	NA	NA	Over Drain	Metal/PVC	2	-19	-0.37	0.29
Random	5326R0063C	NA	NA	Over Drain	Metal/PVC	2	-19	-0.37	-0.93
Random	5326R0064C	NA	NA	Over Drain	Metal/PVC	2	-19	-0.37	0.29
Random	5326R0065C	NA	NA	Over Drain	Metal/PVC	3	-7.9	-0.37	2.75
Random	5326R0067C	NA	NA	Over Drain	Metal/PVC	1	-31	-0.37	2.75

**Table A.5. X-3001, Train 3 Centrifuge Drains Survey Data**

Random/ Judgmental	Smear ID	Coordinates (m)		Surface	Material	Total Activity		Removable Activity	
		X	Y			Alpha		Alpha	Beta
						cpm	dpm/100 cm <sup>2</sup>	dpm/100 cm <sup>2</sup>	
Random	5326R0068C	NA	NA	Over Drain	Metal/PVC	4	3.4	-0.37	-0.93
Random	5326R0069C	NA	NA	Over Drain	Metal/PVC	3	-7.9	-0.37	1.52
Random	5326R0070C	NA	NA	Over Drain	Metal/PVC	3	-7.9	-0.37	3.97
Random	5326R0071C	NA	NA	Over Drain	Metal/PVC	7	37	-0.37	-3.38
Random	5326R0072C	NA	NA	Over Drain	Metal/PVC	2	-19	-0.37	-3.38
Random	5326R0073C	NA	NA	Over Drain	Metal/PVC	6	26	-0.37	-2.16
Random	5326R0074C	NA	NA	Over Drain	Metal/PVC	2	-19	-0.37	1.52
Random	5326R0076C	NA	NA	Over Drain	Metal/PVC	4	3.4	-0.37	-0.93
Random	5326R0077C	NA	NA	Over Drain	Metal/PVC	1	-31	-0.37	5.20
Random	5326R0078C	NA	NA	Over Drain	Metal/PVC	3	-7.9	-0.37	2.75
Random	5326R0079C	NA	NA	Over Drain	Metal/PVC	2	-19	-0.37	3.97
Random	5326R0081C	NA	NA	Over Drain	Metal/PVC	1	-31	-0.37	2.75
Random	5326R0082C	NA	NA	Over Drain	Metal/PVC	1	-31	-0.37	-0.93
Random	5326R0083C	NA	NA	Over Drain	Metal/PVC	2	-19	-0.37	3.97
Random	5326R0084C	NA	NA	Over Drain	Metal/PVC	6	26	-0.37	-0.93
Random	5326R0085C	NA	NA	Over Drain	Metal/PVC	1	-31	-0.37	2.75
Random	5326R0086C	NA	NA	Over Drain	Metal/PVC	1	-31	-0.37	1.52
Random	5326R0087C	NA	NA	Over Drain	Metal/PVC	2	-19	-0.37	2.75
Random	5326R0088C	NA	NA	Over Drain	Metal/PVC	3	-7.9	-0.37	0.29
Random	5326R0089C	NA	NA	Over Drain	Metal/PVC	5	15	-0.37	-0.93
Random	5326R0090C	NA	NA	Over Drain	Metal/PVC	5	15	-0.37	-2.16
Random	5326R0091C	NA	NA	Over Drain	Metal/PVC	1	-31	-0.37	-3.38
Random	5326R0092C	NA	NA	Over Drain	Metal/PVC	1	-31	-0.37	-0.93
Random	5326R0093C	NA	NA	Over Drain	Metal/PVC	0	-42	-0.37	-0.93

**Table A.5. X-3001, Train 3 Centrifuge Drains Survey Data**

Random/ Judgmental	Smear ID	Coordinates (m)		Surface	Material	Total Activity		Removable Activity	
		X	Y			Alpha		Alpha	Beta
						cpm	dpm/100 cm <sup>2</sup>	dpm/100 cm <sup>2</sup>	
Random	5326R0094C	NA	NA	Over Drain	Metal/PVC	1	-31	-0.37	-3.38
Random	5326R0095C	NA	NA	Over Drain	Metal/PVC	2	-19	-0.37	-2.16
Random	5326R0096C	NA	NA	Over Drain	Metal/PVC	4	3.4	-0.37	-0.93
Random	5326R0097C	NA	NA	Over Drain	Metal/PVC	4	3.4	1.92	-3.38
Random	5326R0098C	NA	NA	Over Drain	Metal/PVC	3	-7.9	-0.37	-2.16
Random	5326R0099C	NA	NA	Over Drain	Metal/PVC	7	37	-0.37	0.93
Random	5326R0100C	NA	NA	Over Drain	Metal/PVC	2	-19	-0.37	-3.38
Mean						2.4	-15.0		
Judgmental	5326R0019B	NA	NA	Water Collection Area	Metal	66	710	1.92	5.20
Judgmental	5326R0018B	NA	NA	Water Collection Area	Metal	182	2,000	1.92	7.65
Judgmental	5326R0050C	NA	NA	Water Collection Area	Metal	16	140	1.92	-2.16
Judgmental	5326R0060C	NA	NA	Water Collection Area	Metal	93	1,000	8.79	0.29
Judgmental	5326R0066C	NA	NA	Water Collection Area	Metal	44	460	1.92	1.52
Judgmental	5326R0017B	NA	NA	Water Collection Area	Metal	176	2,000	6.50	3.97
Judgmental	5326R0075C	NA	NA	Water Collection Area	Metal	37	380	-0.37	-0.93
Judgmental	5326R0080C	NA	NA	Water Collection Area	Metal	47	490	4.21	1.52

NA= Not applicable

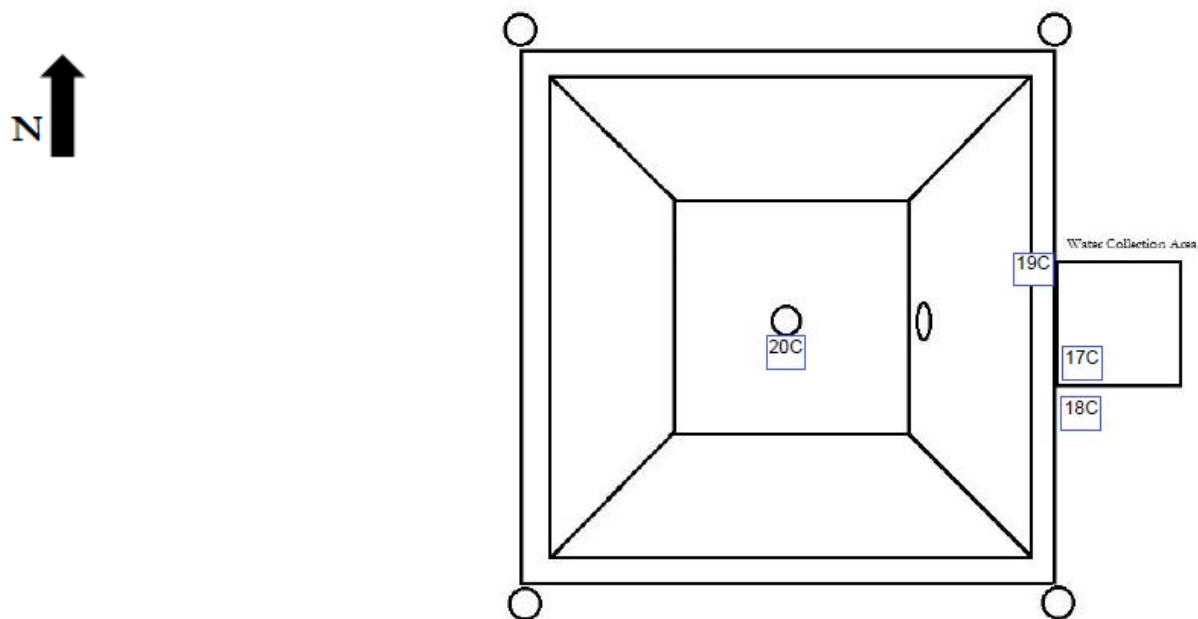


Figure A-6. X-3001 Train 6 Centrifuge Drain Measurement Locations. 9<sup>th</sup> Drain from West and 12<sup>th</sup> Drain from North

Table A.6. X-3001, Train 6 Survey Data									
Random/ Judgmental	Smear ID	Coordinates (m)		Surface	Material	Total Activity		Removable Activity	
		X	Y			Alpha		Alpha	Beta
						cpm	dpm/100 cm <sup>2</sup>	dpm/100 cm <sup>2</sup>	
Judgmental	5326R0017C	NA	NA	Water Collection Area	Metal	188	2,100	1.92	2.75
Judgmental	5326R0018C	NA	NA	Floor	Concrete	96	1,000	-0.37	2.75
Judgmental	5326R0019C	NA	NA	Drain Ledge	Metal	25	240	1.92	5.20
Judgmental	5326R0020C	NA	NA	Drain Floor	Metal	1	-31	-0.37	-2.16

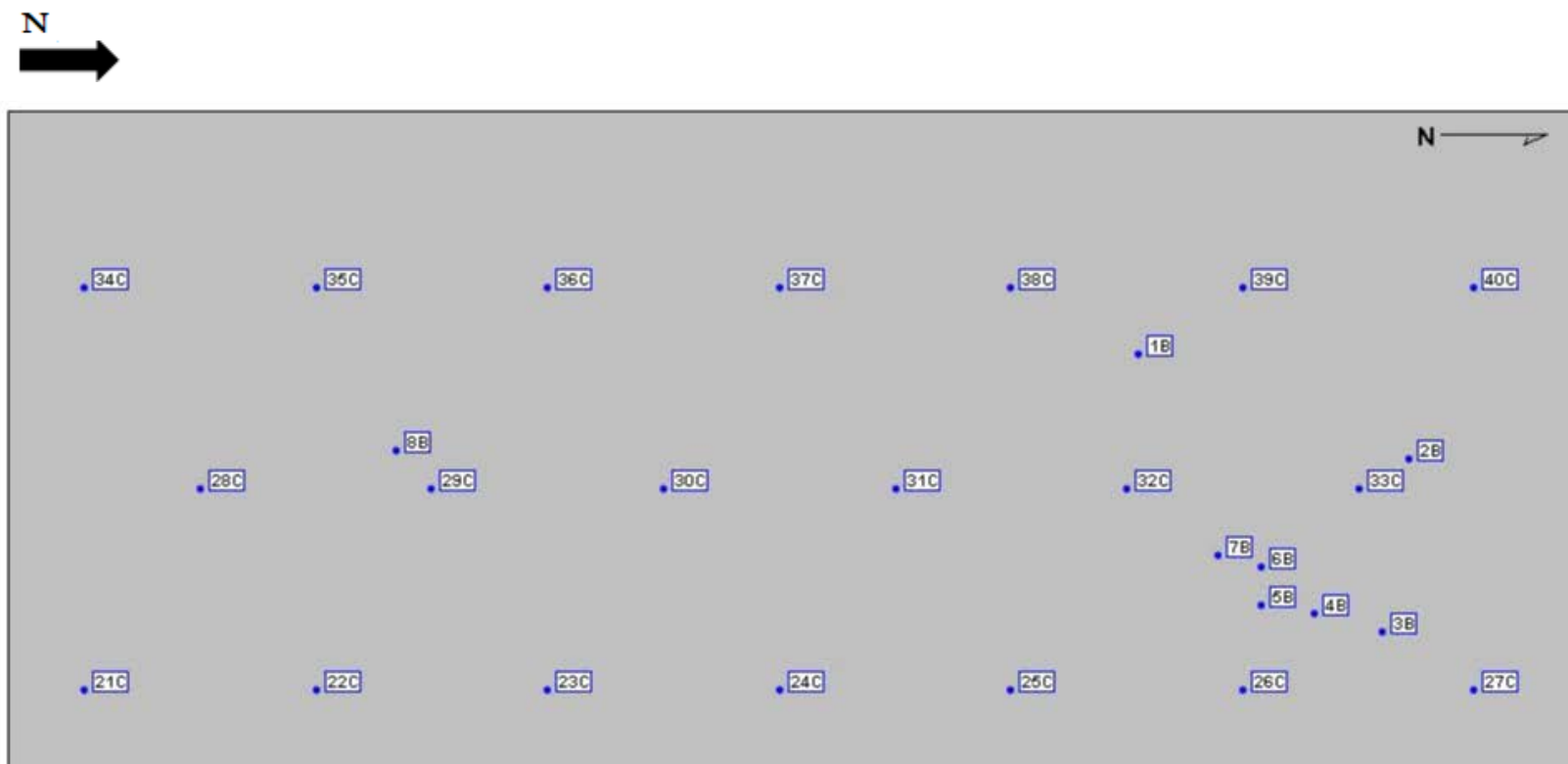


Figure A-7. X-7726 CTTF Measurement Locations

Table A.7. X-7726, CTF Survey Data

Random/ Judgmental	Smear ID	Coordinates (m)		Surface	Material	Total Activity		Removable Activity	
		X	Y			Alpha		Alpha	Beta
						cpm	dpm/100 cm²	dpm/100 cm²	
Random	5326R0021C	2.9	2.9	Floor	Glazed Concrete	6	26	1.92	-0.93
Random	5326R0022C	11.8	2.9	Floor	Glazed Concrete	2	-19	-0.37	-2.16
Random	5326R0023C	20.6	2.9	Floor	Glazed Concrete	4	3.4	-0.37	3.97
Random	5326R0024C	29.4	2.9	Floor	Glazed Concrete	6	26	-0.37	2.75
Random	5326R0025C	38.3	2.9	Floor	Tile	1	-31	-0.37	3.97
Random	5326R0026C	47.1	2.9	Floor	Glazed Concrete	8	49	1.92	3.97
Random	5326R0027C	56.0	2.9	Floor	Glazed Concrete	3	-7.9	-0.37	2.75
Random	5326R0028C	7.3	10.6	Floor	Glazed Concrete	4	3.4	-0.37	-0.93
Random	5326R0029C	16.2	10.6	Floor	Glazed Concrete	5	15	-0.37	3.97
Random	5326R0030C	25.0	10.6	Floor	Glazed Concrete	3	-7.9	-0.37	2.75
Random	5326R0031C	33.9	10.6	Floor	Glazed Concrete	3	-7.9	-0.37	-0.93
Random	5326R0032C	42.7	10.6	Floor	Glazed Concrete	4	3.4	-0.37	0.29
Random	5326R0033C	51.5	10.6	Floor	Glazed Concrete	12	94	-0.37	5.20
Random	5326R0034C	2.9	18.2	Floor	Glazed Concrete	5	15	-0.37	1.52
Random	5326R0035C	11.8	18.2	Floor	Glazed Concrete	5	15	1.92	0.29
Random	5326R0036C	20.6	18.2	Plate in Floor	Metal	7	37	-0.37	2.75
Random	5326R0037C	29.4	18.2	Floor	Glazed Concrete	1	-31	-0.37	0.29
Random	5326R0038C	38.3	18.2	Floor	Glazed Concrete	2	-19	-0.37	-0.93
Random	5326R0039C	47.1	18.2	Floor	Glazed Concrete	7	37	-0.37	1.52
Random	5326R0040C	56.0	18.2	Floor	Glazed Concrete	2	-19	-0.37	1.52
Mean						4.5	9.1		
Judgmental	5326R0001B	6.82	45.0	Floor	Painted Concrete	1	-31	-0.37	-0.93
Judgmental	5326R0002B	13.0	54.0	Floor	Sealed Concrete	5	15	-0.37	2.75

**Table A.7. X-7726, CTTF Survey Data**

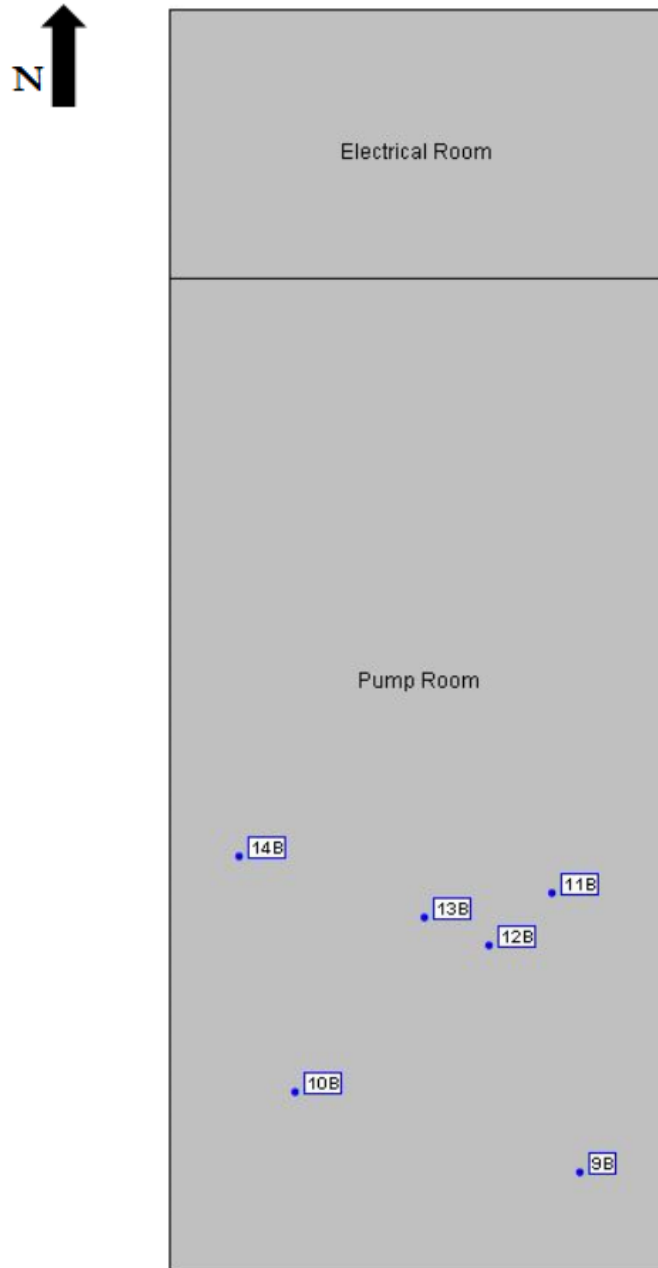
Random/ Judgmental	Smear ID	Coordinates (m)		Surface	Material	Total Activity		Removable Activity	
		X	Y			Alpha		Alpha	Beta
						cpm	dpm/100 cm²	dpm/100 cm²	
Judgmental	5326R0003B	53.0	21.0	Floor	Sealed Concrete	13	110	-0.37	2.75
Judgmental	5326R0004B	51.0	20.0	Floor	Sealed Concrete	2	-19	-0.37	0.29
Judgmental	5326R0005B	48.5	19.5	Floor	Sealed Concrete	11	83	-0.37	6.42
Judgmental	5326R0006B	48.3	16.8	Floor	Sealed Concrete	9	60	1.92	-0.93
Judgmental	5326R0007B	48.2	16.3	Floor	Sealed Concrete	6	26	-0.37	-2.16
Judgmental	5326R0008B	2.6 <sup>a</sup>	11.4 <sup>a</sup>	Floor	Sealed Concrete	6	26	-0.37	1.52
Judgmental	5326R0015B	NA <sup>b</sup>	NA <sup>b</sup>	Equipment	Painted Metal	69	740	-0.37	0.29
Judgmental	5326R0016B	NA <sup>b</sup>	NA <sup>b</sup>	Equipment	Plastic	10	71	1.92	3.97

<sup>a</sup> Local coordinates referenced to CTTF Material Storage Mezzanine

<sup>b</sup> Smears 15B and 16B are not shown in the figure above.

NA = Not applicable





**Figure A-8. X-7726 Second Floor Utility Room Measurement Locations**

**Table A.8. X-7726, Second Floor Utility Room Survey Data**

Random/ Judgmental	Smear ID	Coordinates (m)		Surface	Material	Total Activity		Removable Activity	
		X	Y			Alpha		Alpha	Beta
						cpm	dpm/100 cm²	dpm/100 cm²	
Judgmental	5326R0009B	4.7	1.1	Floor	Concrete	105	1,100	-0.37	-0.93
Judgmental	5326R0010B	1.4	1.7	Floor	Concrete	297	3,300	-0.37	-2.16
Judgmental	5326R0011B	4.0	2.7	Floor	Concrete	174	1,900	-0.37	3.97
Judgmental	5326R0012B	3.1	2.5	Floor	Concrete	41	420	-0.37	2.75
Judgmental	5326R0013B	2.7	2.6	Floor	Concrete	154	1,700	-0.37	-2.16
Judgmental	5326R0014B	1.0	2.9	Floor	Concrete	307	3,400	-0.37	3.97

NA= Not applicable

## **APPENDIX B: SURVEY AND ANALYTICAL PROCEDURES**

## **B.1. PROJECT HEALTH AND SAFETY**

ORISE performed all survey activities in accordance with the *ORAU Radiation Protection Manual*, the *ORAU Health and Safety Manual*, and the *ORAU Radiological and Environmental Survey Procedures Manual* (ORAU 2014, ORAU 2016c, and ORAU 2016a). Prior to on-site activities, a Work-Specific Hazard Checklist was completed for the project and discussed with field personnel. The planned activities were thoroughly discussed with site personnel prior to implementation to identify hazards present. Additionally, prior to performing work, a pre-job briefing and walk down of the survey areas were completed with field personnel to identify hazards present and discuss safety concerns. Should ORISE have identified a hazard not covered in the *ORAU Radiological and Environmental Survey Procedures Manual* (ORAU 2016a) or the project's Work-Specific Hazard Checklist for the planned survey and sampling procedures, work would not have been initiated or continued until the hazard was addressed by an appropriate job hazard analysis and hazard controls.

## **B.2. CALIBRATION AND QUALITY ASSURANCE**

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

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

- *ORAU Radiological and Environmental Survey Procedures Manual* (ORAU 2016a)
- *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual* (ORAU 2017)
- *ORAU Environmental Services and Radiation Training Quality Program Manual* (ORAU 2016b)

The procedures contained in these manuals were developed to meet the requirements of U.S. Department of Energy (DOE) Order 414.1D and the NRC *Quality Assurance Manual for the Office of Nuclear Material Safety and Safeguards* and contain measures to assess processes during their performance.

Quality control procedures include:

- Daily instrument background and check-source measurements to confirm that equipment operation is within acceptable statistical fluctuations.
- Participation in Mixed-Analyte Performance Evaluation Program and Intercomparison Testing Program laboratory quality assurance programs.
- Training and certification of all individuals performing procedures.
- Periodic internal and external audits.

### B.3. SURVEY PROCEDURES

#### B.3.1 SURFACE SCANS

Alpha-plus-beta scans were performed using the large-area (floor monitor) gas proportional detector with a 0.8 mg/cm<sup>2</sup> window and a physical detector area of 584 cm<sup>2</sup>. Alpha scans were performed using hand-held gas proportional detectors with a 0.8 mg/cm<sup>2</sup> window and a physical detector area of 126 cm<sup>2</sup>. Beta scans were performed using a hand-held Geiger-Mueller (GM) detector with a 1.7 mg/cm<sup>2</sup> window and a physical detector area of 15 cm<sup>2</sup>. The distance between the detector and surface was maintained at a minimum. Specific scan minimum detectable concentrations (MDCs) were not determined for the large-area gas proportional detector or the GM detector as these instruments were used solely as a qualitative means to identify elevated radiation levels in excess of background. Identifications of elevated radiation levels that could exceed the site criteria were determined based on an increase in the audible signal from the indicating instrument.

Surface alpha scan MDC for the hand-held gas proportional detectors was estimated using the equation below. The scan MDC is a function of many variables, including a two-second observation interval and a probability of detection of 0.9 (90 percent probability of detecting 1 count). The alpha weighted efficiency for the Ludlum 43-68 was 0.07. Instruments were multi-source calibrated and the weighted efficiency was determined based on the relative fractions of U-234, U-235, and U-238 in natural uranium. The scan MDC was calculated using the following equation:

$$Scan\ MDC = \frac{[-\ln(1 - P(n \geq 1))] \times (60/i)}{\epsilon_t \times \frac{Probe\ Area}{100\ cm^2}}$$

Where:

$P$  = probability of detection (unitless)

$i$  = observation interval (sec)

$\epsilon_t$  = total efficiency =  $\epsilon_i \times \epsilon_s$

The most conservative result for the detectors used was a scan MDC of 756 dpm/100 cm<sup>2</sup>.

### **B.3.2 SURFACE ACTIVITY MEASUREMENTS**

Measurements of gross alpha surface activity levels were performed using hand-held gas proportional detectors coupled to portable ratemeter-scalers. Count rates (cpm), which were integrated over one minute with the detector held in a static position, were converted to activity levels (dpm/100 cm<sup>2</sup>) by dividing the count rate by the total static efficiency ( $\epsilon_i \times \epsilon_s$ ) and correcting for the physical area of the detector plus background. The total weighted alpha efficiency for the Ludlum 43-68 was 0.07. Instruments were multi-source calibrated and the weighted efficiency was determined based on the relative fractions of U-234, U-235, and U-238 in natural uranium. The MDC for static surface activity measurements was calculated using the following equation:

$$MDC = \frac{3 + (4.65\sqrt{B})}{TG\epsilon_{tot}}$$

Where:

$B$  = background in time interval,  $T$  (1 min)

$T$  = count time (min) used for field instruments

$\epsilon_{tot}$  = total efficiency =  $\epsilon_i \times \epsilon_s$

$G$  = geometry correction factor (1.26)

The result for the one detector used for all final quantitative measurements was an alpha static MDC of 105 dpm/100 cm<sup>2</sup>.

## **B.4. RADIOLOGICAL ANALYSIS**

### **B.4.1 GROSS ALPHA/BETA**

Smears were counted on a low-background proportional counter for gross alpha and beta activity. The minimum detectable activity of the procedures is approximately 11 dpm/100 cm<sup>2</sup> for alpha and 14 dpm/100 cm<sup>2</sup> for beta.

## **APPENDIX C: MAJOR INSTRUMENTATION**

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

## **C.1. SCANNING AND MEASUREMENT INSTRUMENT/ DETECTOR COMBINATIONS**

### **C.1.1 ALPHA-PLUS-BETA**

Ludlum Gas-flow Proportional Detector Model 43-37, 584 cm<sup>2</sup> physical area, 0.8 mg/cm<sup>2</sup> Mylar window

(Ludlum Measurements, Inc., Sweetwater, Texas)

coupled to: Ludlum Ratemeter-scaler Model 2221

(Ludlum Measurements, Inc., Sweetwater, Texas)

coupled to: Trimble Geo 7X

(Trimble Navigation Limited, Sunnyvale, CA)

### **C.1.2 ALPHA**

Ludlum Gas-flow Proportional Detector Model 43-68, 126 cm<sup>2</sup> physical area, 0.8 mg/cm<sup>2</sup> Mylar window

(Ludlum Measurements, Inc., Sweetwater, Texas)

coupled to: Ludlum Ratemeter-scaler Model 2221

(Ludlum Measurements, Inc., Sweetwater, Texas)

### **C.1.3 BETA**

Ludlum Geiger-Mueller Detector Model 44-9, 15 cm<sup>2</sup> physical area, 1.7 mg/cm<sup>2</sup> Mylar window

(Ludlum Measurements, Inc., Sweetwater, Texas)

coupled to: Ludlum Ratemeter-scaler Model 2221

(Ludlum Measurements, Inc., Sweetwater, Texas)

## **C.2. LABORATORY ANALYTICAL INSTRUMENTATION**

Low-Background Gas Proportional Counter

Series 5 XLB

(Canberra, Meriden, CT)

Used in conjunction with:

Eclipse Software

Dell Workstation

(Canberra, Meriden, CT)