OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

August 16, 2018

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U.S. Nuclear Regulatory Commission
Office of Nuclear Material and Safeguards
Division of Decommissioning, Uranium Recovery, and Waste Programs
Materials Decommissioning Branch
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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 Bailey

Erika N. Bailey
Survey and Technical Projects Group Manager
ORISE

KME: lw

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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 FOR THE AMERICAN CENTRIFUGE LEAD CASCADE FACILITY IN PIKETON, OHIO

## FINAL REPORT


**Prepared by**
**K. M. Engel**
**ORISE**

**AUGUST 2018**

**Prepared for the**
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This document was prepared for U.S. Nuclear Regulatory Commission by the Oak Ridge Institute for Science and Education (ORISE) through an interagency agreement with the U.S. Department of Energy (DOE) (NRC FIN No. F-1244). ORISE is managed by Oak Ridge Associated Universities under DOE contract number DE-SC0014664.

OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

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

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**FINAL REPORT**

**AUGUST 2018**

# CONTENTS

## FIGURES



## TABLES

## 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 $cm^2$ | 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 | *Multi-Agency Radiation Survey and Site Investigation Manual* |
| 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? | Yes:<br>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.<br><br>No:<br>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. |
| **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 $cm^2$) 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 $UF_6$ feed. In order to demonstrate compliance with the 25 mrem/yr release criterion, a site-specific derived concentration guideline level ($DCGL_W$) was developed and presented in the site's Decommissioning Plan, DP-2605-0001. Using RESRAD-Build, the $DCGL_W$ was determined to be 39,200 dpm/100 $cm^2$ 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[a]**

| Radionuclide | Removable (dpm/100 cm²) | Total (dpm/100 cm²)[b] |
|---|---|---|
| U-natural, U-235, U-238, and associated decay products. Transuranics ≤2 percent by alpha activity, Tc-99 and beta-gamma emitters. | 1,000 | 5,000 |

[a] Table source: ACO 2018b

[b] The levels may be averaged over one square meter provided the maximum surface activity in any area of 100 cm² 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 cm² 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$^2$. 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 scalers. Ratemeter scalers 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 scalers.

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 scalers 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**

| Survey Unit | Type of Direct Measurements / Smears [a] | Number of Random Measurements | Number of Judgmental Measurements | Scans |
|---|---|---|---|---|
| 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 2nd 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 [a]** | **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 |

[a] 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$^2$-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$^2$ 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$^2$ 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$^2$.

## 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 $cm^2$. 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.

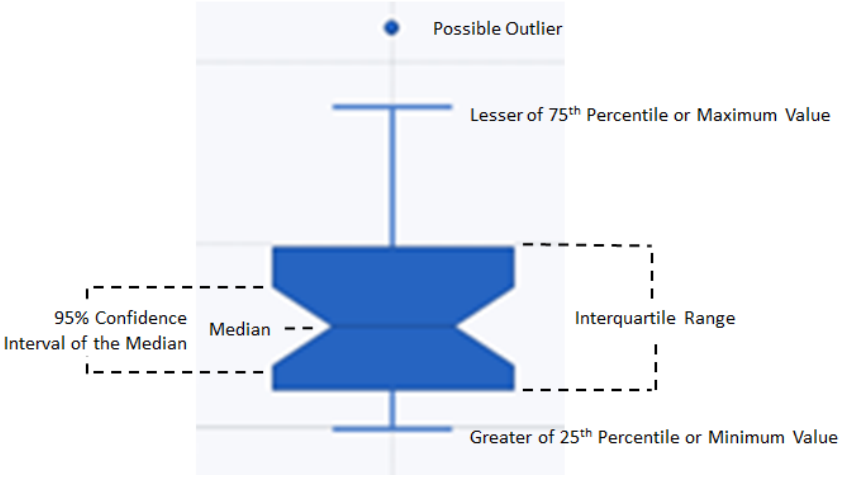


**Figure 6.1. Box Plot Descriptive Statistics**

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 $cm^2$). 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.

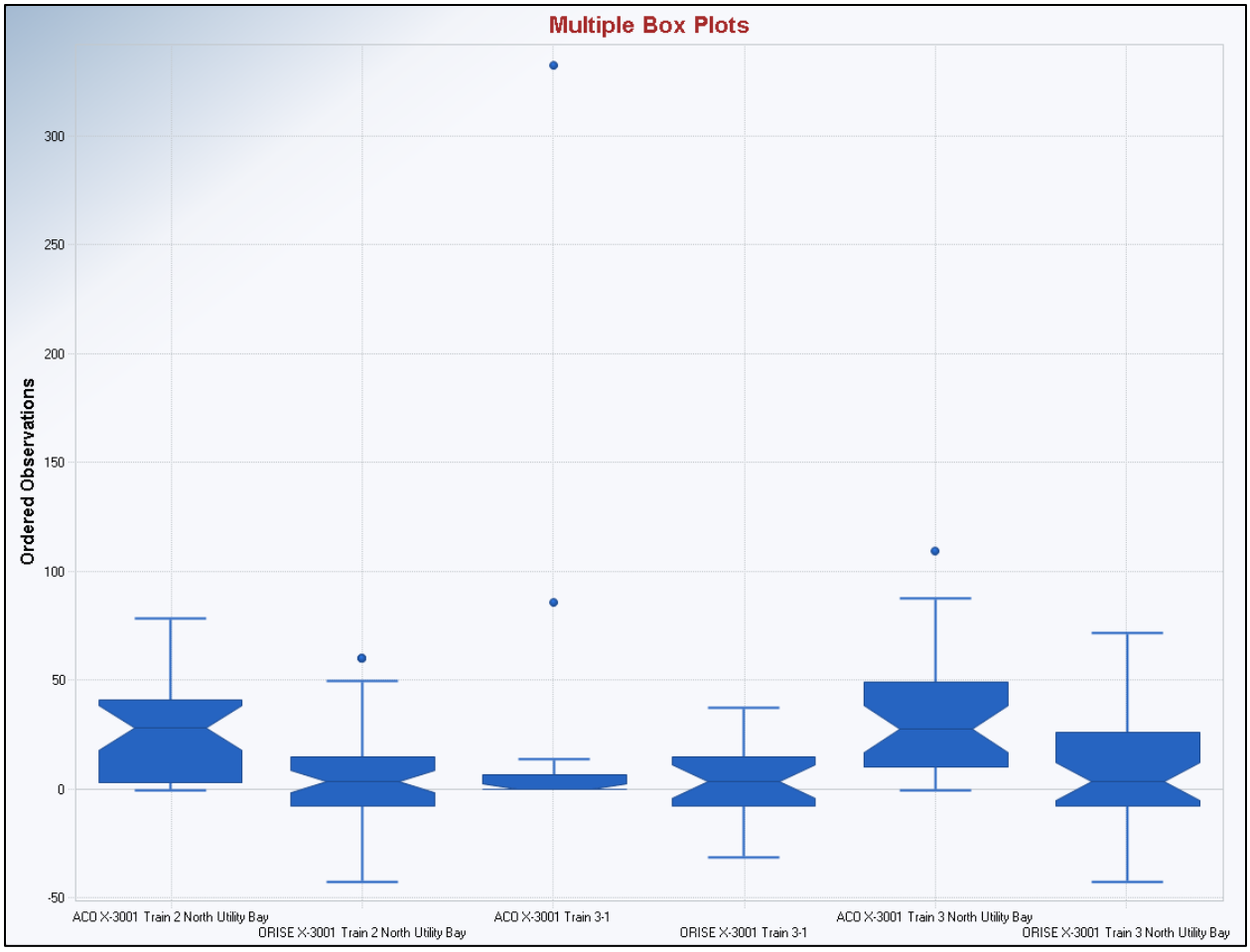


**Figure 6.2. Box Plots for Surface Activity Comparisons**

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 $cm^2$.

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 $cm^2$ for alpha and 14 dpm/100 $cm^2$ 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.

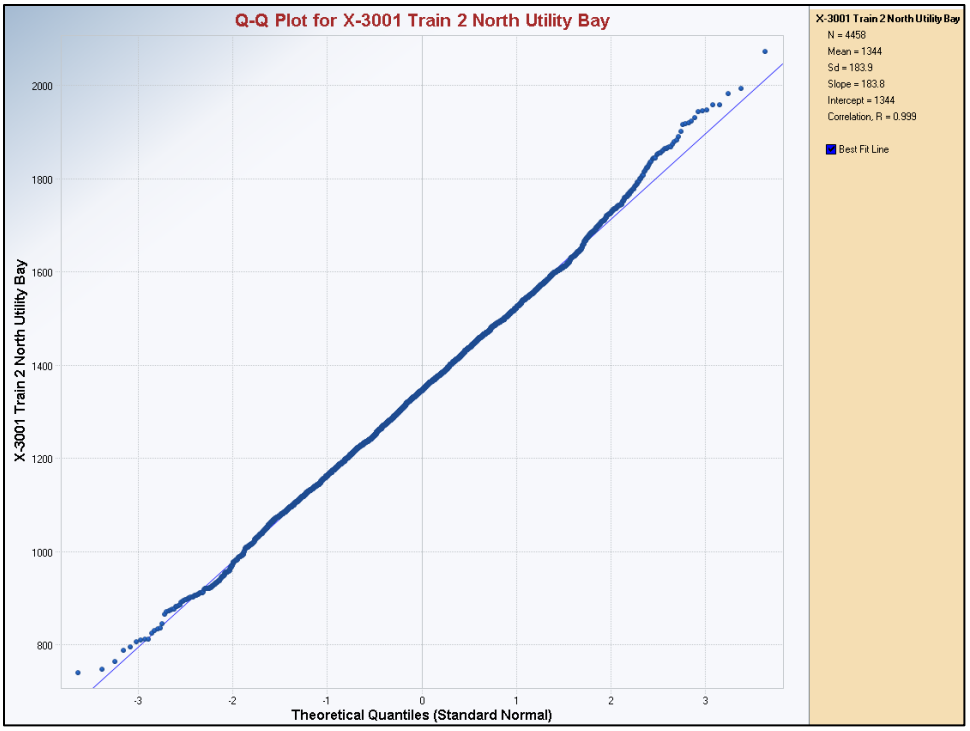


**Figure 7.1. Q-Q Plot for X-3001 Train 2 North Utility Bay**

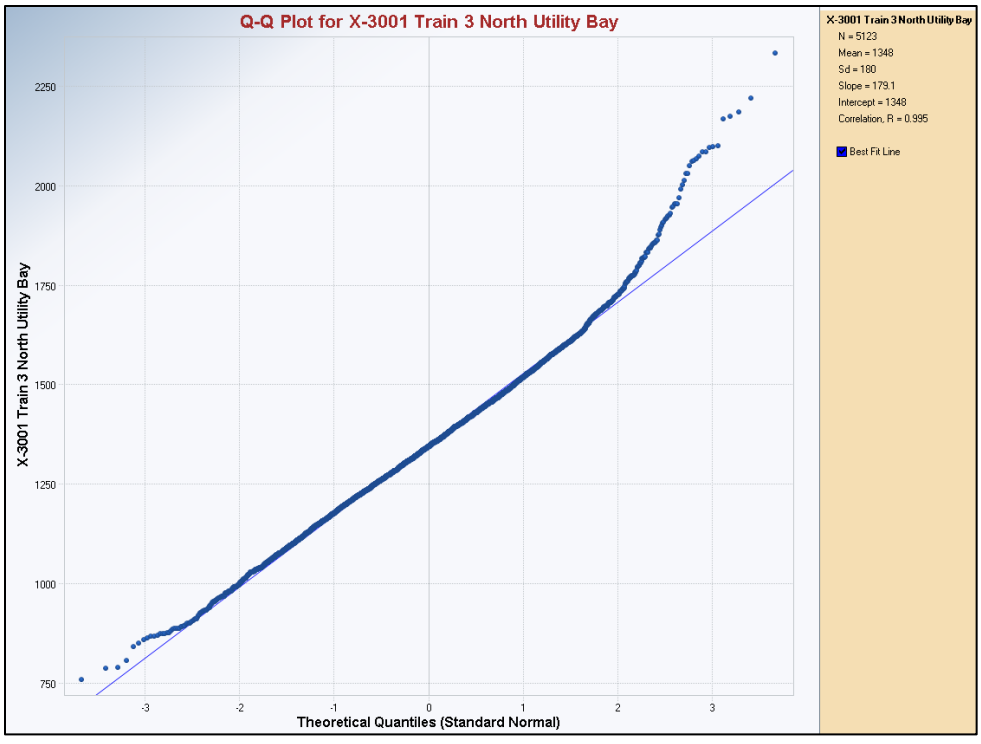


**Figure 7.2. Q-Q Plot for X-3001 Train 3 North Utility Bay**

| 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** | |
| | | | | | **Alpha** | **Beta** |
| | | **dpm/100 cm²** | | **dpm/100 cm²** | | |
| 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.

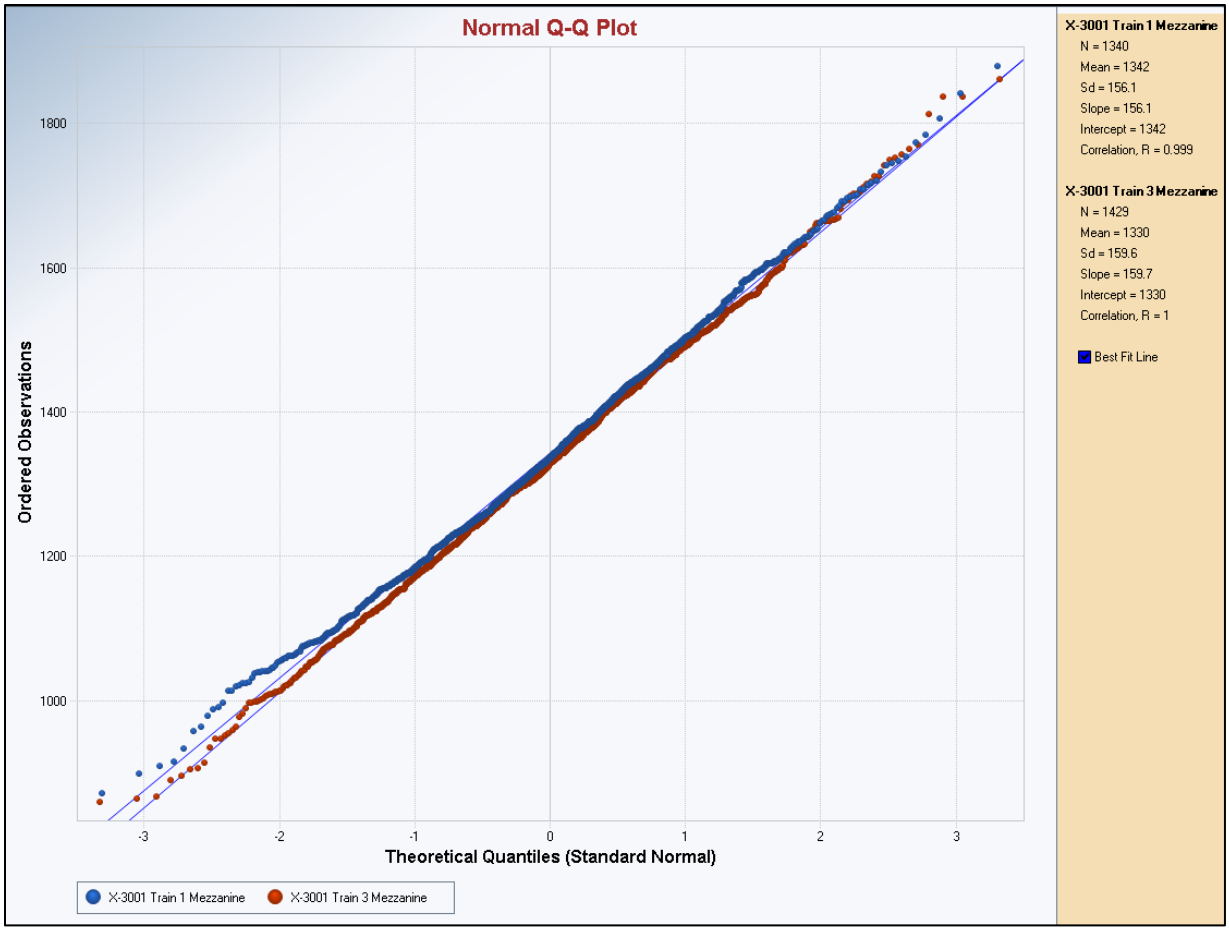


**Figure 7.3. Q-Q Plot for X-3001 Train 1 and Train 3 Mezzanines**

**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 cm² | | dpm/100 cm² | | |
| 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.

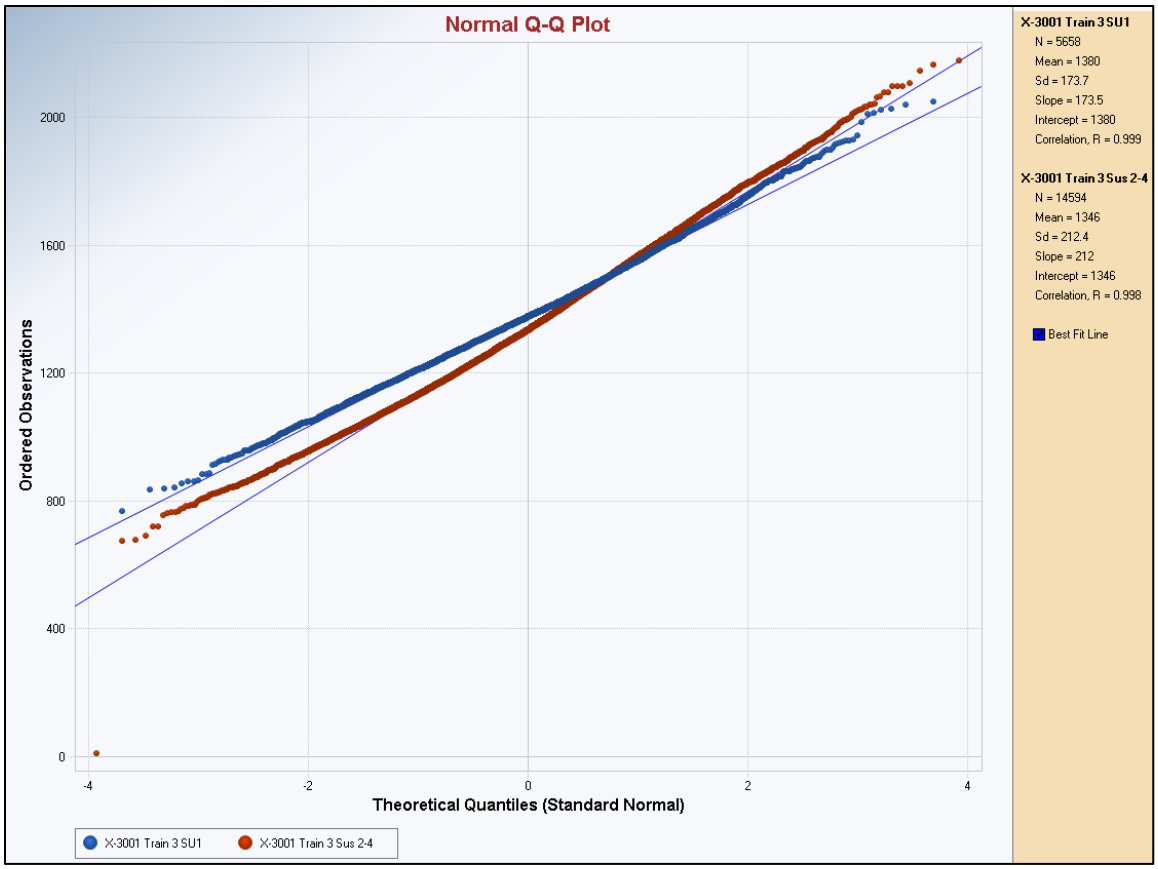


**Figure 7.4. Q-Q Plot for X-3001 Train 3**

| 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 cm² | | dpm/100 cm² | | |
| 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 cm² | | dpm/100 cm² | | |
| 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.

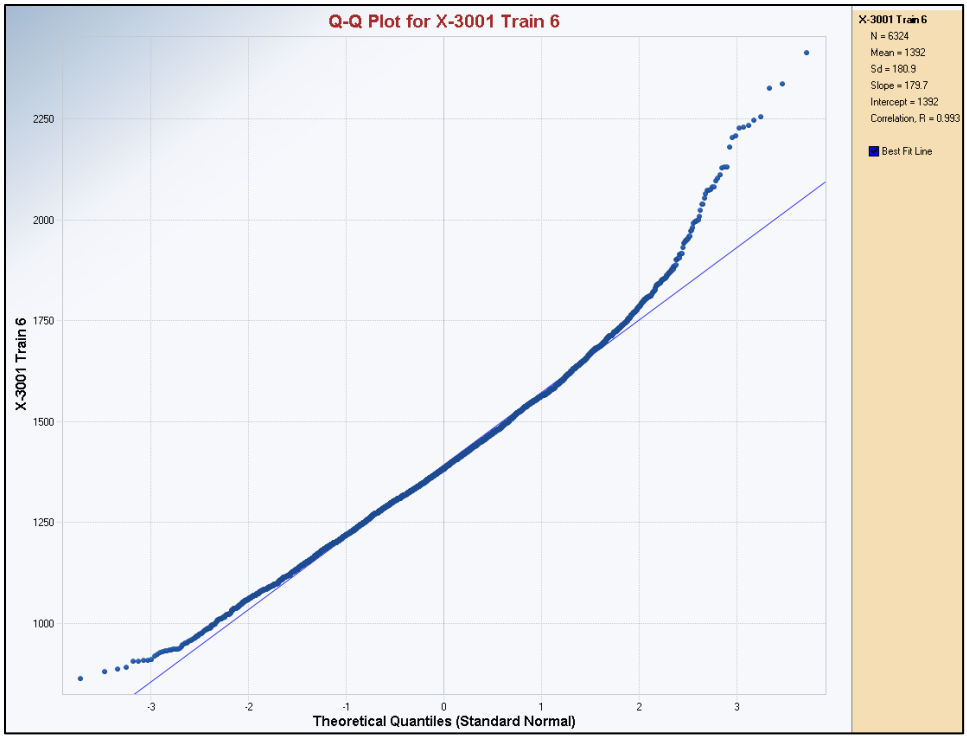


**Figure 7.5. Q-Q Plot for X-3001 Train 6**

| 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 cm² | | dpm/100 cm² | | |
| 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.

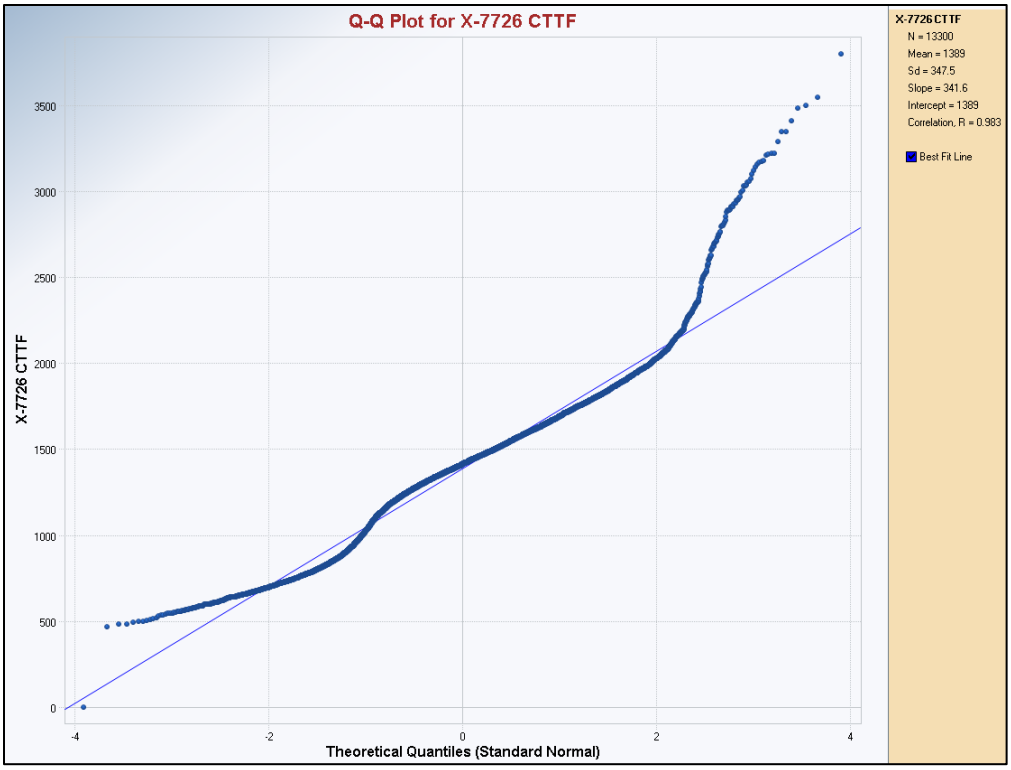


**Figure 7.6. Q-Q Plot for X-7726 CTTF**

**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 cm² | | dpm/100 cm² | | |
| 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.

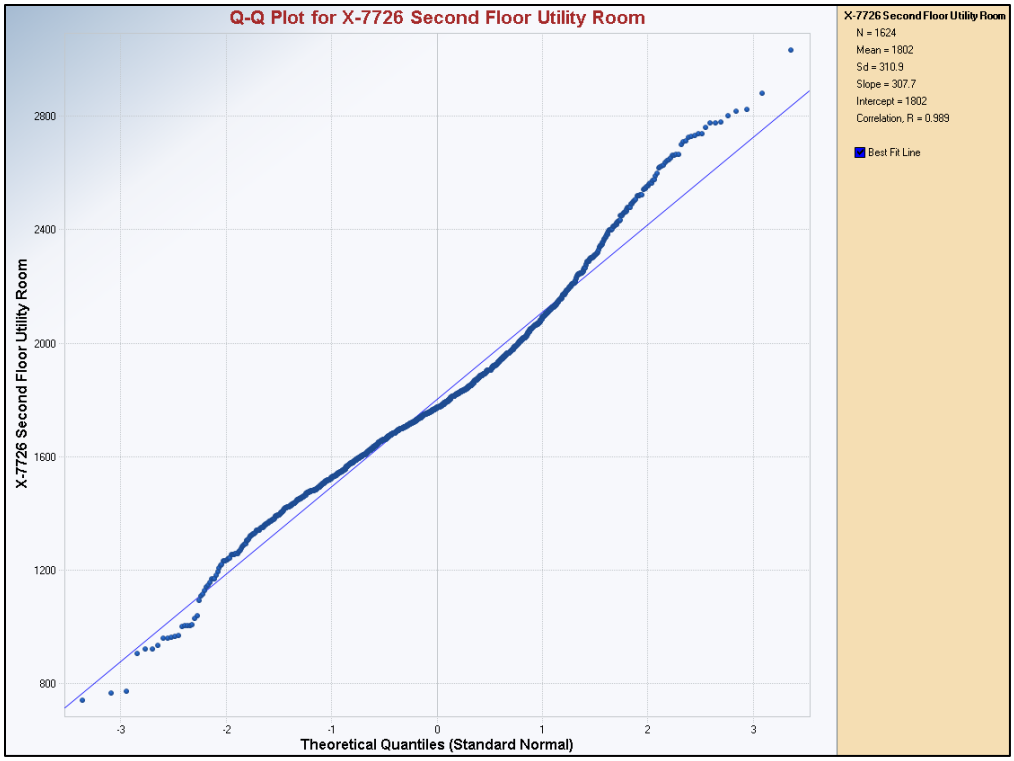


**Figure 7.7. Q-Q Plot for X-7726 Second Floor Utility Room**

| 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 | |
| | | | | | Alpha | Beta |
| | | dpm/100 cm² | | dpm/100 cm² | | |
| 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.

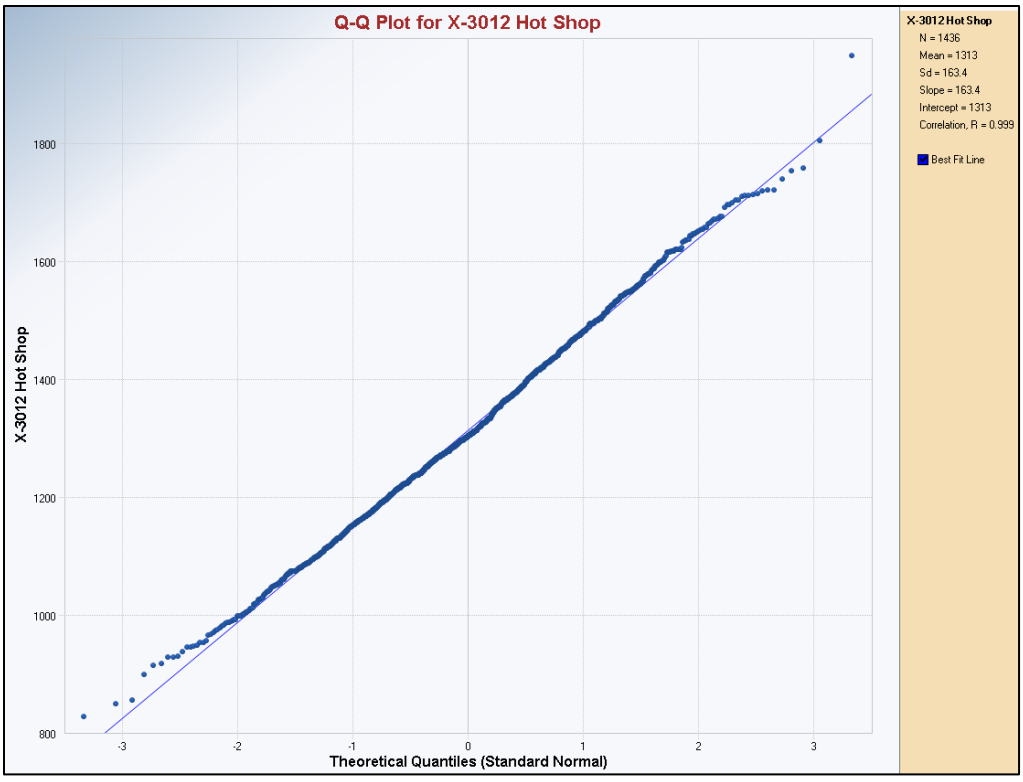


**Figure 7.8. Q-Q Plot for X-3012 Hot Shop**

| 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 | |
| | | | | | Alpha | Beta |
| | | dpm/100 cm² | | dpm/100 cm² | | |
| 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.

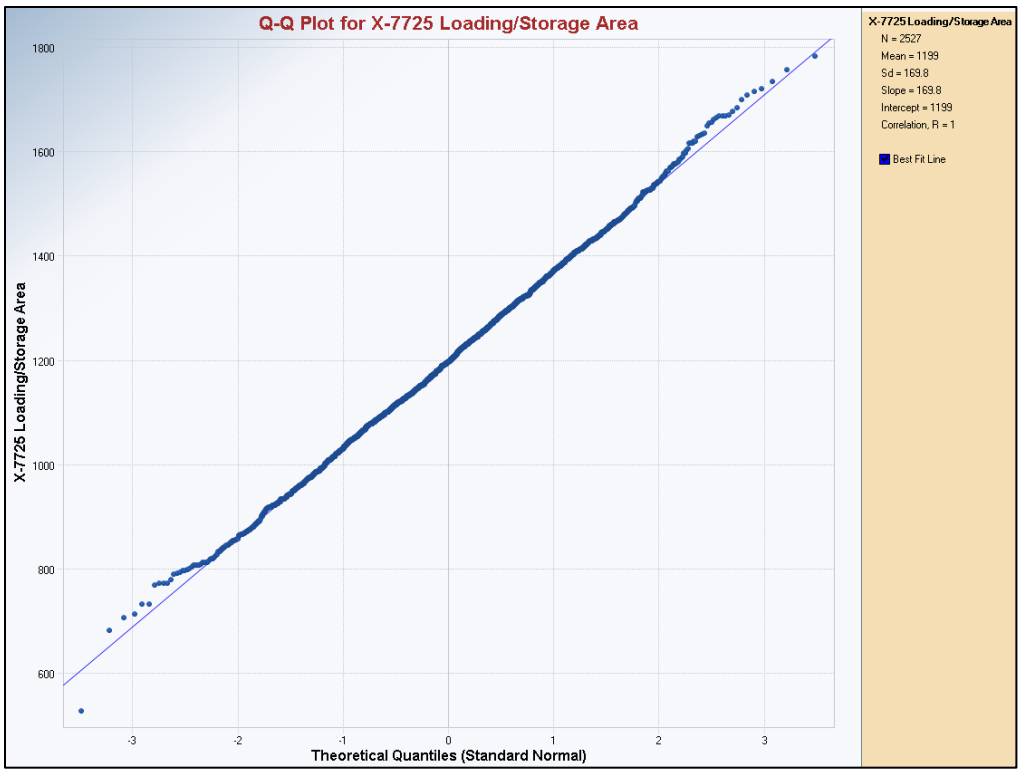


**Figure 7.9. Q-Q Plot for X-7725 Loading/Storage Area**

| 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 cm²** | | **dpm/100 cm²** | | |
| 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 $cm^2$ and all smears were below the MDC of the analytical equipment, which were 11 and 14 dpm/100 $cm^2$ 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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# APPENDIX A: DATA TABLES AND FIGURES

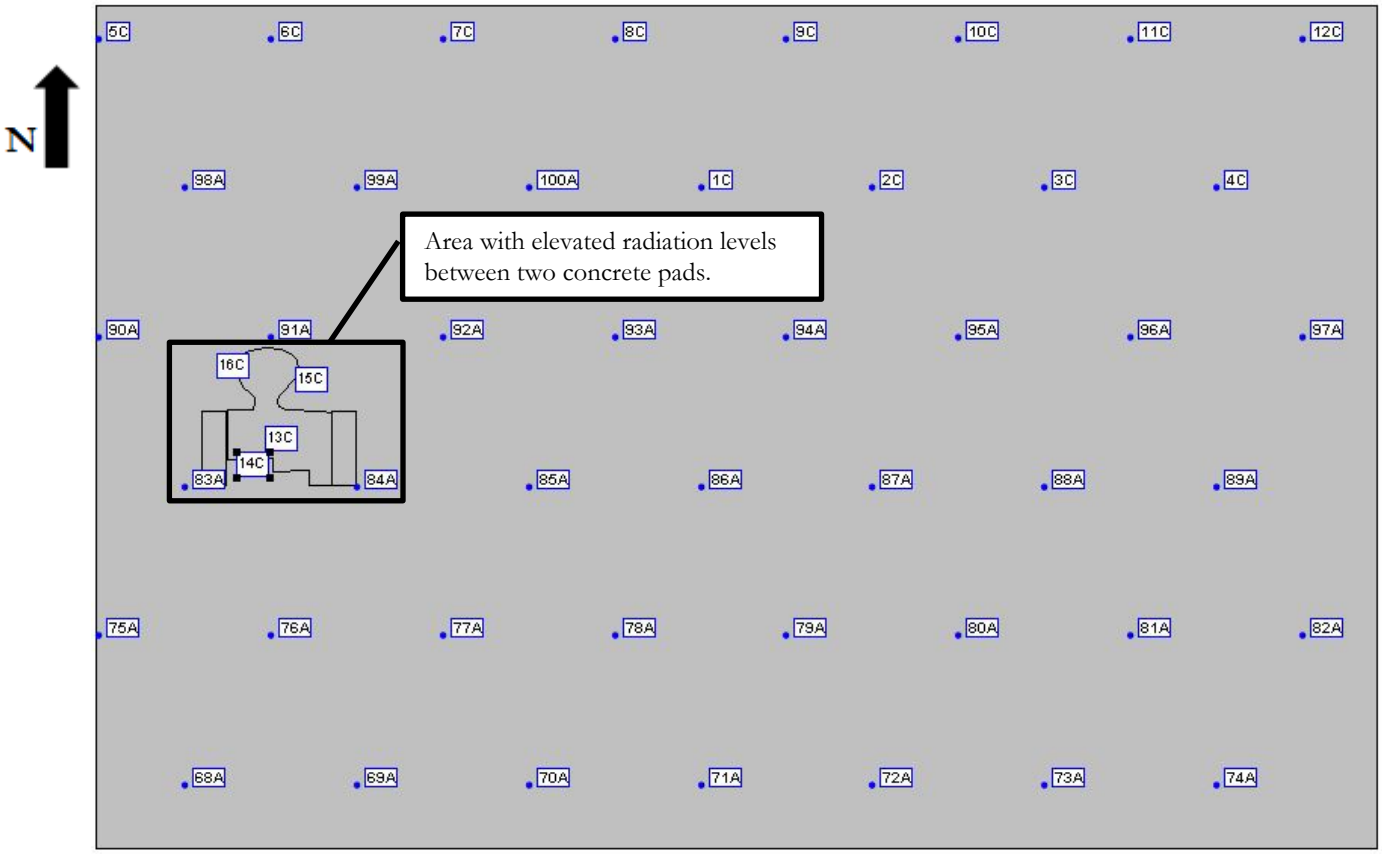


**Figure A-1. X-3001 Train 2 North Utility Bay Measurement Locations**

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

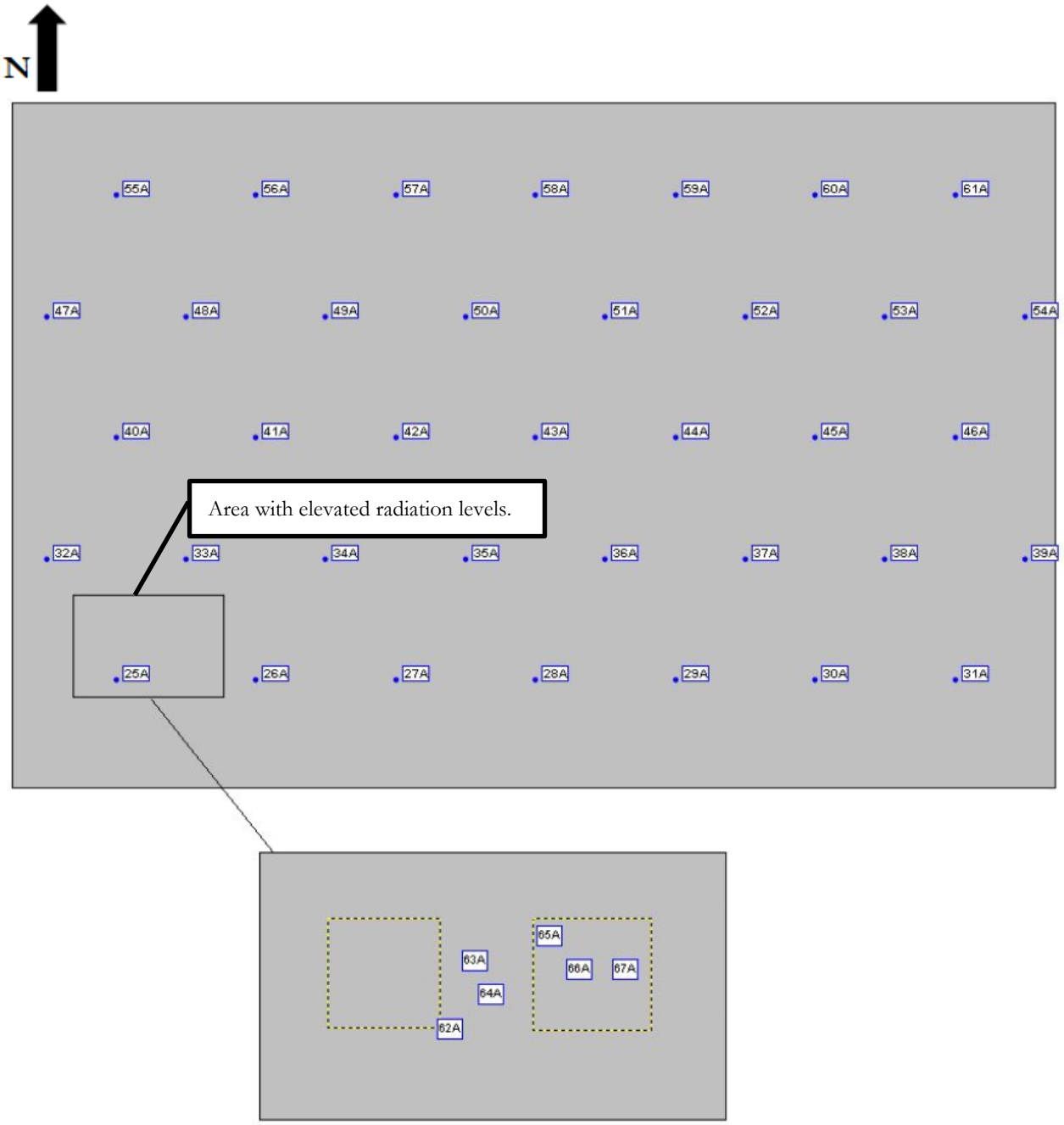


**Figure A-2. X-3001 Train 3 North Utility Bay Measurement Locations**

| 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

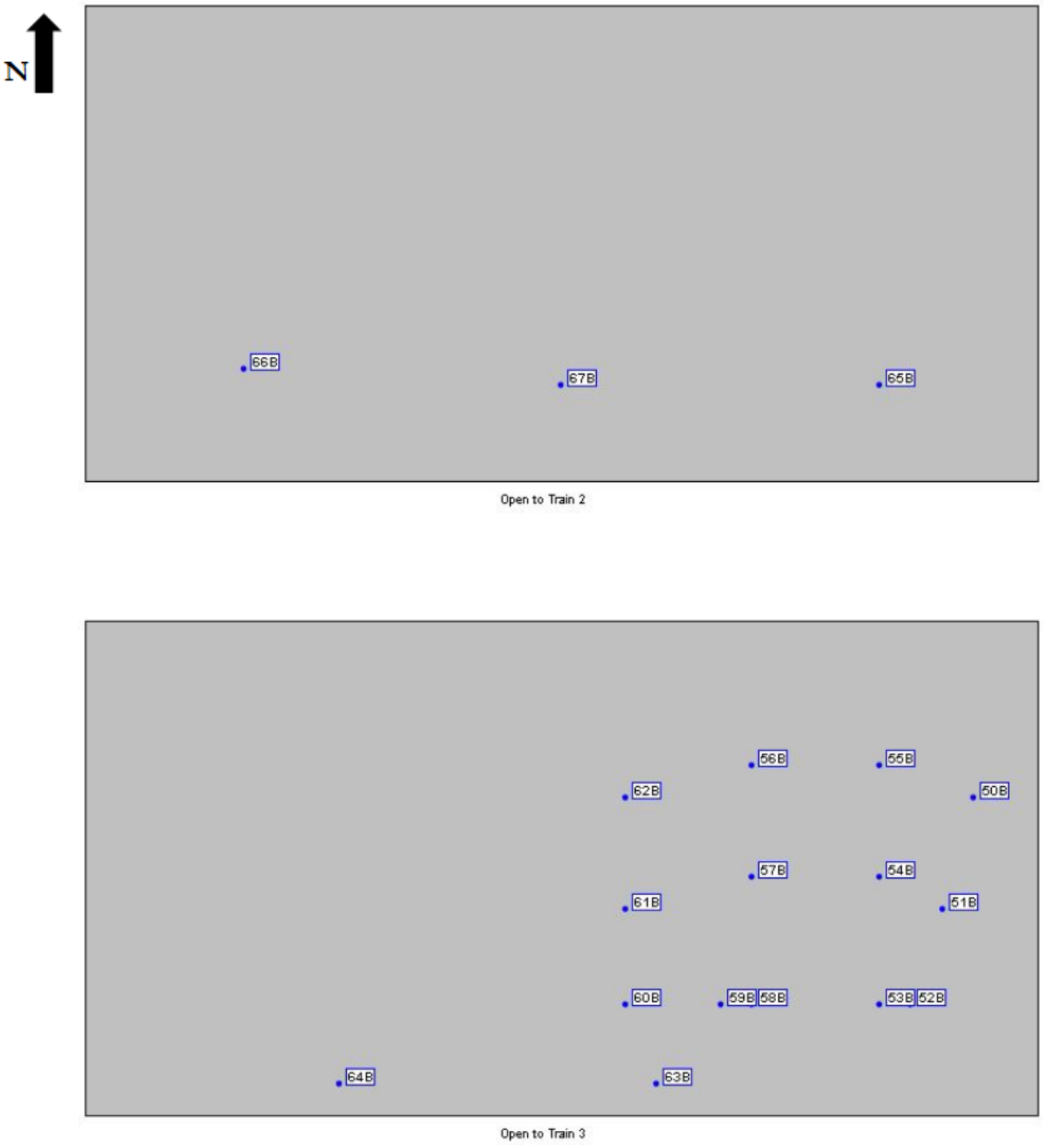


**Figure A-3. X-3001 Trains 2 and 3 North Utility Bay Drains Measurement Locations**

| 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 cm² | dpm/100 cm² | |
| 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

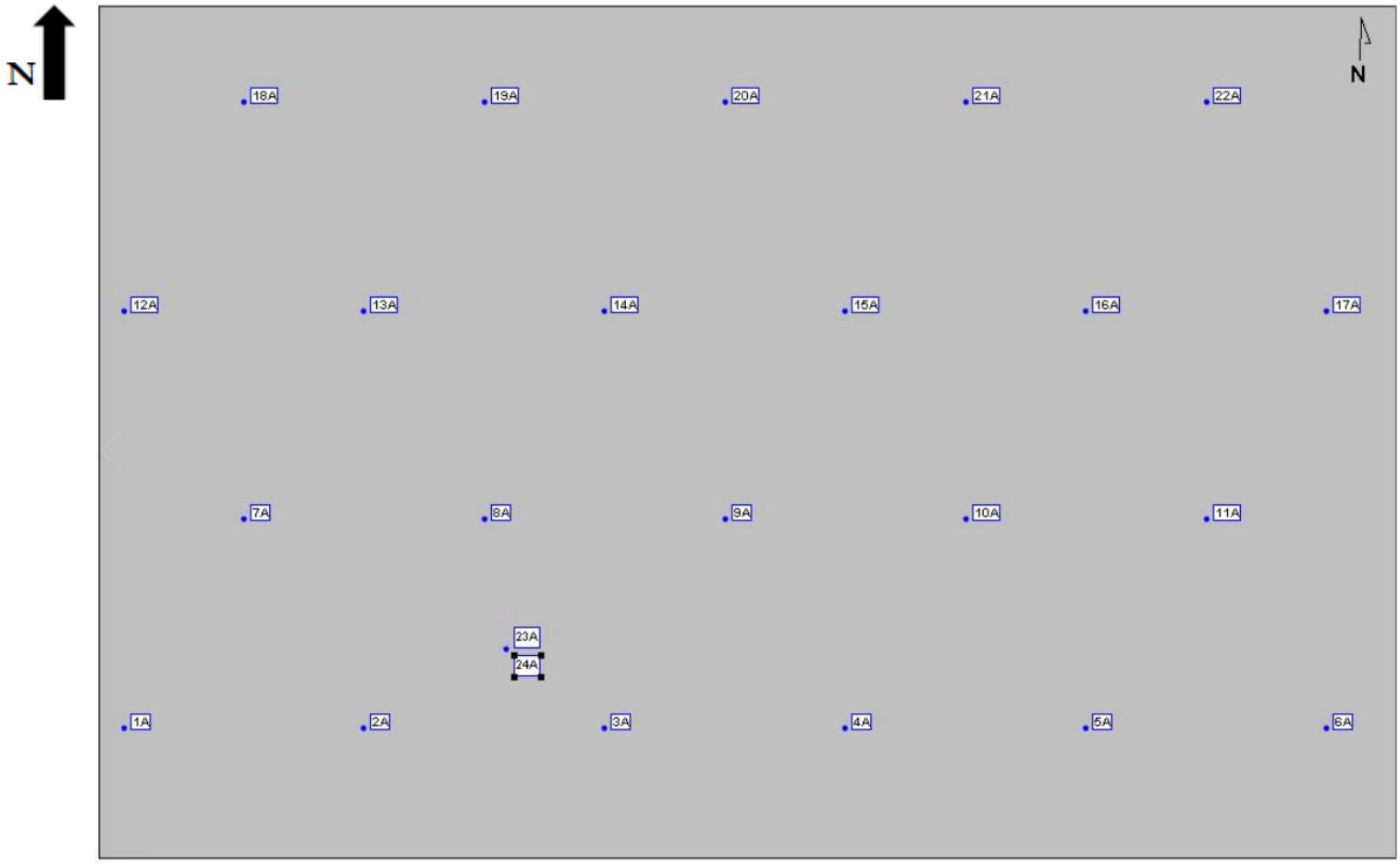


**Figure A-4. X-3001 Train 3 Measurement Locations**

| 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

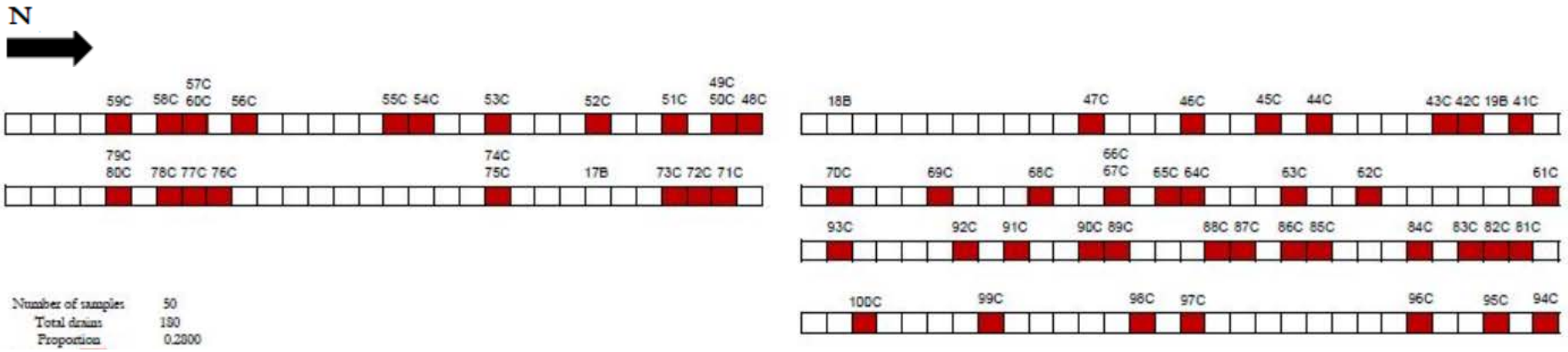


**Figure A-5. X-3001 Train 3 Centrifuge Drains Measurement Locations**

| 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 cm² | dpm/100 cm² | |
| 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 cm² | dpm/100 cm² | |
| 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 cm² | dpm/100 cm² | |
| 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

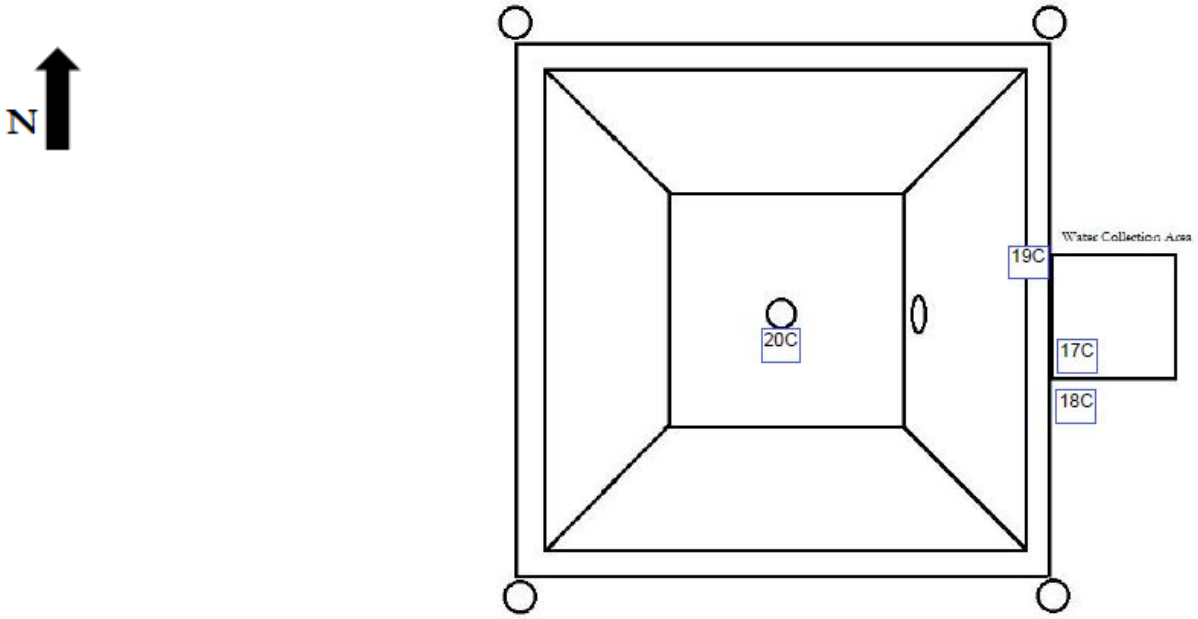


**Figure A-6. X-3001 Train 6 Centrifuge Drain Measurement Locations. 9th Drain from West and 12th Drain from North**

| Table A.6. X-3001, Train 6 Survey Data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Random/ Judgmental | Smear ID | Coordinates (m) | | Surface | Material | Total Activity | | Removable Activity | |
| | | | | | | Alpha | | Alpha | Beta |
| | | X | Y | | | cpm | dpm/100 cm² | dpm/100 cm² | |
| 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 |

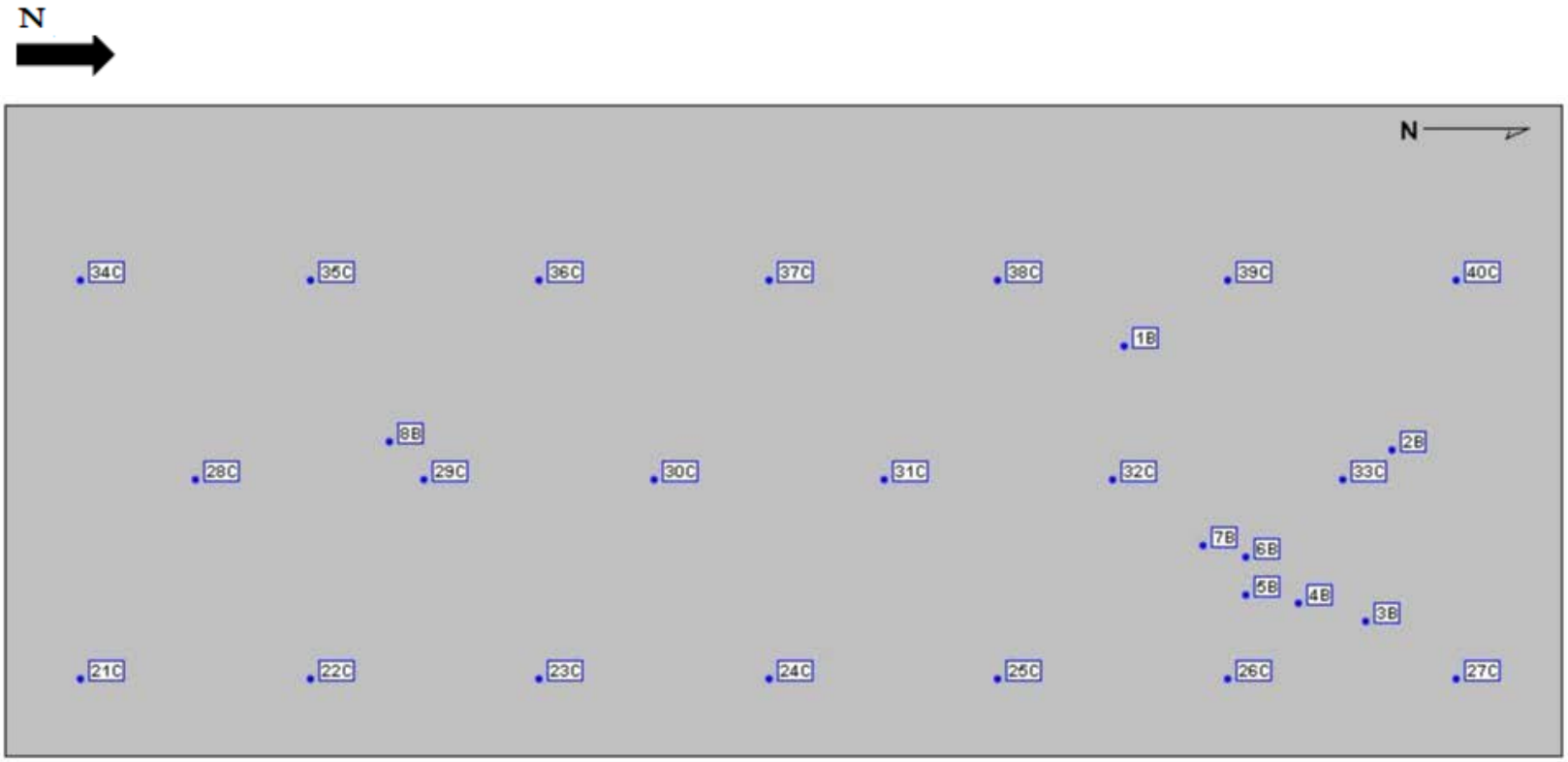


**Figure A-7. X-7726 CTTF Measurement Locations**

| Table A.7. X-7726, CTTF Survey Data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Random/ Judgmental | Smear ID | Coordinates (m) | | Surface | Material | Total Activity | | Removable Activity | |
| | | | | | | Alpha | | Alpha | Beta |
| | | X | Y | | | 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[a] | 11.4[a] | Floor | Sealed Concrete | 6 | 26 | -0.37 | 1.52 |
| Judgmental | 5326R0015B | NA[b] | NA[b] | Equipment | Painted Metal | 69 | 740 | -0.37 | 0.29 |
| Judgmental | 5326R0016B | NA[b] | NA[b] | Equipment | Plastic | 10 | 71 | 1.92 | 3.97 |

[a] Local coordinates referenced to CTTF Material Storage Mezzanine

[b] Smears 15B and 16B are not shown in the figure above.

NA = Not applicable

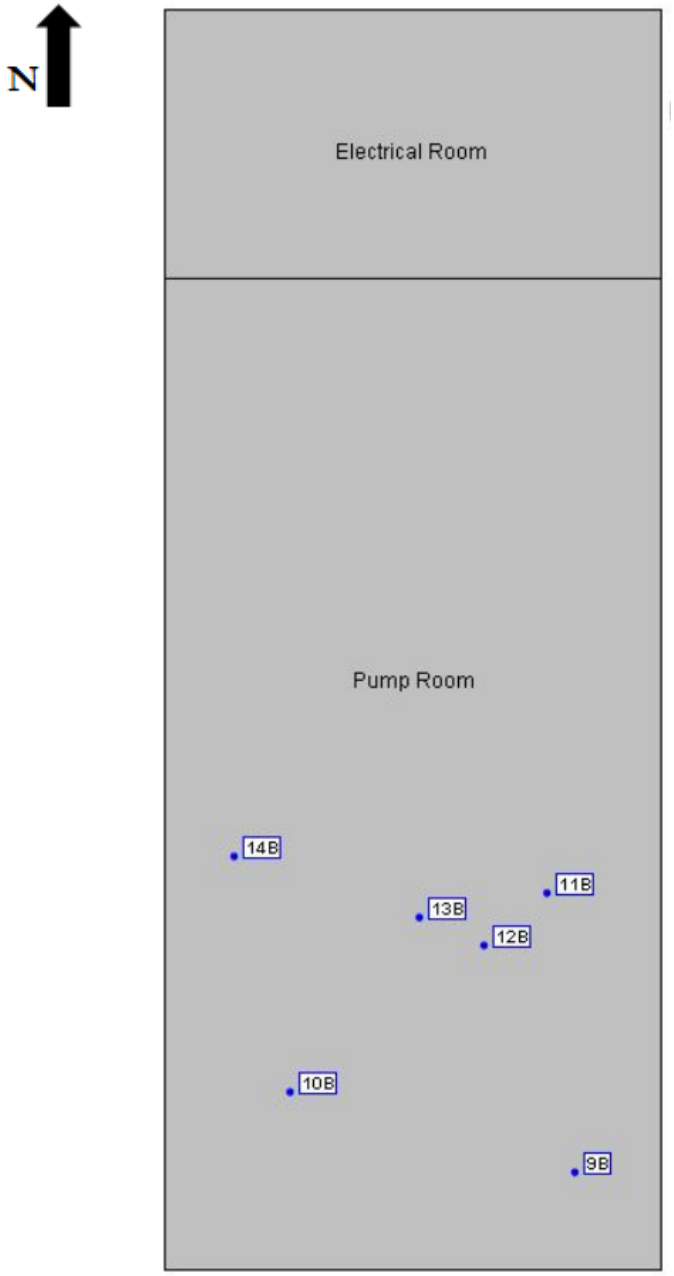


**Figure A-8. X-7726 Second Floor Utility Room Measurement Locations**

| Table A.8. X-7726, Second Floor Utility Room Survey Data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Random/ Judgmental | Smear ID | Coordinates (m) | | Surface | Material | Total Activity | | Removable Activity | |
| | | | | | | Alpha | | Alpha | Beta |
| | | X | Y | | | 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$^2$ window and a physical detector area of 584 cm$^2$. Alpha scans were performed using hand-held gas proportional detectors with a 0.8 mg/cm$^2$ window and a physical detector area of 126 cm$^2$. Beta scans were performed using a hand-held Geiger-Mueller (GM) detector with a 1.7 mg/cm$^2$ window and a physical detector area of 15 cm$^2$. 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:

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

Where:

$P$ = probability of detection (unitless)

$i$ = observation interval (sec)

$\varepsilon_t$ = total efficiency = $\varepsilon_i \times \varepsilon_s$

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

### 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$^2$) by dividing the count rate by the total static efficiency ($\varepsilon_i \times \varepsilon_s$) 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:

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

Where:

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

T = count time (min) used for field instruments

$\varepsilon_{tot}$ = total efficiency = $\varepsilon_i \times \varepsilon_s$

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$^2$.

## 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$^2$ for alpha and 14 dpm/100 cm$^2$ 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 $cm^2$ physical area, 0.8 $mg/cm^2$ 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 $cm^2$ physical area, 0.8 $mg/cm^2$ 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 $cm^2$ physical area, 1.7 $mg/cm^2$ 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)