Advanced Technologies and Laboratories (ATL) International, Inc.

Radiological Survey Report for the Land Area of the Former Blended Low Enriched Uranium Facility at the Nuclear Fuel Services Site

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ACRONYMS

ATL ..... Advanced Technologies and Laboratories International, Inc.
BKGD ..... background count rate
BLEU ..... Blended Low Enriched Uranium
cm ..... centimeter
cm^2 ..... square centimeter
cpm ..... counts per minute
DQO ..... Data Quality Objective
DSV ..... Default Screening Values
g ..... gram
m ..... meter
m^2 ..... square meter
MARSAME ..... Multi-Agency Radiation Survey and Assessment of Materials and Equipment
MARSSIM ..... Multi-Agency Radiation Survey and Site Investigation Manual
MDCR ..... minimum detectable count rate
mV ..... millivolt
NFS ..... Nuclear Fuel Services
pCi/g ..... picocuries per gram
RER ..... replicate error ratio
sec ..... second
SOF ..... Sum of Fractions
Tc-99 ..... technetium 99
U-232 ..... uranium 232
U-233 ..... uranium 233
U-234 ..... uranium 234
U-235 ..... uranium 235
U-236 ..... uranium 236
U-238 ..... uranium 238
U_3O_8 ..... triuranium octoxide
UO_2 ..... uranium dioxide
µrem/h ..... microrem per hour

1.0 INTRODUCTION

The Blended Low Enriched Uranium (BLEU) facility on the Nuclear Fuel Services (NFS) plant site in Erwin, TN received low-enriched (< 5% U-235) uranyl nitrate liquid from the on-site NFS facilities and from the Savannah River Site and converted the liquid to uranium oxide powder. This powder was then shipped to off-site facilities for processing into fuel for commercial nuclear reactors. The BLEU facility operated as a Category III facility under U.S. Nuclear Regulatory Commission Special Nuclear Material License SNM-124, beginning in 2003. The facility ceased operation in 2013.

NFS is deactivating the BLEU facility and has contracted with the DeNuke Services Division of Advanced Technologies and Laboratories (ATL) International, Inc. to provide radiological protection services during deactivation and demolition and to perform monitoring for unrestricted radiological release of equipment, materials, structures, and the site land area.

2.0 SCOPE/APPLICABILITY

This report describes the approach for performing and evaluating the final survey of the land area of the former BLEU site and the results of that survey. The survey approach was based on guidance and recommendations of the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) to provide a graded approach, based on contamination potential, while instilling a high level of confidence that significant concentrations of residual uranium contamination, if any, were identified and evaluated.

3.0 REFERENCES

- ATL-BLEU-RP-134.4, Rev 2, "Release Survey Plan for the Land Area of the Blended Low Enriched Uranium Facility at the Nuclear Fuel Services Site," Advanced Technologies and Laboratories International, Inc., June 2017
- ATL-BLEU-RP-134.1, Rev 0, "Release Survey Plan for Materials and Equipment from the Blended Low Enriched Uranium Facilities at the Nuclear Fuel Services Site," Advanced Technologies and Laboratories International, Inc., April 2016
- ATL-BLEU-RP-100, "Radiation Protection Plan for the Blended Low Enrichment Uranium Facility Restoration Project at the Nuclear Fuel Services Site," Advanced Technologies and Laboratories International, Inc., April 2016
- DeNuke procedures for specific instrumentation use and activities associated with release surveys
- NUREG-1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions," June 1998
- NUREG-1575, Rev 1, "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)," U.S. Nuclear Regulatory Commission, 2002
- NUREG-1575, Supplement 1, "Multi-Agency Radiation Survey and Assessment of Materials and Equipment (MARSAME)," U.S. Nuclear Regulatory Commission, 2009

- NUREG-1757, Vol 2, Rev 1, "Consolidated Decommissioning Guidance: Characterization, Survey, and Determination of Radiological Criteria" U.S. Nuclear Regulatory Commission, September 2006
- NUREG/CR-5512, Vol 3, "Residual Radioactive Contamination from Decommissioning," SAND99-2148, U.S. Nuclear Regulatory Commission, 2002
- Special Nuclear Materials License SNM-124 issued by the U.S. Nuclear Regulatory Commission for activities at Nuclear Fuel Services, November 21, 2016

4.0 DEFINITIONS

The definitions of terms used in this plan that may not be commonly understood are presented in procedure **DENUKE RP-110.1**, "Definitions."

Additional definitions are as follows:

Class 1: Impacted surfaces that have or had (1) the highest potential for or known radionuclide concentration(s) or radioactivity above the action (guideline) levels, (2) the highest potential for small areas of elevated radionuclide concentration(s) or radioactivity, and (3) insufficient evidence to support reclassification as Class 2 or Class 3. Such potential may be based on historical information and process knowledge, while known radionuclide concentration(s) or radioactivity may be based on preliminary surveys. Surfaces that have undergone decontamination to remove residual radioactivity above the release limits were considered Class 1.

Class 2: Impacted surfaces that have or had (1) low potential for radionuclide concentration(s) or radioactivity above the release criteria levels and (2) little or no potential for small areas of elevated radionuclide concentration(s) or radioactivity. Such potential may be based on historical information, process knowledge, or preliminary surveys. This class might consist of surfaces that may have come in contact with radioactive materials but were not directly related to process operations. Radioactive concentrations above the criteria levels were not expected in Class 2.

Class 3: Impacted surfaces that have or had (1) little or no potential radionuclide concentration(s) or radioactivity above background and (2) insufficient evidence to support categorization as non-impacted. Radionuclide concentration(s) and radioactivity above a specified small fraction (approximately 10%) of the guideline levels were not expected on Class 3 surfaces.

Classification: The act of separating surfaces into classes based on contamination potential.

Graded Approach: The process of basing the level of survey rigor on the contamination potential and the level of confidence needed for the final decision.

Impacted: Having known contamination or a reasonable possibility of contamination based on history of use and previous surveys.

Inaccessible Areas: Areas that cannot be surveyed due to location or obstruction.

Non-impacted: Having no reasonable possibility of residual contamination (see Impacted).

Survey Unit: A defined geographical area of specified size and shape, established to facilitate the survey and data evaluation processes, and for which a separate decision will be made as to whether the established release criteria have been attained. A survey unit is a contiguous area with a similar use history and classification of contamination potential.

Unrestricted Release: Release of equipment, materials, structures, and land areas from future radiological controls after confirming that any residual radioactive material satisfies established criteria.

5.0 SITE DESCRIPTION

General

Figure 1 is a layout of the NFS Site showing the location of the BLEU facility relative to major landmarks. **Figure 2** is a drawing of the BLEU facility, indicating the locations of the former five major buildings—Buildings 510, 520, 530, 540, and 550. Uranyl nitrate liquid was received and transferred into storage tanks in Building 510. The liquid feed material was then transferred from Building 510 to Building 520, where it was converted into uranium oxide powder, dried, blended, and packaged for shipment. Process operations were performed in radiologically controlled areas of those two buildings.

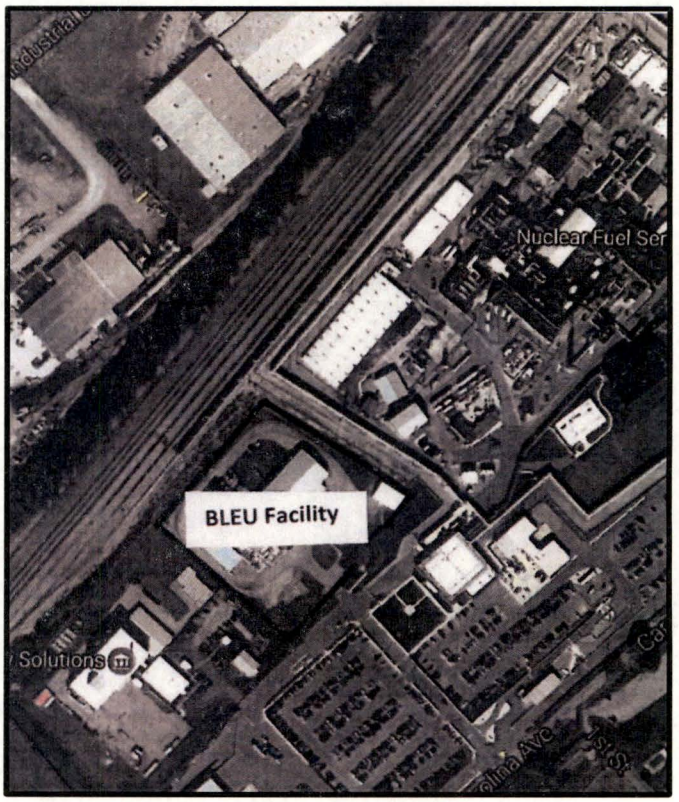


Figure 1. Nuclear Fuel Services Site, Indicating Location of the BLEU Facility

Effluents from the conversion operations in Building 520 were processed in Building 530. Access to the BLEU facility was through Building 540. Building 550 was a warehouse area used to store uncontaminated materials and supplies—many of which were new and unused.

Facility Grounds

The BLEU Facility occupies approximately 5.16 acres (2.09 hectares) of the Nuclear Fuel Services site on Banner Hill Road in Erwin, TN. There were five major structures on

the site, three of which (Buildings 510, 520, and 530) were impacted by the facility operations. The remaining two structures (Buildings 540 and 550) had no history of radiological activities and were not impacted.

Contaminated systems, components, equipment, and material have been removed and disposed of as low-level radioactive waste. Non-contaminated furnishings, equipment, and materials have been surveyed and released for unrestricted future use. Remaining structures, foundations, paved surfaces, and underground drains/piping have been surveyed and either released for future use or disposed of as contaminated waste, as appropriate. What remains is a cleared soil area, similar to the site prior to construction of the BLEU facility and the storm drain system (refer to **Figure 2** and **Figure 3**). A survey of this remaining soil area was performed to characterize the as-left conditions.

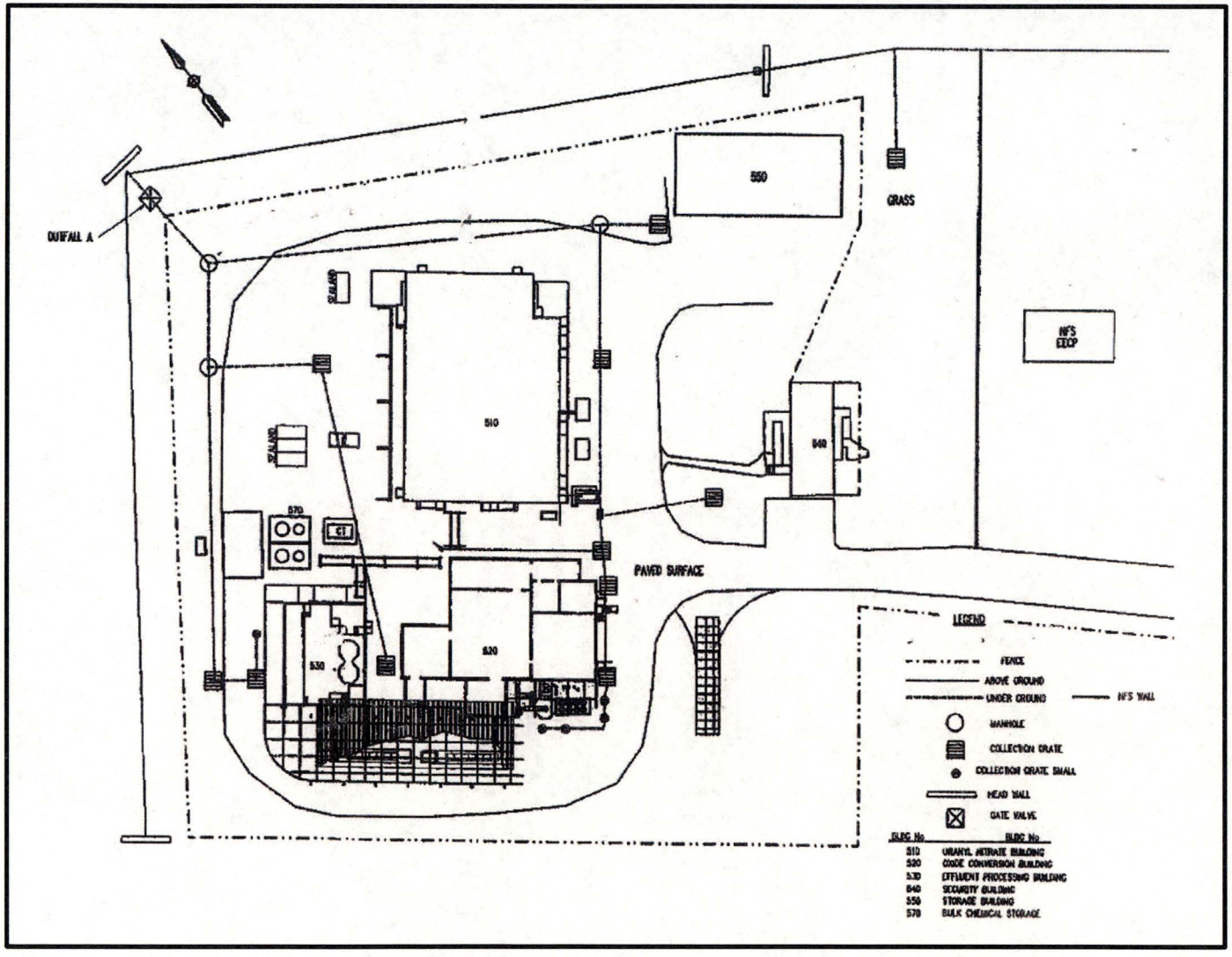


Figure 2. BLEU Facility Layout Before Demolition Activities

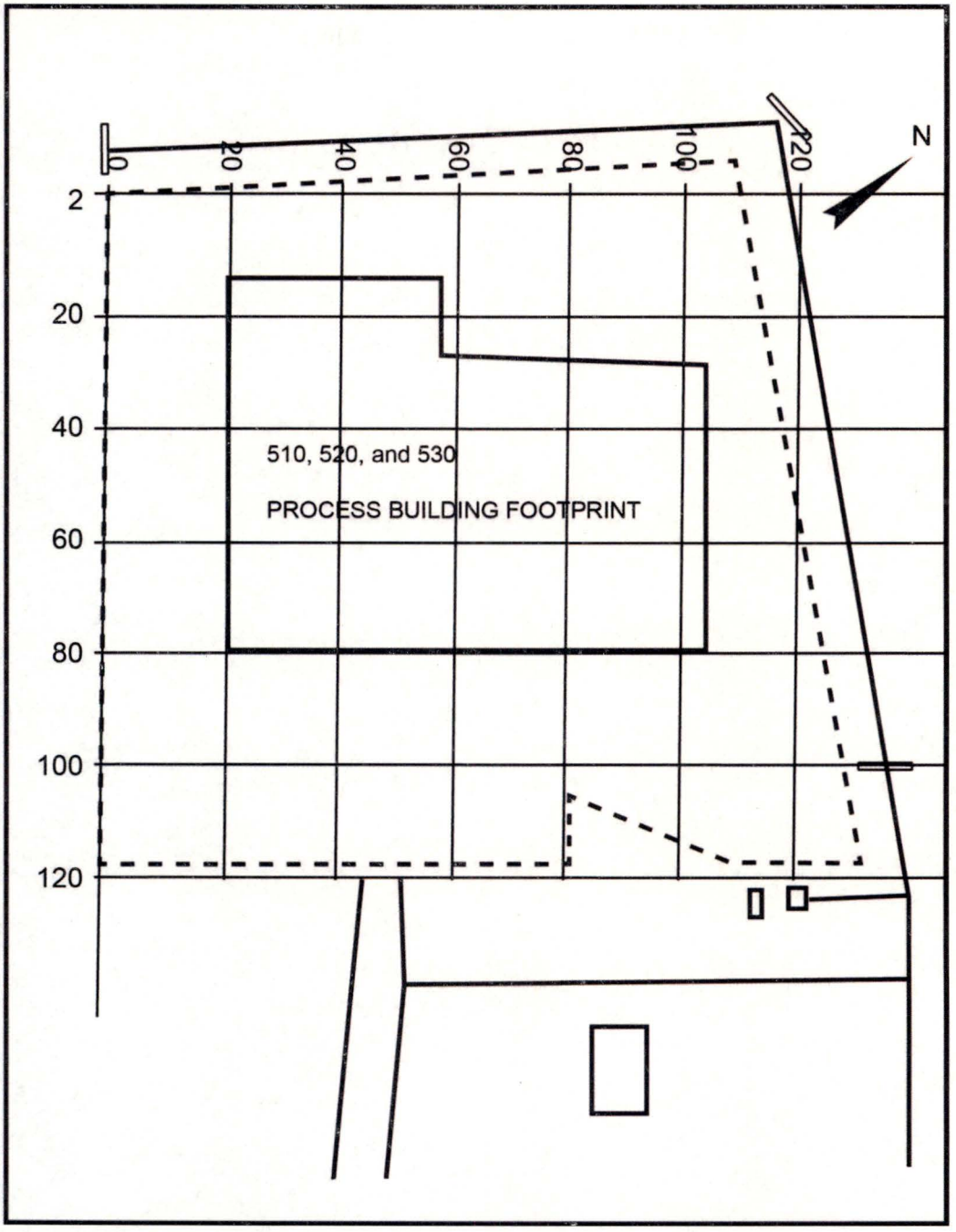


Figure 3. BLEU Facility Site After Demolition, Showing Reference Grid System

6.0 POTENTIAL CONTAMINANTS AND SITE CRITERIA

The BLEU facility received low enriched (< 5% U-235) uranyl nitrate from the adjacent NFS plant site and from the Savannah River Site and converted the liquid to uranium oxide powder(s)—primarily UO_2 with some reaching U_3O_8. These powders were blended to achieve homogeneity and then shipped to an off-site fuel fabrication facility. Radiological material in the BLEU facility is processed uranium up to an enrichment level of approximately 5% U-235. Because some of the feed material included recycled uranium, small quantities of U-232 and U-236 were also present, along with immediate, short half-life progeny of the uranium parent radionuclides. Analyses provided by NFS indicated the following average isotopic uranium activity fractions: U-232, 0.0044; U-233/234, 0.7962; U-235, 0.0147; U-236, 0.1431; and U-238, 0.0437. Uranium-233 and 234 essentially emit only alpha radiation and have no short half-life progeny, while other uranium isotopes emit alpha particles and have short half-life progeny that emit beta and gamma radiations.

Although NFS analyses identified the presence of low concentrations of additional radiological contaminants (e.g., plutonium, americium, Tc-99, and various other fission products) in some BLEU facility feed materials, the average activity fractions of these other radionuclides were less than 0.0001 and therefore negligible in comparison with the uranium levels.

As-left concentrations of uranium isotopes at this site were compared with Default Screening Values (DSVs) developed by the U.S. Nuclear Regulatory Commission for decommissioning actions. These DSVs and their application to decommissioning actions are presented in Table H-2 and Section 5.1.2 of **NUREG-1757, Vol. 2**. DSVs for U-232, U-233, and U-236 are not provided in Table H-2 of **NUREG-1757**; therefore, values for these isotopes were obtained from Table 6.9.1 of **NUREG/CR-5512, Vol. 3**.

These DSVs (refer to **Table 1**) represent concentrations of the longer half-life uranium isotopes, which, if present in surface soil over an area of 10,000 m^2,could be expected to result in maximum radiation doses of 25 millirem/year to site occupants, based on conservative land use conditions and parameters. The DSVs therefore represent radiological conditions that are typically considered acceptable for unrestricted future use of surface soil. Due to the brief in-growth time available for accumulation of longer half-life progeny during the operating life-time of the facility, entire decay chains of these uranium isotopes would not be present.

Table 1. Default Screening Concentrations of Uranium Isotopes in Surface Soil

Uranium Isotope	Concentration (pCi/g)	Source Document	Document Table
U-232	1.96	NUREG/CR-5512	Table 6.9.1
U-233	9.11	NUREG/CR-5512	Table 6.9.1
U-234	13	NUREG-1757	Table H-2
U-235	8	NUREG-1757	Table H-2
U-236	14.0	NUREG/CR-5512	Table 6.9.1
U-238	14	NUREG-1757	Table H-2

7.0 SURVEY APPROACH

The survey approach was prepared in accordance with guidelines and recommendations presented in MARSSIM. This approach emphasizes and incorporates the use of Data Quality Objectives (DQOs) and Data Quality Assessment along with a quality assurance/quality control program. The graded approach concept is followed to ensure that survey efforts are maximized in those areas having the greatest potential for residual contamination or the highest potential for adverse impacts of residual contamination.

Senior radiological technicians, certified in DOE Fundamental Core competency and experienced in final status and release survey implementation, conducted field measurements and sampling, following standard procedures and using calibrated instruments sensitive to the potential contaminants. Professional health physics personnel assessed and evaluated the survey data and prepared a report of the findings. Appendix A contains a list of procedures applicable to this survey.

7.1 Classification and Survey Unit Identification

A comprehensive radiation protection program was implemented by NFS throughout the entire operating lifetime of the BLEU site. During the deactivation, decontamination, and demolition operation, potentially impacted equipment, materials, and construction media were evaluated in accordance with MARSSIM and MARSAME protocols and, if determined to satisfy project criteria of 500 dpm/100 cm^2 direct alpha, 5000 dpm/100 cm^2 direct beta, 100 dpm/100 cm^2 removable alpha, and 200 dpm/100 cm^2 removable beta, were released without restrictions. Otherwise, materials were disposed of as low-level contaminated waste.

Prior to construction of the BLEU facility, the land area was used as a softball field and was not subject to radiological restrictions. NFS contracted with MACTEC to perform a pre-construction survey of the property in 2003 to confirm it was not radiologically impacted. That survey identified the presence of naturally occurring radionuclides (uranium, thorium, and K-40) at levels typical of background soils in the area. Because only isotopes of uranium were present in the materials processed at the BLEU facility, thorium and K-40 background levels were not of concern. Gamma spectrometry of 15 preconstruction samples of surface soil indicated the following average uranium concentrations: U-238, 2.04 ± 0.48 pCi/g and U-235, 0.144 ± 0.157 pCi/g. The analytical method was not able to determine levels of U-234, but at naturally occurring isotopic abundances, the U-234 concentration can be assumed to be the same as the U-238 value. It was initially intended that these results would serve as a reference area for adjusting final survey results for uranium background contributions. However, in view of the very low concentrations observed in the final status survey samples, adjusting the final survey samples for preconstruction background levels was unnecessary. Therefore, uranium concentrations in the survey samples were compared directly with the DSVs, without adjusting for background contributions.

No significant spills or releases that impacted soil occurred during operations. There was one minor spill during capping of the feed line from adjacent NFS facilities to Building 510 after operations were discontinued but prior to the start of this site restoration project. Remediation of the spill was performed at that time by NFS. Complete removal

of the feed line was performed in January 2017 as part of the cleanup and release of Building 510.

Feed Line post-removal surveys identified a small (< 1 m^2) area of uranium-contaminated soil at a depth of approximately 0.5 m at the location of the minor spill. Further excavation of this contaminated area was performed, and follow-up sampling demonstrated that all locations satisfied the DSV criterion and no further action was warranted. The Feed Line and locations of post-remediation sampling are illustrated on **Figure 6** and **Figure 7**, respectively.

Operational history and surveys performed during removal and decontamination operations were used to determine the contamination potential (i.e., classification) of the remaining site soils. Impacted areas were divided into survey units in accordance with the area limits in **Table 2.**

Table 2. Survey Unit Land Areas by Classification

Classification	Maximum Area (m^2)
Class 1	2000
Class 2	10,000
Class 3	No limit

Three land area survey units were established, based on use history and radiological monitoring records. These survey units are identified in **Table 3**.

Table 3. List of Survey Units for Site Land Area

Area	Use/Function	Area (m^2)	MARSSIM Class	Number of Survey Units
A	Process Buildings footprint	4,500	2	1
B	Remainder of site	16,400	3	1
C	Feed Line Trench	30	1	1

7.2 Site Preparation

The site survey plan was initially intended to be applicable to the site that remained following removal of structures, systems, components, materials, equipment, and paved surfaces. The storm drain system was determined to be necessary for future site drainage. Therefore, it was surveyed, demonstrated to satisfy the project criteria for unrestricted release, and left in place. The results of the surveys of the storm drain system can be found in **Appendix C**, Results of Surveys of the BLEU Facility Storm Drain System.

Sanitary drain piping was removed. Impacted Process Building floor slabs were surveyed as part of the structure evaluations, decontaminated and resurveyed where necessary, and determined to satisfy project criteria for unrestricted release. These floor slabs were demolished and removed to expose underlying soil.

Other paved roadways, sidewalks, and pads were surveyed and determined to satisfy project release criteria. Resurfacing was not performed during the operational period

because (1) site history indicated paved surfaces were in place before feed materials were introduced to the site and (2) no spills occurred during the production phase, so there was no significant potential for contamination of the soil beneath the paving. Where selected sampling locations were beneath paved surfaces, cores were removed from the paving to access the underlying soil.

Impacted surfaces were gridded at 20-m intervals within Survey Unit A and Survey Unit B to provide a means for referencing survey locations. Grid origins were in the southwest corner of the survey unit. Measurement and sampling locations were identified by grid coordinate. The reference grid system is shown in **Figure 4** and **Figure 5**.

Sampling locations within Survey Unit C were distributed approximately uniformly throughout the survey unit to ensure representative coverage, but were not calculated in consideration of the small size of the survey unit.

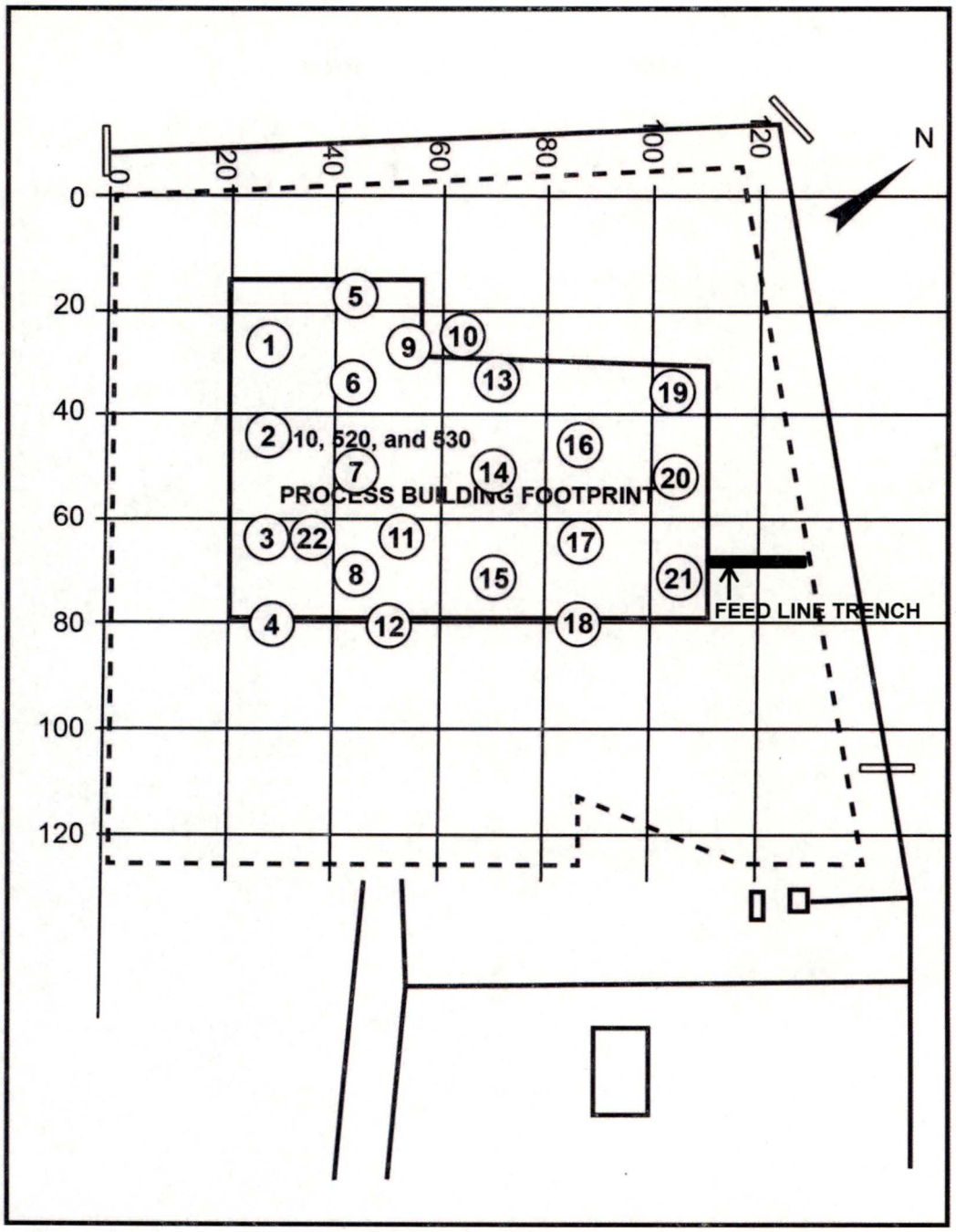


Figure 4. Soil Sampling Locations in Survey Unit A

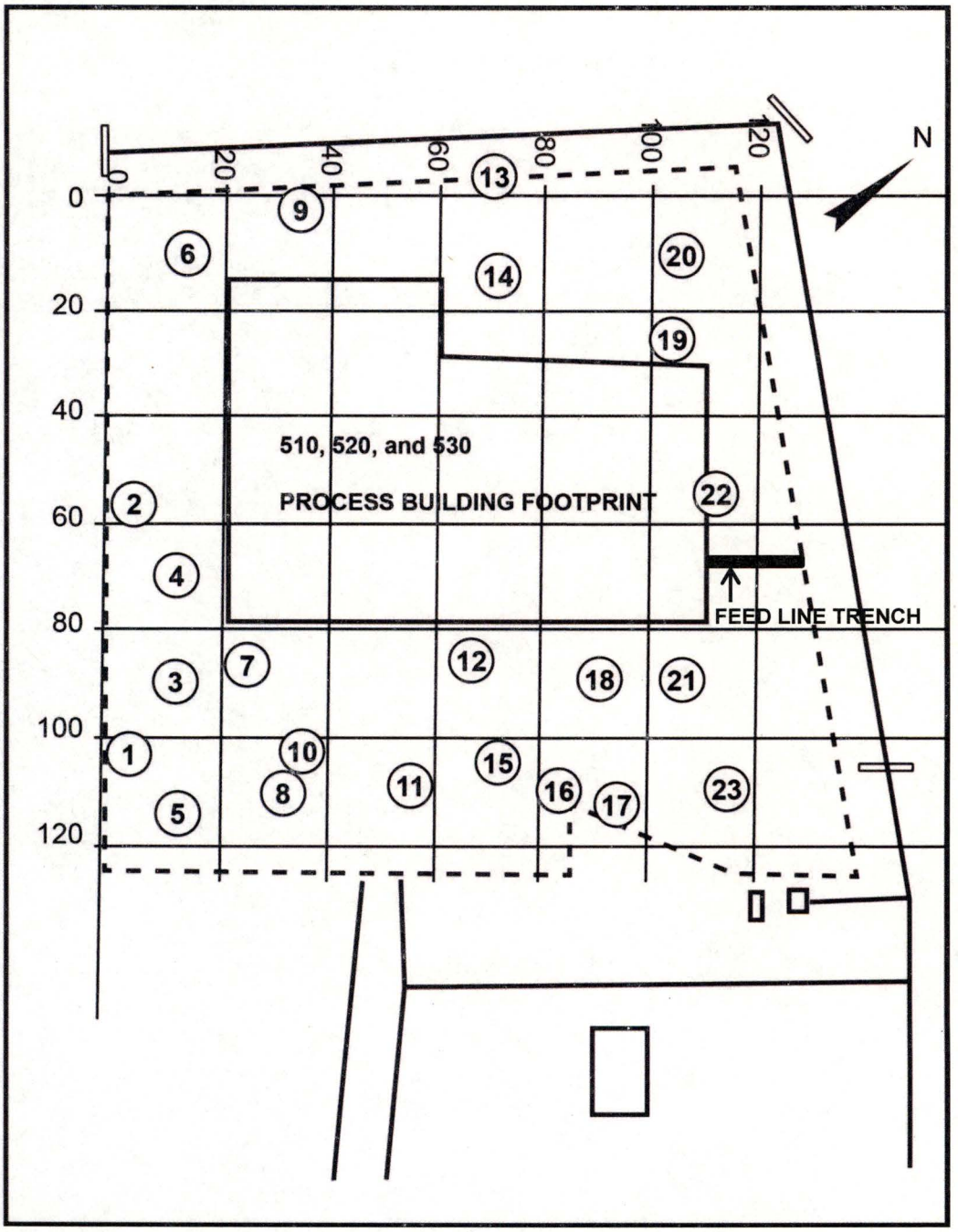


Figure 5. Soil Sampling Locations in Survey Unit B

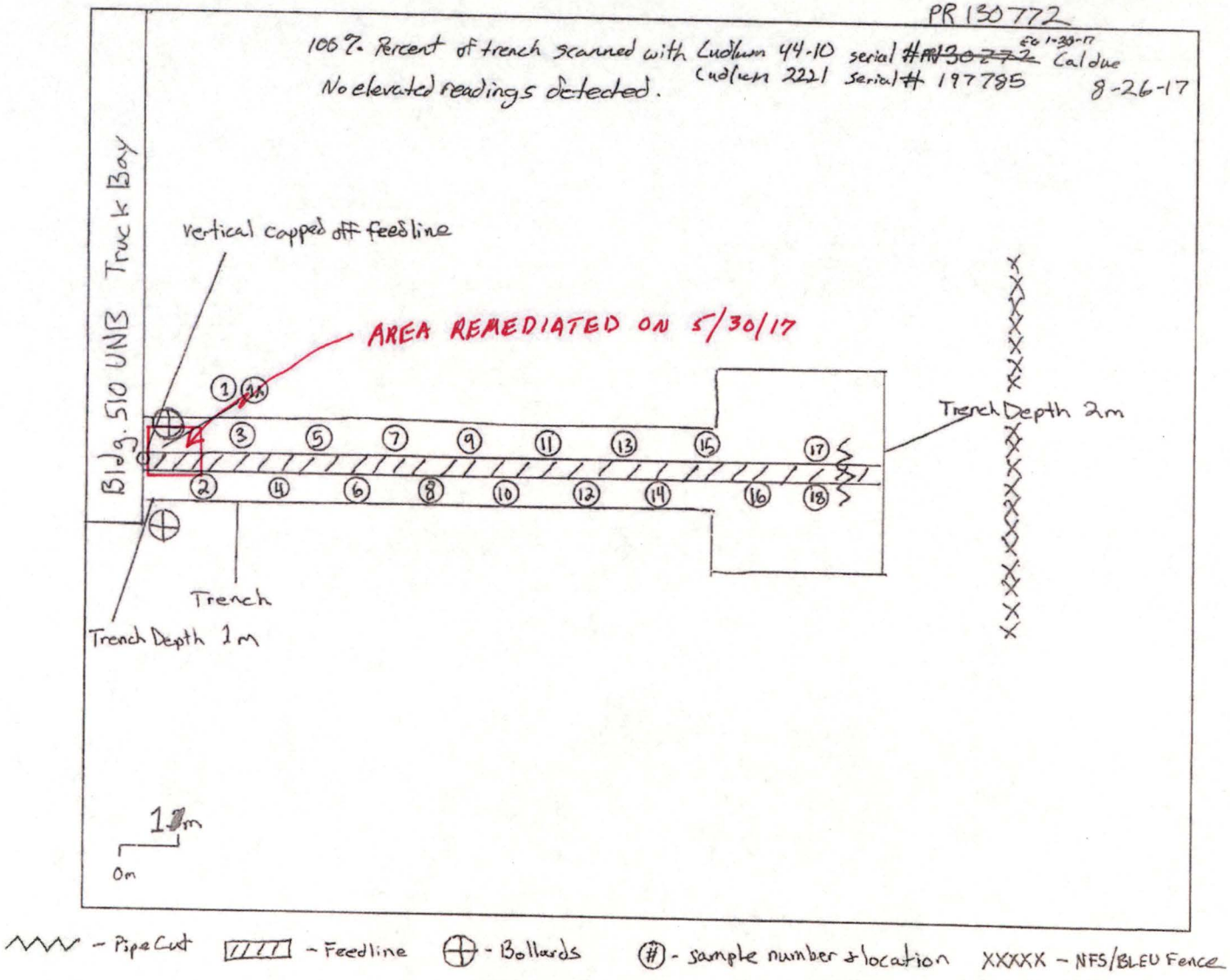


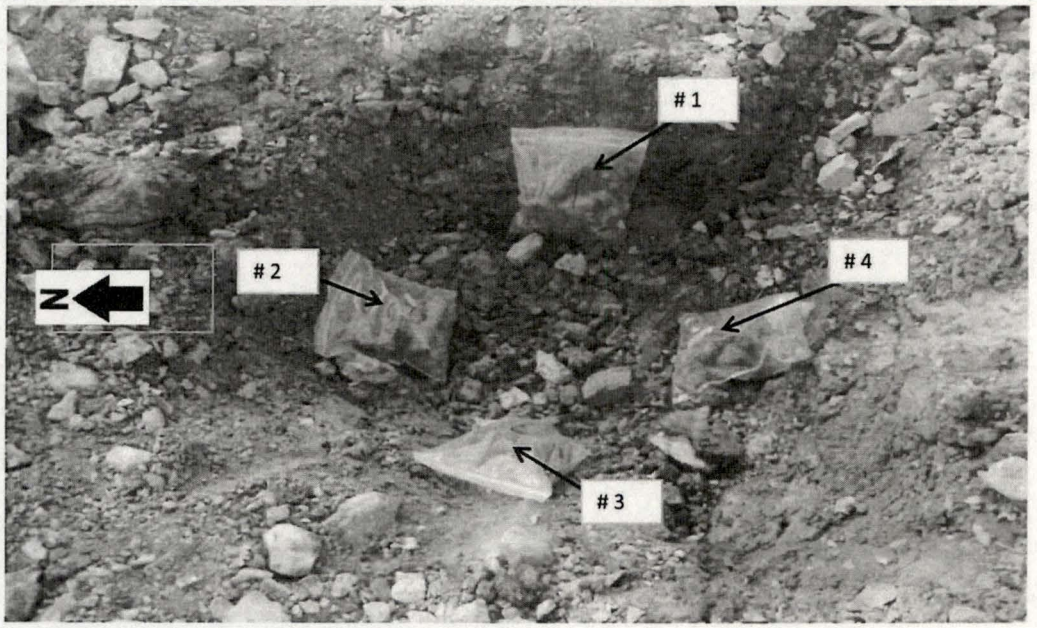
Figure 6. Soil Sampling Locations in Survey Unit C

RADIOLOGICAL SURVEY MAP

Project/Site: BLEU FACILITY / NFS Survey Location: OUTSIDE UNB

Survey Number: BLEU-SY1082 Survey Class Type: VERIFICATION

Date: 5/30/17 Time: 0900 RWP Number:



Smear ID Number & Location: (#) Dose Rate and Location: # Boundary: .....

Figure 7. Post-Remediation Soil Sampling Locations in Survey Unit C

7.3 Integrated Survey Strategy

The null hypothesis for the data evaluation to demonstrate compliance with project criteria is "Residual radiological contamination levels exceed project criteria." The objective of the final release survey was to reject this null hypotheses by demonstrating at a Type I (α) decision error level of 0.05 (i.e., 95% confidence level) that residual activity does not exceed criteria. The Type II (β) decision error level was also 0.05. To establish the number of data points needed to demonstrate that residual contamination criteria have been satisfied, a parameter known as the *relative shift*, which effectively describes the distribution of final sample data, was calculated as follows:

(1)Δ/σ = (DCGL-LBGR)/ σ

where:

Δ/σ= relative shift

DCGL = cleanup criteria

LBGR = lower bound of the gray region and is defined in the DQOs as 50 percent of the DCGL. Where final sample data were not yet available, MARSSIM guidance (Section 5.5.2.2) assigns a value of one-half of the DCGL for the LBGR.

σ = standard deviation of the sample concentrations in the survey unit. Where final sample data were not yet available, MARSSIM guidance (Section 5.5.2.2) is to use a value of 30 percent of the DCGL.

Using the equation for relative shift and MARSSIM guidance for situations where final sample data are not yet available, the relative shift for design purposes is (1 – 0.5)/0.3 for a value of 1.67. Based on the relative shift of 1.67 and Type I and Type II decision errors of 0.05, the number of required data points from each survey unit, as obtained from MARSSIM guidance (Table 5.5), is 17.

Sampling locations on Class 2 soil surfaces [Survey Unit A (see **Figure 4**)], a random start point (41 meters north, 53 meters east) was identified and additional measurement locations were systematically selected by triangular spacing from that start point. Spacing distance, L, was determined to be 18 meters as follows:

$$L = [(\text{Survey Unit Area})/0.866 \times \text{number of data points}]^{0.5}$$

Sampling locations on Class 3 [Survey Unit B (see **Figure 5**)] soil surfaces were determined randomly.

Sampling locations on Class 1 [Survey Unit C (see **Figure 5**, **Figure 6** and **Figure 7**)] soil surfaces were distributed approximately uniformly to ensure representative coverage, but were not calculated in consideration of the small size of the survey unit.

Additional sampling locations in each survey unit were selected based on professional judgment to achieve uniform coverage, provide evaluation of locations with high potential for contamination, and address locations of elevated walkover gamma scan results. Field duplicate samples were obtained at two locations for data quality evaluation.

Radiological surveys consisted of:

- surface scans for elevated gross gamma levels,
- direct measurement of gamma radiation levels at surface and 1 m above the surface, and
- sampling and analysis of surface soil for uranium concentrations.

Survey activities were in the order indicated above. The rigor of survey activities followed the graded approach, based on the likelihood of contamination. **Table 4** indicates the survey rigor for various contamination classifications.

Table 4. Survey Rigor for Each Radiological Survey Unit

Class	Gamma Scan	Direct Gamma Levels	Sampling
1	100%	Uniformly distributed soil samples at a minimum of 17 locations and at additional locations based on professional judgment and/or elevated scan results	At each measurement location
2	50%	Systematic soil samples at a minimum of 17 locations coupled with and 1-m gamma radiation measurements, and at additional locations based on professional judgment and/or elevated scan results	At each measurement location
3	10%	Randomly selected soil samples at a minimum of 17 locations coupled with and 1-m gamma radiation measurements, and at additional locations based on professional judgment and/or elevated scan results	At each measurement location

7.4 Survey Instrumentation

Table 5 lists radiological survey instrumentation used to implement the BLEU facility final release survey. These instruments were maintained, calibrated, and operated in accordance with written procedures.

Table 5. Instrumentation for Final Site Surveys

Detector	Readout	Application
Ludlum 44-10	Ludlum 2221	Gamma scans
Trimble GeoExplorer Model GeoXH	N/A	Logging of scan levels and GPS coordinates
Bicron microrem meter	N/A	Gamma radiation levels

Detection sensitivities (refer to **Appendix B**) were estimated using the guidance in **MARSSIM** and **NUREG-1507**. Instrumentation and survey techniques were chosen with the objective of achieving detection sensitivities that enabled identification of significant concentrations of residual uranium activity in small volumes of surface soil.

Instrument operational and background checks were performed at the beginning and end of each day of release survey activity and whenever there was reason to question instrument performance.

7.5 Survey Techniques

7.5.1 Scan Soil Surfaces for Contamination

Radiological technicians scanned surfaces with a Model 44-10, 2-in diameter sodium iodide gamma scintillation detector by passing the detector over the soil in a serpentine pattern while advancing at a rate of 0.5 m/sec and maintaining a distance of ≤ 5 cm between the detector and surface.

Radiological technicians monitored the audible instrument signal for an indication of detectable increases in count rate and noted/marked locations of elevated count rate for further evaluation.

Count rate and GPS coordinates were automatically recorded every 2 seconds, and results were displayed graphically on a site map.

7.5.2 Measure Direct Radiation Levels

Using a Bicron (ThermoFisher-Scientific) microrem meter, radiological technicians performed measurements of radiation levels at 1 m above the surface at each sampling point. This instrument provides a nearly flat tissue-equivalent response for low photon energies associated with most isotopes of uranium, assuring accurate measurements of gamma dose rate.

7.5.3 Sample Surface Soil

Radiological technicians collected soil samples (minimum 200 g of soil) from the surface (0-15 cm) at each data point. Sampling locations are indicated in **Figure 4**, **Figure 5**, and **Figure 6**. Isotopic uranium analyses for uranium isotopes of concern were performed by Eberline Services in Oak Ridge, TN (National Environmental Laboratory Accreditation Program and ISO 17025 certified). Field duplicate samples were obtained at two locations (minimum of 5% of locations) and provided to a separate contractor for independent analyses as part of the quality assurance program.

7.5.4 Quality Assurance/Quality Control

A written quality assurance and quality control procedure for survey activities was implemented. Quality assurance/quality control activities include instrument checks, calibration, documented procedures, training, standard methods, sample chain of custody, field duplicate sampling/measurements, and use of qualified laboratories.

8.0 DATA EVALUATION

Survey results (i.e., scans, direct measurements, and samples) were documented. Sample analysis results were compared with DSV levels and the SOF calculated for each sample. Because DSVs were used for this evaluation, all SOF values were required to be less than Unity and statistical testing of findings were not applicable.

9.0 SURVEY RESULTS

9.1 Walkover Gamma Scans

Figure 8, **Figure 9** and **Figure 10** illustrate the results of the gamma walkover scans of Survey Units A, B, and C (Feed Line Trench), respectively. It should be noted that count rates displayed for Survey Units A and B are in units of "counts per 2 minutes", while those for Survey Unit Care in "counts per minute". Also note that geospatial instrumentation was used to record the gamma scan data in Survey Units A and B, however the data were manually recorded for Survey Unit C.

Gamma count rates ranged up to 19, 760 counts/2 minutes {9,880 counts/minute) with a median of 14,020 counts/2 minutes {7,010 counts/minute) in the process buildings footprint {Survey Unit A). Over the remainder of the site {Survey Unit B), gamma count rates ranged up to 24, 760 counts/2 minutes {12,380 counts/minute) with a median of 13,960 counts/2 minutes {6,980 counts/minute). Note that levels were higher along the south perimeter due to the proximity of radioactive waste processing operations in the area outside of the southern boundary of the Site. In the west and northwest portions of the Site, levels were higher due to other NFS process operations in the general vicinity of those locations. Gamma count rates did not exceed the background count rate within Survey Unit C.

For comparison purposes, the average site background level for the gamma scintillation instrument used for these surveys was approximately 8,000 counts/minute. No specific locations presented elevated surface count rates, which would indicate potential uranium residues in surface soil, were identified.

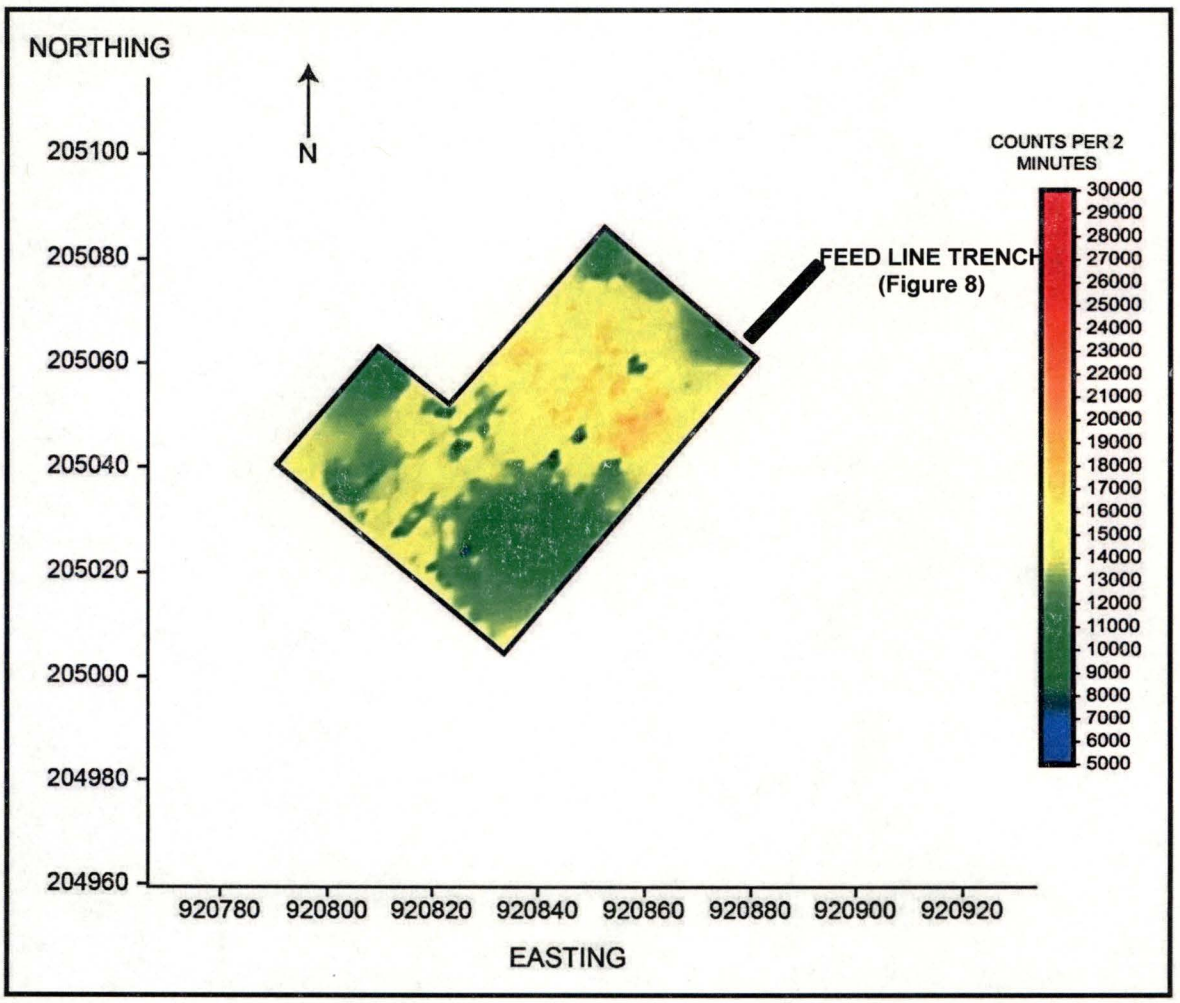


Figure 8. Walkover Gamma Scan Results for Survey Unit A

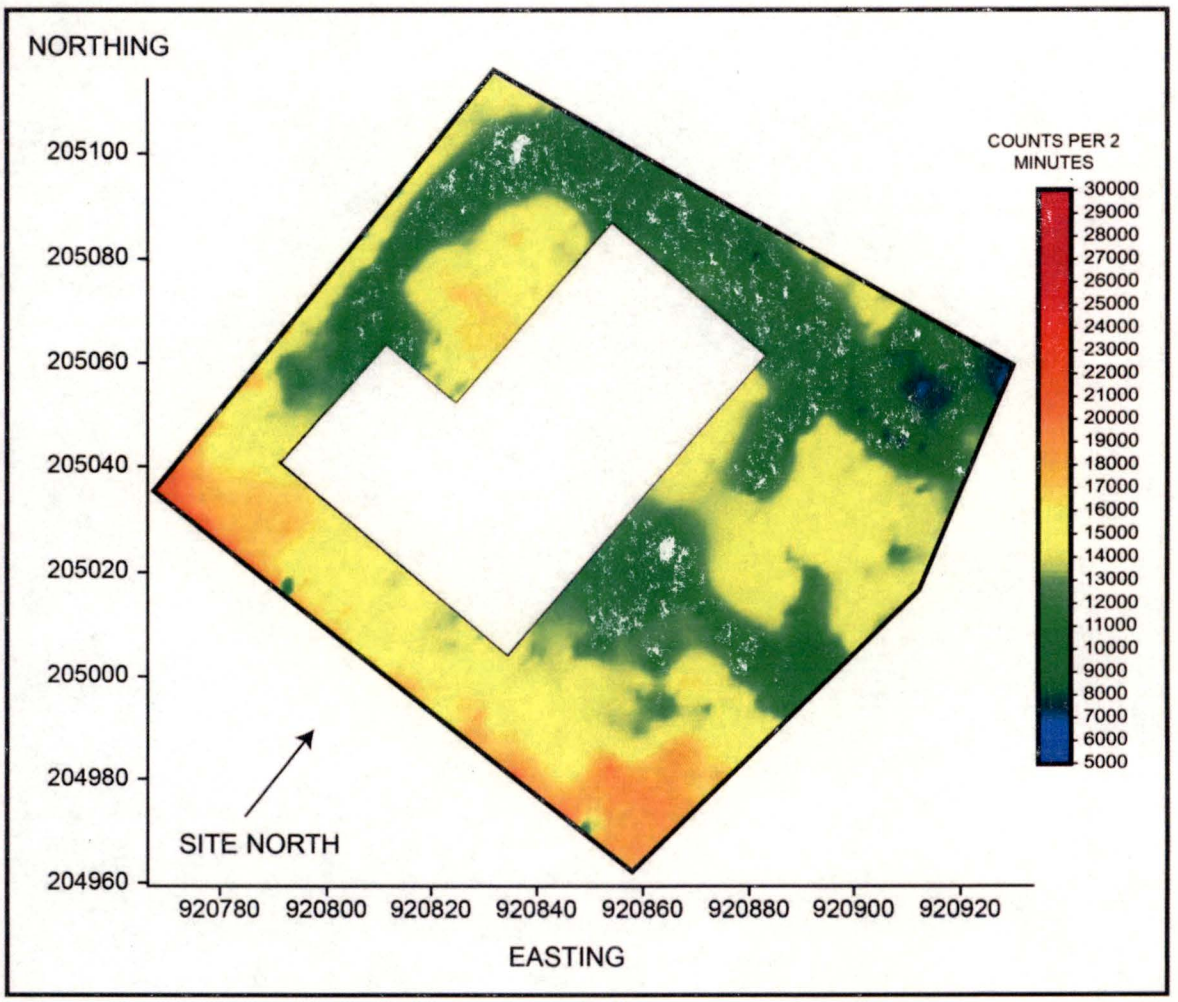


Figure 9. Walkover Gamma Scan Results for Survey Unit B

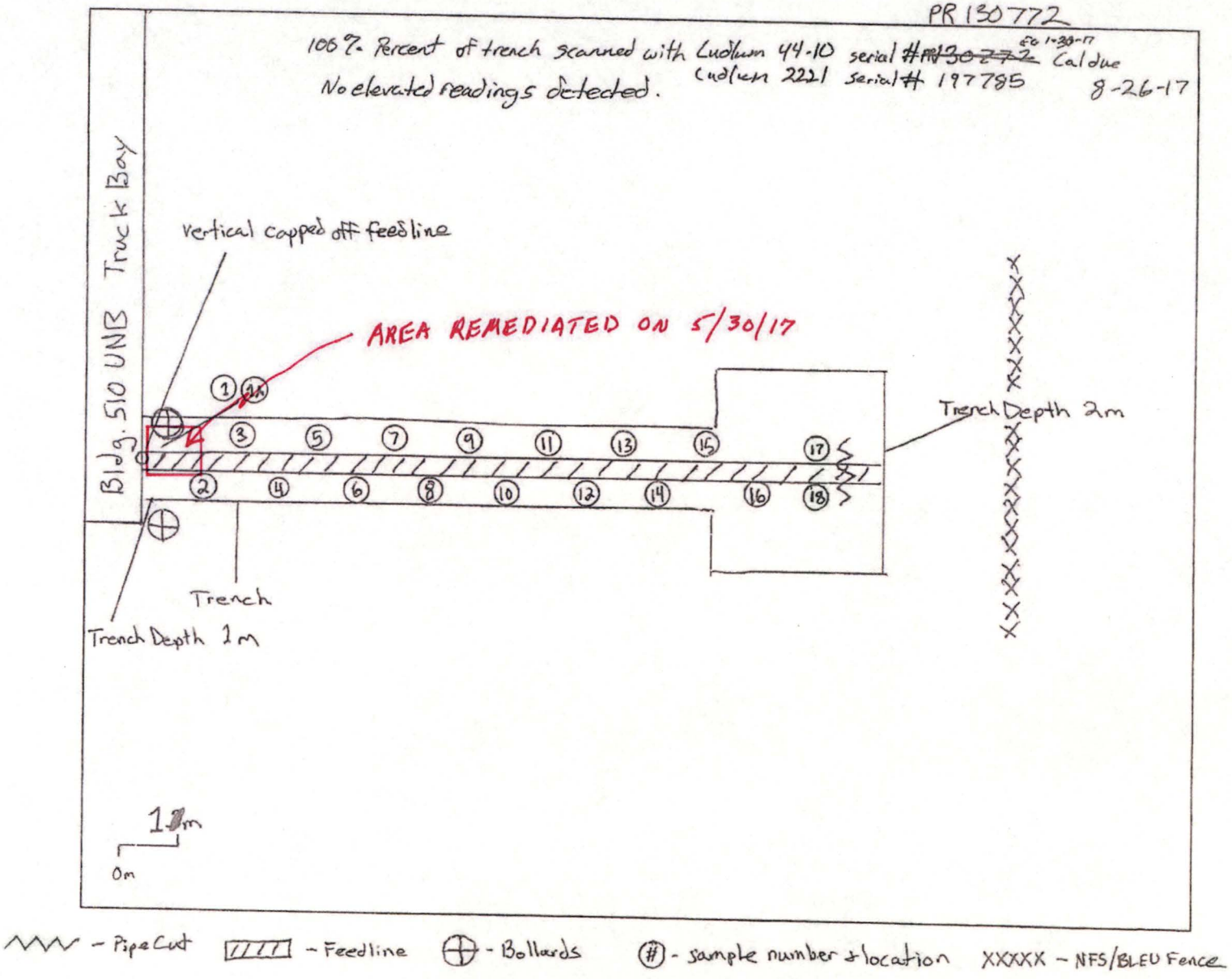


Figure 10. Walkover Gamma Scan Results for Survey Unit C

9.2 Gamma Radiation Levels

Gamma radiation levels were obtained using a Bicron microrem meter at soil sampling locations are summarized in **Table 6** and **Table 7**. Gamma radiation levels were not obtained at soil sampling locations within Survey Unit C (Feed Line Trench). The levels in Survey Unit A ranged from 6 to 11 µrem/h at 1 m above the surface. In Survey Unit B, levels ranged from 5 to 17 µrem/h at 1 m above the surface. The highest level was in Survey Unit B near the south perimeter fenceline. Levels were generally higher in that area due to waste processing operations being conducted to the south of the site. For comparison, the average site background level determined during the execution of this project ranged from 7 to 10 µrem/h.

Table 6. Gamma Radiation Levels at Soil Sampling Locations in Survey Unit A

Location ID*	Grid Coordinates		Dose Rate @ 1 Meter Above Surface (µrem/h)
	North	East	
1	26	26	9
2	26	44	8
3	26	62	7
4	26	80	7
5	41	17	8
6	41	35	8
7	41	53	7
8	41	71	7
9	56	26	10
10	56	44	9
11	56	62	7
12	56	80	7
13	71	35	10
14	71	53	8
15	71	71	6
16	86	44	11
17	86	62	7
18	86	80	8
19	101	35	7
20	101	53	10
21	101	71	7
22	37	61	7

*Refer to **Figure 4**

Table 7. Gamma Radiation Levels at Soil Sampling Locations in Survey Unit B

Location ID*	Grid Coordinates		Dose Rate @ 1 Meter Above Surface (µrem/h)
	North	East	
1	2	101	17
2	4	59	9
3	11	90	6
4	12	69	8
5	13	119	7
6	14	11	7
7	24	85	7
8	32	113	6
9	35	2	9
10	36	106	7
11	58	110	8
12	65	85	9
13	70	-2	8
14	71	17	10
15	72	106	6
16	80	112	7
17	90	17	6
18	90	90	7
19	102	25	5
20	106	10	7
21	107	81	8
22	110	55	8
23	115	110	5

*Refer to **Figure 5**

9.3 Soil Sample Concentrations

Uranium concentrations in surface soil, obtained from the surface of Survey Units A and B, and C are presented in **Table 8**, **Table 9**, and **Table 10**, respectively.

Samples 1 through 21 were collected systematically from Survey Unit A. **S**ample 22 was judgmental, collected from the soil beneath Building 520, where there were frequent transfers of blended uranium product. Field duplicates were also collected from locations 1 and 9 in Survey Unit A. Maximum concentrations in the final status samples from Survey Unit A were <0.14 pCi/g of U-232, 1.77 $\pm$0.35 pCi/g of U-233 plus U-234, 0.36 $\pm$ 0.16 pCi/g of U-235 plus U-236, and 1.43 $\pm$ 0.32 pCi/g of U-238. It should be noted that alpha spectroscopy analyses do not distinguish between U-233 and U-234 or between U-235 and U-236; the totals for U-233 plus U-234 and for U-235 plus U-236 are therefore reported together.

Samples 1 through 17 were collected from randomly determined locations in Survey Unit B. Samples 18 through 23 were collected at judgmentally determined locations to provide coverage of this entire Survey Unit. Maximum concentrations in the final status samples from Survey Unit B were 0.14 ± 0.15 pCi/ of U-232, 1.78 ± 0.38 pCi/g of U-233 plus U-234, <0.27 pCi/g of U-235 plus U-236, and 1.43 ± 0.32 pCi/g of U-238.

Samples 1 through 18 were collected at locations in Survey Unit C to ensure representative coverage throughout the survey unit. Sample 1A Duplicate was collected

in close proximity to Sample 1, and showed concentrations in excess of the DSV. Remediation was performed and Post-Remediation Samples REM1 – REM4 were collected to confirm residual concentrations were less than the DSV. Maximum concentrations in final status samples from Survey Unit C were 0.09 ± 0.07 pCi/ of U-232, 4.72 ± 0.69 pCi/g of U-233 plus U-234, 0.48 +/- 0.18 pCi/g of U-235 plus U-236, and 1.74 ± 0.33 pCi/g of U-238.

Table 8. Uranium Concentrations in Surface Soil Samples from Survey Unit A

Location ID	Grid Coordinates		Uranium Concentration (pCi/g)				Comments
	North	East	U-232	U-233&234	U-235&236	U-238	
1	26	26	0.05*	0.71 ± 0.22	0.10 ± 0.09	0.45 ± 0.17	
1	26	26	0.04*	0.52 ± 0.18	0.11*	0.55 ± 0.19	QC duplicate
2	26	44	0.06*	1.46 ± 0.37	0.23 ± 0.15	0.96 ± 0.28	
3	26	62	0.04*	0.64 ± 0.20	0.16 ± 0.11	0.58 ± 0.19	
4	26	80	0.05*	0.93 ± 0.28	0.10*	1.04 ± 0.30	
5	41	17	0.14*	1.72 ± 0.53	0.24*	0.50 ± 0.32	
6	41	35	0.09*	0.89 ± 0.33	0.30 ± 0.21	0.74 ± 0.30	
7	41	53	0.05*	1.17 ± 0.30	0.30 ± 0.16	1.25 ± 0.31	
8	41	71	0.06*	1.26 ± 0.35	0.26 ± 0.17	0.94 ± 0.29	
9	56	26	0.10 ± 0.13	1.62 ± 0.35	0.21 ± 0.12	1.15 ± 0.28	
9	56	26	0.04*	0.95 ± 0.24	0.07*	0.62 ± 0.19	QC duplicate
10	56	44	0.05 ± 0.08	1.77 ± 0.35	0.20 ± 0.12	1.18 ± 0.27	
11	56	62	0.05*	1.19 ± 0.30	0.14 ± 0.11	1.01 ± 0.27	
12	56	80	0.04*	1.66 ± 0.35	0.36 ± 0.16	1.43 ± 0.32	
13	71	35	0.04*	0.79 ± 0.23	0.10 ± 0.09	0.99 ± 0.26	
14	71	53	0.09 ± 0.08	1.13 ± 0.29	0.10 ± 0.09	0.83 ± 0.24	
15	71	71	0.05 ± 0.06	0.78 ± 0.24	0.13 ± 0.11	0.88 ± 0.27	
16	86	44	0.05 ± 0.06	1.24 ± 0.30	0.07*	1.10 ± 0.27	
17	86	62	0.10 ± 0.11	0.70 ± 0.21	0.11*	0.74 ± 0.21	
18	86	80	0.06*	1.00 ± 0.32	0.15 ± 0.13	0.87 ± 0.29	
19	101	35	0.06 ± 0.07	0.43 ± 0.18	0.11*	0.46 ± 0.19	
20	101	53	0.05 ± 0.06	1.11 ± 0.26	0.10*	0.78 ± 0.21	
21	101	71	0.06*	1.33 ± 0.35	0.22 ± 0.14	0.54 ± 0.21	
22	37	61	0.05*	0.62 ± 0.21	0.08*	0.52 ± 0.18	Waste handling exit

*Indicates result less than the minimum detectable activity of the analytical procedure.

Table 9. Uranium Concentrations in Surface Soil Samples from Survey Unit B

Location ID	Grid Coordinates		Uranium Concentration (pCi/g)				Comments
	North	East	U-232	U-233&234	U-235&236	U-238	
1	2	101	0.05*	1.29 ± 0.33	0.12*	1.22 ± 0.31	
2	4	59	0.04 ± 0.05	1.35 ± 0.27	0.13 ± 0.08	1.04 ± 0.23	
3	11	90	0.04*	1.49 ± 0.31	0.08 ± 0.07	1.02 ± 0.25	
4	12	69	0.05*	1.18 ± 0.30	0.17*	0.76 ± 0.23	
5	13	119	0.11 ± 0.09	1.63 ± 0.32	0.18 ± 0.21	1.07 ± 0.25	
6	14	11	0.09*	0.96 ± 0.38	0.17*	0.86 ± 0.36	
7	24	85	0.04*	1.41 ± 0.31	0.17*	1.05 ± 0.26	
8	32	113	0.05 ± 0.05	1.27 ± 0.30	0.17 ± 0.11	1.32 ± 0.31	
9	35	2	0.04*	1.54 ± 0.32	0.11 ± 0.08	1.15 ± 0.27	
10	36	106	0.05*	1.44 ± 0.34	0.17 ± 0.11	1.08 ± 0.28	
11	58	110	0.06 ± 0.07	1.53 ± 0.33	0.25 ± 0.13	1.43 ± 0.31	
12	65	85	0.06 ± 0.07	1.70 ± 0.42	0.14*	1.14 ± 0.33	
13	70	-2	0.04*	1.37 ± 0.31	0.08 ± 0.08	1.27 ± 0.30	
14	71	17	0.03*	1.22 ± 0.26	0.17 ± 0.10	0.97 ± 0.23	
15	72	106	0.06 ± 0.07	1.56 ± 0.35	0.12 ± 0.09	1.14 ± 0.29	
16	80	112	0.14 ± 0.15	1.78 ± 0.38	0.22 ± 0.13	1.43 ± 0.32	
17	90	17	0.07*	1.20 ± 0.38	0.16*	0.86 ± 0.30	
18	90	90	0.05*	1.19 ± 0.31	0.22 ± 0.13	1.29 ± 0.33	
19	102	25	0.05 ± 0.07	0.62 ± 0.21	0.09*	0.61 ± 0.20	
20	106	10	0.08 ± 0.10	1.21 ± 0.32	0.14 ± 0.11	0.92 ± 0.27	
21	107	81	0.14*	1.49 ± 0.60	0.24*	1.06 ± 0.49	
22	110	10	0.07 ± 0.07	1.49 ± 0.30	0.08*	1.07 ± 0.25	
23	115	110	0.14*	0.81 ± 0.41	0.27*	0.22*	

*Indicates result less than the minimum detectable activity of the analytical procedure.

Table 10. Uranium Concentrations in Surface Soil Samples from Survey Unit C

Location ID	Grid Coordinates		Uranium Concentration (pCi/g)				Comments
	North	East	U-232	U-233&234	U-235&236	U-238	
1	N/A	N/A	N/A	2.60 ± 0.45	0.29 ± 0.14	1.68 ± 0.34	
2	N/A	N/A	N/A	2.24 ± 0.43	0.29 ± 0.15	1.68 ±0.36	
3	N/A	N/A	N/A	1.20 ± 0.27	0.17 ± 0.10	1.01 ± 0.24	
4	N/A	N/A	N/A	1.98 ± 0.40	0.08 ± 0.08	1.17 ± 0.29	
5	N/A	N/A	N/A	1.10 ± 0.27	0.04*	0.96 ± 0.24	
6	N/A	N/A	N/A	1.09 ± 0.26	0.18 ± 0.11	1.06 ± 0.25	
7	N/A	N/A	N/A	0.96 ± 0.24	0.04*	0.95 ± 0.24	
8	N/A	N/A	N/A	1.40 ± 0.41	0.06*	1.15 ± 0.37	
9	N/A	N/A	N/A	1.54 ± 0.33	0.09*	1.03 ± 0.26	
10	N/A	N/A	N/A	1.42 ± 0.29	0.17 ± 0.01	1.17 ± 0.26	
11	N/A	N/A	N/A	1.47 ± 0.31	.014 ± 0.09	1.12 ± 0.26	
12	N/A	N/A	N/A	1.27 ± 0.32	0.15 ± 0.11	1.14 ±0.30	
13	N/A	N/A	N/A	1.28 ± 0.28	0.12 ± 0.09	1.37 ± 0.30	
14	N/A	N/A	N/A	1.08 ± 0.26	0.18 ± 0.11	1.00 ± 0.25	
15	N/A	N/A	N/A	0.84 ± 0.24	0.04*	0.78 ± 0.23	
16	N/A	N/A	N/A	1.71 ± 0.37	0.16*	1.58 ± 0.35	
17	N/A	N/A	N/A	1.50 ± 0.31	0.12 ± 0.09	1.10 ± 0.26	
18	N/A	N/A	N/A	2.09 ± 0.38	0.27 ± 0.13	1.74 ± 0.33	
1A Dup	N/A	N/A	N/A	15.00 ± 2.0	1.12 ± 0.32	3.17 ± 0.58	Pre-Remediation
REM1	N/A	N/A	0.04 ± 0.05	4.72 ± 0.69	0.48 ± 0.18	1.63 ± 0.33	Post- Remediation
REM2	N/A	N/A	0.05 ± 0.07	0.93 ± 0.25	0.21 ± 0.13	0.94 ± 0.26	Post- Remediation
REM3	N/A	N/A	0.09 ± 0.07	2.27 ± 0.42	0.37 ± 0.16	1.30 ± 0.29	Post- Remediation
REM4	N/A	N/A	0.01 ± 0.03	1.59 ± 0.33	0.25 ±0.13	0.84 ± 0.22	Post- Remediation

*Indicates result less than the minimum detectable activity of the analytical procedure.

Uranium concentrations in the survey samples were compared directly with the DSVs, without adjusting for background contributions. For this comparison, the lower of the values for U-233 and U-234 (i.e., 9.11 pCi/g) and for U-235 and U-236 (i.e., 8 pCi/g) were used. **Table 11**, **Table 12** and **Table 13** summarize the results of the comparisons. The maximum resulting SOF for Survey Unit A was 0.349; the maximum for Survey Unit B was 0.394; the maximum for Survey Unit C was 0.69.

All SOF values are well below the criterion of Unity (1.0), even considering (1) sample concentrations were not adjusted for reference background levels and (2) sample concentrations of U-233 plus U-234 and U-235 plus U-236 were compared to conservatively low DSV values.

Table 11. Comparison of Uranium Concentrations in Soil from Survey Unit A with Default Screening Values (DSVs)

Location ID	Grid Coordinates		U-232			U-233 plus U-234			U-235 plus U-236			U-238			Sum of Fractions
	North	East	Activity (pCi/g)	DSV (pCi/g)	Act./DSV	Activity (pCi/g)	DSV(pCi/g)	Act./DSV	Activity (pCi/g)	DSV (pCi/g)	Act./DSV	Activity (pCi/g)	DSV (pCi/g)	Act./DSV	
1	26	26	0.05	1.96	0.026	0.71	9.11	0.078	0.10	8	0.013	0.45	14	0.032	0.149
2	26	44	0.06	1.96	0.031	1.46	9.11	0.160	0.23	8	0.029	0.96	14	0.069	0.289
3	26	62	0.04	1.96	0.020	0.64	9.11	0.070	0.16	8	0.020	0.58	14	0.041	0.151
4	26	80	0.05	1.96	0.026	0.93	9.11	0.102	0.10	8	0.013	1.04	14	0.074	0.215
5	41	17	0.14	1.96	0.071	1.72	9.11	0.189	0.24	8	0.030	0.50	14	0.036	0.326
6	41	35	0.09	1.96	0.046	0.89	9.11	0.098	0.30	8	0.038	0.74	14	0.053	0.235
7	41	53	0.05	1.96	0.026	1.17	9.11	0.128	0.30	8	0.038	1.25	14	0.089	0.281
8	41	71	0.06	1.96	0.031	1.26	9.11	0.138	0.26	8	0.033	0.94	14	0.067	0.269
9	56	26	0.10	1.96	0.051	1.62	9.11	0.178	0.21	8	0.026	1.15	14	0.082	0.337
10	56	44	0.05	1.96	0.026	1.77	9.11	0.194	0.20	8	0.025	1.18	14	0.084	0.329
11	56	62	0.05	1.96	0.026	1.19	9.11	0.131	0.14	8	0.018	1.01	14	0.072	0.247
12	56	80	0.04	1.96	0.020	1.66	9.11	0.182	0.36	8	0.045	1.43	14	0.102	0.349
13	71	35	0.04	1.96	0.020	0.77	9.11	0.087	0.10	8	0.013	0.99	14	0.071	0.191
14	71	53	0.09	1.96	0.046	1.13	9.11	0.124	0.10	8	0.013	0.83	14	0.059	0.242
15	71	71	0.05	1.96	0.026	0.78	9.11	0,086	0.13	8	0.016	0.88	14	0.063	0.191
16	86	44	0.05	1.96	0.026	1.24	9.11	0.136	0.07	8	0.009	1.10	14	0.079	0.250
17	86	62	0.10	1.96	0.051	0.70	9.11	0.077	0.11	8	0.014	0.74	14	0.053	0.195
18	86	80	0.06	1.96	0.031	1.00	9.11	0.110	0.15	8	0.019	0.87	14	0.062	0.222
19	101	35	0.06	1.96	0.031	0.43	9.11	0.047	0.11	8	0.014	0.46	14	0.033	0.125
20	101	53	0.05	1.96	0.026	1.11	9.11	0.122	0.10	8	0.013	0.78	14	0.056	0.217
21	101	71	0.06	1.96	0.031	1.33	9.11	0.146	0.22	8	0.028	0.54	14	0.039	0.244
22	37	61	0.05	1.96	0.026	0.62	9.11	0.075	0.08	8	0.010	0.52	14	0.037	0.148
												Minimum			0.13
												Maximum			0.35
												Mean			0.24
												Std Deviation			0.06

Table 12. Comparison of Uranium Concentrations in Soil from Survey Unit B with Default Screening Values (DSVs)

Location ID	Grid Coordinates		U-232			U-233 plus U-234			U-235 plus U-236			U-238			Sum of Fractions
	North	East	Activity (pCi/g)	DSV (pCi/g)	Act./DSV	Activity (pCi/g)	DSV (pCi/g)	Act./DSV	Activity (pCi/g)	DSV (pCi/g)	Act./DSV	Activity (pCi/g)	DSV (pCi/g)	Act./DSV	
1	2	101	0.05	1.96	0.026	1.29	9.11	0.142	0.12	8	0.015	1.22	14	0.087	0.248
2	4	59	0.04	1.96	0.020	1.35	9.11	0.148	0.13	8	0.016	1.04	14	0.074	0.258
3	11	90	0.04	1.96	0.020	1.49	9.11	0.164	0.08	8	0.010	1.02	14	0.073	0.267
4	12	69	0.05	1.96	0.026	1.18	9.11	0.130	0.17	8	0.021	0.76	14	0.054	0.236
5	13	119	0.11	1.96	0.056	1.63	9.11	0.179	0.18	8	0.023	1.07	14	0.076	0.334
6	14	11	0.09	1.96	0.046	0.96	9.11	0.105	0.17	8	0.021	0.86	14	0.061	0.233
7	24	85	0.04	1.96	0.020	1.41	9.11	0.155	0.17	8	0.021	1.05	14	0.075	0.271
8	32	113	0.05	1.96	0.026	1.27	9.11	0.139	0.17	8	0.021	1.32	14	0.094	0.280
9	35	2	0.04	1.96	0.020	1.54	9.11	0.169	0.11	8	0.014	1.15	14	0.082	0.285
10	36	106	0.05	1.96	0.026	1.44	9.11	0.158	0.17	8	0.021	1.08	14	0.077	0.282
11	58	110	0.06	1.96	0.031	1.53	9.11	0.168	0.25	8	0.031	1.43	14	0.100	0.330
12	65	85	0.06	1.96	0.031	1.70	9.11	0.187	0.14	8	0.018	1.14	14	0.081	0.317
13	70	-2	0.04	1.96	0.020	1.37	9.11	0.150	0.08	8	0.010	1.27	14	0.091	0.271
14	71	17	0.03	1.96	0.015	1.22	9.11	0.134	0.17	8	0.021	0.97	14	0.069	0.239
15	72	106	0.06	1.96	0.032	1.56	9.11	0.171	0.12	8	0.015	1.14	14	0.081	0.297
16	80	112	0.14	1.96	0.071	1.78	9.11	0.195	0.22	8	0.028	1.43	14	0.100	0.394
17	90	17	0.07	1.96	0.036	1.20	9.11	0.132	0.16	8	0.020	0.86	14	0.061	0.245
18	90	90	0.05	1.96	0.026	1.19	9.11	0.131	0.22	8	0.028	1.29	14	0.092	0.277
19	102	25	0.05	1.96	0.026	0.62	9.11	0.068	0.09	8	0.011	0.61	14	0.044	0.144
20	106	10	0.08	1.96	0.041	1.21	9.11	0.133	0.14	8	0.018	0.92	14	0.066	0.258
21	107	81	0.14	1.96	0.071	1.49	9.11	0.164	0.24	8	0.030	1.06	14	0.076	0.341
22	110	55	0.07	1.96	0.036	1.49	9.11	0.164	0.08	8	0.010	1.07	14	0.076	0.286
23	115	110	0.14	1.96	0.071	0.81	9.11	0.089	0.27	8	0.034	0.22	14	0.016	0.210
												Minimum			0.14
												Maximum			0.39
												Mean			0.27
												Std Deviation			0.05

Table 13. Comparison of Uranium Concentrations in Soil from Survey Unit C with Default Screening Values (DSVs) [1]

Location ID	Comments	U-232			U-233 + U-234			U-235 + U-236			U-238			Sum of Fractions
		Activity [2] (pCi/g)	DSV (pCi/g)	Act./DSV	Activity (pCi/g)	DSV(pCi/g)	Act./DSV	Activity (pCi/g)	DSV (pCi/g)	Act./DSV	Activity (pCi/g)	DSV (pCi/g)	Act./DSV	
1		N/A	1.96	N/A	2.60	9.11	0.29	0.29	8	0.04	1.68	14	0.12	0.44
2		N/A	1.96	N/A	2.24	9.11	0.25	0.29	8	0.04	1.68	14	0.12	0.40
3		N/A	1.96	N/A	1.20	9.11	0.13	0.17	8	0.02	1.01	14	0.07	0.23
4		N/A	1.96	N/A	1.98	9.11	0.22	0.08	8	0.01	1.17	14	0.08	0.31
5		N/A	1.96	N/A	1.10	9.11	0.12	0.04*	8	0.01	0.96	14	0.07	0.19
6		N/A	1.96	N/A	1.09	9.11	0.12	0.18	8	0.02	1.06	14	0.08	0.22
7		N/A	1.96	N/A	0.96	9.11	0.11	0.04*	8	0.01	0.95	14	0.07	0.18
8		N/A	1.96	N/A	1.40	9.11	0.15	0.06*	8	0.01	1.15	14	0.08	0.24
9		N/A	1.96	N/A	1.54	9.11	0.17	0.09*	8	0.01	1.03	14	0.07	0.25
10		N/A	1.96	N/A	1.42	9.11	0.16	0.17	8	0.02	1.17	14	0.08	0.26
11		N/A	1.96	N/A	1.47	9.11	0.16	.014	8	0.00	1.12	14	0.08	0.24
12		N/A	1.96	N/A	1.27	9.11	0.14	0.15	8	0.02	1.14	14	0.08	0.24
13		N/A	1.96	N/A	1.28	9.11	0.14	0.12	8	0.02	1.37	14	0.10	0.25
14		N/A	1.96	N/A	1.08	9.11	0.12	0.18	8	0.02	1.00	14	0.07	0.21
15		N/A	1.96	N/A	0.84	9.11	0.09	0.04*	8	0.01	0.78	14	0.06	0.15
16		N/A	1.96	N/A	1.71	9.11	0.19	0.16*	8	0.02	1.58	14	0.11	0.32
17		N/A	1.96	N/A	1.50	9.11	0.16	0.12	8	0.02	1.10	14	0.08	0.26
18		N/A	1.96	N/A	2.09	9.11	0.23	0.27	8	0.03	1.74	14	0.12	0.39
1A Dup [2]	Pre-Remediation	N/A	1.96	N/A	15.00	9.11	1.65	1.12	8	0.14	3.17	14	0.23	2.01
REM1	Post-Remediation	0.038	1.96	0.02	4.72	9.11	0.52	0.48	8	0.06	1.63	14	0.12	0.69
REM2	Post-Remediation	0.054	1.96	0.03	0.93	9.11	0.10	0.21	8	0.03	0.94	14	0.07	0.20
REM3	Post-Remediation	0.085	1.96	0.04	2.27	9.11	0.25	0.37	8	0.05	1.30	14	0.09	0.39
REM4	Post-Remediation	0.013	1.96	0.01	1.59	9.11	0.17	0.25	8	0.03	0.84	14	0.06	0.27
											Minimum			0.15
											Maximum			0.69
											Mean			0.29
											Std Deviation			0.12

NOTES:

1. Soil samples initially obtained from Survey Unit C were not analyzed for U-232.
2. Sample 1A Duplicate excluded from the statistical summary.

9.4 Data Validation

Standard survey procedures were implemented by qualified radiation technicians in accordance with an approved plan to meet MARSSIM guidance. The number of samples obtained for the soil evaluation exceeded that recommended by MARSSIM. Two samples were duplicated and similar analyses were performed on each sample by Eberline Services. Results of these analyses were compared by the replicate error ratio (RER) as follows and are summarized in **Table 14**.

$RER = (C_{smp}-C_{dup})/(U_{smp}^2 + U_{dup}^2)^{0.5}$

Where:

C_{smp} = activity of the original sample
C_{dup} = activity of duplicate sample
U_{smp} = 1 σ uncertainty of the original sample
U_{dup} = 1 σ uncertainty of the duplicate sample

Table 14. Comparison of Analyses of Field Duplicate Samples

Survey Unit A Location ID	Sample Coordinates	Concentration (pCi/g + 1σ)			
		U-232	U-233 plus 234	U-235 plus 236	U-238
1	26N, 26E	<0.05	0.71 ± 0.11	0.10 ± 0.05	0.45 ± 0.09
1	26N, 26Edup	<0.04	0.52 ± 0.09	<0.11	0.55 ± 0.09
	RER	N/A*	1.3	N/A*	0.8
9	56N, 26E	0.10 ± 0.13	1.62 ± 0.18	0.21 ± 0.06	1.15 ± 0.14
9	56N, 26Edup	<0.04	0.95 ± 0.12	<0.07	0.62 ± 0.09
	RER	N/A*	3.1	N/A*	3.2

* Not applicable due to levels less than minimal detectable level of procedure.

A resulting value of 3 (or less) is considered acceptable for analyses of field duplicate samples. The results of this comparison are slightly higher than 3 for U-233 plus 234 and U-238 analyses on the sample from coordinate 56N, 26E; for both of these analyses, the level in the original sample was greater than that reported for the duplicate. Because all analyses indicated concentrations well below the acceptable criteria and the associated uncertainties are relatively large, the elevated RER values are not sufficient reason to not accept the analytical results for the original samples. Data therefore satisfy the project representativeness, completeness, and comparability requirements.

10.0 CONCLUSION

A final survey of the former BLEU site was performed following removal of contaminated facilities and demolition of structures. This survey included walkover gamma scans, direct measurements of gamma radiation levels, and sampling and analysis of surface soil. No locations of potential residual surface soil contamination were identified by the scans. Because all samples satisfy the Unity criterion, residual uranium in site soil is negligible and the site meets the requirements for unrestricted release for future uses.

APPENDIX A – DENUKE PROCEDURES APPLICABLE TO THE FINAL SURVEY OF THE BLEU SITE

DENUKE-QA-100.100	Quality Assurance for Radiological Survey Activities
DENUKE-RP-105	Instrumentation and Measurement: General
DENUKE-RP-105.100	Instrumentation: Calibration
DENUKE-RP-105.200	Instrumentation: Setup and Performance Checks
DENUKE-RP-105.300	Instrument Selection and Use
DENUKE-RP-105.304	Operation of Ludlum Model 2221 Ratemeter/Scaler
DENUKE-RP-105.308	Operation of Ludlum Model 44-10 Gamma Scintillation Detector
DENUKE-RP-105.302	Operation of Bicron Micro Rem Meter
DENUKE-RP-105.318	Operation of Gamma Scintillation Detectors: General
DENUKE-RP-105.320	Checking Satellite Availability for GPS Work
DENUKE-RP-105.328	Data Processing for GPS Data
DENUKE-RP-105.346	Perform QC Check of the Trimble GeoExplorer 2005 Series Model GeoXH
DENUKE-RP-105.355	Field Operation of the Trimble GeoExplorer 2008 Series Model GeoXH
DENUKE-RP-105.400	Calculating Detection Sensitivity
DENUKE-RP-105.500	Radiological Survey Activities

APPENDIX B – DETECTION SENSITIVITIES OF GAMMA SCANNING

The methods for calculating scanning detection sensitivities are presented in MARSSIM (Ref 1) and NUREG-1507 (Ref 2). Detector parameters used in these calculations are typical background count rate, instrument field of view, and instrument response to the potential contaminants of concern. A Ludlum Model 44-10, 2-in diameter x 2-in thick sodium iodide (NaI) detector, coupled with a Ludlum Model 2221 scaler/ratemeter, are used for the scans. An open window is used to accept all photon energies above the input threshold of 10 mV. The detector is suspended within 5 cm of the soil surface and passed in a 0.75- to 1-m wide serpentine pattern over the surface while advancing at a rate of approximately 0.5 m/second. The audible signal from the instrument is monitored by the surveyor, and detectable changes in count rate are noted. If an increase in count rate is detected, the immediate area is resurveyed at a reduced speed to confirm the change and, if applicable, to identify the boundary of the impacted area.

Equation 6-6 of NUREG-1507 provides the following relationship for estimating scan sensitivity:

$$MDCR = d' [BKGD*i/60]1/2 * 60/i]$$

The minimum detectable count rate (MDCR) is a function of the background rate (BKGD) and the time in seconds (i) that the detector is within close proximity to the source of the gamma photons; for the selected survey technique, that time interval is approximately 2 seconds. A high probability (95%) of true detection is the objective, and the survey is willing to accept a high probability of false-positive detections (60%) with resulting investigations. The value of d' (1.38) is thus selected from Table 6.1 in NUREG-1507. The nominal site background is 8,000 cpm.

The resulting MDCR value is 676 cpm.

The detectable count rate is converted to a radionuclide concentration by use of exposure rate factors (μR/h/pCi/g) from the Microshield computer code for a uniform concentration in a 50 cm × 50 cm × 15 cm thick slab of soil (density of 1.5 g/cm^3) and detector response factors (cpm/μR/h). To account for less than ideal survey performance, a surveyor efficiency factor (p) of (0.5)1/2 is also incorporated into the final calculation as follows:

$$\text{Scan Sensitivity} = \frac{\text{MDCR}}{(0.5)^{1/2} * (\mu R/h/pCi/g)\ (cpm/\mu R/h)}$$

The resulting scan sensitivity values are as follows:

U-232	1.7 pCi/g
U-233	Not detectable; negligible photon emissions
U-234	Not detectable; negligible photon emissions
U-235	7.2 pCi/g
U-236	Not detectable; negligible photon emissions
U-238	26 pCi/g

References

1. NUREG-1575, Rev 1, "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)," U.S. Nuclear Regulatory Commission, 2000

2. NUREG-1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions," U.S. Nuclear Regulatory Commission, 1998

APPENDIX C – RESULTS OF SURVEYS OF THE BLEU FACILITY STORM DRAIN SYSTEM

July 14, 2017

Results of Surveys of the BLEU Facility Storm Drain System

The storm drain system for the BLEU site was surveyed to determine residual activity levels and to compare those levels with the following Project criteria:

Direct alpha	500 dpm/100 cm^2
Direct beta	5000 dpm/100 cm^2
Removable alpha	100 dpm/100 cm^2
Removable beta	200 dpm/100 cm^2

The BLEU site storm drain system collected precipitation runoff from the site and directed it offsite, where it was combined with storm drainage from other NFS facilities. The locations of the system components, including catch basins, manholes, and piping, are shown on the attached drawing. There were no access points to the system from inside BLEU process facilities, and an effective contamination control program was implemented by NFS during the BLEU Facility operations. Records do not indicate any accidental or intentional releases of potentially contaminated liquids to the storm drainage system. Although the BLEU site drainage itself was not monitored before leaving the site, NFS sampled and analyzed the combined facility storm drainage to assure concentrations were well within the NRC limits prior to releasing it to the environment. Based on this information, the potential for residual uranium activity in the system is considered very low.

Current plans are to leave this drain system in place to provide future control of storm runoff. The system components must therefore be demonstrated to satisfy the Project Surveys were performed in accordance with the BLEU Project "Release Survey Plan for Materials and Equipment from the Blended Low Enriched Uranium Facilities at the Nuclear Fuel Services Site" (ATL-BLEU-RP-134.1, Rev 0). Manholes and catch basins were accessed. Alpha scans were performed; direct alpha and removable alpha and beta measurements were obtained on the internal surfaces. Due to the limited space within the survey locations, access with a dual scintillator was not possible; beta scans and direct beta measurements were therefore not performed.

A Ludlum Model 43-65 scintillation detector with handheld Model 2221 scaler/ratemeter was used for scanning and direct measurements. . Smears were counted on a Ludlum Model 2929 scaler with an alpha/beta scintillation detector.

Survey Results

The field survey map and record forms are provided as an attachment to this report. No elevated locations of alpha activity were identified by the scans. With few exceptions, direct alpha and removable alpha and beta activity measurements were less than the detection

July 14, 2017

sensitivities of the survey techniques and, consequently, well below the Project release criteria. Because all measurements indicated no residual contamination in excess of the Project criteria, the storm drain system can remain in place for future use without radiological restrictions.

Jim Berger, CHP
ATL Radiation Programs Manager

Attachments

Advanced Technologies and Laboratories International, Inc.

SURFACE ACTIVITY MEASUREMENT FORM

Project/Site: BLEU FACILITY/NFS Survey Location: STORM DRAINS

Survey Number: BLEU-SY1066 Survey Class Type: INVESTIGATIVE

Instrument Data					
	Alpha			Beta	
Cal Due: ~~4/14/18~~ 9-11-2017	Meter	Model	2221	Meter	Model
		Serial #	183997		Serial #
	Detector	Model	43-65	Detector	Model
		Serial #	PR165982		Serial #
	2-pi Efficiency		40.43%	2-pi Efficiency	
	Surface Correction Factor		25%	Surface Correction Factor	
	Total Efficiency		10.108%	Total Efficiency	
	Detector Area (cm^2)		50	Detector Area (cm^2)	
	Background (cpm)		0	Background (cpm)	

Date	Time
5/10/2017	1300

Sample Count Time (min)	1
Bkg. Count Time (min)	1
Alpha MDA (dpm/100cm²)	59.4
Beta MDA (dpm/100cm²)	

		Measurements								
		Scan Results		Alpha			Beta			
Location Description	Grid ID	Alpha	Beta	Gross Counts	Net (cpm)	*Net (dpm/100 cm^2)	Gross Counts	Net (cpm)	*Net (dpm/100 cm^2)	Smear / Location #
Number 3	N/A	ND	N/A				N			7,8
FLOOR	N/A	ND	N/A	1	1	19.8				
WALL	N/A	ND	N/A	2	2	39.6				
WALL	N/A	ND	N/A	2	2	39.6				
PIPE	N/A	ND	N/A	1	1	19.8				
FLOOR	N/A	ND	N/A	4	4	79.1				
TOP	N/A	ND	N/A	5	5	98.9				
Number 7	N/A	ND	N/A							9,10
I/S PIPE	N/A	ND	N/A	0	0	0.0				
I/S PIPE	N/A	ND	N/A	0	0	0.0				
WALL	N/A	ND	N/A	4	4	79.1				
WALL	N/A	ND	N/A	6	6	118.7				
WALL	N/A	ND	N/A	1	1	19.8				
TOP	N/A	ND	N/A	6	6	118.7				
Number 4	N/A	ND	N/A							5,6
I/S PIPE	N/A	ND	N/A	1	1	19.8				
I/S PIPE	N/A	ND	N/A	0	0	0.0				
FLOOR	N/A	ND	N/A	2	2	39.6				
WALL	N/A	ND	N/A	4	4	79.1				
FLOOR	N/A	ND	N/A	3	3	59.4				
TOP	N/A	ND	N/A	9	9	178.1				
Number 5	N/A	ND	N/A							13,14
I/S PIPE	N/A	ND	N/A	1	1	19.8				
FLOOR	N/A	ND	N/A	3	3	59.4				
WALL	N/A	ND	N/A	1	1	19.8				
WALL	N/A	ND	N/A	3	3	59.4				
I/S PIPE	N/A	ND	N/A	0	0	0.0				
TOP	N/A	ND	N/A	16	16	316.6				
STORM DRAIN INFRONT OF 54	N/A	ND	N/A							
I/S PIPE	N/A	ND	N/A	0	0	0.0				
FLOOR	N/A	ND	N/A	1	1	19.8				
FLOOR	N/A	ND	N/A	3	3	59.4				
WALL	N/A	ND	N/A	3	3	59.4				
I/S PIPE	N/A	ND	N/A	2	2	39.6				
TOP	N/A	ND	N/A	5	5	98.9				
N/A	N/A	N/A	N/A	N/A	N/A	N/A			A	

Measurement Notes: * Values indicated in Bold exceed 500 dpm/100cm^2 alpha and/or 5000 dpm/100cm^2 beta

ND- Denotes No increased activity found during scan E - Denotes an Elevated Scan reading N/A-Non Applicable

Surveyor(s) (Print / Sign): Eric Glenn Date: 7-14-17

Reviewer (Print / Sign): J Berger Date: 7/14/17

Advanced Technologies and Laboratories International, Inc.

SURFACE ACTIVITY MEASUREMENT FORM

Project/Site: BLEU FACILITY/NFS Survey Location: STORM DRAINS

Survey Number: BLEU-SY1066 Survey Class Type: INVESTIGATIVE

Instrument Data							Date	Time
Alpha			Beta				5/10/2017	1300
Cal Due: [redacted]	Meter	Model	2221	Meter	Model			
9-11-2017		Serial #	183997		Serial #			
	Detector	Model	43-65	Detector	Model			
		Serial #	PR165982		Serial #		Sample Count Time (min)	1
2-pi Efficiency		40.43%	2-pi Efficiency				Bkg. Count Time (min)	1
Surface Correction Factor		25%	Surface Correction Factor					
Total Efficiency		10.108%	Total Efficiency		0.000%			
Detector Area (cm^2)		50	Detector Area (cm^2)				Alpha MDA (dpm/100cm^2)	59.4
Background (cpm)		0	Background (cpm)				Beta MDA (dpm/100cm^2)	

		Measurements								
		Scan Results		Alpha			Beta			
Location Description	Grid ID	Alpha	Beta	Gross Counts	Net (cpm)	*Net (dpm/100 cm^2)	Gross Counts	Net (cpm)	*Net (dpm/100 cm^2)	Smear / Location #
Number 2	N/A	N/A	N/A				N			3,4
I/S PIPE	N/A	ND	N/A	0	0	0.0				
I/S PIPE	N/A	ND	N/A	5	5	98.9				
FLOOR	N/A	ND	N/A	1	1	19.8				
WALL	N/A	ND	N/A	0	0	0.0				
WALL	N/A	ND	N/A	1	1	19.8				
TOP	N/A	ND	N/A	4	4	79.1				
Number 1	N/A	N/A	N/A							1,2
I/S PIPE	N/A	ND	N/A	0	0	0.0				
I/S PIPE	N/A	ND	N/A	2	2	39.6				
FLOOR	N/A	ND	N/A	2	2	39.6				
WALL	N/A	ND	N/A	1	1	19.8				
WALL	N/A	ND	N/A	1	1	19.8				
TOP	N/A	ND	N/A	3	3	59.4				
Number 6	N/A	N/A	N/A							11,12
I/S PIPE	N/A	ND	N/A	0	0	0.0				
FLOOR	N/A	ND	N/A	0	0	0.0				
FLOOR	N/A	ND	N/A	2	2	39.6				
WALL	N/A	ND	N/A	5	5	98.9				
WALL	N/A	ND	N/A	0	0	0.0				
TOP	N/A	ND	N/A	6	6	118.7			A	
N										
										A

Measurement Notes: * Values indicated in Bold exceed 500 dpm/100cm^2 alpha and/or 5000 dpm/100cm^2 beta

ND- Denotes No increased activity found during scan E - Denotes an Elevated Scan reading N/A-Non Applicable

Surveyor(s) (Print / Sign): Eric Glenn Date: 7-14-17

Reviewer (Print / Sign): J. C. Bagan Date: 7/14/17

FS-3A, Rev. 0

Advanced Technologies and Laboratories International, Inc.

SMEAR / FILTER ANALYSIS RECORD FORM

Project/Site: BLEU FACILITY/NFS **Survey Location:** Storm Drains

Survey Number: BLEU-SY1066 **Survey Class Type:** Investigative

Instrument Data							
Alpha				Beta			
Meter	Model	2929		Meter	Model	2929	
	Serial #	160026			Serial #	160026	
Detector	Model	43-10-1		Detector	Model	43-10-1	
	Serial #	PR164051			Serial #	PR164051	
4-pi Efficiency		29.15%		4-pi Efficiency		24.62%	
Background (cpm)		0		Background (cpm)		67	

Date	Time
7/13/2017	0800
Cal Due:	3/8/2018
Sample Count Time (min)	1

Alpha MDA (dpm/ 100 cm²)	10.3
Beta MDA (dpm/ 100 cm²)	166.8

Smear / Filter / Location #	Alpha Time (min)	Alpha Counts	Alpha Net (cpm)	Alpha Net (dpm)*	Beta Time (min)	Beta Counts	Beta Net (cpm)	Beta Net (dpm)*	Comments
1	1	1	1	3.4	1	60	-7	-28.4	
2	1	0	0	0.0	1	57	-10	-40.6	
3	1	0	0	0.0	1	54	-13	-52.8	
4	1	0	0	0.0	1	68	1	4.1	
5	1	0	0	0.0	1	65	-2	-8.1	
6	1	0	0	0.0	1	72	5	20.3	
7	1	2	2	6.9	1	65	-2	-8.1	
8	1	0	0	0.0	1	65	-2	-8.1	
9	1	1	1	3.4	1	59	-8	-32.5	
10	1	1	1	3.4	1	62	-5	-20.3	
11	1	0	0	0.0	1	54	-13	-52.8	
12	1	1	1	3.4	1	70	3	12.2	
13	1	0	0	0.0	1	68	1	4.1	
14	1	2	2	6.9	1	55	-12	-48.7	
N									
								A	

Notes: * Values indicated in Bold exceed 100 dpm/100cm² alpha &/or 200 dpm/100cm² beta. N/A-Non Applicable

All smears represent a 100 cm2 surface area.

Surveyor (Print / Sign): Erik Hern [signature] Date: 7-14-17

Reviewer (Print / Sign): [signature] Date: 7/14/17

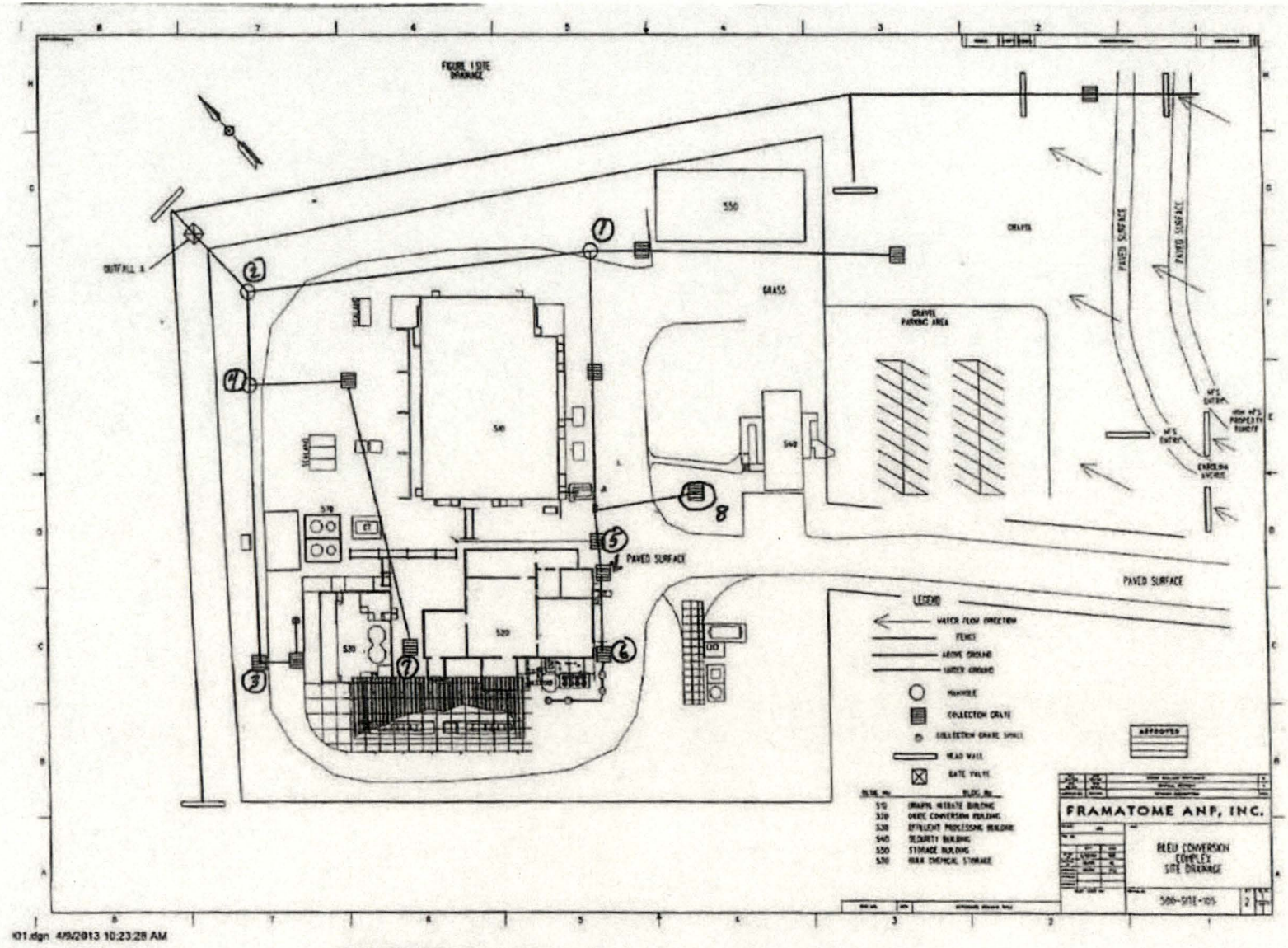


Figure 1 Storm Drainage System Showing Investigative Survey Locations