
Final Status Survey Report Breckenridge Disposal Site Survey Package – SU2

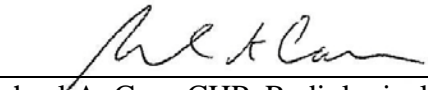
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Project No. 313111**Revision 0**

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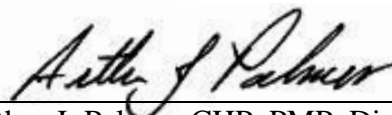


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ABBREVIATIONS and ACRONYMS

Ac	Actinium
AF	area factor
BDS	Breckenridge Disposal Site
bgs	below grade surface
cpm	counts per minute
CWA	contaminated waste area
DCGL	derived concentration guideline level
EMC	elevated measurement comparison
FSS	Final Status Survey
FSSR	Final Status Survey Report
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual (NUREG-1575)
MDA	minimum detectable activity
MDC	minimum detectable concentration
PHP	project health physicist
QA	quality assurance
QC	quality control
Ra	Radium
RE	radiological engineer
RPD	relative percent difference
SOF	sum of fractions
SU	survey unit
Th	Thorium
TEDE	Total Effective Dose Equivalent
U	Uranium

1.0 INTRODUCTION

This Final Status Survey Report (FSSR) data package provides a complete and concise record of the radiological status of Survey Unit (SU) 2 of the Breckenridge Disposal Site (BDS) prior to completion of backfilling activities. The Final Status Survey (FSS) of SU2 incorporated a variety of on-site radiological surveys and measurement techniques as well as off-site laboratory analysis of soil samples for quality control. EnergySolutions used the guidance as provided in NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)* in performing the Final Status Survey(s).

2.0 RELEASE CRITERIA

A summary of the release criteria as applied at the Breckenridge disposal site is provided in the following sections. The detailed development of these release criteria is provided in EnergySolutions document CS-313111-001, *Re-Evaluation of Breckenridge DCGLs, Gamma Scan Sensitivity, Gamma Scan Action Levels and Development of Area Factors*.

2.1 Derived Concentration Guideline Levels

With the recent identification of elevated Th-230 as compared to U-238 and Th-232, the 2006 derived concentration guideline levels (DCGLs) as previously developed are no longer adequate for demonstrating compliance to the total effective dose equivalent (TEDE) limit of 25 millirem per year (mrem/yr). These DCGLs were re-evaluated using RESRAD models that independently determined the DCGLs for each radionuclide, or decay chain, corresponding to 25 mrem/yr as applicable to the conditions as found at the remediation site. As summarized in CS-313111-001, since Th-230 was identified not to be in equilibrium as originally assumed, DCGLs were developed for the following decay chains to most closely model the conditions at the Breckenridge Site.

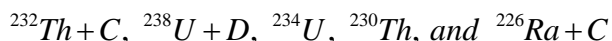


Table 2-1, below, provides the re-evaluated DCGLs for use with the unity (sum of fractions) rule for demonstrating site compliance with the dose based release criteria.

Table 2-1 Re-Evaluated DCGLs

Radionuclide	DCGL (pCi/g)	
	Surface	Subsurface
Th-232+C	5.0	65.9
U-238+D	442.4	8,658
U-234	2,729	6,113
Th-230	276.9	97.9
Ra-226+C	6.2	51.2

2.2 Unity Rule

The unity rule, or sum of fractions, is used to demonstrate compliance to the DCGLs for mixtures of radionuclides using the following equation. Note that U-238 is used as a surrogate for U-234 with a demonstrated 1:1 ratio based upon off-site alpha spec analyses (i.e., secular equilibrium).

$$SOF = \frac{C_{Th-232}}{DCGL_{Th-232+C}} + \frac{C_{U-238}}{DCGL_{U-238+D}} + \frac{C_{U-238}}{DCGL_{U-234}} + \frac{C_{Th-230}}{DCGL_{Th-230}} + \frac{C_{Ra-226}}{DCGL_{Ra-226+C}}$$

When measured by alpha spec analysis, the actual Th-230 activity will be used in the unity equation; otherwise, the concentration of Th-232 is used as a surrogate for Th-230 using the ratio of 9.8:1 for Th-230 to Th-232 activity as documented in EnergySolutions document CS-313111-001, *Re-Evaluation of Breckenridge DCGLs, Gamma Scan Sensitivity, Gamma Scan Action Levels and Development of Area Factors*. This activity ratio is based upon a statistical evaluation of off-site alpha spec analytical data. For simplicity, instead of modifying the Th-232+C DCGL, the Th-230 to Th-232 ratio and Th-232 concentration will be inserted into the Th-230 term above. The revised Th-230 term to be used in the unity equation is illustrated below.

$$\frac{C_{Th-230}}{DCGL_{Th-230}} = \frac{9.8 \cdot C_{Th-232}}{DCGL_{Th-230}}$$

2.3 Scan Sensitivity

To ensure adequate scanning sensitivities for the instrument utilized, it can be shown that the minimum detectable concentrations (MDCs) for open land scanning as provided in NUREG-1507 Table 6.4 are adequately sensitive for every radionuclide listed in Table 2-1 except for Th-230. To account for this lack of scan sensitivity for Th-230, Th-232 will again be used as a surrogate for Th-230 as discussed above. In order to account for the Th-230 activity, a modified Th-232 DCGL was calculated using Equation I-14 of MARSSIM (NUREG-1575) as follows:

$$DCGL_{Th-232_{Mod}} = \frac{1}{\frac{1}{DCGL_{Th-232}} + \frac{R_{Th-230:Th-232}}{DCGL_{Th-230}}}$$

Using the established 9.8:1 activity ratio between Th-230 and Th-232, the modified Th-232 DCGL was calculated to be 4.2 pCi/g and 8.7 pCi/g for Surface and Subsurface soils, respectively. The Th-232 scan MDC of 1.8 pCi/g is less than both modified DCGLs as determined; therefore, adequate scan sensitivity has been demonstrated using the re-evaluated DCGLs with Th-232 accounting for the dose from Th-230.

In addition, it has also been demonstrated through dose modeling, following the guidance of NUREG-1507 and as presented in EnergySolutions document CS-313111-001, *Re-Evaluation of Breckenridge DCGLs, Gamma Scan Sensitivity*,

Gamma Scan Action Levels and Development of Area Factors., that the scanning sensitivity was also adequate for the survey and sampling design to ensure that the area meets the release criteria and that no areas of elevated activity would be missed.

2.4 Area Factors

Sections 2.5.1.1 and 5.5.2.4 of MARSSIM addresses the concern of small areas of elevated activity in the survey unit. A simple comparison to an investigation level (DCGL_{EMC}) is used to assess the impact of potential elevated areas. The DCGL_{EMC} is the DCGL modified by an area factor (AF) to account for the dose from the small area of the elevated activity. The AFs for the radionuclides of concern are provided in Table 2-2.

Table 2-2 Area Factors

Radionuclide	Contaminated Zone Area (m ²)									
	3,800	3,000	1,000	600	300	100	30	10	3	1
Surface										
Th-232+C	1.0	1.0	1.0	--	1.2	1.3	1.7	2.5	5.3	12.4
U-238+D	1.0	1.0	1.1	--	1.2	1.4	1.8	2.6	5.4	12.4
U-234	1.0	1.1	1.2	--	3.8	9.8	23.6	44.0	82.7	130
Th-230	1.0	1.0	1.1	--	1.3	1.6	2.2	3.5	7.4	17.0
Ra-226+C	1.0	1.0	1.0	--	1.3	1.5	1.9	2.8	6.0	14.1
Subsurface										
Th-232+C	--	--	--	1.0	1.9	4.5	8.7	12.9	27.3	54.9
U-238+D	--	--	--	1.0	2.0	5.7	16.3	36.0	38.8	38.8
U-234	--	--	--	1.0	2.0	5.9	18.6	49.0	143	367
Th-230	--	--	--	1.0	2.0	5.6	15.5	32.9	81.6	179
Ra-226+C	--	--	--	1.0	2.0	5.6	15.6	33.1	82.1	181

3.0 FINAL STATUS SURVEY DESIGN

The FSS design was based upon the survey protocols as outlined in *EnergySolutions* document CS-OP-PN-042, *Remedial Work Plan, Waste Excavation and Site Restoration for the Breckenridge Disposal Site* in accordance with the regulatory guidance as provided in NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*. A summary of these survey protocols as applies to Survey Unit 2 is provided in the following sections:

3.1 Survey Unit and Classification

Based upon the size and configuration of the site, the site was delineated into 5 separate survey units, SU1, SU2, SU3, SU4 and the “Clean” overburden. This data package provides the summary for Survey Unit 2.

SU2 is located at the center of the site starting at the northern edge of SU3 extending to slightly north of contaminated waste areas (CWAs) 1 and 8 and the central grouping of trees. The survey unit is 1,644 square meters in size and encompasses CWA-1, CWA-2, the northern tip of CWA-3, CWA-8, CWA-A, CWA-B and CWA-C. Figure 3-1 provides the location of SU2.

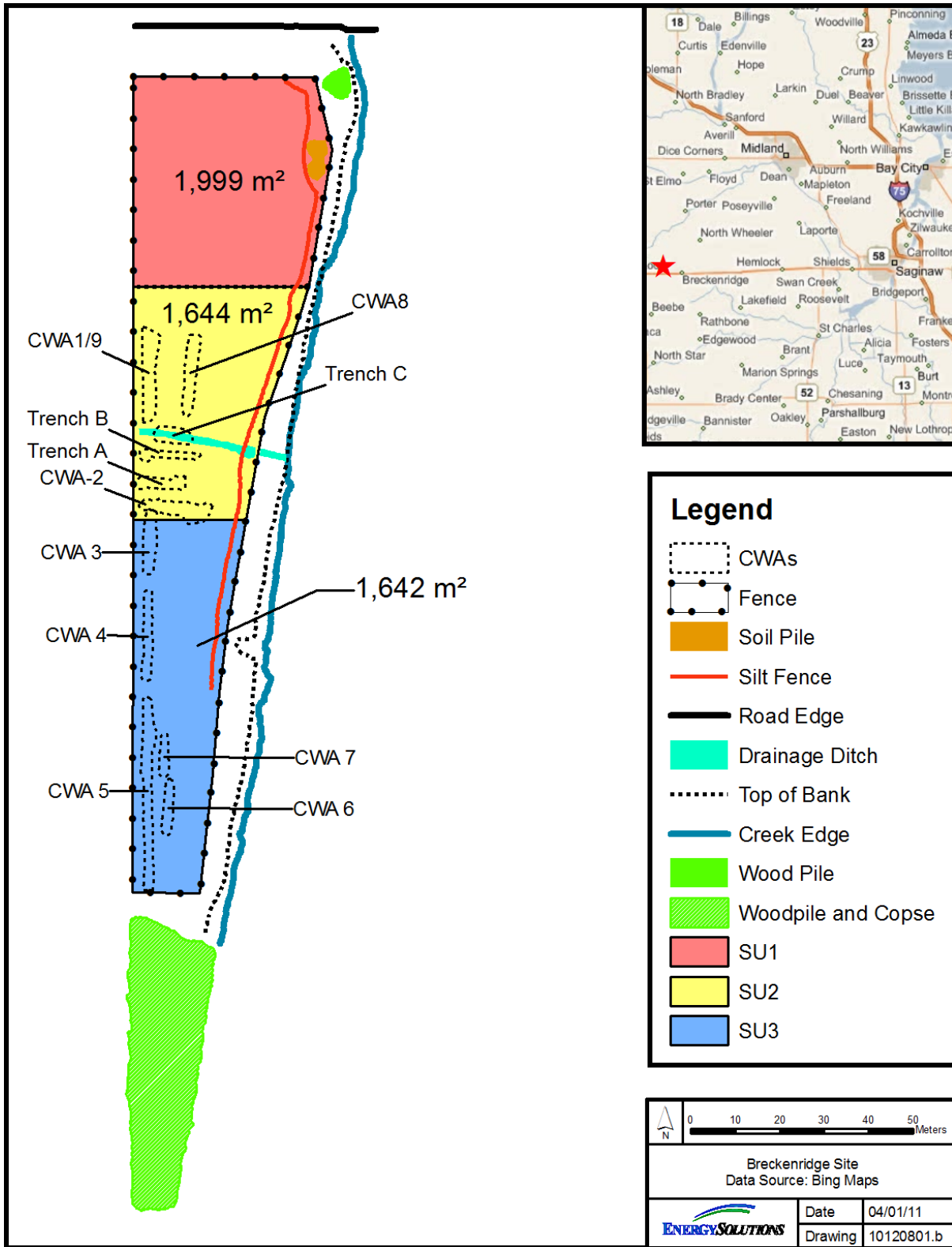


Figure 3-1 Breckenridge Survey Units

3.2 Gamma Scans

During remediation, walkover scans were performed prior to each lift removal. The initial action levels that were implemented to guide the excavation was 3,000 and 23,000 net cpm above background for surface (< 1.5 m bgs) and subsurface soils (> 1.5 m bgs), respectively, as developed empirically and as documented in the project Remedial Work Plan, CS-OP-PN-002. The initial background was established at approximately 8,000 cpm for respective action levels of 11,000 and 31,000 gross cpm. All areas exceeding the action levels were removed, packaged and shipped as radioactive waste. All other areas below the action levels were removed and treated as clean overburden and stockpiled within SU1.

Over the course of site remediation, specifically SU3, these action levels were finalized at 18,000 gross cpm and 31,000 gross cpm as documented in EnergySolutions document CS-313111-001, *Re-Evaluation of Breckenridge DCGLs, Gamma Scan Sensitivity, Gamma Scan Action Levels and Development of Area Factors*.

These final action levels were developed empirically through a statistical analysis of site specific survey and sampling data and through dose modeling using the guidance as provided in NUREG-1507 to account for the presence of elevated Th-230 in the radionuclide mix.

3.3 Systematic Sampling

SU2 is a Class 1 area and systematic sampling and measurement locations were located in a systematic pattern or grid. The grid spacing, L , was determined using the Equation below (form of MARSSIM Equation 5-5) based upon the survey unit size and the minimum number of sampling or measurement locations determined necessary to adequately assess the survey unit as based upon the final walkover survey results.

$$L = \sqrt{\frac{A}{0.866 \times n}}$$

where: A = Area of the survey unit, and

n = Number of sampling and measurement locations.

The starting point was randomly selected and a triangular sampling grid generated using the grid spacing as determined. The grid spacing and sampling design is determined is provided in Attachment A.

In addition, sampling was performed at a frequency of 1 sample location for every 10 linear feet along the bottom of each CWA or waste trench along its centerline.

3.4 Biased Sampling

Biased samples were collected at elevated areas as identified during the walk-over gamma scans and an evaluation of the scan results as plotted. This was performed to investigate any areas of potential concern and to validate the scan sensitivities of the field instruments.

3.5 Subsurface Sampling

Geoprobe sampling was performed at each final status survey location within areas that have been excavated to a depth of greater than 1.5 meters but less than 3 meters. This includes all biased sampling locations along the centerline of each trench as available depending upon accessibility and safety. Additional samples were collected as necessary based upon the direction of the RE and/or PHP.

The purpose of geoprobe sampling is to provide additional assurance no further subsurface contamination exists and to demonstrate that any residual subsurface contamination does not exceed 2 feet thick per the dose models.

3.6 Sign Test

For the Sign test, the number of sampling and measurement locations was determined from Table 5-5 of MARSSIM. It should be noted that the specified values within the table include the recommended 20% adjustment or increase in samples to ensure an adequate set of data is collected for statistical purposes.

4.0 RESULTS SUMMARY

A summary of the Final Status Survey Results for Survey Unit 2 are provided as follows:

4.1 SU2 Walkover Survey

Upon completion of excavation within the Survey Unit, a final walkover scan was performed using the 2x2 NaI(Tl) detector coupled with the GPS unit and the data plotted. The full walkover scan results are provided in Figure 4-1. To aid in the data evaluation of the scan results, all areas exceeding the “surface” action level of 18,000 gross cpm are documented to aid in biased sampling of the area and the release of the site. This final walkover scan illustrating all areas greater than 18,000 cpm is provided as Figure 4-2.

It should be noted that the action level is different for soils greater than 1.5 meters bgs. Based upon the GPS data from the walkover survey, a depth profile of the final excavation was developed and all areas greater than 1.5 meters in depth area provided as part of the walkover scans and as depicted on the maps.

As noted in Figure 4-1 and Figure 4-2, there are some areas, as shown, where the scan data was not recorded as part of the GPS plots. These areas were in fact scanned with no indication of elevated readings based upon the audible response during the surveys. The areas where the clean overburden and waste bags are/were staged had been surveyed multiple times prior to staging any materials with no indication of elevated readings during the walkover surveys. The other areas, i.e., the trees, tanker and excavator, were surveyed as part of the final scan; however, the satellite signal was lost due to obstructions interfering with the satellite signals. Although the data for these areas are not shown, all indications from the audible response during the survey showed no evidence of any areas of elevated activity or response.

Figure 4-3 and Figure 4-4 provide a histogram and data set statistics for the entire walkover scan.

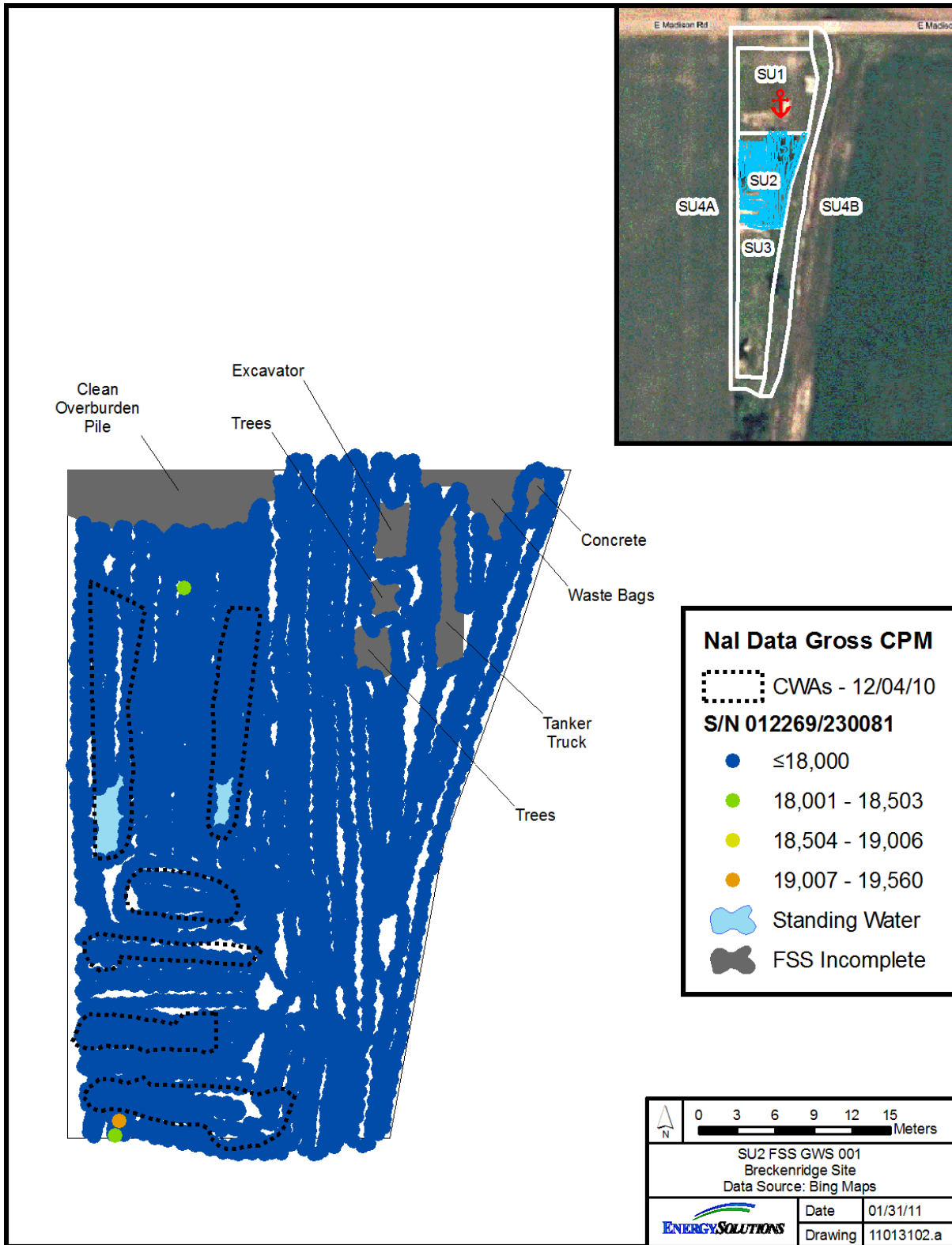


Figure 4-1 SU2 Final Status Survey Map – Walkover Scan

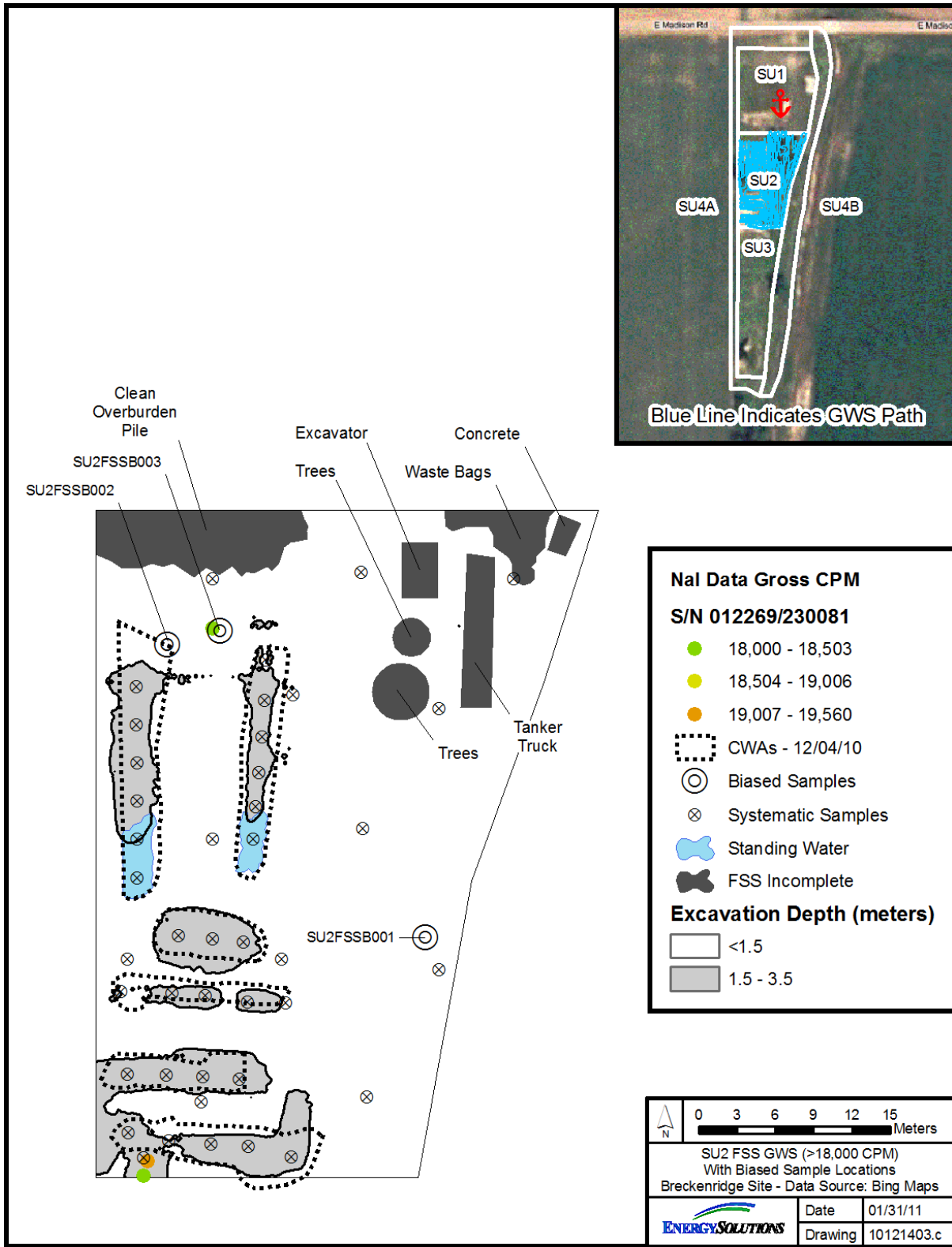


Figure 4-2 SU2 Final Status Survey Map – Walkover Scan > 18,000 cpm

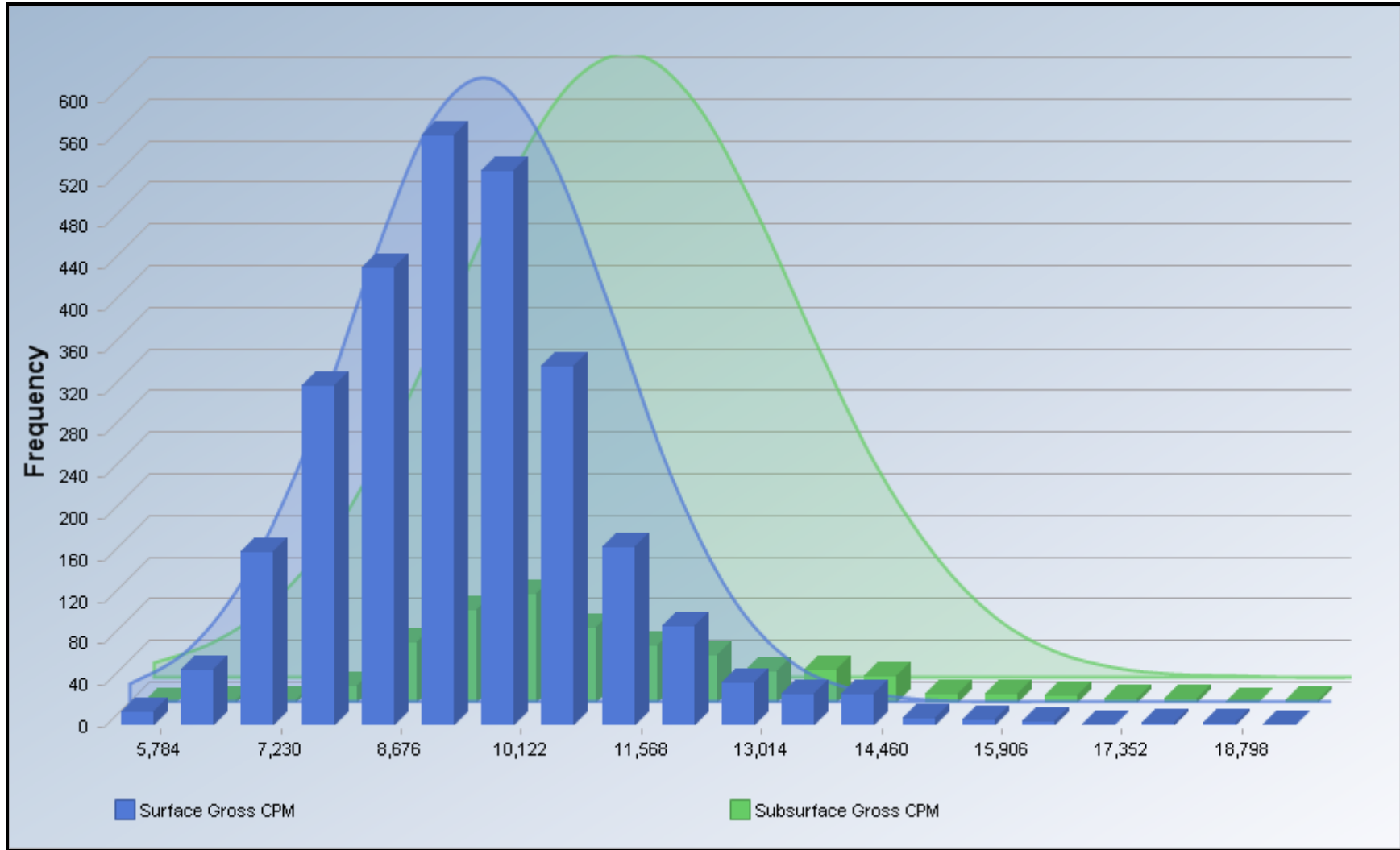


Figure 4-3 SU2 Walkover Scan Histogram

Summary Statistics for Raw Full Data Sets											
Variable	NumObs	Minimum	Maximum	Mean	Median	Variance	SD	MAD/0.675	Skewness	Kurtosis	CV
Surface Gross CPM	2817	5100	18180	9344	9240	2516255	1586	1423	0.729	1.668	0.17
Subsurface Gross CPM	550	6540	19560	10769	10260	4232035	2057	1824	0.943	0.838	0.191
Percentiles for Raw Full Data Sets											

Figure 4-4 SU2 Walkover Scan Statistics

4.2 Surface Soil Sampling and Results – SU2

Following the final walkover scan of the area, the survey unit was sampled and all samples analyzed on site. Surface soil samples (0-6”) were collected throughout the area in accordance with the Final Status Survey Protocols. Systematic samples were collected on a triangular grid with a random starting point. A copy of the survey design using VSP v5.9 for SU2 is provided as Attachment A. The costing information in the Attachment was based on the VSP v5.9 defaults and the information was not used in the FSS planning and should be ignored. Based upon the evaluation of the walkover survey and the VSP design, it was determined that 12 systematic sampling locations were adequate. Systematic samples were also collected along the centerline of each trench every 10 linear feet.

In addition to the systematic sampling locations, 3 biased samples were taken at elevated areas based upon the final walkover scan survey as show in Figure 4-2 and as noted during the walkover survey. No biased sampling was taken within the trenches as the systemic sampling provided adequate coverage of all elevated areas within the trenches.

Figure 4-5 provides a summary of all surface soil sample locations. All sample results are provided in Table 4-1 and Table 4-2 for the systematic/biased samples and trench samples respectively.

In order to evaluate the presence of ^{230}Th and to account for the dose contribution for the potential of elevated ^{230}Th activity, the activity was estimated using a ratio of 9.8:1 for ^{230}Th to ^{232}Th as developed in *EnergySolutions* document CS-313111-001 unless otherwise determined via alpha spec by an off-site laboratory. Activities determined by alpha spec are highlighted within the tables.

Based upon the soil sample results, 4 elevated areas were identified with a SOF near or above unity. These 4 areas are addressed in the Elevated Measurement Comparison section.

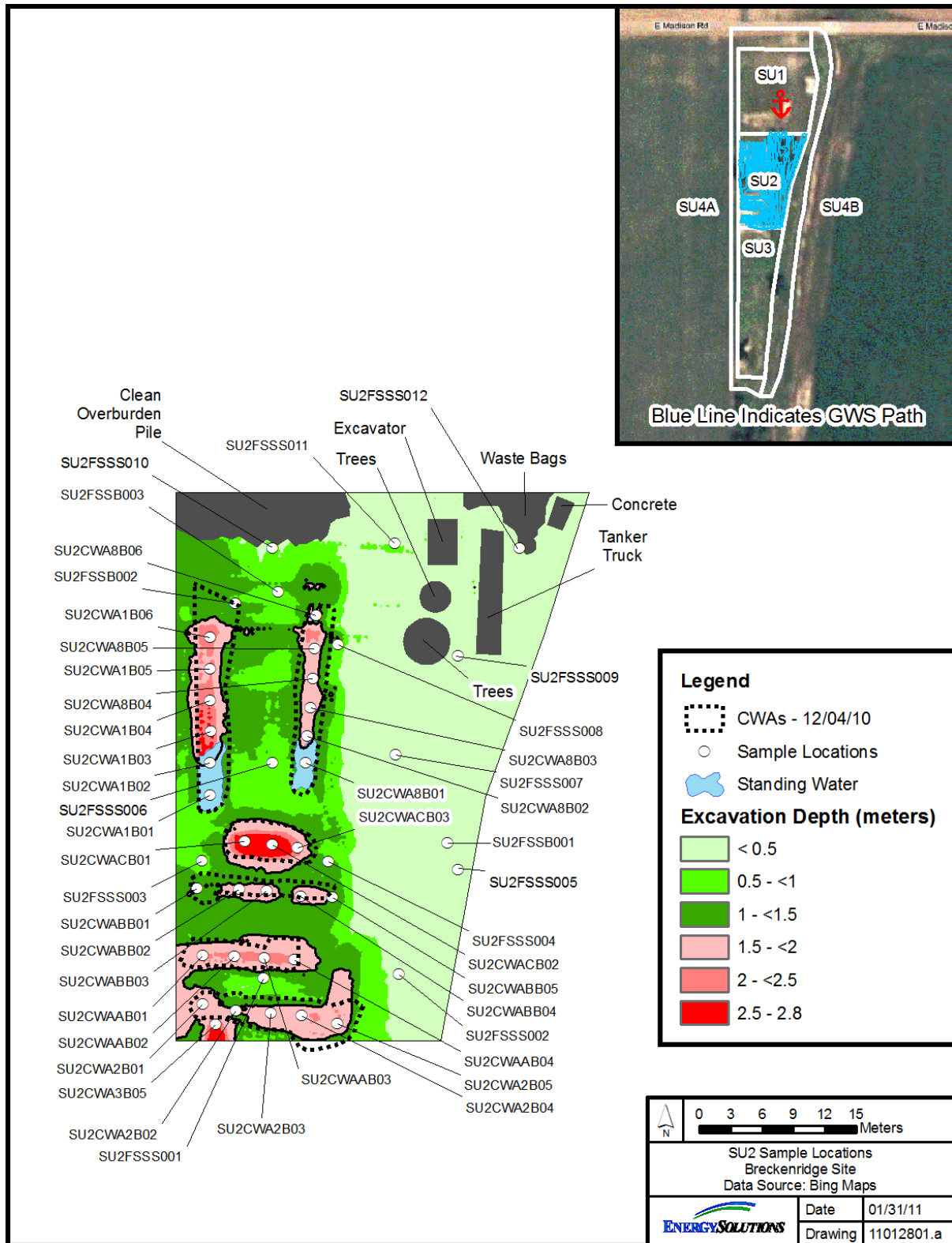


Figure 4-5 SU2 Final Status Surface Sampling Map

Table 4-1 Systematic and Biased Sampling Results

Sample ID	In-growth (days)	Depth (feet)	In- Situ Count Rate (cpm)	²³⁸ U		²³⁰ Th	²²⁶ Ra		²³² Th		SOF
				Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	
<i>Systematic / Biased Samples</i>											
SU2FSSS001	0	2.925	7,849	<i>3.84E-01</i>	4.25E-01	4.55E+00	<i>5.58E-01</i>	6.69E-01	4.65E-01	2.20E-01	0.20
SU2FSSS002	0	1.105	11,253	<i>3.52E-01</i>	8.82E-01	1.52E+01	2.01E+00	9.27E-01	1.55E+00	2.34E-01	0.69
SU2FSSS003	0	3.023	8,198	<i>4.85E-01</i>	7.50E-01	4.84E+00	<i>5.54E-01</i>	1.13E+00	4.94E-01	1.75E-01	0.21
SU2FSSS004	0	3.218	11,371	8.67E-01	5.41E-01	5.01E+00	1.30E+00	1.04E+00	5.12E-01	1.98E-01	0.33
SU2FSSS005	0	0.000	7,084	<i>6.51E-01</i>	7.82E-01	5.23E+00	<i>4.27E-01</i>	8.27E-01	5.33E-01	1.54E-01	0.20
SU2FSSS006	0	2.990	7,982	<i>6.07E-01</i>	7.35E-01	5.59E+00	9.19E-01	8.51E-01	5.70E-01	1.78E-01	0.28
SU2FSSS007	0	0.000	9,097	8.92E-01	6.41E-01	1.09E+01	1.40E+00	9.39E-01	1.11E+00	2.42E-01	0.49
SU2FSSS008	0	3.478	10,496	<i>9.39E-01</i>	1.04E+00	6.29E+00	<i>5.67E-01</i>	9.62E-01	6.42E-01	1.54E-01	0.25
SU2FSSS009	0	0.000	6,563	<i>5.63E-01</i>	5.81E-01	6.88E+00	9.80E-01	8.70E-01	7.02E-01	1.99E-01	0.32
SU2FSSS010	0	2.145	9,300	9.58E-01	6.38E-01	5.68E+00	<i>7.07E-01</i>	1.04E+00	5.80E-01	2.72E-01	0.25
SU2FSSS011	0	0.000	9,556	1.16E+00	6.19E-01	8.70E+00	<i>8.36E-01</i>	1.04E+00	8.88E-01	2.40E-01	0.35
SU2FSSS012	0	0.000	9,782	<i>7.19E-01</i>	1.12E+00	1.49E+01	1.34E+00	1.20E+00	1.52E+00	1.89E-01	0.58
SU2FSSB001	22	0.000	11,621	1.35E+00	7.14E-01	7.20E+00	1.83E+00	1.20E+00	8.27E-01	2.57E-01	0.49
SU2FSSB002	21	3.510	13,892	7.77E+00	1.14E+00	5.32E+01	4.93E+00	1.91E+00	5.62E+00	3.88E-01	2.13
SU2FSSB003	21	2.925	16,248	1.19E+01	1.42E+00	6.22E+01	7.62E+00	2.28E+00	6.96E+00	4.73E-01	2.88
Average:				1.97E+00		1.44E+01	1.73E+00		1.53E+00		0.64
Std Dev.:				3.29E+00		1.80E+01	1.97E+00		1.98E+00		
UCL 95%:				7.38E+00		4.40E+01	4.97E+00		4.79E+00		
Maximum:				1.19E+01		6.22E+01	7.62E+00		6.96E+00		

Notes:

- a Highlighted cells (yellow) are values obtained via alpha spec analysis by the off-site laboratory, all other values were determined via gamma spec.
- b Bold values are values greater than MDA while italics are less than MDA.
- c Bold "red" values are samples from suspect or elevated areas excluded from the survey unit average but included in the EMC evaluations.

Table 4-2 Trench (Contaminated Waste Area) Sampling Results

Sample ID	In-growth (days)	Depth (feet)	In- Situ Count Rate (cpm)	²³⁸ U		²³⁰ Th	²²⁶ Ra		²³² Th		SOF
				Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	
<u>SU2 Trenches (CWAs)</u>											
SU2CWA1B01	0	8.580	10,922	5.04E+00	1.03E+00	4.78E+00	1.57E+00	1.40E+00	9.22E-01	3.63E-01	0.09
SU2CWA1B02	0	8.580	13,502	2.60E+00	1.07E+00	1.19E+01	1.15E+00	1.44E+00	1.21E+00	4.08E-01	0.16
SU2CWA1B03	0	8.580	11,753	1.23E+00	1.09E+00	7.61E+00	1.31E+00	1.31E+00	7.77E-01	3.71E-01	0.12
SU2CWA1B04	0	7.443	10,922	5.87E+00	1.34E+00	6.06E+00	2.14E+00	1.56E+00	6.18E-01	4.01E-01	0.11
SU2CWA1B05	0	6.728	10,806	1.58E+00	9.06E-01	5.31E+00	1.03E+00	1.19E+00	5.41E-01	6.35E-01	0.08
SU2CWA1B06	0	7.020	12,381	2.78E+00	9.68E-01	2.57E+01	2.32E+00	1.70E+00	1.86E+00	4.10E-01	0.34
SU2CWA2B01	0	5.330	9,826	5.36E-01	7.20E-01	7.77E+00	2.10E+00	1.72E+00	7.93E-01	3.82E-01	0.13
SU2CWA2B02	0	4.908	11,326	3.00E+00	1.14E+00	1.08E+01	1.45E+00	1.81E+00	1.10E+00	5.98E-01	0.16
SU2CWA2B03	1	6.013	12,029	1.07E+01	2.67E+00	4.60E+01	5.27E+00	3.58E+00	1.43E+01	7.52E-01	0.79
SU2CWA2B04	1	6.078	13,699	2.93E+00	1.35E+00	5.15E+00	1.32E+00	1.82E+00	5.26E-01	3.53E-01	0.09
SU2CWA2B05	1	5.785	11,298	1.21E+00	9.55E-01	1.01E+01	6.68E-01	1.22E+00	1.03E+00	3.43E-01	0.13
SU2CWA3B05	1	7.800	19,939	3.30E+00	2.38E+00	2.24E+00	1.00E+01	3.10E+00	8.74E+00	8.71E-01	0.35
SU2CWA8B01	0	5.428	10,969	1.65E+00	1.01E+00	6.25E+00	1.35E+00	1.47E+00	6.38E-01	2.94E-01	0.10
SU2CWA8B02	1	5.428	12,180	5.27E-01	1.78E+00	8.42E+00	8.76E-01	1.41E+00	8.60E-01	6.81E-01	0.12
SU2CWA8B03	1	5.460	13,838	3.24E+00	1.50E+00	1.32E+01	2.38E+00	2.41E+00	2.44E+00	5.18E-01	0.22
SU2CWA8B04	0	5.168	11,643	5.67E-01	1.18E+00	5.47E+00	1.55E+00	1.63E+00	5.58E-01	5.85E-01	0.09
SU2CWA8B05	0	5.948	16,842	2.39E+00	1.47E+00	1.13E+01	8.46E-01	1.66E+00	1.15E+00	2.73E-01	0.15
SU2CWA8B06	0	4.778	16,438	4.21E+00	1.08E+00	3.62E+00	2.52E+00	1.61E+00	8.47E-01	3.04E-01	0.60
SU2CWAAB01	0	6.435	10,189	1.15E+00	9.08E-01	9.20E+00	1.47E+00	1.24E+00	9.39E-01	3.60E-01	0.14
SU2CWAAB02	0	6.695	10,778	1.27E+00	1.10E+00	1.12E+01	1.39E+00	1.35E+00	1.14E+00	3.86E-01	0.16
SU2CWAAB03	0	6.988	11,388	9.41E-01	1.27E+00	5.82E+00	1.05E-01	1.00E+00	5.94E-01	6.00E-01	0.07
SU2CWAAB04	0	6.435	9,388	9.97E-01	1.33E+00	8.04E+00	5.57E-01	1.14E+00	8.21E-01	2.59E-01	0.11

Final Status Survey Report
Breckenridge Disposal Site – Survey Package SU2

CS-313111-003
Revision 0

Sample ID	In-growth (days)	Depth (feet)	In- Situ Count Rate (cpm)	²³⁸ U		²³⁰ Th	²²⁶ Ra		²³² Th		SOF
				Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	
<u>SU2 Trenches (CWAs)</u>											
SU2CWABB01	0	4.778	9,733	<i>6.72E-01</i>	8.56E-01	6.36E+00	<i>1.12E+00</i>	1.63E+00	6.49E-01	3.49E-01	0.34
SU2CWABB02	0	4.940	8,942	1.13E+00	1.12E+00	5.50E+00	<i>9.82E-01</i>	1.52E+00	<i>5.61E-01</i>	5.62E-01	0.08
SU2CWABB03	0	5.200	11,101	2.43E+00	1.05E+00	7.79E+00	<i>1.06E+00</i>	1.59E+00	7.95E-01	2.95E-01	0.11
SU2CWABB04	0	5.428	9,767	1.05E+00	9.87E-01	5.72E+00	<i>1.26E+00</i>	1.42E+00	5.84E-01	2.94E-01	0.09
SU2CWABB05	0	4.290	9,361	<i>8.04E-01</i>	1.16E+00	7.27E+00	<i>6.57E-01</i>	1.08E+00	7.42E-01	6.52E-01	0.28
SU2CWACB01	0	9.588	8,772	<i>7.48E-01</i>	8.38E-01	3.49E+00	<i>6.70E-01</i>	8.44E-01	<i>3.56E-01</i>	4.25E-01	0.05
SU2CWACB02	0	10.758	9,780	<i>3.97E-01</i>	1.07E+00	4.47E+00	<i>5.17E-01</i>	1.05E+00	4.57E-01	2.96E-01	0.06
SU2CWACB03	0	7.085	9,752	<i>8.55E-01</i>	1.15E+00	5.78E+00	<i>8.04E-01</i>	1.15E+00	5.89E-01	5.64E-01	0.08
Average:				2.19E+00		9.07E+00	1.68E+00		1.57E+00		0.18
Std Dev.:				2.13E+00		8.20E+00	1.83E+00		2.83E+00		
UCL 95%:				5.69E+00		2.26E+01	4.70E+00		6.22E+00		
Maximum:				1.07E+01		4.40E+01	1.00E+01		1.43E+01		

Notes:

- a Highlighted cells (yellow) are values obtained via alpha spec analysis by the off-site laboratory, all other values were determined via gamma spec.
- b Bold values are values greater than MDA while italics are less than MDA.

4.3 Subsurface Soil Sampling and Results

Following the analysis of all surface soil samples, subsurface samples were collected throughout the area. Geoprobe samples were taken at each systematic sampling location down to an approximate depth of 10 feet bgs or until refusal. The samples were then divided and analyzed in 2-foot composites.

Geoprobe sampling was not performed within trenches 3 and C due to their depth and for safety reasons. Because of the overall depth of these two trenches, it was determined that it was not safe to try and access the trenches with the geoprobe unit and that it was not necessary. Additionally, geoprobe samples were not collected at sample locations 1 and 2 within CWA-1 due to standing water and at each of the 3 biased sample locations due to weather (frozen ground and snow); however, upon review of the sample analysis results, the only two locations that exceeded an SOF were biased sample locations 2 and 3. As an alternative, subsurface samples will be collected upon re-mobilizing in the spring using a pick ax to sample approximately 6-inches below the surface at the two locations, biased samples 1 and 2 where the SOF exceeded unity. Subsurface sampling will not be performed at the other locations as the SOFs were less than one.

Figure 4-6 provides a summary of all locations where subsurface soil samples were collected. All sample results are provided in Table 4-3. All subsurface soil samples were well below a SOF equal to unity. Based upon all subsurface sampling, the soil type and other samples taken it was determined that no further subsurface sampling was required.

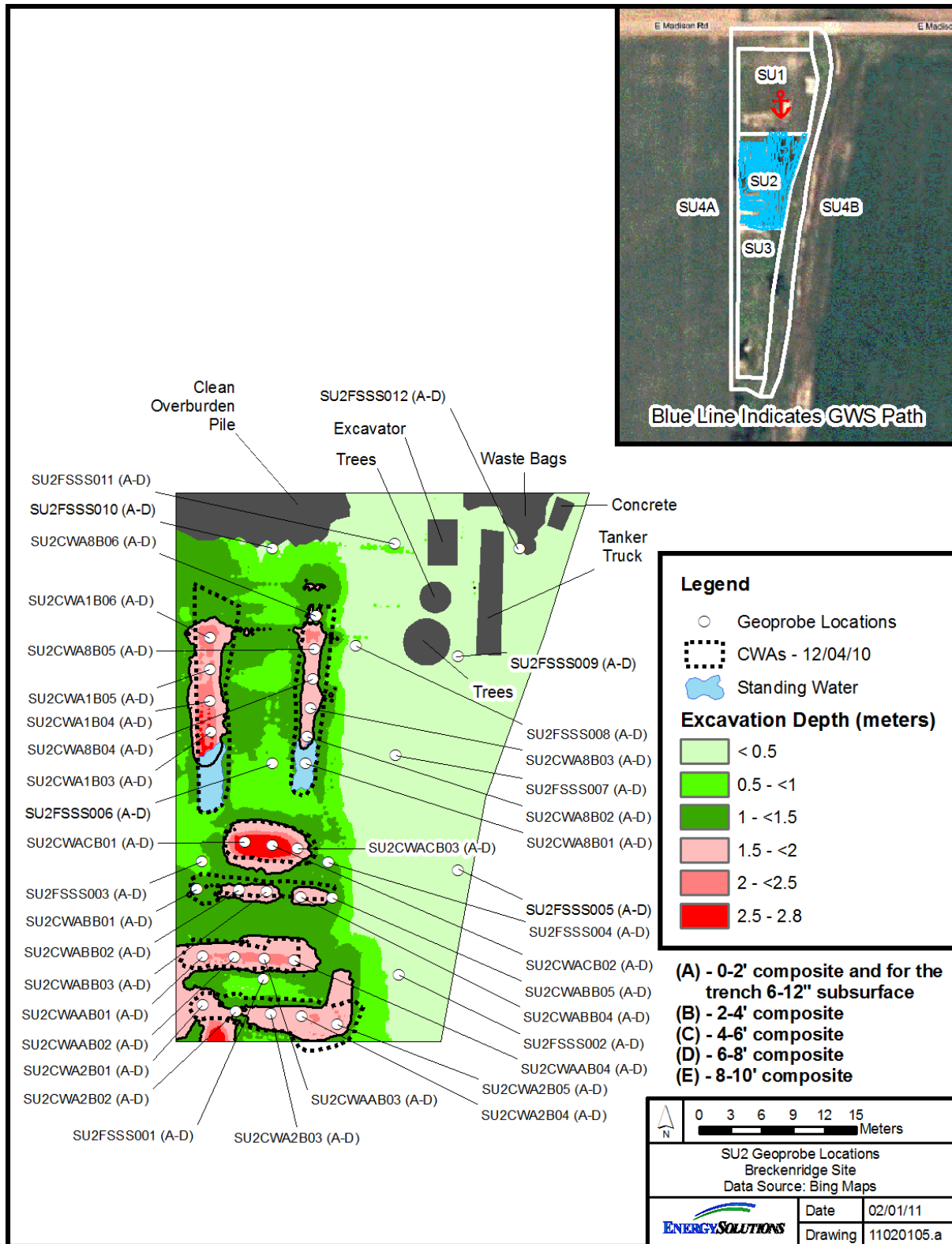


Figure 4-6 SU2 Final Status Subsurface Sampling Map

Table 4-3 Subsurface Sampling Results

Sample ID	In-growth (days)	Depth (feet)	In- Situ Count Rate (cpm)	²³⁸ U		²³⁰ Th	²²⁶ Ra		²³² Th		SOF
				Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	
<i>SU2 Geoprobos</i>											
SU2CWA1B03A	28	8.580	N/A	1.68E+00	1.35E+00	7.87E+00	<i>3.64E-01</i>	1.18E+00	8.03E-01	6.89E-01	0.10
SU2CWA1B03B	28	10.580	N/A	<i>8.52E-01</i>	1.09E+00	4.34E+00	<i>1.69E-01</i>	1.35E+00	<i>4.42E-01</i>	5.17E-01	0.05
SU2CWA1B03C	28	12.580	N/A	<i>4.77E-01</i>	1.16E+00	8.30E+00	<i>8.72E-01</i>	9.85E-01	8.47E-01	6.54E-01	0.11
SU2CWA1B03D	28	14.580	N/A	<i>4.41E-01</i>	5.49E-01	4.21E+00	<i>3.97E-01</i>	8.52E-01	<i>4.30E-01</i>	5.07E-01	0.06
SU2CWA1B04A	27	7.443	N/A	3.12E+00	1.25E+00	7.80E-01	<i>1.45E+00</i>	1.63E+00	1.03E+00	6.77E-01	0.05
SU2CWA1B04B	27	9.443	N/A	<i>8.68E-01</i>	1.16E+00	5.51E+00	2.13E+00	1.64E+00	<i>5.62E-01</i>	5.85E-01	0.11
SU2CWA1B04C	27	11.443	N/A	<i>3.77E-01</i>	1.15E+00	5.38E+00	<i>1.21E+00</i>	1.22E+00	5.49E-01	2.97E-01	0.09
SU2CWA1B04D	27	13.443	N/A	<i>8.19E-01</i>	1.10E+00	5.08E+00	<i>5.85E-01</i>	1.02E+00	5.18E-01	2.94E-01	0.07
SU2CWA1B05A	27	6.728	N/A	<i>1.11E+00</i>	1.15E+00	4.59E+00	<i>1.34E+00</i>	1.64E+00	4.69E-01	3.91E-01	0.08
SU2CWA1B05B	27	8.728	N/A	1.14E+00	1.13E+00	4.59E+00	<i>4.55E-01</i>	9.62E-01	<i>4.69E-01</i>	6.61E-01	0.06
SU2CWA1B05C	27	10.728	N/A	<i>9.22E-01</i>	1.04E+00	5.06E+00	<i>2.80E-01</i>	9.54E-01	<i>5.17E-01</i>	5.76E-01	0.07
SU2CWA1B05D	27	12.728	N/A	<i>9.26E-01</i>	1.17E+00	3.30E+00	<i>1.38E-01</i>	7.84E-01	<i>3.37E-01</i>	6.39E-01	0.04
SU2CWA1B06A	27	7.020	N/A	<i>7.48E-01</i>	1.14E+00	5.79E+00	<i>3.78E-01</i>	1.27E+00	5.91E-01	2.64E-01	0.08
SU2CWA1B06B	27	9.020	N/A	<i>5.13E-01</i>	1.20E+00	5.86E+00	<i>5.95E-01</i>	1.05E+00	<i>5.98E-01</i>	6.16E-01	0.08
SU2CWA1B06C	27	11.020	N/A	1.31E+00	1.09E+00	5.21E+00	1.82E+00	1.53E+00	5.31E-01	2.99E-01	0.10
SU2CWA1B06D	27	13.020	N/A	<i>1.01E+00</i>	1.07E+00	4.66E+00	<i>4.88E-01</i>	1.04E+00	<i>4.76E-01</i>	5.81E-01	0.06
SU2CWA2B01A	0	5.330	N/A	<i>6.50E-01</i>	6.63E-01	6.60E+00	<i>5.36E-01</i>	1.63E+00	6.73E-01	2.23E-01	0.09
SU2CWA2B01B	0	7.330	N/A	<i>2.35E-01</i>	1.16E+00	7.07E+00	<i>1.01E+00</i>	1.12E+00	7.21E-01	3.57E-01	0.10
SU2CWA2B01C	0	9.330	N/A	<i>7.91E-01</i>	1.08E+00	5.61E+00	<i>5.76E-01</i>	1.04E+00	5.73E-01	1.99E-01	0.08
SU2CWA2B01D	1	11.330	N/A	<i>6.79E-01</i>	1.01E+00	4.51E+00	<i>2.54E-01</i>	1.48E+00	<i>4.60E-01</i>	5.26E-01	0.06

Sample ID	In-growth (days)	Depth (feet)	In-Situ Count Rate (cpm)	²³⁸ U		²³⁰ Th	²²⁶ Ra		²³² Th		SOF
				Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	
<u>SU2 Geoprobos</u>											
SU2CWA2B02A	0	4.908	N/A	5.61E-01	9.87E-01	6.67E+00	6.88E-01	9.07E-01	6.81E-01	5.64E-01	0.09
SU2CWA2B02B	2	6.908	N/A	9.63E-01	1.02E+00	5.36E+00	7.28E-01	1.42E+00	5.46E-01	5.27E-01	0.08
SU2CWA2B02C	2	8.908	N/A	8.36E-01	1.07E+00	6.01E+00	3.50E-01	1.04E+00	6.13E-01	6.07E-01	0.08
SU2CWA2B02D	2	10.908	N/A	5.47E-01	1.10E+00	7.30E+00	3.42E-01	1.25E+00	7.45E-01	6.04E-01	0.09
SU2CWA2B03A	2	6.013	N/A	9.44E-01	1.04E+00	5.15E+00	6.25E-01	1.42E+00	5.26E-01	5.06E-01	0.07
SU2CWA2B03B	2	8.013	N/A	5.83E-01	1.06E+00	1.25E+01	7.27E-01	1.10E+00	1.28E+00	3.28E-01	0.16
SU2CWA2B03C	2	10.013	N/A	5.29E-01	8.23E-01	5.16E+00	1.97E+00	1.65E+00	5.27E-01	3.42E-01	0.10
SU2CWA2B03D	26	12.013	N/A	6.59E-01	9.32E-01	7.80E+00	7.53E-01	1.66E+00	7.96E-01	6.10E-01	0.11
SU2CWA2B04A	0	6.078	N/A	6.00E-01	1.46E+00	7.37E+00	8.45E-01	1.08E+00	7.52E-01	5.51E-01	0.10
SU2CWA2B04B	0	8.078	N/A	8.97E-01	9.78E-01	5.38E+00	1.61E-01	7.85E-01	5.49E-01	4.24E-01	0.07
SU2CWA2B04C	0	10.078	N/A	1.42E+00	8.31E-01	4.81E+00	2.01E-01	1.27E+00	4.91E-01	2.98E-01	0.06
SU2CWA2B04D	0	12.078	N/A	9.28E-01	1.15E+00	2.69E+00	5.88E-01	1.09E+00	2.75E-01	6.37E-01	0.04
SU2CWA2B05A	0	5.785	N/A	6.07E-01	9.68E-01	2.83E+00	4.26E-01	8.75E-01	2.88E-01	1.58E-01	0.04
SU2CWA2B05B	0	7.785	N/A	8.16E-01	1.11E+00	5.87E+00	6.72E-01	1.12E+00	5.99E-01	5.63E-01	0.08
SU2CWA2B05C	0	9.785	N/A	9.58E-01	1.21E+00	5.35E+00	2.38E-01	1.06E+00	5.46E-01	6.21E-01	0.07
SU2CWA2B05D	0	11.785	N/A	5.19E-01	9.51E-01	4.31E+00	3.83E-01	9.95E-01	4.39E-01	5.26E-01	0.06
SU2CWA8B01A	26	5.428	N/A	1.17E+00	1.14E+00	6.06E+00	8.35E-01	1.65E+00	6.18E-01	3.31E-01	0.09
SU2CWA8B01B	26	7.428	N/A	5.05E-01	8.84E-01	3.40E+00	2.21E-02	8.27E-01	3.47E-01	4.19E-01	0.04
SU2CWA8B01C	26	9.428	N/A	9.02E-01	1.03E+00	3.45E+00	1.13E-01	8.28E-01	3.52E-01	5.90E-01	0.04
SU2CWA8B01D	26	11.428	N/A	9.68E-01	1.13E+00	7.31E+00	1.66E-01	9.37E-01	7.45E-01	6.18E-01	0.09
SU2CWA8B02A	27	5.428	N/A	7.90E-01	8.06E-01	5.14E+00	6.89E-01	1.59E+00	5.25E-01	2.49E-01	0.07
SU2CWA8B02B	27	7.428	N/A	6.07E-01	9.52E-01	4.01E+00	0.00E+00	1.36E+00	4.10E-01	5.10E-01	0.05
SU2CWA8B02C	27	9.428	N/A	4.68E-01	9.69E-01	5.94E+00	5.31E-01	1.05E+00	6.06E-01	5.03E-01	0.08
SU2CWA8B02D	27	11.428	N/A	9.77E-01	1.16E+00	8.52E+00	2.53E-01	1.10E+00	8.69E-01	6.19E-01	0.11

Sample ID	In-growth (days)	Depth (feet)	In-Situ Count Rate (cpm)	²³⁸ U		²³⁰ Th	²²⁶ Ra		²³² Th		SOF
				Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	
<u>SU2 Geoprobos</u>											
SU2CWA8B03A	27	5.460	N/A	5.87E-01	1.24E+00	4.87E+00	4.94E-01	1.13E+00	4.97E-01	5.98E-01	0.07
SU2CWA8B03B	27	7.460	N/A	4.47E-01	7.07E-01	3.56E+00	5.68E-01	9.70E-01	3.63E-01	3.41E-01	0.05
SU2CWA8B03C	27	9.460	N/A	1.29E+00	1.26E+00	3.95E+00	2.79E-01	1.21E+00	4.03E-01	5.43E-01	0.05
SU2CWA8B03D	27	11.460	N/A	4.73E-01	1.00E+00	3.09E+00	7.71E-01	1.03E+00	3.15E-01	2.96E-01	0.05
SU2CWA8B04A	25	5.168	N/A	6.10E-01	1.24E+00	8.33E+00	1.13E+00	1.59E+00	8.50E-01	5.69E-01	0.12
SU2CWA8B04B	25	7.168	N/A	9.48E-01	9.03E-01	4.81E+00	8.24E-02	9.36E-01	4.91E-01	5.05E-01	0.06
SU2CWA8B04C	25	9.168	N/A	7.82E-01	1.11E+00	4.07E+00	4.98E-01	9.68E-01	4.15E-01	3.20E-01	0.06
SU2CWA8B04D	25	11.168	N/A	6.89E-01	9.91E-01	2.16E+00	4.43E-01	9.32E-01	2.20E-01	5.34E-01	0.03
SU2CWA8B05A	25	5.948	N/A	1.09E+00	1.19E+00	5.79E+00	4.98E-01	9.73E-01	5.91E-01	3.10E-01	0.08
SU2CWA8B05B	25	7.948	N/A	5.85E-01	1.10E+00	7.03E+00	6.97E-01	1.24E+00	7.17E-01	6.03E-01	0.10
SU2CWA8B05C	25	9.948	N/A	5.30E-01	8.91E-01	4.70E+00	4.02E-01	8.74E-01	4.80E-01	4.85E-01	0.06
SU2CWA8B05D	25	11.948	N/A	8.59E-01	1.11E+00	5.02E+00	4.47E-01	1.03E+00	5.12E-01	2.65E-01	0.07
SU2CWA8B06A	25	4.778	N/A	4.26E-01	1.08E+00	5.62E+00	6.81E-01	1.55E+00	5.74E-01	5.98E-01	0.25
SU2CWA8B06B	25	6.778	N/A	5.97E-01	1.12E+00	4.98E+00	1.03E+00	1.54E+00	5.08E-01	3.01E-01	0.08
SU2CWA8B06C	25	8.778	N/A	5.16E-01	1.15E+00	5.63E+00	8.47E-01	1.02E+00	5.75E-01	2.67E-01	0.08
SU2CWA8B06D	25	10.778	N/A	4.54E-01	9.02E-01	6.13E+00	2.02E-01	1.31E+00	6.25E-01	4.84E-01	0.08
SU2CWAAB01A	0	6.435	N/A	9.90E-01	1.21E+00	8.37E+00	5.47E-01	1.38E+00	8.54E-01	6.13E-01	0.11
SU2CWAAB01B	0	8.435	N/A	6.64E-01	7.71E-01	6.06E+00	4.75E-01	1.49E+00	6.18E-01	5.91E-01	0.08
SU2CWAAB01C	0	10.435	N/A	6.97E-01	6.98E-01	4.82E+00	3.96E-01	1.14E+00	4.92E-01	6.02E-01	0.06
SU2CWAAB01D	0	12.435	N/A	3.31E-01	1.10E+00	4.82E+00	9.70E-01	9.09E-01	4.92E-01	5.85E-01	0.08
SU2CWAAB02A	1	6.695	N/A	8.13E-01	1.08E+00	5.34E+00	1.36E+00	1.56E+00	5.45E-01	6.22E-01	0.09
SU2CWAAB02B	1	8.695	N/A	4.42E-01	1.02E+00	5.47E+00	1.05E+00	1.39E+00	5.58E-01	5.21E-01	0.09
SU2CWAAB02C	1	10.695	N/A	4.91E-01	5.99E-01	5.22E+00	3.44E-01	8.79E-01	5.32E-01	5.38E-01	0.07
SU2CWAAB02D	1	12.695	N/A	8.60E-01	1.12E+00	6.38E+00	0.00E+00	1.53E+00	6.51E-01	5.55E-01	0.08

Sample ID	In-growth (days)	Depth (feet)	In-Situ Count Rate (cpm)	²³⁸ U		²³⁰ Th	²²⁶ Ra		²³² Th		SOF
				Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	
<u>SU2 Geoprobos</u>											
SU2CWaab03A	32	6.988	N/A	4.37E-01	1.11E+00	5.21E+00	5.54E-01	1.32E-01	5.32E-01	2.84E-01	0.07
SU2CWaab03B	0	8.988	N/A	1.27E+00	1.30E+00	6.51E+00	7.04E-01	1.40E+00	6.64E-01	6.41E-01	0.09
SU2CWaab03C	0	10.988	N/A	1.35E+00	1.13E+00	4.31E+00	1.65E+00	1.62E+00	4.39E-01	2.61E-01	0.08
SU2CWaab03D	0	12.988	N/A	6.43E-01	8.21E-01	4.36E+00	2.09E-01	1.05E+00	4.45E-01	3.20E-01	0.06
SU2CWaab04A	0	6.435	N/A	1.05E+00	1.05E+00	4.77E+00	1.72E+00	1.57E+00	4.87E-01	1.98E-01	0.09
SU2CWaab04B	0	8.435	N/A	6.87E-01	8.04E-01	6.89E+00	1.10E+00	1.27E+00	7.03E-01	6.72E-01	0.10
SU2CWaab04C	0	10.435	N/A	4.35E-01	1.28E+00	5.09E+00	1.63E+00	1.16E+00	5.19E-01	5.80E-01	0.09
SU2CWaab04D	0	12.435	N/A	3.74E-01	1.00E+00	6.58E+00	3.34E-01	1.06E+00	6.72E-01	5.31E-01	0.08
SU2CWabb01A	22	4.778	N/A	4.69E-01	6.33E-01	9.86E+00	3.19E-01	9.29E-01	1.01E+00	6.73E-01	0.29
SU2CWabb01B	23	6.778	N/A	7.69E-01	9.25E-01	4.33E+00	2.52E-01	9.75E-01	4.42E-01	1.88E-01	0.06
SU2CWabb01C	23	8.778	N/A	9.17E-01	1.15E+00	6.93E+00	7.10E-01	9.76E-01	7.07E-01	6.19E-01	0.10
SU2CWabb01D	23	10.778	N/A	6.04E-01	1.14E+00	9.11E+00	5.21E-01	1.15E+00	9.30E-01	6.64E-01	0.12
SU2CWabb02A	22	4.940	N/A	9.41E-01	7.45E-01	4.79E+00	3.13E-01	1.54E+00	4.88E-01	3.48E-01	0.06
SU2CWabb02B	22	6.940	N/A	9.31E-02	9.56E-01	4.10E+00	5.26E-01	8.45E-01	4.18E-01	4.73E-01	0.06
SU2CWabb02C	22	8.940	N/A	7.56E-01	6.00E-01	3.49E+00	8.50E-01	1.10E+00	3.56E-01	1.48E-01	0.06
SU2CWabb02D	22	10.940	N/A	2.09E-01	8.31E-01	1.63E+00	8.87E-01	1.20E+00	1.66E-01	4.06E-01	0.04
SU2CWabb03A	23	5.200	N/A	6.83E-01	1.31E+00	7.83E+00	7.90E-01	1.26E+00	7.99E-01	6.58E-01	0.11
SU2CWabb03B	23	7.200	N/A	7.89E-01	1.10E+00	4.66E+00	8.85E-01	1.24E+00	4.75E-01	5.70E-01	0.07
SU2CWabb03C	23	9.200	N/A	1.27E+00	1.20E+00	5.01E+00	4.51E-01	1.03E+00	5.12E-01	5.68E-01	0.07
SU2CWabb03D	23	11.200	N/A	1.06E+00	1.12E+00	7.04E+00	4.15E-01	9.46E-01	7.18E-01	6.22E-01	0.09
SU2CWabb04A	28	5.428	N/A	1.00E+00	1.17E+00	1.04E+01	5.56E-01	1.29E+00	1.06E+00	6.10E-01	0.13
SU2CWabb04B	23	7.428	N/A	1.23E+00	1.13E+00	6.75E+00	-2.46E-01	1.01E+00	6.89E-01	4.80E-01	0.07
SU2CWabb04C	23	9.428	N/A	7.97E-01	1.08E+00	2.33E+00	1.23E+00	1.41E+00	2.38E-01	5.59E-01	0.05
SU2CWabb04D	23	11.428	N/A	2.47E-01	1.00E+00	4.91E+00	8.97E-01	9.37E-01	5.01E-01	2.34E-01	0.08

Sample ID	In-growth (days)	Depth (feet)	In-Situ Count Rate (cpm)	²³⁸ U		²³⁰ Th	²²⁶ Ra		²³² Th		SOF
				Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	
<u>SU2 Geoprobos</u>											
SU2CWABB05A	22	4.290	N/A	3.51E-01	1.10E+00	5.55E+00	7.63E-01	9.26E-01	5.66E-01	6.01E-01	0.26
SU2CWABB05B	22	6.290	N/A	1.15E+00	1.15E+00	4.05E+00	4.63E-01	1.20E+00	4.14E-01	5.96E-01	0.06
SU2CWABB05C	22	8.290	N/A	3.30E-01	1.00E+00	3.84E+00	7.32E-01	1.06E+00	3.92E-01	4.72E-01	0.06
SU2CWABB05D	22	10.290	N/A	7.37E-01	1.02E+00	5.53E+00	4.31E-01	1.50E+00	5.64E-01	5.34E-01	0.07
SU2FSSS001A	2	2.925	N/A	7.35E-01	1.13E+00	6.03E+00	4.65E-01	1.29E+00	6.15E-01	5.75E-01	0.22
SU2FSSS001B	2	4.925	N/A	1.15E+00	9.84E-01	6.83E+00	6.79E-02	1.36E+00	6.97E-01	5.39E-01	0.08
SU2FSSS001C	2	6.925	N/A	1.01E+00	1.10E+00	4.98E+00	5.41E-01	9.26E-01	5.09E-01	2.34E-01	0.07
SU2FSSS001D	2	8.925	N/A	8.06E-01	1.09E+00	5.50E+00	2.15E-02	1.18E+00	5.61E-01	3.74E-01	0.07
SU2FSSS002A	2	1.105	N/A	7.43E-01	1.18E+00	8.60E+00	5.37E-01	1.35E+00	8.77E-01	3.73E-01	0.30
SU2FSSS002B	2	3.105	N/A	7.89E-01	1.09E+00	6.10E+00	4.07E-01	1.12E+00	6.23E-01	6.47E-01	0.21
SU2FSSS002C	2	5.105	N/A	8.45E-01	1.21E+00	6.51E+00	1.20E+00	1.64E+00	6.64E-01	3.05E-01	0.10
SU2FSSS002D	2	7.105	N/A	4.41E-01	1.05E+00	4.02E+00	6.68E-01	9.36E-01	4.10E-01	3.16E-01	0.06
SU2FSSS003A	4	3.023	N/A	9.07E-01	6.72E-01	4.52E+00	6.95E-01	1.15E+00	4.61E-01	2.93E-01	0.22
SU2FSSS003B	4	5.023	N/A	5.47E-01	1.10E+00	6.16E+00	1.18E+00	1.11E+00	6.28E-01	3.79E-01	0.10
SU2FSSS003C	4	7.023	N/A	4.55E-01	6.90E-01	3.98E+00	1.70E+00	1.43E+00	4.06E-01	2.46E-01	0.08
SU2FSSS003D	4	9.023	N/A	3.60E-01	9.77E-01	5.73E+00	1.33E+00	8.99E-01	5.84E-01	5.30E-01	0.09
SU2FSSS004A	4	3.218	N/A	1.06E+00	1.12E+00	6.06E+00	3.51E-01	1.16E+00	6.18E-01	6.24E-01	0.20
SU2FSSS004B	4	5.218	N/A	9.68E-01	1.15E+00	6.49E+00	1.44E+00	1.48E+00	6.62E-01	3.37E-01	0.10
SU2FSSS004C	4	7.218	N/A	5.87E-01	9.23E-01	5.47E+00	7.34E-01	1.14E+00	5.58E-01	5.14E-01	0.08
SU2FSSS004D	4	9.218	N/A	1.77E-01	9.20E-01	5.68E+00	7.19E-01	8.98E-01	5.80E-01	5.02E-01	0.08
SU2FSSS005A	4	0.000	N/A	4.83E-01	7.30E-01	4.58E+00	1.16E+00	1.63E+00	4.67E-01	3.16E-01	0.30
SU2FSSS005B	4	2.000	N/A	8.96E-01	1.10E+00	4.61E+00	7.50E-01	1.24E+00	4.71E-01	3.46E-01	0.23
SU2FSSS005C	5	4.000	N/A	5.18E-01	7.79E-01	6.29E+00	1.29E+00	1.47E+00	6.42E-01	2.87E-01	0.36
SU2FSSS005D	5	6.000	N/A	1.13E+00	7.80E-01	5.35E+00	1.65E-01	1.09E+00	5.46E-01	6.09E-01	0.07

Sample ID	In-growth (days)	Depth (feet)	In-Situ Count Rate (cpm)	²³⁸ U		²³⁰ Th	²²⁶ Ra		²³² Th		SOF
				Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	
<u>SU2 Geoprob</u>											
SU2FSSS006A	4	2.990	N/A	5.74E-01	7.33E-01	6.83E+00	6.10E-01	8.48E-01	6.97E-01	5.90E-01	0.26
SU2FSSS006B	4	4.990	N/A	6.40E-01	7.74E-01	3.56E+00	4.25E-01	1.06E+00	3.63E-01	3.19E-01	0.05
SU2FSSS006C	4	6.990	N/A	1.09E+00	1.11E+00	5.45E+00	-1.32E-01	1.11E+00	5.57E-01	3.23E-01	0.06
SU2FSSS006D	4	8.990	N/A	4.16E-01	5.66E-01	4.12E+00	3.38E-01	8.31E-01	4.20E-01	4.16E-01	0.06
SU2FSSS007A	4	0.000	N/A	6.53E-01	1.07E+00	4.98E+00	1.21E+00	1.15E+00	5.08E-01	2.80E-01	0.32
SU2FSSS007B	4	2.000	N/A	1.29E+00	1.18E+00	7.16E+00	2.73E-01	9.24E-01	7.30E-01	2.92E-01	0.22
SU2FSSS007C	4	4.000	N/A	1.16E+00	1.08E+00	8.18E+00	8.18E-03	1.05E+00	8.35E-01	5.77E-01	0.20
SU2FSSS007D	4	6.000	N/A	3.59E-01	6.33E-01	5.20E+00	1.94E+00	1.53E+00	5.31E-01	5.93E-01	0.10
SU2FSSS008A	4	3.478	N/A	1.23E+00	1.27E+00	6.75E+00	5.63E-01	1.20E+00	6.89E-01	3.44E-01	0.26
SU2FSSS008B	4	5.478	N/A	7.01E-01	1.12E+00	5.86E+00	7.68E-01	1.53E+00	5.98E-01	3.30E-01	0.08
SU2FSSS008C	4	7.478	N/A	6.78E-01	7.22E-01	4.92E+00	3.57E-01	8.58E-01	5.02E-01	3.39E-01	0.07
SU2FSSS008D	4	9.478	N/A	1.08E+00	1.13E+00	5.71E+00	1.51E-01	1.36E+00	5.82E-01	2.33E-01	0.07
SU2FSSS009A	26	0.000	N/A	9.21E-01	8.90E-01	5.07E+00	4.72E-01	1.25E+00	5.17E-01	6.66E-01	0.20
SU2FSSS009B	26	2.000	N/A	9.70E-01	1.23E+00	5.90E+00	1.71E+00	1.77E+00	6.02E-01	2.96E-01	0.42
SU2FSSS009C	26	4.000	N/A	6.69E-01	1.15E+00	6.49E+00	6.29E-01	1.13E+00	6.62E-01	3.35E-01	0.26
SU2FSSS009D	26	6.000	N/A	7.89E-01	1.14E+00	5.42E+00	1.76E-01	1.22E+00	5.53E-01	6.71E-01	0.07
SU2FSSS010A	26	2.145	N/A	3.69E-01	1.16E+00	4.66E+00	5.80E-01	1.53E+00	4.76E-01	6.25E-01	0.21
SU2FSSS010B	26	4.145	N/A	8.84E-01	1.30E+00	6.30E+00	7.49E-01	1.25E+00	6.43E-01	6.46E-01	0.27
SU2FSSS010C	26	6.145	N/A	4.30E-01	1.16E+00	5.97E+00	1.02E+00	1.12E+00	6.09E-01	6.31E-01	0.09
SU2FSSS010D	26	8.145	N/A	9.50E-01	1.23E+00	9.88E+00	4.96E-01	1.10E+00	1.01E+00	6.64E-01	0.13
SU2FSSS011A	27	0.000	N/A	5.92E-01	8.29E-01	6.73E+00	4.00E-01	1.13E+00	6.87E-01	3.36E-01	0.23
SU2FSSS011B	26	2.000	N/A	4.98E-01	1.04E+00	4.56E+00	1.01E+00	1.53E+00	4.65E-01	5.30E-01	0.27
SU2FSSS011C	26	4.000	N/A	6.81E-01	1.25E+00	8.38E+00	1.94E+00	1.71E+00	8.55E-01	6.27E-01	0.52
SU2FSSS011D	27	6.000	N/A	3.92E-01	1.22E+00	6.24E+00	1.44E+00	1.69E+00	6.37E-01	3.78E-01	0.10

Sample ID	In-growth (days)	Depth (feet)	In- Situ Count Rate (cpm)	²³⁸ U		²³⁰ Th	²²⁶ Ra		²³² Th		SOF
				Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	Activity (pCi/g)	MDA (pCi/g)	
<i>SU2 Geoprobos</i>											
SU2FSSS012A	27	0.000	N/A	1.33E+00	1.30E+00	5.83E+00	<i>3.82E-01</i>	1.25E+00	<i>5.95E-01</i>	7.46E-01	0.21
SU2FSSS012B	27	2.000	N/A	<i>5.94E-01</i>	1.05E+00	8.23E+00	<i>1.05E+00</i>	1.48E+00	8.39E-01	5.55E-01	0.37
SU2FSSS012C	27	4.000	N/A	<i>1.12E+00</i>	1.16E+00	7.43E+00	<i>2.83E-01</i>	1.30E+00	7.58E-01	5.95E-01	0.23
SU2FSSS012D	27	6.000	N/A	<i>3.97E-01</i>	1.16E+00	7.64E+00	<i>8.13E-01</i>	1.10E+00	7.79E-01	2.73E-01	0.11
Average:				7.66E-01		5.64E+00	6.69E-01		5.82E-01		0.11
Std Dev.:				3.54E-01		1.69E+00	4.70E-01		1.71E-01		
UCL 95%:				1.35E+00		8.41E+00	1.44E+00		8.64E-01		
Maximum:				3.12E+00		1.25E+01	2.13E+00		1.28E+00		

Notes:

- a Highlighted cells (yellow) are values obtained via alpha spec analysis by the off-site laboratory, all other values were determined via gamma spec.
- b Bold values are values greater than MDA while italics are less than MDA.

4.4 Elevated Measurement Comparison

Following the analysis of all soil samples, as collected, there were 2 elevated areas of concern identified based upon the walkover scans and soil sampling results which were further evaluated using the Elevated Measurement Comparison test in accordance with MARSSIM. These 2 areas are provided in Figure 4-7 and the approximate size of each area documented. Based upon the Area Factors (AFs) as developed and provided in CS-313111-001, *Re-Evaluation of Breckenridge DCGLs, Gamma Scan Sensitivity, Gamma Scan Action Levels and Development of Area Factors*, corresponding AFs for each elevated area were determined using logarithmic interpolation. The dose contribution from each elevated area was then determined as provided in Table 4-4 through Table 4-5 as follows. These two elevated areas were identified for further investigation by the Radiological Engineer while performing the walkover scans and a review of the scan results by lowering the flag limit to see if there were any other areas that may be noted for sampling.

In order to conservatively estimate the dose contribution from each elevated area, the average activity was assumed to be equal to the maximum concentration of any samples taken in each corresponding area including any off-site sample result. The dose contribution was then calculated by dividing the corresponding concentration by the product of the applicable DCGL and AF. The SOF was then determined for each elevated area.

To complete the EMC evaluation, the total dose was calculated to the average member of the critical group. This was performed by adding the SOF for each elevated area and the SOF from the remaining soil samples taken throughout the survey unit. This calculation is provided in Table 4-6. The total SOF for Survey Unit 2 including the contribution from all elevated areas was 0.695, well below unity. It should be noted that this calculation is based on gross activity and does not account for natural background.

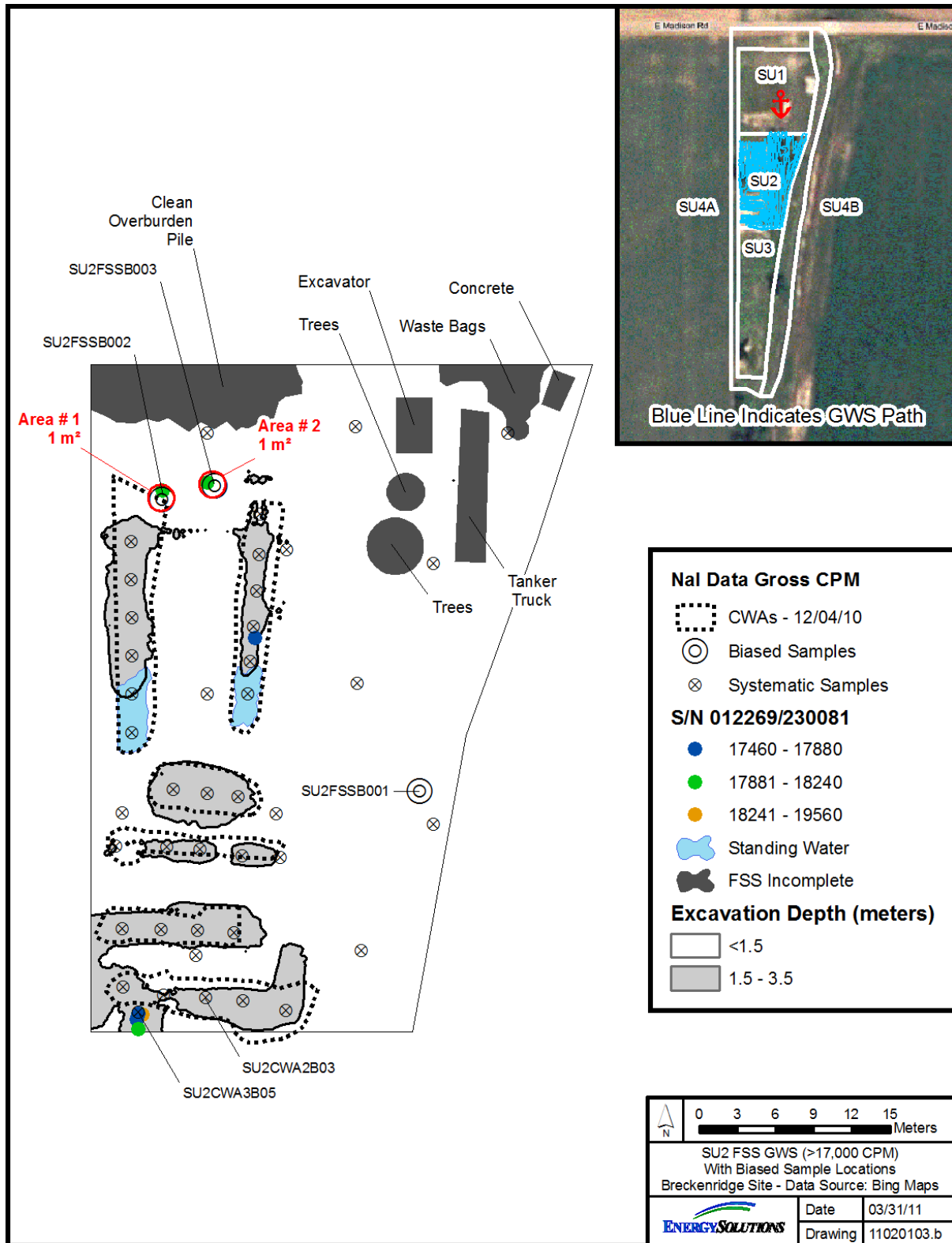


Figure 4-7 SU2 Elevated Area

Table 4-4 Elevated Area 1 SOF Contribution (1.0 m²)

	DCGL	AF	Area Activity	SOF
²³² Th + C	5.0	12.4	5.6	0.091
²³⁸ U + D	442.4	12.4	7.8	0.001
²³⁴ U	2,729	130	7.8	0.000
²³⁰ Th	276.9	17.0	53.2	0.011
²²⁶ Ra + C	6.2	14.1	4.9	0.056
				0.160

Table 4-5 Elevated Area 2 SOF Contribution (1.0 m²)

	DCGL	AF	Area Activity	SOF
²³² Th + C	5.0	12.4	7.0	0.112
²³⁸ U + D	442.4	12.4	11.9	0.002
²³⁴ U	2,729	130	11.9	0.000
²³⁰ Th	276.9	17.0	62.2	0.013
²²⁶ Ra + C	6.2	14.1	7.6	0.087
				0.215

Table 4-6 SU2 EMC Calculation

Area	SOF
S2 Average	0.320
Elevated Area 1	0.160
Elevated Area 2	0.215
	0.695

4.5 Deviations from the FSSP

It should be noted that the FSS protocols were deviated in a couple of instances within SU2 as follows, specifically for geoprobing the centerline of trenches 3 and C. This was done based upon safety considerations. Additionally, geoprobe samples were not collected at locations 1 and 2 within CWA-1 due to standing water.

A second deviation from the FSS protocols was for the geoprobe sample analyses themselves. The top 6 inches were not sampled as the surface soils were already sampled prior to geoprobing. Additionally, the full length of each geoprobe was analyzed in 2-foot composites rather than scanning the tubes and analyzing the highest 1 foot composite.

The last deviation was geoprobing each biased sample location outside the trenches. Due to weather, these biased sample locations have not been geoprobed. Subsurface samples will be collected upon re-mobilization at biased sample locations 2 and 3.

4.6 Quality Assurance

To ensure data quality, sample splits and duplicates were analyzed on-site as well as samples shipped for off-site analysis. As a minimum, 5% of all FSS samples had sample splits and/or duplicates analyzed on-site as well as 5% sent for off-site analysis. There were a total of 189 FSS samples collected and analyzed including the geoprobe composite samples. A total of 12 on-site splits and/or duplicates were analyzed and 10 shipped for off-site gamma spec analysis and isotopic thorium via alpha spec. All QA samples were evaluated using the Relative Percent Difference method with a goal of an RPD of less than or equal to 50% for samples with activity less than 5 times the MDA and 30% for those samples with higher activity.

The RPD was calculated using the equation below.

$$\% RPD = \frac{|S_1 - S_2|}{S} \times 100$$

Where: S_1 = the value for the off-site sample result (pCi/g), and
 S_2 = the value for the on-site sample result (pCi/g).

All on-site QA samples were within the acceptance criteria. A summary of the on-site QC results is provided in Table 4-7.

A summary of the off-site QC results is provided in Table 4-8. Of the 10 samples shipped for off-site QC analysis, there were 3 that failed the RPD test for U-238 as quantified from Th-234, 5 for Ra-226 and one for Th-232 as quantified from Ac-228. All other results were within the acceptance criteria. All off-site discrepancies were investigated and summarized as follows.

In regards to the U-238 analyses via Th-234, based upon discussion with the off-site laboratory, the Th-234 activity as reported is biased high due to the Ac-228 contribution to the 93 keV peak for Th-234 as they did not deconvolute the peak. In the presence of elevated Th-232 activity, the 93 keV peak of Th-234 will result in higher reported values for Th-234 due to interference from Ac-228¹. As part of the on-site laboratory analyses, these peaks were deconvoluted to remove any Ac-228 contribution to more accurately report the Th-234 activity. As part of the investigation, ALS was asked to perform a deconvolution calculation on sample SU3FSSB006 from survey unit 3. The deconvoluted activity was 7.0 pCi/g rather than the 8.9 pCi/g as reported. This resulted in an approximate overestimation of the activity by approximately 27%. Taking this into account and assuming the percent error is consistent, only one of the samples would have failed the RPD test and the result would have only been slightly above 50%. Additionally, in order to bound the impact between the laboratory discrepancies for U-238, assuming an increase in the on-site U-238 values of up to 100%, (i.e., doubling of the reported U-238 results), there would be no impact to the overall dose as the primary drivers of dose at the site are Th-232 and Ra-226.

As for the Ra-226 discrepancies, the off-site laboratory allowed for the in-growth of the Ra-226 daughters by holding the “sealed” samples a minimum of 30 days prior to sample analysis by gamma spec. The Ra-226 activity was then quantified from the Pb-214 and Bi-214 peaks which provide much more accurate results. Alternatively, the on-site samples were analyzed within a couple days of collection and could not be quantified from its daughter products because they were not in equilibrium. The Ra-226 activity was quantified by deconvoluting the 186 keV peak which will typically be overestimated due to the presence U-235. Although the amount of U-235 is low, the high 186 keV yield (approximately 54%), will result in an overestimation of Ra-226, especially, when there is any significant amount of Uranium present. Upon review of the on-site results, biased samples 1 through 3 were analyzed 21 to 23 days after they were sealed which would be close to full in-growth. In reviewing the reported Pb-214 and Bi-214 activities for these three samples, the on-site sample results for Ra-226 would be well within an RPD of 50%. Because the on-site analyses for Ra-226 were based off the 186 keV peak, it should be noted that the Ra-226 values as reported on-site and as provided in this report were generally biased high. This would result in a conservative estimate of any dose as contributed to a member of the critical group due to any residual Ra-226 activity on site.

Lastly, with regards to the one sample that failed for Th-232, the RPD was reported as 51%, slightly above the test criteria. It should be noted that the reported activities are near background and when trying to assess samples using the RPD method with low activity, the RPD can easily fail as any differences between the two analyses will be exaggerated.

¹ E-mail correspondence between Lance Steere (ALS Global) and Michael Carr (EnergySolutions); Subject: FW: Gamma Spec Analysis, questions from EnergySolutions; January 25th 2011.

Table 4-7 On-Site QA Samples (SU2)

Sample	Processed					
	²³⁸ U (pCi/g)	MDA (pCi/g)	²²⁶ Ra (pCi/g)	MDA (pCi/g)	²³² Th (pCi/g)	MDA (pCi/g)
SU2FSSB001	1.35E+00	7.14E-01	1.83E+00	1.20E+00	8.27E-01	2.57E-01
SU2FSSB001S	1.54E+00	9.96E-01	1.66E+00	1.66E+00	1.31E+00	9.25E-01
RPD	13.2%		10.1%		45.3%	
Pass / Fail	Pass		Pass		Pass	
SU2CWA1B02	2.60E+00	1.07E+00	1.15E+00	1.44E+00	1.21E+00	4.08E-01
SU2CWA1B02S	2.80E+00	1.06E+00	1.43E+00	1.46E+00	1.11E+00	3.18E-01
RPD	7.3%		21.4%		9.3%	
Pass / Fail	Pass		Pass		Pass	
SU2CWA1B02	2.60E+00	1.07E+00	1.15E+00	1.44E+00	1.21E+00	4.08E-01
SU2CWA1B02S	2.80E+00	1.06E+00	1.43E+00	1.46E+00	1.11E+00	3.18E-01
RPD	7.3%		21.4%		9.3%	
Pass / Fail	Pass		Pass		Pass	
SU2CWA2B03	1.07E+01	2.67E+00	5.27E+00	3.58E+00	1.43E+01	7.52E-01
SU2CWA2B03S	9.36E+00	2.48E+00	4.69E+00	2.97E+00	1.14E+01	7.40E-01
RPD	13.2%		11.7%		22.6%	
Pass / Fail	Pass		Pass		Pass	
SU2CWA3B05	3.30E+00	2.38E+00	1.00E+01	3.10E+00	8.74E+00	8.71E-01
SU2CWA3B05S	2.83E+00	1.79E+00	1.04E+01	3.18E+00	6.87E+00	6.70E-01
RPD	15.2%		3.5%		24.0%	
Pass / Fail	Pass		Pass		Pass	
SU2CWA1B04A	3.12E+00	1.25E+00	1.45E+00	1.63E+00	1.03E+00	6.77E-01
SU2CWA1B04AS	3.28E+00	1.07E+00	1.39E+00	1.44E+00	1.12E+00	3.38E-01
RPD	4.9%		3.9%		8.0%	
Pass / Fail	Pass		Pass		Pass	
SU2CWA2B03B	5.83E-01	1.06E+00	7.27E-01	1.10E+00	1.28E+00	3.28E-01
SU2CWA2B03BD	8.25E-01	1.35E+00	4.49E-01	1.11E+00	9.56E-01	3.12E-01
RPD	34.4%		47.3%		28.7%	
Pass / Fail	Pass		Pass		Pass	
SU2CWA8B03A	5.87E-01	1.24E+00	4.94E-01	1.13E+00	4.97E-01	5.98E-01
SU2CWA8B03AS	5.07E-01	1.28E+00	4.66E-01	8.90E-01	5.69E-01	2.80E-01
RPD	14.6%		5.8%		13.5%	
Pass / Fail	Pass		Pass		Pass	
SU2CWAAB03A	4.37E-01	1.11E+00	5.54E-01	1.32E-01	5.32E-01	2.84E-01
SU2CWAAB03AS	6.33E-01	6.48E-01	7.59E-01	9.12E-01	5.57E-01	6.41E-01
RPD	36.5%		31.3%		4.6%	
Pass / Fail	Pass		Pass		Pass	
SU2CWABB04A	1.00E+00	1.17E+00	5.56E-01	1.29E+00	1.06E+00	6.10E-01
SU2CWABB04AS	6.86E-01	8.18E-01	5.92E-01	1.16E+00	6.42E-01	3.36E-01
RPD	37.7%		6.3%		49.2%	
Pass / Fail	Pass		Pass		Pass	

Sample	Processed					
	²³⁸ U (pCi/g)	MDA (pCi/g)	²²⁶ Ra (pCi/g)	MDA (pCi/g)	²³² Th (pCi/g)	MDA (pCi/g)
SU2FSSS002A	7.43E-01	1.18E+00	5.37E-01	1.35E+00	8.77E-01	3.73E-01
SU2FSSS002AS	8.16E-01	8.37E-01	3.82E-01	1.19E+00	9.03E-01	4.21E-01
RPD	9.3%		33.6%		2.8%	
Pass / Fail	Pass		Pass		Pass	
SU2FSSS011A	5.92E-01	8.29E-01	4.00E-01	1.13E+00	6.87E-01	3.36E-01
SU2FSSS011AS	8.23E-01	1.23E+00	5.12E-01	9.37E-01	6.71E-01	3.41E-01
RPD	32.7%		24.5%		2.3%	
Pass / Fail	Pass		Pass		Pass	

Table 4-8 Off-Site QA Samples (SU2)

Sample	Processed					
	²³⁸ U (pCi/g)	MDA (pCi/g)	²²⁶ Ra (pCi/g)	MDA (pCi/g)	²³² Th (pCi/g)	MDA (pCi/g)
SU2FSSB001	1.35E+00	7.14E-01	1.83E+00	1.20E+00	8.27E-01	2.57E-01
SU2FSSB001ALS	1.00E+00	2.80E+00	1.84E+00	5.20E-01	9.00E-01	7.40E-01
RPD	29.7%		0.4%		8.5%	
Pass / Fail	Pass		Pass		Pass	
SU2FSSB002	7.77E+00	1.14E+00	4.93E+00	1.91E+00	5.62E+00	3.88E-01
SU2FSSB002ALS	1.24E+01	6.20E+00	2.45E+00	6.50E-01	5.30E+00	1.30E+00
RPD	45.9%		67.2%		5.8%	
Pass / Fail	Fail		Fail		Pass	
SU2FSSB003	1.19E+01	1.42E+00	7.62E+00	2.28E+00	6.96E+00	4.73E-01
SU2FSSB003ALS	1.44E+01	4.10E+00	3.47E+00	5.20E-01	6.59E+00	8.00E-01
RPD	19.3%		74.8%		5.5%	
Pass / Fail	Pass		Fail		Pass	
SU2CWA1B01	5.04E+00	1.03E+00	1.57E+00	1.40E+00	9.22E-01	3.63E-01
SU2CWA1B01ALS	6.22E+00	3.50E+00	1.06E+00	4.10E-01	8.90E-01	6.70E-01
RPD	21.0%		38.6%		3.6%	
Pass / Fail	Pass		Pass		Pass	
SU2CWA1B06	2.78E+00	9.68E-01	2.32E+00	1.70E+00	1.86E+00	4.10E-01
SU2CWA1B06ALS	2.40E+00	2.20E+00	9.40E-01	4.70E-01	1.72E+00	8.40E-01
RPD	14.7%		84.8%		7.7%	
Pass / Fail	Pass		Fail		Pass	
SU2CWA2B03	1.07E+01	2.67E+00	5.27E+00	3.58E+00	1.43E+01	7.52E-01
SU2CWA2B03ALS	2.32E+01	7.10E+00	3.88E+00	8.20E-01	1.40E+01	1.40E+00
RPD	73.8%		30.4%		1.9%	
Pass / Fail	Fail		Pass		Pass	
SU2CWA3B05	3.30E+00	2.38E+00	1.00E+01	3.10E+00	8.74E+00	8.71E-01
SU2CWA3B05ALS	6.60E+00	6.00E+00	1.15E+01	7.00E-01	6.70E+00	1.10E+00
RPD	66.8%		13.7%		26.5%	
Pass / Fail	Fail		Pass		Pass	
SU2CWA8B03	3.24E+00	1.50E+00	2.38E+00	2.41E+00	2.44E+00	5.18E-01
SU2CWA8B03ALS	3.30E+00	3.10E+00	1.59E+00	4.30E-01	1.78E+00	6.90E-01
RPD	1.8%		39.8%		31.5%	
Pass / Fail	Pass		Pass		Pass	
SU2CWA8B06	4.21E+00	1.08E+00	2.52E+00	1.61E+00	8.47E-01	3.04E-01
SU2CWA8B06ALS	4.90E+00	3.10E+00	1.03E+00	3.80E-01	6.50E-01	5.30E-01
RPD	15.2%		83.9%		26.3%	
Pass / Fail	Pass		Fail		Pass	
SU2CWA1B04A	3.12E+00	1.25E+00	1.45E+00	1.63E+00	1.03E+00	6.77E-01
SU2CWA1B04AALS	3.40E+00	3.00E+00	7.60E-01	5.30E-01	6.10E-01	8.20E-01
RPD	8.6%		62.3%		51.4%	
Pass / Fail	Pass		Fail		Fail	

5.0 CONCLUSIONS

Based upon the final walkover survey and sampling as summarized above, Survey Unit 2 meets the requirements for release and backfill. It has been demonstrated through the evaluation of all soil samples as collected and analyzed, including the elevated areas as identified, the overall sum of fractions is estimated to be 0.695 as presented above in the EMC evaluation for an estimated personnel dose to the average member of the critical group following backfilling of approximately 17.4 mrem.

Additionally, based upon all subsurface sampling pending upon the subsurface results at biased sample locations 2 and 3, no remaining contamination exceeds 2 feet in depth as modeled during the DCGL development. As a result, Survey Unit 2 meets the requirements for free release.

Attachment A – SU2 Survey / Sampling Design

Systematic sampling locations for comparing a median with a fixed threshold (nonparametric - MARSSIM)

Summary

This report summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design developed. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean or median to a fixed threshold
Type of Sampling Design	Nonparametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The median(mean) value at the site exceeds the threshold
Formula for calculating number of sampling locations	Sign Test - MARSSIM version
Calculated total number of samples	12
Number of samples on map ^a	12
Number of selected sample areas ^b	1
Specified sampling area ^c	1450.33 m ²
Size of grid / Area of grid cell ^d	38.7581 feet / 1300.93 ft ²
Grid pattern	Triangular
Total cost of sampling ^e	\$7,000.00

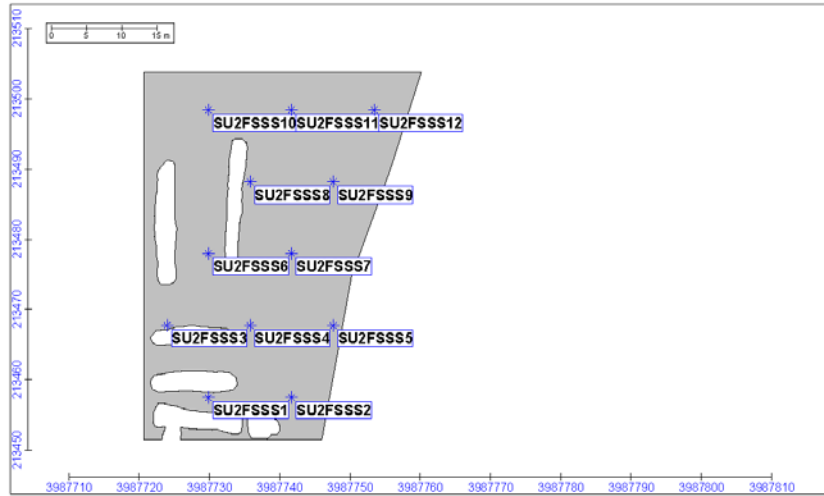
^a This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.

^b The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.

^c The sampling area is the total surface area of the selected colored sample areas on the map of the site.

^d Size of grid / Area of grid cell gives the linear and square dimensions of the grid used to systematically place samples.

^e Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.



Area: SU2						
X Coord	Y Coord	Label	Value	Type	Historical	Ref/Surv
3987729.8985	213457.4698	SU2FSSS1		Systematic		Undefined
3987741.7119	213457.4698	SU2FSSS2		Systematic		Undefined
3987723.9917	213467.7006	SU2FSSS3		Systematic		Undefined
3987735.8052	213467.7006	SU2FSSS4		Systematic		Undefined
3987747.6187	213467.7006	SU2FSSS5		Systematic		Undefined
3987729.8985	213477.9313	SU2FSSS6		Systematic		Undefined
3987741.7119	213477.9313	SU2FSSS7		Systematic		Undefined
3987735.8052	213488.1621	SU2FSSS8		Systematic		Undefined
3987747.6187	213488.1621	SU2FSSS9		Systematic		Undefined
3987729.8985	213498.3929	SU2FSSS10		Systematic		Undefined
3987741.7119	213498.3929	SU2FSSS11		Systematic		Undefined
3987753.5254	213498.3929	SU2FSSS12		Systematic		Undefined

Primary Sampling Objective

The primary purpose of sampling at this site is to compare a site median or mean value with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the median(mean) value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the median(mean) value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative one, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach

A nonparametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A nonparametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that typical parametric assumptions may not be true.

Both parametric and non-parametric equations rely on assumptions about the population. Typically, however, non-parametric equations require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually

less than if a non-parametric equation was used.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs

The equation used to calculate the number of samples is based on a Sign test (see PNNL 13450 for discussion). For this site, the null hypothesis is rejected in favor of the alternative one if the median(mean) is sufficiently smaller than the threshold. The number of samples to collect is calculated so that if the inputs to the equation are true, the calculated number of samples will cause the null hypothesis to be rejected.

The formula used to calculate the number of samples is:

$$n = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4(\text{Sign}P - 0.5)^2}$$

where

$$\text{Sign}P = \Phi\left(\frac{\Delta}{S_{total}}\right)$$

- $\Phi(z)$ is the cumulative standard normal distribution on $(-\infty, z)$ (see PNNL-13450 for details),
- n is the number of samples,
- S_{total} is the estimated standard deviation of the measured values including analytical error,
- Δ is the width of the gray region,
- α is the acceptable probability of incorrectly concluding the site median(mean) is less than the threshold,
- β is the acceptable probability of incorrectly concluding the site median(mean) exceeds the threshold,
- $Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is $1-\alpha$,
- $Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is $1-\beta$.

Note: MARSSIM suggests that the number of samples should be increased by at least 20% to account for missing or unusable data and uncertainty in the calculated value of n. VSP allows a user-supplied percent overage as discussed in MARSSIM (EPA 2000, p. 5-33).

The values of these inputs that result in the calculated number of sampling locations are:

Analyte	n ^a	Parameter					
		S	Δ	α	β	$Z_{1-\alpha}$ ^b	$Z_{1-\beta}$ ^c
Analyte 1	12	2566	6079	0.05	0.1	1.64485	1.28155

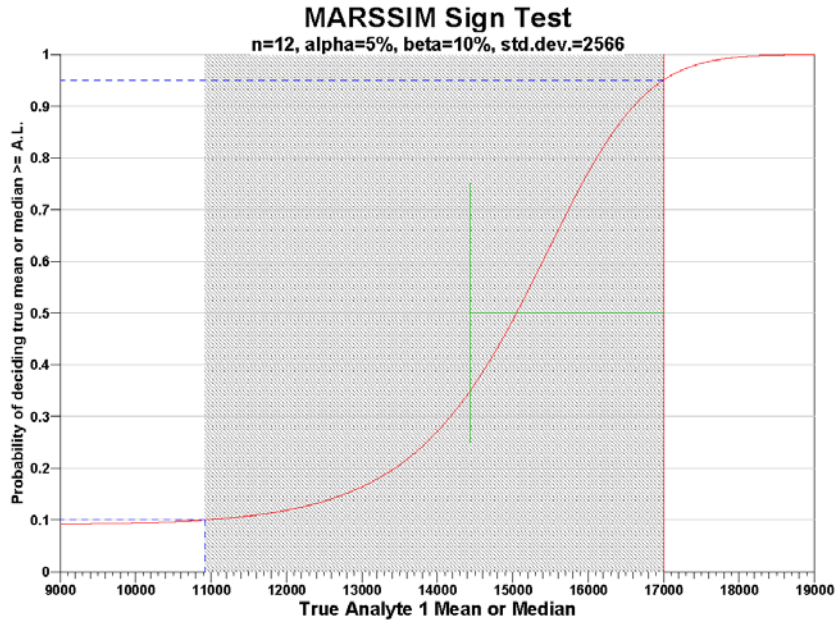
^a The final number of samples has been increased by the MARSSIM Overage of 30%.

^b This value is automatically calculated by VSP based upon the user defined value of α .

^c This value is automatically calculated by VSP based upon the user defined value of β .

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true median(mean) values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ ; the upper horizontal dashed blue line is positioned at $1-\alpha$ on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at $1-\alpha$. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions

The assumptions associated with the formulas for computing the number of samples are:

1. the computed sign test statistic is normally distributed,
2. the variance estimate, S^2 , is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis

The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that $\mu >$ action level and alpha (%), probability of mistakenly concluding that $\mu <$ action level. The following table shows the results of this analysis.

		Number of Samples					
		$\alpha=5$		$\alpha=10$		$\alpha=15$	
		s=5132	s=2566	s=5132	s=2566	s=5132	s=2566
AL=17000	$\beta=5$	210	59	167	47	140	39
	$\beta=10$	167	47	128	37	104	30
	$\beta=15$	140	39	104	30	84	24
LBGR=90	$\beta=5$	59	23	47	17	39	15
	$\beta=10$	47	17	37	13	30	12
	$\beta=15$	39	15	30	12	24	10
LBGR=80	$\beta=5$	32	16	25	13	21	11
	$\beta=10$	25	13	20	11	16	8
	$\beta=15$	21	11	16	8	13	7

s = Standard Deviation
 LBGR = Lower Bound of Gray Region (% of Action Level)
 β = Beta (%), Probability of mistakenly concluding that $\mu >$ action level
 α = Alpha (%), Probability of mistakenly concluding that $\mu <$ action level
 AL = Action Level (Threshold)

Cost of Sampling

The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is \$7,000.00, which averages out to a per sample cost of \$583.33. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	Per Analysis	Per Sample	12 Samples
Field collection costs		\$100.00	\$1,200.00
Analytical costs	\$400.00	\$400.00	\$4,800.00
Sum of Field & Analytical costs		\$500.00	\$6,000.00
Fixed planning and validation costs			\$1,000.00
Total cost			\$7,000.00

Recommended Data Analysis Activities

Post data collection activities generally follow those outlined in EPA's Guidance for Data Quality Assessment (EPA, 2000). The data analysts will become familiar with the context of the problem and goals for data collection and assessment. The data will be verified and validated before being subjected to statistical or other analyses. Graphical and analytical tools will be used to verify to the extent possible the assumptions of any statistical analyses that are performed as well as to achieve a general understanding of the data. The data will be assessed to determine whether they are adequate in both quality and quantity to support the primary objective of sampling.

Because the primary objective for sampling for this site is to compare the site median(mean) value with a threshold value, the data will be assessed in this context. Assuming the data are adequate, at least one statistical test will be done to perform a comparison between the data and the threshold of interest. Results of the exploratory and quantitative assessments of the data will be reported, along with conclusions that may be supported by them.

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