ENERGYSOLUTIONS

CS-313111-002

Final Status Survey Report
Breckenridge Disposal Site
Survey Package - SU3

Madison Road
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Project No. 313111 **Revision 0**

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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) 3 of the Breckenridge Disposal Site (BDS) prior to completion of backfilling activities. The Final Status Survey (FSS) of SU3 incorporated a variety of on-site radiological surveys and measurement techniques as well as off-site laboratory analysis of soil samples for quality control. Energy*Solutions* 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 Energy*Solutions* 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.

$$^{232}Th+C,\ ^{238}U+D,\ ^{234}U,\ ^{230}Th,\ and\ ^{226}Ra+C$$

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 Energy*Solutions* 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 Energy*Solutions* 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 Energy*Solutions* 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 3 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 3.

SU3 is located at the south end of the site from the south fence extending to just south of contaminated waste area (CWA) 2. The survey unit is 1,642 square meters in size and encompasses CWA-4, CWA-5, CWA-6, CWA-7 and most of CWA-3. Figure 3-1 provides the location of SU3.

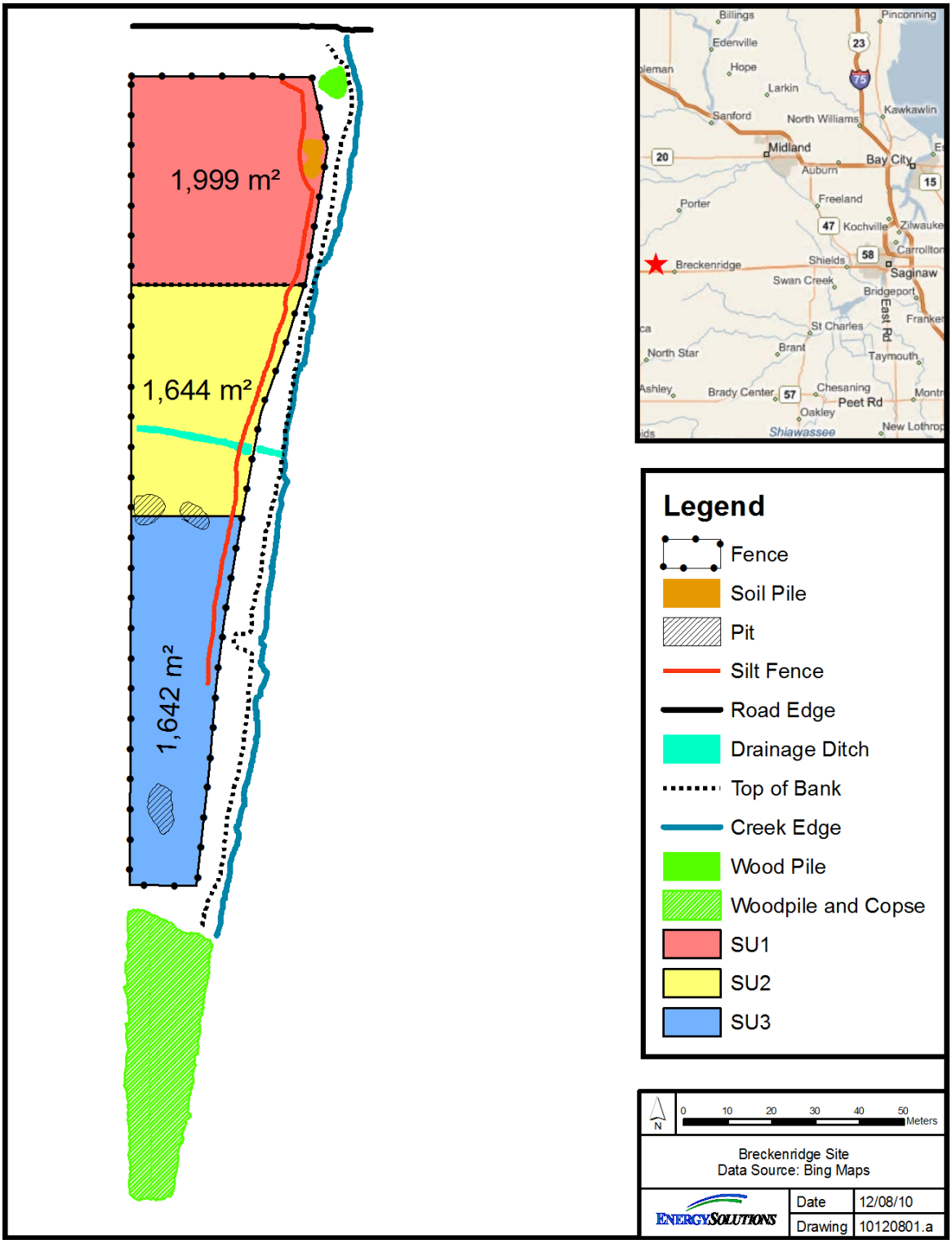


Figure 3-1 Breckenridge Survey Units

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.

As each lift was removed, walkover scans were re-performed, in-situ measurements recorded and samples collected and analyzed throughout the area. This was performed to provide site specific data and to refine the site specific action levels. Over the course of site remediation, these action levels were finalized at 18,000 gross cpm and 31,000 gross cpm as documented in Energy*Solutions* 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

SU3 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.

3.4 Biased Sampling

In addition to the systematic 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.

In addition, biased sampling will be 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.

3.5 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. Each core sample was scanned with gamma detection field instrumentation along its length and the core sample composited into specific sample depths. Provided no elevated measurements were identified, the core was composited as directed by the RE and/or PHP.

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 3 are provided as follows:

4.1 SU3 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, the walkover survey was also plotted and all areas exceeding the “surface” action level of 18,000 gross cpm 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.

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

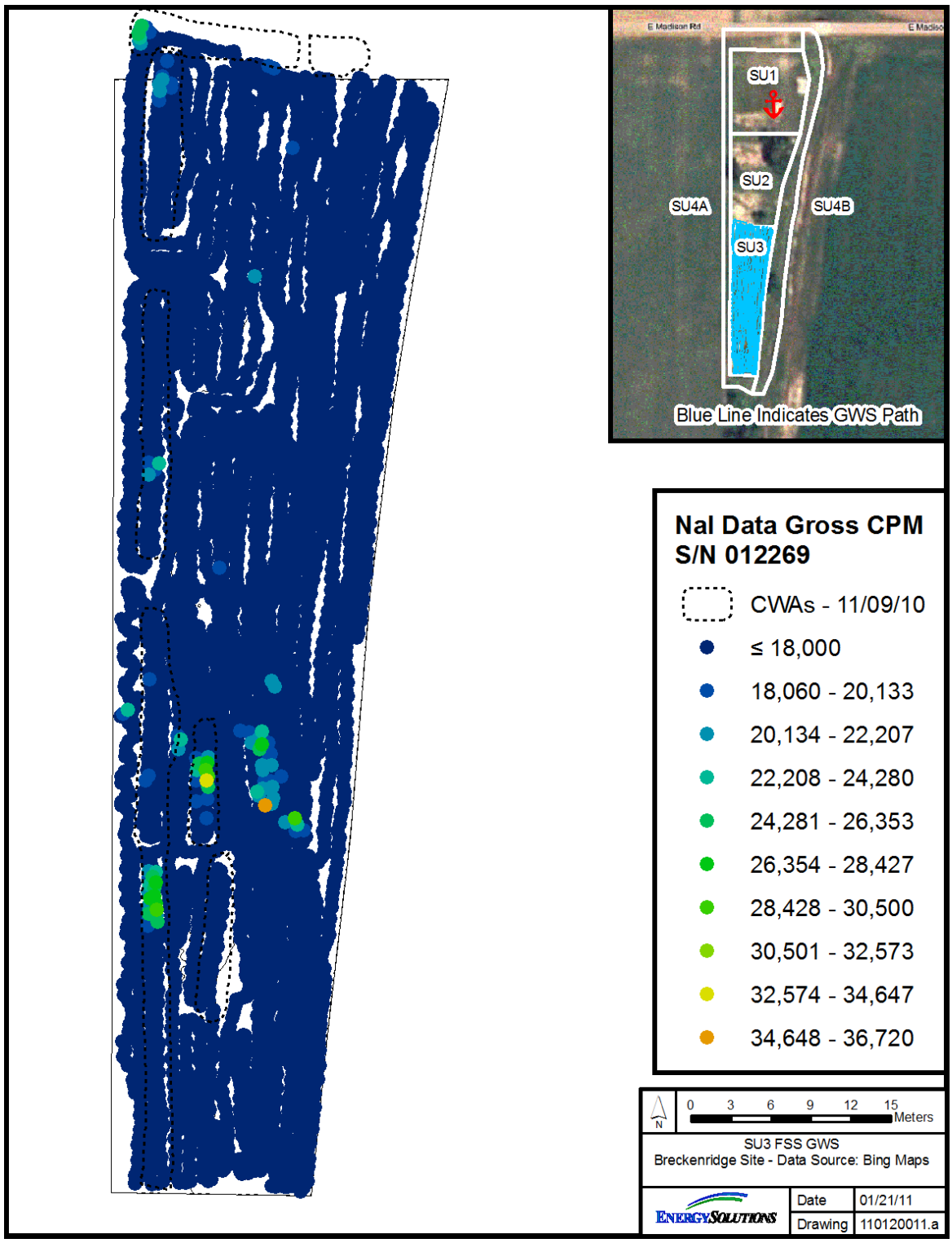


Figure 4-1 SU3 Final Status Survey Map – Walkover Scan

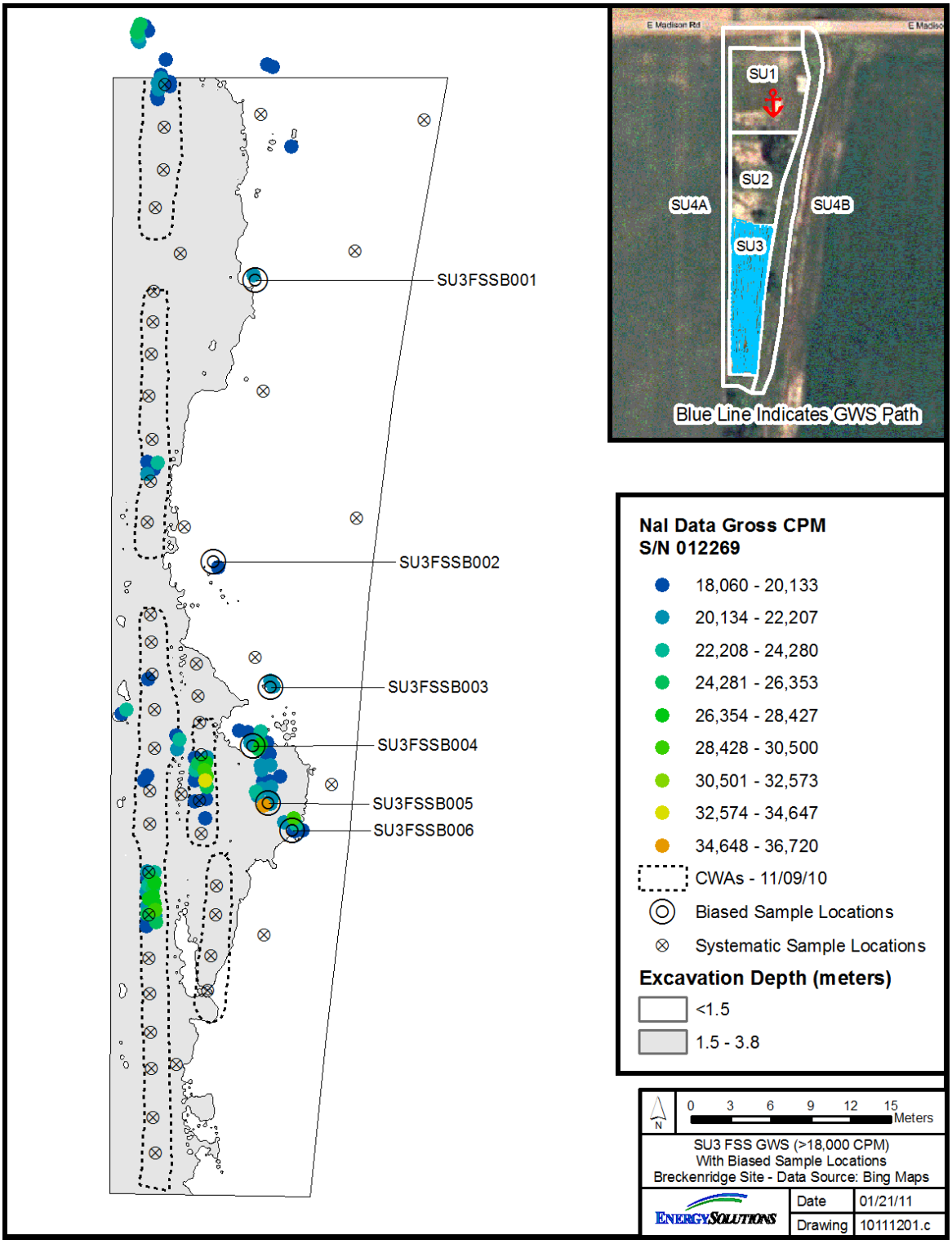


Figure 4-2 SU3 Final Status Survey Map – Walkover Scan > 18,000 cpm

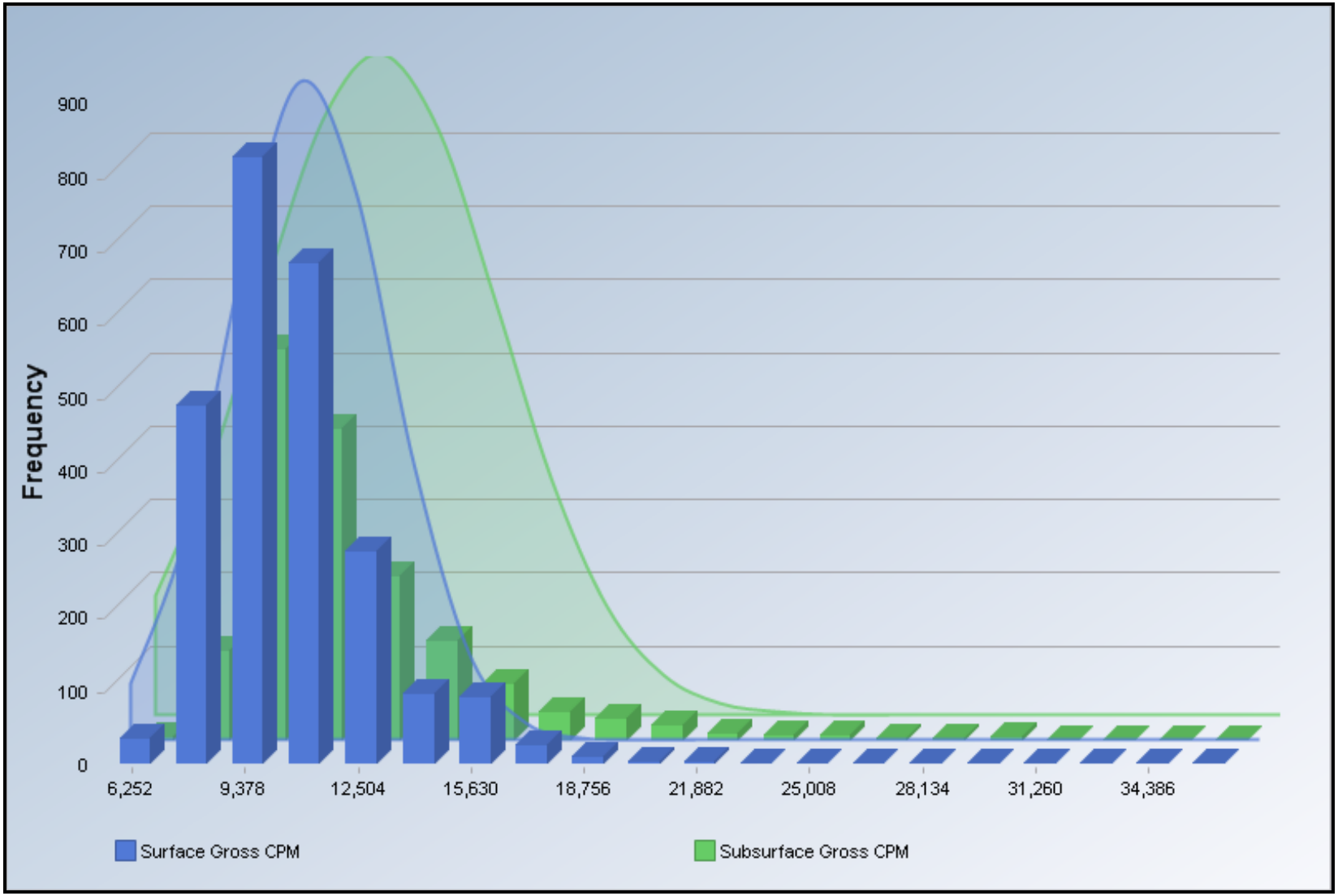


Figure 4-3 SU3 Walkover Scan Histogram

Summary Statistics for Raw Full Data Sets

Variable	NumObs	Minimum	Maximum	Mean	Median	Variance	SD	MAD/0.675	Skewness	Kurtosis	CV
Surface Gross CPM	2544	5460	28320	10362	10020	4883166	2210	1868	1.52	4.847	0.213
Subsurface Gross CPM	1645	6720	36720	11629	10680	11069347	3327	2046	2.288	7.868	0.286

Percentiles for Raw Full Data Sets

Variable	NumObs	5%ile	10%ile	20%ile	25%ile(Q1)	50%ile(Q2)	75%ile(Q3)	80%ile	90%ile	95%ile	99%ile

Figure 4-4 SU3 Walkover Scan Statistics

4.2 Surface Soil Sampling and Results – SU3

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 SU3 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, 6 biased samples were taken at elevated areas based upon the final walkover scan survey as show in Figure 4-2 above. 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 Energy*Solutions* 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, 5 elevated areas were identified with a SOF near or above unity. These 5 areas are addressed in the Elevated Measurement Comparison section below.

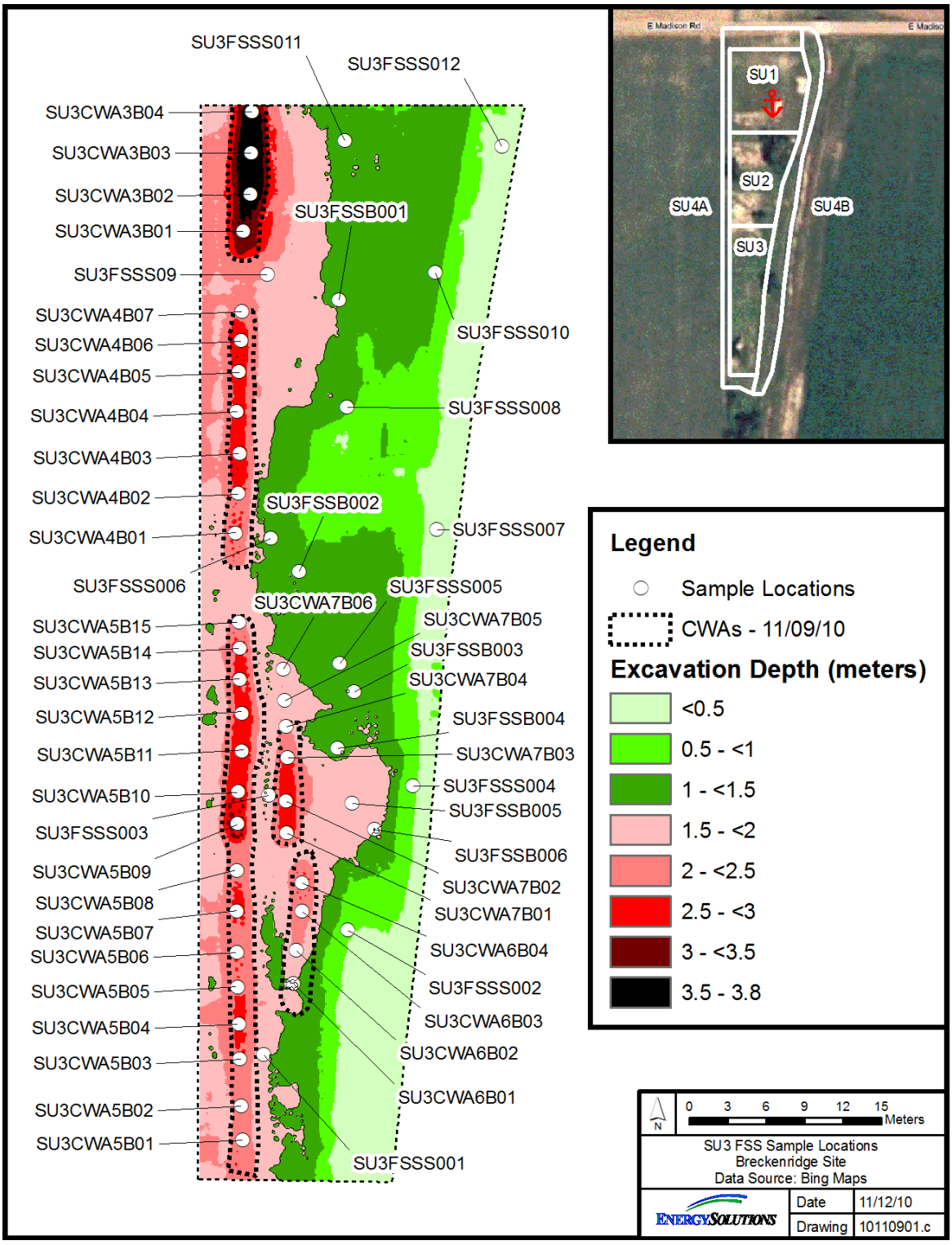


Figure 4-5 SU3 Final Status Surface Sampling Map

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)	
Systematic / Biased Samples											
SU3FSSS001	0	6.877	9,294	*4.47E-01*	6.64E-01	4.28E+00	*2.49E-01*	6.53E-01	**4.36E-01**	1.23E-01	0.06
SU3FSSS002	0	2.657	9,066	**6.31E-01**	5.82E-01	7.35E+00	**1.43E+00**	1.02E+00	**7.50E-01**	1.79E-01	0.41
SU3FSSS003	2	7.610	10,179	**2.42E+00**	9.05E-01	2.80E+01	**2.50E+00**	1.73E+00	**2.86E+00**	2.92E-01	0.38
SU3FSSS004	0	0.000	12,328	**1.08E+00**	6.48E-01	1.24E+01	*2.57E-01*	1.11E+00	**1.26E+00**	2.17E-01	0.34
SU3FSSS005	0	4.901	10,216	**1.08E+00**	8.24E-01	8.21E+00	*8.43E-01*	1.08E+00	**8.37E-01**	1.54E-01	0.11
SU3FSSS006	0	5.257	8,967	*5.44E-01*	6.10E-01	7.23E+00	*9.15E-01*	1.01E+00	**7.38E-01**	2.15E-01	0.10
SU3FSSS007	0	0.000	9,496	*7.69E-01*	8.59E-01	7.57E+00	**9.34E-01**	8.69E-01	**7.72E-01**	2.08E-01	0.33
SU3FSSS008	2	3.979	11,019	*3.22E-01*	7.04E-01	6.55E+00	*9.16E-01*	9.19E-01	**6.69E-01**	2.13E-01	0.31
SU3FSSS009	2	6.655	10,056	*6.76E-01*	9.01E-01	9.77E+00	**1.37E+00**	1.22E+00	**9.97E-01**	2.53E-01	0.14
SU3FSSS010	2	4.191	10,143	*5.02E-01*	5.83E-01	6.46E+00	*1.00E+00*	1.30E+00	**6.59E-01**	2.02E-01	0.32
SU3FSSS011	2	4.931	13,019	**9.27E-01**	7.89E-01	1.40E+01	**1.80E+00**	1.32E+00	**1.43E+00**	3.29E-01	0.20
SU3FSSS012	2	0.000	9,294	*4.46E-01*	8.44E-01	5.42E+00	*4.60E-01*	9.08E-01	**5.53E-01**	1.72E-01	0.21
SU3FSSB001	0	4.875	15,447	**4.73E+00**	1.94E+00	6.10E+01	**2.94E+00**	2.78E+00	**6.20E+00**	7.18E-01	0.78
SU3FSSB002	0	4.875	18,954	*7.66E-01*	2.67E+00	5.13E+01	*2.02E+00*	3.03E+00	**3.60E+00**	9.33E-01	0.62
SU3FSSB003	0	4.875	18,583	**5.55E+00**	1.52E+00	5.41E+01	*2.03E+00*	2.18E+00	**3.73E+00**	5.91E-01	0.65
SU3FSSB004	0	5.257	18,092	**3.05E+00**	1.09E+00	4.14E+00	*7.95E-01*	1.27E+00	**8.21E-01**	4.09E-01	**0.07**
SU3FSSB005	0	5.257	31,578	**3.94E+00**	1.20E+00	1.77E+01	*1.29E+00*	1.79E+00	**1.87E+00**	4.52E-01	**0.24**
SU3FSSB006	0	5.257	22,532	**6.14E+00**	1.80E+00	8.00E+01	**2.91E+00**	2.30E+00	**6.38E+00**	5.48E-01	**0.97**
		Average:		**1.89E+00**		**2.14E+01**	**1.37E+00**		**1.92E+00**		**0.35**
		Std Dev.:		**1.93E+00**		**2.34E+01**	**8.35E-01**		**1.88E+00**		
		UCL 95%:		**5.07E+00**		**6.00E+01**	**2.74E+00**		**5.02E+00**		
		Maximum:		**6.14E+00**		**8.00E+01**	**2.94E+00**		**6.38E+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)	
SU3 Trenches (CWAs)											
SU3CWA3B01	0	11.050	14,679	*5.37E-01*	1.19E+00	5.96E+00	**1.78E+00**	1.50E+00	**6.08E-01**	3.21E-01	0.11
SU3CWA3B02	1	12.025	11,847	*5.03E-01*	1.33E+00	9.90E+00	*8.61E-01*	1.56E+00	**1.01E+00**	3.04E-01	0.13
SU3CWA3B03	1	12.350	12,114	*4.55E-01*	1.19E+00	4.30E+00	**2.43E+00**	1.73E+00	**4.39E-01**	4.10E-01	0.10
SU3CWA3B04	1	11.700	20,201	*1.40E+00*	1.79E+00	2.80E+00	**2.88E+00**	2.40E+00	**4.32E+00**	5.42E-01	0.15
SU3CWA4B01	0	8.668	11,606	**1.17E+00**	1.07E+00	9.73E+00	*7.54E-01*	1.58E+00	**9.93E-01**	3.49E-01	0.13
SU3CWA4B02	0	8.544	13,050	*9.13E-01*	1.22E+00	7.75E+00	*1.02E+00*	1.63E+00	**7.91E-01**	3.57E-01	0.11
SU3CWA4B03	0	9.692	27,490	**9.28E+00**	2.63E+00	2.22E+01	**6.45E+00**	3.32E+00	**1.43E+01**	7.71E-01	0.57
SU3CWA4B04	0	9.828	11,482	**1.74E+00**	1.24E+00	2.59E+00	*1.32E+00*	1.63E+00	**8.39E-01**	4.05E-01	0.07
SU3CWA4B05	0	9.573	11,918	*1.05E+00*	1.24E+00	5.52E+00	*1.12E+00*	1.27E+00	**5.63E-01**	3.19E-01	0.09
SU3CWA4B06	0	9.643	12,857	*1.04E+00*	1.26E+00	8.47E+00	*5.21E-01*	1.12E+00	**8.64E-01**	6.82E-01	0.11
SU3CWA4B07	0	8.872	16,567	**1.23E+01**	1.98E+00	**1.48E+02**	**4.43E+00**	2.85E+00	**1.20E+01**	6.59E-01	**1.78**
SU3CWA5B01	1	7.070	9,374	*6.70E-01*	7.43E-01	9.14E+00	*5.87E-01*	1.19E+00	**9.32E-01**	5.94E-01	0.12
SU3CWA5B02	1	8.096	9,383	*1.85E-01*	1.23E+00	5.52E+00	*8.13E-01*	1.66E+00	**5.63E-01**	2.02E-01	0.08
SU3CWA5B03	1	8.569	9,862	**1.64E+00**	1.54E+00	5.67E+00	*5.50E-01*	1.85E+00	*5.79E-01*	6.86E-01	0.08
SU3CWA5B04	0	9.473	9,530	*6.86E-01*	1.28E+00	5.97E+00	*4.86E-01*	1.03E+00	**6.09E-01**	3.76E-01	0.08
SU3CWA5B05	0	8.520	9,138	*5.22E-01*	1.31E+00	7.75E+00	*1.64E+00*	1.69E+00	**7.90E-01**	3.16E-01	0.12
SU3CWA5B06	0	9.153	9,738	*7.32E-01*	1.31E+00	6.00E+00	*1.13E+00*	1.67E+00	**6.12E-01**	2.97E-01	0.09
SU3CWA5B07	0	9.467	26,693	**4.49E+00**	1.34E+00	8.24E+00	*8.02E-01*	1.82E+00	**8.41E-01**	3.77E-01	0.11
SU3CWA5B08	0	8.144	26,453	**1.30E+01**	2.75E+00	**1.26E+02**	**4.99E+00**	3.50E+00	**1.72E+01**	8.12E-01	**1.65**
SU3CWA5B09	0	10.672	11,366	*1.07E+00*	1.16E+00	6.02E+00	*9.84E-01*	1.52E+00	**6.14E-01**	3.64E-01	0.09
SU3CWA5B10	0	11.282	11,749	*4.51E-01*	1.16E+00	5.87E+00	*8.12E-01*	1.02E+00	*5.99E-01*	6.01E-01	0.09
SU3CWA5B11	0	9.850	14,145	**2.70E+00**	1.08E+00	1.75E+01	*9.98E-01*	1.42E+00	**1.78E+00**	4.34E-01	0.23
SU3CWA5B12	0	10.281	13,186	**1.34E+00**	1.05E+00	8.62E+00	*1.44E+00*	1.83E+00	**8.79E-01**	3.42E-01	0.13
SU3CWA5B13	0	9.511	13,916	*7.39E-01*	1.24E+00	4.68E+00	*4.56E-01*	1.31E+00	*4.78E-01*	5.76E-01	0.06

Sample ID	In-growth (days)	Depth (feet)	In- Situ Count Rate (cpm)	^{238}U Activity (pCi/g)	^{238}U MDA (pCi/g)	^{230}Th Activity (pCi/g)	^{226}Ra Activity (pCi/g)	^{226}Ra MDA (pCi/g)	^{232}Th Activity (pCi/g)	^{232}Th MDA (pCi/g)	SOF
SU3 Trenches (CWAs)											
SU3CWA5B14	0	9.548	14,945	**2.41E+00**	1.29E+00	3.03E+01	**1.93E+00**	1.85E+00	**2.52E+00**	5.29E-01	0.39
SU3CWA5B15	0	7.737	11,299	**1.21E+00**	8.05E-01	4.75E+00	**1.97E+00**	1.88E+00	**6.56E-01**	6.09E-01	0.10
SU3CWA6B01	0	3.152	9,805	*1.12E+00*	1.33E+00	6.26E+00	*7.96E-01*	1.48E+00	*6.38E-01*	6.57E-01	0.28
SU3CWA6B02	0	3.974	10,017	*1.49E+00*	1.65E+00	7.70E+00	*1.31E+00*	1.35E+00	**1.22E+00**	4.05E-01	0.49
SU3CWA6B03	0	4.751	10,425	**1.90E+00**	1.50E+00	7.05E+00	*1.53E-01*	1.33E+00	**7.19E-01**	7.15E-01	0.20
SU3CWA6B04	0	5.745	11,190	**1.47E+00**	1.04E+00	9.59E+00	*1.51E+00*	1.73E+00	**9.79E-01**	3.45E-01	0.14
SU3CWA7B01	0	9.747	13,137	**1.14E+00**	9.59E-01	8.79E+00	*5.37E-01*	1.03E+00	**8.97E-01**	3.05E-01	0.11
SU3CWA7B02	0	8.486	17,485	**8.48E+00**	1.83E+00	**1.31E+02**	**3.75E+00**	2.72E+00	**8.03E+00**	5.67E-01	**1.54**
SU3CWA7B03	0	8.619	18,959	**3.47E+00**	9.59E-01	4.62E+00	*1.19E+00*	1.42E+00	**9.74E-01**	3.21E-01	0.09
SU3CWA7B04	0	7.332	10,275	*1.79E-01*	1.21E+00	9.17E+00	*4.16E-01*	1.74E+00	**9.35E-01**	3.28E-01	0.12
SU3CWA7B05	0	6.581	10,589	**1.96E+00**	9.16E-01	6.90E+00	*3.35E-01*	1.32E+00	**1.30E+00**	3.27E-01	0.10
SU3CWA7B06	0	6.160	11,554	*4.01E-01*	1.33E+00	1.13E+01	*1.22E+00*	1.23E+00	**1.16E+00**	3.29E-01	0.16
		Average:		**2.33E+00**		**1.89E+01**	**1.51E+00**		**2.31E+00**		**0.28**
		Std Dev.:		**3.22E+00**		**3.60E+01**	**1.39E+00**		**4.01E+00**		
		UCL 95%:		**7.64E+00**		**7.81E+01**	**3.80E+00**		**8.92E+00**		
		Maximum:		**1.30E+01**		**1.48E+02**	**6.45E+00**		**1.72E+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.
c Bold “red” values are samples from suspect or elevated areas excluded from the survey unit average and included in the EMC evaluations.

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 the trenches as originally planned due to their depth and for safety reasons. Because of the overall depth of the trenches and the narrow width, it was determined that it was not safe to try and access the trenches with the geoprobe unit. Additionally, based upon the soil type encountered at the bottoms of the trenches, compacted virgin clay, it would not be effective to attempt to geoprobe the trenches within SU3. As an alternative, subsurface samples were collected at sampling locations with activity using a pick ax to sample approximately 6-inches below the surface.

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.

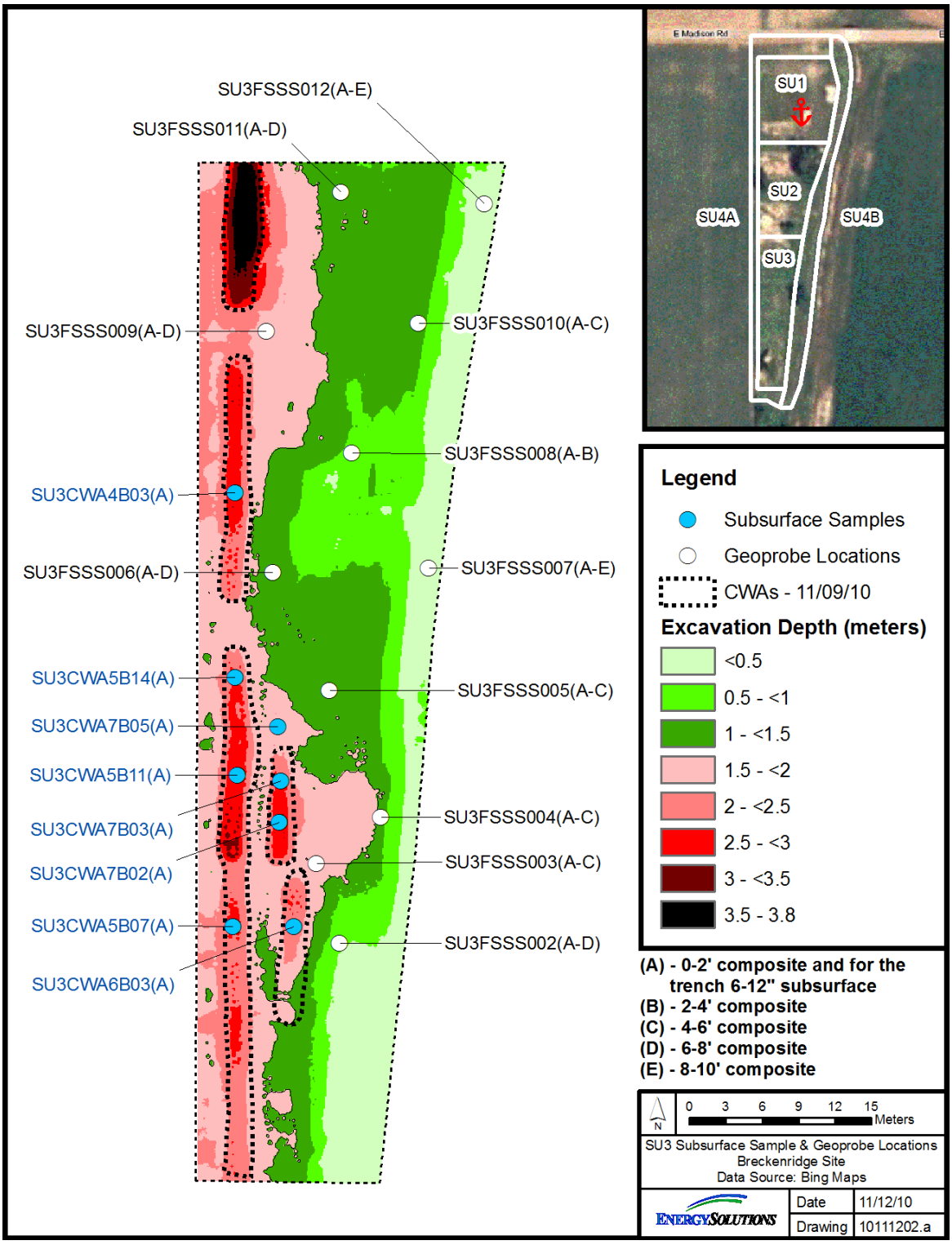


Figure 4-6 SU3 Final Status Subsurface Sampling Map

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)	
SU3 Subsurface / Geoprobes											
SU3FSSS002A	0	2.657	N/A	**1.06E+00**	8.14E-01	5.73E+00	*3.37E-01*	1.09E+00	*5.85E-01*	6.59E-01	0.19
SU3FSSS002B	1	4.657	N/A	*1.05E+00*	1.14E+00	4.41E+00	*3.21E-01*	1.07E+00	**4.50E-01**	3.37E-01	0.16
SU3FSSS002C	0	6.657	N/A	*4.71E-01*	1.08E+00	5.49E+00	*6.44E-01*	1.03E+00	**5.60E-01**	2.04E-01	0.08
SU3FSSS002D	1	8.657	N/A	*6.93E-01*	1.14E+00	5.75E+00	*3.49E-01*	1.60E+00	**5.87E-01**	3.52E-01	0.07
SU3FSSS003A	1	7.610	N/A	*9.73E-01*	1.05E+00	5.40E+00	*2.41E-01*	7.51E-01	**5.51E-01**	3.05E-01	0.07
SU3FSSS003B	0	9.610	N/A	*1.61E-01*	1.17E+00	5.08E+00	*9.57E-01*	1.11E+00	*5.18E-01*	6.51E-01	0.08
SU3FSSS003C	0	11.610	N/A	*5.77E-01*	1.14E+00	3.75E+00	*5.01E-01*	1.55E+00	*3.82E-01*	5.91E-01	0.05
SU3FSSS004A	1	0.000	N/A	*6.33E-01*	1.19E+00	7.39E+00	*8.49E-01*	1.67E+00	**7.54E-01**	2.84E-01	0.32
SU3FSSS004B	1	2.000	N/A	*4.84E-01*	1.16E+00	4.13E+00	*5.23E-01*	1.64E+00	*4.22E-01*	6.55E-01	0.18
SU3FSSS004C	0	4.000	N/A	*9.64E-01*	1.10E+00	6.55E+00	*9.22E-01*	1.15E+00	**6.69E-01**	5.49E-01	0.31
SU3FSSS005A	0	4.901	N/A	*9.64E-01*	1.09E+00	3.83E+00	*5.91E-01*	1.22E+00	**3.91E-01**	2.33E-01	0.06
SU3FSSS005B	0	6.901	N/A	*5.04E-01*	1.08E+00	4.39E+00	*2.69E-01*	1.06E+00	*4.48E-01*	5.88E-01	0.06
SU3FSSS005C	0	8.901	N/A	*5.17E-01*	7.42E-01	5.26E+00	*5.67E-01*	8.78E-01	**5.36E-01**	3.06E-01	0.07
SU3FSSS006A	1	5.257	N/A	*6.08E-01*	1.10E+00	4.62E+00	*3.46E-01*	9.73E-01	*4.72E-01*	5.70E-01	0.06
SU3FSSS006B	1	7.257	N/A	*5.23E-01*	1.26E+00	5.13E+00	*1.35E+00*	1.59E+00	**5.24E-01**	2.45E-01	0.09
SU3FSSS006C	1	9.257	N/A	*1.03E+00*	1.20E+00	6.06E+00	*3.58E-01*	1.55E+00	*6.19E-01*	6.44E-01	0.08
SU3FSSS006D	1	11.257	N/A	*9.09E-01*	1.20E+00	5.71E+00	*4.46E-01*	1.07E+00	**5.83E-01**	5.81E-01	0.08
SU3FSSS007A	1	0.000	N/A	*6.73E-01*	1.28E+00	4.55E+00	*6.41E-01*	1.10E+00	*4.64E-01*	6.35E-01	0.21
SU3FSSS007B	0	2.000	N/A	*7.43E-01*	1.24E+00	2.71E+00	*7.96E-01*	1.35E+00	*2.77E-01*	5.61E-01	0.20
SU3FSSS007C	0	4.000	N/A	*5.40E-01*	1.21E+00	7.27E+00	*7.21E-01*	9.76E-01	**7.41E-01**	2.83E-01	0.29
SU3FSSS007D	0	6.000	N/A	*8.05E-01*	1.08E+00	5.20E+00	*4.33E-01*	1.50E+00	*5.31E-01*	5.45E-01	0.07

Sample ID	In-growth (days)	Depth (feet)	In- Situ Count Rate (cpm)	^{238}U Activity (pCi/g)	^{238}U MDA (pCi/g)	^{230}Th Activity (pCi/g)	^{226}Ra Activity (pCi/g)	^{226}Ra MDA (pCi/g)	^{232}Th Activity (pCi/g)	^{232}Th MDA (pCi/g)	SOF
SU3 Subsurface / Geoprobes											
SU3FSSS007E	0	8.000	N/A	*6.48E-01*	1.12E+00	8.29E+00	*1.07E+00*	1.69E+00	**8.46E-01**	6.43E-01	0.12
SU3FSSS008A	0	3.979	N/A	*8.47E-01*	1.27E+00	9.11E+00	*1.23E+00*	1.84E+00	**9.30E-01**	3.37E-01	0.42
SU3FSSS008B	0	5.979	N/A	*2.42E-01*	1.08E+00	4.45E+00	**1.20E+00**	1.09E+00	*4.54E-01*	5.71E-01	0.08
SU3FSSS009A	0	6.655	N/A	*8.82E-01*	1.15E+00	4.29E+00	*5.32E-01*	1.08E+00	**4.38E-01**	3.20E-01	0.06
SU3FSSS009B	1	8.655	N/A	*4.54E-01*	1.07E+00	4.55E+00	*3.01E-01*	1.06E+00	*4.64E-01*	7.12E-01	0.06
SU3FSSS009C	1	10.655	N/A	*6.63E-01*	1.24E+00	4.98E+00	*1.11E+00*	1.27E+00	**5.08E-01**	3.63E-01	0.08
SU3FSSS009D	1	12.655	N/A	*8.64E-01*	1.11E+00	7.47E+00	**1.35E+00**	1.22E+00	**7.62E-01**	5.80E-01	0.11
SU3FSSS010A	1	4.191	N/A	*5.31E-01*	1.19E+00	6.76E+00	*8.95E-01*	1.35E+00	**6.90E-01**	3.66E-01	0.31
SU3FSSS010B	1	6.191	N/A	*5.81E-01*	1.20E+00	3.36E+00	*4.18E-01*	1.57E+00	*3.43E-01*	5.93E-01	0.05
SU3FSSS010C	1	8.191	N/A	*3.72E-01*	1.29E+00	7.64E+00	*8.96E-01*	1.12E+00	**7.80E-01**	6.63E-01	0.11
SU3FSSS011A	61	4.931	N/A	*5.72E-01*	7.62E-01	4.48E+00	**5.34E-01**	1.33E-01	**4.57E-01**	3.28E-01	0.06
SU3FSSS011B	0	6.931	N/A	*7.54E-01*	1.11E+00	7.58E+00	**1.55E+00**	1.47E+00	**7.74E-01**	4.01E-01	0.12
SU3FSSS011C	0	8.931	N/A	*8.69E-01*	1.04E+00	5.22E+00	*4.25E-01*	1.06E+00	*5.33E-01*	5.86E-01	0.07
SU3FSSS011D	0	10.931	N/A	*5.83E-01*	6.89E-01	4.66E+00	*1.30E+00*	1.46E+00	**4.75E-01**	2.37E-01	0.08
SU3FSSS012A	0	0.000	N/A	*4.75E-01*	1.31E+00	4.40E+00	*6.53E-01*	1.27E+00	**4.49E-01**	2.99E-01	0.21
SU3FSSS012B	0	2.000	N/A	*1.19E+00*	1.22E+00	7.27E+00	*3.71E-01*	1.64E+00	**7.42E-01**	6.63E-01	0.24
SU3FSSS012C	0	4.000	N/A	*9.60E-01*	1.11E+00	5.16E+00	*1.47E-01*	1.06E+00	*5.27E-01*	6.29E-01	0.15
SU3FSSS012D	0	6.000	N/A	*1.02E+00*	1.13E+00	4.25E+00	*5.00E-01*	1.14E+00	*4.34E-01*	6.08E-01	0.06
SU3FSSS012E	0	8.000	N/A	*6.79E-01*	1.28E+00	4.36E+00	*1.22E+00*	1.75E+00	*4.44E-01*	6.65E-01	0.08
SU3CWA4B03A	0	10.192	N/A	**1.19E+00**	7.68E-01	6.59E+00	*6.61E-01*	1.16E+00	*6.72E-01*	6.73E-01	0.09
SU3CWA5B07A	0	9.967	N/A	**3.14E+00**	1.80E+00	2.26E+01	*1.69E+00*	1.96E+00	**4.62E+00**	5.05E-01	0.34
SU3CWA5B11A	0	10.350	N/A	**3.12E+00**	1.83E+00	1.53E+01	*1.64E+00*	1.97E+00	**2.24E+00**	5.44E-01	0.22

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)	
SU3 Subsurface / Geoprobes											
SU3CWA5B14A	0	10.048	N/A	*1.14E+00*	1.29E+00	6.42E+00	*5.87E-01*	1.32E+00	**6.56E-01**	3.16E-01	0.09
SU3CWA6B03A	0	5.251	N/A	*6.57E-01*	8.42E-01	9.30E+00	*1.03E+00*	1.21E+00	**9.49E-01**	6.62E-01	0.13
SU3CWA7B02A	0	8.986	N/A	**1.89E+00**	1.10E+00	1.49E+01	**1.78E+00**	1.66E+00	**1.52E+00**	3.58E-01	0.21
SU3CWA7B03A	0	9.119	N/A	**2.12E+00**	1.02E+00	9.28E+00	*1.26E-01*	1.27E+00	**9.47E-01**	3.28E-01	0.11
SU3CWA7B05A	0	7.081	N/A	*8.01E-01*	8.65E-01	5.71E+00	*7.41E-01*	7.51E-01	*5.82E-01*	6.22E-01	0.08
		Average:		**8.78E-01**		**6.39E+00**	**7.52E-01**		**7.15E-01**		**0.14**
		Std Dev.:		**5.90E-01**		**3.42E+00**	**4.30E-01**		**6.57E-01**		
		UCL 95%:		**1.85E+00**		**1.20E+01**	**1.46E+00**		**1.80E+00**		
		Maximum:		**3.14E+00**		**2.26E+01**	**1.78E+00**		**4.62E+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 4 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 4 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 4-7 as follows. EMC Area 4 was identified through sample analysis and identified for further investigation by the Radiological Engineer while performing the walkover scans. There was a fifth location identified in CWA-4 near sample location 3; however, upon subsequent sample analysis via alpha spec by the off-site laboratory, it was determined that Th-230 was not an issue at this location and the SOF was below unity and was not considered as an elevated area of concern.

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 all 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 4-8. The total SOF for Survey Unit 3 including the contribution from all elevated areas was 0.419, well below unity.

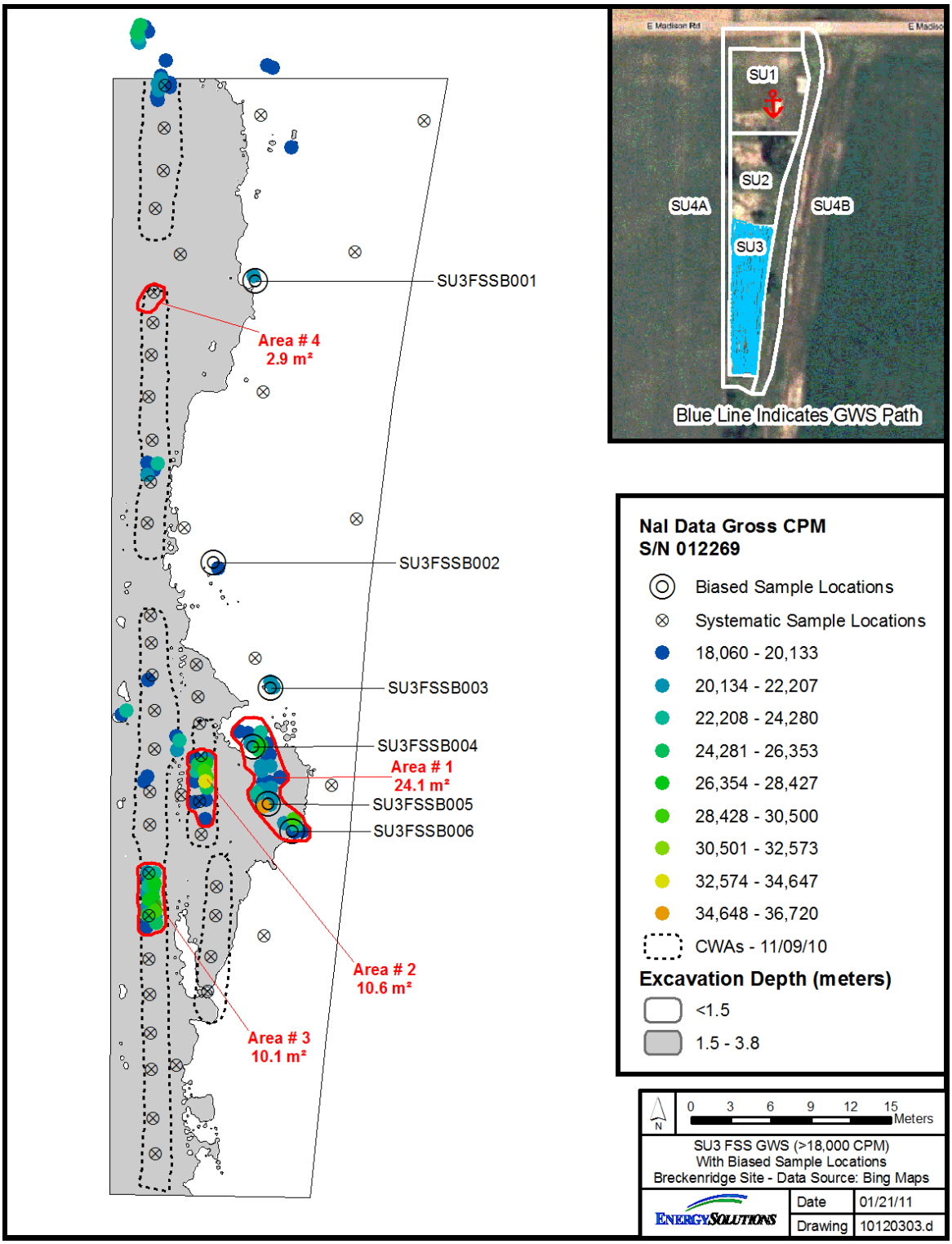


Figure 4-7 SU3 Elevated Area

Table 4-4 Elevated Area 1 SOF Contribution (24.1 m^2)

	DCGL	AF	Area Activity	SOF
^{232}Th + C	65.9	9.4	9.1	0.015
^{238}U + D	8658	19.1	9.2	0.000
^{234}U	6113	22.6	9.2	0.000
^{230}Th	97.9	18.0	80	0.045
^{226}Ra + C	51.2	18.1	2.9	0.003
				0.063

Table 4-5 Elevated Area 2 SOF Contribution (10.6 m^2)

	DCGL	AF	Area Activity	SOF
^{232}Th + C	65.9	12.6	13.1	0.016
^{238}U + D	8658	34.5	11.6	0.000
^{234}U	6113	46.5	11.6	0.000
^{230}Th	97.9	31.6	131	0.042
^{226}Ra + C	51.2	31.8	3.75	0.002
				0.060

Table 4-6 Elevated Area 3 SOF Contribution (10.1 m^2)

	DCGL	AF	Area Activity	SOF
^{232}Th + C	65.9	12.9	17.2	0.020
^{238}U + D	8658	35.7	18.7	0.000
^{234}U	6113	48.6	18.7	0.000
^{230}Th	97.9	32.7	126	0.039
^{226}Ra + C	51.2	32.9	4.99	0.003
				0.063

Table 4-7 Elevated Area 4 SOF Contribution (2.9 m^2)

	DCGL	AF	Area Activity	SOF
^{232}Th + C	65.9	19.9	15.2	0.012
^{238}U + D	8658	38.8	18.1	0.000
^{234}U	6113	141.7	18.1	0.000
^{230}Th	97.9	75.1	148	0.020
^{226}Ra + C	51.2	75.5	6.45	0.002
				0.033

Table 4-8 SU3 EMC Calculation

Area	SOF
SU3 Average	0.200
Elevated Area 1	0.063
Elevated Area 2	0.060
Elevated Area 3	0.063
Elevated Area 4	0.033
	0.419

4.5 Deviations from the FSSP

It should be noted that the FSS protocols were deviated in a couple of instances within SU3 as follows, specifically for geoprobing the centerline of the trenches. This was done based upon safety considerations. Due to the depth of many of the sample locations, greater than 10 feet bgs, it was not necessary to geoprobe; however at those location that were less than 10 feet bgs within the trenches, they could not be safely accessed using the geoprobe.

The bottoms of the trenches consisted of very hard virgin clay that was difficult to excavate or geoprobe. There was a very clear visual and physical delineation once the bottoms of the trenches were reached. Additionally, most of the samples along the centerline of the trenches were well below the SOF of unity for site release. As an alternative, sample locations that did show some activity, specifically those at or near an SOF of unity were sampled below the surface by hand, using a pick ax, to obtain the sample.

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. Based upon the biased samples, no elevated activity was identified with the exception of one area, EMC 1. This area was investigated in the field and 6 to 8 inches removed using the excavator in spots. At each location, the subsurface was scanned using the NaI(tl) detector and confirmed that the levels were reduced to background levels.

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 or duplicates analyzed on site as well as 5% sent for off-site analysis. There were a total of 102 FSS samples collected and analyzed. A total of 8 on-site splits and/or duplicates were analyzed and 6 shipped for off-site gamma spec analysis and isotopic thorium via alpha spec. There were an additional 13 samples shipped for isotopic thorium analysis following the discovery of elevated ^{230}Th. 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. All on-site QA samples were within 50% with the exception of 2 samples both failing for ^{226}Ra which was slighted above 50% which can be accounted for by the low activity and interference from low levels of ^{235}U. A summary of the on-site QC results is provided in Table 4-9.

A summary of the off-site QC results is provided in Table 4-10. Of the 6 samples shipped for off-site QC analysis, there were 4 that failed the RPD test for U-238 as quantified from Th-234. All other results were within the acceptance criteria. Of the 4 that failed, 3 had an RPD slightly higher than 50%. 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 93 keV 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 as a result of interference from Ac-228 [1]. As part of the on-site laboratory, these peaks were deconvoluted to remove any Ac-228 contribution to more accurately report the Th-234 activity. These discrepencies between the the reporting values is currently being evaluated and the findings will be included with Revision 1 of this document to be submitted prior to or with the final FSSR. In order to bound the impact between the laboratory discrepencies, 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.

The RPD was calculated using equation 4 below.

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

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).

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

Table 4-9 On-Site QA Samples (SU3)

	Processed					
Sample	**^{238}U (pCi/g)**	**MDA (pCi/g)**	**^{226}Ra (pCi/g)**	**MDA (pCi/g)**	**^{232}Th (pCi/g)**	**MDA (pCi/g)**
SU3FSSS011	9.27E-01	7.89E-01	1.80E+00	1.32E+00	1.43E+00	3.29E-01
SU3FSSS011S	5.98E-01	6.77E-01	1.33E+00	1.06E+00	1.38E+00	3.01E-01
RPD	43.1%		30.2%		3.5%	
Pass / Fail	Pass		Pass		Pass	
SU3FSSB006	6.14E+00	1.80E+00	2.91E+00	2.30E+00	6.38E+00	5.48E-01
SU3FSSB006S	5.53E+00	1.90E+00	2.18E+00	2.34E+00	6.85E+00	4.32E-01
RPD	10.3%		28.8%		7.2%	
Pass / Fail	Pass		Pass		Pass	
SU3CWA4B03	9.28E+00	2.63E+00	6.45E+00	3.32E+00	1.43E+01	7.71E-01
SU3CWA4B03S	9.67E+00	2.31E+00	6.08E+00	3.69E+00	1.38E+01	7.15E-01
RPD	4.2%		6.0%		3.4%	
Pass / Fail	Pass		Pass		Pass	
SU3CWA5B07	4.49E+00	1.34E+00	8.02E-01	1.82E+00	8.41E-01	3.77E-01
SU3CWA5B07S	4.40E+00	1.36E+00	1.40E+00	1.49E+00	7.89E-01	3.95E-01
RPD	2.1%		54.4%		6.4%	
Pass / Fail	Pass		**Fail**		Pass	
SU3CWA7B03	3.47E+00	9.59E-01	1.19E+00	1.42E+00	9.74E-01	3.21E-01
SU3CWA7B03S	3.31E+00	9.33E-01	1.27E+00	1.54E+00	9.36E-01	4.19E-01
RPD	4.8%		6.8%		4.0%	
Pass / Fail	Pass		Pass		Pass	
SU3FSSS003C	5.77E-01	1.14E+00	5.01E-01	1.55E+00	3.82E-01	5.91E-01
SU3FSSS003CS	8.94E-01	1.10E+00	8.65E-01	1.18E+00	3.06E-01	6.05E-01
RPD	43.1%		53.3%		22.1%	
Pass / Fail	Pass		**Fail**		Pass	
SU3FSSS008A	8.47E-01	1.27E+00	1.23E+00	1.84E+00	9.30E-01	3.37E-01
SU3FSSS008AS	9.15E-01	8.12E-01	1.10E+00	1.04E+00	8.17E-01	3.57E-01
RPD	7.7%		11.4%		12.9%	
Pass / Fail	Pass		Pass		Pass	
SU3FSSS011A	5.72E-01	7.62E-01	5.34E-01	1.33E-01	4.57E-01	3.28E-01
SU3FSSS011AS	5.85E-01	1.12E+00	4.94E-01	3.00E-01	6.28E-01	3.37E-01
RPD	2.4%		7.8%		31.5%	
Pass / Fail	Pass		Pass		Pass	

Table 4-10 Off-Site QA Samples (SU3)

	Processed					
Sample	**^{238}U (pCi/g)**	**MDA (pCi/g)**	**^{226}Ra (pCi/g)**	**MDA (pCi/g)**	**^{232}Th (pCi/g)**	**MDA (pCi/g)**
SU3FSSB001	4.73E+00	1.94E+00	2.94E+00	2.78E+00	6.20E+00	7.18E-01
SU3FSSB001ALS	8.10E+00		2.46E+00		6.45E+00	
RPD	52.6%		17.8%		3.9%	
Pass / Fail	**Fail**		Pass		Pass	
SU3FSSB006	6.14E+00	1.80E+00	2.91E+00	2.30E+00	6.38E+00	5.48E-01
SU3FSSB006ALS	8.90E+00		2.57E+00		5.99E+00	
RPD	36.7%		12.3%		6.3%	
Pass / Fail	Pass		Pass		Pass	
SU3CWA4B03	9.28E+00	2.63E+00	6.45E+00	3.32E+00	1.43E+01	7.71E-01
SU3CWA4B03ALS	2.27E+01		4.30E+00		1.62E+01	
RPD	84.0%		40.0%		12.4%	
Pass / Fail	**Fail**		Pass		Pass	
SU3CWA4B07	1.23E+01	1.98E+00	4.43E+00	2.85E+00	1.20E+01	6.59E-01
SU3CWA4B07ALS	2.11E+01		3.25E+00		1.27E+01	
RPD	52.4%		30.7%		5.6%	
Pass / Fail	**Fail**		Pass		Pass	
SU3CWA5B08	1.30E+01	2.75E+00	4.99E+00	3.50E+00	1.72E+01	8.12E-01
SU3CWA5B08ALS	1.87E+01		4.24E+00		1.73E+01	
RPD	35.8%		16.2%		0.7%	
Pass / Fail	Pass		Pass		Pass	
SU3CWA7B02	8.48E+00	1.83E+00	3.75E+00	2.72E+00	8.03E+00	5.67E-01
SU3CWA7B02ALS	1.46E+01		2.66E+00		8.50E+00	
RPD	53.0%		33.9%		5.7%	
Pass / Fail	**Fail**		Pass		Pass	

5.0 CONCLUSIONS

Based upon the final walkover survey and sampling as summarized above, Survey Unit 3 meets the requirements for release and backfill. Based upon 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 0.419 as presented above in the EMC evaluation for an estimated personnel dose to the average member of the critical group following backfilling of approximately 10.5 mrem.

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

Attachment A - SU3 Survey / Sampling Design

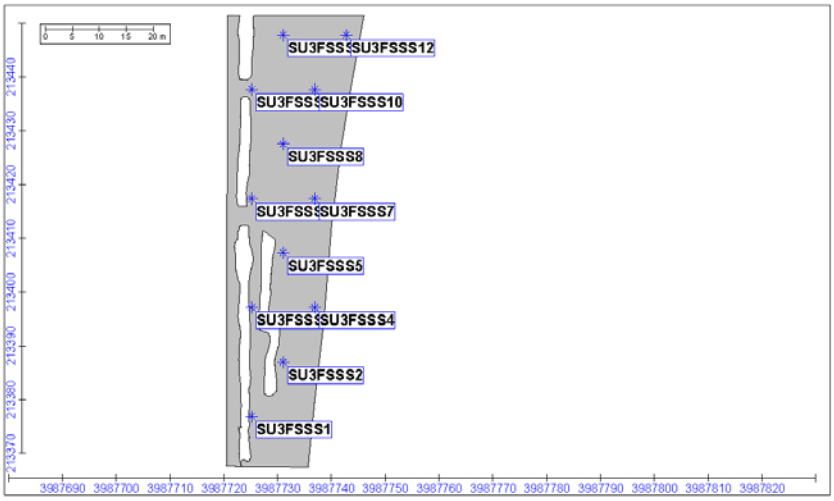
Systematic sampling locations for comparing a median with a fixed threshold (nonparametric - MARSSIM)

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]	1422.97 m^2
Size of grid / Area of grid cell [d]	38.3907 feet / 1276.39 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: SU3						
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**	**Ref/Surv**
3987725.2092	213376.8740	SU3FSSS1		Systematic		Undefined
3987731.0599	213387.0078	SU3FSSS2		Systematic		Undefined
3987725.2092	213397.1416	SU3FSSS3		Systematic		Undefined
3987736.9107	213397.1416	SU3FSSS4		Systematic		Undefined
3987731.0599	213407.2754	SU3FSSS5		Systematic		Undefined
3987725.2092	213417.4092	SU3FSSS6		Systematic		Undefined
3987736.9107	213417.4092	SU3FSSS7		Systematic		Undefined
3987731.0599	213427.5430	SU3FSSS8		Systematic		Undefined
3987725.2092	213437.6768	SU3FSSS9		Systematic		Undefined
3987736.9107	213437.6768	SU3FSSS10		Systematic		Undefined
3987731.0599	213447.8106	SU3FSSS11		Systematic		Undefined
3987742.7614	213447.8106	SU3FSSS12		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:

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

where

$$SignP = \Phi\left(\frac{\Delta}{s_{total}}\right)$$

$\Phi(z)$ 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).

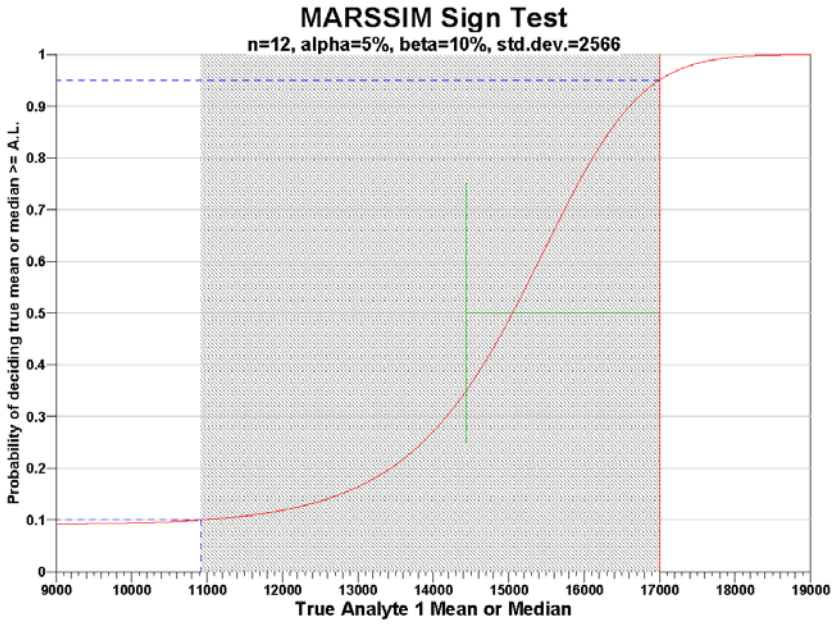
The values of these inputs that result in the calculated number of sampling locations are:

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 μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=17000		α=5		α=10		α=15	
		s=5132	s=2566	s=5132	s=2566	s=5132	s=2566
LBGR=90	β=5	210	59	167	47	140	39
	β=10	167	47	128	37	104	30
	β=15	140	39	104	30	84	24
LBGR=80	β=5	59	23	47	17	39	15
	β=10	47	17	37	13	30	12
	β=15	39	15	30	12	24	10
LBGR=70	β=5	32	16	25	13	21	11
	β=10	25	13	20	11	16	8
	β=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 μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < 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.