CAMECO RESOURCES
CROW BUTTE OPERATION

86 Crow Butte Road
P.O. Box 169
Crawford, Nebraska 69339-0169

June 12, 2018

USPS PRIORITY MAIL
<u>SIGNATURE CONFIRMATION</u>

40-8943

Attn: Document Control Desk Director
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Correction to the proposed survey program for beta/gamma contamination
Crow Butte Resources, Inc., Crawford, Nebraska
Source Materials License SUA-1534
TAC No: L00760

Dear Director:

By letter dated October 31, 2017, Crow Butte Resources (CBO), submitted a proposed survey program for beta/gamma contamination for NRC approval. The purpose of the program was to comply with the requirements of License Condition 11.10. Upon further review of the language in the proposed program, CBO staff realized that some sections of the program do not clearly communicate the procedures CBO intends to follow to comply with the requirements. CBO staff discussed these issues with Mr. Ron Burrows and Mr. David Brown in a PM to PM conference call on April 10, 2018. NRC staff suggested that CBO submit a revised version to the proposed program for review.

Enclosed, please find a "redline" version of the revised program, as well as a final copy of the program. The "redline" version will make the changes to the original submittal readily identifiable. It is CBO's intention to replace the survey program for beta/gamma contamination submitted in the October 31, 2017 letter with the attached final copy of the proposed program.

If there are any further questions or concerns feel free to contact me at (308) 665–2215 ext. 117.

NMSS20

Sincerely,

Walter D. Nelson
SHEQ Coordinator
Enclosure

cc: Deputy Director
Division of Decommissioning
Uranium Recovery and Waste Programs
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Mail Stop T-8F5
11545 Rockville Pike
Two White Flint North, Rockville, MD 20852-2738

CBO- File

ec: CR-Electronic File

Crow Butte Resources, Inc. (CBR)
d/b/a Cameco Resources
Crow Butte Operation

SURVEY PROGRAM FOR BETA/GAMMA CONTAMINATION

June 2018

SURVEY PROGRAM FOR BETA/GAMMA CONTAMINATION

The Survey Program for Beta/Gamma Contamination will be used for beta/gamma surveys of personnel and equipment exiting restricted areas at the Crow Butte facility to meet the requirements of 10 CFR Part 20, Subpart F. The program includes surface contamination detection capability (minimum detection concentration (MDC)) for radiation survey instruments, including scan MDC for portable instruments, used for contamination surveys to release equipment and materials for unrestricted use and for personnel contamination surveys. The detection capability in the scanning mode for alpha and beta radiation are in terms of dpm per 100 cm^2.

Training

The Survey Program for Beta/Gamma Contamination will be conducted by an RSO or a qualified HPT. The training will be included as part of New Employee Radiation Safety Training and Annual Refresher Training.

Survey Equipment

The following equipment will be used for personnel monitoring; either Ludlum model 177 counters and 43-5 probes or Ludlum model 2241 scalar/ratemeter or equivalents along with a 43-5 probes or equivalents will be used. For equipment alpha scanning, a Ludlum 2241 scaler/ratemeter or equivalent and, nominally, a 43-65 probe are used. There are several probes that are compatible with these meters that may be used in the future. If these meters are used with alternate compatible probes, the MDC will be verified by the RSO to ensure it meets the requirements. To meet the requirement for measurement of beta radiation, where ambient background conditions permit, monitoring for both alpha and beta radiation will be performed using a 2224 scaler/ratemeter or equivalent along with a 43-93 probe or equivalent equipment.

Personnel Surveys

Personnel entering an unrestricted area after leaving a restricted area will be required to perform alpha and beta/gamma surveys as well as record the results and sign the survey logs. The requirements to be free of visible uranium prior to leaving the restricted area will reduce the potential for the spread of contamination outside of the restricted area. The monitoring will consist of an examination to detect any visible yellowcake. To eliminate the possibility of attenuated alpha particles from the scanning of wet boots, boot wash stations will not be utilized prior to exiting the restricted areas.At a minimum the hands and soles of the boots/shoes will be surveyed.

All contamination on skin and clothing is considered removable, therefor the limit of 1,000 dpm/100cm^2 is applied to personnel monitoring. If this limit is exceeded, personnel must decontaminate their skin and/or clothing and repeat the survey along with RSO notification. As stated in Regulatory Guide 8.30, if the action level is exceeded, the RSO will perform an investigation of the cause of the contamination and take corrective action if appropriate. Survey stations will be posted with the limit in terms of either the total counts or disintegrations per minute allowed in specified time and/or count rate, depending on the available meter. The limits will be established based on routine background measurements taken at the survey stations Surveys of personnel will generally be performed using scalar, or integrated, counting instead of scanning.

Personnel must complete the beta/gamma scanning process and be below the limit of 1000 dpm/100 cm^2 before entering an unrestricted area such as the office areas, eating areas, or leaving the site.

The minimum detectable concentration (MDC) for scalar alpha and beta/gamma measurements using hand held probes will be determined based on the method in NUREG 1507, shown in the following equation:

$$MDC\left(\frac{DPM}{100cm^2}\right) = \frac{3 + 3.29\sqrt{R_b\, t_g(1 + \frac{t_g}{t_b})}}{(counting\ efficiency)t_g(\frac{SA}{100cm^2})}$$

where: R_b = the background count rate

t_g = the sample count time

t_b = the background count time

counting efficiency = $\Sigma F_{activity}\, F_{branching}\, \varepsilon_i \varepsilon_s$ (as per Issue 2)

SA = probe surface area (cm^2)

$F_{activity}$ = fraction of isotopes activity to total activity of source

$F_{branching}$ = frequency of emission for specific beta energy

ε_i = instrument efficiency

ε_s = surface efficiency for emission

The maximum allowable MDC for alpha static and scanning measurements is 500 dpm per 100 cm2, as per NRC Regulatory Guide 8.30, "Health Physics Surveys in Uranium Recovery Facilities" (NRC 2002). For beta measurements, static and scanning, the maximum allowable MDC is 1000 DPM/100cm2, which is the stated applicable removable surface contamination limit from Table 1 of Policy and Guidance Directive FC 83-23 (NRC, 1993) and aligns with previously approved allowable MDC values (NRC, 2016).

CBO will utilize the method described in (Strata Energy Inc., 2015) for calculating radionuclide-weighted alpha and beta counting efficiencies for the major radionuclide mixtures, namely aged yellowcake and pregnant lixiviant.

First, in regards to aged yellowcake alpha emissions, CBO uses a certified NIST traceable natural uranium source for determining alpha efficiencies of the hand held contamination monitoring equipment. The records are available on site for inspection. Because the source is identical in energy emissions to the alpha emitters from aged yellowcake (i.e. U238, U235 and U234 in natural abundance), the alpha instrument efficiencies calculated with this source are radionuclide-weighted efficiencies for aged yellowcake alpha emissions. No additional calculations are required for this radiation type and product. These sources have a 150 cm^2 surface area and the ratio between source and probe surface areas are included in the equipment efficiency calculation. A source efficiency of 0.25, as recommended by ISO 7503-1, will be used in combination with the instrument efficiency to calculate total efficiency. Table 2 below, shows an example of calculation of instrument efficiency using this source; the instrument efficiency was 35.9%. Multiplying that by the source efficiency of 25% results in a total efficiency of 9%. Note, this is the same efficiency that would be calculated using the activity fraction and branching ratio method discussed in more detail below.

In regards to beta emissions from aged yellowcake, Sr/Y-90 and C14 sources, which are NIST traceable with records available on site for inspection, will be used to determine instrument efficiency for beta emissions and the methodology from (Strata Energy Inc., 2015) used to determine a total radionuclide weighted efficiency.

Tables 1 and 2 show an example of the calculation of the instrument efficiency for the Ludlum Model 43-93. The instrument efficiency, ε_i, was calculated according to the method outlined in ISO 7503-1 (ISO, 1988), namely that ε_i = (measured counts (cpm) – background counts (cpm)) / source surface emission rate (dpm). Note if the source area is greater than the probe area, source emissions (dpm) must be modified by ratio of (probe area/source area) to ensure the correct emissions are used. The instrument efficiency for the Model 43-93 is 35.9% for alpha (as per discussion above) and 52.2% for beta. It is important to note for clarity that the term 'source efficiency' as used by ISO 7503-1 refers to an actual alpha or beta contamination source (i.e. the object being measured for release), not to a reference source.

Table 1: Calibration Source Data

Source Isotope	**Source ID**	**Source Activity (dpm)**	**Source Surface Emission (dpm)**
U^{nat}	K1-076	23000	11390
Sr/Y-90	M2-098	189800	113800

Table 2: Instrument Efficiency Calculation

Source #	K1-076	M2-098
Total Activity (dpm)	11390	113800
Alpha 5 min bkg	31	
Beta 5 min bkg		1093
Source Size	150 cm^2	
Probe Size	100 cm^2	100 cm^2
	Alpha	Beta
Count 1	2657	59567
Count 2	2799	59632
Count 3	2772	59479
Count 4	2791	59319

Count 5	2747	60018
Count 6	2638	59449
Count 7	2781	59937
Count 8	2720	59637
Count 9	2671	59535
Count 10	2764	59924
Average cpm	2734	59649.7
Source Surface Emission (dpm)	11390	113800
Instrument Efficiency**	**35.9%**	**52.2%**
	**(radionuclide weighted)	

The radionuclide mixture weighted counting efficiency for beta for aged yellowcake was calculated using the methodology outlined in the draft (Strata Energy Inc., 2015) and is shown in Table 3. The efficiency for the lower energy emissions will be determined using a C14 source, however, it was not available at the time of writing of this document, and therefore in this example the instrument efficiency has been assumed to be zero for these energies. The source for the uranium and activity fraction are NRC, 2015. The source for the energy and branching ratio are from Table 2-2 of DOE, 2009 (low yield radiations are not included). The total weighted beta efficiency for the Model 43-93 for aged yellowcake is 12.5%. As stated earlier the total weighted alpha instrument efficiency for aged yellowcake is 9.0%.

Table 3: Mixture Weighted Beta Efficiency for Aged Yellowcake for Model 43-93

Isotope	Energy (keV)	Activity Fraction	Branching Ratio	Instrument Efficiency	Surface Efficiency	Weighted Efficiency
Th-234	103	0.489	0.21	0	0.25	0.0000
Th-234	193	0.489	0.79	0	0.25	0.0000
Pa-234m	2290	0.489	0.98	0.522	0.50	0.1251
Th-231	206	0.022	0.13	0	0.25	0.0000
Th-231	287	0.022	0.12	0	0.25	0.0000
Th-231	288	0.022	0.37	0	0.25	0.0000
Th-231	305	0.022	0.35	0	0.25	0.0000

Beta Counting Efficiency = 0.1251

The pregnant lixiviant is the process fluid which is returning from the wellfield to the plant, and will contain higher concentrations of radionuclides than the "barren lixiviant", or the process fluids which return to the wellfield after passing over the resin beds. In considering the mixtures, CBO has not taken into account radon gas (Rn-222) nor the short lived decay products of radon (radon daughters). Although the radon daughters are alpha and beta emitters, they were excluded from the calculations as the calculations are considering surface contamination levels, not airborne contamination levels.

Strata (Strata Energy Inc., 2015; hereon referred to as "Strata") provided a very detailed explanation as to the assumptions used to determine the radionuclide composition for pregnant lixiviant. Currently, no assays of the Crow Butte lixiviant are available, therefore the same assumptions as those in the approved Strata application will be used. Crow Butte Operation uses an alkaline based mining method similar to Stata and the referenced data sources. As such, the same assumptions will be adopted for CBO. Specifically, Strata identified (DOE, 2009) as the source for aged yellowcake composition and two sources of data were identified regarding the radionuclide composition in lixiviant (Brown, 1982 and LCI, 2015). The LCI, 2015 document contained a radionuclide composition analysis on pregnant lixiviant from a Uranium Recovery facility in Wyoming, using alkaline based mining techniques similar to that proposed by CBO. The LCI, 2015 document showed that the concentrations of the long-lived decay products of natural uranium in the pregnant lixiviant are negligible. Two radionuclides had elevated concentrations, namely Ra-226 and Th-234, with concentrations of 2,700 and 2,290 pCi/L respectively. Converting to Bq/L yields Ra-226 and Th-234 concentrations of 99.9 and 84.7 Bq/L respectively. The paper (Brown, 1982) lists concentrations for Th-230 and Ra-226. The concentration ranges for Th-230 are 56 - 93 Bq/L, and for Ra-226 are 10 - 150 Bq/L. To be conservative, the upper end of the higher concentrations, specifically 150 Bq/L for Ra-226 and 93 Bq/L for Th230, will be used for this analysis.

As there was no data regarding the concentrations of Th-231 and Pa-234m for the pregnant lixiviant, in alignment with the Strata application, CBO made the following estimations: for Th-231 and Pa-234m, it is assumed that Th-231 was in secular equilibrium with U-235 and Pa-234m was in secular equilibrium with Th-234. This estimation is valid as the half-lives of the parent radionuclides are much longer than the half-lives of the daughter radionuclides.

The activity fractions for pregnant lixiviant were calculated using the data and estimations listed above. The specific activity of 6.77E-7 Ci/g for natural Uranium was found in footnote (3) to Appendix B of 10 CFR 20. An average concentration of uranium in pregnant lixiviant is 25-30 ppm, and a conservative estimate of the concentration of uranium in the pregnant lixiviant which will be used is 40 ppm. Converting to Bq/L yields:

Concentration of U in pregnant lixiviant = 40 ppm = 40 mg/L = 0.04 g/L = 1E3 Bq/L

Therefore, the primary radionuclides of concern for contamination from pregnant lixiviant in regards to alpha and beta radiation are shown in Tables 4 and 5. Natural uranium, in Table 4, has been broken down by radionuclide according to natural abundance ratios.

Table 4: Primary Alpha Emitting Radionuclides in Lixiviant

	Bq/L	Fraction
U (total)	1,000	0.805
U-238	486	0.391

U-235	22	0.018
U-234	492	0.396
Th-230	93	0.075
Ra-226	150	0.121

Table 5: Primary Beta Emitting Radionuclides in Lixiviant

	Bq/L	Fraction
Th-234	84.7	0.443
Th-231	22	0.115
Pa-234m	84.7	0.443

Again following the process described in (NRC, 2015) the radionuclide mixture weighted counting efficiency was determined for lixiviant for both alpha and beta, shown in Tables 6. The instrument efficiencies were again taken from Table 2 and the default source efficiencies, as recommended by ISO 7503-1 were used. The source for the activity fractions are Strata Energy Inc., 2015, LCI, 2015, and Brown, 1982. The sources for the energy and branching ratio are from Table 2-2 of DOE, 2009 and the Health Physics and Radiological Health Handbook (1992) (low yield radiations are not included).

Because CBO does not have a traceable beta calibration source which emits beta particles at energies similar to the lower energy betas emitters (i.e. Th-231 and Th-234), the instrument efficiency for those radionuclides is listed as zero. The Y90 emission at 2.245 MeV is comparable to the 2.29 MeV emission of Pa-234m. To better account for the low energy emissions, a C-14 source will be purchased and the beta mixture efficiency recalculated at that time.

Table 6: Mixture Weighted Efficiencies for Pregnant Lixiviant.

Isotope	Energy (MeV)	Activity Fraction	Branching Ratio	Instrument Efficiency	Surface Efficiency	Weighted Efficiency
U-238	4.15	0.391	0.21	0.359	0.25	0.0074
U-238	4.20	0.391	0.79	0.359	0.25	0.0277
U-234	4.72	0.396	0.28	0.359	0.25	0.0100
U-234	4.77	0.396	0.72	0.359	0.25	0.0256
U-235	4.21	0.018	0.06	0.359	0.25	0.0001
U-235	4.37	0.018	0.17	0.359	0.25	0.0003
U-235	4.40	0.018	0.55	0.359	0.25	0.0009
U-235	4.60	0.018	0.05	0.359	0.25	0.0001
Th-230	4.62	0.075	0.24	0.359	0.25	0.0016
Th-230	4.68	0.075	0.76	0.359	0.25	0.0051
Ra-226	4.60	0.121	0.06	0.359	0.25	0.0007
Ra-226	4.78	0.121	0.95	0.359	0.25	0.0103

Alpha Counting Efficiency = 0.089

Isotope	Energy (keV)	Activity Fraction	Branching Ratio	Instrument Efficiency	Surface Efficiency	Weighted Efficiency
Th-234	103	0.443	0.21	0	0.25	0.0000
Th-234	193	0.443	0.79	0	0.25	0.0000
Pa-234m	2290	0.443	0.98	0.522	0.50	0.1133
Th-231	206	0.115	0.13	0	0.25	0.0000
Th-231	287	0.115	0.12	0	0.25	0.0000
Th-231	288	0.115	0.37	0	0.25	0.0000
Th-231	305	0.115	0.35	0	0.25	0.0000

Beta Counting Efficiency = 0.113

In regards to the alpha efficiency for pregnant lixiviant, the same final efficiency can be achieved by simply multiplying the instrument efficiency (35.9%) by the source efficiency (25%). Therefore, for alpha efficiency determination, the simpler methodology of multiplying the instrument and source efficiency will be used for both yellowcake and lixiviant total efficiency calculations.

In summary, the two mixture weighted efficiencies for alpha and beta are shown in Table 7, note this is based on the instrument efficiency calculation shown in Table 2.

Table 7: Summary of Instrument Weighted Efficiencies

Mixture	Radiation Type	Total Efficiency (NRC, 2015 method)
Aged Yellowcake	Alpha	9.0%
	Beta	12.5%
Pregnant Lixiviant	Alpha	9.0%
	Beta	11.3%

While in some cases it may be possible to establish the actual nature of the contaminant on a surface, e.g. yellowcake drums; this would be the exception. In most cases, it will not be possible to conclusively say that a surface had the potential to be contaminated exclusively by only one form of material or another. In addition, trying to manage material specific efficiencies actually increases error potential due to the increased complexity of the process. Therefore, practically, the only reasonable option is to use the more restrictive efficiency unless it is possible to conclusively say what the contaminant is. Crow Butte will calculate the efficiency for both mixtures for its equipment, however, if the contaminant is unclear, it will be the more restrictive efficiency that is used for the calculations.

Material & Equipment Surveys for free release

For materials and equipment being released for unrestricted use, Regulatory Guide 8.30 indicates the removable release limit is 1000 dpm/100cm^2, the average total activity limit is 5000 dpm/100cm^2 and the total maximum activity limit is 15,000 dpm/100 cm^2. Using the previously mentioned assumptions, if the background levels for beta/gamma reach 3450 counts in 5 minutes or 500 counts in 1 minute, this will result in MDCs of 745 dpm/100cm^2 and 741 dpm/100cm^2, respectively. If this background count rate is exceeded then smears will be required in order to release the equipment, as per existing site procedure, or the equipment will need to be moved to a lower background area within the controlled area for surveying. If contamination levels exceed 750 dpm/100cm^2, an alpha smear will be required. Prior to leaving the restricted zone, the equipment must meet the removable alpha and beta release limits outlined in Regulatory Guide 8.30.

Surveys of materials and equipment will be performed by the RSO or a qualified HPT. Equipment must meet the limits for removable alpha and beta contamination before entering a controlled area (controlled area is described in more detail below)

Though scanning is not the preferred method, it is a potential survey option. For instruments used in ratemeter mode, the beta/gamma MDC will be based on Regulatory Guide 1507. The beta/gamma scan MDC is calculated as follows:

$$Scan\ MDC\left(\frac{DPM}{100cm^2}\right) = \frac{d'\left(\frac{60}{t_s}\right)\sqrt{b_i\left(\frac{t_s}{60}\right)}}{\sqrt{p\epsilon_i\epsilon_s}\,\frac{Probe\ Area}{100\ cm^2}} \tag{2}$$

Where: t_s = Scan time (sec)
d' = level of performance (Table 6.1 from NUREG 1507) (false positive portion =0.6, true positive = 0.95)
b_i = average number of bkg counts in interval (cpm)
p = surveyor efficiency; assumed 0.5
ϵ_i = instrument efficiency (18%)
ϵ_s = surface efficiency (0.5) from section 5 of NUREG 1507

From NUREG-1575, the level of performance value, d', will be 1.38. This is based on a true positive proportion of 0.95 and false positive portion of 0.60. As described above, the beta/gamma efficiency of 18% will be used in the nominal MDC calculations. The surface efficiency is 0.50, based on the beta emission energy of 2.195 MeV from Pa234m, the primary beta emitter of Uranium 238. The planned scan rate is 1 cm/sec. With a 15 cm probe length, this scan rate equates to a scan time of 15 seconds. Using this method, a background count rate of 575 cpm will result in an MDC of 750 dpm/100cm^2. If the background count rate is exceeded, either smears will be required in order to release the equipment or the equipment will need to be moved to a low background area within the controlled area and resurveyed. If a different scanning rate is used, the MDC will be recalculated based on actual values.

The MDC of 500 dpm/100cm^2, as referenced in Regulatory Guide 8.30, will be used for the alpha MDC value. The alpha static MDC will be calculated using the following formula:

$$MDC\left(\frac{DPM}{100cm^2}\right) = \frac{3 + 3.29\sqrt{R_b\, t_g(1 + \frac{t_g}{t_b})}}{(counting\ efficiency)t_g(\frac{SA}{100cm^2})}$$

where: R_b = the background count rate
t_g = the sample count time
t_b = the background count time
counting efficiency = $\Sigma F_{activity} F_{branching}\, \varepsilon_i \varepsilon_s$ (as per Issue 2)
SA = probe surface area (cm^2)
$F_{activity}$ = fraction of isotopes activity to total activity of source
$F_{branching}$ = frequency of emission for specific beta energy
ε_i = instrument efficiency
ε_s = surface efficiency for emission

Assuming a background count rate of 15 counts in 1 minutes, a 100 cm^2 probe area and a 30 second sample count time, the MDC for a mixture efficiency of 9.0% would be 312 dpm/100 cm^2. These values are conservative, because alpha background rates are typically less than 15 cpm, meaning actual MDC's will typically be less than this value.

In rooms where work with uranium is not performed, a lower level of surface contamination is likely to be present such as eating rooms, change rooms, control rooms, and offices. Therefore, weekly spot checks will be performed for removable surface contamination using smear tests. All eating rooms, change rooms, control rooms, and offices will be spot checked monthly. If surface contamination levels exceed the values shown in Regulatory Guide 8.30, Table 2, the RSO will be notified and the contaminated area will be promptly cleaned and resurveyed.

The instrument used to quantify removable beta/gamma contamination is the Ludlum model 2929 counter or an equivalent. The typical efficiency for this instrument is 25%. A background count will be taken daily prior to use for 50 minutes and samples will be counted for 1 minute. Using the equation (3), to achieve an MDC of 250 dpm/100 cm^2, the background count must be below 15,000 counts in 50 minutes. Actual MDC values will be calculated based on measured instrument efficiencies.

$$MDC = \frac{3+3.29\sqrt{R_b\, t_g(1+\frac{t_g}{t_b})}}{\varepsilon_i t_g} \qquad (3)$$

Where: R_b = the background count rate
t_g = the sample count time

t_b = the background count time
ε_i = the instrument efficiency

Radiation staff performing a scan will stop and perform a scalar measurement if the scan result exceeds 1000 DPM/100 cm^2 beta or the applicable number of counts in the scanning interval as described for alpha scanning.

Controlled Area

Crow Butte Resources, Inc. has the right and ability to carry out mining operations within the license boundaries as described in Source Material License 1534 (Renewed November 2014). CBR has the right to control access to areas within the license boundary. Controlling access is done for both a safety and operational standpoint to protect CBR employees and members of the public. CBR has the right to remove any person who has not been through CBR's required training or does not have permission from CBR to be in the controlled area. CBR has defined the controlled areas as all areas within the license boundary as shown on the map behind Appendix A. Proof of ownership and proof of control over leased lands are also included in Appendix A.

By definition in 10 CFR Part 20 Subpart A, a controlled area is defined as an area outside of a restricted area but inside the site boundary, access to which can be limited by the licensee for any reason. As described above, CBR has the right to remove anyone from inside the license boundary and has designated the entire area within the license boundary as a controlled area.

In circumstances where free release is required to move materials and equipment from a restricted area and the background count rate is exceeded, the materials and equipment will be transported to a low background area within the controlled area and surveyed for free release. The free release surveys will be conducted in areas immediately adjacent to the Central Processing Plant, R.O. Building and Maintenance Building. No materials or equipment that have not been surveyed for free release will be allowed to be stored in the controlled area. If equipment is moving from one restricted area to another through the controlled area, it must meet the removable alpha and beta outlined in Regulatory Guide 8.30 prior to leaving the first restricted area.

Personnel are required to perform alpha and beta/gamma surveys as well as record and sign the logs prior to entering an unrestricted area. If personnel are required to move through the controlled area to perform the required survey after exiting the restricted area, they may not enter into the office area, lunchroom or their personal vehicles prior to performing the alpha and beta/gamma surveys.

Crow Butte Resources, Inc. (CBR)
d/b/a Cameco Resources
Crow Butte Operation

SURVEY PROGRAM FOR BETA/GAMMA CONTAMINATION

SURVEY PROGRAM FOR BETA/GAMMA CONTAMINATION

The Survey Program for Beta/Gamma Contamination will be used for beta/gamma surveys of personnel and equipment exiting restricted areas at the Crow Butte facility to meet the requirements of 10 CFR Part 20, Subpart F. The program includes surface contamination detection capability (minimum detection concentration (MDC)) for radiation survey instruments, including scan MDC for portable instruments, used for contamination surveys to release equipment and materials for unrestricted use and for personnel contamination surveys. The detection capability in the scanning mode for alpha and beta radiation are in terms of dpm per 100 cm^2.

Training

The Survey Program for Beta/Gamma Contamination will be conducted by an RSO or a qualified HPT. The training will be included as part of New Employee Radiation Safety Training and Annual Refresher Training.

Survey Equipment

The following equipment will be used for personnel monitoring; either Ludlum model 177 counters and 43-5 probes or Ludlum model 2241 scalar/ratemeter or equivalents along with a 43-5 probes or equivalents will be used. For equipment alpha scanning, a Ludlum 2241 scaler/ratemeter or equivalent and, nominally, a 43-65 probe are used. There are several probes that are compatible with these meters that may be used in the future. If these meters are used with alternate compatible probes, the MDC will be verified by the RSO to ensure it meets the requirements. To meet the requirement for measurement of beta radiation, where ambient background conditions permit, monitoring for both alpha and beta radiation will be performed using a 2224 scaler/ratemeter or equivalent along with a 43-93 probe or equivalent equipment.

Personnel Surveys

Personnel entering an unrestricted area after leaving a restricted area will be required to perform alpha and beta/gamma surveys as well as record the results and sign the survey logs~~Personnel leaving a restricted area will be required to perform alpha and beta/gamma surveys and record and sign the logs prior to exiting the area~~. The requirements to be free of visible uranium prior to leaving the restricted area will reduce the potential for the spread of contamination outside of the restricted area. The monitoring will consist of an examination to detect any visible yellowcake. To eliminate the possibility of attenuated alpha particles from the scanning of wet boots, boot wash stations will not be utilized prior to exiting the restricted areas.~~-~~At a minimum the hands and soles of the boots/shoes will be surveyed. ~~The release limit for personnel scanning will be 1000 dpm/100 cm² for alpha and beta/gamma radiation. Scanning~~

All contamination on skin and clothing is considered removable, therefor the limit of 1,000 dpm/100cm^2 is applied to personnel monitoring. If this limit is exceeded, personnel must decontaminate their skin and/or clothing and repeat the survey along with RSO notification. As stated in Regulatory Guide 8.30, if the action level is exceeded, the RSO will perform an investigation of the cause of the contamination and take corrective action if appropriate. Survey stations will be posted with the limit in terms of either the total counts or disintegrations per minute allowed in specified time and/or count rate, depending on the available meter. The limits will be established based on routine background measurements taken at the ~~scanning~~ survey stations. ~~If a reading above the limit occurs, decontamination and resurveying will be required along with notification to the RSO.~~ Surveys of personnel will generally be performed using scalar, or integrated, counting instead of scanning.

Personnel must complete the beta/gamma scanning process and be below the limit of 1000 dpm/100 cm^2 before entering an unrestricted area such as the office areas, eating areas, or leaving the site.

The minimum detectable concentration (MDC) for scalar alpha and beta/gamma measurements using hand held probes will be determined based on the method in NUREG 1507, shown in the following equation:

$$MDC\left(\frac{DPM}{100cm^2}\right) = \frac{3 + 3.29\sqrt{R_b\, t_g(1 + \frac{t_g}{t_b})}}{(counting\ efficiency)t_g(\frac{SA}{100cm^2})}$$

where: R_b = the background count rate
t_g = the sample count time
t_b = the background count time
counting efficiency = $\Sigma F_{activity}\, F_{branching}\, \varepsilon_i \varepsilon_s$ (as per Issue 2)
SA = probe surface area (cm^2)
$F_{activity}$ = fraction of isotopes activity to total activity of source
$F_{branching}$ = frequency of emission for specific beta energy
ε_i = instrument efficiency
ε_s = surface efficiency for emission

The maximum allowable MDC for alpha static and scanning measurements is 500 dpm per 100 cm2, as per NRC Regulatory Guide 8.30, "Health Physics Surveys in Uranium Recovery Facilities" (NRC 2002). For beta measurements, static and scanning, the maximum allowable MDC is 1000 DPM/100cm2, which is the stated applicable removable surface contamination limit from Table 1 of Policy and Guidance Directive FC 83-23 (NRC, 1993) and aligns with previously approved allowable MDC values (NRC, 2016).

CBO will utilize the method described in (Strata Energy Inc., 2015) for calculating radionuclide-weighted alpha and beta counting efficiencies for the major radionuclide mixtures, namely aged yellowcake and pregnant lixiviant.

First, in regards to aged yellowcake alpha emissions, CBO uses a certified NIST traceable natural uranium source for determining alpha efficiencies of the hand held contamination monitoring equipment. The records are available on site for inspection. Because the source is identical in energy emissions to the alpha emitters from aged yellowcake (i.e. U238, U235 and U234 in natural abundance), the alpha instrument efficiencies calculated with this source are radionuclide-weighted efficiencies for aged yellowcake alpha emissions. No additional calculations are required for this radiation type and product. These sources have a 150 cm^2 surface area and the ratio between source and probe surface areas are included in the equipment efficiency calculation. A source efficiency of 0.25, as recommended by ISO 7503-1, will be used in combination with the instrument efficiency to calculate total efficiency. Table 2 below, shows an example of calculation of instrument efficiency using this source; the instrument efficiency was 35.9%. Multiplying that by the source efficiency of 25% results in a total efficiency of 9%. Note, this is the same efficiency that would be calculated using the activity fraction and branching ratio method discussed in more detail below.

In regards to beta emissions from aged yellowcake, Sr/Y-90 and C14 sources, which are NIST traceable with records available on site for inspection, will be used to determine instrument efficiency for beta emissions and the methodology from (Strata Energy Inc., 2015) used to determine a total radionuclide weighted efficiency.

Tables 1 and 2 show an example of the calculation of the instrument efficiency for the Ludlum Model 43-93. The instrument efficiency, ε_i, was calculated according to the method outlined in ISO 7503-1 (ISO, 1988), namely that ε_i = (measured counts (cpm) – background counts (cpm)) / source surface emission rate (dpm). Note if the source area is greater than the probe area, source emissions (dpm) must be modified by ratio of (probe area/source area) to ensure the correct emissions are used. The instrument efficiency for the Model 43-93 is 35.9% for alpha (as per discussion above) and 52.2% for beta. It is important to note for clarity that the term 'source efficiency' as used by ISO 7503-1 refers to an actual alpha or beta contamination source (i.e. the object being measured for release), not to a reference source.

Table 1: Calibration Source Data

Source Isotope	**Source ID**	**Source Activity (dpm)**	**Source Surface Emission (dpm)**
U^{nat}	K1-076	23000	11390
Sr/Y-90	M2-098	189800	113800

Table 2: Instrument Efficiency Calculation

Source #	K1-076	M2-098
Total Activity (dpm)	11390	113800
Alpha 5 min bkg	31	
Beta 5 min bkg		1093
Source Size	150 cm^2	
Probe Size	100 cm^2	100 cm^2

	Alpha	Beta
Count 1	2657	59567
Count 2	2799	59632
Count 3	2772	59479
Count 4	2791	59319
Count 5	2747	60018
Count 6	2638	59449
Count 7	2781	59937
Count 8	2720	59637
Count 9	2671	59535
Count 10	2764	59924
Average cpm	2734	59649.7
Source Surface Emission (dpm)	11390	113800
Instrument Efficiency**	**35.9%**	**52.2%**
	**(radionuclide weighted)	

The radionuclide mixture weighted counting efficiency for beta for aged yellowcake was calculated using the methodology outlined in the draft (Strata Energy Inc., 2015) and is shown in Table 3. The efficiency for the lower energy emissions will be determined using a C14 source, however, it was not available at the time of writing of this document, and therefore in this example the instrument efficiency has been assumed to be zero for these energies. The source for the uranium and activity fraction are NRC, 2015. The source for the energy and branching ratio are from Table 2-2 of DOE, 2009 (low yield radiations are not included). The total weighted beta efficiency for the Model 43-93 for aged yellowcake is 12.5%. As stated earlier the total weighted alpha instrument efficiency for aged yellowcake is 9.0%.

Table 3: Mixture Weighted Beta Efficiency for Aged Yellowcake for Model 43-93

Isotope	Energy (keV)	Activity Fraction	Branching Ratio	Instrument Efficiency	Surface Efficiency	Weighted Efficiency
Th-234	103	0.489	0.21	0	0.25	0.0000
Th-234	193	0.489	0.79	0	0.25	0.0000
Pa-234m	2290	0.489	0.98	0.522	0.50	0.1251
Th-231	206	0.022	0.13	0	0.25	0.0000
Th-231	287	0.022	0.12	0	0.25	0.0000
Th-231	288	0.022	0.37	0	0.25	0.0000
Th-231	305	0.022	0.35	0	0.25	0.0000

Beta Counting Efficiency = 0.1251

The pregnant lixiviant is the process fluid which is returning from the wellfield to the plant, and will contain higher concentrations of radionuclides than the "barren lixiviant", or the process fluids which return to the wellfield after passing over the resin beds. In considering the mixtures, CBO has not taken into account radon gas (Rn-222) nor the short lived decay products of radon (radon daughters). Although the radon daughters are alpha and beta emitters, they were excluded from the calculations as the calculations are considering surface contamination levels, not airborne contamination levels.

Strata (Strata Energy Inc., 2015; hereon referred to as "Strata") provided a very detailed explanation as to the assumptions used to determine the radionuclide composition for pregnant lixiviant. Currently, no assays of the Crow Butte lixiviant are available, therefore the same assumptions as those in the approved Strata application will be used. Crow Butte Operation uses an alkaline based mining method similar to Stata and the referenced data sources. As such, the same assumptions will be adopted for CBO. Specifically, Strata identified (DOE, 2009) as the source for aged yellowcake composition and two sources of data were identified regarding the radionuclide composition in lixiviant (Brown, 1982 and LCI, 2015). The LCI, 2015 document contained a radionuclide composition analysis on pregnant lixiviant from a Uranium Recovery facility in Wyoming, using alkaline based mining techniques similar to that proposed by CBO. The LCI, 2015 document showed that the concentrations of the long-lived decay products of natural uranium in the pregnant lixiviant are negligible. Two radionuclides had elevated concentrations, namely Ra-226 and Th-234, with concentrations of 2,700 and 2,290 pCi/L respectively. Converting to Bq/L yields Ra-226 and Th-234 concentrations of 99.9 and 84.7 Bq/L respectively. The paper (Brown, 1982) lists concentrations for Th-230 and Ra-226. The concentration ranges for Th-230 are 56 - 93 Bq/L, and for Ra-226 are 10 - 150 Bq/L. To be conservative, the upper end of the higher concentrations, specifically 150 Bq/L for Ra-226 and 93 Bq/L for Th230, will be used for this analysis.

As there was no data regarding the concentrations of Th-231 and Pa-234m for the pregnant lixiviant, in alignment with the Strata application, CBO made the following estimations: for Th-231 and Pa-234m, it is assumed that Th-231 was in secular equilibrium with U-235 and Pa-234m was in secular equilibrium with Th-234. This estimation is valid as the half-lives of the parent radionuclides are much longer than the half-lives of the daughter radionuclides.

The activity fractions for pregnant lixiviant were calculated using the data and estimations listed above. The specific activity of 6.77E-7 Ci/g for natural Uranium was found in footnote (3) to Appendix B of 10 CFR 20. An average concentration of uranium in pregnant lixiviant is 25-30 ppm, and a conservative estimate of the concentration of uranium in the pregnant lixiviant which will be used is 40 ppm. Converting to Bq/L yields:

Concentration of U in pregnant lixiviant = 40 ppm = 40 mg/L = 0.04 g/L = 1E3 Bq/L

Therefore, the primary radionuclides of concern for contamination from pregnant lixiviant in regards to alpha and beta radiation are shown in Tables 4 and 5. Natural uranium, in Table 4, has been broken down by radionuclide according to natural abundance ratios.

Table 4: Primary Alpha Emitting Radionuclides in Lixiviant

	Bq/L	Fraction
U (total)	1,000	0.805
U-238	486	0.391
U-235	22	0.018
U-234	492	0.396
Th-230	93	0.075
Ra-226	150	0.121

Table 5: Primary Beta Emitting Radionuclides in Lixiviant

	Bq/L	Fraction
Th-234	84.7	0.443
Th-231	22	0.115
Pa-234m	84.7	0.443

Again following the process described in (NRC, 2015) the radionuclide mixture weighted counting efficiency was determined for lixiviant for both alpha and beta, shown in Tables 6. The instrument efficiencies were again taken from Table 2 and the default source efficiencies, as recommended by ISO 7503-1 were used. The source for the activity fractions are Strata Energy Inc., 2015, LCI, 2015, and Brown, 1982. The sources for the energy and branching ratio are from Table 2-2 of DOE, 2009 and the Health Physics and Radiological Health Handbook (1992) (low yield radiations are not included).

Because CBO does not have a traceable beta calibration source which emits beta particles at energies similar to the lower energy betas emitters (i.e. Th-231 and Th-234), the instrument efficiency for those radionuclides is listed as zero. The Y90 emission at 2.245 MeV is comparable to the 2.29 MeV emission of Pa-234m. To better account for the low energy emissions, a C-14 source will be purchased and the beta mixture efficiency recalculated at that time.

Table 6: Mixture Weighted Efficiencies for Pregnant Lixiviant.

Isotope	Energy (MeV)	Activity Fraction	Branching Ratio	Instrument Efficiency	Surface Efficiency	Weighted Efficiency
U-238	4.15	0.391	0.21	0.359	0.25	0.0074
U-238	4.20	0.391	0.79	0.359	0.25	0.0277
U-234	4.72	0.396	0.28	0.359	0.25	0.0100
U-234	4.77	0.396	0.72	0.359	0.25	0.0256
U-235	4.21	0.018	0.06	0.359	0.25	0.0001

U-235	4.37	0.018	0.17	0.359	0.25	0.0003
U-235	4.40	0.018	0.55	0.359	0.25	0.0009
U-235	4.60	0.018	0.05	0.359	0.25	0.0001
Th-230	4.62	0.075	0.24	0.359	0.25	0.0016
Th-230	4.68	0.075	0.76	0.359	0.25	0.0051
Ra-226	4.60	0.121	0.06	0.359	0.25	0.0007
Ra-226	4.78	0.121	0.95	0.359	0.25	0.0103

Alpha Counting Efficiency = 0.089

Isotope	Energy (keV)	Activity Fraction	Branching Ratio	Instrument Efficiency	Surface Efficiency	Weighted Efficiency
Th-234	103	0.443	0.21	0	0.25	0.0000
Th-234	193	0.443	0.79	0	0.25	0.0000
Pa-234m	2290	0.443	0.98	0.522	0.50	0.1133
Th-231	206	0.115	0.13	0	0.25	0.0000
Th-231	287	0.115	0.12	0	0.25	0.0000
Th-231	288	0.115	0.37	0	0.25	0.0000
Th-231	305	0.115	0.35	0	0.25	0.0000

Beta Counting Efficiency = 0.113

In regards to the alpha efficiency for pregnant lixiviant, the same final efficiency can be achieved by simply multiplying the instrument efficiency (35.9%) by the source efficiency (25%). Therefore, for alpha efficiency determination, the simpler methodology of multiplying the instrument and source efficiency will be used for both yellowcake and lixiviant total efficiency calculations.

In summary, the two mixture weighted efficiencies for alpha and beta are shown in Table 7, note this is based on the instrument efficiency calculation shown in Table 2.

Table 7: Summary of Instrument Weighted Efficiencies

Mixture	Radiation Type	Total Efficiency (NRC, 2015 method)
Aged Yellowcake	Alpha	9.0%
	Beta	12.5%
Pregnant Lixiviant	Alpha	9.0%

	Beta	11.3%

While in some cases it may be possible to establish the actual nature of the contaminant on a surface, e.g. yellowcake drums; this would be the exception. In most cases, it will not be possible to conclusively say that a surface had the potential to be contaminated exclusively by only one form of material or another. In addition, trying to manage material specific efficiencies actually increases error potential due to the increased complexity of the process. Therefore, practically, the only reasonable option is to use the more restrictive efficiency unless it is possible to conclusively say what the contaminant is. Crow Butte will calculate the efficiency for both mixtures for its equipment, however, if the contaminant is unclear, it will be the more restrictive efficiency that is used for the calculations.

~~The requirements to be free of visible uranium and to meet the limit for alpha contamination prior to leaving the restricted area will reduce the potential for the spread of contamination outside of the restricted area. The monitoring will consist of a visual examination to detect any visible yellowcake and an alpha meter survey to ensure that any suspected contamination is below the acceptable limits. To eliminate the possibility of attenuated alpha particles from the scanning of wet boots, boot wash stations will not be utilized prior to exiting the restricted areas.~~

~~All contamination on skin and clothing is considered removable, so the limit of 1,000 dpm/100cm^2 is applied to personnel monitoring. If this limit is exceeded, personnel must decontaminate their skin and/or clothing and repeat the alpha survey. As stated in Regulatory Guide 8.30, if the action level is exceeded, the RSO will perform an investigation of the cause of the contamination and take corrective action if appropriate.~~

~~Personnel must complete the beta/gamma scanning process and be below the limit of 1000 dpm/100 cm^2 before entering the office areas, eating areas, or leaving the site. If the background beta/gamma count rate exceeds the allowed values, personnel will be required to pass the 1000 dpm/100 cm^2 limit for alpha contamination and then move to a lower background area within the controlled area to monitor for beta/gamma radiation.~~

Material & Equipment Surveys for free release

For materials and equipment being released for unrestricted use, Regulatory Guide 8.30 indicates the removable release limit is 1000 dpm/100cm^2, the average total activity limit is 5000 dpm/100cm^2 and the total maximum activity limit is 15,000 dpm/100 cm^2. Using the previously mentioned assumptions, if the background levels for beta/gamma reach 3450 counts in 5 minutes or 500 counts in 1 minute, this will result in MDCs of 745 dpm/100cm^2 and 741 dpm/100cm^2, respectively. If this background count rate is exceeded then smears will be required in order to release the equipment, as per existing site procedure, or the equipment will need to be moved to a lower background area within the controlled area for surveying. If contamination levels exceed 750 dpm/100cm^2, an alpha smear will be required. Prior to leaving the restricted zone, the equipment must meet the removable alpha and beta release limits outlined in Regulatory Guide 8.30.

Surveys of materials and equipment will be performed by the RSO or a qualified HPT. Equipment must meet the limits for ~~both~~removable alpha and beta contamination ~~prior to being assigned~~

~~controlled release status.~~before entering a controlled area (controlled area is described in more detail below)

Though scanning is not the preferred method, it is a potential survey option. For instruments used in ratemeter mode, the beta/gamma MDC will be based on Regulatory Guide 1507. The beta/gamma scan MDC is calculated as follows:

$$Scan\ MDC\left(\frac{DPM}{100cm^2}\right) = \frac{d'\left(\frac{60}{t_s}\right)\sqrt{b_i\left(\frac{t_s}{60}\right)}}{\sqrt{p}\epsilon_i\epsilon_s\frac{Probe\ Area}{100\ cm^2}} \quad (2)$$

Where: t_s = Scan time (sec)
d' = level of performance (Table 6.1 from NUREG 1507) (false positive portion =0.6, true positive = 0.95)
b_i = average number of bkg counts in interval (cpm)
p = surveyor efficiency; assumed 0.5
ϵ_i = instrument efficiency (18%)
ϵ_s = surface efficiency (0.5) from section 5 of NUREG 1507

From NUREG-1575, the level of performance value, d', will be 1.38. This is based on a true positive proportion of 0.95 and false positive portion of 0.60. As described above, the beta/gamma efficiency of 18% will be used in the nominal MDC calculations. The surface efficiency is 0.50, based on the beta emission energy of 2.195 MeV from Pa234m, the primary beta emitter of Uranium 238. The planned scan rate is 1 cm/sec. With a 15 cm probe length, this scan rate equates to a scan time of 15 seconds. Using this method, a background count rate of 575 cpm will result in an MDC of 750 dpm/100cm^2. If the background count rate is exceeded, either smears will be required in order to release the equipment or the equipment will need to be moved to a low background area within the controlled area and resurveyed. If a different scanning rate is used, the MDC will be recalculated based on actual values.

The MDC of 500 dpm/100cm^2, as referenced in Regulatory Guide 8.30, will be used for the alpha MDC value. The alpha static MDC will be calculated using the following formula:

$$MDC\left(\frac{DPM}{100cm^2}\right) = \frac{3 + 3.29\sqrt{R_b\, t_g(1+\frac{t_g}{t_b})}}{(counting\ efficiency)t_g(\frac{SA}{100cm^2})}$$

where: R_b = the background count rate
t_g = the sample count time
t_b = the background count time
counting efficiency = $\Sigma F_{activity}\, F_{branching}\, \varepsilon_i\varepsilon_s$ (as per Issue 2)
SA = probe surface area (cm^2)
$F_{activity}$ = fraction of isotopes activity to total activity of source
$F_{branching}$ = frequency of emission for specific beta energy

ε_i = instrument efficiency
ε_s = surface efficiency for emission

Assuming a background count rate of 15 counts in 1 minutes, a 100 cm^2 probe area and a 30 second sample count time, the MDC for a mixture efficiency of 9.0% would be 312 dpm/100 cm^2. These values are conservative, because alpha background rates are typically less than 15 cpm, meaning actual MDC's will typically be less than this value.

In rooms where work with uranium is not performed, a lower level of surface contamination is likely to be present such as eating rooms, change rooms, control rooms, and offices. Therefore, weekly spot checks will be performed for removable surface contamination using smear tests. All eating rooms, change rooms, control rooms, and offices will be spot checked monthly. If surface contamination levels exceed the values shown in Regulatory Guide 8.30, Table 2, the RSO will be notified and the contaminated area will be promptly cleaned and resurveyed.

The instrument used to quantify removable beta/gamma contamination is the Ludlum model 2929 counter or an equivalent. The typical efficiency for this instrument is 25%. A background count will be taken daily prior to use for 50 minutes and samples will be counted for 1 minute. Using the equation (3), to achieve an MDC of 250 dpm/100 cm^2, the background count must be below 15,000 counts in 50 minutes. Actual MDC values will be calculated based on measured instrument efficiencies.

$$MDC = \frac{3+3.29\sqrt{R_b\, t_g(1+\frac{t_g}{t_b})}}{\varepsilon_i t_g} \tag{3}$$

Where: R_b = the background count rate
t_g = the sample count time
t_b = the background count time
ε_i = the instrument efficiency

Radiation staff performing a scan will stop and perform a scalar measurement if the scan result exceeds 1000 DPM/100 cm^2 beta or the applicable number of counts in the scanning interval as described for alpha scanning.

Controlled Area

Crow Butte Resources, Inc. has the right and ability to carry out mining operations within the license boundaries as described in Source Material License 1534 (Renewed November 2014). CBR has the right to control access to areas within the license boundary. Controlling access is done for both a safety and operational standpoint to protect CBR employees and members of the public. CBR has the right to remove any person who has not been through CBR's required training or does not have permission from CBR to be in the controlled area. CBR has defined the controlled areas as all areas within the license boundary as shown on the map behind Appendix A. Proof of ownership and proof of control over leased lands are also included in Appendix A.

By definition in 10 CFR Part 20 Subpart A, a controlled area is defined as an area outside of a restricted area but inside the site boundary, access to which can be limited by the licensee for any reason. As described above, CBR has the right to remove anyone from inside the license boundary and has designated the entire area within the license boundary as a controlled area.

In circumstances ~~were~~ where free release is required to move materials and equipment ~~are moved~~ from a restricted area and the background count rate is exceeded, the materials and equipment will ~~need to~~ be transported ~~moved~~ to a low background area within the controlled area and surveyed for free release. The free release surveys will be conducted in areas immediately adjacent to the Central Processing Plant, R.O. Building and Maintenance Building. No materials or equipment that have not been surveyed for free release will be allowed to be stored in the controlled area. If equipment is moving from one restricted area to another through the controlled area, it must meet the removable alpha and beta outlined in Regulatory Guide 8.30 prior to leaving the first restricted area.

Personnel ~~leaving a restricted area will be~~are -required to perform alpha and beta/gamma surveys ~~and~~ as well as record and sign the logs prior to ~~exiting the area~~entering an unrestricted area. If personnel are required to move through the controlled area to perform the required survey after exiting the restricted area, they may not enter into the office area, lunchroom or their personal vehicles prior to performing the alpha and beta/gamma surveys.