Cameco Resources
Crow Butte Operation

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

(308) 665-2215
(308) 665-2341 – FAX

July 3, 2017

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

2017 Annual ALARA Report
Source Materials License SUA-1534
Docket Number 40-8943

Dear Director:

Enclosed please find a copy of the Crow Butte Mine 2017 Annual ALARA Report and 2017 Land Use Survey. These reports are required under License Condition 11.2 of Source Materials License SUA-1534.

If you have any questions, please feel free to contact me at (308) 665-2215 ext 117.

Sincerely,

Walter D. Nelson

Walt Nelson
SHEQ Coordinator

Attachments: As Stated

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: Amanda Jones – NDEQ Program Coordinator
CR – Electronic File

NMSS20

ALARA Audit Report for 2017

Crow Butte Operations

Prepared for:
Cameco Crow Butte Operations
P. O. Box 169
Crawford, NE 69399

Prepared by:
Kari Toews
And
Elise Normand

SHEQ Systems
Cameco Corporation

June 18, 2018

EXECUTIVE SUMMARY

An ALARA audit of the Crow Butte Operations (CBO) in situ uranium recovery facility was conducted by Cameco's SHEQ Systems department on April 10 – 12, 2018. The audit commenced with an opening meeting on Tuesday, April 10th led by the auditors, Kari Toews and Elise Normand. A close out meeting at which preliminary audit results were presented was held on Thursday afternoon, April 12th.

For purposes of the ALARA audit, numerous records were examined prior to and during the audit visit including those shown in the table below. The site personnel were very helpful and both electronic and paper records were readily available during the audit.

Radiation Program Documents
Nuclear Regulatory Commission inspection reports
Previous audit reports
RSO and HPT training Records
Annual radiation worker training records
Visitor orientation records
Bioassay laboratory reports
Worker dosimetry reports
Radon decay product measurements
Air particulate measurement data
Routine inspection logs (daily walk through and weekly RSO inspection)
Monthly RSO reports
SERP records
Monthly Safety Meeting records
Quarterly planned task observation
Survey instrument calibration records
On-site survey records
SHEQ Monthly Reports
Radiation Work Permits
Semi-annual environmental monitoring reports
Environmental gamma measurement data
Environment air particulate concentrations
Respirator program

In summary, one finding and 7 recommendations were identified and are included in Section 3.2 of this document.

The maximum occupational dose for 2017 was 0.30 rem. The average total effective dose equivalent (TEDE) was 0.15 rem. The overall maximum doses are continuing a downward trend, although this year's average dose is slightly higher than the average dose in 2016. The radiation safety data, including the dose records, are entered into Cameco's CamRad database or recorded on paper. The trends in average and maximum annual doses are shown in Appendix A.

The TEDE of the maximally exposed member of the public, namely the nearest resident, for 2017 was 15.9 mrem. This TEDE value includes estimated doses from inhalation of uranium, radium-226 and radon as well as a gamma dose for the year. The 2017 dose to the public has continued to drop from 66 mrem in 2015 and 32.4 mrem in 2016. This drop appears be associated with the decrease in production, however, as a significant component of this dose is from radon improvements in the instrumentation discussed within this report may be playing a part in this as well.

The ALARA report is divided into fourteen sections having to do with various aspects of the facility's operation as shown in the following table.

Report Section	Audit Records Discussed
1	Dosimetry Summary
2.1	Routine operations (bioassay data, internal doses, external doses)
2.2	Safety meeting minutes, attendance records, training program
2.3	Inspection reports
2.4	Radiological survey and monitoring data
2.5	Radiation work permits
2.6	Safety and Environmental Review Panel (SERP)
2.7	Environmental radiological effluent and surveillance data
2.8	Instrument calibration records
2.9	Source leak tests
2.10	Review of radiation protection records
2.11	Unusual events
2.12	Review of 2016 ALARA audit recommendations
3	Summary of 2017 audit findings and recommendations
4.0	References

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LIST OF ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
µCi	Micro Curie
µg/L	Microgram per liter
ALARA	As Low As Reasonably Achievable
ALI	Annual Limit of Intake
APR	Air Purifying Respirator
Bq/m^3	Becquerel per cubic meter
CBO	Crow Butte Operations
CEDE	Committed Effective Dose Equivalent
Ci	Curie
CPP	Central Processing Plant
DAC	Derived Air Concentration
HPT	Health Physics Technician
ICRP	International Commission on Radiological Protection
keV	Thousand electron volts
ND	Non detect
NRC	Nuclear Regulatory Commission
NVLAP	National Voluntary Laboratory Accreditation Program
OSHA	Occupational Safety and Health Administration
OSL	Optically Stimulated Luminescent (Dosimeter)
pCi/L	Picocuries per liter
RML	Radioactive Materials License
RO	Reverse Osmosis
RPF	Respirator Protection Factor
RSO	Radiation Safety Officer
RWP	Radiation Work Permit
SERP	Safety and Environment Review Panel
TEDE	Total Effective Dose Equivalent
WL	Working Level – measure of the concentration of radon decay products

1.0 INTRODUCTION

The ALARA Audit for 2017 at the Crow Butte Operations (CBO) in situ uranium recovery facility was conducted by Cameco's SHEQ Systems department on April 10 – 12th, 2018. The audit commenced with an opening meeting on Tuesday, April 10th led by the auditors, Kari Toews and Elise Normand, both Health Physicists from Cameco's corporate Safety, Health, Environment and Quality (SHEQ) department. A closeout meeting at which preliminary audit results were presented was held on Thursday afternoon, April 12th. Attendees of the kickoff and closeout meetings were:

Auditors:

- Kari Toews, Lead Auditor
- Elise Normand, Auditor

Crow Butte Operations:

- Tami Dyer, Radiation Safety Officer
- Casey Yada, Health Physics Technician
- Walter Nelson, Coordinator, SHEQ, Environmental Affairs
- Robert Tiensvold, Manager, Restoration, Maintenance
- Tate Hagman, Plant Supervisor
- Brian Taylor, Sr. Technician, Safety, Health Safety & Environmental Affairs

Crow Butte personnel were very helpful in conducting this audit. Documents and records were clear, accessible and produced efficiently by the site upon request.

1.1 Site History

Commercial operations at the Crow Butte Operations commenced in April 1991. The in situ recovery process extracts uranium from the Basal Chadron sandstone aquifers at a depth of approximately 400 to 800 feet below the ground surface. The uranium in the formations is leached by a solution pumped through injection wells. The uranium-rich solution is pumped through recovery wells to the Central Processing Plant (CPP) where the uranium is extracted by ion exchange, precipitated, and dried in a "zero emissions" vacuum dryer. The purified uranium product, called yellowcake, is packaged in 55-gallon drums and transported to the Blind River refinery in Port Hope, Ontario for chemical processing. Based on the process used for drying the precipitate and laboratory data, the uranium product is classified as "soluble" for the purpose of radiation protection.

Liquid waste from the plant, primarily "bleed" water is disposed of in the evaporation ponds or through deep well injection. Solid waste (11e2 byproduct) is transported to either Pathfinder or the White Mesa uranium facility in Blanding, Utah under a contract for disposal.

1.2 ALARA Audit Requirements

License Condition (LC) 9.7 of the License SUA-1534[1] requires an annual ALARA audit of the CBO mill radiation safety program consistent with the recommendations in Nuclear Regulation Commission Regulatory Guide 8.31 (NRC, 2002). In accordance with LC 9.7 and the guidance in Regulatory Guide 8.31, the records reviewed in the ALARA audit were as follows:

- Bioassay results
- Records of internal and external exposures
- Safety meeting minutes, attendance records, and training program records
- Routine inspection reports and Monthly RSO reports
- Radiological survey and monitoring data
- Environmental radiological effluent and monitoring data
- Radiation Work Permits (RWPs)
- Surveys required by RWPs
- Reports of overexposures submitted to the NRC
- Reviews of operating and monitoring procedures completed during the period
- Results of required leak tests on radioactive sources
- Instrument calibration records

In addition, the following topics were addressed:

- Trends in occupational radiation doses
- Operation and maintenance of effluent control devices

1.3 Summary of General Site Activities in 2017

One mine unit was in stability, four mine units were in restoration, and five mine units were in production in 2017. The plant was fully operational for 2017 with a total yellowcake production of approximately 146,207 pounds. Tami Dyer is the current RSO. Casey Yada is the Health Physics Technician (HPT).

[1] The license, issued on November 5, 2014, retains the same license number but is not a numbered amendment as it is considered a new license.

1.4 Occupational Dose Summary

Occupational radiation doses are discussed in detail in Section 2.1. The committed effective dose equivalent (CEDE) for each monitored worker is calculated monthly based on average uranium concentration in airborne particulate material and the radon daughter concentration in each area in which the individual worked and the time spent in the area. The total effective dose equivalent (TEDE) is calculated quarterly based on the deep dose equivalent measured by the worker's badge and the total CEDE for the three months of the quarter. The maximum occupational dose for 2017 was 0.300 rem for a plant operator. The maximum dose in 2016 was 0.323 rem, which was also received by a plant operator. The average TEDE for 2017 was 0.151 rem; the average TEDE for 2016 was 0.133 rem. The distribution of TEDEs for all workers is shown in Figure 1 and Table 1.

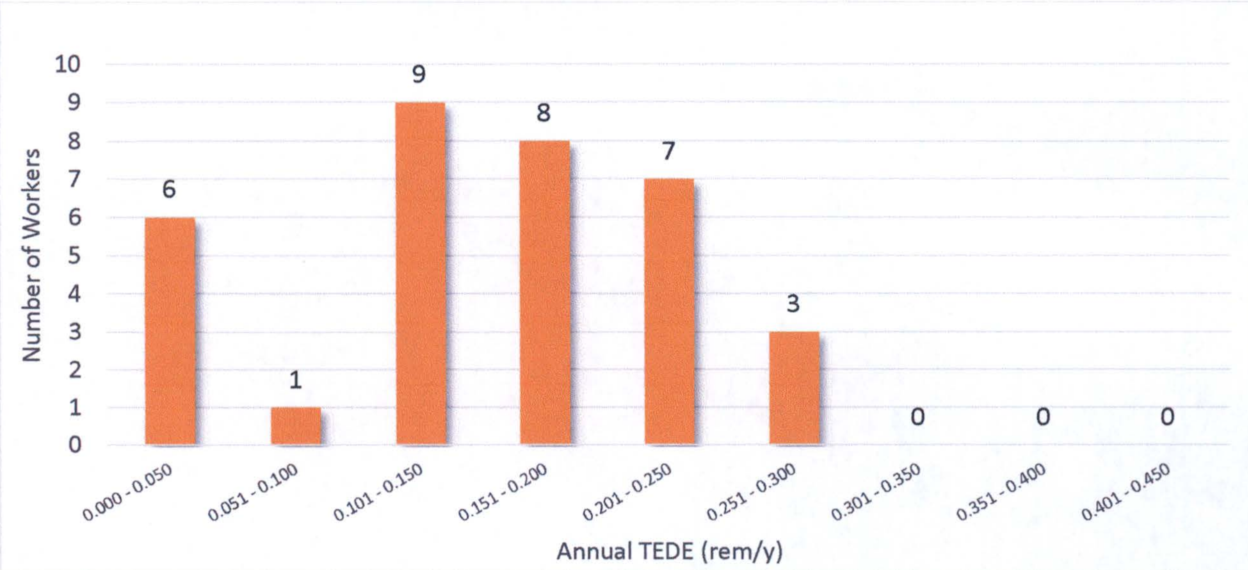
Table 1: Distribution of Annual TEDE for 2015 to 2017.

Dose Range (rem/y)	2015 (rem/y)	2016 (rem/y)	2017 (rem/y)
	Number of workers	**Number of workers**	**Number of workers**
0.000 – 0.050	16	10	6
0.051 - 0.100	3	3	1
0.101 – 0.150	2	10	9
0.151 – 0.200	11	9	8
0.201 – 0.250	6	5	7
0.251 – 0.300	4	1	3
0.301 – 0.350	4	2	0
0.351 – 0.400	3	0	0
0.401 – 0.450	2	0	0
0.451 – 0.500	0	0	0
Total number of monitored workers	51	40	34

The distribution of workers by dose is similar for all years, with a peak below 0.05 rem and a second peak at somewhat higher doses. All annual doses were less than the 0.5 rem per year criterion that requires dose tracking under 10 CFR 20. In 2017, the second peak occurred between 0.1 and 0.15 rem/y, which is similar to the distribution in 2016, and there were fewer workers at the high end of the distribution. This decrease continues to be related to the decrease in production rate and reduction in overall activities at the facility.

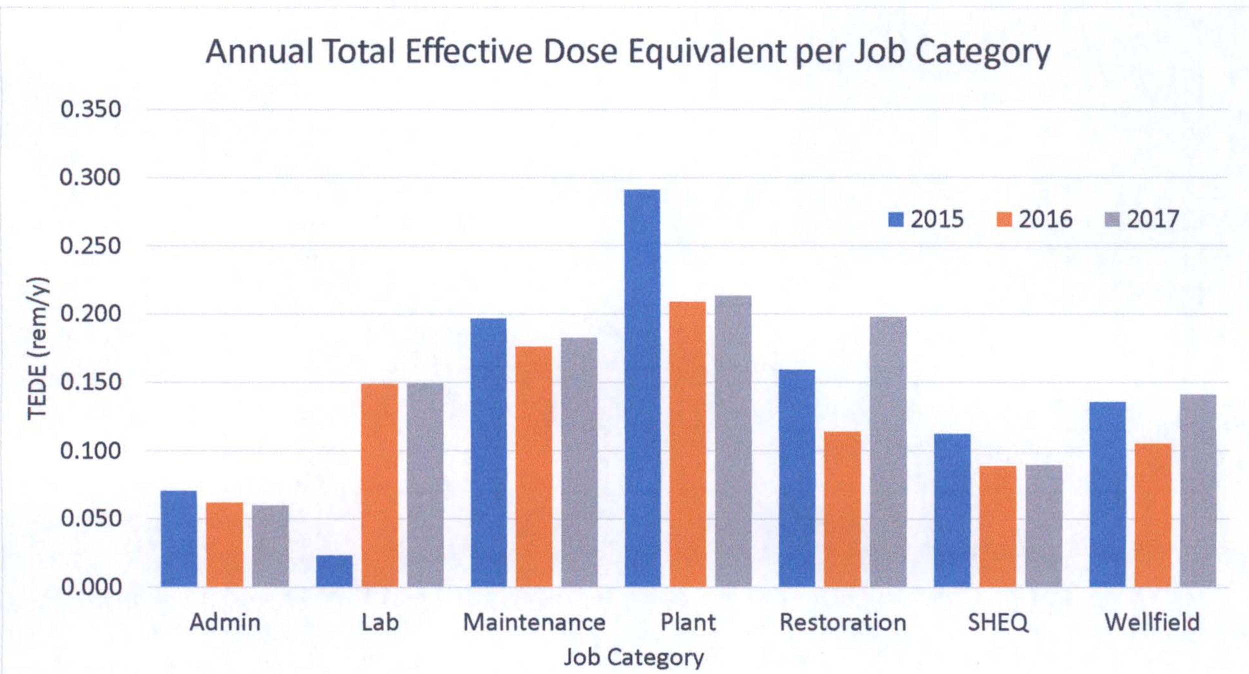
The radiation safety data used for dosimetry are entered into Cameco's CamRad database. The trends in average and maximum annual doses are shown in Appendix A.

Figure 1. 2017 Annual Worker TEDE Distribution.



Workers are classified into seven job categories based on the type of work typically performed and area of the facility in which they normally perform their work. The CamRad database utilizes these categories for reporting and trending of information. The annual TEDE per job category for between 2015 and 2017 is shown in Figure 2.

Figure 2. 2017 Annual TEDE per Job Category.



Most groups remained relatively stable compare to 2016. The Restoration job category experienced the greatest increase in TEDE among the job categories followed by the Wellfield category between 2016 and 2017. The TEDE for the Restoration category in 2016 and 2017 were 0.114 rem and 0.198 rem, respectively, and the TEDE for the Wellfield category in 2016 and 2017 were 0.106 rem and 0.141 rem, respectively. The increase in the average TEDE for the Restoration group was likely due to clean-up activities. The reduced workforce caused some workers to perform tasks that were previously outside their scope of work, and these tasks led to an increase in TEDE. The Wellfields group saw a minor increase in average TEDE, because the hours spent in the plant 2017 was estimated conservatively. All working hours were attributed to the plant even though some of worker time was actually spent outdoors.

1.5 Public Dose Summary

The potential dose to members of the public is calculated based on the net average concentrations of radionuclides in airborne particulate matter measured, radon concentration, and measured total gamma dose for the calendar year. The potential doses at all monitoring stations are calculated and reported in the Semi-Annual Radiological Effluent and Environmental Monitoring Report submitted at the end of the calendar year.

Monitoring Station AM-9 is located at the nearest residence, where the maximally exposed member of the public resides. Monitoring station AM-6 is the background monitoring station. Table 2 contains the data from AM6 and AM9 and the calculated dose to the maximum receptor. The complete table from the Semi-Annual Radiological Effluent and Environmental Monitoring Report is included in Appendix B.

Table 2: Summary of Data from AM9 in 2017.

Location	Analyte	Measured Value	Background Value (AM6)	Net Value	10 CFR 20 App. B, Table 2	Occupancy Factor	Indoor Equilibrium Factor	Dose to Public (mrem/y)
AM9 (nearest resident)	Uranium (μCi/ml)	1.2E-16	8.9E-17	3.2E-17	9.E-14			0.02
	Radium-226 (μCi/ml)	8.5E-17	8.5E-17	0	9.E-13			0.00
	Lead-210 (μCi/ml)	1.5E-14	1.6E-14	0	6.E-13			0.00
	Radon-222 (μCi/ml)	2.8E-10	2.4E-10	3.7E-11	1.E-10	0.75	0.50	6.9
	Gamma (mrem/yr)	44.2	35.2	9	--			9
							TEDE (mrem/y)	**15.9**

The average net uranium, radium-226 and lead-210 concentrations at AM-9 were 3.2E-17 μCi/ml, 0 μCi/ml and 0 μCi/ml, respectively. Dose from inhalation of these radionuclides are calculated by dividing the net average measured concentration for each radionuclide by its respective 10 CFR 20 Appendix B, Table 2 effluent standard (included in Table 3 for each radionuclide), and then multiplying that ratio by 50 mrem/y. The total dose from these radionuclides for 2017 is 0.02 mrem.

The net annual average radon concentration was 3.7E-11 µCi/mL, which is slightly lower than the 10 CFR 20, Appendix B effluent standard for Rn-222 in equilibrium with its decay products. However, because the measurement location is not at the boundary to the restricted zone, this is not an acceptable criterion for comparison. The radon dose to the maximum receptor, as per commitments references in LC 9.2 of the Materials License (SUA-1534), is calculated as per equation (1).

$$Dose\ Rn222\ (mrem) = \frac{Average\ Concentration\ above\ Background * 50\ mrem * Occupancy\ Factor * Equilibrium\ Factor}{10\ CFR\ 20\ AppB\ Table\ 2\ value\ in\ \mu Ci/ml} \quad (1)$$

The occupancy factor is based an estimate of the time spend in the residence. This estimate was made as follows:

> Total hours per year (8760) – time spend at work (40 hrs * 49 weeks worked) – time away due to hobbies/vacations/errands/etc. (48 hr * 10 weekends + 2hrs * 180 days) = 5960 hours.

This value represents and occupancy factor of 68%. However, because this is estimated, the site used an occupancy factor of 75% to be conservative and consistent with previous years. The nearest resident was determined based on a land use survey, which is attached to this ALARA report in Appendix C. The equilibrium factor is assumed to be 0.50 for an indoor receptor as per the recommendations of the NRC draft radon guidance (FSME-ISG-01, NRC 2014) and LC 9.2 of the Materials License. The estimated dose from radon decay products was 6.9 mrem for 2017.

The net gamma dose for the year 2017 was 9.0 mrem/y. The total effective dose equivalent (TEDE) for the member of the public was 15.9 mrem, which is less than the 10 CFR 20.1301 dose limit for members of the public.

This methodology for calculation of public dose has been in place since 2015. The public dose in 2015 was 66 mrem and 32.4 mrem in 2016. The trend is roughly a halving of public dose annually over this time frame. The difference in public dose between 2015 and 2017 seems to be related primarily to a decrease in production. In addition, a review of the results of individual track etch dosimeters indicates that variability in the results from these devices has been decreasing over time as well, which is resulting in a reduction in variability of the net radon concentration used in this dose estimate.

It was noted during the audit that there is not formalized procedure of documentation of how public dose is calculation. In addition, it was noted that the table currently submitted in the Semi-Annual Report to document the public dose includes data for monitoring locations not related to dose to the maximum receptor and due to the need to manually update numerous results and validate calculations could be prone to data entry errors (e.g. typos). It is recommended that the process for determining the maximum receptor and calculating dose to that receptor be documented. As an opportunity for improvement, considering simplifying the public dose table to only include dose to the maximum receptor be presented to help reduce potential for data entry errors.

Recommendation 1: Document the process for determining the maximum receptor and calculating dose to that receptor.

Recommendation 2: Considering simplifying the public dose table to only include dose to the maximum receptor.

2.0 ALARA AUDIT RESULTS

2.1 Routine Operations

2.1.1 Bioassay Data

Routine bioassays are conducted quarterly for all CBO personnel with the potential for exposure to uranium and monthly for individuals working in the dryer facility and yellowcake packaging area. The samples are submitted to Intermountain Laboratories (IML) in Sheridan, Wyoming for analysis. IML operates under Radioactive Materials License No. 49-29405-01, which expires on 10/30/2020.

As summarized in Table 5, 162 samples were submitted to IML in 2017. They included routine monthly and quarterly samples as well as pre-employment and termination samples. Each batch of samples was accompanied by two spiked and one blank samples. The spiked and blank samples were prepared from synthetic urine in the CBO laboratory and submitted as blind samples under the names of workers. As shown in Table 5, the results of all spiked samples were within the quality control limits. The largest deviation between the actual spike concentration and laboratory result was 12%, with the majority below 5%. All measured blank sample concentrations were below the reporting limit of 5 micrograms per liter (μg/L).

All urine bioassay concentrations were less than the laboratory reporting limit, 5 μg/L, with the exception of one sample that was 17.1 μg/L. This sample was part of a Radiation Work Permit (RWP-17-10) under which a worker was chipping pipe for disposal. Respiratory protection was worn during this work and breathing zone air samples were collected during the task. The first sample was collected prior to the worker's break and a second sample after the worker's break. The second sample filter was lost, however the first sample collected on that day while performing the same task was available and was used to estimate worker dose. Because there was a question as to the effectiveness of the respiratory protection, the dose was estimate assuming no PPE was worn. The site suspended chipping activities temporarily and will review the controls for chipping of pipe to reduce potential to exposures prior to it occurring again. The worker provided additional urine samples over a 24 hour period following being informed of the elevated sample by the lab. All subsequent samples for this individual were below the detection limit of the lab (5 μg/L).

Table 5. Results of Urine Bioassay Samples Submitted During 2017.

Date collected	No. samples	% Difference in spike and result		Uranium concentrations (µg/L)
		Spike 1	Spike 2	
01/10/2017	1	0.2	0.3	<5.0
02/19/2017	1	1.0	2.0	<5.0
03/13/2017 – 03/20/2017	33	4.3	5.8	<5.0
04/16/2017	1	2.5	3.0	<5.0
05/05/2017	6	6.0	8.0	<5.0
05/22/2017 – 05/24/2017	6	0.3	3.5	<5.0
06/08/2017 – 06/15/2017	33	7.1	12.0	<5.0
06/18/2017 – 06/21/2017	2	3.0	6.1	<5.0
07/11/2017	1	0.9	0.4	<5.0
08/14/2017	1	3.0	2.0	<5.0
09/09/2017 – 09/19/2017	33	12.0	6.0	<5.0
10/25/2017	1	5.6	5.8	<5.0
11/27/2017	1	0.3	2.4	<5.0
12/02/2017 – 12/03/2017	2	4.0	4.0	17.1
12/10/2017 – 12/15/2017	30	3.5	2.5	<5.0
12/12/2017 – 12/13/2017	7	4.0	2.7	<5.0
12/18/2017 – 12/22/2017	3	2.3	2.5	<5.0
Total	162			

The process for assigning a worker dose based on a bioassay sample was discussed with the site. The site procedure, CBR-RPP-008, Section 1.6.7, indicates that Regulatory Guides 8.22, 8.11, and 8.9 will be used to assign dose. These references are the applicable references for use to assign dose from bioassay samples,

2.1.2 Internal Doses

The Committed Effective Dose Equivalent (CEDE) for workers is calculated based on the estimated intake of uranium (µCi) and exposure to radon decay products (WLM). The ratio of the calculated annual uranium intake to the Annual Limit of Intake (ALI) for soluble uranium is multiplied by 5 rem to obtain the dose. The maximum and average doses to workers are reported in the Monthly Radiation Safety Report.

2.1.2.1 Radionuclide Concentrations in Airborne Particulate Matter

Uranium concentrations in air are measured in plant areas using area samplers with flow rates in the range of 40 to 50 l/min and breathing zone samplers with flow rates of approximately 5 l/min. The gross alpha concentrations are calculated and assumed to be attributable to uranium.

The estimated uranium concentrations are used in conjunction with the worker's time spent in the area to calculate the potential uranium inhalation intake.

The concentration calculations and formulas used in CamRad were checked and found to be accurate. Users can classify samples as either dosimetry or engineering in the database. Dosimetry samples are used in the calculation of worker doses. Engineering samples are generally related to samples taken to investigate issues and not indicative of routine worker exposures. Sample classifications and results are reviewed monthly by the RSO to ensure they are entered and categorized correctly.

The dosimetry samples in CamRad are averaged monthly by exposure area. Worker doses (in µCi) are calculated by multiplying the monthly average airborne uranium concentration (in µCi/ml) by the number of hours each worker was exposed and the standard breathing rate (1.2×10^{6} ml/hr). Currently there is one exposure area at the site, the main plant, and all exposure hours are assigned to that location; this includes time spent in the wellfields, deep disposal well and laboratory. Dosimetry reports are generated on a monthly basis and reviewed by the RSO.

The monthly maximum and average uranium intakes, as reported in the Monthly Radiation Safety Summary Reports, are shown in Table 6. All calculated monthly intakes were less than 2% of the 10 CFR 20 ALI, pro-rated over a 12 month period (8.33E-2 µCi).

Table 6. Monthly Maximum and Average Uranium Intakes by Workers for 2017.

Month	Maximum U Intake (µCi)	Average U Intake (µCi)
January	9.05E-4	6.95E-4
February	1.13E-3	7.76E-4
March	1.02E-3	7.81E-4
April	8.84E-4	5.98E-4
May	1.03E-3	7.12E-4
June	7.76E-4	4.92E-4
July	7.72E-4	4.46E-4
August	3.94E-4	2.43E-4
September	3.30E-4	2.20E-4
October	7.03E-4	3.89E-4
November	8.65E-4	5.40E-4
December	7.15E-4	4.23E-4

The reports available from CamRad also include an estimate of the soluble uranium intake by individuals for the time frames specified by the report to allow the site to demonstrate compliance to the weekly intake limit of 10 mg. Soluble intake values were reviewed on a monthly basis for 2017. The maximum intake over an entire month was 1.664 mg, therefore, the weekly intake limit was also not exceeded.

The site also performed semi-annual isotopic monitoring of airborne particulates in the plant. The site has requested and been granted an exemption for the reporting of Th-234, Pb-210 and

Bi-210 doses. The exemption was granted provided that these radionuclides be present at concentrations below 1% of their respective DACs. The sampling results for 2017 are shown below for these radionuclides; each radionuclide is below the required 1% of its DAC.

Table 7. Average Airborne Beta Particulate Concentrations Compared to DAC - 2017.

Radionuclide	Average Concentration (μCi/ml)	DAC (μCi/ml)	Percent of DAC
Th234	2.8E-14	8E-8	0.00004 %
Pb-210	2.6E-14	2E-10	0.013 %
Bi-210	2.6E-14	1E-8	0.0003 %

2.1.2.2 Radon Decay Product Concentrations

Radon decay product concentrations are measured monthly in 12 locations in the plant using and the Modified Kusnetz method is used to calculate worker doses from these measurements. The collected samples used in worker dose calculations are entered into CamRad. The concentration calculations and formulas used in CamRad were checked and found to be accurate. Similar to airborne uranium samples, users can classify samples as either dosimetry or engineering in the database and dosimetry samples are used in the calculation of worker doses. Sample classifications and results are reviewed monthly by the RSO to ensure they are entered and categorized correctly.

Monthly samples in CamRad are averaged by exposure area to calculate the average concentration. Worker doses are calculated by multiplying the average monthly radon daughter concentration (in Working Levels (WL)) by the number of hours each worker was exposed in the month, then dividing by 170 working level hours per month to obtain a worker exposure in Working Level Months (WLM). Currently there is one exposure area at the site, namely the main plant, and all exposure hours are assigned to this location including time spent in the wellfields, deep disposal well and lab areas. Dosimetry reports are generated on a monthly basis and reviewed by the RSO.

The practice of assigning all time that workers are potentially exposed to radiation sources to the plant area will conservatively estimate doses to workers in these other areas, because the site has demonstrated in their license application that the plant radon daughter average is higher than other areas within the facility.

The monthly maximum and average radon decay product exposures are reported in the Monthly Radiation Safety Report and are given in Table 8. All radon decay product exposures were less than 5% of the prorated monthly exposure limit, namely 0.33 WLM, based on 4 WLM per year.

Table 8. Worker Radon Decay Products Exposures during 2017.

Month	Maximum WLM	Average WLM
January	0.0089	0.0068
February	0.0059	0.0040
March	0.0093	0.0070
April	0.0106	0.0072
May	0.0106	0.0073
June	0.0143	0.0090
July	0.0060	0.0035
August	0.0070	0.0043
September	0.0036	0.0024
October	0.0081	0.0045
November	0.0067	0.0041
December	0.0056	0.0033

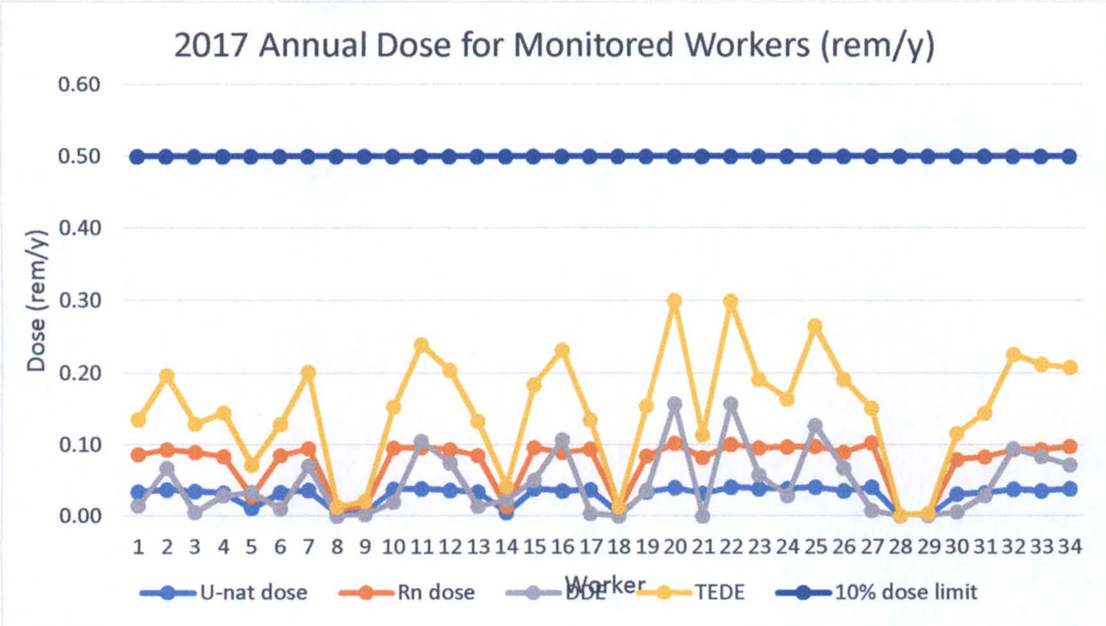
2.1.3 External Doses

Occupational direct gamma and beta radiation doses are measured using Optically Stimulated Luminescent (OSL) dosimeters supplied by Landauer, Inc. All Crow Butte workers are issued dosimeters except for four individuals in administration who do not routinely access the restricted areas of the facility. The OSL dosimeters measure deep dose equivalent, shallow (skin) dose and dose to the lens of the eye. The deep and shallow doses are imported into the CamRad database. During a review of a quarterly report from Landauer, it was confirmed that the shallow and eye dose were comparable to the deep dose and no elevated readings were observed. The dosimeters are exchanged quarterly. When not in use, dosimeters are stored on a badge board near the building entry. Workers pick up their dosimeters at the start of the shift and return them to the badge board at the end of the shift. The control badge is stored on the badge board. The vendor subtracts the control badge dose from the worker badge dose to obtain the reported dose to the worker while at work. The maximum gamma dose to an individual worker in 2017 was 0.158 rem. The average external dose was 0.049 rem.

2.1.4 Total Effective Dose Equivalent (TEDE)

The TEDE for each worker is calculated by adding the dose from inhalation of radon decay products and uranium in airborne dust to the deep dose equivalent (DDE) measured using the worker's OSL badge. The Annual TEDE, including the breakdown by dose component, for individual workers is shown in Figure 3. The annual average 2017 CEDE from inhalation of radon decay products was 0.075 rem; the CEDE from inhalation of uranium was 0.03 rem; the average DDE from direct radiation was 0.049 rem. The average TEDE was 0.151 rem or 3.0 percent of the annual occupational dose limit. The maximum annual TEDE was 0.300 rem or 6.0 percent of the annual dose limit. All of the worker doses were less than 10 percent of the annual dose limit, the level that requires dose monitoring under 10 CFR 20.1502.

Figure 3. Worker Doses by Pathway in 2017.



Workers are grouped into categories in the CamRad database according to the tasks they perform, as explained in Section 1.4. Dose trends have been reviewed by dose group and by dose component. Table 9 contains the average and maximum TEDE dose by worker category for the years 2015 through 2017. Table 10 contains the breakdown of the average dose by dose component. Table 11 contains the percentage of average TEDE by component.

The most noticeable trends from the data in Table 9 are a drop in the total number of personnel working on-site and a continual descending trend in the overall maximum TEDE over the last three years. The average TEDE has remained fairly constant over the last three years, however there was a slight increase in the overall average TEDE in 2017 compared to 2016. Looking by job category, the average TEDE are very comparable to 2016, though an observable increase was noted in the Restoration and Wellfield groups. The increase in the average TEDE for the Restoration group was likely due to clean-up activities. The reduced workforce caused some workers to perform tasks that were previously outside their scope of work, and these tasks led to an increase in TEDE. The Wellfields group saw an increase in average TEDE because their plant time in 2017 was estimated conservatively. All working hours were attributed to the plant even though some of this time was actually spent outdoors. As in the past few years, the maximum TEDE was received by a Plant worker.

Figure 4 shows the breakdown of the average TEDE by dose component for each worker category. Consistent with last year's results, the dose from radon daughters contributed the most toward the total dose for each worker category with the exception of the Plant workers whose gamma and radon daughter doses were comparable. As expected, the Plant and Maintenance workers had the highest overall doses due to the time the workers spent in the main plant.

Table 10 provides the average dose by component over time across all job categories. There has been an increase in the average doses from both radon daughter and gamma components. As with the TEDE, the increase in these components is primarily associate with a change in work assignments for the Restoration group and more conservative methodology for calculation of radon progeny (i.e. assuming all time is spent in the plant). The airborne uranium dose was the same in 2017 as in 2016, and both years were lower than 2015.

The breakdown of the percent of TEDE by component, Table 11, has remained relatively constant over the previous three years. The dose due to radon daughters makes up just under half (49%) of the total dose of the TEDE, with gamma consisting of the second largest contributor (32%) and airborne uranium the smallest (19%).

Table 9. Total Effective Dose Equivalent (TEDE) by Worker Classification for 2015 - 2017.

Year	2015			2016			2017		
Work Group	# of workers	Average TEDE (rem)	Maximum TEDE (rem)	# of workers	Average TEDE (rem)	Maximum TEDE (rem)	# of workers	Average TEDE (rem)	Maximum TEDE (rem)
Administration	4	0.07	0.23	4	0.06	0.19	4	0.06	0.16
Laboratory	2	0.02	0.03	2	0.15	0.15	2	0.15	0.15
Maintenance	3	0.20	0.30	3	0.18	0.21	3	0.18	0.23
Plant	11	0.29	0.39	10	0.21	0.32	9	0.21	0.30
Restoration	3	0.16	0.25	3	0.11	0.17	2	0.20	0.20
SHEQ	5	0.11	0.22	5	0.09	0.18	5	0.09	0.21
Wellfield	14	0.14	0.28	13	0.11	0.19	9	0.14	0.19
Overall	**42**	**0.17**	**0.39**	**40**	**0.13**	**0.32**	**34**	**0.15**	**0.30**

Figure 4: Breakdown of TEDE by Dose Component for Each Worker Category.

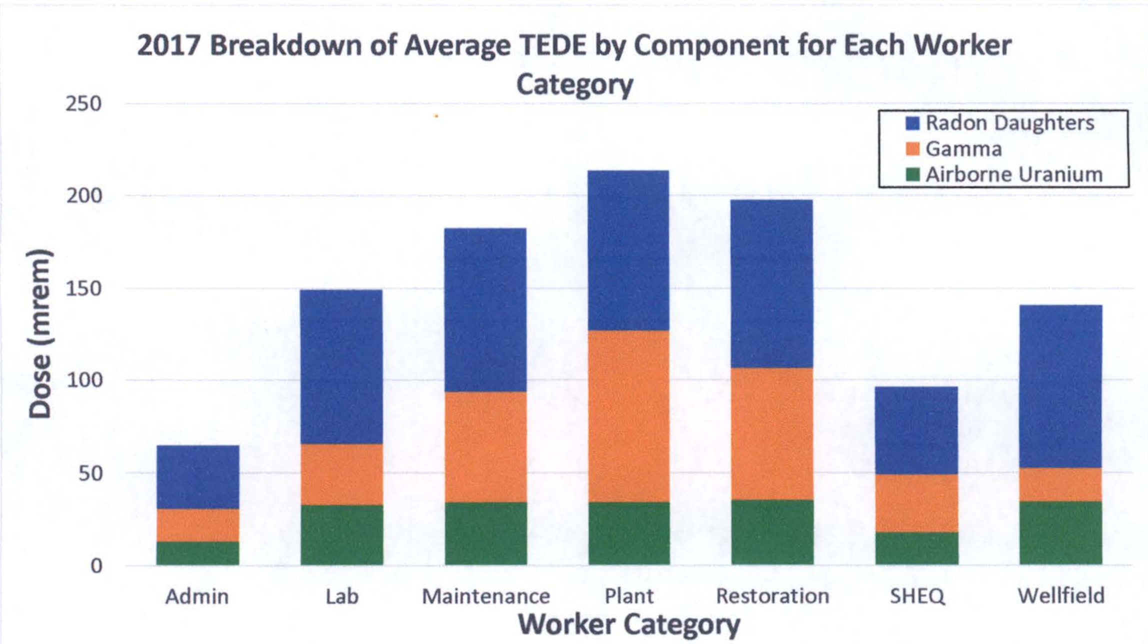


Table 10. Average Dose (mrem) by Component for 2015 – 2017.

Dose Component	2015	2016	2017
Radon Daughters	95	67	75
Airborne Uranium	37	30	30
Gamma	47	39	49

Table 11. Percent of TEDE by Component for 2015 – 2017.

Dose Component	2015	2016	2017
Radon Daughters	53%	50%	49%
Airborne Uranium	21%	22%	19%
Gamma	26%	28%	32%

The annual dose is reported to each employee in a Cameco-specific format that includes the same information as is provided on the NRC Form 5 Occupational Dose Record for a Monitoring Period. As was noted in the previous ALARA report, the Cameco form does not report the eye or shallow equivalent doses. The shallow dose is imported into the CamRad database and is available for trending and reporting. The shallow dose was reviewed as was found to be comparable to the deep dose equivalent and well below applicable dose limits.

2.1.5 Personal Contamination Surveys and Material Release Surveys

A sampling of the Surveys of Material Release forms from each quarter of 2017 were reviewed. It was noticed that the calculation for the beta efficiency for the survey instrument 3030P (319870) used the 2π source DPM value rather than the total emission rate (4π DPM value). As a result, the beta efficiency was roughly 58%, which is double the expected value should the 4π DPM value be used in the calculation. The site recognized this error and a corrective action plan is in progress, including correction of all impacted samples and reports. The beta contamination surveys using this instrument were reviewed and it was determined that even with a corrected efficiency, no exceedances occurred.

Beyond the issue identified with the counter efficiency, a sampling of radiological monitoring associated with shipments of radioactive materials in 2017 were reviewed and found to be acceptable. During the review it was noted that the "Tagged and Released to" and the "Date Tag Returned" fields were not always completed. The site explained that they were used for different purposes and were not always both required to be filled in. The site procedures related to both transport of radioactive material (CBR-RPP-009) and contamination control (CBR-RPP-005) were reviewed. These documents describe the basis and process for performing the measurements.

Frisker station records were reviewed, no issues were identified. In addition, it was confirmed that the RSO or designate performed a monthly review of the records from the frisker stations.

Workers receive initial training on use of the equipment and scanning process. In addition on a monthly basis the HPT performs a task observation on a sampling of workers while performing a scan. Generally 8-12 workers are observed on a monthly basis to verify the monitoring procedure is being followed.

Finding 1: An incorrect efficiency was being used to calculate surface contamination measurements for samples measured on the 3030P survey instrument. The correct efficiency for this instrument must be determined and associated survey results corrected. Site has self-identified this issue and has developed an action plan to correct the impacted samples.

2.2 Safety Meeting Minutes, Attendance Records, and Training Program Records

2.2.1 Safety Meeting Records

"All Hands" safety meetings are to be held monthly. Records of the meetings were reviewed. The safety meeting records presented are complete and indicate a variety of topics covered. However, there were no safety meetings recorded for the months of May and August, 2017. The dates and topics discussed at the meetings are given in Table 12.

Table 12. Safety Meeting Date and Topics during 2017.

Date	Subjects	Attendees
01/25/2017	Instrument Arc Flash – Use of Experience HO-2017-000013	25
02/28/2017	Hazards due to Winter Storms Hazards in the wellfield from recent winter storms	26
03/29/2017	Handrails: Use of Experience Lanyards: Use of Experience Fall Protection: Must be trained before use of equipment	25
04/06/2017	Review of Recent Health & Safety: Injury Incidents (Smith Ranch Highlands)	23
06/21/2017	Car Accident Review: Need to wear seatbelt	28
07/27/2017	Hot Weather Safety	21
09/20/2017	Hazards of Rushing	22
10/26/2017	Slips and Falls: Get winter ready	23
11/08/2017	Fire Extinguisher Use	23
12/13/2017	Proper Winter Gear: Use cleats and poles	20

2.2.2 Radiation Worker Training

Introductory radiation safety training is conducted for all new employees according to materials reviewed by the auditors. Worker radiation safety refresher training is conducted in April every year. A quiz is administered at the end of training. A sample of completed tests was reviewed by the auditors and found to be acceptable and complete. As part of the refresher training, the RSO conducts a "Rad Bowl" competition, to test the workers knowledge. The training program is adequate and meets the requirements of Regulatory Guide 8.31.

RSO and HPT training was also reviewed during the audit. All records were found to be up to date and meet the requirements of Regulatory Guide 8.31.

Recommendation 3: Based upon a review of current qualifications, Casey Yada now meets the qualifications for RSO. It is recommended that the site consider designating Mr. Yada as an RSO.

2.2.3 Planned Task Observation

The RSO conducts a "Planned Task Observation" quarterly to evaluate the performance of the HPTs. Table 13 lists the topics covered by the evaluations in 2017.

Table 13. Topics Covered in Planned Task Observation Evaluations in 2017.

Date	Evaluator	Task Observed
03/29/2017	Tami Dyer	Monthly radon samples
06/28/2017	Tami Dyer	Surveying drums
08/22/2017	Tami Dyer	Wellhouse isotopic air samples
12/05/2017	Tami Dyer	Plant gamma

As noted in Section 2.1.5 task observations of workers performing personal monitoring at the frisker stations are also performed on a sampling basis.

Best Practice 1: Routine reinforcement of procedural compliance (specifically personal monitoring and HPT activities) through observation programs.

2.3 Inspection Reports

2.3.1 Routine Inspections

Daily walk-through inspections are conducted in the plant. As per section 9.7 of site license, the site is permitted to identify one or more qualified designees who may perform daily inspections in the absence of the RSO and HPTs. The training program as well as the results of exams and on the job training (proficiency checks) were reviewed and found to be present for all designees. As previously noted, during the review of inspection records, it was found that the requirements for review by the RSO or HPT were met.

The daily walk-through inspection forms were reviewed during the audit. Each walk-through inspection log form covers a full week. The area owner/operator fills out the checklist and initials the form. The RSO then uses that checklist for her walk-through and then signs the form.

All checklists from 2017 were reviewed and the timelines required by the license were met with the exception of two occasions. No RSO or designate was present on the daily inspections between Saturday, July 1 and Tuesday, July 4th, 2017 inclusive (4 days) for both the RO and CPP. The 4th of July fell on the Tuesday. No RSO or designate was present on the daily inspections between Saturday, December 23 and Tuesday, Dec 26, 2017 inclusive (4 days) for both the RO and CPP. This is during the Christmas holiday. While Thanksgiving is specifically permitted within the License to allow a 4 consecutive-day inspection by designees, these other two holidays are not.

The RSO or her qualified designee performs a weekly inspections of the site, accompanied by the Restoration Manager or Plant Supervisor. Representative copies of the form were reviewed. The inspection is documented in a memo to the Restoration Manager that is printed and kept on file along with a monthly inspection form, both are signed by the RSO. The inspections are compliant with Regulatory Guide 8.31.

The recommendation from the 2016 ALARA Audit to include an explicit place on the inspection form for the RSO to sign was not fulfilled on the daily inspection form.

Recommendation 4: Consider requesting a revision to Section 9.7 of SUA-1534 to include all major holidays, not just Thanksgiving, in the allowance for qualified designees to perform daily inspections for four consecutive days.

2.3.2 NRC Inspections

The last annual NRC inspection took place June 20-22, 2016. There was one Severity Level IV violations identified in the inspection report: Failure to appropriately survey and label an environmental sample prior to shipment to an offsite laboratory. Because the licensee identified the violation, corrected the violation within a reasonable period of time, the violation was non-repetitive, and the violation was not willful, the violation is being treated as a Non-Cited Violation, in accordance with Section 2.3.2 of the Enforcement Policy. These Non-Cited Violations were addressed and corrected prior to the inspection and were closed by the NRC with no further action.

2.3.3 ALARA Audit

The 2016 ALARA Audit was conducted by Kari Toews and Morgan Bradford, both Health Physicists from Cameco's corporate office, in March of 2016. The recommendations from that audit are discussed in Section 2.12.

2.4 Radiological Survey and Monitoring Data

2.4.1 Quarterly Gamma Exposure Rate Surveys

Quarterly gamma exposure surveys are conducted outside the Central Processing Plant (CPP), Reverse Osmosis (RO) facility and the Well Houses. The maximum exposure rates at various locations inside and outside the plant are recorded and compared to the previous month's data. All Well Houses exposures rates above 5 mrem/hr are posted as Radiation Areas. No areas outside the Well Houses had exposure rates exceeding 2 mrem/hr.

The maximum exposure rates measured outside the CPP and the RO facility are given in Table 14.

Table 14. 2016 Maximum Gamma Dose Rate Measured Outside (mrem/hr).

	Maximum dose rate measured outside (mrem/hr)	
Quarter	CPP	RO plant
1	0.6	0.8
2	0.6	0.8
3	0.6	0.8
4	0.6	0.8

2.4.2 Contamination Surveys

Routine alpha and beta removable contamination surveys are performed monthly in the restricted and unrestricted areas. Representative records were reviewed.

Locations within the unrestricted area are sampled on set schedule, as well as a focus on transition points out of the restricted area to ensure that contamination is not being tracked. There were no elevated samples in the unrestricted zone. Some samples within the restricted zone were elevated. In these cases, the area operator was notified and the contamination was cleaned up.

The issue with an incorrect efficiency on survey instrument 3030P, identified previously in Section 2.1.5, also impacted these contamination surveys. As with other sample types a review of the survey results was performed and no items were found that would have exceeded a release limit using the corrected efficiency.

2.5 Radiation Work Permits (RWPs)

Ten Radiation Work Permits (RWPs) were issued in 2017. RWPs are issued for non-routine activities that involved the potential for significant exposure to radioactive materials and for which there were no standard operating procedures. The 2017 RWPs are listed in Table 15. RWPs describe the activity, personnel involved, radiological data and protective equipment required. The RWPs were reviewed to confirm that those individuals on the permit had read and signed the permit form. Participants did so by initialing the RWP in the Personnel section after their printed or written names. The review of RWPs also confirmed that protective measures were identified, requirements for PPE had been specified where necessary, and monitoring had been performed.

During Radiation Work Permit (RWP-17-10) where one worker was chipping pipe for disposal, the worker provided a bioassay sample at 17.1 μg/L. Details of the incident and investigation are included in Section 2.1.1.

RWPs for which workers are assigned a dose are entered into CamRad. It was found that the airborne uranium and radon daughter samples pertaining to RWPs were only entered into CamRad when they contributed dose to workers. It is suggested that, moving forward, all records should be entered into CamRad even if their dose contribution is null or negligible to ensure completeness of records.

Table 15. Radiation Work Permits Issued during 2017.

RWP #	Description of work	Date Initiated	Date Terminated	Record complete?
RWP 17-1	Entry and repair the inner Manifolds on IX-1	17/02/2017	01/06/17	yes
RWP 17-2	Install down-flow tangential valve	09/03/2017	01/06/17	yes
RWP 17-3	Dryer baghouse maintenance	02/05/2017	01/06/17	yes
RWP 17-4	Inside DF columns, remove inner manifolds, down-flow tangential repairs, reassemble inner manifolds, grind and paint inside DF columns	19/05/2017	01/06/17	yes
RWP 17-5	Remove 12 inch T in the down flow injection piping and remove bicarb scale and buildup	19/05/2017	01/06/17	yes
RWP 17-6	Weld main shaft on spooling drum.	24/05/2017	01/06/17	yes
RWP 17-7	Replace filter media in Precip A demister box	13/06/2017	02/11/17	yes
RWP 17-8	Grind and prep for a repair patch on manhole for Precip A	29/06/2017	02/11/17	yes
RWP 17-9	Replace bottom valve on Resin Trailer	20/10/2017	02/11/17	yes
RWP 17-10	Chipping pipe, scoop pipe chips into a super sack	28/11/2017	12/12/2017	yes

Recommendation 5: All records should be entered into CamRad even if their dose contribution is null or negligible to ensure completeness of records.

2.6 Safety and Environmental Review Panel (SERP)

The SERP is tasked with approving changes in the facility or procedures as described in the license application and conduct tests or experiments not described in the license application as long as conditions specified in License Condition 9.4. (Amendment 1) are met. License Condition 9.4D defines the purpose and makeup of the SERP. The SERP approved four actions in 2017, which are briefly described in Table 16.

Table 16. 2017 SERP Actions.

SERP Evaluation Number	Date	Action Taken
SERP 17-01	16/03/2017	Rescind SERP 16-02 that made revisions to Figs. 1, 2, and 5 in the Evaporation Pond Onsite Inspection Program.
SERP 17-02	14/06/2017	Modification of the organizational structure to remove the position Director Safety, Health, Environment and Quality
SERP 17-03	17/10/2017	Review and assess a new liner and leak detection system for Commercial Evaporation Pond #4
SERP 17-04	21/11/2017	Modification of the organization structure to remove the positions Manager Safety, Health, Environment and Quality and SHEQ Specialist and reassign the responsibilities to a new position, SHEQ Coordinator.

2.7 Environmental Radiological Effluent and Surveillance Data

As part of the environmental monitoring program, airborne radionuclide concentrations and direct gamma radiation dose rates are measured quarterly at eight air monitoring stations around the permitted area boundary, including a background location (AM6) and the residence of the maximum receptor (AM9). Radon gas concentration is measured semi-annually at the same locations. The measured concentrations and the gamma exposure rate are used to calculate the potential dose to a member of the public.

2.7.1 Radon Gas

Radon gas concentrations are measured using the Landauer, Inc. RadTrak alpha track detector. The detectors are exchanged semi-annually with a minimum detectable concentration of 2E-10 µCi/mL (0.2 pCi/L). The annual average radon concentrations for 2015 to 2017 are given in Table 17. In 2017, annual average radon concentrations were comparable to averages in previous years.

Table 17. Annual Average Environmental Radon Concentration in Air.

Station	2015 (μCi/mL)	2016 (μCi/mL)	2017 (μCi/mL)
AM-1 (residence)	3E-10	3E-10	3E-10
AM-2 (permit area boundary)	4E-10	4E-10	3E-10
AM-3 (permit area boundary)	3E-10	2E-10	3E-10
AM-4 (permit area boundary)	3E-10	3E-10	3E-10
AM-5 (residence)	5E-10	3E-10	3E-10
AM-6 (background)	3E-10	3E-10	2E-10
AM-8 (site boundary)	5E-10	3E-10	3E-10
AM-9 (nearest resident – max receptor)	6E-10	4E-10	3E-10

As an additional note, beginning in 2017, as part of the license application, 6 track etch cups were placed at the background and maximum receptor locations to help reduce uncertainty and any potential issues with outliers. Beginning in 2014, Landauer, Inc. adjusted their procedure for handing the RadTrak detectors prior to deployment. Previously, the detector material had been stored for a period up to a year or more prior to deployment in the field and some of the packaging leaked prior to deployment resulting in spuriously high radon measurements. An analysis of track etch cup data for 8 quarters before and 8 quarters after this change indicates an observable increase in stability of the results. A simple analysis of the range (the maximum minus the minimum) over the Pre and Post 2014 time periods indicates a significant reduction in apparent variability of the results. The Pre-2014 measurements had a range that was between 2 and 25 times higher than the range from Post-2014. An analysis was not performed to statistically identify outliers, however it is worth noting that Pre-2014, there are 13 measurements (23%) at or above 1E-9 μCi/ml, compared with none Post-2014.

Given that track etch cup stability and reduction in outliers has remained relatively consistent for the previous eight quarters, the site may want to consider whether the devices are sufficiently stable to warrant a reduction in the number of track etch cups deployed to the background and maximum receptor stations.

Table 18: Assessment of the Variability of Trach Etch Cup Results Over Time

Radon Gas Concentration (1E-9 μCi/ml)									
	Semi-Annual Period	AM-1	AM-2	AM-3	AM-4	AM-5	AM-6	AM-8	AM-9
Pre-2014	1st Q 2010	0.4	0.5	0.3	0.3	0.5	0.3	0.4	
	2nd Q 2010	0.3	0.5	0.4	0.4	0.5	0.5	0.5	
	1st Q 2011	0.2	0.2	0.2	0.2	0.4	0.2	0.2	
	2nd Q 2011	2.3	1.6	2.2	1.5	0.6	0.2	2.1	
	1st Q 2012	0.2	0.3	0.2	0.3	0.6	0.2	0.3	
	2nd Q 2012	0.4	0.9	0.5	0.4	1	1.3	0.5	

	1st Q 2013	0.6	0.2	0.6	1	1.1	1	0.9	
	2nd Q 2013	0.7	2.5	2.6	0.2	0.3	0.2	3	
Post-2014	1st Q 2014	0.2	0.2	0.2	0.2	0.2	0.2	0.2	
	2nd Q 2014	0.3	0.6	0.3	0.4	0.5	0.4	0.4	
	1st Q 2015	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3
	2nd Q 2015	0.3	0.5	0.3	0.3	0.6	0.3	0.5	0.6
	1st Q 2016	0.2	0.4	0.2	0.3	0.2	0.3	0.4	0.7
	2nd Q 2016	0.3	0.4	0.3	0.3	0.4	0.3	0.3	0.3
	1st Q 2017	0.2	0.3	0.3	0.4	0.3	0.2	0.3	0.3
	2nd Q 2017	0.3	0.4	0.2	0.3	0.3	0.2	0.3	0.3
Range Pre-2014 (max-min)		2.1	2.3	2.4	1.3	0.8	1.1	2.8	
Range Post-2014 (max-min)		0.1	0.4	0.1	0.2	0.4	0.2	0.3	0.4

Recommendation 6: Consider if the stability of track etch cups has increased sufficiently to warrant use of fewer track etch cups at the background and maximum receptor sites.

2.7.2 Radionuclides in Airborne Particulate Matter

Particulates are collected on a quarterly basis on filters at the same locations as the radon concentrations. The filters are exchanged weekly but composited quarterly. The flow rate is approximately 50 liters per minute (L/m). The filters are analyzed for Ra-226, Pb-210, Uranium and Th-230, and the resulting concentrations in air are listed in Table 19.

The radionuclide concentrations in airborne particulate matter are comparable for all four years at all eight locations. Results remain low and there are no observable trends.

Table 19. Annual Average Radionuclide Concentrations in Airborne Particulate Matter.

Year	**Annual Average Ra-226 Conc. (μCi/mL)**				**Annual Average Pb-210 Conc. (μCi/mL)**			
Location	**2014**	**2015**	**2016**	**2017**	**2014**	**2015**	**2016**	**2017**
Effluent Limit	*9E-13*				*6E-13*			
AM-1	1E-16	1E-16	7E-17	1E-16	2E-14	2E-14	1E-14	2E-14
AM-2	1E-16	1E-16	6E-17	1E-16	2E-14	2E-14	2E-14	2E-14
AM-3	1E-16	1E-16	1E-16	7E-17	1E-14	2E-14	1E-14	2E-14
AM-4	1E-16	1E-16	6E-17	7E-17	2E-14	2E-14	2E-14	2E-14
AM-5	2E-16	1E-16	5E-17	9E-17	2E-14	2E-14	1E-14	2E-14
AM-6	1E-16	1E-16	5E-17	9E-17	2E-14	2E-14	2E-14	2E-14
AM-8	1E-16	1E-16	6E-17	8E-17	2E-14	2E-14	2E-14	2E-14
AM-9		1E-16	1E-16	8E-17		2E-14	2E-14	2E-14

Table 19. Continued.

Year	Annual Average U-nat Conc. (µCi/mL)				Annual Average Th-230 Conc. (µCi/mL)			
Location	**2014**	**2015**	**2016**	**2017**	**2014**	**2015**	**2016**	**2017**
Effluent Limit	*9E-14*				*3E-14*			
AM-1	1E-16	8E-17	2E-16	2E-16	6E-17	5E-17	3E-17	3E-17
AM-2	2E-16	3E-16	3E-16	4E-16	5E-17	5E-17	2E-17	4E-17
AM-3	1E-16	2E-16	1E-16	4E-17	9E-17	5E-17	0E+00	2E-17
AM-4	1E-16	1E-16	2E-16	2E-16	2E-16	5E-17	0E+00	1E-17
AM-5	2E-16	2E-16	2E-16	2E-16	5E-17	5E-17	2E-17	3E-16
AM-6	1E-16	7E-17	1E-16	8E-17	5E-17	5E-17	1E-17	2E-15
AM-8	1E-16	1E-16	1E-16	7E-17	5E-17	5E-17	1E-17	2E-16
AM-9		1E-16	1E-16	8E-17			1E-16	1E-15

2.7.3 Direct Gamma Radiation

Direct gamma radiation doses at the nine air monitoring stations are measured using Landauer, Inc. dosimeters. The dosimeters are exchanged quarterly. The total annual gamma doses for each monitoring location are given in Table 20. Annual gamma doses (without background (AM6) subtraction) measured at these location in 2017 are higher than in previous years. As per a concern raised by the NRC and a recommendation from the previous ALARA report, additional shielding was added to the storage location for the Deployment Control badges to reduce accumulated dose on these badges while in storage. The result is a somewhat higher net dose rate at the monitoring locations. When the site background gamma dose rate at AM6 is subtracted from the measurement at each monitoring location to estimate the incremental gamma dose rate, the results are similar to 2016.

Table 20. Annual Measured Gamma Dose from 2015 to 2017.

	Annual Dose (mrem/y)		
Year/Station	**2015**	**2016**	**2017**
AM-1	30.0	25.8	34.3
AM-2	31.6	25.9	41.0
AM-3	33.7	32.3	42.8
AM-4	29	23	37.2
AM-5	32.6	28.2	44.2
AM-6	33.3	21.1	35.2
AM-8	37.9	38.7	45.2
AM9	16.3	31.0	44.2

2.7.4 Emissions Calculation

As per License Amendment 1 of SUA-1534, a new airborne effluent monitoring program was approved for the site in late 2016 for compliance with 10 CFR 40.65 requirements. Technical review of this program by the NRC was completed and approved in January of 2016. Sampling commitments for this new monitoring plan are as follows:

Table 21. Sampling Commitments for the Monitoring Program.

Sample Type	Location	Frequency
Radon Gas	Main Plant - tanks	Specified tank vents – quarterly
	Main Plant - general area	6 specified locations - semi-annually
	Wellfield	Venting well head - quarterly
	Wellhouse	4 production and 4 restoration wellhouses – semi-annually
	Spills	As required
Radon Daughters	Main Plant - tanks	Specified tank vents – quarterly
	Main Plant - general area	Routine sampling as per approved schedule
	Wellhouse	4 production and 4 restoration wellhouses – semi-annually
Particulate	Main Plant	Semi-annually (routine locations) for 2 years, annually after that
	Wellhouse	4 production and 4 restoration wellhouses – semi-annually

These samples were reviewed to confirm if they were collected as per the schedule and that the results were included in the semi-annual report. All samples were collected according to the schedule with the exception wellheads while venting, which were not collected as there were no wellheads vented in 2017. It was noted that a value of zero was provided in the Semi-annual Report. If no samples were collected, the report should state this and the reason, not a zero value.

Table 22 summarizes the yearend emissions results. The tanks clearly contribute the vast majority of the emissions. A review of the tanks sampling data indicated that the final emission rate is relatively consistent year to year, however, there is significant variability in the results from quarter to quarter. As previously noted, the use of a maximum result rather than use of a steady state or average over the course of the year will inherently overestimate emissions. During 2017, use of the maximum emission caused the semi-annual emissions rate to be approximately 40% higher than the average and 50% higher than steady state measurements.

Use of an average emission rate would have resulted in a total emission of 5493 Ci per year and use of the steady state measurements would have resulted in an emission rate of 4317 Ci/yr. Both options, but particularly the steady state measurements result in an emission rate that is very comparable to the calculated emissions of 4542 Ci/yr from the previous approved methodology.

Table 22. Emissions in Ci/Yr by Source 2017.

Source	Radon Progeny	Radon Gas	Particulate	Total by Source	% by Source
Plant	0.43	3.68	1.03E-04	**4.11**	**0.0%**
Wellhouses	0.32	9.25	1.76E-05	**9.57**	**0.1%**
Well Fields (Wellheads)	N/A	0.00E+00	N/A	**0.00E+00**	**0.0%**
Tanks/vents	155.4	8872.0	N/A	**9027.5**	**99.8%**
Spills (enter manually)	N/A	8.51E-02	N/A	**8.51E-02**	**0.0%**
Deepwells	N/A	N/A	1.03E-06	**1.03E-06**	**0.0%**
Total by Type	**156.19**	**8885.04**	**1.22E-04**		
Total Emissions for Full Year		**9041.2**	**Ci**		

Recommendation 7: If no samples were collected, the Semi-Annual report should state this and the reason, not a zero value.

2.8 Instrument Calibration Records

Instrument calibration records were reviewed. Most of the radiation detection instruments are sent to the manufacturer (Ludlum Measurements) for calibration. The auditors checked the calibration dates on the instruments in service and determined that all are in current calibration.

Proper operation of the instruments used for personal scanning at the south plant location ("primary bunker") and the RO facility is verified weekly. The verification for the south plant instrument includes a battery check and instrument alpha and beta efficiency checks. Also, the calculation of the maximum allowable alpha and beta counts for a 0.5 minute count time and the minimum detectable activity in disintegrations per minute per 100 cm^2 are determined. A Ludlum Model 3030 in the bunker has been set up to count both alpha and beta radiation and integrate the total counts for each 30-sec count, which makes it easier for workers to scan out of the restricted area. Measurements of alpha and beta on each hand, each foot and clothing are recorded on the log sheet. The bunker also contains a Ludlum Model 2224-1 with an alpha/beta probe that may be used as needed. The correction factor for the efficiency includes both the instrument efficiency and a factor to take into account the area of the detector

High voltage verification and reliability factor checks are performed after calibration or repair or if the instrument response is questionable. The reliability factor calculation was checked and found to be accurate.

2.9 Source Leak Tests

The Crow Butte facility has no radioactive sources that require leak testing. The only sources on site are exempt instrument check sources, however a leak test were performed for the Radium-226 check source.

2.10 Review of Radiation Protection Records

In addition to those already discussed, radiation protection records related to addition areas of the program were reviewed, as detailed below. While it was noted in the previous ALARA report, it remains true that all records that were requested we readily available, clear and in good order.

Best Practice 2: The records were readily available, clear, and in good order facilitating the audit and other uses of the information.

2.10.1 Respiratory Protection

The Respiratory Protection Program was reviewed. Full face piece air purifying respirators are used in situations where respiratory protection is required. When the dryer is operating, the dryer room is designated as an Airborne Radioactivity Area and respiratory protection is required. The Respiratory Protection Program includes evaluation of medical fitness for respirator use, fit testing and training. Cameco uses Legends Butte Health Services in Crawford, Nebraska as the medical provider. Respirator training is included in the annual radiation worker training. Respirator training and medical evaluation records were reviewed and are in good condition.

2.10.2 Visitor Records

Visitors to the Cameco Crow Butte facility are not given an access badge or issued personal dosimeters. Passes are issued to site visitors at the time of entry. Visitors are escorted when entering the Restricted Areas of the site.

Contractors and other individuals who may be on the site for an extended period of time must receive documented Hazard Recognition and Safety Orientation. The training, which includes radiation hazards, must be renewed annually and allows the individual unescorted access to specific work areas on the site. Contract workers who will enter the Restricted Area receive additional training from the RSO or HPT. Training and orientation is documented on the Hazard Recognition Recognition/Safety Orientation form.

2.10.3 Equipment Release Surveys

Equipment and materials to be released for unrestricted use are surveyed for total contamination and wipe tested for removable contamination. Total contamination surveys for alpha and beta radiation are performed using a Ludlum Model 43-93 alpha/beta probe. Beta surveys were initiated in November 2014. The action limit is 750 dpm per 100 cm^2. Removable contamination surveys (wipe tests) are required when the action limit is exceeded. The Reg. Guide 8.30 release criterion for uranium and its decay products is 1000 dpm alpha per 100 cm^2 and 5000 dpm per 100 cm^2 total (fixed plus removable) alpha. The release criteria for beta radiation are the same. A representative sample of release surveys was reviewed and found to be compliant with these requirements.

The issue with an incorrect efficiency on survey instrument 3030P, identified previously in Section 2.1.5, also impacted release surveys. As with other sample types a review of the survey results was performed and no items were found that would have exceeded a release limit using the corrected efficiency.

2.10.4 Annual Review of Operating Procedures

The applicable operating procedures are reviewed annually by the RSO. The review is documented on a log sheet with the date the procedure was reviewed and the initials of the reviewer. The RSO reviewed all of the operating procedures in 2017. Documents are maintained electronically in Management Document System (MDS), official reviews and approvals are tracked within that system as well. All site documents in MDS were reviewed and found to have been approved in that system as per the required annual schedule at the time of the assessment.

2.11 Unusual Events

There was one unusual events reported during 2017 that required reporting: During Radiation Work Permit (RWP-17-10) where one worker was chipping pipe for disposal, the worker provided a bioassay sample at 17.1 μg/L. Details of the incident and investigation are included in Section 2.1.1.

2.12 Review of 2016 ALARA Audit Recommendations

Recommendation 1: Include two significant figures in the airborne contaminant and radon concentrations in the Public Dose report.

Response: Completed

Recommendation 2: It is recommended that additional detail be added to Section 1.6.7 of CBR-RPP-008 to provide more guidance on the process for calculating and assigning a dose from bioassay samples.

Response: In progress, pending finalizing of all license conditions.

Recommendation 3: It is recommended the site consider use of the database for all sample entries and develop suitable reports for printing and record keeping purposes to improve efficiency and reduce potential for error.

Response: Report developed and sample entry to database now available for all samples.

Recommendation 4: It would be good practice to have an explicit place on the daily inspection form for the RSO to indicate a review was performed, instead of just initialing below the operators checkmark column.

Response: Completed

Recommendation 5: site should consider defaulting the indicator for use in dosimetry to be checked at all times and manually removed if it is not applicable to use a result for dose calculation purposes.

Response: Completed

Recommendation 6: Revise the text of Appendix J of the semi-annual report to clarify the usage of the deployment and transient badges.

Response: Completed

Recommendation 7: It is recommended that the storage container for the deployment and transient badges be increased to try to reduce the ambient exposure rate as much as possible.

Response: Completed

3.0 SUMMARY OF 2017 AUDIT FINDINGS AND RECOMMENDATIONS

3.1 Findings

There was one finding from this audit:

Finding 1: An incorrect efficiency was being used to calculate surface contamination measurements for samples measured on the 3030P survey instrument. The correct efficiency for this instrument must be determined and associated survey results corrected. Site has self-identified this issue and has developed an action plan to correct the impacted samples.

3.2 Opportunities for Improvement

There were 7 recommendations from this audit:

Recommendation 1: Document the process for determining the maximum receptor and calculating dose to that receptor.

Recommendation 2: Considering simplifying the public dose table to only include dose to the maximum receptor.

Recommendation 3: Based upon a review of current qualifications, Casey Yada now meets the qualifications for RSO. It is recommended that the site consider designating Mr. Yada as an RSO.

Recommendation 4: Consider requesting a revision to Section 9.7 of SUA-1534 to include all major holidays, not just Thanksgiving, in the allowance for qualified designees to perform daily inspections for four consecutive days.

Recommendation 5: All records should be entered into CamRad even if their dose contribution is null or negligible to ensure completeness of records.

Recommendation 6: Consider if the stability of track etch cups has increased sufficiently to warrant use of fewer track etch cups at the background and maximum receptor sites.

Recommendation 7: If no samples were collected, the Semi-Annual report should state this and the reason, not a zero value.

3.3 Best Practices

There were two best practices identified during this audit:

Best Practice 1: Routine reinforcement of procedural compliance (specifically personal monitoring and HPT activities) through observation programs.

Best Practice 2: The records were readily available, clear, and in good order facilitating the audit and other uses of the information.

4.0 REFERENCES

[NRC] Nuclear Regulatory Commission. 2002. Information Relevant to Ensuring that Occupational Radiation Exposures at Uranium Recovery Facilities Will Be As Low As Reasonably Achievable. Regulatory Guide 8.31. Revision 1. May.

[NRC] Nuclear Regulatory Commission. 2014. Bioassay at Uranium Mills. Regulatory Guide 8.22. Revision 2. May.

[NRC] Nuclear Regulatory Commission. 2014. Evaluation of Uranium Recovery Facility Surveys of Radon and Radon Progeny in Air and Demonstration of Compliance with 10 CFR 20.1301. Revised Draft for Comment FSME-ISG-01. March.

APPENDIX A

Occupational Dose Trends

Trends in occupational radiation doses for the past 15 years are shown in the tables and figures below. The average and maximum annual exposures and doses for the past 15 years are given in Table A-1. The average and maximum annual doses from exposure to uranium in airborne particulate matter are given in Figure A-1. The average and maximum annual doses from inhalation of radon decay products are given in Figure A-2. The average and maximum annual doses from direct radiation are given in Figure A-3. The average and maximum Total Effective Dose Equivalent (TEDE) values are shown in Figure A-4.

The average annual doses from the three pathways have remained relatively consistent for the past five years. Maximum doses appear to have deceased since the years 2009 through 2011 reflecting attention to ALARA issues. Since 2016, the average dose due to radon daughters and the deep dose have slightly increased, but the dose due to airborne uranium has decreased. Consequently, the overall average TEDE has increased since 2016. Despite this decrease, the average TEDE is very much comparable to the average TEDE in all years since 2013.

Note: There may be some slight discrepancies between the values represented in the figures and the values given in the text of the ALARA audit report, primarily due to rounding.

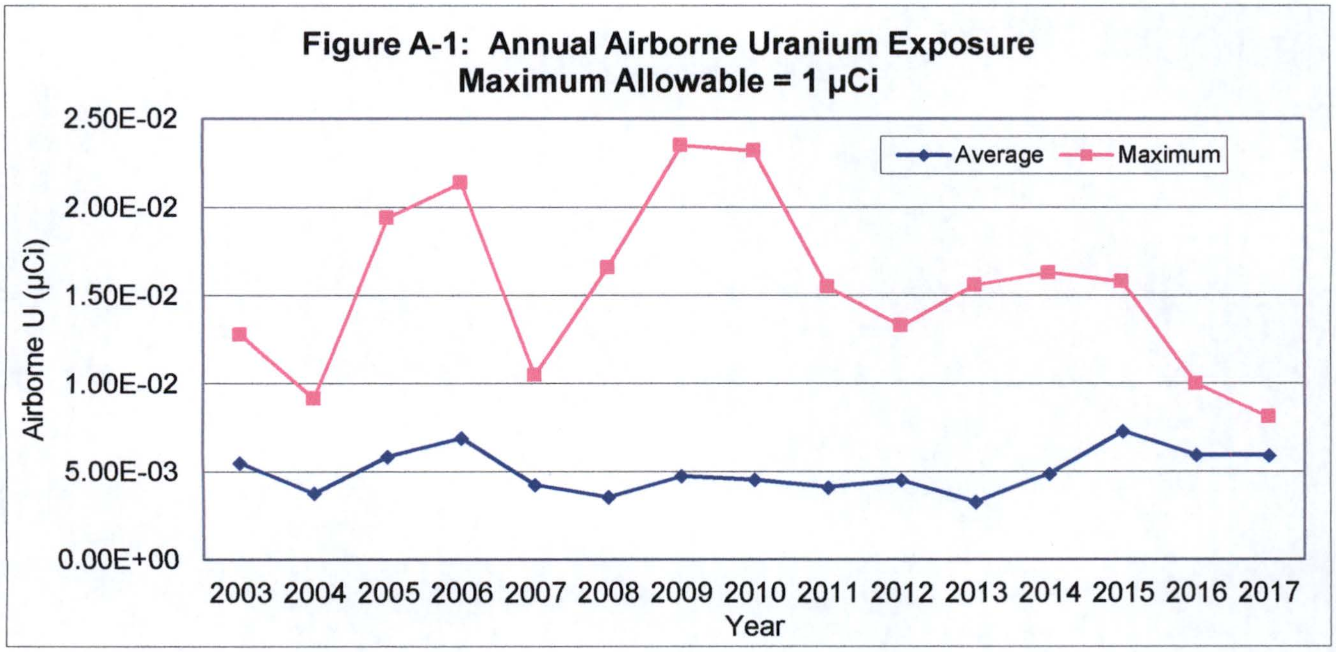
Table A-1: Average and Maximum Annual Employee Exposure and Dose

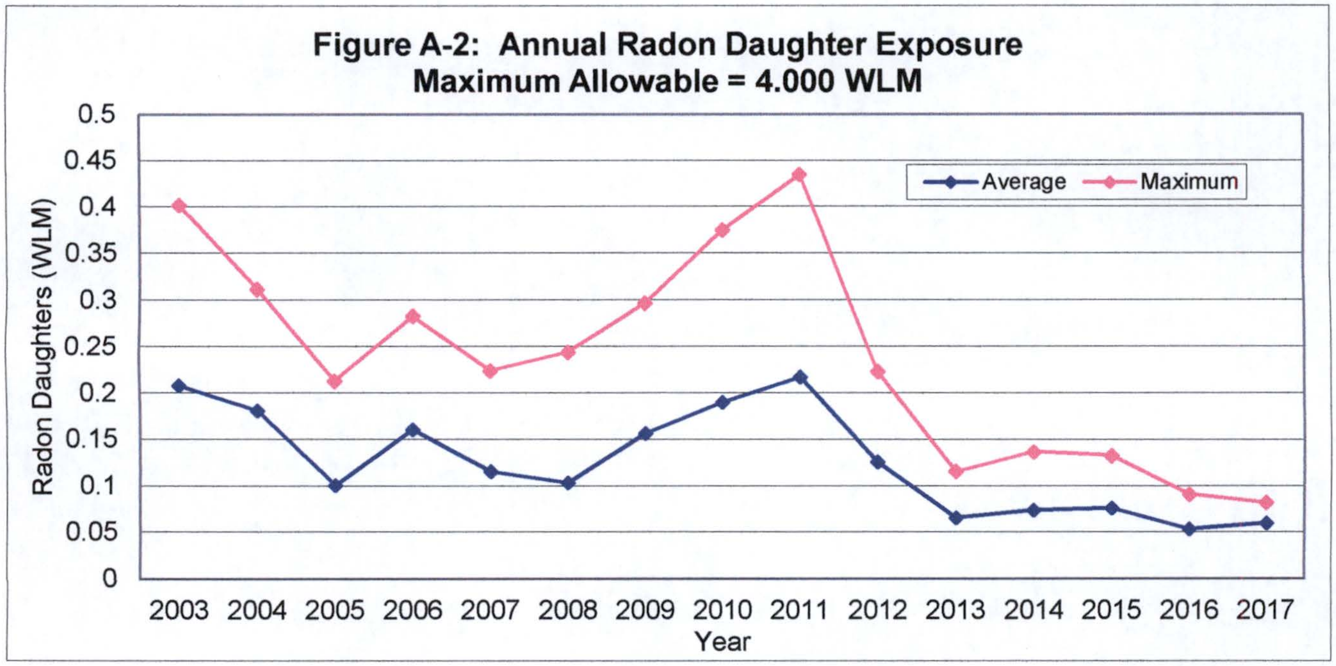
ANNUAL EMPLOYEE EXPOSURE AND DOSE

Average and Maximum

Year	Airborne Uranium-µCi		Radon Daughters-WLM		Deep Dose-rem		TEDE-rem	
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
2003	5.53E-03	1.28E-02	0.208	0.402	92	238	0.380	0.759
2004	3.76E-03	9.17E-03	0.181	0.312	121	276	0.367	0.678
2005	5.88E-03	1.94E-02	0.101	0.213	118	425	0.274	0.675
2006	6.94E-03	2.14E-02	0.161	0.283	88	252	0.323	0.713
2007	4.26E-03	1.05E-02	0.116	0.224	82	250	0.248	0.576
2008	3.55E-03	1.66E-02	0.104	0.244	48	184	0.197	0.524
2009	4.75E-03	2.35E-02	0.157	0.297	62	197	0.281	0.681
2010	4.54E-03	2.32E-02	0.190	0.375	62	226	0.322	0.713
2011	4.11E-03	1.55E-02	0.217	0.435	56	268	0.309	0.842
2012	4.52E-03	1.33E-02	0.126	0.223	69	316	0.243	0.661
2013	3.29E-03	1.56E-02	0.066	0.116	58	262	0.153	0.446

2014	4.89E-03	1.63E-02	0.074	0.137	52	196	0.164	0.437
2015	7.33E-03	1.58E-02	0.076	0.133	47	184	0.168	0.389
2016	5.98E-03	1.00E-02	0.054	0.091	39	160	0.133	0.323
2017	5.94E-03	8.12E-03	0.060	0.082	49	158	0.151	0.300





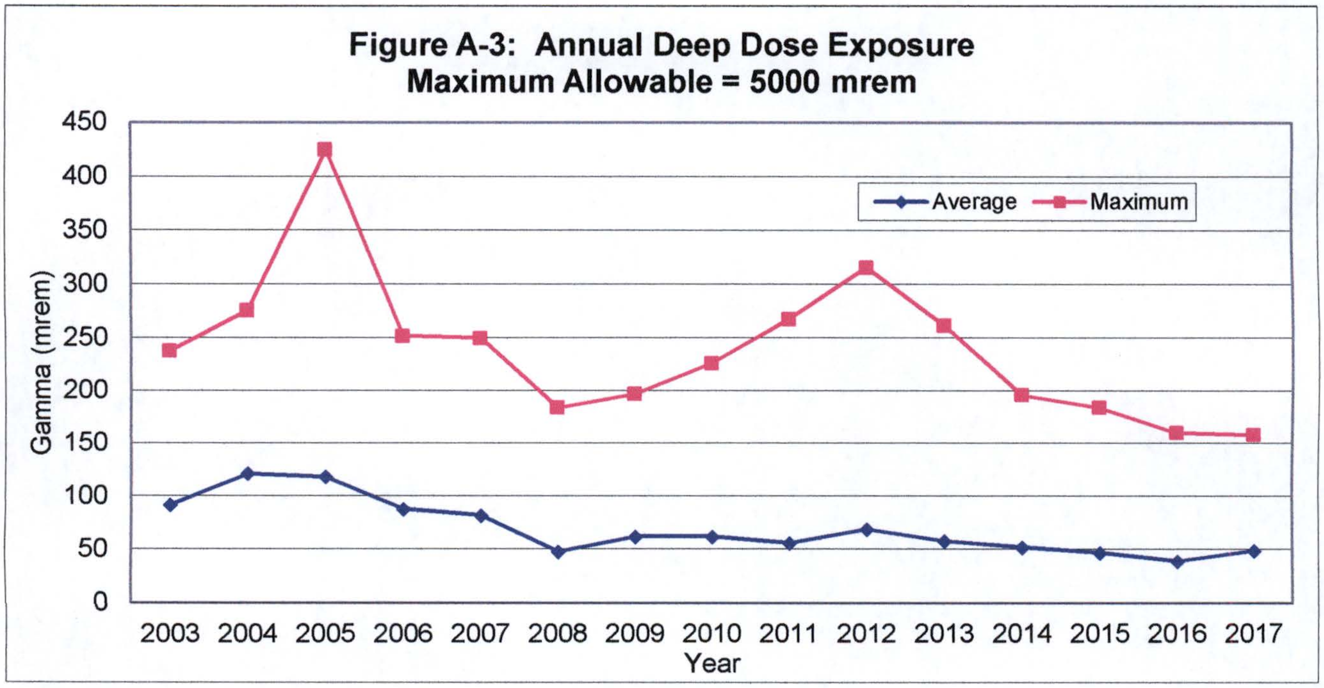


Figure A-3: Annual Deep Dose Exposure
Maximum Allowable = 5000 mrem
450
400
350
300
250
200
150
100
50
0
Gamma (mrem)
Average
Maximum
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
Year

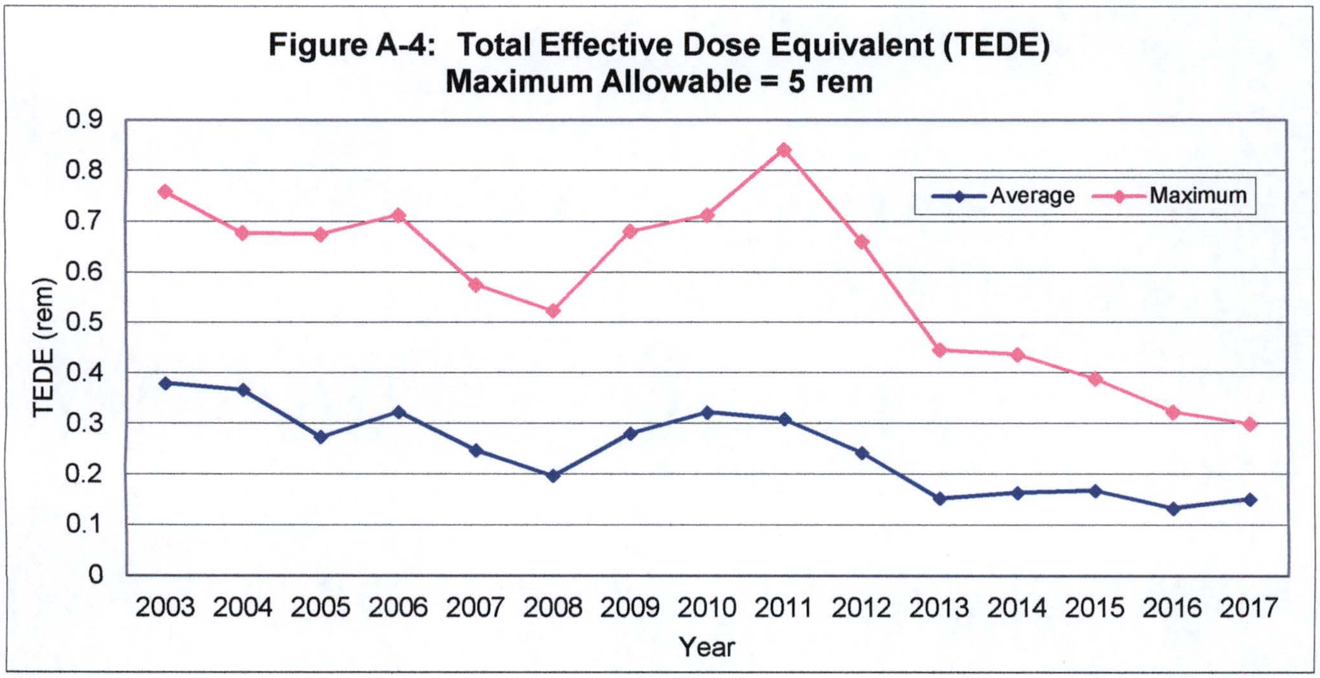


Figure A-4: Total Effective Dose Equivalent (TEDE)
Maximum Allowable = 5 rem
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
TEDE (rem)
Average
Maximum
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
Year

APPENDIX B

Public Dose Calculations

2017 DOSE TO PUBLIC CALCULATIONS

Nearest Receptor Location	Measurement Type	Measured Value	Background (AM6)	Effluent Limit (10 CFR 20 App B Table 2)	Occupancy Factor	Equilibrium Factor (Rn222)	Dose to the Public (mrem/yr)
AM-9	Uranium (µCi/ml)	1.2E-16	8.9E-17	9E-14			0.02
	Radium-226 (µCi/ml)	8.5E-17	8.5E-17	9E-13			0.00
	Lead-210 (µCi/ml)	1.5E-14	1.6E-14	6E-13			0.00
	Radon-222 (µCi/ml)	2.8E-10	2.4E-10	1E-10	0.75	0.5	6.9
	Gamma (mrem/yr)	44.2	35.2				9
						TEDE (mrem)	**15.9**

Notes

TEDE Total Effective Dose Equilent (mrem/yr)

< One or more of the Lower limits of Detection used to determine average concentrations

1 $$Dose\ from\ Radionuclides\ (mrem/yr) = \frac{Average\ Concentration\ above\ Background * 50\ mrem}{10\ CFR\ 20\ AppB\ Table\ 2\ value\ in\ \mu Ci/ml}$$

2 $$Dose\ from\ Radon\ 222\ with\ Daughters\ (mrem) = \frac{Average\ Concentration\ above\ Background * 50\ mrem * Occupancy\ Factor * Equilibrium\ Factor}{10\ CFR\ 20\ AppB\ Table\ 2\ value\ in\ \mu Ci/ml}$$

APPENDIX C

Land Use Survey

Interoffice

Memo

Cameco Resources
Crow Butte Operation

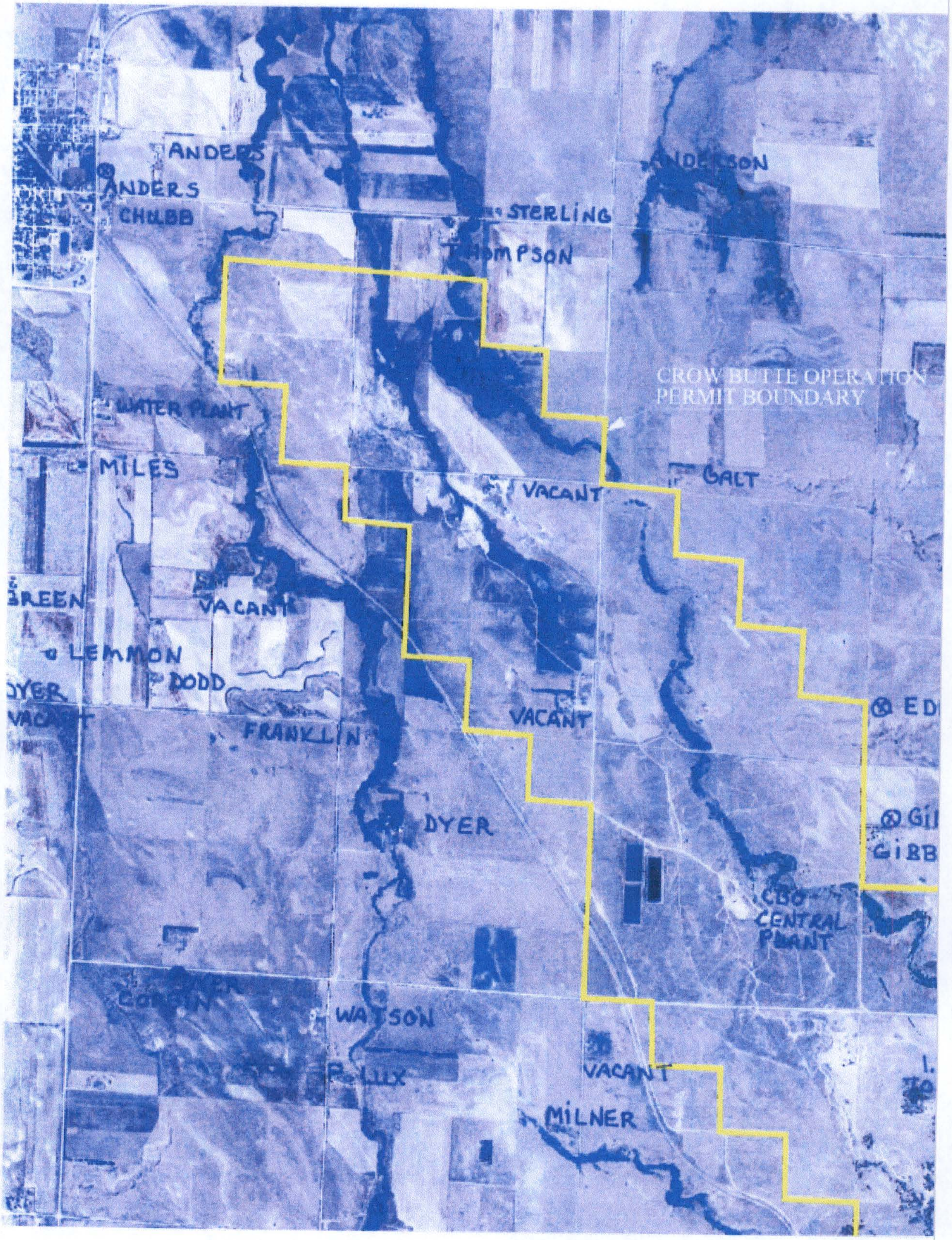
Date: February 22, 2018

To: File

From: Walt Nelson, SHEQ Coordinator WN
Tami Dyer, Radiation Safety Officer TD

Re: License Renewal (November 2014) License Condition 11.2, Land Use Survey

Source Material License SUA-1534 (Renewed November 2014) License Condition 11.2 requires the licensee to conduct an annual land use survey. This survey was conducted by the Radiation Safety Officer and SHEQ Manager using aerial maps, interviews and ground verification. Attached is an aerial photo of the survey. No new occupied structures were identified that would affect dose to the public of the nearest resident to the Crow Butte operation.


ANDERS
ANDERS
CHUBB
STERLING
THOMPSON
CROW BUTTE OPERATION
PERMIT BOUNDARY
WATER PLANT
MILES
VACANT
GALT
VACANT
LEMMON
DODD
VACANT
FRANKLIN
DYER
CBO
CENTRAL
PLANT
WATSON
P. LUX
VACANT
MILNER