CAMECO RESOURCES
CROW BUTTE OPERATION

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

June 27, 2017

USPS PRIORITY MAIL
SIGNATURE CONFIRMATION

Mr. Thomas Lancaster, Project Manager
Uranium Recovery and Waste Programs
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Mailstop T-8F5
11545 Rockville Pike
Two White Flint North
Rockville, MD 20852-2738

Response to Open Issues – Marsland Expansion Area Technical Report
Teleconference on June 14, 2016
Source Materials License SUA-1534
CAC NO. J00683

Dear Mr. Lancaster:

On June 14, 2016, the U.S. Nuclear Regulatory Commission (NRC) staff and representatives of Crow Butte Resources, Inc. (CBR) held a teleconference to discuss open issues associated with CBR's application for the Marsland Expansion Area (MEA) license amendment. The purpose of the teleconference was to explain the open issues in NRC's letter dated June 6, 2016 (ADAMS Accession No. ML16154A281) to ensure that CBR understood the information being requested by the NRC staff. A summary of this meeting, containing the open issues and a brief synopsis of any response by CBR was issued by letter dated July 5, 2016 (ML16176A198).

Please find below Crow Butte Resources, Inc. d/b/a Cameco Resources (CR) Crow Butte Operation (CBO) responses to open issues identified during the June 14, 2016 teleconference. This response includes the redline changes, replacement pages, and an electronic copy.

Issue 1: Quality of Sample Results
The laboratory results for several environmental media do not appear to be consistent with the data quality objectives of Regulatory Guide (RG) 4.14 (NRC, 1980), Section 5 through Section 7.

NMSS01

Discussion

RG 4.14 (NRC, 1980) provides recommendations on the collection of samples and the reporting of results, including the lower limit of detection, precision and accuracy of results, and how to report results.

RG 4.14 (NRC, 1980) recommends that if the recommended lower limit of detection (LLD) is not used, then the standard deviation estimated for random error should be no greater than 10 percent of the measured value. In addition, RG 4.14 (NRC, 1980) recommends that the magnitude of the systematic error should be reported if it is significant relative to the random error. Lastly, RG 4.14 (NRC, 1980) recommends that the term "not detected," "less than the lower limit of detection (LLD)," or similar terms should never be used. Each reported result should be a value and its associated error estimate, including values less than the lower limit of detection or less than zero.

The applicant's results for preoperational sampling of forage, livestock, fish, and sediment were reported with an associated precision. It is not clear to the U. S. Nuclear Regulatory Commission (NRC) staff how this precision was calculated and how much of the precision was due to random error and how much was due to systematic error. For example, several samples for meat and sediment were reported with a precision of ± 100 percent of the measured value. Some fish samples were reported with a precision of ± 200 percent of the measured value. In addition, several meat, fish and sediment samples were reported as less than the reporting limit.

Lastly, the NRC staff observes that the sample results for MED-7 are not included in Appendix W-2 as indicated in Section 2.9.7.2 of the application (CBR, 2015).

NRC Staff Comment

Please provide a description of how the precision for the environmental media samples was calculated, including a discussion of random and systematic errors. If available, please submit values for samples reported as less than the reporting limit.

In addition, please submit sample results for MED-7, or indicate where this data can be found.

CBO Response Issue 1
The laboratory has revised the results to include values less than the reporting limit. The response includes the following revisions:

Meat (Appendix DD)
Vegetation (Appendix Q)

Fish (Appendix X)
Sediment (Appendix W-2)

The MED-7 sample results were inadvertently omitted from the September 2015 submittal. The samples are included with this response as an addition to Appendix W-2. The case narrative describing precision calculations and QA/QC summaries have been included with the laboratory sheets and added to Appendices DD, Q, X, and W-2.

Tables 2.9-33, 2.9-37, 2.9-38 and 2.9-39 have been revised to match laboratory results.

Issue 2: Meat samples
The applicant stated that no preoperational samples of game animals were collected.

Discussion

According to the applicant, there are a limited number of game animals in the licensed area, hunting access is limited by landowners, and that due to the migratory nature of game animals it would be difficult to attribute any radionuclide concentration origins to the site (CBR, 2015).

However, this explanation is not consistent with the applicant's description of big game species in the vicinity of the Marsland Expansion Area (MEA) in Section 2.8.6.1 of the technical report (TR) (CBR, 2015). For example, the applicant stated that pronghorn were observed regularly throughout the project area in 2011 and they appear to be relatively common year-round. In addition, the applicant stated that the home ranges for pronghorn can vary between 162 and 2268 hectares (400 and 5,600 acres) (CBR, 2015). Compared to the size of the MEA license area (1872 hectares (4,622 acres)) (refer to Table 2.2-3 of CBR, 2015) and the size of the 3.6 kilometer (km) (2.25 mile (mi)) radius Area of Review (15,341 hectares (37,879 acres)) (refer to Table 2.2-2 and Figure 2.2-1 of CBR, 2015), this range does not appear to be significant. Lastly, the applicant reported only that some pronghorn make seasonal migrations but that the migrations are not triggered by local weather conditions (CBR, 2015). Regarding access to hunters by landowners, there is currently at least one Open Fields and Waters hunting area of approximately 457 hectares (1,128 acres) located within approximately 8 km (5 mi) of the MEA in Box Butte County (refer to Public Access Atlas Mapsheet #2 of NGPC, 2016a and Figure 2.22 of CBR, 2015). According to the applicant, the daily movement of pronghorn does not typically exceed 9.7 km (6 mi). This range exceeds the distance to the Box Butte County hunting area discussed above. In addition, according to the Nebraska Game and Parks Commission, private landowners may enroll their land for allowing public hunting access at any time (NGPC, 2016a). Since the majority of the land is privately owned in, and directly adjacent to, the MEA (refer to Figure 1.3-2 of CBR, 2015) open hunting access could be granted at any

time in the future. In any case, hunters may still hunt on private land with the landowner's consent (NGPC, 2016a).

Another example is the applicant's description of elk. According to the applicant, the Marsland Project Area is located in the Pine Ridge area, within the Ash Creek Elk Unit game management area (CBR, 2015, NGPC, 2016b). In addition, most of Nebraska's elk population inhabits the Pine Ridge area (CBR, 2015). The applicant stated that relatively large numbers of elk are known to occur year-round within the project area (CBR, 2015). The NRC staff observes that this observation is consistent with the results of the study by Benkobi, et al. (2005) that showed a significant overlap between the summer and winter ranges for elk in the Black Hills area. In addition, it has been documented that elk compete more with cattle for forage than other big game species because they have similar diets to cattle (Fricke, et al., 2008). The NRC staff observes that approximately 80 percent of the MEA license area, and 73 percent of land within 3.6 km (2.25 mi), is rangeland (refer to Tables 2.2-3 and 2.2-2, respectively, of CBR, 2015).

Since cattle account for more than 90 percent of livestock in Dawes County (refer to Section 2.2.2.1 of CBR, 2015), it seems reasonable that elk would use rangeland in and around the MEA site for grazing.

Because of the observations above on game animals, and the lack of information on the consumption of locally raised beef, there is insufficient clarity for the NRC staff to conclude that the applicant has analyzed the consumption of game animals sufficiently and that it doesn't need to collect meat samples from game animals for analysis consistent with RG 4.14 (NRC, 1980).

NRC Staff Comment

Please provide preoperational meat samples from relevant game animals within 3 km (1.9 mi) of the MEA site.

CBO Response Issue 2

Although elk and pronghorn have been observed in the MEA, preoperational samples of game animals were not collected due to limited hunting access, limited availability, and movement of the animals which increased the difficulty of obtaining the quantity of sample necessary. However, livestock was determined to be a more relevant food sample because it is the only animal raised within 3 km of the MEA, it is the only animal anticipated to remain on site for an extended period of time and therefore more likely to be in the pathway-to-man. Livestock samples of the edible portions of livestock raised within 3 km of the site at the time of slaughter were collected per RG 4.14.

The text in Section 2.9.5.2, Game Animals, was revised. The approach is consistent with recommendations contained in RG 4.14.

Operational sampling in Section 5.7.7.6 of the text was revised. The approach is consistent with the recommendations contained in RG 4.14 Table 2, footnote "o".

Issue 3: Crop samples
Other than vegetable gardens, the applicant did not address preoperational sampling of crops in the area.

Discussion

The NRC staff observes that cultivated fields make up approximately 6.3 percent of the project area (approximately 118 hectares (291 acres)) and include crops such as alfalfa, wheats, oats, corn, barley, and rye (refer to Section 2.8.5.3 of CBR, 2015). Additional cropland can be found in the vicinity of the MEA (refer to Figure 2.2-1 of CBR, 2015). Consistent with RG 4.14 (NRC, 1980), the applicant should consider food crops raised within 3 km (1.9 mi) of the MEA or provide justification for an alternate program.

NRC Staff Comment

Consistent with RG 4.14 (NRC, 1980), please provide preoperational crop samples from within 3 km (1.9 mi) of the MEA site or provide justification for an alternate program.

CBO Response Issue 3
CBR will collect preoperational crop samples as recommended in RG 4.14. Three preoperational crop samples from available crops, at the time of harvest will be collected within 3 km of the mill site. This sampling is scheduled to be completed in 2017. According to the Nebraska Agricultural Statics Service, corn, wheat and alfalfa made up the majority of crops grown in Dawes County from 2013-2015 (NASS 2016). The laboratory results will be added to Appendix Q upon receipt.

The text in Section 2.8.5.3 and 2.9.5.2 was revised to reflect this commitment. Operational sampling was revised in Section 5.7.7.6 of the text.

Figure 2.7-4 was revised to include crop sample locations.

Issue 4: Vegetable Gardens
The applicant did not provide sufficient justification for its alternative sampling methodology for vegetable gardens.

Discussion

As an alternative to sampling the garden crops directly, the applicant proposed sampling the soil in the gardens and relating the radioactivity concentration in the soil to an estimate of the radioactivity concentration in the garden crops by calculating a concentration factor. This concentration factor is based on crop type and is radionuclide specific. The applicant used the methodology discussed in NUREG/CR-5512 (NRC, 1992a) to develop the concentration factors for seven private gardens. The variables used to calculate the concentration factors are listed in Table 2.9-36 and the resulting soil analyses and estimated radioactivity concentration in the garden crops are presented in Appendix CC of the TR. The applicant evaluated three generic crop types: root vegetables, leafy vegetables, and fruits.

The NRC staff evaluated the applicant's alternative sampling program for its ability to reasonably estimate the radioactivity concentration in various crops. The NRC staff observes that the methodology presented in NUREG/CR-5512 (NRC, 1992a) is intended for estimating doses due to residual radioactivity as a result of decommissioning. It does not address ongoing effluents from an operating facility, nor does it address ongoing gardening activities during operations that could affect the results of the soil sample analyses (refer to SER Section 5.7.8). For example, the addition of fertilizer and soil conditioners worked into the top layer of soil could dilute the resulting radiological analysis of the soil and thus the estimated crop radioactivity.

As a result, the agricultural pathway analysis (i.e., dose from consuming crops) utilized in NUREG/CR-5512 (NRC, 1992a) includes the direct root uptake of radioactivity from soil and the deposition of re-suspended soil on plant surfaces. As discussed in RG 3.51 (NRC, 1982a), and elsewhere (Persson and Holm, 2011), the concentration of released particulate radionuclides can be transferred to edible portions of plants by root uptake and foliar (i.e., leaves) retention. For polonium-210 and lead-210, it has been reported that atmospheric deposition is the main source of these radionuclides in above-ground parts of plants (Vandenhove, 2009; Watters, et al., 1969). One study indicated that actual root uptake and translocation into edible portions of plants used as human food were observed to equal less than 1 percent for polonium-210 and lead-210 (Watson, 1983).

The applicant did not propose deriving a total crop radioactivity concentration, which includes foliar deposition, based on the radioactivity concentration it calculated using measured soil radioactivity concentrations and the methodology presented in NUREG/CR-5512 (NRC, 1992a). Therefore, the NRC staff does not have reasonable assurance that the applicant can reasonably estimate the radioactivity concentration in various crops using the proposed methodology.

As part of the applicant's alternative sampling program, it proposed a lower limit of detection (LLD) for polonium-210 in soil equal to 2 picoCuries/gram (pCi/g) [2 x 10^{-6} microCuries (μCi)/g] (refer to Appendix CC of CBR, 2015). This was necessary as there is no LLD listed for polonium-210 in soil in RG 4.14 (NRC, 1980).

The NRC staff also evaluated the applicant's proposed LLD for polonium-210 in soil samples. Using the proposed LLD value of 2 pCi/g (2×10^{-6} µCi/g, or 2×10^{-3} µCi/kg) for polonium-210 in soil, the applicant reported "Not Detectable" for plant radioactivity concentration of polonium-210 for all seven private gardens for all crop types (root vegetables, leafy vegetables, and fruits). The NRC staff observes that while this LLD value is only one order of magnitude higher than the LLD recommended in RG 4.14 (NRC, 1980) for the other radionuclides (Natural uranium, thorium-230, radium-226, and lead-210) in soil, it is three orders of magnitude higher than the LLD recommended for polonium-210 in vegetation (1×10^{-6} µCi/kg).

Since the calculated plant radioactivity concentration of polonium-210 is directly related to the measured polonium-210 concentration in soil samples by the concentration factor, the LLD for polonium-210 in soil should be a value that will enable the applicant to reasonably estimate plant radioactivity concentrations of polonium-210 that it would be able to determine by direct analysis (i.e., by collecting crop samples as recommended by RG 4.14 (NRC, 1980). The NRC staff observes that, as discussed above, the applicant collected forage vegetation samples three times from three different locations. The LLD values for these samples ranged from 1.2×10^{-6} µCi/kg to 4.6×10^{-6} µCi/kg, all samples having measured values of polonium-210 concentrations of 2.1×10^{-6} µCi/kg to 5.9×10^{-5} µCi/kg. Referring to Figure 2.7-4 of the applicant's TR, several of the private gardens (Troester1, Troester2, and Furman) are near at least one of the forage sampling sites. The forage sampling sites were chosen based on wind data indicating maximum predicted airborne radionuclide concentrations during operations. For a baseline analysis, it seems reasonable to expect similar polonium-210 concentrations in above-ground portions of plants. Therefore, the NRC staff does not have reasonable assurance that the applicant's proposed soil concentration LLD for polonium-210 will yield useful results for estimates of polonium-210 concentration in crops.

NRC Staff Comment

For the proposed alternate methodology for determining radionuclide concentrations in vegetable crops, please provide the following information:

1. Please describe how total plant radionuclide concentration, including that deposited by foliar deposition, will be determined using the proposed methodology.
2. Please provide a justification for using an LLD for polonium-210 concentration in soil that is not sufficient to relate calculated polonium-210 concentration in vegetation to actual polonium-210 concentration in vegetation at levels that were measured at the MEA site.
3. Discuss how ongoing gardening activities, such as the addition of fertilizers and soil conditioners to the top layer of garden soil, could affect the results of the radiological analyses of the garden soil.

4. Provide the depth of soil collected for use in the preoperational garden soil radioactivity analyses.

CBO Response Issue 4
CBR will no longer pursue an alternative garden approach to estimating baseline radionuclide concentrations in garden vegetables. Discussion of the alternative garden approach has been removed from the text. The Garden Analysis in Appendix CC will remain in the application as a reference only.

The text in Section 2.9.5.2 (Gardens), was revised.

Table 2.9-32 was revised to remove the alternative approach.

Table 2.9-36 was revised. The alternative approach was removed and now summarizes the garden soil radiological laboratory analysis.

Issue 5: Soil Sampling Field Investigation
Data missing from the applicant's preoperational soil sampling program.

Discussion

As part of an applicant's description of its site characteristics, RG 3.46 (NRC, 1982b) recommends that an applicant report site-specific radiological data, including results of measurements of concentrations of radioactive materials occurring in soil that could be affected by the proposed activities. RG 4.14 (NRC 1980) recommends that up to 40 surface soil samples be collected at 300 meter (984.25 ft) intervals to a distance of 1500 meters (4921.26 ft) in eight meteorological sectors, as well as 5 or more surface soil samples collected at air particulate stations. In addition to the soil samples collected at a depth of 5 cm (2 in.) as recommended in RG 4.14 (NRC, 1980), soil sampling is recommended in NUREG-1569 (NRC, 2003), Acceptance Criteria 2.9.3(2) at depths of 15 cm (6 in.) for background decommissioning.

The NRC staff observes that 10 CFR Part 40, Appendix A, Criterion 6(6) specifies decommissioning criteria in terms of soils analyzed for Ra-226 at a depth averaged over the first 15 cm below the surface and subsequent 15-cm thick layers below the first 15 cm thereafter for subsurface soils. While the applicant recognized the additional sampling recommendations in NUREG-1569 (NRC, 2003), Acceptance Criteria 2.9.3(2) (i.e., collecting soil samples at depths of 15 cm (6 in.) for background decommissioning) (refer to Appendix BB, Section 2.1.1), it did not appear to incorporate these recommendations into its sampling strategy for the soil samples collected in accordance with the recommendations of RG 4.14 (NRC, 1980).

To address the first part of its soil sampling field investigation, the applicant established a radial grid pattern centered on the location of the proposed MEA satellite building (CBR, 2015). In addition, the applicant sampled soil at air monitoring stations MAR-1 through MAR-5 (CBR, 2015). A summary description of these sampling locations and analyses performed is found in Table 1 and illustrated in Figures 3 and 4 (refer to Appendix BB of CBR, 2015). The sampling results are presented in Section 4 of Appendix BB in CBR, 2015.

The purpose of the secondary soil sampling investigation was to collect a sufficient number of soil samples to show that the results of the background natural uranium and Ra-226 soil concentrations were representative of the MEA site (CBR, 2015). The first set of soil samples performed under this investigation constituted 10 locations (labeled as SOILCORR1 through SOILCORR10) chosen based on the range of gamma radiation observed at the site. These locations are illustrated in Figure 8 (refer to Appendix BB). The sampling results are presented in Section 4 of Appendix BB. CBR, 2015.

To determine the total number of background samples needed, the applicant followed guidance presented in draft NUREG/CR-5849 (NRC, 1992b) (CBR, 2015). Using the results of the initial 10 soil samples described above, the applicant calculated that 14 additional Ra-226 samples, and one additional natural uranium soil sample, were required to satisfy the statistical objectives described in draft NUREG/CR-5849 (refer to Section 8.6 of NRC, 1992b). To ensure that the sampled areas represented the extent of the disturbed area of the MEA, the applicant collected 23 supplemental background soil samples (labeled as MARSS-01 through MARSS-23). These supplemental soil sampling locations are illustrated in Figure 5 (refer to Appendix BB). The sampling results are presented in Section 4 of Appendix BB (CBR, 2015).
As described above, the applicant did not sample at 15 cm (6 in.) depths for the RG 4.14 radial soil samples. This is not consistent with Acceptance Criterion 2.9.3(2) of NUREG-1569 (NRC, 2003). As discussed above, 10 CFR Part 40, Appendix A, Criterion 6(6) decommissioning criteria for land (i.e., soil) is prescribed in terms of 15 cm (6 in.)-thick layers of soil. Therefore, the 5 cm (2 in.) depth radial soil samples collected by the applicant can't be used for decommissioning purposes.

The NRC staff observes that the applicant incorporated 13 of the 5 cm (2 in.) depth radial soil samples into its background soil investigation (refer to Table 4, Table 5, footnote 3 of Table 8, and Appendix F of Appendix BB in CBR, 2015).

Because the applicant is lacking 15 cm (6 in.) depth soil samples in and around the proposed location of the MEA satellite building, and because the applicant incorporated 5 cm (2 in.) depth radial soil samples into its background soil investigation (e.g., calculation of required number of samples in Appendix F of Appendix BB, soil samples collected in various soil types in Table 4 of Appendix BB), there is insufficient clarity for the NRC staff to determine that the applicant's soil sampling field investigation results comply with

10 CFR Part 40, Appendix A, Criterion 7. The NRC staff requires additional analysis by the applicant to address these information gaps.

NRC Staff Comment

Please provide 15 cm (6 in.) depth soil sample results for the area around the proposed location of the MEA satellite building and a revised analysis of the secondary soil investigation to include only 15 cm (6 in.) depth soil sample results.

CBO Response Issue 5
During 2017, CBR will collect 15 cm (6 in.) depth radial soil samples as required by NUREG 1569 Criterion 2.9.3(2). The sample locations are depicted on Figure 3, Appendix BB. The additional laboratory results will be added to Appendix BB upon receipt.

CBR will no longer pursue the analysis of the secondary soil correlation for decommissioning as discussed in Appendix BB. Refer to Open Issue 10 for CBR's commitment to surface soil cleanup verification and sampling plan.

The footnote in Table 2.9-41 was revised to include the commitment to collect 15 cm samples.

The text in Section 2.9.6 was revised to include Acceptance Criterion 2.9.3(2) of NUREG-1569.

Issue 6: License Condition (LC) 11.10
The NRC staff has not received a response to its comments on the applicant's contamination survey program, including a demonstration of minimum detectable concentrations (MDC) for survey instruments.

Discussion

By letter dated February 24, 2016, the NRC staff transmitted comments on the applicant's proposed contamination survey program (NRC, 2016a). The NRC staff has not received a response to these comments.

NRC Staff Comment

Since the contamination survey program for the MEA facility is contingent on the NRC staff's verification of the applicant's response to LC 11.10, the NRC staff can't begin its review of Section 5.7.6 of the applicant's TR until this verification is complete.

CBO Response Issue 6
Section 5.7.6 of the text was revised and will follow the requirements of the Survey Program for Beta/Gamma Contamination, submitted as a license condition requirement under Crow Butte Source Materials License, SUA-1534.

Issue 7: Airborne Effluent Monitoring
The applicant's proposed airborne effluent and environmental monitoring program for the Marsland facility is not consistent with what has been approved for the main facility.

Discussion

By letter dated January 6, 2016 (NRC, 2016b), the NRC staff verified the adequacy of the applicant's response to LC 11.11 (NRC, 2014). This verification occurred after the submittal of the most recent revised application (CBR, 2015). As a result, the proposed airborne effluent and environmental monitoring program is insufficient to demonstrate compliance with 10 CFR 40.65, 10 CFR 20.1302, and 10 CFR 20.1501.

The NRC staff recognizes that certain "as built" drawings are not available to demonstrate compliance for items such as tank vents and general ventilation discharge points.

NRC Staff Comment

Please update the Marsland application to reflect commitments made to address LC 11.11 (NRC, 2014) for the main facility. Please also specifically address those aspects of the facility that will have to be submitted at a later date (e.g., tank vents and general ventilation discharge points). The NRC staff can't begin its review of Section 5.7.7 of the applicant's TR until these actions are completed.

CBO Response Issue 7
Section 5.7.7.2 was revised to align with the airborne effluent and environmental monitoring program approved for the main facility.

Prior to operation, CBR will submit, for NRC staff review, a figure showing the sampling locations of the tank vents and general ventilation discharge points.

Issue 8: Inconsistent Operational Surface Soil Analytes
It is unclear which analytical tests will be performed on annual surface soil samples.

Discussion

In Section 5.7.7.3 of the application, the applicant committed to sampling surface soils annually during operations and analyzing them for natural uranium, radium-226, thorium-

230, and lead-210 (CBR, 2015). In Table 5.7-1 of the application, the applicant committed to sampling surface soils annually during operations, but only analyzing them for natural uranium, radium-226, and lead-210 (CBR, 2015).

NRC Staff Comment

Please clarify which isotopes will be analyzed for the annual surface soil samples.

CBO Response Issue 8
Annual surface soil samples will be sampled for natural uranium, radium-226 and lead-210.

Section 5.7.7.3 was revised to remove thorium-230 from operational surface soil sampling.

Issue 9: Insufficient Justification for not Sampling Vegetation and Livestock during Operations
The applicant proposed evaluating surface soil and sediment samples during operations as a substitute for forage, crop, and livestock sampling.

Discussion

RG 4.14 (NRC, 1980) recommends vegetation, food and fish samples where a significant pathway to man is identified in individual licensing cases. A significant pathway is further clarified in Table 2, footnote "o" of RG 4.14 (NRC, 1980) to mean that the predicted dose to an individual would exceed 5 percent of the applicable radiation protection standard.

The applicant proposed an alternative to the RG 4.14 (NRC, 1980) methodology. However, the applicant provided no analysis to demonstrate that the soil and sediment samples would provide as good as, or better, indicator of licensed material potentially accumulating in the environment.

NRC Staff Comment

Please provide additional analyses regarding the relationship between radionuclides found in soils and sediments and their relationship to vegetation and livestock samples. In addition, please propose levels of radionuclides in the soils and sediments that would trigger vegetation and livestock sampling and a basis for those trigger levels.

An alternative would be to either perform vegetation and livestock sampling or demonstrate that no significant pathway to man exists.

CBO Response Issue 9
Revisions were made to Sections 5.7.7.5 and 5.7.7.6 CBR's operational sampling commitments.

Issue 10: Surface Soil Cleanup Verification and Sampling Plan
In Section 6.4.2 of its application, the applicant proposed the use of global positioning system (GPS)-based gamma surveys to evaluate potentially contaminated surface soils against the requirements of 10 CFR Part 40, Appendix A, Criterion 6(6) (CBR, 2015).

Discussion

The applicant described the results of its preoperational gamma exposure rate survey for the approximately 784 hectares (1,938 acre) of disturbed area of the MEA site in Appendix BB of its application (CBR, 2015). The applicant's survey included 122,795 data points with summary statistics as shown in Table 19 of Appendix BB in the application (CBR, 2015). The applicant identified the distribution of gamma exposure rate measurements in the MEA disturbed area as a normal distribution. Since the data are normally distributed, the mean, or average, value of the gamma measurements and the median are the same, as indicated in Table 19 (Appendix BB in CBR, 2015). As such, the frequency of gamma measurements above the average value is the same as the frequency of gamma measurements below the average. These individual measurements were then applied to the entire MEA disturbed area using a geospatial interpolation technique known as kriging. The result of the kriged data is shown on Figure 14 in Appendix BB of the application (CBR, 2015).

In addition, the applicant described its attempt to correlate gamma exposure rate measurements at the site with radium-226 (Ra-226) soil concentrations (refer to Section 1.1 of Appendix BB in CBR, 2015). The applicant was not successful in demonstrating a relationship between these variables as the background exposure rate was too uniform across the MEA site.

The applicant proposed performing a final GPS-based gamma survey and sampling soil in areas that exceeded the average background gamma exposure rate (CBR, 2015). However, the NRC staff observes that half of the background data already exceed the average value due to the normal distribution of the data. In addition, the applicant has not demonstrated a minimum detectable concentration for radium or other radionuclides in soil for the methodology it proposed. As a result, the NRC staff doesn't have confidence that the applicant can detect contaminants (e.g., Ra-226, natural uranium) in the soil using gamma exposure rate measurements for the purpose of complying with 10 CFR Part 40, Appendix A, Criterion 6(6).

NRC Staff Comment

Please provide calculations for the minimum detectable concentrations of Ra-226 and natural uranium in soil using the methodology proposed for surface soil cleanup verification in Section 6.4.2 of the application.

CBO Response Issue 10
CBR will no longer pursue the analysis of the secondary soil correlation for decommissioning as discussed in Appendix BB. CBR will use the "benchmark approach" to define the cleanup criteria for other radionuclides, as described in the soil cleanup criteria established in 10 CFR 40 Appendix A, Criterion 6(6).

CBR has revised Section 6.4.2 of the application.

Issue 11: Update Tornado Data and Analysis
The revised technical report (CBR, 2015) was not updated with tornado data and analysis for the period after 2012.

Discussion

The applicant reported five tornado events occurred in Dawes County, Nebraska from 2000 and 2012 (CBR, 2015). These five tornado events did not exceed a Fujita or Enhanced Fujita scale (F- or EF-scale, respectively) magnitude of F0 or EF0 and no injuries, deaths, property or crop damage occurred.

Prior to the Revised Technical Report (CBR 2015), staff observes that three additional tornado events occurred in Dawes County, Nebraska from 2013 to April 2016 (NOAA, 2016), one of which was reported to have a magnitude of EF1. This tornado occurred on June 11, 2013 and damaged 16 buildings, with at least eight outbuildings destroyed (NOAA, 2016).

Staff observes that the updated analysis should include the effects to smaller MEA structures (e.g. buildings, wellhouses), chemical storage and the possible reaction of process chemicals. Staff also observes that the analysis should include an evaluation of the future probability of the occurrence of tornados at the MEA.

NRC Staff Comment

Please update tornado data and analysis to include tornados that occurred since 2012. The updated analysis should include an evaluation of environmental impacts from the tornadoes that occurred since 2012 and the future probability of the occurrence of tornados at the MEA. Additionally, the update should consider effects to MEA structures (e.g. buildings, wellhouses) and potential environmental impacts. Finally, the updated tornado data should

be used to consider impacts from tornadoes on the chemical storage of materials and the possible reaction of process chemicals.

CBO Response Issue 11
Section 7.5.6.1 was revised to include tornado activity that has occurred since 2012, including the evaluation of environmental impacts in Dawes county and adjacent Sheridan county. The frequency and probability of tornado occurrence at the MEA was assessed along with the consideration of impacts to structures (buildings/wellhouses), chemical storage of materials, and the possible reaction of process chemicals.

Issue 12: Update to corporate organization and associated administrative procedures
As indicated by an e-mail from Mike Thomas (Cameco Resources) to Doug Mandeville (NRC) on May 31, 2016, staff observes that updates to the corporate organization occurred since CBR's submittal of the revised technical report for the MEA (CBR, 2015).

Discussion

An e-mail received by NRC on May 31, 2016 provided a revised Cameco Resources regulator contact list. This email appears to reflect changes in the corporate organization that may have changed the corporate organization and associated administrative procedures for the MEA.

NRC Staff Comment

Please provide an update to the corporate organization and associated administrative procedures for the MEA.

CBO Response Issue 12
CBR has revised Section 5 of the text and Figure 5.1-1 to reflect the current organizational structure.

Issue 13: Identification of the Orella Member of the Brule Formation
In Sections 2.7.2 of the Revised 2015 Technical Report (TR) (CBR, 2015), the Brown Siltstone Member of the Brule Formation is described as constituting the first overlying aquifer above the production zone. However, in a letter dated April 20, 2016, to the Nebraska Department of Environmental Quality (NDEQ) in support of its Aquifer Exemption Application (AEP) (CBR, 2016), CBR makes the following statements:

Geophysical logs in Figure 6 of "Cenozoic Paleogeography of Western Nebraska", show several ash beds in relation to accepted formational boundaries of the Arikaree, Brule and Chadron Formations. A review of geophysical logs from the MEA show similar log traces

for some of these air-fall tuff horizons; in particular, the Nonpareil, upper Whitney, and lower Whitney ash zones.... Therefore, in the revised AEP, the base of the Brule Formation has been moved downward, below the lower Whitney Ash.

Discussion

NRC staff notes that, although the Orella Member of the Brule Formation is identified in the TR as the lowermost Brule unit above the Chadron Formation, it is not mentioned in these representations to NDEQ, which appears to reflect that information sent to the NDEQ is inconsistent with information sent to NRC.

NRC Staff Comment

The applicant should revise the TR as necessary with respect to the identification of the Orella Member of the Brule Formation at the site.

CBO Response Issue 13
Additional characterization of the Brule Formation is described as a new Appendix HH, the Deep Brule Monitor Well Installation Program.

Additional field work and an analysis of the deep Brule observation wells (DBOW) has been completed at the MEA resulting in the following conclusions regarding the characterization of the lower Brule Formation:

- Geophysical and geologic sample logging and well development results demonstrate that the lower Brule Formation is composed of non-aquifer sediments and that it does not produce water in usable, significant or economic amounts and cannot be classified as an aquifer.
- Additional testing which includes water quality, water level measurements and pumping tests is not recommended.
- The first overlying aquifer to the mining zone at MEA should remain the Brown Siltstone Member of the upper Brule Formation.

The response includes the following submissions/revisions:

The text was revised in Sections: 2.6.1.1, 2.7.2.1, 2.7.2.2, 2.7.2.4, 2.9.3.2
Table 2.6-2 – Representative Stratigraphic Section
Figures 2.6-3a through 2.6-3n – MEA Cross Sections
Appendix E – Deep Brule Monitor Well (DBOW) - Well Completion Reports
Appendix HH - Deep Brule Monitor Well Installation Program (DBOW)
Appendix EE – Kozeny-Carman Calculations

Issue 14: Additional Characterization of the Lower Brule Formation
CBR notes in its letter to NDEQ (CBR, 2016) that:

As the base of the Brule Formation has been revised downward, a corresponding decrease in the thickness of the upper Chadron Formation is observed....As these lower portions of the Brule Formation were not monitored for water quality and water levels, CBR proposes to install additional monitoring wells to assess quarterly water quality and water levels for this portion of the Brule Formation for a period of one year to assess seasonal conditions....The original Marsland pump test did not assess potential impacts to this lower portion of the Brule Aquifer. Therefore, CBR proposes to perform an additional pumping test, once the above monitoring wells are completed, to assess if any hydrologic connections exist between the mining zone and the lower portion of the Brule Formation.

Discussion

The proposed additional characterization of the lower Brule Formation described above to the State is new information that the NRC has not seen before and is not mentioned in the TR submitted to NRC.

Criterion 5G(3) of Appendix A requires that the applicant supply information about the "Location, extent, quality, capacity and current uses of any ground water at and near the site." In reference to the ground-water resources adjacent to ISR facilities, Section 2.7.1(3ii) of NUREG-1569 calls for "a description of aquifer properties, including material type, formation thickness, effective porosity, hydraulic conductivity, and hydraulic gradient." An aquifer is defined in 10 CFR 40, Appendix A, as "...a geologic formation, group of formations, or part of a formation capable of yielding a significant amount of ground water to wells or springs." Section 2.7.2 of NUREG1569 also calls for an evaluations of "the site hydrogeologic conceptual model for ground-water flow in potentially affected aquifers" as well as an examination of "...pumping tests that are used to investigate vertical confinement or hydraulic isolation between the ore production zone and upper and lower aquifers."

If an aquifer deeper than the previously identified one in the Brown Siltstone Member is determined to represent the first overlying aquifer within the Brule Formation, additional pump test and chemical data to demonstrate the isolation of such an aquifer from the production zone would be required. Furthermore, the vertical and horizontal effects on the groundwater flow system of water withdrawals from a deeper Brule aquifer (if found) would have to be evaluated by the applicant. The vertical and horizontal effects on the groundwater flow system of water withdrawals from a deeper Brule aquifer (if found) would also have to be evaluated by the applicant.

NRC Staff Comment

The applicant should revise the TR to encompass the additional characterization of the Brule Formation and address the related NRC regulatory requirements.

CBO Response Issue 14
See CBO Response to Issue 13 for additional characterization of the Brule Formation.

Issue 15: Lack of Water Samples from Ephemeral Streams
In the Section 2.9.4 of the Revised 2015 TR, the applicant states, "Lack of water flow in ephemeral drainages in the MEA has prevented collection of surface water samples." This same statement was also contained in the original 2012 TR. However, in section 2.9.7.2 of the 2015 TR, although only sediment samples were collected, the applicant makes the statement that "...the ephemeral drainages at the designated sampling points were sampled twice, once following spring runoff, and in late summer following period of extended low flow."

Discussion

Section 1.1.2 of Regulatory Guide 4.14 stipulates that: "Any stream beds that are dry part of the year should be sampled when water is flowing."

NRC Staff Comment

The applicant should clarify how the "following spring runoff" and "following period of extended flow" statements reconcile with the "lack of water flow" statement in the TR. Given the lack of water samples from ephemeral drainages to date, the applicant should also commit to obtaining such samples during flow events that may occur at any time during the pre-operational period.

CBO Response Issue 15
A revision was made to Section 2.9.7.2 which states, "if water flow becomes available at any time prior to mining at any of the sampling points (MED-1 through MED-7), CBR will collect baseline water samples."

Minor Edits to Text
Minor edits to correct references to section numbers were made to the text in sections: 5.7.7.1, 5.7.7.4, 5.7.7.8, 5.7.8.1, 5.7.9.3 and 6.1.3. The replacement pages are included with this response.

Summary
Enclosed are three sets of revisions and replacement pages along with an electronic copy of the revised Marsland Expansion Area Technical Report.

If there are any further questions or concerns feel free to contact me at (308) 665–2215 ext. 114.

Sincerely,

Larry Teahon

Larry Teahon
SHEQ Manager

cc: NRC – Document Control Desk
CBO- File

MEA Open Issue RAI Responses - June 27, 2017

Open Issue	Revision Type	Location	Description - Title/Section
13 & 14	Text	2.6.1.1	MEA Stratigraphy
13 & 14	Text	2.6.1.1	Upper Chadron (Includes minor correction - figures 2.6-3a through 2.6-3n)
13 & 14	Text	2.6.1.1	Brule Formation
13 & 14	Text	2.7.2.1	Groundwater Occurrence and Flow Direction
13 & 14	Text	2.7.2.1	Brule Formation
13 & 14	Text	2.7.2.2	Aquifer Testing and Hydraulic Parameter Identification Information
13 & 14	Text	2.7.2.4	Description of Proposed Operation & Relationship to Site Geology & Hydrology
3	Text	2.8.5.3	Cultivated
3	Text	2.8.5.3	Cultivated
13 & 14	Text	2.9.3.2	CBR Groundwater Monior Wells
2	Text	2.9.5.2	Livestock, Game Animals
3	Text	2.9.5.2	Crops
4	Text	2.9.5.2	Gardens
5	Text	2.9.6	Baseline Soil Monitoring
15	Text	2.9.7.2	Ephemeral Drainages
12	Text	5 through 5.1.1.13	Operations
6	Text	5.7.6	Contamination Control Program
na	Text	5.7.7.1	Minor correction to fix referenced section number 5.7.10
7	Text	5.7.7.2	Radon and Radon Progeny (Satellite Facility, Wellhouses, Wellfields)
8	Text	5.7.7.3	Surface Soil
na	Text	5.7.7.4	Minor correction to fix referenced section number 5.7.10
9	Text	5.7.7.5	Vegetation
2	Text	5.7.7.6	Livestock, Game Animals
3	Text	5.7.7.6	Crops
9	Text	5.7.7.6	Food
na	Text	5.7.7.8	Minor correction to fix referenced section number 5.7.10
na	Text	5.7.8.1	Minor correction to fix referenced section number 5.7.10
na	Text	5.7.9.3	Minor correction to fix referenced section number 5.7.10
na	Text	6.1.3	Minor correction to fix referenced section number 5.7.10
10	Text	6.4.2	Surface Soil Cleanup Verification and Sampling Plan
11	Text	7.5.6.1	Tornado Risk
13 & 14	Table	2.6.2	Stratagraphic Cross Section
4	Table	2.9-32	Marsland Expansion Area Vegetation Seasonal Radiological Laboratory Analysis
1	Table	2.9-33	Radionuclide Analyses for Livestock Samples
4	Table	2.9-36	MEA Garden Soil Radiological Laboratory Analysis
1	Table	2.9-37	Box Butte Reservoir
1	Table	2.9-38	Radionuclide & Metal Analyses - Niobrara River Sediment Sample Locations N-1 & N-2
1	Table	2.9-39	Radionuclide & Metal Analyses for Marsland Ephemeral Drainage (MED) Sediment Sample Locations
5	Table	2.9-41	MEA Preoperationa/Preconstruction Monitoring Program
13	Figures	2.6-3a to 2.6-3n	MEA Cross Sections
3	Figure	2.7-4	Sampling Locations
12	Figure	5.1-1	Organizational Chart
13	Appendix	E	Well Completion Reports
1	Appendix	Q	Vegetation Sample Results
1	Appendix	W-2	Sediment Samples Results
1	Appendix	X	Fish Sample Results
1	Appendix	DD	Meat Sample Results
13	Appendix	EE	Kozeny-Carman
13	Appendix	HH	Deep Brule Monitor Well Installation Program
na	Text	Table of Contents	Revised Table of Contents
na	Text	References	Revised References



Response to Request for Additional Information (RAI)
Combined Revisions May 2012 through June 2017

Volume I - Sections 1-10

COPY 1 of 6	Document Control Desk, Director Office of Nuclear Material Safety and Safeguards U.S. Nuclear Regulatory Commission
COPY 2 of 6	Tom Lancaster, Project Manager Office of Nuclear Material Safety and Safeguards U.S. Nuclear Regulatory Commission
COPY 3 of 6	Tom Lancaster, Project Manager Office of Nuclear Material Safety and Safeguards U.S. Nuclear Regulatory Commission
COPY 4 of 6	Tom Lancaster, Project Manager Office of Nuclear Material Safety and Safeguards U.S. Nuclear Regulatory Commission
COPY 5 of 6	Crow Butte Resources, Inc.
COPY 6 of 6	Crow Butte Resources, Inc.

Replacement Pages – Table of Contents

Instructions:

Remove and Replace pages 1-28 of the Table of Contents

MEA TR

Reponses to Open Issues

6-29-2017



Technical Report
Marsland Expansion Area

Table of Contents

1 PROPOSED ACTIVITIES 1-1

1.1 Licensing Action Requested 1-1
1.2 Crow Butte Uranium Project Background 1-2
1.3 Site Location and Description 1-3
1.4 Ore Body Description 1-3
1.5 Solution Mining Method and Recovery Process 1-3
1.5.1 Advantages of ISR Uranium Mining 1-4
1.5.2 Ore Amenability to the ISR Mining Method 1-4
1.6 Operating Plans, Design Throughput, and Production 1-5
1.7 Proposed Operating Timelines 1-6
1.7.1 Current Production Area 1-6
1.7.2 Marsland Expansion Area 1-6
1.7.3 Three Crow Expansion Area Timeline 1-6
1.7.4 North Trend Expansion Area Timeline 1-7
1.8 Waste Management and Disposal 1-8
1.8.1 Liquid Waste 1-8
1.8.2 Solid Waste 1-9
1.8.3 Contaminated Equipment 1-9
1.9 Groundwater Restoration 1-11
1.10 Decommissioning and Reclamation 1-11
1.11 Surety Arrangements 1-11

2 SITE CHARACTERISTICS 2-1

2.1 Site Location and Layout 2-1
2.2 Uses of Adjacent Lands and Waters 2-3
2.2.1 General Setting 2-3
2.2.2 Land Use 2-3
2.2.2.1 Agriculture 2-4
2.2.2.2 Recreation 2-5
2.2.2.3 Residential 2-6
2.2.2.4 Habitat 2-6
2.2.2.5 Industrial and Mining 2-7
2.2.2.6 Commercial and Services 2-7
2.2.2.7 Transportation and Utilities 2-8
2.2.3 Water Use Information 2-8
2.2.3.1 Dawes County Water Use 2-8
2.2.4 Marsland Expansion Area Project Area 2-9
2.2.4.1 Wellhead Protection Area 2-12
2.3 Population Distribution 2-13

2.3.1 Demography 2-13
2.3.1.1 Regional Population 2-13
2.3.1.2 Population Characteristics 2-14
2.3.1.3 Population Projections 2-15
2.3.1.4 Seasonal Population and Visitors 2-15
2.3.1.5 Schools 2-16
2.3.1.6 Sectorial Population 2-16
2.3.2 Local Socioeconomic Characteristics 2-17
2.3.2.1 Major Economic Sectors 2-17
2.3.2.2 Housing 2-17
2.3.3 Environmental Justice 2-19
2.4 Regional Historic, Archeological, Architectural, Scenic, and Natural Landmarks 2-20
2.4.1 Historic, Archeological, and Cultural Resources 2-20
2.4.2 Scenic Resources 2-22
2.4.2.1 Introduction 2-22
2.4.2.2 Methods 2-22
2.4.2.3 Affected Environment 2-24
2.4.2.4 MEA Visual Inventory 2-25
2.5 Climate, Meteorology, and Air Quality 2-28
2.5.1 Introduction 2-28
2.5.2 Regional 2-30
2.5.2.1 Temperature 2-30
2.5.2.2 Relative Humidity 2-30
2.5.2.3 Precipitation 2-31
2.5.2.4 Wind Patterns 2-31
2.5.2.5 Heating, Cooling, and Growing Degree Days 2-32
2.5.2.6 Evapotranspiration 2-32
2.5.3 Site-Specific Analysis 2-33
2.5.3.1 Introduction 2-33
2.5.3.2 Temperature 2-33
2.5.3.3 Wind Patterns 2-33
2.5.3.4 Precipitation 2-34
2.5.3.5 Evapotranspiration 2-34
2.5.3.6 Justification of Baseline Year as Representative of Long Term 2-35
2.5.3.7 Onsite Meteorological Instrument Specifications 2-37
2.5.3.8 Upper Atmosphere Characterization 2-37
2.5.3.9 Bodies of Water and Special Terrain Features 2-38
2.5.4 Conclusion 2-38
2.5.5 Air Quality 2-39
2.5.5.1 National Ambient Air Quality Standards 2-39

2.6 Geology and Seismology 2-41
2.6.1 Geology and Seismology 2-41
2.6.1.1 Regional Setting 2-41
2.6.1.2 Geochemical Description of the Mineralized Zone 2-55
2.6.1.3 Structural Geology 2-55
2.6.1.4 Seismology 2-59
2.6.1.5 Inventory of Economically Significant Deposits and Paleontological Resources 2-62
2.6.1.6 Soils 2-62
2.6.1.7 Prevention of Significant Deterioration 2-76
2.7 Hydrology 2-77
2.7.1 Surface Water 2-77
2.7.1.1 Water Features Descriptions 2-77
2.7.2 Groundwater 2-78
2.7.2.1 Groundwater Occurrence and Flow Direction 2-79
2.7.2.2 Aquifer Testing and Hydraulic Parameter Identification Information 2-81
2.7.2.3 Hydrologic Conceptual Model for the Marsland Expansion Area 2-84
2.7.2.4 Description of the Proposed Mining Operation and Relationship to Site Geology and Hydrology 2-87
2.7.2.5 Lateral and Vertical Extent of the Proposed Exempt Aquifer 2-89
2.8 Ecological Resources 2-91
2.8.1 Regional Setting 2-91
2.8.2 Local Setting - Marsland Expansion Area 2-91
2.8.3 Climate 2-91
2.8.4 Pre-existing Baseline Data 2-92
2.8.5 Terrestrial Ecology 2-92
2.8.5.1 Methods 2-92
2.8.5.2 Existing Disturbance 2-93
2.8.5.3 Vegetation and Land Cover Types 2-93
2.8.6 Mammals 2-95
2.8.6.1 Big Game 2-95
2.8.6.2 Carnivores 2-98
2.8.6.3 Small Mammals 2-98
2.8.7 Birds 2-99
2.8.7.1 Passerines 2-99
2.8.7.2 Upland Game Birds 2-100
2.8.7.3 Raptors 2-100
2.8.7.4 Waterfowl 2-102
2.8.8 Reptiles and Amphibians 2-102
2.8.9 Threatened, Endangered, or Candidate Species 2-103

2.8.10 Aquatic Ecology 2-105
2.8.10.1 Fish 2-105
2.8.10.2 Macroinvertebrates 2-106
2.8.10.3 Wetlands 2-106
2.9 Background Radiological and Non-radiological Characteristics 2-109
2.9.1 Introduction 2-109
2.9.2 Baseline Air Monitoring 2-109
2.9.2.1 Selection of Air Monitoring Locations 2-109
2.9.2.2 Air Particulate Monitoring Program 2-111
2.9.2.3 Radon Gas Monitoring Program 2-112
2.9.2.4 Quality of Air Measurements 2-113
2.9.3 Baseline Groundwater Monitoring 2-113
2.9.3.1 Private Water Supply Wells 2-114
2.9.3.2 CBR Groundwater Monitor Wells 2-115
2.9.3.3 Groundwater Quality Data for Arikaree Group, Brule, and Chadron Formations 2-119
2.9.4 Baseline Surface Water Monitoring 2-119
2.9.4.1 NDNR Niobrara River Ambient Stream Monitoring Program 2-120
2.9.4.2 NDEQ Niobrara River Ambient Stream Monitoring Program 2-121
2.9.4.3 Crow Butte Sampling of the Niobrara River 2-122
2.9.4.4 USBR Box Butte Reservoir Storage Content 2-123
2.9.5 Baseline Vegetation, Food, and Fish Monitoring 2-123
2.9.5.1 Vegetation 2-124
2.9.5.2 Food 2-124
2.9.5.3 Fish 2-125
2.9.6 Baseline Soil Monitoring 2-126
2.9.7 Baseline Sediment Sampling 2-127
2.9.7.1 Niobrara River Sediments 2-127
2.9.7.2 Ephemeral Drainages 2-128
2.9.8 Baseline Direct Radiation Monitoring 2-128
2.9.8.1 Survey Intervals 2-128
2.9.8.2 Survey Measurements at Air Particulate Monitoring Stations 2-128
2.9.9 Preoperational/Preconstruction Baseline Monitoring Program Summary 2-129

3 DESCRIPTION OF PROPOSED FACILITY 3-1

3.1 Solution Mining Process and Equipment 3-1
3.1.1 Orebody 3-1
3.1.2 Well Construction and Integrity Testing 3-1
3.1.2.1 Well Materials of Construction 3-2
3.1.2.2 Well Construction Methods 3-4

3.1.2.3 Cement/Grout Specifications 3-6
3.1.2.4 Logging Procedures and Other Tests 3-6
3.1.2.5 Field Observations and Core Samples Analysis 3-9
3.1.2.6 Well Development 3-9
3.1.2.7 Well Integrity Testing 3-10
3.1.3 Wellfield Design and Operation 3-10
3.1.4 Assessment of Flooding and Erosion Potential 3-15
3.1.4.1 Data Collection 3-15
3.1.4.2 Analysis Procedures 3-16
3.1.4.3 Erosion Risk Analysis 3-17
3.1.4.4 Flood Risk Analysis 3-18
3.1.4.5 Flood Risk Planning 3-19
3.1.4.6 Surface Water Management and Erosion Control 3-19
3.1.4.7 Erosion Control during Construction and Decommissioning 3-20
3.1.5 Process Description 3-20
3.1.5.1 Uranium Extraction 3-21
3.1.5.2 Resin Transport and Elution 3-22
3.1.5.3 Precipitation 3-22
3.1.6 Wellfield and Process Wastes 3-23
3.1.7 MEA Water Balance 3-23
3.2 Central Processing Facility, Satellite Facility, Wellfield, and Chemical Storage Facilities – Equipment Used and Material Processed 3-29
3.2.1 Marsland Satellite Facility Equipment 3-29
3.2.2 Chemical Storage Facilities 3-30
3.2.2.1 Process-Related Chemicals 3-30
3.2.2.2 Non-Process Related Chemicals 3-31
3.3 Satellite Facility Instrumentation and Control 3-33

4 EFFLUENT CONTROL SYSTEMS 4-1

4.1 Gaseous and Airborne Particulates 4-1
4.1.1 Non-radioactive Airborne Emissions 4-1
4.1.2 Radioactive Airborne Emissions 4-1
4.1.2.1 Airborne Uranium Emissions 4-2
4.1.2.2 Wellfield Radon Emissions 4-2
4.1.2.3 Satellite Plant Radon Emissions 4-3
4.1.3 Response to Emergency Events Associated with Effluent Control Systems 4-4
4.1.4 ALARA Evaluations of Effluent Control Systems 4-5
4.2 Liquids and Solids 4-7
4.2.1 Liquid Waste 4-7

4.2.1.1 Water and Drill Cuttings Generated during Well Drilling and Development 4-7
4.2.1.2 Liquid Process Waste 4-8
4.2.1.3 Waste Petroleum Products and Chemicals 4-8
4.2.1.4 Aquifer Restoration Waste 4-8
4.2.1.5 Stormwater Runoff 4-9
4.2.1.6 Domestic Liquid Waste 4-9
4.2.1.7 Liquid Waste Disposal 4-9
4.2.1.8 Deep Disposal Well 4-10
4.2.1.9 Disposal of Other Radioactive Liquids as per NRC License SUA-1534 4-13
4.2.1.10 Potential Pollution Events Involving Liquid Waste 4-13
4.2.1.11 Wellfield Buildings and Piping 4-13
4.2.1.12 Satellite Facility 4-13
4.3 Deep Well Pumphouse and Wellhead 4-15
4.3.1.1 Transportation Vehicles 4-15
4.3.1.2 Spills 4-15
4.3.2 Solid Waste 4-16
4.3.2.1 Non-contaminated Solid Waste 4-16
4.3.2.2 11(e).2 Byproduct Material 4-16
4.3.2.3 Septic System Solid Waste 4-17
4.3.2.4 Hazardous Waste 4-17

5 OPERATIONS 5-1

5.1 Corporate Organization and Administrative Procedures 5-1
5.1.1 Board of Directors 5-1
5.1.2 President 5-1
5.1.3 General Manager of US Operations 5-2
5.1.4 Restoration Manager 5-2
5.1.5 Safety, Health, Environment, and Quality Manager 5-2
5.1.6 Plant Supervisor 5-2
5.1.7 Radiation Safety Officer 5-3
5.1.8 Health Physics Technician 5-3
5.1.9 SHEQ Specialist 5-3
5.1.13 ALARA Program Responsibilities 5-4
5.1.14 Management Responsibilities 5-4
5.1.14.1 Radiation Safety Officer ALARA Responsibility 5-4
5.1.14.2 Supervisor Responsibility 5-5
5.1.14.3 Worker Responsibility 5-5
5.1.15 Contractor Management 5-6
5.2 Management Control Program 5-7

5.2.1 Safety Health Environment and Quality Management System (SHEQMS) 5-7
5.2.1.1 Operating Procedures 5-8
5.2.1.2 Radiation Work Permits 5-8
5.2.1.3 Record Keeping and Retention 5-9
5.2.2 Performance Based License Condition 5-9
5.2.3 Safety and Environmental Review Panel 5-10
5.2.3.1 Safety and Environmental Review Panel Review Procedures 5-10
5.2.3.2 Documentation of SERP Review Process 5-11
5.3 Management Audit and Inspection Program 5-13
5.3.1 Radiation Safety Inspections 5-13
5.3.1.1 Daily Inspections 5-13
5.3.1.2 Monthly Reviews 5-13
5.3.2 Annual ALARA Audits 5-14
5.4 Health Physics Staff Qualifications 5-17
5.4.1 Radiation Safety Officer Qualifications 5-17
5.4.2 Health Physics Technician Qualifications 5-17
5.5 Radiation Safety Training 5-19
5.5.1 Training Program Content 5-19
5.5.1.1 Visitors 5-19
5.5.1.2 Contractors 5-19
5.5.1.3 Crow Butte Resources Employees 5-19
5.5.2 Testing Requirements 5-21
5.5.3 On-The-Job Training 5-21
5.5.3.1 Health Physics Technician 5-21
5.5.3.2 Refresher Training 5-21
5.5.3.3 Training Records 5-21
5.5.4 Qualifications and Requirements for Daily Inspections 5-21
5.5.4.1 Minimum Qualifications for Designated Operators 5-22
5.5.4.2 Additional Training for Designated Operators 5-23
5.5.4.3 Demonstration of Proficiency 5-23
5.5.4.4 Documentation 5-24
5.5.4.5 Maintaining Designated Operator Status 5-24
5.6 Security 5-25
5.6.1 License Area and Facility Security 5-25
5.6.1.1 MEA Security 5-25
5.6.1.2 Transportation Security 5-27
5.7 Radiation Safety Controls and Monitoring 5-29
5.7.1 Effluent Control Techniques 5-30
5.7.1.1 Gaseous and Airborne Particulate Effluents 5-30
5.7.1.2 Liquid Effluents 5-31

5.7.1.3 Spill Contingency Plans 5-32
5.7.2 External Radiation Exposure Monitoring Program 5-35
5.7.2.1 Gamma Surveys 5-35
5.7.2.2 Personnel Dosimetry 5-36
5.7.2.3 Cumulative Exposures 5-36
5.7.2.4 Exposure Reporting 5-37
5.7.3 Satellite Facility Airborne Radiation Monitoring Program 5-37
5.7.3.1 Airborne Uranium Particulate Monitoring 5-38
5.7.3.2 CBR Site-Specific DAC 5-39
5.7.3.3 Radon Daughter Concentration Monitoring 5-40
5.7.3.4 Respiratory Protection Program 5-40
5.7.4 Exposure Calculations 5-41
5.7.4.1 Natural Uranium Exposure 5-41
5.7.4.2 Radon Daughter Exposure 5-43
5.7.4.3 Prenatal and Fetal Exposure 5-44
5.7.5 Bioassay Program 5-45
5.7.6 Contamination Control Program 5-46
5.7.6.1 Surface Contamination 5-46
5.7.6.2 Personnel Contamination 5-47
5.7.6.3 Controlled Release Survey Program 5-47
5.7.7 Airborne Effluent and Environmental Operational Monitoring Programs 5-51
5.7.7.1 Air Particulate Monitoring 5-51
5.7.7.2 Radon and Radon Progeny 5-51
5.7.7.3 Surface Soil 5-53
5.7.7.4 Subsurface Soil 5-54
5.7.7.5 Vegetation 5-54
5.7.7.6 Food 5-54
5.7.7.7 Direct Radiation 5-55
5.7.7.8 Sediment 5-55
5.7.8 Groundwater/Surface Water Monitoring Program 5-55
5.7.8.1 Program Description 5-55
5.7.8.2 Groundwater Monitoring 5-56
5.7.9 Private Well Monitoring 5-56
5.7.9.1 Monitor Well Baseline Water Quality 5-56
5.7.9.2 Upper Control Limits and Excursion Monitoring 5-56
5.7.9.3 Excursion Verification and Corrective Action 5-57
5.7.10 Quality Assurance Program 5-58

6 GROUNDWATER QUALITY RESTORATION, SURFACE RECLAMATION, AND FACILITY DECOMMISSIONING 6-1

6.1 Plans and Timelines for Groundwater Restoration 6-1
6.1.1 Ore Body Genesis 6-1
6.1.2 Chemical and Physical Interactions of Lixiviant with the Ore Body 6-1
6.1.2.1 Ion Exchange 6-2
6.1.2.2 Precipitation 6-2
6.1.2.3 Hydrolysis 6-3
6.1.2.4 Oxidation 6-3
6.1.2.5 Organics 6-4
6.1.3 Basis of Restoration Goals 6-4
6.1.3.1 Establishment of Baseline Water Quality 6-5
6.1.3.2 Establishment of Restoration Goals 6-5
6.1.4 Groundwater Restoration Methods 6-6
6.1.4.1 Introduction 6-6
6.1.4.2 Restoration Process 6-7
6.1.5 Stabilization Phase 6-10
6.1.6 Reporting 6-11
6.2 Plans for Reclaiming Disturbed Lands 6-13
6.2.1 General Surface Reclamation Procedures 6-14
6.2.1.1 Topsoil Handling and Replacement 6-14
6.2.1.2 Contouring of Affected Areas 6-15
6.2.1.3 Revegetation Practices 6-15
6.2.2 Process Facility Site Reclamation 6-15
6.2.3 Wellfield Decommissioning 6-16
6.2.3.1 Well Plugging and Abandonment 6-17
6.2.3.2 Buried Trunklines, Pipes, and Equipment 6-19
6.3 Removal and Disposal of Structures, Waste Materials, and Equipment 6-21
6.3.1 Preliminary Radiological Surveys and Contamination Control 6-21
6.3.2 Removal of Process Buildings and Equipment 6-22
6.3.2.1 Building Materials, Equipment, and Piping to be Released for Unrestricted Use 6-22
6.3.2.2 Disposal at a Licensed Facility 6-23
6.3.2.3 Release for Unrestricted Use 6-23
6.3.3 Waste Transportation and Disposal 6-24
6.4 Methodologies for Conducting Post-Reclamation and Decommissioning Radiological Surveys 6-25
6.4.1 Cleanup Criteria 6-25
6.4.2 Surface Soil Cleanup Verification and Sampling Plan 6-26
6.4.3 Subsurface Soil Cleanup Verification and Sampling Plan 6-26
6.4.4 Temporary Ditches and Impoundments Cleanup Verification and Sampling Plan 6-27

6.4.5 Quality Assurance 6-27
6.5 Decommissioning Health Physics and Radiation Safety 6-29
6.5.1 Records and Reporting Procedures 6-29
6.6 Financial Assurance 6-31
6.6.1 Bond Calculations 6-31
6.6.2 Financial Surety Arrangements 6-31

7 ENVIRONMENTAL EFFECTS 7-1

7.1 Environmental Effects of Site Preparation and Construction 7-1
7.1.1 Air Quality Effects of Construction 7-3
7.1.2 Land Use Impacts of Construction 7-3
7.1.3 Geologic and Soil Impacts of Construction 7-4
7.1.3.1 Geologic Impacts of Construction 7-4
7.1.3.2 Soil Impacts of Construction 7-4
7.1.4 Surface Water Impacts of Construction 7-7
7.1.5 Population Impacts of Construction 7-7
7.1.6 Social and Economic Impacts of Construction 7-8
7.1.7 Noise Impacts of Construction 7-8
7.2 Environmental Effects of Operations 7-9
7.2.1 Air Quality Impacts of Operations 7-9
7.2.1.1 Particulate Emissions During Operations 7-9
7.2.1.2 Criteria Pollutant Regulatory Compliance Issues 7-13
7.2.2 Land Use Impacts of Operations 7-14
7.2.3 Geologic and Soil Impacts of Operations 7-15
7.2.3.1 Geologic Impacts of Operations 7-15
7.2.3.2 Soil Impacts of Operations 7-16
7.2.4 Archeological Resources Impacts of Operations 7-16
7.2.5 Groundwater Impacts of Operations 7-17
7.2.5.1 Groundwater Consumption 7-17
7.2.5.2 Potential Declines in Groundwater Quality 7-20
7.2.5.3 Potential Groundwater Impacts from Accidents 7-20
7.2.5.4 Cumulative Impacts 7-21
7.2.6 Surface Water Impacts of Operations 7-25
7.2.6.1 Surface Water Impacts from Sedimentation 7-25
7.2.6.2 Potential Surface Water Impacts from Accidents 7-25
7.2.7 Ecological Impacts of Operations 7-26
7.2.7.1 Impact Significance Criteria 7-26
7.2.7.2 Vegetation 7-27
7.2.7.3 Surface Waters and Wetlands 7-28
7.2.7.4 Wildlife and Fisheries 7-29
7.2.7.5 Big Game Mammals 7-29

7.2.7.6 Carnivores and Small Mammals 7-30
7.2.7.7 Passerines and Upland Game Birds 7-31
7.2.7.8 Raptors 7-31
7.2.7.9 Reptiles and Amphibians 7-32
7.2.7.10 Fish and Macroinvertebrates 7-32
7.2.7.11 Threatened and Endangered Species 7-33
7.2.8 Noise Impacts of Operations 7-34
7.3 Radiological Effects 7-35
7.3.1 Exposure Pathways 7-35
7.3.2 Exposures from Water Pathways 7-36
7.3.3 Exposures from Air Pathways 7-37
7.3.3.1 MILDOS Output – Radiation Dose Rates 7-37
7.3.3.2 MILDOS Output – Public and Occupational Radiation Dose Rates. 7-38
7.3.3.3 Radon Release Points 7-38
7.3.4 Exposure to Flora and Fauna 7-39
7.3.4.1 Radon Releases 7-39
7.3.4.2 Fluid Discharges 7-40
7.4 Non-Radiological Effects 7-41
7.5 Effects of Accidents 7-43
7.5.1 Chemical Risk 7-43
7.5.1.1 O_2 7-44
7.5.1.2 CO_2 7-44
7.5.1.3 $NaHCO_3$ 7-44
7.5.2 Radiological Risk 7-44
7.5.2.1 Tank Failure 7-44
7.5.2.2 Facility Pipe Failure 7-45
7.5.3 Groundwater Contamination Risk 7-45
7.5.3.1 Lixiviant Excursion 7-45
7.5.4 Wellfield Spill Risk 7-46
7.5.5 Transportation Accident Risk 7-47
7.5.5.1 Accidents Involving Shipments of Process Chemicals 7-47
7.5.5.2 Accidents Involving Radioactive Wastes 7-47
7.5.5.3 Accidents Involving Resin Transfers 7-47
7.5.6 Natural Disaster Risk 7-49
7.5.6.1 Tornado Risk 7-49
7.5.6.2 Seismic Risk 7-50
7.5.6.3 Fires 7-51
7.5.6.4 Flooding 7-51
7.6 Economic and Social Effects of Construction and Operation 7-0
7.6.1 Tax Revenues 7-0
7.6.2 Temporary and Permanent Jobs 7-1

7.6.2.1 Current Staffing Levels 7-1
7.6.2.2 Projected Short-Term and Long-Term Staffing Levels 7-1
7.6.3 Impact on the Local Economy 7-3
7.6.4 Economic Impact Summary 7-3

8 ALTERNATIVES TO PROPOSED ACTION 8-1

8.1 No-Action Alternative 8-1
8.1.1 Summary of Current Activity 8-1
8.1.2 Impacts of the No-Action Alternative 8-1
8.2 Proposed Action 8-3
8.3 Reasonable Alternatives 8-7
8.3.1 Process Alternatives 8-7
8.3.1.1 Lixiviant Chemistry 8-7
8.3.1.2 Groundwater Restoration 8-7
8.3.1.3 Waste Management Alternatives 8-7
8.4 Alternatives Considered but Eliminated 8-10
8.4.1 Mining Alternatives 8-11
8.4.2 Production Facility Alternatives 8-12
8.5 Cumulative Effects 8-13
8.5.1 Cumulative Radiological Impacts 8-13
8.5.2 Future Development 8-13
8.6 Comparison of the Predicted Environmental Impacts 8-15

9 COST-BENEFIT ANALYSIS 9-1

9.1 General 9-1
9.2 Economic Impacts 9-1
9.2.1 Tax Revenues 9-1
9.2.2 Temporary and Permanent Jobs 9-1
9.2.2.1 Current Staffing Levels 9-1
9.2.2.2 Projected Short-Term and Long-Term Staffing Levels 9-2
9.2.3 Impact on the Local Economy 9-2
9.2.4 Economic Impact Summary 9-3
9.2.5 Estimated Value of Marsland Resource 9-3
9.2.6 Short-Term External Costs 9-3
9.2.6.1 Housing Impacts 9-3
9.2.6.2 Noise and Congestion 9-4
9.2.6.3 Local Services 9-4
9.2.7 Long-Term External Costs 9-4
9.2.7.1 Housing and Services 9-4
9.2.7.2 Noise and Traffic Congestion 9-4
9.2.7.3 Aesthetic Impacts 9-5

9.2.7.4 Land Access Restrictions 9-5
9.2.8 Most Affected Population 9-6
9.2.9 Satellite Facility Decommissioning Costs 9-6
9.3 The Benefit-Cost Summary 9-9
9.4 Summary 9-9

10 ENVIRONMENTAL APPROVALS AND CONSULTATIONS 10-1

10.1 Environmental Approvals for the Current Licensed Area 10-1
10.1.1 Environmental Approvals and License/Permits 10-1
10.1.2 Licensing and Permitting Consultations 10-1
10.1.3 Environmental Consultations 10-2
10.1.4 List of Preparers 10-4

This page intentionally blank

Tables

Table 1.7-1	Current Crow Butte Production Area Mine Unit Status
Table 2.1-1	Latitude and Longitude and Coordinates for Marsland License Boundary and Satellite Facility
Table 2.2-1	Major Land Use Definitions
Table 2.2-2	Present Major Land Use within a 2.25-Mile (3.62 km) Radius of the Proposed Marsland Expansion Area License Boundary
Table 2.2-3	Present Land Use within the Proposed Marsland Expansion Area License Boundary
Table 2.2-4	Agricultural Yields for Croplands in Dawes County 2010
Table 2.2-5	Livestock Inventory for Dawes County 2007
Table 2.2-6	Recreational Facilities Within 50 Miles (80 km) of the Proposed Marsland Expansion Area
Table 2.2-7	Distance to Nearest Residence and Site Boundary from Center of MEA for Each Compass Sector
Table 2.2-8	Uranium Recovery Activities in Region of Proposed Marsland Expansion Area
Table 2.2-9	USGS Estimated Water Use in Dawes County 2005
Table 2.2-10	Summary of Non-Abandoned Registered Water Wells for Dawes County, NE on File as of April 08, 2013
Table 2.2-11	Active, Inactive, Seasonal and Abandoned Water Supply Wells in the MEA and 2.25-Mile Area Of Review
Table 2.2-12	Minimal Horizontal Distance Separating a Municipal Water Well from Potential Sources of Contamination
Table 2.3-1	Historical and Current Population Change for Counties and Cities within 80 km of the Marsland Expansion Area, 1970-2010
Table 2.3-2	Population by Age and Sex for Counties within the 80-Kilometer Radius of the Marsland Expansion Area 2010
Table 2.3-3	Population Projections for Counties within an 80-Kilometer Radius of the Current Crow Butte Project Area 2000-2030
Table 2.3-4	2010 Population within an 80-Kilometer Radius of the Marsland Expansion Area
Table 2.3-5	Annual Average Labor Force and Employment Economic Sectors for Dawes and Box Butte Counties (1994 and 2009)
Table 2.3-6	Population and Demographics for Census Blocks Overlain or Adjacent to the MEA with Populations Recorded in 2010 Census
Table 2.4-1	Scenic Quality Inventory and Evaluation for the Marsland Expansion Area

Table 2.4-2	Determining BLM Visual Resource Inventory Classes
Table 2.5-1	Meteorological Stations Included in Climate Analysis
Table 2.5-2	Annual and Monthly Temperature Statistics for Scottsbluff Airport, NE
Table 2.5-3	Scottsbluff Airport Monthly Wind Parameters Summary
Table 2.5-4	Scottsbluff Airport 15-Year Wind Frequency Distribution
Table 2.5-5	Marsland Expansion Area Maximum, Minimum, and Average Monthly Temperatures
Table 2.5-6	Marsland Meteorological Summary
Table 2.5-7	Marsland Expansion Area Meteorological Station
Table 2.5-8	Marsland Expansion Annual Wind Summary
Table 2.5-9	Marsland Annual Joint Frequency Distribution
Table 2.5-10	Marsland Winter Joint Frequency Distribution
Table 2.5-11	Marsland Spring Joint Frequency Distribution
Table 2.5-12	Marsland Summer Joint Frequency Distribution
Table 2.5-13	Marsland Fall Joint Frequency Distribution
Table 2.5-14	Marsland Onsite Meteorological Station Description
Table 2.5-15	Rapid City Mixing Heights
Table 2.5-16	EPA National Ambient Air Quality Standards (NAAQS)
Table 2.5-17	Nebraska and South Dakota Ambient Air Monitoring Network Near Marsland Expansion Area
Table 2.5-18	Comparison of Ambient Particulate Matter (PM_{10}) Monitoring Data for Regional Monitoring Sites
Table 2.5-19	PM_{10} Annual Average Monitoring Data for South Dakota Monitoring Sites
Table 2.5-20	$PM_{2.5}$ Annual Average Monitoring Data for Regional Monitoring Sites
Table 2.5-21	Comparison of Ambient Particulate Matter ($PM_{2.5}$) Monitoring Data for Regional Monitoring Sites
Table 2.5-22	Comparison of Sulfur Dioxide Values for Wind Cave and Badlands, SD Monitor Sites
Table 2.5-23	Comparison of Nitrogen Dioxide 1-Hour 98th Percentile Concentrations for Wind Cave and Badlands, SD
Table 2.5-24	Comparison of Nitrogen Dioxide Annual Average Values for Wind Cave and Badlands, SD Monitor Sites
Table 2.5-25	Ozone Yearly 4th Highest 8-Hour Averages for Regional Monitoring Sites
Table 2.5-26	Prevention of Significant Deterioration (PSD) of Air Quality Allowable Increments

Table 2.6-1	General Stratigraphic Chart for Northwest Nebraska
Table 2.6-2	Representative Stratigraphic Section – Marsland Expansion Area
Table 2.6-3	Marsland Expansion Area Coring Summary
Table 2.6-4	USGS Abbreviated Modified Mercalli (MM) Intensity Scale
Table 2.6-5	Historical Earthquakes in Northwestern Nebraska in Proximity to the Chadron and Cambridge Arches (1884 – 2009)
Table 2.6-6	Earthquakes in Wyoming and South Dakota Within 125 Miles of City of Crawford, NE (1992 – 2007)
Table 2.6-7	Summary of MEA Soil Resources
Table 2.7-1	Stream Classification of Niobrara River Subbasin N14
Table 2.7-2	Summary of 2011 Marsland Pumping Test #8 Well Information
Table 2.7-3	Summary of 2011 Marsland Pumping Test Results
Table 2.7-4	Summary of Marsland Pumping Test Results Compared to Previous Testing
Table 2.7-5	Baseline and Restoration Values for Mine Unit 1 of Current Commerical License Area
Table 2.7-6	Anticipated Changes in Water Quality during Mining
Table 2.8-1	Monthly Climate Summary for Scottsbluff WSO Airport, NE (257665)
Table 2.8-2	Marsland Expansion Area Vegetation and Land Cover Types
Table 2.8-3	Federal and State Threatened, Endangered, and Candidate Species with the Potential to Occur within the Vicinity of the Marsland Expansion Area
Table 2.9-1	Locations of Environmental Sampling Stations, SAT Facility, and MET Station at the Marsland Expansion Area Site
Table 2.9-2	Airborne Particulate Concentrations for Marsland Expansion Area
Table 2.9-3	Ambient Atmospheric Radon-222 Concentration for Marsland Expansion Area
Table 2.9-4	Summary of Water Quality for the Marsland Expansion Area and Vicinity (2011 - 2014)
Table 2.9-5	Radiological Analyses for Private Water Supply Wells in Marsland Area of Review
Table 2.9-6	Non-Radiological Analyses for Private Water Supply Wells in Marsland Area of Review
Table 2.9-7	Water Levels - Arikaree Group, Brule Formation and Basal Sandstone of Chadron Formation
Table 2.9-8	Non-Radiological Analytical Results for Brule Formation (2013-2014)
Table 2.9-9	Radiological Analytical Results for Brule Formation (2013-2014)

Table 2.9-10	Marsland Expansion Area Non-Radiological Analytical Results (November 2011 to August 2012) – Chadron Wells
Table 2.9-11	Marsland Expansion Area Radiological Analytical Results (November 2011 to August 2012) – Chadron Wells
Table 2.9-12	Stream Gaging Stations on Niobrara River in Vicinity of Headwaters of Niobrara River
Table 2.9-13	Summary of Niobrara River Flow Measurements 1999 – 2012
Table 2.9-14	Water Flow Measurements for Upper Reaches of Niobrara River – 1999 to 2012
Table 2.9-15	NDEQ 2002 Field Measurements of pH and Dissolved Oxygen for Station Number SNI4NIOBR402 (Niobrara River above Box Butte Reservoir)
Table 2.9-16	NDEQ Water Quality Data for Niobrara River Above Box Butte Reservoir (SNI4NIOBR402) - 2002
Table 2.9-17	NDEQ Water Quality Data for Niobrara River above Box Butte Reservoir (SNI4NIOBR402) - 2003
Table 2.9-18	NDEQ Water Quality Data for Niobrara River above Box Butte Reservoir (SNI4NIOBR402) – 2004
Table 2.9-19	NDEQ Water Quality Data for Niobrara River above Box Butte Reservoir (SNI4NIOBR402) – 2005
Table 2.9-20	NDEQ Water Quality Data for Niobrara River above Box Butte Reservoir (SNI4NIOBR402) - 2006
Table 2.9-21	NDEQ Water Quality Data for Niobrara River above Box Butte Reservoir (SNI4NIOBR402) - 2007
Table 2.9-22	NDEQ Water Quality Data for Niobrara River above Box Butte Reservoir - 2008
Table 2.9-23	NDEQ Water Quality Data for the Niobrara River above Box Butte Reservoir - 2009
Table 2.9-24	NDEQ Water Quality Data for Niobrara River above Box Butte Reservoir (SNI4NIOBR402) – 2010
Table 2.9-25	NDEQ Water Quality Data for Niobrara River above Box Butte Reservoir (SNI4NIOBR402) – 2011
Table 2.9-26	Summary of NDEQ Non-Radiological Water Quality Data for Niobrara River Above Box Butte Reservoir 2003 - 2011
Table 2.9-27	NDEQ Water Quality Data for Niobrara River below Box Butte Reservoir - 2008
Table 2.9-28	NDEQ Water Quality Summary for Niobrara River below Box Butte Reservoir - 2008
Table 2.9-29	Niobrara River N-1 Radiological Results 2013-2014
Table 2.9-30	Niobrara River N-2 Radiological Results 2013-2014

Table 2.9-31	Summary of Radiological Baseline Data for Niobrara River Near Marsland Expansion Area Collected by Crow Butte
Table 2.9-32	Marsland Expansion Area Vegetation Seasonal Radiological Laboratory Analysis
Table 2.9-33	Radionuclide Analyses for Livestock Samples
Table 2.9-34	Daily Contents in Acre-Feet of Water for Box Butte Reservoir (USGS 06455000)– 2003 to 2013
Table 2.9-35	Range Values for Box Butte Reservoir Water Contents
Table 2.9-36	MEA Garden Soil Radiological Laboratory Analysis
Table 2.9-37	Total Radionuclides and Metals in Tissue of Northern Pike Collected from Inlet of Box Butte Reservoir
Table 2.9-38	Radionuclide and Metal Analyses for Niobrara River Sediment Sample Locations N-1 and N-2
Table 2.9-39	Radionuclide and Metal Analyses for Marsland Ephemeral Drainage (MED) Sediment Sample Locations
Table 2.9-40	Marsland Expansion Area Gamma Exposure Results
Table 2.9-41	Marsland Expansion Area Preoperational/Preconstruction Monitoring Program
Table 2.9-42	Marsland Expansion Area Radiological Analytical Results (Q4 2013 - Q3 2014) – Arikaree Wells
Table 2.9-43	Marsland Expansion Area Non-Radiological Analytical Results (Q4 2013 - Q3 2014) – Arikaree Wells
Table 3.1-1	Background Information for Logging Probes Used at the Marsland Expansion Area
Table 3.1-2	Summary of Risk of Erosion for Proposed Marsland Expansion Area Mine Units
Table 3.1-3	The Peak Flow for Hydrologic Project South
Table 3.1-4	The Peak Flow for Hydrologic Project East
Table 3.1-5	Typical Lixiviant Concentrations
Table 3.1-6	Lixiviant Parameters Measured in the Injection Stream at Crow Butte MU-3, MU-4, MU-5, and MU-6
Table 3.1-7	Disposal Water Balance (Marsland Expansion Area)
Table 4.2-1	Deep Disposal Well No. 1 Injection Radiological Data for Crow Butte Central Processing Facility (2008-2012)
Table 4.2-2	Deep Disposal Well No. 2 Injection Radiological Data for Crow Butte Central Processing Facility 2012
Table 4.2-3	Deep Disposal Wells Injection Non-Radiological Data for Current Crow Butte Operations for 2012
Table 5.7-1	Marsland Expansion Area Operational Effluent and Environmental Monitoring Plan



Table 6.1-1	NRC and NDEQ Groundwater Restoration Standards
Table 6.1-2	Typical Reverse Osmosis Membrane Rejection Percentages
Table 6.4-1	Soil Cleanup Criteria and Goals
Table 7.1-1	Estimated Acres Disturbed by Marsland Expansion Area Project Development
Table 7.2-1	Crow Butte Resources Excursion Summary
Table 7.3-1	Radiation Dose Rates to Receptors from MEA Only & Cumulative Dose Rates
Table 7.3-2	Public and Occupational Doses for Marsland Expansion Area
Table 7.6-1	Tax Revenues from the Current Crow Butte Project
Table 7.6-2	Current Economic Impact of Crow Butte Uranium Project and Projected Impact from Marsland Expansion Area
Table 8.6-1	Comparison of Predicted Environmental Impacts
Table 10.1-1	Environmental Approvals for Crow Butte Project
Table 10.1-2	Environmental Approvals for Proposed Marsland Expansion Area

Figures

Figure 1.3-1	Crow Butte Resources Inc. Current License Area and Proposed Expansion Areas
Figure 1.3-2	Marsland Expansion Area Land Ownership
Figure 1.4-1	Marsland Expansion Area Estimated Ore Body
Figure 1.7-1	Current Production Area Mine Unit Timeline
Figure 1.7-2	Current License Area Project Layout
Figure 1.7-3	Project Location Map, ZOEI and AOR
Figure 1.7-4	Marsland Expansion Area Mining and Restoration Timeline
Figure 1.7-5	General Arrangement Satellite Facility View
Figure 2.2-1	Marsland Expansion Area Land Use
Figure 2.2-2	Marsland Expansion Area Proximity to Recreation Areas and Wildlife Management Areas
Figure 2.2-3	Aerial Photo Depicting Location of Rural Residences and Other Land Features in the Area of Review
Figure 2.2-4	Marsland Expansion Area Location of Gravel Pits and Oil/Gas Test Holes
Figure 2.3-1	Significant Population Centers within an 80 km (50 mi) Radius of the Marsland Site
Figure 2.5-1	Marsland Project Met Stations
Figure 2.5-2	Scottsbluff AP Monthly Temperatures
Figure 2.5-3	Scottsbluff AP Seasonal Diurnal Temperature Variations
Figure 2.5-4	Regional Annual Average Minimum Temperatures
Figure 2.5-5	Regional Annual Average Maximum Temperatures
Figure 2.5-6	Monthly Relative Humidity Statistics for Scottsbluff AP
Figure 2.5-7	Diurnal Variation in Relative Humidity for Scottsbluff by Season
Figure 2.5-8	Scottsbluff AP Monthly Average Precipitation
Figure 2.5-9	Regional Monthly Average Precipitation
Figure 2.5-10	Scottsbluff AP Monthly Snowfall
Figure 2.5-11	Regional Monthly Average Snowfall
Figure 2.5-12	Regional Annual Average Precipitation
Figure 2.5-13	Regional Annual Average Snowfall
Figure 2.5-14	Scottsbluff AP 15-Year Wind Speeds
Figure 2.5-15	Scottsbluff AP 15-Year Wind Rose
Figure 2.5-16	Scottsbluff AP Diurnal Wind Speeds by Season
Figure 2.5-17	Scottsbluff AP Cooling, Heating, and Growing Degree Days
Figure 2.5-18	Scottsbluff AP Potential Evapotranspiration

Figure 2.5-19 Marsland Expansion Area Monthly Temperatures
Figure 2.5-20 Marsland Expansion Area Wind Rose
Figure 2.5-21 Marsland Expansion Area Seasonal Wind Roses
Figure 2.5-22 Marsland Expansion Area Diurnal Wind Speeds
Figure 2.5-23 Marsland Expansion Area Wind Speed Distribution
Figure 2.5-24 Project Area Monthly Average Wind Speeds
Figure 2.5-25 Marsland Expansion Area Total Monthly Precipitation
Figure 2.5-26 Marsland Expansion Area Potential Monthly Evapotranspiration
Figure 2.5-27 Scottsbluff 15-Year vs. Baseline Year Wind Roses
Figure 2.5-28 Scottsbluff 15-Year vs. Baseline Year Wind Directions
Figure 2.5-29 Scottsbluff 15-Year vs. Baseline Year Wind Speeds
Figure 2.5-30 Scottsbluff 15-Year vs. Baseline Year Wind Speed Distributions
Figure 2.5-31 Scottsbluff 15-Year vs. Baseline Year Wind Direction Distributions
Figure 2.5-32 Alliance West 10-Year Wind Rose 1996 -2005
Figure 2.5-33 Locations of Regional Ambient Air Monitoring Sites
Figure 2.6-1 Bedrock Geology of the Marsland Expansion Area
Figure 2.6-2 Marsland Cross-Section Map Showing Artificial Penetrations
Figure 2.6-3a Marsland Structural Cross-Section A – A'
Figure 2.6-3b Marsland Structural Cross-Section B – B'
Figure 2.6-3c Marsland Structural Cross-Section C – C'
Figure 2.6-3d Marsland Structural Cross-Section D – D'
Figure 2.6-3e Marsland Structural Cross-Section E – E'
Figure 2.6-3f Marsland Structural Cross-Section F - F'
Figure 2.6-3g Marsland Structural Cross-Section G - G'
Figure 2.6-3h Marsland Structural Cross-Section H - H'
Figure 2.6-3i Marsland Structural Cross-Section I - I'
Figure 2.6-3j Marsland Structural Cross-Section J - J'
Figure 2.6-3k Marsland Structural Cross-Section K - K'
Figure 2.6-3l Marsland Structural Cross-Section L - L'
Figure 2.6-3m Marsland Structural Cross-Section M - M'
Figure 2.6-3n Marsland Structural Cross-Section N - N'
Figure 2.6-3o Expanded Marsland Cross-Section A – A' Panel 1
Figure 2.6-3p Expanded Marsland Cross-Section A – A' Panel 2
Figure 2.6-3q Expanded Marsland Cross-Section A – A ' Panel 3
Figure 2.6-3r Expanded Marsland Cross-Section A – A' Panel 4
Figure 2.6-3s Expanded Marsland Cross-Section A – A' Panel 5



Figure 2.6-3t	Expanded Marsland Cross-Section A – A' Panel 6
Figure 2.6-3u	Expanded Marsland Cross-Section E – E'
Figure 2.6-4	Marsland Expansion Area Coring Location
Figure 2.6-5	Marsland Expansion Area Type Log (M-1252)
Figure 2.6-6	Marsland Isopach Map – Arikaree Group
Figure 2.6-7	Marsland Isopach Map – Brule Formation
Figure 2.6-8	Marsland Isopach Map – Upper and Middle Chadron Formation
Figure 2.6-9	Marsland Isopach Map – Basal Sandstone of the Chadron Formation
Figure 2.6-10	Marsland Structure Map — Top of Brule Formation
Figure 2.6-11	Marsland Structure Map – Top of Chadron Formation
Figure 2.6-12	Marsland Structure Map – Top of Basal Sandstone of the Chadron Formation
Figure 2.6-13	Marsland Structure Map – Top of Pierre Shale
Figure 2.6-14	Regional Structure Contour Map – Top of Pierre Shale
Figure 2.6-15	Location of Chadron Arch and Cambridge Arch in Nebraska
Figure 2.6-16	Structural Features Map of the Crawford Basin
Figure 2.6-17	Earthquake Hazard Ranking in the U.S.
Figure 2.6-18	Seismic Hazard Map for Nebraska (2008)
Figure 2.6-19	Seismicity of Nebraska 1973 – 2013
Figure 2.6-20	Soils
Figure 2.6-21	Regional Geologic Cross-Section Location Map
Figure 2.6-22	Regional Geologic Cross-Section R0-R0'
Figure 2.6-23	Regional Geologic Cross-Section R1-R1'
Figure 2.6-24	Regional Geologic Cross-Section R2-R2'
Figure 2.7-1	Nebraska's Major River Basins
Figure 2.7-2	Niobrara River Basin (And Subbasins)
Figure 2.7-3	Niobrara River Subbasin N14
Figure 2.7-4	Sampling Locations
Figure 2.7-5	Mirage Flats Project, Nebraska
Figure 2.7-6	Major Surface Features/Structures Within AOR as per Title 122, Chapter 11, Section 006.09
Figure 2.7.7	Marsland Expansion Area Pumping Test Well Locations
Figure 2.7-8	Marsland Arikaree and Brule Monitor Wells
Figure 2.7-9	Location of MEA Active, Inactive, and Abandoned Chadron Monitor Wells That Penetrate the Injection Zone
Figure 2.8-1	Wetland and Vegetation
Figure 2.8-2	Wildlife Map

Figure 2.9-1	Marsland Expansion Area Preoperational/Preconstruction Monitoring Program Timeline
Figure 2.9-2	Locations of Environmental Air Sampling Stations at Marsland Expansion Area
Figure 2.9-3	Private Wells Located Within One and Two Kilometers of the MEA License Boundary
Figure 2.9-4a	Marsland Expansion Area Potentiometric Surface Arikaree Group (10/17/2013)
Figure 2.9-4b	Marsland Expansion Area Potentiometric Surface Arikaree Group (1/21/2014)
Figure 2.9-4c	Marsland Expansion Area Potentiometric Surface Arikaree Group (4/22/2014)
Figure 2.9-4d	Marsland Expansion Area Potentiometric Surface Arikaree Group (7/14/2014)
Figure 2.9-5a	Marsland Expansion Area Potentiometric Surface Brule Formation (10/17/2013)
Figure 2.9-5b	Marsland Expansion Area Potentiometric Surface Brule Formation (1/21/2014)
Figure 2.9-5c	Marsland Expansion Area Potentiometric Surface Brule Formation (4/22/2014)
Figure 2.9-5d	Marsland Expansion Area Potentiometric Surface Brule Formation (7/14/2014)
Figure 2.9-6a	Marsland Expansion Area Potentiometric Surface BasalSandstone of the Chadron Formation (10/17/2013)
Figure 2.9-6b	Marsland Expansion Area Potentiometric Surface Basal Sandstone of the Chadron Formation (1/21/2014)
Figure 2.9-6c	Marsland Expansion Area Potentiometric Surface Basal Sandstone of the Chadron Formation (4/22/2014)
Figure 2.9-6d	Marsland Expansion Area Potentiometric Surface Basal Sandstone of the Chadron Formation (7/14/2014)
Figure 2.9-7	Upper Niobrara River Average Flows at USGS/NDNR Stream Gaging Stations
Figure 2.9-8	USGS/NDNR Stream Gaging Stations and NDEQ Sampling Locations for Niobrara River
Figure 3.1-1	Typical Mineralized Zone Completion for Injection/Production Wells – Method No. 1
Figure 3.1-2	Typical Liner Completion for Monitor or Injection/Production Wells – Method No. 2

Figure 3.1-3	Typical Cement Basket Completion for Monitor or Injection/Production Wells – Method No. 3
Figure 3.1-4	Typical Wellfield Layout
Figure 3.1-5	Water Balance for Marsland Facility
Figure 3.1-6	Marsland Expansion Area Satellite Facility and Current CBR Production Facility Process Flow Diagram
Figure 3.1-7	Disposal Water Balance Marsland Expansion Area
Figure 3.1-8	Marsland Water Balance and Process Flow Diagram
Figure 3.1-9	Marsland Hydraulic Containment Analyses
Figure 4.2-1	Proposed Access Route between Marsland Expansion Area Satellite Facility and Crow Butte Central Processing Facility
Figure 5.1-1	Cameco Resources Organizational Chart
Figure 5.7-2	Marsland Expansion Area Satellite Building Layout
Figure 6.1-1	Restoration Process Flow Diagram
Figure 7.3-1	Marsland Human Exposure Pathways for Known and Potential Sources of Radiological Emissions
Figure 7.3-2	MILDOS Receptors Residences and Designated MEA License Boundary Locations
Figure 7.3-3	MILDOS Receptors Cities and Towns in Region around MEA

This page intentionally blank

Appendices (Volume II & Volume III)

Appendix A	Water User Survey Information for Water Supply Wells within 2.25-Mile Area of Review
Appendix B	Calibration Records for Marsland Expansion Area Meteorological Station
Appendix C	Geophysical Boring Logs
Appendix D	Well Plugging and Abandonment Records
D-1	Oil and Gas Plugging Records
D-2	Water Well Abandonment Records
Appendix E	Water Well Registration and Completion Records
E-1	Water Well Registration Records
E-2	Water Well Completion Reports
Appendix F	Pump Test # 8 Report
Appendix G	Mineralogical and Particles Size Distribution Analyses
Appendix G-1	Mineralogical and Particles Size Distribution Analyses (2011)
G-2	Mineralogical and Particles Size Distribution Analyses (2013)
Appendix H	Flora and Fauna Lists
H-1	Plant Species List
H-2	Mammal Species List
H-3	Bird Species List
H-4	Amphibian and Reptile Species List
H-5	Fish Species List
H-6	Macroinvertebrate Species and Relative Abundance
H-7	Range Maps for State and Federally Listed Threatened and Endangered Species for Dawes County, Nebraska
Appendix I	Standard Operating Procedures for Air Particulate Samplers
Appendix J	Groundwater Analytical Lab Results
Appendix K	Hydrologic, Erosion and Flood Study Reports for Marsland Expansion Area
K-1	Hydrologic and Erosion Study Report for Marsland Expansion Area
K-2	Hydrologic and Flood Study for Marsland Expansion Area
Appendix L	Crow Butte Solubility Characteristics of Crow Butte Yellowcake
Appendix M	MILDOS Analysis for Marsland Expansion Area
Appendix N	Wellfield Decommissioning Plan for Marsland Expansion Area
Appendix O	Swift Fox Survey Protocol
Appendix P	Cost Estimate for Decontamination, Decommissioning and Reclamation of Proposed Marsland Expansion Area (One Mine Unit)



Appendix Q	MEA Baseline Crop and Vegetation Sampling Analytical Data
Appendix R	Siting of Meteorological Instruments
Appendix S	Justification for Use of 15 Years of Scottsbluff Meteorological Data
Appendix T	Marsland Water Balance (Production, Restoration and Stabilization Sampling)
Appendix U	Air Particulate Composite Laboratory Records
Appendix V	Radiological Records
Appendix V-1	Air Sampling Pump Calibration Records
Appendix V-2	Radon (Track Etch Cups) Laboratory Records
Appendix V-3	Gamma (OLSs) Laboratory Records
Appendix W-1	Niobrara River Surface Water Laboratory Records
Appendix W-2	Niobrara River and Ephemeral Drainages Sediment Laboratory Records
Appendix X	Niobrara River Fish Tissue Laboratory Records
Appendix Y	Cameco Evaluation of Site Ventilation Systems
Appendix Z	Three Crow Expansion Area Cross-Sections
Appendix AA-1	MEA Agricultural Well Impact Analysis
Appendix AA-2	Validation of Agricultural Well Impact Analysis
Appendix AA-3	AquiferTek Hydraulic Containment (October 2015)
Appendix BB	MEA Baseline Radiological Investigation Report – Tetra Tech
Appendix CC	Garden Analysis and Polonium LLD Evaluation
Appendix DD	Livestock Analytical Data
Appendix EE	Kozeny-Carman Calculations
Appendix FF	Quarterly Water Level Data – MEA
Appendix GG	Drawdown Impact Assessment MEA
Appendix HH	Deep Brule Monitor Well Installation Program

Replacement Pages – Section 2

Instructions:

Remove pages 2-41 through 2-130
Replace with this packet 2-41 through 2-130

MEA TR

Reponses to Open Issues

6-29-2017

2.6 Geology and Seismology

This section describes the regional and local geology and seismology of the MEA area. The geology of the CPF, NTEA, and TCEA has been discussed in previous license applications submitted to the NRC. Detailed information contained in those reports (e.g., laboratory results and field data that describe formation characteristics [lithology, mineralogy, permeability] for the Pierre Shale, Chadron Formation, and the Brule Formation at the CPF), also applies in a general sense to the MEA. These data, in addition to new information from exploratory drilling/logging activities within the MEA, are used to describe the geology and seismology in this section.

2.6.1 Geology and Seismology

2.6.1.1 Regional Setting

As shown on **Figure 4.2-1**, the centerpoint proposed MEA satellite building is approximately 15.1 miles (24.3 km) south-southeast to the centerpoint of the City of Crawford, Nebraska in Sections 26 35, and 36 Township 30 North, Range 51 West; Sections 1, 2, 11, 12, and 13 Township 29 North, Range 51 West; and Sections 7, 18, 19, 20, 29, and 30 Township 29 North, Range 50 West. The City of Crawford is 25 miles (40.2 km) west of Chadron, Nebraska and 70 miles (112.6 km) north of Scottsbluff, Nebraska. The City of Crawford is 21 miles (33.8 km) south of the South Dakota state line and 33 miles (53.1 km) east of the Wyoming state line. The Marsland area is located near the northern limits of the High Plains section of the Great Plains physiographic province. Topography of the Marsland area includes gently sloping, rolling hills with outlying, broad ridges dissected by intermittent and perennial streams. The most prominent physiographic feature in the region is the Pine Ridge Escarpment, which rises roughly 300 to 900 feet above the basal plain and bounds three sides of the Crawford Basin. Colluvial and alluvial deposits originating from this escarpment cover the license area. The elevation of the MEA ranges from 3,880 to 4,400 feet above mean sea level (amsl).

Regional Stratigraphy

Table 2.6-1 summarizes the regional stratigraphic section for northwest Nebraska that includes the White River Group (Brule Formation through basal sandstone of the Chadron Formation). A geologic map of bedrock in northwestern Nebraska is shown on **Figure 2.6-1**. The bedrock map depicts the occurrence of the Miocene Ogallala Group, Miocene Arikaree Group, the Eocene-Oligocene White River Group, and Upper Cretaceous strata belonging to the Montana Group and Colorado Group. The Upper Cretaceous Pierre Shale, the unconformably overlying White River Group (Brule Formation, Chadron Formation, and Chamberlain Pass Formation), and the Arikaree Group outcrop in the vicinity of the City of Crawford and MEA (**Figure 2.6-1**, see inset). In general, the stratigraphic nomenclature of Schultz and Stout (1955) is used in this application for consistency with historical permitting.

MEA Stratigraphy

The local stratigraphy at the MEA consists of the following geological units in descending order: alluvial sediments, Upper Harrison Beds, Harrison-Monroe Creek Formation, Gering Formation, Brule Formation, Upper Chadron Formation, Middle Chadron Formation, basal sandstone of the Chadron Formation, and Pierre Shale. The channel sandstone facies of the basal sandstone of the Chadron Formation represents the production zone and target of solution mining in the MEA. The

general stratigraphic section for the MEA is summarized in **Table 2.6-2. Figure 2.6-2** is a cross-section index map depicting the locations of 14 north-south and east-west cross-sections through the MEA depicted on **Figures 2.6-3a** through **2.6-3n**. Expanded views of two cross-sections are presented as **Figures 2.6-3o** through **2.6-3u** to provide more detailed examples of the geophysical logs within the basal sandstone of the Chadron Formation. Typical geophysical log responses for the geologic units encountered within the MEA are shown on a typical (i.e., type) log on **Figure 2.6-5**.

CBR completed coring programs in 2011 and 2013 across the MEA. In 2011, two core holes were completed and an additional five were completed in 2013. Data were collected from these cores to provide site-specific information across the project area. The site-specific results of the coring programs have been incorporated into discussions of stratigraphy, lithology, and hydraulic properties throughout the document. A summary of the coring programs is presented in **Table 2.6-3,** and coring locations are illustrated on **Figure 2.6-4**.

A thick (approximately 1,200 to 1,500 feet), regionally extensive stratigraphic section of sedimentary units underlies the Pierre Shale; however, those units are not relevant to this proposal. The absence of sandstone units for more than 1,000 feet below the top of the Pierre Shale precludes the need for monitoring zones below the surface of the Pierre Shale. Discussion in this report is limited to the Arikaree Group, White River Group, and Pierre Shale (Petrotek 2004; Wyoming Fuel Company 1983).

This section provides a detailed description of the stratigraphy of the MEA based on an extensive review of existing site-specific drilling logs and published literature. Geological units are described from stratigraphically youngest to stratigraphically oldest. Revised nomenclature for these stratigraphic units is discussed, where applicable, and referred to throughout this application. To be consistent with historical permitting, the majority of stratigraphic nomenclature used in previous submittals to the NRC and the NDEQ has been preserved.

Alluvium

Quaternary alluvium as thick as 30 feet overlies the Arikaree Group along drainages in the study area. In general, the alluvium consists of fragments of locally outcropping Oligocene-Miocene sedimentary rocks, sand, gravel, sandy soil horizons, and may include weathered portions of the Arikaree Group. Because alluvium is unconsolidated and may incorporate one or both of the vadose and phreatic (shallow groundwater) zones, log signatures within this unit vary in comparison with those of geologic units in the underlying units. On most MEA logs, resistivity values for alluvium are very high, beyond the log scale, indicating the presence of either soil vapor or fresh water (**Figure 2.6-5**). In general, shallow zones with elevated resistivity are also distinguished by a negatively deflected spontaneous potential (SP) curve, suggesting the presence of a permeable zone and formation fluid with lower resistivity than the fluid within the borehole. Although these log signatures suggest that the base of the alluvium can be readily identified in geophysical logs, the base of the alluvium is best defined by observations of drill cuttings. Therefore, the alluvium-Arikaree Group contact illustrated on cross-sections **Figure 2.6-3a** through **Figure 2.6-3n** is based on lithologic descriptions of drill cuttings recovered from individual boreholes.

Arikaree Group (Oligocene-Miocene)

The Oligocene–Miocene Arikaree Group lies unconformably above the Brule Formation and is subdivided from youngest to oldest into the Upper Harrison Beds, Harrison-Monroe Creek and Gering Formations, respectively (**Table 2.6-2;** Schultz and Stout 1955; Swinehart et al. 1985; Terry and LaGarry 1998; Retallack 1983).

Historically, subunits of the Arikaree Group have been variously referred to as the Marsland, Harrison, or Monroe Creek Formations. This application follows the revised nomenclature presented in Swinehart et al. (1985), which uses the Upper Harrison Beds, Harrison-Monroe Creek, and Gering Formations.

The Arikaree Group contains numerous interbedded channel and floodplain deposits, along with the eolian volcaniclastic deposits. Grain size analyses of core samples (**Appendix G-2**) support observations of drill cuttings and cores indicating a wide range of interbedded lithologies within the Arikaree Group, including illite/smectite-dominated siltstones (e.g., M-533C Run 1 Sample 2), and fine-grained sandstones (e.g., M-1912C Run 1 Sample 1). The coarsest materials are epiclasts from the White River Group and the Rocky Mountains (Bradley and Rainwater 1956; Tedford et al. 1985; Hoganson et al. 1998).

An isopach map of the undifferentiated Arikaree Group is shown on **Figure 2.6-6**. Within the license boundary, the thickness of the Arikaree Group ranges from approximately 40 to 160 feet and averages about 105 feet. The unit is thickest in the northern portion of the license boundary, and generally thins southward. The unit is stratigraphically continuous across the MEA. All three subunits of the Arikaree Group are represented on the northern end of the project, but due to stratigraphic pinch-out and erosion from the Niobrara River, it is likely that only portions of the Monroe Creek and Gering Formations are present on the south end of the project.

On geophysical logs, the Arikaree Group is characterized by an off-scale resistivity signature (**Figure 2.6-5**). The SP curve exhibits small fluctuations and is relatively straight, but can also be off scale. The gamma curve indicates no anomalous radioactivity. No distinguishing features are seen within the geophysical logs to ascertain contacts within the Arikaree Group. The contact between the Arikaree Group and the overlying alluvium is difficult to ascertain. Often the SP curve will begin on scale near the base of the alluvium and resistivity will remain off scale. The SP curve typically fluctuates due to interbedded fluvial sediments within the Arikaree Group. Corresponding decreases in resistivity and SP characterize the transition from the overlying coarser-grained Arikaree Group to the Brule Formation. Little distinction can be made within the gamma curve between the Arikaree Group and Brule Formation.

Upper Harrison Beds

Lithologically, the Upper Harrison Beds are composed of eolian volcaniclastic sandstones interbedded with lenticular freshwater limestones. Regionally, thickness of this unit can be up to 150 feet. The thickness of this unit at MEA is interpreted to be significantly thinner than 150 feet within the MEA license boundary based on observations of outcrops in the northern MEA; however, distinction between the Upper Harrison Beds and underlying Harrison-Monroe Creek Formation based on geophysical logs is difficult. Published grain size and mineralogic analysis indicate that the Upper Harrison Beds contain three dominant units; buff to gray fine sand without

abundant silt and clay, white sand with abundant silt and clay, and a siliceous pedogenic horizon (MacFadden and Hunt, 1998).

Convolute laminae occur within the fine sand and contain very little silt or clay. The massive unlaminated white sand has been previously interpreted to have been deposited by sheet flow following rains and/or flooding after a heavy ash fall. The lower part of the Upper Harrison Beds contains large blocks of sandstone derived from underlying strata, indicating fluvial channel deposition. Cross-stratified beds are also found (Cook 1915; Hunt 1981; Vicars and Breyer 1981).

The Upper Harrison Beds also contain silica-cemented paleosols, some of which (e.g., Agate paleosurface) have preserved paleotopographic features due to the resistant nature of the silica cement. Freshwater ostracods have been observed within limestone units, whereas abundant animal burrows and root casts characterize paleosols within the Upper Harrison Beds (Hunt 1981).

Harrison - Monroe Creek Formation

The upper and middle portions of the Harrison-Monroe Creek Formation consist of fine-grained grey sandstone. In the northern MEA, outcrops of this formation consist of massively bedded, fine-grained, grey, poorly consolidated sandstone. Grey concretions, which weather into elongated irregular masses, are common. The massive grey sandstones of the Harrison-Monroe Creek Formation are interpreted to represent channel fill deposits (MacFadden and Hunt Jr. 1998).

The lower portion of the formation is composed of compact fine sandy silt and clay, pinkish to buff in color, and a fine to medium grained gray sand (MacFadden and Hunt 1998).Grey concretions composed of long, irregular, fine grained cylindrical masses are found in the middle and lower portions of the Harrison-Monroe Creek Formation (Lugn 1939; Collings and Knode 1984). According to Schultz (1941) and Svoboda (1951), the concretions were formed when groundwater enriched with calcium carbonate flowed through deposited sediments and calcite was precipitated "...in a situation similar to stalactite formation only in a horizontal direction" (Svoboda 1951). Schultz (1941) mapped the orientations of the concretions and found that, within northwest Nebraska, the orientation trend was to the southeast and away from uplift.

Gering Formation

The Gering Formation is mainly composed of gray and grayish-brown volcaniclastic fine to medium grained sandstones, silty sandstones, silt and local beds of ash, coarse sand, and fine gravel. Most of the sand is laminated and contains local cross beds. Beds of greenish-white bentonitic diatomaceous earth, which weathers into hard white layers, are found throughout most of the Gering. Wellman (1964) divided the Gering into upper and lower units. The two portions of the Gering Formation are separated by a volcanic ash which is up to 6 feet thick (Cady and Scherer 1946; Collings and Knode 1984; MacFadden and Hunt 1998). The upper portion of the Gering is finer grained than the lower portion. It is composed of sandy siltstones and silty, fine grained sandstones which were deposited by floodplains. Some clay pebble conglomerates and clay lenses are present.

The lower portion of the Gering Formation contains coarse to fine grained sandstone, silty fine grained sandstone, sandy siltstone, and silty claystone. Coarse to fine grained sandstones are interpreted to have been deposited in fluvial channels, whereas the sandy siltstone and silty claystone units are interpreted to have been deposited on proximal and distal floodplains,

respectively. Lithologic observations of outcrops in the northern MEA and Pine Ridge area north of MEA, drill cuttings, and interpretation of geophysical logs indicate that the Gering Formation makes up the majority of the stratigraphic thickness of the Arikaree Group at MEA.

The unconformable contact between the Brule and Gering Formations is readily observed when coarse sediments of the Gering Formation are in contact with the finer grained Brule Formation. When the sediments of the Gering Formation are fine grained, the contact is more difficult to discern based on observations of drill cuttings.

White River Group (Eocene-Oligocene)

At the MEA, the Eocene-Oligocene White River Group consists of the Chadron Formation overlain by the Brule Formation (**Table 2.6-2**). Strata assigned to this group were deposited within fluvial, lacustrine, and eolian environments (Terry and LaGarry 1998). In northwest Nebraska, the White River Group rests unconformably on weathered Pierre Shale. The bulk of the White River Group consists of airfall and reworked volcaniclastics derived from sources in Nevada and Utah (Larson and Evanoff 1998; Terry and LaGarry 1998).

There have been various interpretations of the history of stratigraphic nomenclature for the White River Group of Nebraska and South Dakota as described by Harksen and Macdonald (1969). The following stratigraphic nomenclature retains the formal and informal members based on nomenclature by Schultz and Stout (1955), but also includes more recent nomenclature (Terry and LaGarry 1998; Terry 1998; LaGarry 1998; Hoganson et al. 1998).

Brule Formation

The Oligocene Brule Formation represents the youngest unit within the White River Group present in the subsurface of the MEA. The Brule Formation conformably overlies the Chadron Formation and is unconformably overlain by the Arikaree Group (**Figure 2.6-1**). The Brule Formation was originally subdivided by Swinehart et al. (1985) and later revised by LaGarry (1998) into three members, from youngest to oldest: the Brown Siltstone Member, the Whitney Member, and underlying Orella Member (**Table 2.6-2**).

The Brown Siltstone Member consists of pale brown and brown, nodular, cross bedded eolian volcaniclastic siltstones and sandy siltstones. The contact with the underlying Whitney Member varies from a gradational contact to a sharp disconformity where the "brown siltstone" fills valleys incised into the older strata of the Whitney Member. Thick, fine to medium grained sandstones appear near the base of the Brown Siltstone Member. These sandstones are present across the MEA. The Whitney Member consists mostly of pale brown, massive, typically nodular eolian siltstones with rare thin interbeds of brown and bluish-green sandstone, and volcanic ash. The basal 10 meters of the Whitney Member consist of white or green laminated fluvial siltstones and thin sheet sandstones. The contact between the Whitney Member and the underlying Orella Member is intertonguing. The Orella Member consists of pale brown, brown, and brownish-orange volcaniclastic overbank clayey siltstones and silty claystones, brown and bluish-green overbank sheet sandstones, and thin volcanic ashes. At the MEA, the Brule Formation is predominated by the Brown Siltstone and Whitney Members while the presence of the Orella Member is minimal as determined by cuttings, descriptions and geophysical log interpretation. Further discussion of the interpretation of the base of the Brule Formation follows later in this section. The overall thickness of the Brule Formation within the MEA ranges from approximately 350 to 550 feet. In

approximately the northern third of the MEA, the Brule Formation is generally 475 feet thick or more, and thins southward to a thickness generally between 350 and 450 feet. An isopach map of the undifferentiated Brule Formation is shown on **Figure 2.6-7.** **Figure 2.6-10** illustrates the elevation of the top of the Brule Formation across the MEA.

The contact between the Brule Formation and underlying Chadron Formation is difficult to identify in some places, as the contact between the two formations is intertonguing (LaGarry 1998). Regionally, the contact is recognized as the lithologic change from thinly interbedded and less pedogenically modified brown, orange, and tan volcaniclastic clayey siltstones and sheet sandstones of the Orella Member to pedogenically modified green, red, and pink volcaniclastic silty claystones of Big Cottonwood Creek Member in the upper Chadron Formation (Terry and LaGarry 1998).

On geophysical logs, the Brown Siltstone Member is characterized by rapidly fluctuating geophysical log curves, or "log chatter" (**Figure 2.6-5**). This response is recognized in resistivity curves, and to a lesser extent in SP curves, throughout the MEA. Such fluctuations result from resistivity contrasts between the thinly interbedded siltstones and sandstones. Because the sandstones are porous and constitute a part of the regional aquifer, the contacts with the interbedded, dry siltstones are sharp and easily recognized on logs (Gutentag et al. 1984). These interbedded sandstones and siltstones are present across the entire MEA project area, and represent the base of the first overlying aquifer above the production zone. **Figures 2.6-7** and **2.6-10** depict the thickness and elevation of the top of the Brule Formation across the MEA, respectively.

The contact between the interbedded siltstones and sandstone of the Brown Siltstone Member and the underlying Whitney and Orella Members is distinguished on geophysical logs by a change from highly variable log readings (i.e., "log chatter") to relatively flat or straight curves (i.e., the shale baseline) on both resistivity and SP logs (**Figure 2.6-5**).

Two lithified volcanic ash horizons (tuffs) within the Whitney Member are identified in the MEA drill logs and are designated the Upper and Lower Whitney ash zones. Geophysical log signatures of the Whitney ash zones typically show increased resistivity as well as elevated natural gamma levels, most likely due to the presence of uranium within the volcanic ash (Swinehart et al. 1985; LaGarry 1998). These ash zone tuffs were deposited over a wide area and have been correlated throughout the MEA (**Figures 2.6-3a through 2.6-3n**). A detailed analysis of the lower Brule Formation (Whitney Member) is discussed in **Appendix HH**. The Orella Member as described previously is difficult to distinguish by drill cuttings or by log signature and may have minimal presence at the MEA.

The contact between the lower Brule Formation and the upper Chadron Formation is difficult to identify on geophysical logs because of intertonguing of the siltstones and silty claystones. As a result, the formation contact appears deeper on some geophysical logs and varies locally on the Brule Formation isopach map (**Figure 2.6-7).** Observed lithologic changes from brown and tan siltstones towards green and gray silty-claystones in drill cuttings have been used to assist in identifying this contact (**Appendix HH**). **Figure 2.6-3a** through **2.6-3n** depict the subsurface geology of the Brule Formation within the MEA.

Chadron Formation (Eocene-Oligocene)

The Eocene-Oligocene Chadron Formation is in the lower part of the White River Group (**Table 2.6-2**). The Chadron Formation unconformably overlies the Cretaceous Pierre Shale. From top to bottom, the Chadron Formation historically consists of the following stratigraphic units: Big Cottonwood Creek Member (herein referred to as the informal upper Chadron and upper/middle Chadron to be consistent with historical permitting), Peanut Peak Member (herein referred to as the informal middle Chadron to also be consistent with historical permitting), and basal sandstone of the Chadron Formation (also known formally as the Chamberlain Pass Formation). The basal sandstone of the Chadron Formation represents the production zone and target of ISR mining within the MEA. **Figures 2.6-3a** through **2.6-3n** depict the subsurface geology of the Chadron Formation within the MEA. **Figure 2.6-11** illustrates the elevation of the top of the Chadron Formation across the MEA. A unit locally referred to as the upper/middle Chadron has been observed in regional outcrops and in the subsurface at other CBR operations (e.g., North Trend Expansion Area); however, this unit has been determined to be absent at MEA based on geophysical logs and observations of cores and drill cuttings, and is not discussed in this application.

Upper Chadron

The upper Chadron is the youngest subdivision of the Chadron Formation recognized at MEA (**Table 2.6-2**). Descriptions of the upper Chadron at Toadstool Park (approximately 22 miles [35.4 km] northwest of MEA) indicate that the unit is composed primarily of volcaniclastic overbank silty claystones interbedded with tabular and lenticular channel sandstones, lacustrine limestones, pedogenic calcretes, marls, volcanic ashes, and gypsum (Terry and LaGarry 1998). Drill cuttings, cores, and geophysical logs from MEA support these observations, except the presence of limestones which have not been observed. At MEA, the upper part of the upper Chadron is light green-gray bentonitic clay grading downward to green and frequently red clay, though thin interbedded sheet sandstones also occur. This observation is consistent with Terry and LaGarry's (1998) observation of thin (0.1 to 0.15 meter) sandstones at Toadstool Park. Water has not been observed in upper Chadron sandstones at MEA. Tuffs in the Toadstool Park area that occur in the upper Chadron were dated by 40Ar/39Ar methods as late Eocene (~34 million years ago [Ma]) in age (Terry and LaGarry 1998). Based on geophysical data, the upper Chadron is continuous across the MEA. The available data suggest that the upper Chadron ranges in stratigraphic thickness from approximately 190 to 250 feet and averages about 220 feet across the MEA (**Figure 2.6-3a** through **Figure 2.6-3n**).

As supported by observations at the MEA, the lower boundary of this unit is an intertonguing contact with the underlying middle Chadron (Terry and LaGarry 1998; **Table 2.6-2**). The upper boundary is recognized by a lithologic change from thinly bedded and less pedogenically modified brown, orange, and tan volcaniclastic clayey siltstones, sheet sandstones, and channel sandstones of the overlying Orella Member of the Brule Formation to more pedogenically modified green, red, and pink volcaniclastic silty claystones of the upper Chadron (Terry and LaGarry 1998; **Table 2.6-2**).

Three core samples (M-1454C, Run 1; M-1624C, Run 1; and M-1635C Run 3, Sample 1) were collected from the upper Chadron by CBR at boreholes M-1454C, M1624C, and M-1635C (**Figure 2.6-4; Appendix G-1** and **G-2**). X-ray diffraction (XRD) analyses of upper Chadron core samples indicate varied mineralogical compositions. Sample M-1454C Run 1 was primarily composed of calcite, montmorillonite, and quartz with minor amounts of plagioclase, potassium feldspar, and

illite/mica. The samples from M-1635C and M-1624C were both primarily composed of montmorillonite, calcite, quartz, and plagioclase with minor amounts of illite/mica and potassium feldspar.

Particle size distribution analysis of the three upper Chadron core samples produced median grain sizes between 0.056 and 0.040 millimeter (mm), which are within the silt size range. The weight percent of sand in these samples ranged from 28.79 (M-1635C) to 43.11 (M-1454C). The sample from M-1454C contained significant proportions of medium sand (24.31 weight percent). The weight percent of clay in the upper Chadron samples ranged from 8.73 percent (M-1624C) to 10.20 percent (M-1635C). M-1454C Run 1, M-1624C Run 1, and M-1635C Run 3 Sample 1 give median grain sizes of 0.056 millimeter (mm; fine sand), 0.049 mm (silt), and 0.040 mm (silt) respectively. All samples are dominated by silt-sized grains; however, M-1454C Run 1, contained more medium sand than M-1624C or M-1635C which increased the median grain size. M-1454C Run 1 contained 47.25 percent silt and 9.64 percent clay. M-1624C Run 1 contained 54.65 percent silt and 8.73 percent clay. M-1635C Run 3 Sample 1 contained 61.01 percent silt and 10.20 percent clay. All three upper Chadron core samples contained greater than 50 percent combined silt and clay-sized particles, and because greater than 67 percent of the silt+clay component was silt in each sample, they are classified as siltstones (Brown and Harrell 1991). Hydraulic properties of the upper Chadron based on grain size analysis of core samples are discussed in Section 2.7.2.3 (confining layers).

Typical gamma ray (GR), SP, and resistivity log signatures for the upper Chadron exhibit curves representative of the relatively flat shale baseline (**Figure 2.6-5**). Fluctuations are present among upper Chadron log curves, representing interbedded siltstones, silty claystones, silty sandstones, limestones, and volcanic ash deposits that occur less commonly than in the overlying Brule Formation. Logging tools/procedures and other tests are described in Section 3.1.2.4.

Middle Chadron

The middle Chadron is a variegated clay-rich interval that may be red, grey, grey-green, or bluish-green in color with interbedded bentonitic clay and sands. A light green-gray "sticky" clay within this unit serves as an excellent marker bed in drill cuttings and has been observed in virtually all regional test holes within the MEA, TCEA, NTEA, and the CPF. The middle Chadron unconformably overlies the basal sandstone of the Chadron Formation (Chamberlain Pass Formation) in South Dakota and Nebraska (Terry 1998; **Table 2.6-2**). As described above, this unit is overlain by the upper Chadron at the MEA (**Table 2.6-2**). The middle Chadron differs from the overlying upper Chadron in that the middle Chadron is composed of bluish-green, smectite-rich mudstone and claystone is less variegated in color; and contains less silt (Terry 1998). The predominantly clay lithology of the middle Chadron represents a distinct and rapid facies change from the underlying basal sandstone of the Chadron Formation. The available data suggest that the middle Chadron typically ranges in thickness from approximately 150 to 290 feet and averages about 180 feet across the MEA.

Two core samples (M-1454C Run 2 and M-1624C Run 2) were collected from the middle Chadron by CBR at boreholes M-1454C and M1624C (**Figures 2.6-2** and **2.6-4; Appendix G-1**). XRD analyses of M-1454C Run 2 and M-1624C Run 2 samples indicate varied compositions. Samples M-1454C Run 2 and M-1624C Run 2 are primarily composed of mixed layered illite/smectite; however, M-1454C Run 2 also contains a high amount of calcite. Other minor minerals found

within the samples include quartz, plagioclase, potassium feldspar, chlorite, and illite/mica. Particle size distribution analyses of M-1454C Run 2 and M-1624C Run 2 give median grain sizes of 0.027 mm (silt) and 0.065 (very fine sand) mm, respectively. Both were mainly composed of silt-sized particles; however, M-1624C Run 2 contained more medium sand than M-1454C Run 2, which increased the median grain size. M-1454C Run 2 contained 46.36 percent silt and 20.65 percent clay. M-1624C Run 2 contained 34.6 percent silt and 16.54 percent clay. Both are classified as siltstones (Brown and Harrell 1991). Hydraulic properties of the middle Chadron based on grain size analysis of core samples are discussed in Section 2.7.2.3 (confining layers).

Typical GR, SP, and resistivity log signatures for the middle Chadron exhibit curves representative of the shale baseline (**Figure 2.6-5**). At the MEA, the contact between the top of the middle Chadron and the overlying upper Chadron is difficult to ascertain due to similarities in grain size and geophysical log responses. Therefore, **Figures 2.6-3a** through **Figure 2.6-3n** show an inferred stratigraphic location for the contact between the upper Chadron and middle Chadron across the license area, as based upon lithologic report observations of drill cuttings.

Together, the upper and middle Chadron units represent the upper confining zone for the basal sandstone of the Chadron Formation within the MEA (see detailed discussion in Section 2.7.2.3). An isopach map created for the combined upper and middle Chadron Formation that comprises the upper confining zone is presented on **Figures 2.6-8.** The total thickness of the upper confining zone ranges from approximately 360 to 450 feet, averages about 410 feet, and generally appears to thin toward the south across the MEA.

Basal Sandstone of the Chadron Formation – Mining Unit

The basal sandstone of the Chadron Formation is the oldest unit in the White River Group. The Upper Interior Paleosol, occurring as a persistent clay horizon, typically brick red in color (referred to locally as the "red clay"), developed on top of the basal sandstone of the Chadron Formation and generally marks the upper limit of the basal sandstone of the Chadron Formation (**Table 2.6-2**). **Figure 2.6-12** illustrates the elevation of the top of the basal sandstone of the Chadron Formation across the MEA. The "red clay" horizon is indicated on more than half of the geophysical logs and driller's notes that were reviewed. The Upper Interior Paleosol is interpreted to represent pedogenically modified distal overbank deposits of a distinct fluvial system developed on the surface of the basal sandstone of the Chadron Formation prior to deposition of the remainder of the Chadron Formation (Terry 1998).

Below the Upper Interior Paleosol, the basal sandstone of the Chadron Formation consists of coarse grained, arkosic sandstone with common, discontinuous interbedded thin silt and clay lenses of varying thickness. Cross-sections providing a more detailed view of the basal sandstone of the Chadron Formation are presented as **Figure 2.6-3o** through **Figure 2.6-3u**.

The basal sandstone of the Chadron Formation overlies a distinct regional unconformity with the underlying Yellow Mounds Paleosol (Terry 1998). The lower contact is easily recognized as a change from the underlying black or bright yellow, pedogenically modified surface of the Pierre Shale (i.e., the Yellow Mounds Paleosol) to white channel sandstone. In places, the basal sandstone of the Chadron Formation grades upward to fine sandstone containing varying amounts of interstitial clay and persistent clay interbeds. Vertebrate fossils from the basal sandstone of the Chadron Formation in northwestern Nebraska and South Dakota indicate a late Eocene age Chadronian (Clark et al. 1967; LaGarry et al. 1996; Lillegraven 1970; Vondra 1958).

The basal sandstone of the Chadron Formation occurs at depths ranging from about 850 to 1,200 feet bgs and was encountered in all exploration holes. An isopach map of the basal sandstone of the Chadron Formation across the MEA is presented on **Figure 2.6-9**. Stratigraphic thickness of the unit within the MEA ranges from approximately 20 to 90 feet and averages about 55 feet. The thickest sections of the unit occur in the western portions of the MEA (**Figure 2.6-9**). Up to four distinct sandstone packages are present in the thickest portions of this unit and are separated by variable amounts of interbedded clay. Cross-sections depicting the basal sandstone of the Chadron Formation in detail are presented as **Figures 2.6-3o** through **2.6-3u**. Variations in the number and thickness of individual sandstone packages present in individual boreholes is interpreted to have resulted from facies changes and from varying degrees of erosion of fine-grained interbedded sediments and stacking of multiple channel deposits.

A structure contour map was generated of the contact between the basal sandstone of the Chadron Formation and the Pierre Shale (**Figure 2.6-13**). The structure map indicates that the elevation of the unconformity separating the Chadron Formation from the underlying Pierre Shale decreases to the south-southeast across the MEA from approximately 3,240 to 3,160 feet amsl (**Figure 2.6-13**).

The greenish-white channel sandstones of the basal sandstone of the Chadron Formation are the target of ISR mining activities in the MEA. Regionally, deposition of the basal sandstone of the Chadron Formation has been attributed to large, high-energy braided streams (Collings and Knode 1984; Hansley et al. 1989; Hansley and Dickinson 1990). This depositional environment produced lenticular sandstone deposits with numerous facies changes occurring within short distances. Interbedded thin silt and clay lenses most likely represent floodplain or low velocity deposits normally associated with fluvial sedimentation.

Two core samples (M-1454C Run 3, and M-1624C Run 4) were collected from the basal sandstone of the Chadron Formation by CBR at boreholes M-1454C and M-1624C (**Figures 2.6-2 and 2.6-4; Table 2.6-3**). A core sample was also collected in 2013 from the basal sandstone of the Chadron Formation at borehole M-1912C (M-1912C Run 4 Sample 2). However, three separate analyses of the same sample produced median grain sizes ranging from 0.003 mm (clay) to 0.850 mm (medium sand); therefore, the results from grain size analysis of this sample are not included in this document. Particle size distribution analyses of M-1454C, Run 3 and M-1624C, Run 4 give median grain sizes of 0.075 mm (very fine sand) and 0.711 mm (coarse sand), respectively. M-1454C, Run 3 contained 29.85 percent silt and 19.92 percent clay. M-1624C, Run 4 contained 11.56 percent silt and 4.5 percent clay. Both are classified as sandstones (Brown and Harrell 1991).

XRD analysis of the M-1454C sample indicates a varied composition. Run 3 is mainly composed of quartz, whereas Run 4 is mainly composed of mixed-layered smectite. Minor amounts of plagioclase feldspar, potassium feldspar, kaolinite, and illite/mica were found in both samples. Run 3 also yielded trace amounts of calcite, siderite, pyrite, magnetite, and magnesium vanadium oxide, while Run 4 had minor amounts of dolomite and chlorite. The sample from M-1912C was primarily composed of quartz and mixed-layered illite/smectite with minor amounts of potassium and plagioclase feldspars, illite/mica, calcite, and ferroan dolomite. The sandstones of the basal sandstone of the Chadron Formation within the CPF are dominated by quartz (50 percent monocrystalline) and feldspar (30 to 40 percent undifferentiated feldspar) with the remainder made up of chert, pyrite, various heavy metals, and polycrystalline and chalcedonic quartz (Collings and Knode 1984). XRD analyses indicate that the basal sandstone of the Chadron Formation within the area of the CPF is 75 percent quartz, with the remaining 25 percent consisting of a combination

of potassium feldspar, plagioclase, illite, smectite, expandable mixed layer illite-smectite, and kaolinite (Collings and Knode 1984).

Geophysical logs record a unique signature for the basal sandstone of the Chadron Formation (**Figure 2.6-5**). A distinct GR spike is often present at the base of the unit in most of the MEA exploration boreholes, indicating an abundance of radioactive material. Increased resistivity (i.e., log curve shift to the right) and a decreased SP (i.e., log curve shift to the left) are often associated with GR spikes. These log signatures support interpretations of a uranium-bearing, fluid-filled sandstone interval. Other channel sandstone intervals present in the unit may have lower GR readings, indicative of both lower amounts of radioactive materials and potentially non-uranium-bearing intervals. Such intervals are typically marked by increased resistivity and decreased SP curve deviations (log curves shift to the left) without the associated GR spike. Pervasive interbedded clay intervals are indicated by high GR responses accompanied by lower resistivity (i.e., reduced porosity and decrease in water content), an interpretation that is further supported by driller or geologist's notes. The high radioactivity of these clay-rich units suggests the presence of rhyolitic ash (Hansley and Dickinson 1990). The top of the formation is marked by a gradual return of SP and resistivity curves to the shale baseline.

Sediments rich in rhyolitic ash contained both within and above the basal sandstone are considered to be the most likely source of the uranium compounds that make up the ore body (Gjelsteen and Collings 1988). Larson and Evanoff (1998) used 40AR/39AR dating methods on nine known White River tuff deposits. The ages ranged from 35.97 Ma to 30.05 Ma. Dissolution of these uranium compounds most likely occurred shortly after deposition. This period represents the time of greatest permeability for solutions to liberate the uranium compounds as they moved through the various ash-rich zones prior to compaction and alteration.

The White River volcaniclasts were first described by Darton (1901), who proposed the Black Hills uplift as the source for the material (Darton 1912). Further study by Wanlass (1923) argued that the Black Hills plutons were too small to have produced the volume of material seen throughout the White River Formation. Other studies have continued to pursue the source area of the volcaniclastic material. Larson and Evanoff (1998) identified the Great Basin in eastern Nevada and western Utah as the most likely source area based on age, grain size, and thickness observations. The Great Basin region was active with explosive rhyolitic volcanism during the ~36 to 29 mya time period of White River deposition.

Montana Group

Interior Paleosol (Yellow Mounds Paleosol)

The Interior Paleosol of Schultz and Stout (1955) was subsequently divided into the younger Eocene Upper Interior Paleosol and the older Cretaceous Yellow Mounds Paleosol (Pierre Shale) (Terry 1991; Evans and Terry 1994; Terry and Evans 1994; Terry 1998; **Table 2.6-2**). As noted above, the Upper Interior Paleosol is interpreted to represent pedogenically modified distal overbank deposits of a distinct fluvial system developed on the surface of the basal sandstone of the Chadron Formation which predates deposition of the middle Chadron Formation. The Yellow Mounds Paleosol developed on the Cretaceous Pierre Shale and altered the normally black marine shale to bright yellow, purple, light bluish-grey, and orange. Review of available data for the MEA indicates that neither of the two paleosol units could be consistently interpreted based solely on geophysical logs. For simplicity, these units are not represented on the type log or cross-sections.

Pierre Shale

Offshore deposition in the Cretaceous Interior Seaway produced the late Cretaceous Pierre Shale (**Table 2.6-2**). The Pierre Shale is a thick, homogenous black marine shale with low permeability that represents one of the most laterally extensive formations of northwest Nebraska. Regional geologic data indicate that this formation can be up to 1,500 feet thick in the Dawes County area (Wyoming Fuel Company 1983; Petrotek 2004). The southward retreat of the Cretaceous Interior Seaway resulted in the subaerial exposure and weathering of rock units from Early Cretaceous to Eocene age across the northern Great Plains (Lisenbee 1988). This event resulted in the erosion and pedogenic modification of the surface of the Pierre Shale and formation of the brightly colored Yellow Mounds Paleosol (Terry and LaGarry 1998; **Table 2.6-2**). Consequently, the pedogenically modified surface of the Pierre Shale marks a major unconformity with the overlying White River Group and exhibits a paleotopography with considerable relief (DeGraw 1969). The Pierre Shale is underlain by organic-rich shale and marl with minor amounts of sandstone, siltstone, limestone, and chalk of the Niobrara Formation (**Table 2.6-1**). The structure contour map of the top of the Pierre Shale indicates that the contact between the Pierre Shale and the overlying basal sandstone of the Chadron Formation slopes slightly to the south-southeast across the MEA (**Figure 2.6-13**). This sloping surface is consistent with the surface described by DeGraw (1971) and rises northward to the axial crest of the Cochran Arch located north of the MEA.

Seven core samples were collected from the Pierre Shale by CBR at boreholes M-1454C, M-1624C, M-2169C, M-533C, M-1956C, M-1912C, and M-1635C, as summarized in **Table 2.6-3** (**Figure 2.6-4** and **Appendix G-1** and **G-2**). XRD analysis of the samples indicated a primary composition of mixed layered illite/smectite and quartz, with minor amounts of plagioclase, potassium feldspar, dolomite, pyrite, kaolinite, chlorite, and illite/mica. Particle size distribution analyses of the samples indicated clay weight percentages ranging from 39.40 (M-1454C Run 4) to 75.95 (M-1635C Run 6 Sample 1). Median grain sizes for four of the seven samples were within the range for clay and within the range of silt for three samples (**Appendix G-1** and **G-2**). Fine grained sand was only detected in the two samples collected in 2011, with a maximum weight percent of 1.28 in the sample collected from core M-1624C. All samples from the Pierre Shale submitted for particle size analysis are classified as claystones (Brown and Harrell 1991). Typical geophysical log responses for the Pierre Shale exhibit shale baseline curves that are relatively flat or straight (**Figure 2.6-5**; **Appendix C**). On resistance logs, the top of the Pierre Shale is noted where the curves break either sharply to the left (SP) or to the right (resistivity) and represent the occurrence of the basal sandstone of the Chadron Formation. Spontaneous potential and resistivity curves qualitatively indicate a lack of permeable water-bearing zones within the Pierre Shale.

Six deep oil and gas exploration wells were drilled in the vicinity of the MEA; Chicoine 1, Chicoine 1A, Hollibaugh 1, Porter, Royal 1, and Smith 1-A. Available geophysical logs are included in **Appendix C** (NOGCC 2011). Oil and gas exploration wells have typically been drilled to depths much greater than on-lease uranium exploration wells. Plugging records for the oil and gas exploration wells are shown in **Appendix D-1**. The character of the entire Pierre Shale in the vicinity of the MEA can best be observed in geophysical logs from four of the six nearby abandoned oil and gas wells (Hollibaugh 1, Chicoine 1A, Royal 1, and Smith 1-A), and two CBR deep disposal wells (DDW#1, DDW#2), which were completed through the entire thickness of the unit. Based on observations from oil and gas exploration logging, the thickness of the Pierre Shale in the vicinity of the MEA ranges from approximately 769 to 1,000 ft KB.

Oil & Gas Exploration Wells	Township, Range, Section	Total Depth (ft KB)	Pierre Shale Depth (ft KB)	Niobrara FM Depth (ft KB)	Thickness of Pierre Shale	Distance from Permit Boundary (miles)
Hollibaugh 1	T29N, R51W, Section 12	3,295	1,040	1,915	875	Inside Permit Boundary
Chicoine 1A	T30N, R50W, Section 30	3,050	1,258	2,144	886	1.15 (east)
Royal 1	T30N, R51W, Section 23	3,956	1,200	2,200	1,000	~ 0.5 (north)
Smith 1-A	T29N, R50W, Section 29	2,901	947	1,716	769	~ 0.25 (east)

Source: NOGCC 2011, Petrotek 2015

Based on observations from CBR disposal well logs, the thickness of the Pierre Shale in the vicinity of the DDW's range from approximately 1,369 to 1,550 ft KB.

Deep Disposal Wells	Township, Range, Section	Total Depth (ft KB)	Pierre Shale Depth (ft KB)	Niobrara FM Depth (ft KB)	Thickness of Pierre Shale	Distance from Permit Boundary (miles)
DDW#1	T31N R52W Section 19	3,880	764	2,133	1,369	7.8
DDW#2	T31N R52W Section 13	3,803	511	2061	1,550	11.9

Source: Petrotek 2015

Stratigraphy of Units Below the Pierre Shale

Underlying the Pierre Shale is a thick sequence of Mississippian through Cretaceous age strata that unconformably overlie Precambrian granite (**Table 2.6-1**). Together with the Pierre Shale, the underlying Niobrara Formation, Carlile Shale, Greenhorn Limestone, and Graneros Shale compose a composite lower confining interval approximately 2,500 feet thick which immediately underlies the basal sandstone of the Chadron Formation. With exception of the hydrocarbon-bearing "D", "G", and "J" sandstones of the Dakota Group (occasionally interbedded with the Graneros and Huntsman Shales; **Table 2.6-1**), there do not appear to be significant sandstone units within this thick sequence of low-permeability strata.

All geologic units encountered during the drilling of oil and gas exploration wells in the vicinity of the MEA appear to be consistent with known regional stratigraphy. Geologic units that are consistently identified in all wells include the Niobrara Formation, Carlile Shale, Greenhorn Limestone, "D" and "J" sandstones of the Dakota Group, and the Skull Creek Formation (**Table 2.6-1**).



This page intentionally blank

2.6.1.2 Geochemical Description of the Mineralized Zone

The depth to the ore body within the basal sandstone of the Chadron Formation in the MEA ranges from approximately 850 to 1,200 feet bgs (**Table 2.6-2**). The ore grade as U_3O_8 ranges from 0.11 to 0.33 percent with an average ore grade of 0.17 percent.

Hansley et al. (1989) conducted detailed geochemical analysis of the Crow Butte uranium ore to assess both ore genesis and composition. The Crow Butte deposits, including Marsland, the current Crow Butte site, North Trend, and Three Crow are roll-type deposits with coffinite being the predominant uranium mineral species present. The origin of the uranium is rhyolitic ash, which is abundant within the matrix of the basal sandstone of the Chadron Formation (Hansley et al. 1989). Coffinite is associated with pyrite, and high silica activity due to dissolution of the rhyolitic ash which favored formation of coffinite over uraninite in most parts of this sandstone. In addition, smectite is present in the samples examined, with the most common minerals in the sandstone being quartz, plagioclase, K-feldspar, coffinite, pyrite, marcasite, calcite, illite/smectite, and tyuyamunite. The heavy mineral portion of the samples contained several minerals including those above as well as garnet, magnetite, marcasite, and illmenite. Vanadium was detected in the samples primarily as an amorphous species presumed to have originated from the *in-situ* ash. Hansley et al. (1989) state that at least some uranium and vanadium remain bound to amorphous volcanic material and/or smectite rather than as discrete mineral phases.

Petrographic data obtained and examined by Hansley et al. (1989) suggest that uranium mineralization occurred before lithification of the basal sandstone of the Chadron Formation. Hansley states: *"Dissolution of abundant rhyolitic volcanic ash produced uranium (U) and silicon (Si) rich ground waters that were channeled through permeable sandstone at the base of the Chadron by relatively impermeable overlying and underlying beds. The precipitation of early authigenic pyrite created a reducing environment favorable for precipitation and accumulation of U in the basal sandstone. The U has remained in a reduced state, as evidenced by the fact that the unoxidized minerals, coffinite and uraninite, comprise the bulk of the ore."*

Based on similar regional deposition, the MEA ore body is expected to be similar mineralogically and geochemically to that of the ore body at the CPF. The ore bodies in the two areas are within the same geologic unit (the basal sandstone of the Chadron Formation) and have the same mineralization source. The sites are separated by only a few miles, and the cause of mineral deposition in the two areas appears to be similar. Neither site is anticipated to be significantly affected by recharge or other processes.

2.6.1.3 Structural Geology

Regional uplift during the Laramide Orogeny forced the southward retreat of the Cretaceous Interior Seaway, resulting in the subaerial exposure and weathering of rock units from Early Cretaceous to Eocene age across the northern Great Plains (including the Pierre Shale). The depositional basin associated with deformation of the Wyoming thrust belt and initial Laramide uplifts to the west of Nebraska, represented a structural foredeep. The greatest uplift occurred in the Black Hills, which lie north of Sioux and Dawes Counties in southwestern South Dakota. Lisenbee (1988) provides a comprehensive summary of the tectonic history of the Black Hills Uplift. The pre-Oligocene Black Hills Uplift (<37 Ma) occurred prior to the deposition of the Eocene-Oligocene strata of the White River Group. Strata of the White River Group cover most

of the eroded roots of the Black Hills Uplift as well as the syntectonic sedimentary rocks in the Powder River and Williston basins. The Hartville, Laramie, and Black Hills Uplifts supplied sediment for rivers that flowed east-southeast across the study area (Clark 1975; Stanley and Benson 1979; Swinehart et al. 1985).

The most prominent structural expression in northwest Nebraska is the Chadron Arch (**Figures 2.6-15** and **2.6-16**). Together with the Chadron Arch, the Black Hills Uplift produced many of the prominent structural features presently observed in the region. The Chadron Arch is an anticlinal feature that strikes roughly northwest-southeast along the northeastern boundary of Dawes County. Swinehart et al. (1985) suggested multiple phases of probable uplift in northwestern Nebraska near the Chadron Arch between about 28 Ma and <5 Ma. The only known surficial expressions of the Chadron Arch are outcroppings of Cretaceous rocks that predate deposition of the Pierre Shale in the northeastern corner of Dawes County, as well as in small portions of Sheridan County, Nebraska and Shannon County, South Dakota. The general locations of faults in northwest Nebraska are depicted on the State Geologic Map shown on Figure 2.6-1.

The 230-mile (370-km) long Pine Ridge escarpment exhibits an average of 1,200 feet of relief (Nixon 1995). The Pine Ridge is an arc roughly concentric to the Black Hills Dome, which suggests an apparent structural relationship. Nixon (1995) interpreted the escarpment as representing the southern outermost cuesta of the Black Hills Dome. The escarpment is capped by sandstone of the Arikaree Group with exposed deposits of the White River Group mapped along the topographically lower northern side of the escarpment.

Crow Butte operations, including the CPF, NTEA, and TCEA, are within the Crawford Basin (DeGraw 1969). The proposed MEA lies just outside of the southern boundary of the basin along the Cochran Arch. DeGraw (1969) substantiated known structural features and proposed several previously unrecognized structures in western Nebraska based on detailed studies of primarily deep, oil test hole data collected from pre-Tertiary subsurface geology. The Crawford Basin was defined by DeGraw (1969) as a triangular asymmetrical basin about 50 miles (80 km) long in an east-west direction and 25 miles (40.2 km) to 30 miles (48.3 km) wide. The basin is bounded by the Toadstool Park Fault on the northwest, the Chadron Arch and Bordeaux Fault to the east, and the Cochran Arch and Pine Ridge Fault to the south (**Figures 2.6-15** and **2.6-16**). The Crawford Basin is structurally folded into a westward-plunging syncline that trends roughly east-west. Note that the Bordeaux Fault, Pine Ridge Fault, and Toadstool Park Fault proposed by DeGraw (1969) are not presented on the State Geologic Map (**Figure 2.6-1**). The Toadstool Park Fault has been mapped at one location (T33N, R53W) and is estimated to have had approximately 60 feet of displacement (Singler and Picard 1980). The City of Crawford is located near the axis of the Crawford Basin. More recent fault interpretations by Hunt (1990) for northwest Nebraska are also shown on **Figure 2.6-16**, which include the Whetstone Fault, Eagle Crag Fault, Niobrara Canyon Fault, and Ranch 33 Fault in the vicinity of the Town of Harrison in Sioux County. The faults identified by Hunt (1990) all trend to the northeast-southwest, sub-parallel to the Pine Ridge Fault (**Figure 2.6-16**).

Niobrara River Fault

The structural map by DeGraw (1969) referenced above, was subsequently modified by DeGraw (1971) to include additional features. Of these, the Niobrara River Fault is most relevant to the MEA. DeGraw (1971) mapped the Niobrara River Fault as occurring parallel to the Niobrara River

in southernmost Dawes County and northernmost Box Butte County (**Figure 2.6-16**). No description of the Niobrara River Fault is provided, nor is evidence provided in DeGraw (1971) to support the interpretation of its location. As described above, many of the fault locations (e.g., Pine Ridge Fault) interpreted by DeGraw (1969), were based on the apparent displacement of the pre-Tertiary geologic surface (e.g., top of Pierre Shale) on an unpublished structural contour map of western Nebraska. It is unknown whether the published location of the Niobrara River Fault (DeGraw 1971) is based on an unpublished revision of the pre-Tertiary geologic surface provided in DeGraw (1969) or other data sources. Structural contour mapping of the pre-Tertiary surface by CBR does not provide evidence of displacement by the Niobrara River Fault within the MEA.

As presented by DeGraw (1971), the Niobrara River Fault appears to be a western extension of the Hyannis-North Platte Fault and forms the northern boundary of a graben which contains the Niobrara River valley. An unnamed fault forms the southern boundary of the graben. These faults appear to be generally continuous with the Agate Spring Fault complex of eastern Sioux County (Hunt 1990; **Figure 2.6-16**). Approximately 60 feet of vertical displacement of Arikaree Group sediments has occurred along the Agate Springs Fault in T28N, R55W. Radiometric dating of volcanic tuff displaced by the Agate Springs Fault indicates a maximum age of approximately 19.2 million years for the Agate Springs Fault, and by extension, the Niobrara River Fault (Hunt 1990). Because the Agate Springs and Niobrara River Faults are not included in the USGS Quaternary Fold and Fault Database (USGS 2010), a compendium of faults with evidence of movement between 1.6 million years and ago and the present), it can be inferred that the most recent movement along both faults was between 19.2 and 1.6 million years ago. Neither the exact location of the Niobrara River Fault, nor the amount of potential offset of the fault at depth in the vicinity of the MEA can be determined based on known information.

Cameco geophysical data was reviewed to determine if additional data supports the location of the Niobrara River Fault and associated graben proposed by Stout et al. (1971). **Figure 2.6-14** presents a regional structural contour map of the top of the Pierre Shale. Boring data indicate the presence of a west-east trending structural trough along the top of the Pierre Shale in the vicinity of the Niobrara River. This trough is generally parallel to, but slightly to the north of the proposed graben location (**Figure 2.6-16**). The best evidence of the structural trough is from Cameco exploration borings located west of the MEA license boundary and the feature may extend to the southern portion of the MEA license boundary. Due to lithologic similarities between the lower Arikaree Group and upper Brule Formation, identifying the geologic contact between those units based on geophysical logs or drill cuttings observation is tenuous; therefore, potential offset of the Arikaree Group correlative to that observed in outcrop at the Agate Springs Fault has not been assessed. It cannot be determined from existing data whether the structural trough represents a graben related to the proposed Niobrara River Fault, a synclinal feature related to the southern limb of the Cochran Arch, or a paleotopographical feature. As further work is completed at MEA, more data will become available regarding the potential presence of the proposed Niobrara River Fault. Additional aquifer pumping tests will be conducted to provide coverage to all areas to be mined to demonstrate the natural confinement of the basal sandstone of the Chadron Formation in the southern portion of the MEA.

Diffendal (1994) performed lineament analyses on a mosaic of early Miocene synthetic-aperture radar images and largely confirmed known faults in the vicinity of Chadron. Lineaments in the radar image along Pine Ridge, located to the south of Chadron, are attributed to jointing or faulting and trend N40E and N50W (Diffendal 1982). Similar features were also noted west of Fort

Robinson. Swinehart et al. (1985) report that these features are likely an extension of the Wheatland-Whalen trend in Wyoming (Hunt 1981; Wheeler and Crone 2001).

Structural features, such as faults and folds, can be identified and characterized using borehole geophysical data. These data, when correlated and combined with additional borehole data from other nearby holes, provides one of the best methods for identifying and describing subsurface features. Drill hole density (distance between successive drill holes) must be high enough to provide confidence that any observed potential structure seen between two drill holes is the result of movement along a fault and not the result of erosion, depositional variation, or lateral discontinuity. It is only when many of these individual data points (drill holes) are plotted together along with other observations that they can be interpreted to discover the presence of these structural features. As drilling density increases, the minimum size of offset required for detection decreases. Within MEA, the drill holes are located mostly on 100-foot centers with scattered areas of greater density. CBR estimates that with this density of drilling, it would require an offset of at least 10 to 15 feet to be obviously notable, and the offsets would need to be noted within multiple holes across more than a single horizon.

Former drilling activities at the Crow Butte Project identified a structural feature, referred to as the White River Fault, located between the current CPF Class III permit area and the NTEA (**Figure 2.6-16**). Evidence of a fault was identified during the exploration drilling phase of the Crow Butte Project (Collings and Knode 1984). The fault is manifested in the vicinity of the NTEA as a significant northeast-trending subsurface fold. The detailed kinematics of the White River Fault were investigated during preparation of the NTEA Petition for Aquifer Exemption. An extensive review of drilling and logging data determined that, while the White River Fault may cut the Pierre Shale at depth along with stratigraphically lower units, there is no evidence that a fault offsets the geologic contact between the Pierre Shale and overlying White River Group nor individual members of the White River Group. This fault does not appear to be present in the vicinity of the MEA.

Pine Ridge Fault

Approximately 5 miles north of the MEA is the inferred Pine Ridge Fault, located along the northern edge of the Pine Ridge Escarpment (**Figure 2.6-16**). The east-west trending fault is inferred from several lines of evidence, but no detailed study of it has yet been published. The fault was initially proposed by DeGraw (1969) based on subsurface oil and gas test hole data which indicated the possible presence of a normal fault, with north-side down displacement of about 300 feet. The fault is inferred to be sub-parallel to the Cochran Arch as shown in **Figure 2.6-16**. Souders (1981) inferred the presence of an unnamed fault near the same location proposed by DeGraw, but estimated only 120 feet of displacement on the basis of limited test well data south of the fault and extrapolated measurements of the dip of the Pierre Shale from outcrop several miles to the north. Swinehart et al. (1985) reported normal faulting along the feature that post-dates the Upper Harrison Beds (Arikaree Group), but does not describe the location where the observation was made.

Geophysical data from Cameco Resources exploration test holes have been reviewed to substantiate the presence of the inferred Pine Ridge Fault, and to determine the extent and potential impact of this fault on operations at the MEA. Regional cross-sections prepared as part of clarifying information provided to NRC concerning the Niobrara River Fault are also useful for discussions about the Pine Ridge Fault. These regional cross-sections, **Figures 2.6-22 through 2.6-24** (R0,



R1, R2), extend from south of the Niobrara River (south of MEA) northward though the Marsland Expansion Area, across the Crow Butte License Area and the North Trend Expansion Area. **Figure 2.6-21** shows these cross-sections and a map of their locations. Each of the three sections, R0, R1 and R2, cross the Niobrara River Fault, Cochran Arch, Pine Ridge Fault and White River Fault. The principle cross-section, R1 runs from south of the MEA northward through the center of the project along the same transect as A-A' (**Figure 2.6-23**), and continues to the northwest, intersecting the Crow Butte Project and the North Trend Expansion Area. Sections R0 and R2 are located approximately one mile east and one mile west of R1 respectively. The geophysical logs shown on the figures are vertically exaggerated 10X to accentuate any structural features present. The Pierre Shale, top of Chadron sandstone, and a pair of persistent marker beds have been highlighted.

Cross-Section R0-R0' transects the proposed Pine Ridge Fault at a point about one mile west of where Souders (1981) places the fault. The surface of the Pierre Shale at this point drops 22 vertical feet over a distance of 2.3 miles. On sections R1 and R2, the Pierre Shale rises 24 feet and 29 feet from south to north as the location of the proposed fault is crossed respectively. These topographic changes in the Pierre surface are likely erosional rather than structural. At no point on the cross-sections with the exception of the White River Fault/Fold, is an offset of ~300 feet observed as reported by DeGraw, nor is an offset of ~120 feet observed that impacts all overlying strata as would be expected by fault movement that post-dates deposition of the overlying strata.

The Three Crow Expansion Area Technical Report also addressed concerns for the presence of the Pine Ridge Fault. These sections are presented as **Appendix Z** of this application. Five cross-sections were prepared showing the Pierre Shale surface contact with the overlying Chadron Formation as determined on geophysical logs. The surface depicted has been plotted with a 10X vertical scale to visually accentuate any structural features present. These sections do not support the presence of the Pine Ridge Fault within the AOR for the TCEA permit as inferred by DeGraw (1969), nor do they support the presence within the MEA AOR. The cross-sections do not substantiate a reported north side down vertical displacement of 300 feet and in two of the cross-sections, the top of the Pierre Shale surface elevations decrease southward, which is contradictory to a north side down vertical displacement. The sections show gentle increases in the elevation for the top of the Pierre Shale that are most likely a result of topographic lows on the eroded surface of the Pierre Shale or structural dip due to flexing associated with the formation of the Crawford Basin. Given the magnitude of folding observed elsewhere in the Crawford Basin, it is entirely feasible that displacement along an inferred fault would not be required to explain observed elevation changes for the top surface of the Pierre Shale.

While the data presented in these sections refutes the estimated offset of the Pine Ridge Fault, it does not entirely rule out the possibility that a short offset fault may be present. The data clearly shows however, that there is not a large offset fault that could act as a boundary for groundwater flow and movement that would impact production operations at MEA.

2.6.1.4 Seismology

National Seismic Hazard Maps and Risks

The USGS updated the National Seismic Hazard Maps in 2008, which includes changes in the methodology used to model potential seismicity in any given region (Petersen et al. 2008). Wheeler and Crone (2001) described Quaternary fault zones and their potential seismic activity. Their findings were used to develop the prior National Seismic Hazard Map. The revised maps

incorporate new seismic, geologic, and geodetic information on earthquake rates and associated ground shaking. The maps supersede versions released in 1996 and 2002. The next update to the National Seismic Hazard Maps is scheduled for 2014.

The National Hazard Maps show the distribution of earthquake shaking levels that have a certain probability of occurring in the U.S. (**Figure 2.6-17**). The hazard rating ranges from the lowest hazard (0.4 %g) to the highest (64+ %g), with the City of Crawford area and the majority of Nebraska being located in a low hazard ranking level of 4 to 8 %g. The term "%g" is a unit of acceleration (movement of earth) measured in terms of gravity (g) (i.e., acceleration due to gravity). Peak acceleration refers to the maximum acceleration (movement) experienced during a non-uniform earthquake event (i.e., starts off small, achieves a maximum, and then decreases).

The seismic hazard map for Nebraska (**Figure 2.6-18**), represents the peak acceleration (%g) with a 2 percent probability of exceedances in 50 years (USGS 2009a), meaning that in a given 50-year period, there is only a 2 percent chance of seismic shaking exceeding any given equivalent percentage of acceleration due to Earth's gravity. **Figure 2.6-18** also shows that the modeled peak acceleration due to seismic shaking in the City of Crawford area is very low: 6 to 8 %g for the majority of the immediate area and 8 to 10 %g in a much smaller area, meaning that the maximum shaking due to any given earthquake in the region during a 50-year period would be equivalent to only 10 percent or less of the force of gravity at Earth's surface. These estimates demonstrate that the Marsland and City of Crawford area are at the low end of the USGS' hazard ranking system for earthquake risks. Note that the differences between **Figures 2.6-17** and **2.6-18** in hazard ranking values are due to the use of different scales (i.e., 4 to 8 versus 6 to 8, respectively).

Earthquake Magnitude and Intensity

Earthquakes release different amounts of energy, and the strength of this energy can be measured by magnitude and intensity (CDERA 2009). A comparison of the magnitude and intensity scales is shown in **Table 2.6-4** as well as the USGS abbreviated descriptions of the 12 levels on the Modified Mercalli (MM) scale. The Richter Scale is used to measure the magnitude of an earthquake and is a measure of the physical energy released or the vibrational energy associated with the earthquake. In general, earthquakes below 4.0 on the Richter Scale do not cause damage, and earthquakes below 2.0 usually cannot be felt. However, earthquakes over 5.0 on the Richter Scale can cause damage. An earthquake of a magnitude 6.0 is considered strong, and a magnitude of 7.0 is considered a major earthquake.

The MM scale measures the intensity and consists of 12 increasing levels of intensity that range from imperceptible shaking to catastrophic destruction (USGS 2009b). It is an arbitrary ranking by the USGS based on observed effects rather than mathematics.

For states in the U.S. that had reported earthquakes with a magnitude of 3.5 or greater from 1974 to 2003, the State of Nebraska had a total of eight (less than 0.05 percent of the total of 21,080 earthquakes occurring in the U.S.; USGS 2009d). **Figure 2.6-18** is a seismic hazard map of Nebraska (USGS 2009e). A seismicity map of Nebraska that shows the distribution of earthquakes from 1973 through 2013 is shown on **Figure 2.6-19**.

The first significant earthquake recorded in Nebraska occurred on April 24, 1867, apparently centered near Lawrence, Kansas. It affected an estimated area of 301,159 square miles (mi^2) (780,000 square kilometers [km^2]) including much of Nebraska. Since 1867, there have been at



least seven earthquakes of MM Intensity V or greater originating within Nebraska's boundaries. It is thought that the strongest earthquake in Nebraska occurred on November 15, 1877. The total area affected was approximately 138,996 mi^2 (360,000 km^2) including most of Nebraska. The most recent earthquake occurred on November 18, 2010 (depth of 3.1 miles [5 km]), approximately 15 miles (24.1 km) east-southeast of Columbus, Nebraska in Platte County, east central Nebraska (lat. 41.37N long. 97.07W). The magnitude of this earthquake was 3.3 on the Richter Scale. The epicenter was approximately 326 miles (525 km) east southeast of the City of Crawford.

Earthquakes along the Chadron and Cambridge Arches in Western Nebraska

The locations of the Chadron and Cambridge Arches in Nebraska are shown on **Figure 2.6-15**. Earthquakes that have occurred in Nebraska in the vicinity of the Chadron and Cambridge Arches from 1884 to 2009 are identified in **Table 2.6-5**. The MM Intensity of these earthquakes ranged from I to VI, with the majority between I and III. The strongest of these earthquakes centered in Dawes County (near Chadron) occurred July 30, 1934 with an intensity of VI. It affected an estimated area of approximately 23,166 mi^2 (60,000 km^2) in Nebraska, South Dakota, and Wyoming. This earthquake resulted in damaged chimneys, plaster, and china. An earthquake that occurred on March 24, 1938 near Fort Robinson had an intensity of IV; no additional information is available. An Intensity IV earthquake should be felt indoors by many and cause dishes, windows, and doors to be disturbed. An earthquake occurred on March 9, 1963 near Chadron, and was reported to last about a second. It was not accompanied by any damage or noise and was not even noticed by many of the residents of Chadron. An earthquake occurred on March 28, 1964 near Merriman, the vibrations from which lasted about a minute and caused much alarm, but no major damage occurred. Books were knocked off shelves, and closet and cupboard doors swung open. On May 7, 1978 an earthquake with Intensity V occurred in southwestern Cherry County, also near the Chadron Arch. No major damage was reported from this earthquake.

Earthquakes occurring from 1992 through 2007 within 125 miles (201.2 km) of the City of Crawford in Wyoming and South Dakota are shown in **Table 2.6-6**. The Richter Magnitude measurements ranged from 3.0 to 3.8 for Wyoming and 2.5 to 4.0 for South Dakota. The MM Intensity values for Wyoming ranged from II to IV, with all but one of the total nine observations ranging from II to III. The MM Intensity values for South Dakota ranged from I to IV, with all but one of the total observations ranging from I to III. The most recent earthquake within the region occurred on November 19, 2011, in South Dakota with the epicenter located 30 miles (48.3 km) west-northwest of the City of Chadron. The earthquake had a magnitude of 2.8 with a depth of approximately 3.0 miles (4.9 km). The most recent earthquake in Wyoming occurred on November 19, 2011 and was located 69 miles (111 km) north of Jackson, Wyoming, a significant distance from the City of Crawford. It had a magnitude reading of 1.7 with a depth of approximately 1.0 mile (1.2 km).

Although the risk of major earthquakes in Dawes County and the State of Nebraska is low (Burchett 1990), some low to moderate tectonic activity has occurred (Rothe 1981). This tectonic movement is also suggested by geomorphic and sedimentation patterns during the Pleistocene (Rothe 1981), which reflect such movement. Previous seismic activity along the Cambridge Arch has been reported as possibly related secondary recovery of oil in the Sleepy Hollow oil field located in Red Willow County in southwest Nebraska (Rothe et al. 1981). However, deeper events suggest more recent low-level tectonic activity on the Chadron and Cambridge Arches.

Based on information discussed above, and the historical records for the proposed MEA in northwest Nebraska, no major effects would be expected from earthquakes on ISR activities in the MEA area.

2.6.1.5 Inventory of Economically Significant Deposits and Paleontological Resources

According to the NOGCC, there never has been any oil and gas production in Dawes County (NOGCC 2013a). There are no current applications for permits to drill in Dawes County. Two wells are currently producing in Sioux County, but are located at a significant distance southwest of MEA in section 8 Township 25 North, Range 55 West and section 11 Township 25 North, Range 56 West (NOGCC 2013b). The only non-fuel mineral produced in Dawes County is sand and gravel. Coal is not produced anywhere in Nebraska (Nebraska 2010), nor are coal beds expected to be encountered during drilling within the MEA.

Significant fossil resources, particularly mammalian, are recognized from the Arikaree Group and White River Group in northwestern Nebraska (Hunt 1981; LaGarry et al. 1996; Terry and LaGarry 1998; Tedford et al. 2004). The White River Group, Arikaree Group, and Ogallala Formation are all ranked as Class 5 geologic units in Wyoming under the Potential Fossil Yield Classification (PFYC) System (BLM 2008). Class 5 units are highly fossiliferous geologic units that predictably produce vertebrate fossils or scientifically significant invertebrate or plant fossils that are at risk of human-caused adverse impacts or natural degradation (BLM 2009). PFYC rankings have not been assigned for Nebraska, but due to the abundance of fossils known from these units nearby, similar potential for scientifically significant paleontological resources can be reasonably inferred.

Several quarries near Agate Fossil Beds National Monument, located in Sioux County, contain Miocene mammals. The sites are located about 25 miles (40.2 km) from the MEA. Mammalian orders represented within the upper Harrison Beds and the Harrison-Monroe Creek Formation include Carnivora, Canidae, Amphicyonidae, Ursidae, Mustelidae, Perissodactyla, and Artiodactyla. Fossilized terrestrial beaver burrows called *Daemonelix* are also found in these units (Hunt 1981; NPS 2010). Brontothere (ancient rhinoceros) fossils have been identified in the basal sandstone of the Chadron Formation (Chamberlin Pass Formation) of Sioux County (LaGarry et al. 1996).

2.6.1.6 Soils

The current Crow Butte License Area and the MEA are located in the semiarid northwest region of Nebraska in southern Dawes County. Climate is semiarid (precipitation averages approximately 18 inches per year; SCS 1977). Physiographically, the MEA is located along the southern flank of Pine Ridge, an area of steep dissected terrain. The numerous drainages present within and adjacent to the MEA are tributary to the Niobrara River, located immediately to the south. Box Butte is the dominant physiographic feature immediately south of the Niobrara River and is slightly lower than, but topographically similar to Pine Ridge. Native vegetative cover in the Pine Ridge region is typically mixed-grass prairie and Ponderosa pine trees, but varies across the MEA, with significant areas that are currently cultivated or are degraded rangeland.

An investigation of MEA soils included review of available published soils data. Soils data for the MEA were obtained from the United States Department of Agriculture (USDA), Natural Resource

Conservation Service (NRCS 2007) Web Soil Survey (NRCS 2011). The sources for the Dawes County soils data available from the Web Soil Survey include the Soil Survey of Dawes County, Nebraska, published in February 1977 (SCS 1977), and updated unpublished materials derived from remote sensing images and other digitized soils mapping of Dawes County. Thirty-one soil map units are identified in the project area. Their spatial distributions are illustrated on **Figure 2.6-20**, and their aerial extents summarized in **Table 2.6-7**.

Soils in the MEA formed through the weathering of Tertiary bedrock material, loess (windblown silt), colluvium, or unconsolidated alluvium. Soils in the project area are shallow to deep silt loams and loamy very fine sands. Soil depth, grain size, and drainage typically increase closer to the Niobrara River and away from the steeper uplands of the MEA (SCS 1977).

Due to the loamy and fine sandy texture of most soils in the MEA, wind and water erosion pose the most significant risks to soil health and productivity, especially where vegetation has been disturbed. These soil textures also dictate the good drainage and high infiltration rates characteristic of most soils in the MEA.

From specific to general, the MEA landscape is composed of various soil series (soils with similar profiles), complexes (two or more series or miscellaneous areas that cannot be mapped separately), and associations (two or more geographically associated series or miscellaneous areas that have a consistent pattern and relative proportion of soils). In certain areas, the soil material is so rocky, so shallow, so severely eroded, or so variable that it has not been classified by soil series. These areas are called land types and are given descriptive names. An example of this is "sandy alluvial land" found within the Busher-Tassel-Vetal association. The General Soil Map of Dawes County, Nebraska (SCS 1977) illustrates the three soil associations that dominate the MEA, which are generally segregated north-to-south according to topographic and physiographic regimes and parent material. The three soil associations described below are not depicted on **Figure 2.6-20**; however, the individual components of each association are illustrated and described fully later in this section. The Canyon-Alliance-Rosebud soil association is generally found in the northern portion of the MEA and makes up approximately 40 percent of the project area. This upland soil association consists of "deep to shallow, gently sloping to steep, well-drained loamy and silty soils that formed in material weathered from sandstone". Canyon series soils make up about 25 percent of this association, Alliance series soils about 24 percent, and Rosebud series soils about 16 percent. Minor soils and land types make up the remaining 35 percent (SCS 1977) .

The Busher-Tassel-Vetal soil association is the most extensive within the MEA (35 percent of the project area) and is found on uplands and footslopes. This soil association consists of "deep and shallow, very gently sloping to steep, well-drained to somewhat excessively-drained, sandy soils that formed in colluvium and in material weathered from sandstone". Busher series soils make up about 35 percent of this association, Tassel series soils about 32 percent, and Vetal series soils about 15 percent. Minor soils and land types make up the remaining 18 percent (SCS 1977).

The Valent-Dwyer-Jayem soil association makes up about 25 percent of the project area and is typically found in uplands adjacent to the Niobrara River in the southern portion of the MEA. This soil association consists of "deep, gently sloping to steep, well-drained to excessively-drained sandy soils". Together, the Valent and Dwyer series soils (which are typically mapped as one unit) make up 68 percent of the association, with Jayem series soils and minor soils and land types both making up about 16 percent each (SCS 1977).

Soil Limitations

The NRCS characterizes soil mapping units and their limitations for a variety of uses based on a wide range of properties such as soil texture, slope, and thickness. In general, MEA soils are moderately to highly susceptible to water erosion, with K-factors (for all soil horizons) of dominant soil map units ranging from 0.15 to 0.55. Hazards for water erosion are lowest in the southern MEA and generally increase uphill and away from the Niobrara River. Hazards for wind erosion are generally high to moderately high within the proposed Mine Units. Exceptions include MU-6 and portions of MU-1, where the hazard is moderate. MEA soils are particularly susceptible to wind erosion where vegetation cover has been removed. Almost all soils in the MEA have severe or moderate potential for rutting and compaction and have limited suitability as natural road surfaces. Due to the high susceptibilities for wind and water erosion that are prevalent across the MEA, most soils are susceptible to degradation during disturbance. However, almost all MEA soils likely to be disturbed by project activities are also considered to have high soil resiliency (i.e., inherent ability to recover degradation) and high potential for successful restoration. The Tassel soils and Canyon soils in the northern MEA have moderate, or generally favorable, characteristics for restoration. Soil resilience and restoration potential is dependent upon adequate organic matter content, soil structure, low sodium levels, and other factors (NRCS 2011).

Soil Range Classifications

Most land within the MEA is currently used for rangeland. Different soil units support different types and proportions of rangeland vegetation. Knowledge of which types of vegetation represent healthy or poor rangeland conditions facilitates evaluation of restoration efforts and selection of re-vegetation seed mixes. Five major rangeland site classifications are present within the MEA and are described below: sandy, savannah, shallow limey, silty, and sub-irrigated. Minor acreages of sandy lowland, shallow to gravel, silty overflow, and mixed rangelands are also present but are not described. Decreaser plants form the majority of climax cover in all range sites (SCS 1977).

Sandy Range Site

Map units 1881, 1882, 5070, 5978, 6091, and portions of unit 5118 are classified as sandy range. Moderately rapid to rapid permeability of the soils heavily influences vegetation types on these soils. A typical climax plant community is about 50 percent a mixture of decreaser plants such as sand bluestem, little bluestem, and prairie junegrass. The remaining 50 percent is perennial grass, forbs, and shrubs. The principal increasers are blue grama, threadleaf sedge, prairie sandreed, needle-and-thread, sand dropseed, western wheatgrass, fringed sagewort, and small soapweed. A site in poor condition will commonly have blue grama, threadleaf sage, sand dropseed, and western ragweed.

Savannah Range Site

Only map unit 5153 is classified as savannah range; however, this range site makes up approximately 10 percent of the MEA. The types of vegetation that occur on this range site are primarily influenced by the wide variations in soil depth, available water capacity, and relief. About 65 percent of climax plant cover is a mixture of such decreaser grasses as little bluestem, big bluestem, side-oats grama, plains muhly, green needlegrass, prairie junegrass, slender wheatgrass, bearded wheatgrass, and western wheatgrass. About 35 percent consists of other perennial grasses, forbs, shrubs, and trees. A site in poor condition typically consists of Ponderosa pine and various species of shrubs and vines.

Shallow Limey Range Site

Map units 5152; 6028; and portions of units 1742, 5118, 5211, and 6043 are classified as shallow limey range sites. The alkaline nature of these soils, along with very low to low available water capacity and shallow rooting depths, influences vegetation types on these soils. Approximately 75 percent of climax plant cover is a mixture of decreaser grasses such as little bluestem, sand bluestem, side-oats grama, needle-and-thread, prairie sandreed, plains muhly, and western wheatgrass. Perennial grasses, forbs, and shrubs make up the remaining 25 percent. These increasers include blue grama, hairy grama, threadleaf sedge, fringed sagewort, common prickly pear, broom snakeweed, skunkbush sumac, and western snowberry.

Silty Range Site

Map units 1356, 1357, 1620, 5105, 5106, 5107, 5200, 5871, and 5947 are classified as silty range sites. The vegetation which grows on these sites is influenced mainly by the moderately slow or moderate permeability of the soils and by their moderate to high available water capacity. About 50 percent of the climax plant cover is a mixture of such decreaser grasses as big bluestem, little bluestem, side-oats grama, western wheatgrass, and prairie junegrass. About 50 percent consists of other perennial grasses, forbs, and shrubs. Blue grama; buffalograss; threadleaf sedge; needle-and-thread; Arkansas rose; and numerous forbs such as dotted gayfeather, false boneset, heath aster, skeletonplant, and scarlet globemallow are the principal increasers. A site in poor condition will typically have blue grama, buffalograss, threadleaf sedge, and sand dropseed.

Subirrigated Range Site

Bankard series soils within the MEA (units 1013 and 1014) are classified as sub-irrigated range sites. The water table in this range site is typically at a depth of 2 feet in the spring and 6 feet in the early fall. Moisture available from the high water table during the growing season is the main influence on vegetation types on these sites. About 70 percent of the climax cover is a mixture of such decreaser grasses as big bluestem, little bluestem, indiangrass, switchgrass, prairie cordgrass, and Canada wildrye. About 30 percent consists of other perennial grasses such as Kentucky bluegrass, green muhley, western wheatgrass, and sedges. A site in poor condition will typically have Kentucky bluegrass, redtop, foxtail barley, dandelion, western ragweed, blue verbena, and lesser amounts of western wheatgrass and sedges.

Soil Mapping Units

As defined by the NRCS, a map unit is identified and named according to the taxonomic classification of the dominant soils. Map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. **Table 2.6-7** summarizes the soils in map units found within the MEA. The table provides the map unit symbols, map unit names, and estimated acres of the dominant soils in the MEA. The description of each soil mapping unit includes the potential for wind erosion, water erosion, the farmland classification, and the hydric rating. The farmland classification identifies map units as prime farmland, farmland of statewide importance, farmland of local importance, or unique farmland by identifying which soils are best suited to food, feed, fiber, forage, and oilseed crops. The hydric rating indicates the proportion of the map units that meets the criteria for hydric soils, which are an indicator for wetlands. The soils in the MEA are also shown as soil map units on **Figure 2.6-20**.

Soil map units illustrated in **Figure 2.6-20** consist of soil series, soil complexes, and soil associations, as described above. In addition, certain soil map units represent undifferentiated soil groups, which are made up of two or more soils that could be delineated individually but are shown as one unit because similar interpretations can be made for use and management. The name states the two dominant soil series represented in the group, joined by "and". Four soil map units within the MEA (1742, 5118, 5211, and 6043) are soil complexes, two soil map units (1882 and 5070) are undifferentiated soil groups, and one soil map unit (6043) is a soil association with minor distribution within the MEA (**Figure 2.6-20**). The remaining soil map units represent soil series.

The following section describes the soil series and mapping units for those soils in Dawes County which occur within the MEA as shown on **Figure 2.6-20**. Soil map units 1014, 1356, 1882, 5105, 5126, and 5153 depicted on **Figure 2.6-20** are composite map units consisting of multiple NRCS units. All units combined are divisions of the same soil series, complex, group, or association and were combined to provide a less complex soil map. The map unit number used to label composite map units on **Figure 2.6-20** represents the NRCS map unit with the greatest extent within the Proposed MEA. Soil map units that represent combined NRCS map units are noted below and their constituent NRCS map units are described individually. The descriptions of soil map units that occur within the MEA, as shown on **Figure 2.6-20** and listed in **Table 2.6-7,** are extracted from the NRCS custom Soil Resource Report as provided by the NRCS Web Soil Survey.

Bankard Series Soils

The Bankard series consists of deep, somewhat poorly drained soils that formed in sandy alluvium on bottom lands along tributaries to the Niobrara River. Slopes range from 0 to 2 percent. Within the MEA, the water table is typically at a depth of 2 to 4 feet, and soils are occasionally frequently flooded. Permeability is rapid, and available water capacity is low. Natural fertility is medium to low, and organic matter content is low. Runoff is slow. Although suited for irrigation, most areas of Bankard series soils are in areas of native grass used for hay or grazing. These soils are not considered prime farmland. They are partially hydric. Bankard soils comprise approximately 7 percent of the MEA. They are mapped as composite unit 1014 on **Figure 2.6-20** and include the following map units:

1013 – Bankard loamy coarse sand, frequently flooded

This soil is found in bottom lands in the southern portion of the MEA. It is similar to unit 1014 as described below, but is formed in coarser grained alluvial material. Approximately 127 acres of this soil unit are present in the MEA.

1014 – Bankard loamy fine sand, frequently flooded

This soil is found in bottom lands in the MEA. It is similar to other frequently flooded Bankard soils. Some areas are strongly affected by salts and alkali, and salts are visible on the surface in early spring. This soil is marginal for cultivation of alfalfa and forage crops, and drainage systems are necessary to lower the water table in this unit prior to irrigation. Deep-rooted dry farmed crops benefit from the high water table during dry periods. Soil blowing is a hazard if the soil surface is not protected. Approximately 189 acres of this soil unit are present in the MEA.

Glenberg Series Soils

The Glenberg series consists of very deep, well drained soils that formed in stratified calcareous alluvium on floodplains and river terraces. Slopes range from 0 to 8 percent. Permeability is rapid, and available water capacity is moderate. Natural fertility and organic content are moderate to low. Glenberg series soils are suitable for dry farming and irrigated farming. Because they are restricted to steeper areas near drainages, only portions of the Glenberg soils within the MEA are currently cultivated. Glenberg soils comprise less than 1 percent of the MEA and include the following map unit:

1036 – Glenberg loamy very fine sand, 0 to 3 percent slopes

This map unit is located on high bottom land areas that are seldom flooded. A lime layer may be present at the surface, and stratification may be less distinct than in other Glenberg soils. Soil blowing is a hazard if the soil is unprotected. Runoff is slow. This map unit is dry farmed for wheat, oats, and alfalfa and irrigated for alfalfa to a lesser extent. This map unit occurs in areas as large as 100 acres. Approximately 8.5 acres of this soil unit are present within the MEA.

Bridget Series Soils

The Bridget series consists of deep, well-drained soils that formed in loamy colluvial and alluvial sediment on foot slopes and stream terraces. Permeability is moderate, and available water capacity is high. Natural fertility is medium, and organic matter content is moderate. In areas where slopes are less than 9 percent, these soils are used mostly for cultivated dry farmed wheat, oats, or alfalfa. These soils are prime farmland if irrigated. The Bridget soils present within the MEA are partially hydric. Bridget series soils comprise approximately 8 percent of the MEA. They are mapped as composite map unit 1356 on **Figure 2.6-20** and include the following map units:

1356 – Bridget silt loam, 1 to 3 percent slopes

This soil occurs in areas as large as 500 acres on foot slopes and stream terraces near large drainages. Minor areas in higher landscape positions may have a fine sandy loam surface layer or transitional horizon. This soil is partially hydric. Water erosion and gullying are hazards in areas that receive runoff from adjacent slopes. Soil blowing is a hazard if the soil surface is unprotected. Runoff is slow to medium. Approximately 269 acres of this soil unit are present within the MEA.

1357 – Bridget silt loam, 3 to 6 percent slopes

This soil occurs in areas as large as 200 acres on colluvial foot slopes and uplands. It is similar to map unit 1356, but has a thinner surface layer and occurs on steeper slopes. Bayard, Keith, or Rosebud series soils may make up 25 percent of this unit in the Pine Ridge area. Water erosion is a hazard due to runoff received from adjacent higher areas. Soil blowing is a hazard if the soil surface is unprotected. Runoff is medium. Approximately 105 acres of this soil unit are present within the MEA.

Keith Series Soils

The Keith series consists of deep, well drained soils that formed in loess on uplands and tablelands. Permeability is moderate, and available water capacity is high. Natural fertility is medium, and organic matter content is moderate. Keith series soils are suited for dryfarmed and irrigated crops, primarily winter wheat and alfalfa. These soils are prime farmland if irrigated. Keith series soils comprise approximately 1 percent of the MEA and include the following map unit:

1620 – Keith silt loam, 1 to 3 percent slopes

This soil occurs in areas as large as 500 acres on uplands. The soil profile of this unit is similar to other Keith series soils but has a thicker subsoil and may have a loam or fine sandy loam surface layer. Small areas of Alliance, Duroc, and Richfield soils may be present within this map unit. Water erosion is a hazard in some areas, but soil blowing is the main hazard. Runoff is slow. This soil unit is partially hydric. Approximately 53 acres of this soil unit are present in the MEA.

Rosebud-Canyon Complex Soils

The Rosebud-Canyon soil complex consists of intricately adjoining areas of Rosebud series and Canyon series soils. Rosebud soils are moderately deep, well drained soils that formed in material weathered from sandstone on upland areas. Permeability is moderate, and available water capacity is moderate. Natural fertility is medium, and organic matter content immoderate. Rosebud soils are suited to both dry farmed and irrigated crops, such as wheat, oats, and alfalfa. Canyon series soils are described further below. Rosebud-Canyon complex soils comprise approximately 4 percent of the MEA and include the following map unit:

1742 – Rosebud-Canyon loams, 3 to 9 percent slopes

These soils occur in areas as large as 500 acres on gently rolling and rolling uplands. Rosebud soils make up approximately 50 to 70 percent of the map unit, and Canyon soils approximately 15 to 30 percent. Lesser amounts of other soil series make up 10 to 25 percent. Rosebud soils are found on side slopes, and the Canyon soils are on ridgetops and knolls. Soil blowing and water erosion are hazards if these soils are cultivated and the soil surface is not protected. Runoff is medium to rapid, depending on slope gradient and the type and amount of vegetative cover. Canyon soils are shallow but may be cultivated where adjacent to deeper soils. This soil unit is partially hydric. Approximately 188 acres of this soil unit are present in the MEA.

Valent and Dwyer Group Soils

The Valent and Dwyer soil group consists of intermingled areas of Valent series and Dwyer series soils. Both Valent and Dwyer soils are deep, excessively drained soils that formed in eolian sands on uplands and stream terraces. Both soils have rapid permeability and low available water capacity. Natural fertility and organic matter content of both soils are low. Runoff is slow because both soils absorb water rapidly. Dwyer soils have lime higher in the profile than Valen soils, but are otherwise very similar. These soils are best suited for rangeland grasses, but not for dryland farming. Some irrigated alfalfa is grown in these soils. Both Valent and Dwyer soil units present within the MEA are partially hydric. These soils comprise approximately 23 percent of the MEA. Valent and Dwyer group soils are mapped as composite unit 1882 on **Figure 2.6-20** and include the following units:

1881 – Valent and Dwyer loamy fine sands, 0 to 3 percent slopes

This map unit occurs in areas as large as 200 acres on uplands and stream terraces, either of which may be hummocky. Soil component distribution varies, and some areas consist almost entirely of either soil series or may have both. Dwyer soils may have pebbles on the surface and throughout the profile. Soil blowing is a hazard in cultivated areas. Approximately 284 acres of this soil unit are present in the MEA.

1882 – Valent and Dwyer loamy fine sands, 3 to 20 percent slopes

This map unit occurs in areas as large as 1,000 acres on uplands. It is very similar to map unit 1881, but occurs on steeper slopes. Wind erosion is a very severe hazard if grass is removed, and blowouts occur in some areas. Approximately 786 acres of this soil unit are present in the MEA.

Vetal and Bayard Group Soils

The Vetal and Bayard soil group consists of intermingled areas of Vetal series and Bayard series soils. Both Vetal and Bayard soils are deep, well-drained soils that formed in sandy alluvium and colluvium on foot slopes. Vetal soils are found on upland swales, and Bayard soils may be found on stream terraces as well as foot slopes. Both soils have moderately rapid permeability and moderate available water capacity. Natural fertility and organic matter content of both soils are moderate. Bayer soils have a thinner surface horizon than Vetal soils. Both soils are suited for dry farmed and irrigated crops such as wheat, oats, and alfalfa. These soils are prime farmland if irrigated. Vetal and Bayard group soils comprise approximately 2.4 percent of the MEA and include the following map unit:

5070 – Vetal and Bayard soils, 1 to 6 percent slopes

This map unit occurs in areas as large as 300 acres on foot slopes and stream terraces. Vetal soils make up 55 to 75 percent of the map unit, and Bayard soils make up 25 to 45 percent. Areas may be dominated by a single component or may have both present. Soil blowing is a hazard in cultivated areas, and runoff is slow due to rapid absorption of rainfall. Approximately 111 acres of this soil unit are present in the MEA.

Alliance Series Soils

The Alliance series consists of deep, well drained soils that formed in material weathered from sandstone on uplands. Permeability is moderate, and available water capacity is high. Natural fertility is medium, and organic matter content is moderate. These soils are generally suited for dry farmed and irrigated crops and are prime farmland if irrigated. All Alliance series soils present within the MEA are partially hydric. All Alliance soil units present within the MEA are partially hydric. Alliance series soils comprise approximately 8 percent of the MEA. Alliance series soils are mapped as composite unit 5105 on **Figure 2.6-20** and include the following map units:

5105 – Alliance silt loam, 1 to 3 percent slopes

This map unit occurs in areas as large as 500 acres on smooth upland areas. This map unit is similar to other Alliance series soils but may have lime present below a depth of 30 inches. Small areas of Rosebud, Dwyer, and Richfield series soils may be present. Soil blowing and water erosion are a moderate hazard if the soil surface is not protected. Runoff is slow. Most crops are dry farmed, and wheat is the primary crop, with lesser amounts of oats and alfalfa. Corn is the main crop in irrigated areas. Approximately 242 acres of this soil unit are present in the MEA.

5106 – Alliance silt loam, 3 to 9 percent slopes

This map unit occurs in areas as large as 300 acres on uplands. The soil profile of this map unit is similar to other Alliance series soils, but has a slightly thinner surface layer. This soil is partially hydric. Water erosion and soil blowing are hazards in cultivated areas. Runoff is medium. This

soil is used primarily for rangeland or native grass hay. It is suited for cultivation, but effective management practices and cropping systems are needed to help control erosion. Approximately 88 acres of this soil unit are present in the MEA.

5107 – Alliance silt loam, 3 to 9 percent slopes, eroded

This map unit is similar to unit 5106, but has a surface layer thinner than 7 inches which has been at least partially removed by erosion. Lime may be present at the surface, and the subsoil may be thinner than other Alliance series soils. Slope steepness limits irrigation development. Approximately 29 acres of this soil unit are present in the MEA.

Busher and Tassel Complex Soils

The Busher and Tassel soil complex consists of intricately adjoining areas of Busher series and Tassel series soils on uplands. Busher soils are found on the middle and lower portions of slopes and Tassel soils are on ridgetops, knolls, and sides of small drainages. This soil unit is not hydric. Busher and Tassel complex soils comprise approximately 4 percent of the MEA and include the following map unit:

5118 – Busher and Tassel loamy very fine sands, 6 to 20 percent slopes

This map unit occurs in areas as large as 100 acres on uplands. Slopes are mostly from 9 to 20 percent, but may be as low as 6 percent. Busher loamy very fine sand makes up about 60 percent of this unit, and Tassel loamy very fine sand makes up about 40 percent. Areas of shallower soils are present where bedrock is at a depth of 20 to 36 inches. Soil blowing and water erosion are serious hazards if the native grass cover is removed. Runoff is medium. Most of this soil unit is used for native grass rangeland. Approximately 185 acres of this soil unit are present in the MEA.

Busher Series Soils

The Busher series consists of deep, well drained to somewhat excessively drained soils that formed in material weathered from sandstone on uplands. Permeability is moderately rapid, and available water capacity is moderate. Natural fertility is medium to low, and organic matter content is moderate. Soil blowing and water erosion are serious hazards on all Busher series soils if the protective vegetation cover is removed. Where slopes are less than 9 percent, these soils are suited for cultivation and irrigation. Areas with slopes less than 6 percent (map units 5123 and 5124 below) are considered Farmland of Statewide Importance. No other Busher soils are considered prime farmland. Soil units 5123, 5124, and 5128 are partially hydric, but unit 5126 is not. Busher series soils comprise approximately 15 percent of the MEA. Busher series soils are mapped as composite unit 5136 on **Figure 2.6-20** and include the following map units:

5123 – Busher loamy very fine sand, 1 to 6 percent slopes

This map unit occurs in areas as large as 100 acres on uplands. This unit is similar to other Busher series soils, but may have a surface layer consisting of very fine sandy loam or sandy loam, a transitional layer of loam or very fine sandy loam, or areas of shallower soil where bedrock is at a depth of 20 to 40 inches. Areas of Bridget, Jayem, Vetal, and Tassel soils may be present and make up as much as 15 percent of this unit. Management concerns include conserving soil moisture and maintaining soil fertility. This soil unit typically occurs in areas of native grass. Approximately 142 acres of this soil unit are present in the MEA.

5124 – Busher loamy very fine sand, 1 to 6 percent slopes, eroded

This map unit is similar to unit 5123, but occurs in areas as large as 200 acres and typically has a thinner (4 to 7 inches) surface layer due to erosion. This soil unit typically occurs in areas cultivated for dry farmed wheat, alfalfa, and oats. Approximately 131 acres of this soil unit are present in the MEA.

5126 – Busher loamy very fine sand, 6 to 9 percent slopes

This map unit occurs in areas as large as 250 acres on uplands. This unit is similar to other Busher series soils, but may have a surface layer thinner than 7 inches and may have lime at a depth of 12 to 18 inches. Areas of Bridget, Jayem, Vetal, and Tassel soils are present and make up as much as 15 percent of this unit. This soil unit typically occurs in areas of native grass. Approximately 162 acres of this soil unit are present in the MEA.

5128 – Busher loamy very fine sand, 6 to 9 percent slopes, eroded

This map unit is similar to unit 5126, but occurs in areas as large as 100 acres and has a surface layer that is 4 to 7 inches thick. Bedrock may be present in areas of shallow soils at a depth of 20 to 36 inches. Small areas of rock outcrop may be present within this unit. This soil is somewhat droughty and typically occurs in areas cultivated for dry farmed wheat, alfalfa, and oats. Approximately 135 acres of this soil unit are present in the MEA.

5129 – Busher loamy very fine sand, 9 to 20 percent slopes

This map unit occurs in areas as large as 200 acres on uplands. This unit is similar to other Busher series soils, but has a surface layer that is 4 to 7 inches thick and lime at a depth of 10 to 18 inches in places. Bedrock may be present in areas of shallow soils at a depth of 20 to 36 inches. Conserving soil moisture is a major management concern in this soil. Runoff is medium. This unit occurs primarily in areas of native grass. Areas with flatter slopes are cultivated, but the steepness of this unit makes most areas unsuitable. Approximately 141 acres of this soil unit are present in the MEA.

Canyon Series Soils

The Canyon series consists of shallow, well drained soils that formed in material weathered from sandstone on ridges, knolls, and the sides of upland drainages. These soils are found only in the northern half of the MEA. Canyon soils are typically loams that are at 15 inches or shallower. Permeability is moderate, and available water capacity is low. Natural fertility and organic matter content are also low. Because Canyon soils are steep and shallow, cultivation is limited to areas where they are adjacent to deeper, more suitable soils. These soils are not hydric. Canyon series soils comprise approximately 12 percent of the MEA. Canyon series soils are mapped as composite unit 5153 on **Figure 2.6-20** and include the following map units:

5152 – Canyon soils, 3 to 30 percent slopes

This map unit occurs in areas as large as 500 acres. This unit is similar to other Canyon series soils, but has a surface layer that may be silt loam or very fine sandy loam. Bedrock may be present at depths of less than 10 inches. Areas of Bridget, Rosebud, Oglala, and Tassel series soils make up

less than 20 percent of this unit. Water erosion and soil blowing are very severe hazards if the soil surface is unprotected. These soils are droughty due to low available water capacity and shallow root zones. Conserving soil moisture is a management concern. Runoff is medium until soils are saturated, and then becomes rapid. This unit is typically found in areas of native grass used for grazing. Approximately 13 acres of this soil unit are present in the MEA.

5153 – Canyon soils, 30 to 50 percent slopes

This map unit occurs in areas as large as 500 acres on the sides of upland drainages. These soils are similar to map unit 5152, but occur in areas of steeper slopes that may also contain rock outcroppings. Very steep slopes, shallowness, and rock outcrops limit the use of these soils to range, woodland, and wildlife habitat. Runoff is very rapid. Approximately 537 acres of this soil unit are present in the MEA.

Oglala Series Soils

The Oglala series consists of deep, well drained soils that formed in material weathered from fine-grained sandstone on the middle and lower parts of side slopes in uplands. These soils are found only in the northern half of the MEA. Oglala soils typically have a loam surface layer overlying a silt loam subsoil. Permeability is moderate, and available water capacity is high. Natural fertility and organic matter content are moderate. In general, these soils are better suited to native grass than cultivation due to steep slopes. These soils are not hydric. Oglala series soils comprise less than 1 percent of the MEA and include the following map unit:

5200 – Oglala loam, 9 to 30 percent slopes

This map unit occurs in areas as large as 200 acres on hillsides. The surface horizon of this unit may be thinner (3 to 6 inches) in areas and lime may be present at depths of less than 20 inches. Areas of Bridget, Canyon, Rosebud, and Ulysses soils may be present and make up less than 15 percent of this unit. Water erosion and soil blowing are hazards if the soil surface is not protected. Runoff is medium to rapid, depending on slope steepness and type and amount of vegetative cover. Most of this unit is used for livestock grazing on native grass. Approximately 2 acres of this soil unit are present in the MEA.

Oglala-Canyon Complex Soils

The Oglala-Canyon soil complex consists of intricately adjoining areas of Oglala series and Canyon series soils on side slopes, ridges, and knolls in the northern portion of the MEA. Oglala soils are found on the middle and lower part of side slopes, and Canyon soils are on ridgetops and knolls. These soils are not hydric. The Oglala-Canyon complex comprises approximately 5 percent of the MEA and includes the following map unit:

5211 – Oglala-Canyon loams, 9 to 20 percent slopes

This map unit is found in areas as large as 1,000 acres. Oglala soils make up approximately 60 to 75 percent of this unit, and Canyon soils approximately 25 to 40 percent. Areas of Bridget, Duroc, Keith, Rosebud, and Ulysses soils may be present and make up 25 percent or less of this unit. Fragments of sandstone may be present at the surface in some areas. Water erosion is a hazard if the soil surface is not protected. Runoff is medium to rapid, depending on slope steepness and the

type and amount of vegetative cover. This unit is not suited for cultivation and is typically found in areas of native grass. Approximately 236 acres of this soil unit are present in the MEA.

Schamber Series Soils

The Schamber series consists of shallow, somewhat excessively drained soils that occur on escarpments of stream terraces along tributaries of the Niobrara River in the southern portion of the MEA. Schamber series soils typically have a gravelly, very fine sandy loam surface layer and subsoil overlying coarse sandstone gravel at a depth of approximately 12 inches. Permeability is rapid to very rapid, and available water capacity is very low. Natural fertility and organic matter content are low. These soils are not well suited for cultivation and are not hydric. Schamber series soils comprise less than 1 percent of the MEA and include the following map unit:

5254 – Schamber soils, 3 to 30 percent slopes

This map unit is found in areas as large as 50 acres. The surface layer of this unit may be gravelly loam in areas. Areas of deeper soil exist where gravel is present at a depth of 20 to 40 inches. Areas of Keith, Mitchell, and Pierre series soils are present at lower elevations and may comprise up to 15 percent of this unit. Soil blowing and water erosion are hazards if the soil surface is not protected. Runoff is medium to rapid. These soils are typically found in areas of native grass that are used for grazing. The substrate of these soils may be a useful source of gravel for construction activities. Approximately 13 acres of this soil unit are present in the MEA.

Haverson Series Soils

The Haverson series consists of deep, well-drained soils that formed in stratified silty and loamy alluvium on bottom lands and low stream terraces. Areas on very low bottom lands are subject to occasional to frequent flooding. Haverson soils are found only in the northern portion of the MEA. Permeability is moderate to moderately slow, and the available water capacity is high. Natural fertility is medium to low, and organic matter content is low. These soils are rich in lime, which typically occurs at the surface, and are suited for grass and irrigated crops. Haverson soils comprise approximately 1 percent of the MEA and include the following map unit:

5640 – Haverson loam, frequently flooded

This map unit is found in areas of irregular size and shape on low bottom lands and low stream terraces. Flooding frequently occurs due to their low position on the landscape. Areas of Glenberg soils may be included in higher elevation portions of this unit. Flooding is the main hazard and management concern in this unit. Soil blowing can also be a hazard if the soil surface is unprotected. Runoff is slow. Alfalfa is the main crop where cultivated and is suited for irrigation if flooding can be controlled. This soil unit is partially hydric. Approximately 50 acres of this soil unit are present in the MEA.

Tripp Series Soils

The Tripp series consists of deep, well drained soils that formed in silty and loamy alluvium on stream terraces along major drainages. Permeability is moderate in the upper part of the subsoil and decreases with depth where lime has accumulated. Available water capacity is high, natural fertility is medium, and organic matter content is moderate. These soils are suited for dryfarming

and irrigation. Tripp soils comprise less than 1 percent of the MEA and include the following map unit:

5871 – Tripp silt loam, 1 to 3 percent slopes

This map unit occurs in areas as large as 200 acres on stream terraces in the north-central portion of the MEA. This unit is similar to other Tripp soils, but may be thinner and may have lime at shallower depths. This map unit may include areas of Bayard and Bridget soils at high elevations and Duroc and Halverson soils at low elevations. Soil blowing and water erosion are hazards if the soil surface is not protected. Runoff is slow. If irrigated, this soil is categorized as prime farmland; however, it is mostly used for dry farming of alfalfa, wheat, and oats. This soil unit is partially hydric. Approximately 20 acres of this soil unit are present in the MEA.

Duroc Series Soils

The Duroc series consists of deep, well drained soils that formed in colluvium and alluvium derived from loess and weathered sandstone. Permeability is moderate, and available water capacity is high. Natural fertility and organic matter content are moderate. These soils are well suited to cultivation and irrigation. Duroc soils are primarily found as minor components of other soil map units within the MEA. Areas mapped as Duroc soils comprise less than 1 percent of the MEA and include the following map unit:

5947 – Duroc very fine sandy loam, 1 to 3 percent slopes

This map unit occurs on the northern boundary of the MEA on a stream terrace. It occurs in areas as large as 300 acres elsewhere in Dawes County. Alliance, Bridget, Keith, Richfield, and Rosebud soils may be associated with this unit at higher elevations. This soil is partially hydric. Runoff is slow. This unit is suited to irrigation but is mostly dry farmed for wheat, oats, and alfalfa. This soil is prime farmland if irrigated. Less than 1 acre of this soil unit is present in the MEA.

Jayem Series Soils

The Jayem series consists of deep, well drained to somewhat excessively drained soils that formed in eolian sands on uplands. Permeability is moderately rapid, and available water capacity is moderate. Natural fertility and organic matter content are moderate. These soils are suited to both dry farmed and irrigated crops. Jayem soils comprise less than 1 percent of the MEA and include the following map unit:

5978 – Jayem loamy very fine sand, 1 to 6 percent slopes

This map unit is found in areas as large as 200 acres on uplands. The surface horizon may consist of very fine sandy loam, and lime occurs at a depth of 10 to 26 inches. Areas of Keith, Sarben, and Vetal soils make up less than 15 percent of this unit. Soil blowing is a hazard if the soil surface is unprotected. Runoff is slow due to moderately rapid infiltration of rainfall. This unit is primarily found in areas of native grass used for grazing or hay, but is well suited for irrigation. This unit is considered to be Farmland of Statewide Importance. Wheat and alfalfa are the most commonly cultivated crops. This soil unit is partially hydric. Approximately 11 acres of this soil unit are present in the central portion of the MEA.

Tassel Series Soils

The Tassel series consists of shallow, well drained soils that formed in material weathered from fine grained sandstone on uplands. The surface horizon and subsoil of Tassel soils are typically composed of loamy very fine sand. Permeability is moderately rapid, and available water capacity is very low. Natural fertility and organic matter content are low. The shallow nature of these soils makes them poorly suited for commonly cultivated crops and better suited for range and wildlife habitat. Lime is typically present at the surface of Tassel series soils. These soils are not hydric. Tassel soils comprise approximately 8 percent of the MEA and include the following map unit:

6028 – Tassel soils, 3 to 30 percent slopes

This map unit is found in areas as large as 500 acres on ridges, knolls, and the sides of upland drainages in the northern and central portions of the MEA. Areas of shallow soils where sandstone occurs at depths of 4 to 10 inches and areas of deeper soils where sandstone occurs at depths of 20 to 40 inches are present within this unit. Small outcrops of sandstone are also included in this unit. Areas of Bayard, Busher, Canyon, Jayem, and Sarben soil comprise up to 20 percent of this unit. Soil blowing is a hazard if the grass cover is removed or damaged. These soils are often droughty, and conserving moisture is a management concern. Runoff is slow to rapid, depending on the slope steepness and type and amount of vegetative cover. This unit is primarily found in areas of native grass used for grazing. Because shallowness and steep slopes make this unit unsuitable for cultivation, it is typically only cultivated where adjacent to deeper soils. Approximately 346 acres of this soil unit are present in the MEA.

Tassel-Ponderosa-Rock Outcrop Association

The Tassel-Ponderosa-Rock outcrop soil association consists of well drained soils that are mapped together in steep upland areas. Tassel series soils are found on ridges. Ponderosa series soils are deep, well drained, very fine sandy loams that formed from residuum weathered from fine-grained sandstone on side slopes. Available water capacity of Ponderosa soils is moderate and permeability is high (NRCS 2011). Rock outcrops are very shallow, excessively drained weathered sandstone that occur on ridges. These soils are not hydric. This soil association comprises less than 1 percent of the project area and includes the following map unit:

6043 – Tassel-Ponderosa-Rock outcrop association, 9 to 70 percent slopes

This map unit occurs along the western margin of the MEA in areas smaller than 10 acres. These soils have a very high potential for wind and water erosion. Runoff is medium to rapid, depending on the slope steepness, type and amount of cover, and presence of rock outcrops. This association is unsuited for cultivation due to steep slopes and shallow soils. Approximately 1 acre of this soil unit is present in the MEA.

Sarben Series Soils

The Sarben series consists of deep, well drained soils that formed in eolian sands on uplands. Permeability is moderately rapid and available water capacity is moderate. Natural fertility is medium to low, and organic matter content is low. Lime occurs at a depth of 24 inches. These soils are suited to dry farming and irrigation and are considered prime farmland if irrigated. Sarben series soils present within the MEA are not hydric. Sarben soils comprise less than 1 percent of the MEA and include the following map unit:

6091 – Sarben fine sandy loam, 1 to 6 percent slopes

This map unit occurs in areas as large as 100 acres on gently rolling uplands in the south-central portion of the MEA. This unit is similar to other Sarben soils, but has lime deeper in the profile and may be deeper than other variations. Soil blowing and water erosion, to a lesser extent, are hazards if vegetative cover is removed. These soils are moderately droughty, and conserving moisture and improving fertility are management concerns. Runoff is slow. Dryfarmed wheat, alfalfa, and oats are the main uses of this unit, but grass for grazing and hay is also cultivated. Approximately 19 acres of this soil unit are present in the MEA.

2.6.1.7 Prevention of Significant Deterioration

In addition to the ambient air quality standards, there are national standards for the Prevention of Significant Deterioration (PSD) of air quality (40 CFR 51.166). The PSD program is administered by the States of Nebraska and South Dakota, with their programs designed to protect the air quality in area that are in attainment with the NAAQS and to prevent degradation of air quality in areas below the standard (designated as clean air areas). PSD differs from the NAAQS in that the NAAQS provides for maximum allowable concentrations of pollutants, while PSD requirements provide maximum allowable increases in concentrations of pollutants for areas already in compliance with the NAAQS. The PSD requirements establish allowable pollution "increments" that may be added to the air in each area while still protecting air quality. The increment is the maximum allowable deterioration of air quality. The maximum allowable increments applicable to Nebraska and South Dakota are shown in **Table 2.5-26.**

The allowable increments vary by location across the states. Those areas characterized as Class I (i.e., National Parks and Wilderness Areas) allow for less incremental pollution increase. Class III areas are planning areas set aside for industrial growth. The areas classified as Class II are essentially all other areas of the state not designated as Class I or Class III. There are no Class I National Park and Wilderness Areas in Nebraska. The Soldier Creek Wilderness Area, located north of Fort Robinson, is not designated as Class I. The State of South Dakota has two Class I Areas: Badlands and Wind Caves National Parks. The Wind Caves National Park is closer to the MEA, at a distance of approximately 75 miles (120.7 km).

No potential impacts to NAAQS parameters or PSD Class I, II, or III areas are expected to occur as the result of the MEA operations. The primary emissions from the proposed MEA will be tailpipe emissions of nitrogen oxides (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2), non-methane-ethane volatile organic compounds (VOCs) and particulate matter with a diameter less than ten microns (PM_{10}) resulting from vehicle traffic within the MEA. The majority of the emissions generated during construction will be fugitive dust and vehicle combustion emissions. Effects of air emissions and impacts associated with construction and operations are discussed in Section 7.2.1.



2.7 Hydrology

2.7.1 Surface Water

2.7.1.1 Water Features Descriptions

Rivers, Creeks and Drainages

The USGS maintains a hierarchical hydrologic unit code (HUC) system that divides the United States into 21 regions, 222 sub-regions, 352 accounting units, and 2,149 cataloging units based on surface hydrologic features or drainages (USGS 2011a). The smallest USGS unit, the 8-digit HUC (or 4th level HUC), averages about 448,000 acres, and is usually the level referred to as an HUC. The Hydrologic Unit system is a standardized watershed classification system. The State of Nebraska's major river basins are shown on **Figure 2.7-1**.

Below the cataloging units, the surface hydrologic features or drainages are further broken down into watersheds and sub watersheds. The MEA project site is located in the following HUC classification system (USGS 2011b):

Region:	Missouri (10)
Sub Region:	Niobrara River: The Niobrara River Basin and the Ponca Creek Basin [Nebraska South Dakota: Wyoming] (1015)
Accounting Unit:	Niobrara River [Nebraska: South Dakota: Wyoming] (101500)
Cataloging Unit:	Niobrara Headwaters [Nebraska: Wyoming] (10150002
Basin:	Niobrara River (**Figure 2.7-2, Table 2.7-1** ([NAC 2011a])
Subbasin:	Subbasin N14 (**Figure 2.7-3** [NAC 2011a])

The Niobrara Accounting Unit and Niobrara Headwaters Cataloging Unit consist of an area of 13,900 mi^2 (36,001 km^2) and 1,460 mi^2 (3,781 km^2), respectively (USGS 2011b). The Niobrara River Basin, with the majority of it located in Dawes and the adjacent Sheridan County, is composed of a watershed area of approximately 11,870 mi^2 (NDEQ 2005a).

There are 25 segments within the Niobrara River Subbasin N14 (**Figure 2.7-3**). The MEA is located within the Niobrara River Subbasin N14, with the southernmost license boundary being located approximately 0.24 mile (0.4 km) from the Niobrara River in Segment 4000 (**Figure 2.7-3**). The distance from the southern boundary of Mine Unit MU-F (southernmost mine unit in the MEA site) to the nearest point on the Niobrara River is approximately 0.42 mile (0.7 km).

The Niobrara River originates near Manville, Niobrara County, eastern Wyoming and flows in an east-southeast direction into western Nebraska (**Figure 2.7-3 and 2.7-4**). The river flows across Sioux County in Nebraska, east through the Agate Fossil Beds National Monument, past Marsland to the south of the proposed MEA project site, and through Box Butte Reservoir. From the reservoir, the river flows east across northern Nebraska, and joins the Snake River approximately 13 miles (20.9 km) southwest of Valentine. The Niobrara River joins the Keya Paha River approximately 6 miles (9.6 km) west of Butte, Nebraska. The river eventually joins the Missouri River northwest of Niobrara, Nebraska in northern Knox County.

Water flow and water quality information on sampling points on the Upper Niobrara River are presented in Section 2.9.4.

Surface Impoundments

Based on available maps and site investigations conducted by CBR, no surface water impoundments, lakes, or ponds have been identified within the MEA. Rainfall runoff occasionally creates temporary small pools in a few places on the MEA site, but there is no evidence of persistent stream flow in recent times (Hayden-Wing 2011).

Box Butte Reservoir is located approximately 3 miles (4.8 km) to the east of the southeast corner of the MEA license boundary (**Figure 2.7-4**). Box Butte Reservoir Dam is located within Segment 4000 of Subbasin N14. The primary purpose of the reservoir is for irrigation with secondary benefits for recreation, fish, and wildlife (USBR 2008). The Box Butte Reservoir Dam has altered the hydrology of the Niobrara River by diverting water for irrigation (Alexander et al. 2010). The reservoir is part of the Mirage Flats Irrigation Project, which consists of the Box Butte Reservoir, the Dunlap Diversion Dam, and associated canal and laterals to irrigate 11,662 acres (**Figure 2.7-5**; USBR 2008). Dunlap Diversion Dam is located approximately 10 miles (16.1 km) downstream of the Box Butte Reservoir Dam. Average flows below the Box Butte Reservoir Dam are reduced by 90 percent relative to inflow to Box Butte Reservoir, but the river gains significant flow downstream from the Dunlap Diversion Dam, mainly due to groundwater seepage (Bentall and Shaffer 1979).

The Box Butte Reservoir was constructed from 1941 to 1946 and is under the control of the U.S. Bureau of Reclamation (USBR). The total storage capacity of the Box Butte Reservoir is 29,161 acre-feet (USBR 2008) and the pool elevation is 3997.6 feet. The reservoir occupies approximately 1,600 surface acres with 14 miles (22.5 km) of shoreline. The reservoir has stabilized the agricultural economy of the area that has resulted in larger farm populations and increased employment in related industries. The lake is well suited for recreation activities (aquatic and outdoor sports). Recreation at the reservoir is managed for the USBR by the Nebraska Game and Parks Commission (NGPC 2011a).

There are no direct drainages from the MEA project site to the reservoir. Any discharges from the MEA site that could enter the Niobrara River could commingle with river water flowing into Box Butte Reservoir.

The storage contents of the Box Butte Reservoir are discussed in Section 2.9.4.

2.7.2 Groundwater

This section describes the regional and local groundwater hydrology including local and regional hydraulic gradient and hydrostratigraphy, hydraulic parameters, baseline water quality conditions, and local groundwater use (including well locations related to the MEA). The discussion is based on information from investigations performed within the MEA, data presented in previous applications/reports for the current CPF where ISR mining is being conducted, the proposed NTEA and TCEA, and the geologic information presented in Section 2.6. In this regard, the hydrogeology of the MEA is expected to be similar in many respects to that encountered in the CPF, NTEA, and TCEA. The hydrostratigraphic section of interest for MEA includes the following (presented in descending order):

- Alluvium
- Arikaree Group
- Brule Formation (first overlying aquifer in Brown Siltstone Member)
- Chadron Formation (Upper Confining Unit including the combined upper and middle Chadron Basal sandstone of the Chadron Formation (Mining Unit)
- Pierre Shale (Lower Confining Unit)

With regard to the CPF, NTEA, TCEA, and MEA in particular, two groundwater sources are of interest in the Crow Butte and surrounding area. These are the Brule Formation sand and the basal sandstone of the Chadron Formation. The basal sandstone of the Chadron Formation contains the uranium mineralization at the CPF, NTEA, TCEA, and MEA.

2.7.2.1 Groundwater Occurrence and Flow Direction

In the vicinity of the MEA, water has been observed in the alluvium, Arikaree Group, Brule Formation, and basal sandstone of the Chadron Formation. Alluvial deposits are discontinuous at MEA and have not been shown to contain usable amounts of water. Of the wells identified in **Table 2.7-9**, none are known to be completed within alluvial deposits, and those that are shallow enough (e.g., less than 50 feet) are understood to be completed within bedrock aquifers. Additionally, except during large storms that produce surface runoff, water within the alluvium is expected to recharge to underlying porous units of the Arikaree Group. Similarly, in areas where the Arikaree Group is deeply dissected by erosion, the Arikaree Group is not typically considered to be a reliable water source; however, within the MEA, the Arikaree Group is locally used for domestic and livestock purposes.

The Arikaree Group and Brule Formation within the MEA meet the NDEQ definition (Nebraska Administrative Code Title 122, Chapter 1, Part 006) of an aquifer: "a geological formation, group of formations, or part of a formation that is capable of yielding a useable amount of water to a well, spring, or other point of discharge." For the purposes of permitting at MEA, alluvium is not considered an aquifer. Likewise, although thin sandstones are present within the upper Chadron Formation, drill cuttings, cores, and geophysical logs have not indicated a potential for the existence of water bearing units within any portions of the upper Chadron or middle Chadron Formation at the MEA. As described in Section 2.7.2.3 (confining layer), the upper Chadron and middle Chadron Formation constitute the confining unit between the basal sandstone of the Chadron Formation and overlying aquifers of the Brule Formation and Arikaree Group. Aquifer properties of the basal sandstone of the Chadron Formation are discussed in Section 2.7.2.2 in relation to aquifer pumping tests conducted in 2011.

Hydraulic conductivities for the Arikaree Group and Brule Formation were estimated using particle grain-size distribution data from core samples. Results of the particle size distribution analyses indicate sediments variably dominated by sands, silts, and clays. Hydraulic conductivity estimates were developed using the Kozeny-Carman equation, which is appropriate for sands and silts, but not for cohesive clayey soils with a high degree of plasticity. Published literature validates the use of the Kozeny-Carman equation for fine grained non-plastic silts (Carrier 2003). For samples that have high plasticity, hydraulic conductivity values are likely overestimated. Therefore, the Kozeny-Carman equation provides a conservative estimate of hydraulic conductivity. Additionally, Falling Head Permeameter Tests were completed on one Brule Formation core sample (M-2169C, Run 5, Sample 1) and one Upper Chadron Formation core (M-1635C, Run 3,

Sample 1). Both permeameter tests indicate measured hydraulic conductivity values two orders of magnitude lower than the estimated Kozeny-Carman results demonstrating the conservative nature of the Kozeny-Carman values.

Arikaree Group

The Arikaree Group contains multiple sand-dominated units that may represent locally water-bearing units. In general, these deposits are most likely to occur as buff to gray fine sand without abundant silt and clay within the Upper Harrison Beds, massively bedded, and poorly consolidated fine grained grey sandstones within the Harrison-Monroe Creek Formation, and coarse to fine grained sandstones of the Gering Formation. Many of the potential water-bearing units have limited lateral extent and are interbedded with low-permeability mudstone units. The lateral and horizontal distribution of these sandy-dominated units is highly variable, as they may range between ten to several hundred feet wide and can be up to 50 feet thick.

In 2013, ten wells were installed across the MEA to acquire Arikaree Group water level and water quality data (**Figure 2.7-8**). Nine of the ten wells encountered measurable water (**Figure 2.9-4a through 2.9-4d; Table 2.9-7**). The greatest saturated thickness (78 feet) was observed on the north end of the MEA in well AOW-8 with considerably thinner saturated intervals (0 to 35 feet) observed near the central portion of the project. Saturated thickness increased from the central portion of the MEA southward toward the Niobrara River to approximately 30 to 35 feet. One well (AOW-7) located in the west-central portion of the MEA, did not contain measureable water during well development or monitoring, even though a review of the well completion data indicate that the screened interval is below the observed potentiometric surface shown in **Figure 2.9-4a**. This well demonstrates the potential for locally restricted groundwater flow and overall unreliable nature of water within the Arikaree Group that has been observed elsewhere in Dawes and Sioux Counties.

A total of 10 core samples have been collected from the Arikaree Group for grain size analysis. Samples were collected from core intervals demonstrating visually observed textural compositions that ranged from siltstones to sandstones. Grain size analysis of core samples collected from the Arikaree Group indicates four samples dominated by sand-sized particles (M-533C Run 1 Sample 1; M-1912C Run 1 Sample 1; M-1912C Run 2 Sample 1; and M-1956C Run 1 Sample 1). Calculated hydraulic conductivity values for these samples range from 1.0×10^{-4} to 2.9×10^{-3} cm/sec. By contrast, the remaining core samples from the Arikaree Group are silt-dominated and have calculated hydraulic conductivity values ranging from 2.3×10^{-5} to 9.2×10^{-5} cm/sec. Based on grain size distributions, the average intrinsic permeability of sand-dominated units within the Arikaree Group is estimated to be approximately 1.5×10^{-6} cm^2.

Brule Formation

Within the Brown Siltstone Member of the Brule Formation, sandy siltstones, overbank sheet sandstones, and occasional thick sandstones may be locally water-bearing units. These sandstone and siltstone units can be difficult to correlate over any large distance and are often discontinuous lenses rather than laterally continuous strata. The Brule Formation produces widely variable amounts of water at MEA. CBR experience shows that, in typical water wells, flow in the Brule Formation can vary between 0.5 gpm to 50 gpm. At the upper end of the spectrum, agricultural well #732 produces in excess of 800 gpm from a 16-inch well. This variability in flow rate between wells within the same aquifer makes water production and aquifer thickness difficult to predict. Despite this characteristic, water supply wells are frequently completed in this unit.

At the base of the Brown Siltstone Member is a channel sandstone that has incised into the underlying Whitney Member and constitutes the first overlying aquifer above the production zone. This 10 to 35 foot thick sandstone is present across the entire MEA, as observed in drill cuttings and geophysical logs. Other sand-rich horizons that may produce water within the Brule Formation are also present above this lower sandstone, but are limited in lateral extent and do not extend across the entire MEA. **Figures 2.9-5a through 2.9-5d** shows the potentiometric surface as determined by groundwater level gauging of the 11 water wells that are completed in the Brule Formation. Because the Brule Formation potentiometric surface extends upward into the Arikaree Group, it can be assumed that the entire thickness of the overlying Brule Formation is saturated where local aquifer properties permit the flow of groundwater. That said, not all stratigraphic horizons of the Brule Formation are capable of producing water in useable quantities **(Appendix HH).**

A total of 13 core samples have been collected from the Brule Formation for grain size analysis, from units demonstrating a range in visually observed textural composition (mudstones to sandstones). However, grain size analysis of core samples collected from the Brule Formation indicate that all 13 samples are dominated by silt-sized particles. The two samples with the highest weight percent of sand (39.31 percent [M-1956C Run 4 Sample 1; 48.09 percent [M-1912C Run 3 Sample 1]) have calculated hydraulic conductivity values of 1.4×10^{-4} cm/sec and 2.3×10^{-4} cm/sec, respectively. By comparison, the geometric mean of all samples collected from the Brule Formation is 8.9×10^{-5} cm/sec. Based on grain size distributions, average intrinsic permeability of Brule Formation core samples is estimated to be approximately 4.2×10^{-7} cm^2.

Falling Head Permeameter Testing (ASTM D5084) of core sample (M-2169C, Run 5, Sample 1) from the Brule Formation returned an average measured hydraulic conductivity value of 1.31×10^{-7} cm/s. The same core sample (M-2169C, Run 5, Sample 1); using the Kozeny-Carman equation to calculate hydraulic conductivity based on particle grain size, results in an estimate of 5.4×10^{-5} cm/s. The difference between the two results is most likely due to the presence of high plasticity clay-sized particles that can result in an over estimated hydraulic conductivity value when calculated using the Kozeny-Carman equation.

The coefficient of variation (standard deviation divided by geometric mean) for all Brule Formation samples calculated using Kozeny-Carman are an order of magnitude less than for all Arikaree Group samples. This may represent a higher level of lithologic heterogeneity within the Arikaree Group and higher potential for local barriers to groundwater flow to be present.

Baseline groundwater monitoring for private water supply wells and CBR monitor wells (water levels and water quality) is presented in Section 2.9.3.

Basal Sandstone of the Chadron Formation

Discussions of the groundwater conditions for the basal sandstone of the Chadron Formation are presented below in Sections 2.7.2.2 and 2.7.2.3.

2.7.2.2 Aquifer Testing and Hydraulic Parameter Identification Information

Prior to initiation of ISR mining activities, the NDEQ regulations require hydrologic testing and baseline water quality sampling. During the initial permitting and development activities within

the MEA, an aquifer pumping test was performed between May 16 and May 20, 2011. The final report on pumping test activities in the MEA (Marsland Regional Hydrologic Testing Report – Test #8 [Aqui-Ver 2011]) is included in **Appendix F**. The pumping test was performed in accordance with the NDEQ approved Regional Pumping Test Plan dated September 27, 2010 (WorleyParsons 2010) and subsequent approved changes to the Regional Pumping Test Plan dated March 16, 2011 (Snowhite 2011). Testing activities and findings from pumping test activities in the MEA are summarized below.

Prior to testing activities, CBR installed 14 monitoring wells in the basal sandstone of the Chadron Formation (CPW-2010-1, CPW-2010-1A, Monitor-1, Monitor-2, Monitor-3, Monitor-4, Monitor 4A, Monitor-5, Monitor-6, Monitor-7, Monitor-8, Monitor-9, Monitor-10, and Monitor-11) and nine wells in the Brule Formation (BOW-2010-1, BOW-2010-2, BOW-2010-3, BOW-2010-4, BOW-2010-4A, BOW-2010-5, BOW-2010-6, BOW-2010-7, and BOW-2010-8; **Figure 2.7-6**). Well information for wells used during the 2011 pumping test is summarized in **Table 2.7-2**. Monitor-4 and BOW-2010-4 were replaced by Monitor-4A and BOW-2010A, respectively, prior to pumping test activities. To assess pre-test baseline water level fluctuations, water level data and barometric pressure data were recorded prior to the pumping period starting on May 6, 2011 for a period of 7 days before initiating the pumping test. The locations of wells used during pumping test #8 are shown in **Figure 2.7-7**. These data were interpreted as representative of static conditions within the aquifer. Based on these data, groundwater in the Brule Formation was interpreted to flow predominantly to the southeast toward the Niobrara River with a lateral hydraulic gradient of 0.011 ft/ft. (**Appendix F**).

To provide baseline groundwater elevation data for the pumping test, static water levels were collected from all 12 wells in the monitoring network on November 12, 2010 from the Brule Formation and the basal sandstone of the Chadron Formation. Water levels ranged from approximately 4,134 to 4,213 feet amsl in the Brule Formation and 3,709 to 3,714 feet amsl in the basal sandstone of the Chadron Formation (**Table 2.7-2**).

Static water levels of the Arikaree Group, Brule Formation, and Chadron Formation measured for existing and new CBR monitor wells in 2013 are discussed in Section 2.9.3.2.

As part of the NRC License Amendment Application to conduct ISR operations in the MEA, the 2011 regional groundwater pumping test was designed to accomplish the following:

- Evaluate the degree of hydraulic communication between the production zone pumping well and the surrounding production zone observation wells
- Evaluate the presence or absence of the production zone aquifer within the test area
- Assess the hydrologic characteristics of the production zone aquifer within the test area including the presence or absence of hydraulic boundaries
- Demonstrate sufficient confinement (hydraulic isolation) between the production zone and the overlying aquifer for the purpose of ISR mining

The 2011 pumping test was conducted while pumping at CPW-2010-1A at an average discharge rate of 27.08 gpm for 103 hours (4.29 days). Based on the drawdown response observed at the most distant observation well locations (Monitor 2 and Monitor 8), the radius of influence (ROI) during the pumping test was estimated to be in excess of approximately 8,800 feet. More than 0.8 foot of drawdown was achieved during testing in all observation wells completed in the basal

sandstone of the Chadron Formation in the observation well network, with a maximum drawdown of 23.40 feet observed in CPW-2010-1A (pumping well) during the test.

The drawdown response measured in all basal sandstone of the Chadron Formation observation wells monitored during the test confirm hydraulic communication between the production zone pumping well and the surrounding observation wells across the entire test area. During the test (pumping and recovery periods), no discernible drawdown or recovery responses attributed to the test were observed in overlying Brule Formation observation wells, which supports the conclusion that adequate confinement exists between the overlying Brule Formation and the basal sandstone of the Chadron Formation.

Drawdown and recovery data collected from observation wells were graphically analyzed to determine the aquifer properties, including transmissivity and storativity. The methods of analysis included the Theis (1935) drawdown and recovery methods and the Jacob Straight-Line Distance-Drawdown method (Cooper and Jacob 1946).

Estimated hydraulic parameters for individual well locations for the 2011 pumping test are summarized in **Table 2.7-3**. Results of the 2011 pumping test within the basal sandstone of the Chadron Formation indicate a mean hydraulic conductivity of 25 feet per day (ft/day; ranging from 7 to 62 ft/day) or 8.82×10^{-3} centimeters per second (cm/sec) based on an average net sand thickness of 40 feet and a mean transmissivity of 1,012 square feet per day (ft^2/day; ranging from 230 to 2,469 ft^2/day). Based on both the drawdown and recovery analyses, hydraulic conductivities of the aquifer materials in the vicinity of the pumping well (CPW-2010-1A, CPW-2010-1, and Monitor-3) were approximately three to nine times greater than hydraulic conductivities estimated for other observation wells in the pumping test area. An apparent higher conductivity boundary condition effect in these wells was indicated by a flattening of drawdown and recovery curves. Transmissivities for the recovery data were slightly higher than for the drawdown data and are considered more representative of the aquifer properties due to the slight variability in the discharge rate during the drawdown phase of the test. The mean storativity was 2.56×10^{-4} (ranging from 1.7×10^{-3} to 8.32×10^{-5}). Storativity units are a measure of the volumes of water that a permeable unit will absorb or expel from the storage unit per unit of surface area per unit of change in head. Storativity is a dimensionless quantity.

The hydrologic parameters observed at the MEA are consistent with, although slightly higher than, the aquifer properties determined for the areas of the CPF, TCEA, and NTEA (**Table 2.7-4**). No water level changes of concern were observed in any of the overlying wells during testing. The pumping test results demonstrate the following important conclusions:

- The pumping well and all observation wells completed in the basal sandstone of the Chadron Formation exhibited significant and predictable drawdown during the test, demonstrating that the production zone has hydraulic continuity throughout the MEA test area.
- The average transmissivity of the basal sandstone of the Chadron Formation within the portion of the MEA investigated during the test is significantly higher than the areas investigated within the TCEA, NTEA, and existing Crow Butte operations.
- A zone of relatively lower permeability is apparent in the vicinity of the pumping well (CPW-2010-1A) and observation wells CPW-2010-1 and Monitor-3, with significantly higher transmissivity noted elsewhere within the ROI of the test.



- Adequate confinement exists between the overlying Brule Formation and the basal sandstone of the Chadron Formation, as evidenced by no discernible drawdown in the Brule Formation observation wells.
- The hydrologic properties of the basal sandstone of the Chadron Formation have been adequately characterized within the majority of the proposed MEA to proceed with Class III UIC permitting and an NRC License Amendment Application for the MEA.

These conclusions indicate that, though variance in thickness and hydraulic conductivity may impact mining operations (e.g., well spacing, completion interval, and injection/production rates), it is not anticipated to impact regulatory issues.

Based on conclusions drawn from the geophysical and geologic sample logging and well development results, the lower Brule Formation is composed of non-aquifer sediments and it does not produce water in usable, significant or economic amounts and cannot be classified as an aquifer. Therefore, additional testing such as water quality, water level measurements and pumping tests were not recommended (**Appendix HH**). The first overlying aquifer to the mining zone at MEA should remain the Brown Siltstone Member of the upper Brule Formation.

2.7.2.3 Hydrologic Conceptual Model for the Marsland Expansion Area

Tables 2.6-1 and 2.6-2 present the regional and local stratigraphic columns in the vicinity of MEA. As discussed above in Section 2.7.2.1, aquifers within the stratigraphic section present at the MEA include permeable intervals of the Arikaree Group, permeable intervals in the Brown Siltstone Member of the shallow Brule Formation, and the deeper confined basal sandstone of the Chadron Formation. Discussions below describe the upper and lower confining units and the hydrologic conditions for the water-bearing intervals present at the MEA.

Confining Layers

Upper confinement for the basal sandstone of the Chadron Formation within the MEA is represented by 360 to 450 feet of smectite-rich mudstone and siltstones of the upper Chadron and middle Chadron (**Figures 2.6-3a** through **2.6-3n and 2.6-8**). Particle grain-size analyses of five core samples from the upper confining layer within the MEA indicate the samples were predominately siltstone. (**Appendix G-1 and G-2**). All MEA core samples were laboratory tested using ASTM D4464 methods for determining particle-size distributions by laser light scattering. The procedure is a modification of ASTM D4464-85 used to measure particle sizes of catalytic material. The procedure has been extended to include measurement of unconsolidated soils and sediments, and is recognized as an alternative to ASTM D422 (hydrometer) and the pipette method. X-Ray Diffraction (XRD) analyses indicate that the chemical compositions of core samples from the middle Chadron are highly similar to the Pierre Shale (e.g., predominantly mixed-layered illite/smectite or montmorillonite with quartz), which would be expected if the Pierre Shale was a contributing source of materials for the overlying middle Chadron (**Appendix G-1**).

The estimated hydraulic conductivities for the upper confining units were developed using the Kozeny-Carman method (**Appendix EE**) based on particle grain-size distribution data from the five core samples collected from the upper Chadron and middle Chadron. Use of the Kozeny-Carman method is acceptable for developing hydraulic conductivity estimates for sands and silts, but not for cohesive clayey soils with a high degree of plasticity. Results of the particle size

distribution analyses (**Appendix G-1, Appendix G-2**) indicate sediments dominated by silts and fine sand with less than 25% clay. Estimated hydraulic conductivities of the three core samples collected within the upper Chadron ranged from 4.3×10^{-5} to 5.9×10^{-5} cm/sec. Estimated hydraulic conductivities of the two core samples collected within the middle Chadron ranged from 1.7×10^{-5} to 2.9×10^{-5} cm/sec.

Falling Head Permeameter Testing (ASTM D5084) of core sample (M-1635C, Run 3, Sample 1) from the upper Chadron Formation returned an average measured hydraulic conductivity value of 1.32×10^{-7} cm/s. The same core (M-1635C, Run 3, Sample 1) using the Kozeny-Carman equation to calculate hydraulic conductivity based on particle grain size returned an estimate of 4.3×10^{-5} cm/s. The difference between the two results is most likely due to the presence of high plasticity clay-sized particles that can result in an over estimated hydraulic conductivity value when calculated using the Kozeny-Carman equation.

Hydraulic resistance to vertical flow is expected to be high due to the significant thickness of the upper confining zone which ranges from 360 to 450 feet. Vertical anisotropy will result in even lower vertical hydraulic conductivities across both the upper and lower confining layers. As a result, the Brule Formation and Arikaree Group are vertically and hydraulically isolated from the underlying aquifer proposed for exemption as shown in **Appendix AA-3** (AquiferTek, 2015).

Lower confinement for the basal sandstone of the Chadron Formation in the vicinity of the MEA is represented by approximately 750 to more than 1,000 feet of black marine shale deposits of the Pierre Shale. Additional low permeability confining units are represented by the underlying Niobrara Formation, Carlile Shale, Greenhorn Limestone, and Graneros Shale. Together with the Pierre Shale, these underlying low-permeability units hydraulically isolate the basal sandstone of the Chadron Formation from the underlying "D", "G", and "J" sandstones of the Dakota Group by more than 1,000 vertical feet (**Table 2.6-1**). The Pierre Shale is not a water-bearing unit, exhibits very low permeability, and is considered a regional aquiclude.

The Pierre Shale consists primarily of illite and smectite clays as indicated by x-ray diffraction of CBR core samples collected in 2011 and 2013 (**Appendix G-1** and **G-2**). The swelling nature of these clays in the presence of water makes it unlikely that any fractures or penetrations within the Pierre would provide a pathway for loss of confinement through this thick unit. Regional estimates of hydraulic conductivity for the Pierre Shale range from 10^{-7} to 10^{-12} cm/sec (Neuzil and Bredehoeft 1980; Neuzil et al. 1982; Neuzil 1993). The Pierre Shale has a measured vertical hydraulic conductivity at the CPF of less than 1×10^{-10} cm/sec (WFC 1983a), which is consistent with other studies in the region. Particle grain-size analyses of seven samples collected from the Pierre Shale within the MEA indicate low permeability silty clay compositions. Kozeny-Carman estimated hydraulic conductivities for the seven core samples collected within the Pierre Shale were not reported due to significant levels (up to 76 weight percent) of clay.

The upper surface of the Pierre Shale illustrated on **Figure 2.6-13** and cross-section A-A' (**Figure 2.6-3a**) is a gentle, southeasterly-sloping surface consistent with that described by DeGraw (1971). This sloping surface rises northwesterly to the axial crest of the Cochran Arch north of the MEA. Cross-section A-A' does not show evidence of major folding across the axis of the Cochran Arch that could have created significant vertical fractures within the Pierre Shale. Regional studies also indicate that there is no observed transmissivity between vertical fractures in the Pierre Shale, which if present, are short and not interconnected (Neuzil et al. 1982). All oil and gas wells in the

area of review which penetrate the Pierre Shale were abandoned in accordance with accepted regulatory practices at that time. Oil and gas well plugging records are provided as **Appendix D-1.**

Hydrologic Conditions

Potentiometric maps and cross-sections of the basal sandstone of the Chadron Formation indicate confined groundwater flow (**Figures 2.9-6a through 2.9-6d and 2.6-3a** through **2.6-3n**). Elevations of the potentiometric surface of the basal sandstone of the Chadron Formation indicate that the recharge zone must be located above a minimum elevation of 3,715 feet amsl. Confined conditions exist at the MEA as a result of an elevated recharge zone most likely located west or southwest of the MEA. The top of the basal sandstone of the Chadron Formation occurs at much lower elevations within the MEA, ranging from approximately 3,210 to 3,290 feet amsl (**Figures 2.6-3a** through **2.6-3n**).

In the vicinity of the MEA, groundwater flow in the basal sandstone of the Chadron Formation is predominantly to the northwest toward the White River drainage at a lateral hydraulic gradient of 0.0004 ft/ft (Aqui-Ver 2011). Regional water level information for the basal sandstone of the Chadron Formation is currently only available in the vicinity of the current production facility and the NTEA, but suggest a discharge point at an elevation of at least 3,700 feet amsl (or below) located east of Crawford, presumably at a location where the basal sandstone of the Chadron Formation is exposed.

Regional water level information for the Brule Formation is currently only available in the vicinity of the current production facility. However, within the MEA, groundwater generally flows to the southeast across the entire MEA toward the Niobrara River at a lateral hydraulic gradient of 0.011 ft/ft (Aqui-Ver 2011). Though the Brule Formation is the primary groundwater supply in the vicinity of the MEA, low production rates indicate that the discontinuous sandstone lenses of the Brown Siltstone Member may not be hydraulically well connected. Recharge to this unit likely occurs directly within the MEA, as the unit is unconformably overlain by 50 to 210 feet of overlying Arikaree Group and 0 to 30 feet of unconsolidated alluvial and colluvial deposits (depending on local topography). Alluvial deposits along the margins of the Niobrara River may offer limited groundwater storage depending on river levels.

At MEA, groundwater elevations for the Arikaree Group and the Brule Formation are distinctly different from those of the basal sandstone of the Chadron Formation (**Figures 2.6-3a** through **2.6-3n, Table 2.9-7**). The available water level data suggest hydrologic isolation of the basal sandstone of the Chadron Formation with respect to the overlying water-bearing intervals in the MEA. This inference is further supported by the difference in geochemical groundwater characteristics between the basal sandstone of the Chadron Formation and the Brule Formation (see Section 2.9.3; **Tables 2.9-8, 2.9-9, 2.9-10,** and **2.9-11**).

In summary, the following multiple lines of evidence indicate adequate hydrologic confinement of the basal sandstone of the Chadron Formation within the MEA.



- Results of the May 2011 aquifer pumping test demonstrate no discernible drawdown in the overlying Brule Formation observation wells screened throughout the MEA (see Section 2.7.2.2).
- Large differences in observed hydraulic head (330 to 500 feet) between the Brule Formation and the basal sandstone of the Chadron Formation indicate strong vertically downward gradients and minimal risk of naturally occurring impacts to the overlying Brule Formation (see Section 2.7.2.1).
- Significant historical differences exist in geochemical groundwater characteristics between the basal sandstone of the Chadron Formation and the Brule Formation (Section 2.9.3.3).
- Site-specific XRD analyses, particle grain-size distribution analyses, and geophysical logging confirm the presence of a thick (between 360 and 450 feet), laterally continuous upper confining layer consisting of low permeability mudstone and claystone, and a thick (more than 750 feet), regionally extensive lower confining layer composed of very low permeability black marine shale (see Section 2.7.2.3).
- Falling Head Permeameter testing of two core samples M-2169C, Run 5, Sample 1 (Brule Formation) and M-1635C, Run 3 (Chadron Formation), measured hydraulic conductivities of 1.31×10^{-7} and 1.32×10^{-7} cm/s, respectively.
- Analyses of particle size distribution results using the Kozeny-Carman equation suggests a conservative maximum hydraulic conductivity of 5.9×10^{-5} cm/s for core samples from the upper confining layer and an average estimated hydraulic conductivity of 3.7×10^{-5} cm/s. Actual hydraulic conductivities are expected to be at least one to two orders of magnitude lower as demonstrated by Falling Head Permeameter Testing of the core samples.
- Hydraulic resistance to vertical flow is expected to be high due to the significant thickness of the upper confining zone within the MEA.
- The vertical hydraulic conductivity across the upper and lower confining layers is likely to be even lower than 10^{-5} cm/sec due to vertical anisotropy (see Section 2.7.2.3).

2.7.2.4 Description of the Proposed Mining Operation and Relationship to Site Geology and Hydrology

The basal sandstone of the Chadron Formation is currently mined using ISR techniques within the mine units of the current Crow Butte operations and represents the production zone and target of solution mining in the MEA. Ore-grade uranium deposits underlying the MEA are located in the basal sandstone of the Chadron Formation (**Figure 1.4-1**). The ore body located within the MEA is a stacked roll-front system, which occurs at the boundary between the up-dip and oxidized part of a sandstone body and the reduced part of the sandstone body. Stratigraphic thickness of the unit within the MEA ranges from approximately 20 to 90 feet, with an average thickness of approximately 55 feet.

The unit occurs at depths ranging from about 850 to 1,200 feet bgs within the MEA (**Figures 2.6-3a** through **2.6-3n** and **2.6-12**). The competent upper confining layer consists of the overlying middle Chadron and upper Chadron, which are composed of predominantly clay, claystone, and siltstone. Based on extensive exploration hole data collected to date (more than 1,650 drill

locations), the thickness of the upper confining layers in the MEA range from 360 to 450 feet (**Figures 2.6-3a** through **2.6-3n** and **2.6-8**). Estimated hydraulic conductivities based on particle grain-size distribution analyses for site-specific core samples collected within the upper confining layer are on the order of 10^{-5} cm/sec (see Section 2.7.2.3). Geophysical logs from nearby oil and gas wells indicate that the thickness of the Pierre Shale lower confining layer ranges from approximately 750 to more than 1,000 feet (see discussions in Montana Group under Section 2.6.1.1). The full thickness of the Pierre Shale is not depicted on **Figures 2.6-3a** through **2.6-3n**, as the required scale would obscure stratigraphic details of the overlying White River Group. The Pierre Shale exhibits very low permeability on the order of 0.01 millidarcies (md; less than 1×10^{-10} cm/sec; Wyoming Fuel Company 1983).

Based on similar regional deposition, the MEA ore body is expected to be similar mineralogically and geochemically to that of the CPF. The ore bodies in the two areas are within the same geologic unit (i.e., basal sandstone of the Chadron Formation) and have the same mineralization source (see Section 2.6). The sites are separated by only a few miles, and the cause of mineral deposition in the two areas appears to be similar (see Section 2.6). Neither site is anticipated to be affected by any recharge or other processes that would uniquely affect each area, so the groundwater characteristics of the current Crow Butte mineralized zone are presumed to be representative of the MEA. **Table 2.7-5** is the Baseline and Restoration Values for MU 1 in the current Crow Butte operations area. The values in this table are expected to be representative of the geochemical characteristics of the MEA ore body. The MEA ore body, the outline of which is provided on **Figure 1.4-1,** is considered a zone of distinct water quality characteristics primarily due to the presence of relatively concentrated uranium and radium in the zone when compared to the concentrations of these parameters outside of the production zone (e.g., **Table 2.9-4**).

During the course of mining, the water quality is expected to change as outlined in **Table 2.7-6**. The chemicals used in the mining and recovery process will include sodium bicarbonate ($NaHCO_3$), and total dissolved solids (TDS). Significant increases are also likely to occur in calcium concentrations as a result of IX with clays. The oxidant will cause significant increases in uranium, vanadium, and radium and minor increases in trace metals such as copper, arsenic, molybdenum, and selenium. The genesis of the ore body and the facies of the host rock at the MEA are similar to that of the current Crow Butte site, so it is probable the change in water quality at the MEA will be similar to that experienced at the current Crow Butte site. Historical restoration activities at the current Crow Butte site have demonstrated the ability to successfully restore groundwater to established restoration standards. Groundwater restoration is discussed in detail in Section 6. The site-specific ISR mining process for the MEA is described in Section 3.1.5.

Net withdrawal within the wellfield must be maintained in order to capture injected mining solutions (see discussion below). Under NDEQ Title 122, Chapter 19, Section 002.02, injection of mining solutions shall not exceed the formation fracture pressure (see Section 3.1.3), but must be significant enough to overcome existing pressure heads within the confined aquifer while assuring that the pressure in the injection zone during injection does not cause migration of injection fluids into an underground source of drinking water. From an operations standpoint, procedures must be in place for responding to leaking well casings or well valves (see Section 3.1). Mechanical integrity testing is conducted following installation of all wells and subsequently every 5 years after a well begins operation. In addition, all wells that have had rig work completed with the drill string entering the well casing will be tested for mechanical integrity before being returned to service. Water quality is sampled bi-weekly at all monitoring well locations, which would detect an



excursion (i.e., presence of mining solutions). Contingency plans in the event of well failure are discussed in Section 7.5.4, which may either include identifying and patching the leaking well casing or abandoning the well if the leak cannot be repaired.

Maintenance of hydraulic control will be demonstrated by exterior monitoring wells surrounding each wellfield. Planned procedures for monitoring the capture of injected mining solutions are discussed in Section 3.1.3. These procedures include routine water level measurements in the production zone and overlying water-bearing zones and water quality sampling at monitoring wells every 2 weeks. Any changes in water levels or water quality within the production zone will be evaluated after sample collection to ensure that the system is operating properly and successfully. The proposed procedures will also allow for flow rate adjustments to ensure capture of mining fluids. ISR mining at the MEA will be undertaken via a recirculation system with a close mass balance resulting from the over-production (or bleed) rates. Within the wellfield and its vicinity, there will be local changes in head and flow direction. However, beyond the MEA license boundary, the magnitude of regional groundwater flow will not be meaningfully affected and will resume to regional flow conditions within a few hundred feet outside the license boundary. The monitoring procedures proposed in Section 3.1.3 are considered an adequate trigger for hydraulic adjustments to the production system in response to increases in pumping by private wells screened in basal sandstone of the Chadron Formation.

The hydrologic properties of the basal sandstone of the Chadron Formation must be known to formulate the best injection/extraction well arrays and for appropriate containment. Based on the pumping rate, test duration, and formation characteristics, the ROI (i.e., the area over which drawdown occurs) can also be determined for a given test. **Tables 2.7-3** and **2.7-4** present relevant hydrologic information based on an aquifer test performed in the MEA in May 2011, compared with the same properties in the CPF, NTEA, and TCEA. These data indicate that mean transmissivity and hydraulic conductivity at the MEA are more than adequate to successfully develop the MEA for ISR mining activities.

2.7.2.5 Lateral and Vertical Extent of the Proposed Exempt Aquifer

The lateral extent of the area requested being requested by CBR for an aquifer exemption under a separate application to the NDEQ is shown on **Figure 1.4-1**. The lateral extent of the proposed aquifer exemption is equivalent to the proposed NDEQ Class III UIC Application license boundary.

The vertical extent of the requested exemption is the full thickness of the basal sandstone of the Chadron Formation, which extends from the top of the Pierre Shale to the base of the middle Chadron (**Table 2.6-2; Figures 2.6-3a** through **2.6-3n**). This vertical extent is slightly different than the vertical extent requested and received in the 1983 Aquifer Exemption Petition for the current Crow Butte operations, which includes the middle Chadron and upper/middle Chadron, but it is similar to the vertical extent requested for the NTEA and TCEA.



This page intentionally blank

2.8 Ecological Resources

This section describes the existing ecological resources within the MEA. The potential impacts associated with the proposed project and mitigation measures that would offset such impacts are discussed in Section 7. The analysis consisted of a review of documents, databases, and reports in conjunction with biological field surveys to determine the potential impacts, if any, to special-status plant and wildlife species and their habitats in the proposed expansion area. Pre-existing baseline ecological studies, including field observations, agency contacts, and literature searches, have been conducted for several other uranium ISR projects in the general area of the MEA, including CBR's main processing facility and for the proposed NTEA and TCEA uranium ISR satellite facilities. Baseline studies date from 1982 through 2008 for these project sites. These studies are discussed in more detail in this section. The purpose of the consultations and associated correspondence was to help identify biological issues and potential occurrences and distribution of special-status plants and wildlife and their habitats.

2.8.1 Regional Setting

The project area occurs within the Western High Plains Level III ecoregion and is characterized by a semi-arid to arid climate, with annual precipitation ranging from 13 to 20 inches. Higher and drier than the Central Great Plains to the east, much of the Western High Plains comprises a smooth to slightly irregular plain having a high percentage of dryland agriculture. Potential natural vegetation in the Western High Plains ecoregion is dominated by drought-tolerant short-grass prairie and large areas of mixed-grass prairie in the northwest portion of the state. The northern portion of the project area occurs within the Pine Ridge Escarpment Level IV ecoregion, with ponderosa pine (*Pinus ponderosa*) woodlands associated with mixed-grass prairie on ridge tops and north-facing and east-facing slopes. The southern portion of the project area, predominantly rangelands, is made up of mixed-grass prairie with areas of moderate relief and is characteristic of the Sandy and Silty Tablelands Level IV ecoregion (Chapman et al. 2001).

2.8.2 Local Setting - Marsland Expansion Area

The proposed MEA is located in southwest Dawes County, Nebraska within sections 26, 35, and 36 T30N:R51W; sections 1, 2, 11, 12, and 13 T29N:R51W; and sections 7, 18, 19, 20, 29, and 30 T29:R50W. The project area encompasses 4,622.3 acres approximately 4.6 miles (7.4 km) northeast of Marsland, Nebraska (centerpoint of MEA satellite building to centerpoint of Town of Marsland; **Figure 1.7-3, Figure 2.2-1**). All of the land surface within the MEA license boundary and AOR is privately owned, with the exception of section 36 T30N R51W, which is State Trust Land. The southwest ¼ of section 36 is located within the MEA license boundary, with the surface and mineral rights under lease between Cameco and the State of Nebraska. **Figure 1.3-2** shows surface land ownership in the proposed MEA.

2.8.3 Climate

The proposed MEA near Crawford, Nebraska is located in a semi-arid or steppe climate. The area is characterized by abundant sunshine, low relative humidity, and sustained winds which lead to high evaporative demand. There are also large diurnal and annual variations in temperature. The region has cold, harsh winters; hot, dry summers; and relatively warm, moist springs and autumns.

Temperature extremes range from roughly -25° F in the winter to 100° F in the summer. The "last freeze" occurs during late May and the "first freeze" in mid to late September. The area has a growing season of approximately 120 days (HPRCC 2011).

Historical average minimum and maximum meteorological data (i.e., temperature, precipitation, and snowfall) typical of the Scottsbluff area are presented in **Table 2.8-1** (HPRCC 2011). Scottsbluff is located approximately 45 miles (72.4 km) to the southwest of the MEA. A detailed discussion of more recent and expanded meteorological data (2010 through 2011) considered representative of the MEA project site can be found in Section 2.5.

2.8.4 Pre-existing Baseline Data

Ecological studies have been conducted for several other mines in the general area of the MEA, including the CBR Crow Butte Uranium Project (Radioactive Source Materials License SUA-1534) and the TCEA. The first baseline study was conducted for the Crow Butte Mine in 1982 (WFC 1983b) and additional baseline data were collected in 1987, 1995, 1996, 1997, and 2004 (CBR 2007). Baseline data, including field observations, agency contacts, and literature searches, were conducted for the TCEA in 2005 and 2008 (CBR 2010a).

2.8.5 Terrestrial Ecology

The information presented in this report summarizes the baseline data collected for the Crow Butte Mine and TCEA between 1982 and 2008, and from field observations, surveys, and mapping conducted for the MEA in in 2011.

2.8.5.1 Methods

Baseline studies were performed during 2011 to determine presence or absence of federally or state-listed species as well as regional species of concern deemed by the state. Surveys were conducted in accordance with approved protocols established by state and federal agencies for: (1) winter bald eagle (*Haliaeetus leucocephalus*) roosts, (2) raptor nests, (3) burrowing owl (*Athene cunicularia*) nests, (4) black-tailed prairie dog (*Cynomys ludovicianus*) colonies, (5) swift fox (*Vulpes velox*), (6) threatened and endangered fish species, and (7) wetland habitat. In addition, amphibian breeding habitat was opportunistically documented, as well as all other wildlife species observed within or near the project area.

The goal was to document and summarize the ecological resources not only within the project area but also within a 2.5-mile (4.0-km) radius of the project area, referred to as the Ecological Study Area (ESA). The 2.5-mile (4.0-km) ESA boundary overlaps the 2.25-mile (3.62 km) AOR buffer. Aerial surveys conducted included the entire 2.5-mile (4.0-km) ESA, but groundwork was almost entirely restricted to the project area due to limited access to private lands. Thus, certain ecological resources within the 2.5-mile (4.0-km) ESA were identified using aerial surveys, documented from public roads, and/or mapped using National Agriculture Imagery Program (NAIP) imagery (e.g., prairie dog colonies). When possible, these resources were later verified and mapped from the ground if landowner permission was granted.

Information was also gleaned from recent field surveys conducted for the TCEA in 2005 and 2008, and from the baseline surveys conducted for the Crow Butte Mine in 1982. In 2005, primary floral



and faunal species were identified through observation to determine the distribution and composition of vegetation communities that occurred within the project area. Raptor surveys were also conducted and compiled with past ecological data collected during 2008.

2.8.5.2 Existing Disturbance

Human expansion into the region was prompted by the development of the transcontinental railroad by the Union Pacific Railroad during the late 1800s. As a result of this expansion, the region became a regional railroad trade hub and eventually a source for agriculture, intensive rangeland, mining, and human development. Disturbance within the project area is limited to one small residence (i.e., farmhouse), farming and ranching activity, watering sites for cattle (e.g., windmills, water tanks), improved gravel and unimproved two-track roads, and one small gravel pit.

2.8.5.3 Vegetation and Land Cover Types

Vegetation classifications were applied to the MEA through heads-up digitizing of NAIP imagery and categorized into eight vegetation communities similar to the definitions in the TCEA Technical Report (**Figure 2.8-1**). These communities include mixed-grass prairie, degraded rangeland, mixed-conifer, cultivated, drainage, structure biotope, range-rehabilitation, and deciduous streambank forest. The mixed-conifer vegetation type was not defined in the TCEA Technical Report, but was present in the MEA. The degraded rangeland class was added following field observations. Vegetation types were ground-truthed, and species composition of each type was recorded. Vegetation types represent a variety of species compositions and relative abundances. **Table 2.8-2** summarizes the abundance of vegetation types within the MEA.

The Chadron State College herbarium contains 468 plant species from Dawes County (WFC 1983c). In addition, the Institute of Agriculture and Natural Resources lists 603 native and 123 introduced plant species that occur in Dawes County. During the 1982 baseline study (WFC 1983c), more than 400 species of plants were collected (**Appendix H-1**).

Mixed-Grass Prairie

The most common vegetation type present in the MEA is mixed-grass prairie, comprising 64 percent of the area (**Table 2.8-2**). Common species observed in this vegetation type include the following grasses: needle-and-thread grass (*Hesperostipa comata*), junegrass (*Koeleria macrantha*), Sandberg bluegrass (*Poa secunda*), and threadleaf sedge (*Carex filifolia*). The non-native species cheatgrass (*Bromus tectorum*) and Kentucky bluegrass (*Poa pratensis*) were also abundant in this vegetation type. Common forbs observed included white sagebrush (*Artemisia ludoviciana*), fringed sagebrush (*A. frigida*), phlox (*Phlox sp.*), locoweed (*Oxytropis sp.*), lupine (*Lupinus sp.*), pussytoes (*Antennaria sp.*), and yucca (*Yucca glauca*). This vegetation type is the most common in the northern portion of the project area, and is quite variable in composition (**Figure 2.8-1**).

Degraded Rangeland

Areas where non-native species, predominantly cheatgrass, have overtaken the landscape are classified as degraded rangeland. Considerable portions of the southern half of the project area were observed to have larges patches dominated by cheatgrass (*Bromus tectorum*) and Kentucky bluegrass (*Poa pratensis*). The southernmost portion of the project area has large patches

dominated by smooth brome (*Bromus inermus*). Overall biodiversity in these areas is lower than in areas of mixed-grass prairie. While non-native grasses are common throughout the project area, the southern portion of the project area had sections that were particularly dominated by these species. The degraded rangeland vegetation type comprises 14.0 percent of the project area (**Table 2.8-2**; **Figure 2.8-1**).

Mixed Conifer

Mixed-conifer forests are concentrated along drainages in the northern third of the project area, often expanding out onto nearby hills and plains (**Figure 2.8-1**). This vegetation type is dominated by Ponderosa pine, with chokecherry (*Prunus virginiana*), skunkbush sumac (*Rhus trilobata*), and snowberry (*Symphoricarpus albus*) common in the understory. A combination of native and non-native grasses were common, with smooth brome (*Bromus inermus*) being particularly abundant in low-lying areas. Pussytoes was a commonly observed forb. Mixed-conifer forests comprise 9.1 percent of the project area, making this the most common of the forested vegetation types (**Table 2.8-2**).

Cultivated

Cultivated fields make up approximately 6.3 percent of the project area and include crops such as alfalfa (*Medicago sativa*), wheat (*Triticum* spp.), oats (*Avena* spp.), corn (*Zea mays*),. According to the Nebraska Agricultural Statics Service, corn, wheat and alfalfa made up the majority of crops grown in Dawes County from 2013-2015 (NASS 2016). In an environment not altered by humans, areas occupied by this vegetation type would most likely be occupied by mixed-grass prairie.

Drainages

Drainages in the south end of the project area are well drained and usually dry, covering 2.9 percent of the project area (**Table 2.8-2**; **Figure 2.8-1**). The vegetation composition in these intermittent tributaries to the Niobrara River is similar to that of surrounding grassland, though the vegetation is generally more robust. Meadow death camas *(Zigadenus venenosus)*, wild onion (*Allium sp.),* and monkeyflower (*Mimulus sp.)* were observed in these areas. In the north side of the project area, conifers dominate the overstory of drainages with smooth brome in the understory. Standing water was only observed in the northern portion of the survey area, mostly in the area mapped as deciduous streambank forest. The weed houndstongue (*Cynoglossum officinale*) was observed in low densities.

Deciduous Streambank Forest

Deciduous stands found along ephemeral streams make up a very small portion of the project area, totaling less than 1 percent (**Table 2.8-2**; **Figure 2.8-1**). The most common overstory species observed within this habitat type include eastern cottonwood (*Populus deltoides*), boxelder (*Acer negundo*), and willow (*Salix sp.*). Snowberry was the dominant shrub, with Kentucky bluegrass, smallwing sedge (*Carex microptera*), *Rumex sp.*, and annual mustards (*Brassicaceae sp.*) common in the understory.

Structure Biotopes

The term "structure biotopes" refers to man-made features, with the exception of cultivated land. Common examples include roads, highways, buildings, farmlands, cities, and industry infrastructure. This cover type comprises 1.5 percent of the project area (**Table 2.8-2**; **Figure 2.8-**



1). Dominant plant species in these areas are often non-native weedy species, including smooth brome, cheatgrass, white sweetclover (*Melilotus alba*), yellow sweetclover (*Melilotus officinalis*), and mustard species.

Range Rehabilitation

Previously cultivated fields are defined as range rehabilitation areas, and are generally heavily grazed. Seasonal haying is also an important component of these areas. Vegetation of this habitat type is variable, with weedy species being more prevalent in areas with greater disturbance from cattle. Crested wheatgrass (*Agropyron cristatum*) was the dominant grass species observed, while fringed sagebrush was also common. This habitat type comprises less than 1.5 percent of the project area (**Table 2.8-2**; **Figure 2.8-1**).

2.8.6 Mammals

Information concerning current and historical mammal observations and distribution within and near the MEA were obtained from a variety of sources including the NGPC and the Nebraska Natural Heritage Program (NNHP). The NNHP is a primary repository for wildlife information in the State of Nebraska and contains records of wildlife observations for birds, mammals, herptiles, fish, and species at risk in the state. Wildlife information for the MEA was supplemented with survey data collected by Hayden Wing Associates during spring/summer 2011 as part of the baseline and monitoring data requirements. A list of known and expected mammal species for Dawes County can be found in **Appendix H-2**.

2.8.6.1 Big Game

Six big game species occur or potentially occur in the vicinity of the MEA, including pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), elk (*Cervus elaphus*), bighorn sheep (*Ovis canadensis*), and bison (*Bison bison*). Big game populations are managed by the NGPC. Population objectives are set annually based on multiple factors including, but not limited to, the carrying capacity of the habitat, herd production and health, and weather (e.g., drought).

Pronghorn

Pronghorn typically inhabit grasslands and semi-desert shrublands of the western and southwestern United States. This species is most abundant in short- and mixed-grass habitats and is less abundant in more xeric habitats. Home ranges for pronghorn can vary between 400 and 5,600 acres, according to several factors including season, habitat quality, population characteristics, and local livestock occurrence. Typically, daily movement does not exceed 6 miles (9.6 km). Some pronghorn make seasonal migrations between summer and winter habitats, but these migrations are often triggered by availability of succulent plants and not local weather conditions (Fitzgerald et al. 1994). Pronghorn occur mainly in the western half of Nebraska, with the highest densities occurring in Sioux and Dawes Counties. In Nebraska, this species primarily inhabits short-grass prairies and badlands (NGPC 2011b).

The project area is located in the Box Butte Antelope Hunt Unit, which extends from the Wyoming/Nebraska border, north from the North Platte River, east to Nebraska Highway 250, and south from the Pine Ridge Escarpment. In 2007 and 2008, 34 and 32 pronghorn, respectively, were

harvested within this hunt unit (NGPC 2008a). In 2009, 36 pronghorn were harvested (NGPC 2010), and in 2010, 48 pronghorn were harvested (NGPC 2011c). Pronghorn populations in Nebraska are increasing, and harvest is at a 25-year high (NGPC 2011c). Pronghorn were observed regularly throughout the project area in 2011 and they appear to be relatively common year-round.

Mule Deer

Mule deer occur throughout western North America from central Mexico to northern Canada. Mule deer are found throughout Nebraska, but are more common in the western half of the state (NGPC 2011b). They inhabit a wide variety of habitats (e.g., sagebrush-steppe, grasslands, foothills) and feed on succulent grasses, forbs, shrubs, and agricultural crops. Mule deer tend to have elevational migrations, moving from uplands during the warmer months to lowlands in the winter where denser, taller vegetation cover allows for manageable snow levels for foraging (Fitzgerald et al. 1994). Mule deer fawn mortality is typically due to predation or starvation. Adult mortality often occurs from hunting, winter starvation, and automobile collisions. Typical mule deer predators may include coyotes, bobcats, golden eagles, mountain lions, bears, and domestic dogs (Fitzgerald et al. 1994).

The MEA is located within the Pine Ridge Mule Deer Hunt Unit, which encompasses areas of Box Butte, Dawes, Sheridan, and Sioux Counties north of the Niobrara River and west of Nebraska Highway 27. Due to concerns with harvest of buck deer, the NGPC conducted a study (based on aged sample projected by total kill) of adult bucks 2.5 years or older during the 1987, 1992, and 1997 regular firearm hunting seasons. Adult mule deer buck harvest in the Pine Ridge unit for 1987, 1992, and 1997 was 202, 446, and 385, respectively (NGPC 2011d). The adult mule deer buck harvest for the Pine Ridge unit was 735 in 2008 (NGPC 2008a) and 922 in 2009 (NGPC 2010). In 2010, 10,709 mule deer were harvested in Nebraska; 957 of these were adult bucks harvested in the Pine Ridge Unit (NGPC 2011c). Mule deer were seen within the project area during field work in 2011 but not in high numbers, though numbers are likely higher during winter.

White-tailed Deer

White-tailed deer occur throughout North America from the southern United States to Hudson Bay in Canada. Across much of its range, this species inhabits forests, swamps, brushy areas, and nearby open fields. In Nebraska, white-tailed deer are found throughout the state, but have higher densities in the eastern half. They are typically concentrated in riparian woodlands, mixed-shrub riparian areas, and irrigated agricultural lands, and are generally absent from dry grasslands and coniferous forests (NGPC 2011b). White-tailed deer have a diverse diet, capitalizing on the most nutritious plant matter available at any time. In addition to native browse, grass, and forbs, this species often relies on agricultural crops, fruits, acorns, and other nuts. Mortality of white-tailed deer is typically related to hunting, winter starvation, collisions with automobiles, and predation. Predators may include coyotes; mountain lions; wolves; and occasionally bears, bobcats, and eagles (Fitzgerald et al. 1994).

White-tailed deer hunting in the region encompasses the same unit as previously described for mule deer. Results of the white-tailed deer buck harvest for the Pine Ridge area were 186, 318, and 363 in 1987, 1992, and 1997, respectively (NGPC 2011d). In 2008 and 2009, the white-tailed deer adult buck harvest for the Pine Ridge unit was 824 (NGPC 2008a) and 1,053 (NGPC 2010), respectively. In 2010, the white tailed deer adult buck harvest for the Pine Ridge Unit was 1,252 (NGPC 2011c). According to the NGPC (2011b), the fall white-tailed deer population in Nebraska

is estimated to be between 150,000 and 180,000 animals. Currently, the NGPC has a goal of reducing white-tailed deer populations in eastern Nebraska by increasing harvest numbers. In 2010, a record 77,028 white-tailed deer were harvested in the state (NGPC 2011e).

Within the MEA, white-tailed deer were commonly seen during the 2011 survey around the agricultural and riparian habitats, but they were also seen in the higher elevations and in the forested areas.

Elk

Elk formerly ranged over much of central and western North America from the southern Canadian Provinces and Alaska south to the southern United States, and eastward into the deciduous forests. In Nebraska, this species occurs primarily in the northwestern region in a variety of habitats, including coniferous forests, meadows, short- and mixed-grass prairies, and sagebrush and other shrub lands. Similar to other members of the deer family, this species relies on a combination of browse, grasses, and forbs, depending on their availability throughout the seasons. Elk tend to be migratory, moving between summer and winter ranges. Typically, mortality is a result of predation on calves, hunting, and winter starvation. Predators may include coyotes, mountain lions, bobcats, bears, and golden eagles (Fitzgerald et al. 1994).

NGPC estimates the state elk population at approximately 2,300 individuals, and most of the population inhabits the Pine Ridge area (NGPC 2011f). The Marsland Project Area is located in the Pine Ridge area, within the Ash Creek Elk Unit, specifically located east of Nebraska Highway 2, north of Spur L7E and west of U.S. Highway 385. The 2008 elk harvest was 73 individuals in the Pine Ridge area, and 10 individuals in the Ash Creek Elk Unit (NGPC 2008a). The 2009 elk harvest was 85 individuals in the Pine Ridge area, and 17 individuals in the Ash Creek Elk Unit (NGPC 2010). In 2010, elk harvest in the Pine Ridge included 114 individuals (17 in the Ash Creek Elk Unit) with an estimated 1,000 to 1,200 individuals comprising the population (NGPC 2011c).

Relatively large numbers of elk are known to occur year-round within the project area. During the fall and winter, the elk occupy many of the agricultural fields and lower elevation upland habitat. Although still found in the lower elevations during the spring and summer, the majority of the herd appears to move north to higher elevations in the forested portions of the Pine Ridge during the warmer portions of the year.

Bighorn Sheep

Prior to the 1900s, the Audubon bighorn sheep (*O. canadensis auduboni*) inhabited parts of western Nebraska including the Wildcat Hills, the Pine Ridge, along the North Platte River to eastern Lincoln County, and along the Niobrara River. It is thought that the Audubon bighorn probably became extinct in the early 1900s, with its last stronghold being the South Dakota badlands (NGPC 2011b).

Bighorn sheep were reintroduced into Nebraska in the early 1980s; the current population is estimated at 300 sheep, divided between two populations in the Pine Ridge and Wildcat Hills (NGPC 2011c). The reintroduction project began in 1981, when 12 bighorn sheep were first released in Fort Robinson State Park. Between 1988 and 1993, a total of 44 sheep were released in the state park. Twenty-two sheep were released in the Wildcat Hills south of Gering, Nebraska in 2001, and in 2005, an additional 49 were released into the Pine Ridge area. The most recent

reintroduction occurred in 2007, with 51 bighorn sheep from Montana released in the Wildcat Hills south of McGrew, Nebraska (NGPC 2011g). As a result of disease, herd growth is limited; consequently, only a single lottery and a single auction permit were authorized for bighorn sheep hunting in 2011 (NGPC 2011c). Appropriate escape terrain habitat is not present within the MEA, and it is therefore extremely unlikely that bighorn sheep would occur within the project area.

Bison

Fort Robinson State Park currently manages a herd of 200 bison. These bison are contained in a compound and do not occur within the project area boundary.

2.8.6.2 Carnivores

The following species have been documented or are expected to be present within the MEA: coyotes (*Canis latrans*) and red foxes (*Vulpes vulpes*) typically occupy grassland, shrub-steppe, and agricultural habitats; long-tailed weasels (*Mustela frenata*) are habitat generalists and can be found in a wide variety of habitats; bobcats (*Lynx rufus*) tend to occupy woodland and shrubland habitat; badgers (*Taxidea taxus*) inhabit areas with loose soils that are suitable for digging burrows which frequently includes roadsides, prairie dog colonies, and areas near surface disturbance; and mountain lions (*Puma concolor*) prey upon mule and white-tailed deer and tend to occupy wooded habitats. Coyotes are considered non-game species, and residents do not need a permit to harvest this species. Mountain lion permits are not available, and lions cannot be trapped or hunted in Nebraska. Badger, bobcat, long-tailed weasel, raccoon (*Procyon lotor*), red fox, and striped skunk (*Mephitis mephitis*) are open to hunting and trapping with appropriate permits.

Using infrared-triggered remote trail cameras, which were deployed for documenting the presence/absence of swift fox (see Section 2.8.9). Hayden Wing Associates documented the presence of coyotes and badgers within the project area (HWA 2011). Several other carnivore species are expected to be present, such as red fox, bobcat, raccoon, striped skunk, and long-tailed weasel, even though they were not detected by the cameras.

2.8.6.3 Small Mammals

Small mammals occupy a wide variety of habitats within the region but most are considered common and widespread. Species known to occur or that are potentially present in the MEA include the deer mouse (*Peromyscus maniculatus*), white-footed mouse (*Peromyscus leucopus*), thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), meadow jumping mouse (*Zapus hudsonius*), plains pocket gopher (*Geomys bursarius*), least chipmunk (*Tamias minimus*) and meadow vole (*Microtus pennsylvanicus*). Muskrat (*Ondatra zibethicus*) and beaver (*Castor canadensis*) are known to occur in or near the project area, especially near the Niobrara River along the southern edge of the project area. Porcupine (*Erethizon dorsatum*) occurs in the wooded areas of the project area, as does the eastern fox squirrel (*Sciurus niger*). Four rabbit species are known or suspected to occur within the project area, including the white-tailed jackrabbit (*Lepus townsendii*), black-tailed jackrabbit (*Lepus californicus*), eastern cottontail (*Sylvilagus floridanus*), and desert cottontail (*Sylvilagus auduboni*) (HWA 2011).

Two bat species have been recorded within a few miles of the MEA: the fringe-tailed myotis (*Myotis thysanodes pahasapensis*) and the long-legged myotis (*Myotis volans*). Both bat species are listed at Tier I At-Risk species by Nebraska Natural Legacy Project (NNLP), and the fringe-

tailed myotis is listed as Sensitive in the nearby Pine Ridge Ranger District by the U.S. Forest Service (USFS) Nebraska National Forest. According to the USFS (Abegglen, pers. comm. 2011), the fringe-tailed myotis is known to occur in the Ponderosa pine habitat near the MEA. Both species may be present in the project area if suitable hibernacula exist (e.g., caves, mines, buildings, cliff crevices, hollows in snags, or hollow areas under the bark of trees). Also, it is likely that these and other bat species use the project area for foraging, but no formal bat surveys were conducted by HWA in 2011.

Black-tailed prairie dogs, which are listed as Sensitive in the Pine Ridge Ranger District by the USFS, are known to occur in the vicinity of the project area. Four colonies were found during aerial surveys: two are situated along the project area border, and two are located within a 2.5-mile (4.0-km) ESA (HWA 2011). All four are occupied with prairie dogs. The smallest is only 0.63 acre in size, which is located just east of the project boundary in section 7, T29N:R50W. The other colony that borders the project area is approximately 20 acres in size and is located in section 30, T29N:R50W. The current boundaries of both of these colonies were mapped on foot in 2011. The two colonies in the 2.5-mile (4.0-km) ESA were much larger: one south of the project area measured 47 acres and one east of the project area measured 151 acres in size. The southernmost colony (section 36, T29N:R51W and sections 2 and 3, T28N:R51W) was mapped entirely using NAIP 2010 imagery due to a lack of access, but the colony to the east (sections 16 and 21, T29N:R50W) was partly mapped from the ground (i.e., portion in section 21), and the remaining portion was mapped using NAIP imagery due to a lack of landowner access permission. Prairie dogs, groundhogs (*Marmota monax*), and porcupine are considered non-game species in Nebraska, and residents do not need a permit to harvest these species. Prairie dog colonies, however, provide habitat for several other at-risk or sensitive species, such as swift foxes, long-billed curlews (*Numenius americanus*), ferruginous hawks (*Buteo regalis*), and burrowing owls. Therefore, avoidance of prairie dog colonies is recommended by the U.S. Fish Wildlife Service (USFWS) and NGPC for projects involving ground disturbance activity.

2.8.7 Birds

The Nebraska Ornithologists Union lists 291 bird species occurring in Dawes County (**Appendix H-3**) and 455 species recorded in the state (NOU 2011). Of the 455 species in the state, 329 occur regularly (reported 9 out of the past 10 years); 78 are accidental (occurring less than two times in the past 10 years); 42 are casual (occurring between four and seven times in the past 10 years); four are extirpated, and two are extinct (NOU 2011). During a survey conducted in 1982, 201 bird species were documented in an area just north of the MEA (CBR 2010a). Although formal point count bird surveys were not performed for the project area, a total of 73 bird species were documented in and around the project area in 2011, the majority of which are believed to breed locally (HWA 2011). Of the 73 species, 68 were documented during the 1982 baseline survey, four were listed as "reported by knowledgeable individual" in previous ecological surveys (blue jay [*Cyanocitta cristata*], eastern bluebird [*Sialia sialis*], northern mockingbird [*Mimus polyglottos*], and peregrine falcon [*Falco peregrinus*]), and one was new for the list of species (Eurasian collared-dove [*Streptopelia decaocto*]).

2.8.7.1 Passerines

Many species of passerines (perching birds, including songbirds) use the MEA for breeding, feeding, migration, wintering, and as year-round habitats. All habitats throughout the project area



are likely used to some degree by various species. The Migratory Bird Treaty Act (16 USC, §703 *et seq.)* protects 836 migratory bird species (to date) and their eggs, feathers, and nests from disturbances (USFWS 2011a). See **Appendix H-3** for a list of known or expected bird species for the project area and surrounding 2.5-mile (4.0-km) ESA.

The Crawford Breeding Bird Survey (BBS) route passes within 4 miles (6.4 km) of the MEA to the north. In an analysis of data collected along this BBS route from 1966 to 2007, the five most abundant species were western meadowlark (*Sturnella neglecta*; 181.1 birds per route), mourning dove (*Zenaida macroura*; 56.1 birds per route); American robin (*Turdus migratorius*; 18.1 birds per route); American crow (*Corvus brachyrhynchos*; 16.4 birds per route); and lark sparrow (*Chondestes grammacus*; 16.3 birds per route) (Sauer et al. 2011).

2.8.7.2 Upland Game Birds

Wild turkey (*Meleagris gallopavo*), ring-necked pheasant (*Phasianus colchicus*), gray partridge (*Perdix perdix*), and sharp-tailed grouse (*Tympanuchus phasianellus*) occur in the MEA. The site is located in the Panhandle hunting region for upland game birds and is managed by the NGPC. Wild turkeys in the Pine Ridge area use habitats in the foothills, plateaus, forest habitats, and riparian draws and are likely to be distributed throughout the project area. Ring-necked pheasants often use open grasslands and agricultural areas and are fairly common. Gray partridge, which are introduced and uncommon, are often located in areas near dense shrub cover. Sharp-tailed grouse inhabit open grassland and steppe habitats with scattered trees and shrubs. The scattering of trees and shrubs plays an important role in their life cycle for food and cover, and this species is known to occur in the project area in low numbers. Upland game birds designated as migratory that are confirmed or potentially present in the project area include mourning dove, Virginia rail (*Rallus limicola*), sora (*Porzana carolina*), and Wilson's snipe (*Gallinago delicata*). Mourning doves occupy a wide variety of habitats including sagebrush, grasslands, shrubland, and riparian areas. Sora and Virginia rail typically occupy areas near wetlands, and snipe are frequently found in flooded fields and ditches (HWA 2011).

2.8.7.3 Raptors

Several raptor species are known or expected to occur in or around the MEA. Grasslands, shrublands, and scattered trees provide suitable nest substrates for a variety of species for breeding, hunting, and wintering. The Niobrara River drainage immediately south of the site provides habitat for tree-nesting species and provides potential roosting sites for wintering raptors (e.g., bald eagle, rough-legged hawk [*Buteo lagopus*]). All raptors and their nests are protected from "take" or disturbance under the Migratory Bird Treaty Act (16 USC, §703 *et seq.*; USFWS 2011a). Golden eagles and bald eagles also are afforded additional protection under the Bald and Golden Eagle Protection Act, amended in 1973 (16 USC, §669 *et seq.*). In addition, several raptor species are considered at-risk or sensitive by NNLP and/or Nebraska National Forest-Pine Ridge Ranger District.

Aerial surveys were conducted for documenting raptor nests throughout the MEA and the 2.5-mile (4.0-km) ESA on April 28 and May 13, 2011. A ground survey for confirming nest locations, determining nest status, and searching for new nests was conducted from May 10 to 12, 2011. The ground survey was limited to the project area and areas adjacent to public roads in the 2.5 ESA due to minimal access to private lands. Additional ground surveys for determining productivity of

known nests, including nests in the 2.5-mile (4.0-km) ESA found during the aerial surveys, were conducted from June 7 to 8 and July 7 to 8, 2011 (HWA 2011).

A total of seven raptor nests were documented within the MEA during 2011, including two active red-tailed hawk (*Buteo jamaicensis*) nests, two active burrowing owl nests, one active great horned owl (*Bubo virginianus*) nest, and two inactive stick nests of unknown species (**Figure 2.8-2**). An additional 19 nests were documented within the 2.5-mile (4.0-km) ESA, including five active red-tailed hawk nests, two active great horned owl nests, nine active burrowing owl nests, one active Swainson's hawk (*Buteo swainsoni*) nest, one active ferruginous hawk nest, and one inactive stick nest of an unknown species. One additional active great horned owl nest was located just outside the 2.5-mile (4.0-km) ESA (HWA 2011). Of the five species documented to be nesting in and around the MEA, two (ferruginous hawk and burrowing owl) are designated by the NNLP as Tier I At-Risk species. All but one of the burrowing owl nests were found in active prairie dog colonies.

Of the five active nests in the MEA, only one great horned owl nest (nest #13) and one red-tailed hawk nest (nest #20) were confirmed productive (i.e., at least one fledged chick) at the time of the last survey. Both great horned owl nests in the 2.5-mile (4.0-km) ESA had large chicks during the first ground survey and both likely fledged young, and red-tailed hawk nest #12 in the 2.5-mile (4.0-km) ESA was confirmed productive during the last survey. The remaining active nests still had young to medium-aged nestlings when surveyed last or, in the case of the burrowing owl nests, production could not be determined due to chicks remaining underground or the burrow entrances being too obscured by vegetation to observe chicks during the final ground survey (HWA 2011).

Several additional raptor species were observed in and around the project area during the spring surveys, including Cooper's hawk (*Accipiter cooperii*), northern harrier (*Circus cyaneus*), golden eagle (*Aquila chrysaetos*), American kestrel (*Falco sparverius*), and peregrine falcon (HWA 2011).

With the exception of peregrine falcons, for which little nesting habitat exists within the project area, all the other species are possible breeders in and around the project area. Other species documented within 10 miles (16.1 km) of the MEA and that have the potential to occur and breed within the MEA include bald eagle, osprey (*Pandion haliaetus*), merlin (*Falco columbarius*), prairie falcon (*Falco mexicanus*), sharp-shinned hawk (*Accipiter striatus*), northern goshawk (*Accipiter gentilis*), short-eared owl (*Asio flammeus*), long-eared owl (*Asio otus*), barn owl (*Tyto alba*), northern saw-whet owl (*Aegolius acadicus*), and eastern screech owl (*Megascops asio*). Rough-legged hawks are common within the MEA during the winter, and other species that have the potential to occur during migration or winter include broad-winged hawk (*Buteo platypterus*), red-shouldered hawk (*Buteo lineatus*), gyrfalcon (*Falco rusticolus*), and snowy owl (*Bubo scandiacus*).

Northern goshawk, Cooper's hawk, and sharp-shinned hawk are typically forest-nesting raptors. Potential nesting habitat includes scattered, mixed-conifer forests which are located in the northern portion of the project area and in the 2.5-mile (4.0-km) ESA. These forests may also provide nesting habitat for red-tailed hawks, osprey, merlins, American kestrels, and long-eared owls. Owls and falcons with only a few exceptions are dependent on other species for the availability of nests. Long-eared owls and merlins are secondary stick nesters (they use stick nests of other species, such as magpies and crows), and the smaller owls and kestrels are secondary cavity nesters (they use tree cavities established by other species, such as woodpeckers). Ferruginous hawks are found primarily in mixed-grass prairie and sagebrush steppe habitats during the spring, summer, and fall.

They generally build nests on the ground, rock outcrops, cliff ledges, or small isolated trees. The one ferruginous hawk nest documented in the 2.5-mile (4.0-km) ESA of the project is in a small isolated tree. Swainson's hawks typically nest in small trees or large shrubs along water features (e.g., irrigation ditches, streams), frequently near agricultural areas. Within the project area, the majority of *Buteo* nests are located in the deciduous trees along the Niobrara River, shelterbelts, trees around farmhouses and old homesteads, and the Ponderosa pine trees in the northern portion of the project area. Golden eagles commonly nest on cliffs and in large trees. Although cliff habitat is limited within the project area, golden eagle nests are known to occur just north of the project area, and suitable nesting habitat (i.e., large trees) occurs within the MEA and the 2.5-mile (4.0-km) ESA. Prairie falcons and peregrine falcons are strictly cliff-nesting species, and although they have been documented near the project area, cliff habitat within the project area is limited and nests are unlikely (HWA 2011).

Wintering Bald Eagles

All potential bald eagle roosting habitat within 2.5 miles (4.0 km) of the MEA was surveyed on three separate occasions during the 2010/2011 winter (HWA 2011). Potential roosting habitat was defined as any medium or large deciduous or coniferous tree or group of trees. All potential habitat was identified and delineated using NAIP imagery from 2010. Aerial surveys were conducted using a Cessna 172 fixed-winged aircraft. Survey dates included December 14, 2010, January 12 and February 8, 2011, and all surveys were conducted between 30 minutes pre-sunrise to 1 hour post-sunrise or between 1 hour pre-sunset to 30 minutes post-sunset. Large blocks of potential habitat (i.e., conifer forest) were flown using north-south transects spaced by 0.5 mile (0.8 km). Linear habitat (i.e., riparian habitat) was flown by flying parallel to the habitat type. Information recorded for each eagle sighting included number of adults, number of subadults, behavior, and perch type.

During the winter surveys, no bald eagles were seen within the MEA and one adult bald eagle was seen on one occasion (Dec. 14, 2010) in the 2.5-mile (4.0-km) ESA. The results suggest bald eagles are present in the vicinity of the MEA during the winter and likely use the surrounding habitat for feeding and roosting, but apparently regularly attended roost locations are not present even though suitable roosting habitat exists in the area (HWA 2011).

2.8.7.4 Waterfowl

During spring and fall migration, some waterfowl species may use the area for feeding, nesting, or resting, specifically those areas along the Niobrara River which occur within the 2.5-mile (4.0-km) ESA, but little open water exists within the project area. Box Butte Reservoir is likely used heavily during migration; however, this waterway is just outside the 2.5-mile (4.0-km) ESA. The baseline study in 1982 documented 24 species of waterfowl (CBR 2010a). A complete list of waterfowl species that may potentially occur in the project area is included in **Appendix H-3**.

2.8.8 Reptiles and Amphibians

The baseline study in 1982 documented 13 species of reptiles and amphibians (CBR 2010a). Though formal surveys were not conducted for the MEA, several species of herptiles were documented opportunistically, including: plains spadefoot toad (larval stage) (*Spea bombifrons*), northern leopard frog (*Rana pipiens*), and common snapping turtle (*Chelydra serpentina*). Only

the spadefoot toads were found within the project area; the other two species were found along the Niobrara River corridor near the project area. The spadefoot toad tadpoles were found in a small ephemeral wetland in NW section 13, T29N:R51W. Identification of the tadpoles to species was aided by D. Ferraro, Extension Associate Professor and Herpetologist, School of Natural Resources, University of Nebraska-Lincoln (Ferraro, pers. comm. 2011). A complete list of known or expected herptiles for Dawes and Box Butte Counties can be found in **Appendix H-4** (Fogell 2010).

2.8.9 Threatened, Endangered, or Candidate Species

Under the Federal Endangered Species Act (FESA) of 1973 and the Nongame and Endangered Species Conservation Act (Neb. Rev. Stat. §37-430 *et seq.*), several species receive unique protections due largely to their rarity, population declines, and/or habitat loss. A summary of potentially occurring threatened and endangered species within the MEA is presented in **Table 2.8-3** (also see **Appendix H-7** for range maps in Nebraska).

Black-footed Ferret

The black-footed ferret (*Mustela nigripes*) is listed by the USFWS as endangered and is considered the most endangered mammal species in the United States. Several factors have contributed to declines in ferret populations, including eradication of prairie dogs by humans and disease outbreaks (i.e., sylvatic plague and canine distemper). Distributions of black-footed ferrets closely correspond to those of prairie dogs. Black-footed ferrets depend heavily on prairie dogs for food and they also use prairie dog burrows for shelter, parturition, and raising young. Black-tailed prairie dog colonies occur in the project area. However, no known ferret populations occur in Nebraska (NGPC 2011b), therefore, the likelihood of black-footed ferrets occurring within the project area is minimal.

Whooping Crane

The whooping crane (*Grus americana*) is North America's tallest bird, with males close to 5 feet tall. The species is listed as endangered by USFWS and NGPC, and according to USFWS, they have the potential to occur in Dawes County (USFWS 2011b). Whooping cranes migrate through central Nebraska during spring and fall, and primarily stop over along the Platte River Valley (NGPC 2011b). Whooping cranes use a variety of habitats during the non-breeding season, including wetland mosaics, cropland, and riverine habitat in Nebraska. They depend on seasonally and semi-permanently flooded wetlands for roosting. Such habitat is limited or absent in the MEA. The USFWS maintains a database of confirmed whooping crane sightings within the known migration corridor for this species. According to this database, there has been one confirmed whooping crane sighting in Dawes County in the last 50 years: a sighting of one individual adult whooping crane in 1991, approximately 17 miles (27.3 km) north of the MEA (USFWS 2011c). It is unlikely that whooping cranes would occur within or near the project area due to the lack of suitable habitat.

Gray Wolf

Gray wolves were first listed as endangered in the lower 48 states in 1967. After decades of intensive management, including reintroductions in Idaho and Wyoming, the species was delisted in the Northern Rocky Mountain Distinct Population Segment (DPS) except Wyoming on May 5, 2011 (USFWS 2011d). There are no known populations of wolves in Nebraska. However,

dispersing individuals from either Montana or Wyoming into the state would be afforded full protection under the FESA as an endangered species. Wolves are capable of dispersing significant distances, but it is extremely unlikely that wolves would occur in or near the project area.

Swift Fox

The swift fox is a state-listed endangered species that inhabits short-grass and mixed-grass prairies over most of the Great Plains. It appears to prefer flat to gently rolling terrain. Swift foxes feed primarily on lagomorphs, but arthropods and birds are also included in their diets. They mate between late December and February. A mating pair can bear two to five pups in late March to early May, and pups emerge from the den in June. Dens are generally located along slopes or ridges that offer good views of the surrounding area (Fitzgerald et al. 1994). In a study completed in southeastern Colorado, the home range size of an adult swift fox was approximately 3 mi^2 (9.4 square km) at night, and their day ranges are typically much smaller (Schauster et al. 2002).

The swift fox is found in native short-grass prairies in northwestern Nebraska. Unlike coyotes or red fox, the swift fox uses dens in the ground year-round. Some characteristics of swift fox dens differentiate them from other dens. Swift fox den entrances measure about 8 inches in diameter, similar to the size of a badger den. However, swift fox usually have more than one entrance, whereas badgers and most other animals have only one. Swift fox tend to spread excavated soil over a larger area than most other animals, resulting in a less prominent mound near the burrow's entrance. Dens are located on relatively flat ground away from human activity. Where coyotes are abundant, predation by coyotes is a significant cause of mortality for swift fox, and den availability is an important aspect of swift fox survival (Schauster et al. 2002).

Numerous natural and anthropocentric factors influence swift fox populations. Natural factors include fluctuating prey availability, interspecies competition, disease, and landscape physiography. Anthropogenic factors include habitat loss from agricultural, industrial, and urban conversion; land uses on remaining habitat, including hydrocarbon production, military training, and grazing; and pesticide use. Competition with coyotes and red foxes may currently be the most significant threat to swift fox populations, though habitat loss is also a major threat (Stephens and Anderson 2005).

Presence of swift foxes has been confirmed by NGPC in Dawes, Box Butte, and Sioux Counties (NGPC 2009), and potentially suitable habitat occurs in and around the project area; thus, the presence of swift fox within the MEA is possible. However, much of the habitat within the project area appears to be marginal, and previous site-specific surveys in the area have failed to detect the species. Grass height in particular appears to create unsuitable conditions throughout the majority of the project area, where dense fields of cheatgrass exceed 14 inches in many areas during summer (HWA 2011).

As general surveillance for carnivore species in the project area, and with a focus on sampling areas most suitable for swift fox, Hayden Wing Associates deployed remote infrared trail cameras throughout mixed-grassland portions of the project area in 2011. Cameras were used instead of the conventional track station methods because of time and budget constraints. HWA used Reconyx© HyperFire™ HC600 passive infrared (no glow illuminator) remote trail cameras for the monitoring. A total of four cameras were deployed simultaneously among eight locations throughout the southern half of the project area. Cameras were deployed continuously from June 6 to July 7, 2011. Number of sampling days per location was largely determined by the timing of other field surveys,

but cameras were deployed for 9 to 22 days per location. Cameras were positioned along fencelines and other likely travel corridors and baited with a combination of skunk scent (to act as a long-distance lure) and fish oil. Camera locations were deliberately selected based on quality of habitat, proximity to prairie dog colonies, and presence of cattle (to protect cameras).

No swift fox were detected using the remote cameras during 2011. Only two species of carnivores were detected: coyote and badger. Other species detected using the cameras included pronghorn, white-tailed deer, elk, cottontail *sp.*, jackrabbit *sp.*, cattle, and a lark bunting (*Calamospiza melanocorys*) (HWA 2011).

Fish

Three species of state-listed fish are found in the Niobrara River system and may potentially be impacted by a reduction in river flow or impairment of stream quality (**Table 2.8-3**).

The blacknose shiner (*Notropis heterolepis*), a state-listed endangered species that was once commonly distributed throughout the state, is now restricted to three main areas along the Niobrara and Snake Rivers (NGPC 2009). This species typically inhabits cool weedy creeks, rivers, and lakes, usually with a sand substrate (NatureServe 2010). Reductions in stream flows and/or quality are important considerations for this species, as it resides downstream from the project area.

The northern redbelly dace (*Phoxinus eos*) and finescale dace (*Phoxinus neogaeus*) are state-listed threatened species. These species are both found in pools and beaver ponds in the headwaters of creeks and small rivers, usually in areas with a silty substrate (NatureServe 2010). Both of these species are downstream residents from the project area and could be impacted by reductions in water quantity and/or quality.

2.8.10 Aquatic Ecology

The MEA is located within the Niobrara River Basin. Annual flows within the Niobrara River Basin are regulated mainly by snowmelt, precipitation, and groundwater discharge. No perennial streams occur within the MEA. The Niobrara River, located just south of the project area, is the prominent drainage in the vicinity of the MEA and flows into Box Butte Reservoir. Other small drainages include Dooley Spring, Willow Creek, and other small unnamed drainages, but all are dry and re-vegetated. All lack distinct stream channels and banks. Occasional runoff may create small pools in a few places, but there is no evidence of persistent stream flows in recent times (HWA 2011). Based on existing land uses, intensive grazing and agricultural practices are likely the largest factors influencing water quality in the area.

2.8.10.1 Fish

The 1982 and 1996 studies for the Crow Butte Mine recorded 21 species of fish throughout various streams and the White River (CBR 2010a; **Appendix H-5**). Game fish collected included rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), and white sucker (*Catostomus commersonii*). Minnow species included longnose dace (*Rhinichthys cataractae*), common shiner (*Luxilus cornutus*), fathead minnow (*Pimephales promelas*), and creek chub (*Semotilus atromaculatus*). Many of the same species are thought to occur, or to have formerly occurred, in the Niobrara River. According to a local landowner (Troester, pers. comm. 2011), trout previously occurred in the Niobrara River just south of the MEA. However, a combination of drought and



northern pike (*Esox lucius*) becoming more numerous upstream from Box Butte Reservoir during the past 10 years may have altered the fish community dramatically because pike are major predators of minnows and small trout (NPS 2002).

The local fish population was sampled at three sites along the Niobrara River during early June and mid-September, 2011 (HWA 2011). The goal was to collect baseline information on the species composition and general abundance upstream and downstream of the proposed project for comparison with future monitoring efforts. The sampling was intended also as surveillance for the state-listed species (black-nose shiner, northern redbelly dace, and finescale dace) known to occur in the Niobrara River. Sampling methods involved mainly electroshocking techniques, but seine nets were also used. Methods complied with the U.S. Environmental Protection Agency's Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers (Barbour et al. 1999).

During the June sampling effort, only two species were detected: northern pike and white sucker. Green sunfish (*Lepomis cyanellus*) and red shiner (*Cyprinella lutrensis*) were also detected during the training period. None of the state-listed species were detected (HWA 2011).

During the September sampling effort, eight species were detected: northern pike, white sucker, common carp (*Cyprinus carpio*), largemouth bass (*Micropterus salmoides*), yellow perch (*Perca flavescens*), bluegill (*Lepomis macrochirus*), pumpkinseed sunfish (*Lepomis gibbosus*), and central stoneroller (*Campostoma anomalum*). Again, no state-listed species were detected (HWA 2011).

2.8.10.2 Macroinvertebrates

Macroinvertebrates were also sampled during the baseline study in 1982, and results suggested that streams in the Crow Butte area were stressed, with low water quality and degraded stream habitats (CBR 2010a; **Appendix H-6**). Aquatic conditions within the MEA may be similar, but macroinvertebrates were not sampled directly, although crayfish (unknown species) were commonly found during the fish sampling in the Niobrara River (HWA 2011).

2.8.10.3 Wetlands

The MEA was surveyed for areas that qualify as wetlands as defined by the U.S. Army Corps of Engineers (USACE 2008). All locations within the MEA identified in the National Wetlands Inventory (NWI) as wetlands or potential mesic sites were assessed as well (USFWS 2011e). Because ground-disturbing activity is not planned for wetland areas, only wetland habitat was surveyed and delineated. All drainages and low-lying areas were surveyed by all-terrain vehicle (ATV) or on foot. Three types of indicators were used for assessing whether a site qualified as a wetland, including hydric soil, hydrophytic vegetation, and hydrology. Sites containing all three indicators of hydric conditions were classified and delineated as wetlands.

A total of four sites were evaluated as potential wetlands within the MEA (**Figure 2.8-1**):

- Site #1 – location identified in the NWI as "freshwater emergent wetland." Low-lying depression in a grassy field with ephemeral open water created by run-off and rainwater. Tadpoles were present. Location had appropriate hydric soil, vegetation, and hydrology. Qualifies as wetland.

- Site #2 – representative location in bottom of dry drainage. Wetland-like conditions not present, but location assessed in order to compare dry drainages to mesic locations. Does not qualify as wetland or mesic.
- Site #3 – location identified in the NWI as "freshwater emergent wetland." Site satisfied the vegetation and hydrology indicators for a wetland, but hydric soils were absent. Does not qualify as wetland, but mesic conditions exist.
- Site #4 – location not identified in the NWI, but found during ground surveys. Site satisfied the vegetation and hydrology indicators for a wetland, but hydric soils were absent. Does not qualify as wetland, but mesic conditions exist.



This page intentionally blank

2.9 Background Radiological and Non-radiological Characteristics

2.9.1 Introduction

CBR is in the process of completing the remaining sampling task of the PPMP in support of the MEA application, following the criteria outlined in RG 4.14 (NRC 1980a). PPMP monitoring was delayed in order to allow for the collection of 1 year of onsite meteorological data. The meteorological (MET) data were needed for the proper location of the air and other environmental sampling locations and for completion of the MILDOS calculations. At the time of this application, a considerable amount of the PPMP has been completed, with at least 1 year of data collected for the following:

- Air particulate monitoring
- Radon gas
- Ore zone groundwater monitoring (CBR MWs in Basal SS of Chadron Formation)
- Non-ore zone groundwater monitoring (CBR MWs in Brule Formation)
- Surface water (Niobrara River)
- Fish tissue samples (Niobrara River)
- Sediment samples (ephemeral drainages and Niobrara River)

The Marsland Expansion Area Preoperational/Preconstruction Monitoring Program timeline is provided in the **Figure 2.9-1**.

This section discusses the environmental sampling program that has been implemented to assess PPMP radiological background conditions in the vicinity of the MEA. The results of the PPMP, in contrast to the operational monitoring program implemented during satellite operations, will be used to determine the effects on the environment, if any, of the satellite facility and associated operations. The operational monitoring program is discussed in Section 5.7.7.

2.9.2 Baseline Air Monitoring

The PPMP and operational monitoring plans are designed to be consistent with the criteria outlined in RG 4.14 (NRC 1980a). Monitoring began in the fourth quarter of 2011 and was completed in the fourth quarter 2012.

2.9.2.1 Selection of Air Monitoring Locations

Figure 2.9-2 shows the locations of the air monitoring stations, two nearby occupiable structures, with one located inside the license boundary, and the satellite facility. **Figure 7.3-2** depicts all of the residences within the vicinity of the MEA license boundary and the estimated dose predicted by MILDOS modeling.

In regard to collection of air particulate samples, RG-4.14 states that air particulates should be:

- Collected continuously at a minimum of three locations at or near the site boundary
- Collected continuously at or near the residence or occupiable structure within 10 kilometers of the site that is most likely to be impacted by the milling operation

- Collected from a remote location representing background, usually upwind from the project site and milling operation

RG-4.14 also enumerates five criteria that should be considered when determining the sampling locations:

1. Average meteorological conditions
2. Prevailing wind direction
3. Site boundaries nearest to mill
4. Direction of nearest occupiable structure
5. Location of estimated maximum concentrations of radioactive materials

In accordance with these criteria, **Figure 2.9-2** shows the locations of the five sampling stations (MAR-1, MAR-2, MAR-3, MAR-4, and MAR-5) three sampling sites were located at the project boundary (Sites MAR-1, MAR-3 and MAR-4). MAR-2, near the project boundary, was located directly south of the proposed mill. Due to landowner preference, MAR-2 was placed 2,891 ft. south and 1,371 ft. west of the permit boundary. MAR-1 coincides with the nearest, and most likely to be impacted, occupiable structure. A fifth sampling site (Site MAR-5) was selected to represent background conditions. Because the on-site wind rose indicates northeasterly winds to be the least frequent, this background monitoring site was located southwest of the project boundary at a distance of approximately 4 miles (6.4 km). A summary of monitor locations and elevations for each of the monitors is shown in **Table 2.9-1**.

The on-site wind rose shows north-northwesterly, northwesterly, and northerly winds to be the most frequent, accounting for more than 25 percent of the time. Hence, these three monitoring sites (MAR-2, MAR-3 and MAR-4) are located south-southeast, southeast and south of the proposed milling operation. The wind roses are shown in **Figures 7.3-2, 2.5-20** and **2.5-21**.

When selecting air monitor locations, it was expected that the maximum short-term concentrations of radioactive materials would be found in the vicinity of the combined satellite facility and mine unit source terms. Similarly, long-term maximum concentrations are also expected in the vicinity of the satellite plant, given the larger proportion source term present at that location. In addition, maximum concentrations were expected where the radon has the longest residence time with the least mixing, allowing the ingrowth of Radium 226. It was believed that this would occur where the wind was less frequent and at lower velocity. Based upon the wind rose, this would occur WSW and SW of the satellite facility. That information was considered in selecting the location for MAR-1.

Following completion of preoperational baseline monitoring, the MILDOS Area assessment was significantly refined. Those revisions are now included as part of Section 7. The location of estimated maximum contaminant concentrations due to dose associated with radon progeny is located approximately 1.5 km southeast of the Satellite Plant (see Figure 5 in **Appendix M**). During operational monitoring, to satisfy RG 4.14, a new station (MAR-6) will be added according to criteria 5, of RG 4.14 (**Figure 7.3-2**).

The wind rose was developed from data generated at an MEA onsite MET station. The MET monitoring station monitored temperature, precipitation, evaporation, wind speed and direction, and the standard deviation of the wind direction. The local meteorological station was operated



from August 28, 2010 through August 29, 2011. From this information, joint frequency data were compiled. Further information on meteorological conditions is provided in Section 2.5.

2.9.2.2 Air Particulate Monitoring Program

RG 4.14 recommends that a total of five particulate monitoring stations be established as discussed above in Section 2.9.2.1. The locations of the air particulate samplers are shown on **Figure 2.9.2.** There are no operations at the satellite facility that could cause a significant release of airborne particulate radionuclides (e.g., lack of yellowcake drying). Therefore, radiological-contaminated air particulates are expected to be minimal.

Five quarters of air particulate monitoring have been conducted and are discussed in this section. The PPMP monitoring program will be incorporated into the operations monitoring program. The results of the air monitoring data at sampling sites MAR-1 through MAR-5 for the fourth quarter of 2011 through the fourth quarter 2012 are presented in **Table 2.9-2** are summarized as follows:

- Lead 210 measurements were a consistent 2E-14 microCuries per milliliter (μCi/ml) at all monitor sites (reporting limit of 2E-15 μCi/ml) for all quarters except for the second quarter of 2012, when the lead level was 1E-14 μCi/ml (reporting limit of 2E-15 μCi/ml).

- Radium 226 levels at all monitor sites for all quarters exhibited a level at or less than 1E-16 μCi/ml (reporting limit of 1E-16 μCi/ml), except for the third quarter of 2012 when the radium-226 μCi/ml level was 5E-10 μCi/ml.

- Thorium 230 levels at monitor sites MAR-1 through MAR-4 for all quarters were at or less than 1E-16 μCi/ml, while the thorium 230 level at M-3 was 2E-16 μCi/ml (reporting limit of 1E-16 μCi/ml).

- Uranium levels all monitor sites for all quarters were measured at <1E-16 μCi/ml (reporting limit of 1E-16 μCi/ml), with the exception of the first quarter of 2012, when levels of 3E-16 μCi/ml (reporting limit of 1E-16 μCi/ml) were measured at MAR-2, MAR-3 and MAR-4, with MAR-5 exhibiting a level of 2E-16 μCi/ml (reporting limit of 1E-16 μCi/ml.

The air sampling analytical laboratory reports and QA/QC summary reports are shown in **Appendix U.**

The airborne particulate samples are collected on the inlet filter of a regulated vacuum pump on a Type A/E 47 mm glass fiber filter paper. The low volume air samplers employed is the F&J Portable DF-75L-BL-AC brushless powered air sampler, 60 liter/min, 24 voltage current direct (VCD). This air particulate sampler runs on solar power and batteries. The sampler has a filter holder and a set flowrate maintained automatically in case of dust loading. It does not require operator attention.

The sampler is placed in protective enclosures (with an exhaust fan and temperature controller) that provides protection from the elements while allowing unimpeded sampling of the ambient air. The vendor provided CBR with a standard operating procedure (SOP) for the F&J DF-75L-BL-AC that provides guidance in meeting NRC requirements **(Appendix I).**

Clean filters are installed in the filter holder at the beginning of each sampling period. The pump flow-rate is adjusted as necessary. The filter replacement schedule is determined based on the dust loading at a particular location. In general, historical operations of samplers without automatic flow rate controllers at the CPF have shown that samplers can run for 1 to 2 weeks without a significant reduction in the flow rate due to dust loading.

The air sampler draws air and suspended particulate matter through a 47 millimeter (mm) collection filter at a known volumetric rate for a known period of time. The collected set of filters for each air sampling unit is sent for contract laboratory analysis at the end of each quarter using standard chain-of-custody procedures. The filters are composited according to location. The composite samples are analyzed for the concentrations of natural uranium, radium-226, lead-210, and thorium-230. Filter sample replacement and additional handling procedures are described in the air sampler SOP.

The flowrate on the F&J portable sampler is calibrated at 6-month intervals using accepted calibration methods to ensure the accuracy of the volume of air sampled. Records of sampler calibration are available on file at the CPF. Calibration records for the air sampling pumps for the first year of sampling are shown in **Appendix V-1.** CBR will continue to operate all five samplers as part of the operational air particulate monitoring.

2.9.2.3 Radon Gas Monitoring Program

RG 4.14 recommends collection of radon gas samples at each of the air particulate monitoring stations (five or more sample points). Continuous sampling will be performed, or at least one week per month, representing about the same time of the month. Samples are analyzed for radon gas. The proposed PPMP and operational monitoring programs are shown in **Tables 2.9-41 and 5.7-1**.

Monitoring is being performed using RadTrak® Type DRNF outdoor air radon detectors located approximately 80 inches above the ground surface. RadTrak® cups contain a sensitized chip covered with a selectively permeable material allowing only the infiltration of radon. The sensitized chip records alpha disintegrations from radon daughters, allowing determination of average radon concentrations. The analysis of quarterly sampling has a sensitivity of 30 pCi/L - days. The semiannual interval was chosen to ensure that monitoring results meet the lower limit of detection (LLD) requirement of 0.2 pCi/L (2×10^{-10} mCi/ml) from RG 4.14 and to be consistent with the semiannual intervals approved by NRC for the current operational monitoring.

The PPMP and operational monitoring plan are designed to meet the criteria outlined in RG 4.14 (NRC 1980a). Radon-222 monitoring for sampling site MAR-1 through MAR-5 was conducted from the fourth quarter of 2011 through the fourth quarter of 2012 (**Table 2.9-3**). The gross count for the entire time period for all sampling points ranged from 43 to 362, with an average of 168. The gross count for sampling points MAR-1 through MAR-4 ranged from 43 to 362 (average of 163), compared to MAR-5 (background location) with a range of 70 to 255 (average of 191). The average radon concentration for the entire sampling period ranged from 0.07 to 1.6 uCi/ml (average of 0.5 uCi/ml). The average radon concentrations for sampling points MAR-1 through MAR-4 ranged from 0.07 to 1.6 uCi/ml (average of 0.5), compared to MAR-5 (background location) with a range of 0.1 to 1.0 uCi/ml (average of 0.6 uCi/ml).

The radon laboratory records are shown in **Appendix V-2**.

2.9.2.4 Quality of Air Measurements

The accuracy of monitoring data is critical to ensure that the PPMP air monitoring program precisely reflects air quality. RG 4.14 specifies the following LLDs for air measurements:

Radionuclide	Recommended LLD µCi/ml	Actual LLD µCi/ml
Natural Uranium	1×10^{-16}	1×10^{-16}
Thorium-230	1×10^{-16}	1×10^{-16}
Radium-226	1×10^{-16}	1×10^{-16}
Radon-222	2×10^{-10}	2×10^{-10}
Lead-210	2×10^{-15}	2×10^{-15}

Note: µCi/ml – microCurie per milliliter

2.9.3 Baseline Groundwater Monitoring

This section discusses the results of the radiological and non-radiological analyses for private water supply wells with the MEA and CBR monitor wells installed within the MEA for purposes of assessing the MEA site. In general, groundwater quality in the vicinity near the MEA is poor (Engberg and Spalding 1978). Groundwater obtained from the basal sandstone of the Chadron Formation has a strong sulfur odor as a result of localized reducing conditions associated with the ore body. Background and restoration values are discussed in Section 6.

Locations of all Arikaree, Brule, and basal sandstone of the Chadron Formation monitoring wells in the vicinity of the MEA are shown on **Figures 2.7-6** and **2.9-3**.

Radiological Water Quality Sampling

Radiological water quality analyses for private water wells in the area of review are provided in **Table 2.9-5.** Groundwater samples for the CBR monitor wells were collected from December 2013 to September 2014 for the Brule monitor wells (**Table 2.9-9**), November 2013 to September 2014 for the Arikaree monitor wells (**Table 2.9-42**) and November 2011 to August 2012 for the basal sandstone of the Chadron Formation monitor wells (**Table 2.9-11**).

During sampling for the private water supply wells, there were a total of 43 wells sampled for four quarters. Twelve wells were sampled less than four quarters, seven were seasonal wells and did not operate year-round and five became inoperable during the sampling event. An additional 17 water supply wells were not sampled due to inoperability; including broken wells, power off, not working, and not in use (**Table 2.2-11**). These wells are privately owned and in the control of the private land owners.

A summary of the groundwater quality data collected to date in the vicinity of the MEA, are presented in **Table 2.9-4.** The data are presented for the three water-bearing zones at the MEA: the Arikaree Group, Brule Formation, and basal sandstone of the Chadron Formation.

2.9.3.1 Private Water Supply Wells

There were a total of 135 private water supply wells within the license boundary and associated AOR identified during the water user survey. The number of wells and their general location within the MEA project AOR can be broken down as follows (**Table 2.2-11**):

- Located within License Boundary: 10 active, 5 inactive, and 1 seasonal (irrigation).
- Located within 0.62 miles (1 km) radius of the License Boundary: 12 active, 18 inactive, and 2 seasonal.
- Located between 0.62 miles (1 km) and 1.24 miles (2 km) radius of the license boundary: 15 active, five inactive, and 4 seasonal.
- Located between 1.24 miles (2 km) radius and to the 2.25-mile (3.62 km) AOR radius of the License Boundary: 54 active and 9 inactive.

The remainder of this section discusses the results of the radiological and non-radiological analyses for private water supply wells within the MEA. Other information on the selected wells, including formation, depth, and usage, is shown in **Appendix A.** Available well registration and well completion records are shown in **Appendix E.**

The radiological and non-radiological analytical results for the individual private wells are shown in **Tables 2.9-5** and **2.9-6,** respectively, and summarized in **Table 2.9-4.** Quarterly preoperational radiological and non-radiological water quality samples were collected on all active private wells within the permit area and 2 km license boundary during 2011 and 2014.

The radiological analytical results for the Arikaree and Brule Formations were at levels that would be expected for background concentrations of the area (**Table 2.9-4 and 2.9-5**).

Suspended uranium concentrations for the private wells completed in the Arikaree and Brule Formations were at a range of <0.0003 mg/L to 0.001 mg/L (average of 0.00021 mg/L), and dissolved uranium levels were 0.0028 to 0.0282 mg/L (average of 0.0071 mg/L). Suspended uranium activity for the private wells ranged from <0.0003 to 0.001 µCi/mL (average of 0.0002 µCi/mL), and dissolved uranium ranged from 3.8E-10 to 3.9E-9 µCi/mL (average of 2.14E-9 µCi/mL).

Suspended radium-226 values for the private wells ranged from 3.0E-11 to 2.0E-10 µCi/mL (average of 8.5E-11 µCi/mL) and dissolved radium-226 ranged from <1.3E-10 to 9.5E-9 µCi/mL (average of 2.3E-10 µCi/mL). The majority of the values for suspended and dissolved lead-210, polonium-210, and thorium-230 were below the reporting limit.

The concentrations of dissolved uranium in the private wells completed in the Arikaree and Brule Formations within the NTEA, TCEA, and MEA compared as follows based on available data:

NTEA	<0.0003 to 0.05 mg/L
TCEA	0.004 to 0.04 mg/L
MEA	0.0028 to 0.0282 mg/L

Dissolved uranium values for the TCEA tended to be somewhat higher than those for the NTEA and MEA.

Concentrations of dissolved radium-226 from private wells in the NTEA, TCEA, and MEA compared as follows:

NTEA	<0.2 to 1.3 x 10^{-9} µCi/mL
TCEA	1E-10 to 1.5E-9 µCi/mL
MEA	<1.3E-10 to 9.5E-9 µCi/mL

The non-radiological analytical results were at levels consistent with what would be expected for background concentrations for the area (**Tables 2.9-4** and **2.9-6**). Concentrations of the parameters for the private wells versus CBR monitor wells completed in the Brule Formation are comparable, with some parameters for the private wells having somewhat lower average values than for the CBR monitor wells (e.g., dissolved sodium, sulfate, chloride, and conductivity; **Table 2.9-4**). The average values for sodium and sulfate for the private wells versus CBR Brule Formation monitor wells was 19.8 versus 104 mg/L and 10.2 versus 26.2 mg/L, respectively. The average values for sodium and sulfate for the Brule Formation monitor wells versus the CBR basal sandstone of the Chadron Formation monitor wells was 104 versus 394 mg/L and 26.2 versus 172 mg/L, respectively.

Overall, similar trends in the NTEA and TCEA were seen for the same MEA water-bearing units.

2.9.3.2 CBR Groundwater Monitor Wells

Arikaree Group and Brule Formation

Ten Arikaree Group monitoring wells (AOW-1, AOW-3 through AOW-11) were installed in 2013. Well AOW-2 was not installed. There are 11 active monitoring wells screened in the Brule Formation (BOW-2010-1, BOW-2010-2, BOW-2010-3, BOW-2010-4A, BOW-2010-5, BOW-2010-6, BOW-2010-7, BOW-2010-8, BOW-9, BOW-10 and BOW-11). Three of these wells (BOW-9, BOW-10, and BOW-11) were screened in the Brule Formation in September 2013. The Walters Drillers Pond-720 (Walters-2) and Walters Drillers Pond-721 (Walters-1) wells have been employed as monitoring wells for the Brule Formation, but these wells will not be part of future monitoring, specifically for the Brule Formation, because these wells are screened across the Arikaree and Brule Formations. In September 2013, ten wells were screened in the Arikaree Group. The primary purpose of the Arikaree and Brule monitor wells is to further the site-specific understanding of the hydrologic characteristics of the Arikaree Group and Brule Formation. Installation and subsequent monitoring of water levels and water quality is intended to provide more information about potentiometric surfaces of groundwater within aquifers, identify the potential for seasonal or annual flow variations, and provide data by which the hydrologic connectivity between the aquifers, or lack thereof, can be determined. The locations of CBR's Arikaree and Brule monitor wells within the MEA are shown on **Figure 2.7-8.** A report on wells installed in the lower portion of the Brule Formation is found in **Appendix HH**.

Well BOW-2010-4 is not being used for baseline monitoring, and plans are to abandon this well in the future. During reaming of this well for casing, the driller lost a bit that he was unable to retrieve. Unsuccessful attempts made to convert the well to a shallow monitor well resulted in the well being considered unacceptable for baseline monitoring. A new replacement well (BOW-2010-4A) was

drilled nearby. Well completion records for these monitoring wells are included in **Appendix E-2.**

Thirteen active monitoring wells are screened in the basal sandstone of the Chadron Formation (CPW-2010-1, CPW-2010-1A, Monitor-1, Monitor-2, Monitor-3, Monitor-4A, Monitor-5, Monitor-6, Monitor-7, Monitor-8, Monitor-9, Monitor-10, and Monitor-11; **Figures 2.7-6** and **2.7-9**). Well completion reports for these monitoring wells are included in **Appendix E-2**.

In 2013, a sampling program was implemented for all MEA Arikaree, Brule and Chadron wells to monitor water level changes to those aquifers over a one year time span to determine what effect, if any, seasonal flow, annual variation, or nearby irrigation wells may have upon the observed groundwater movement. Water level data was collected in October 2013, January 2014, April 2014, and July 2014 and is presented in **Appendix FF.** Potentiometric surface maps for the three aquifers for each sampling period are shown on **Figures 2.9-4a through 2.9-4d, 2.9-5a through 2.9-5d, and 2.9-6a through 2.9-6d.**

Static water levels measured for the Arikaree Group monitoring wells range from 19 to 142 feet below the top of the well casing (btoc). Calculated groundwater elevations ranged from approximately 4,049 to 4,294 feet amsl. The potentiometric surface maps **(Figures 2.9-4a through 2.9-4d)** indicate that groundwater flow within the Arikaree Group is to the south-southeast toward the Niobrara River at an average lateral hydraulic gradient of approximately 0.009 ft/ft.

Static water level for wells screened in the Brule Formation in the vicinity of the MEA typically range from approximately 37 to 156 feet btoc. Groundwater elevations measured during the sampling events ranged from approximately 4,050 to 4,296 feet amsl. Potentiometric surface maps indicate groundwater in the Brule Formation flows predominantly to the south-southeast across the entire MEA toward the Niobrara River drainage at a lateral hydraulic gradient of 0.011 ft/ft **Figures 2.9-5a through 2.9-5d** (Aqui-Ver 2011). Regional water level information for the Brule Formation is currently only available in the vicinity of the current production facility.

As shown in **Figures 2.9-4a** and **2.9-5a**, October 2013 groundwater level data for the Arikaree Group and Brule Formation indicate potentiometric surfaces that are nearly equal in elevation. Particular care was taken during installation of monitoring wells to avoid screening individual wells within both the Arikaree Group and Brule Formation. Although the wells are screened at different intervals, nearby pairs of monitoring wells screened in the two units demonstrate groundwater elevations with differences of approximately 5 feet or less. While some minor variation exists between the two potentiometric surfaces, the similarity in groundwater elevations and shared south-southeast groundwater flow direction indicates significant hydraulic connectivity between the Arikaree Group and Brule Formation within the MEA. The shared hydraulic head between the two geologic units likely indicates that groundwater within the Brule Formation is not confined by overlying units, and the Arikaree Group and Brule Formation function as a single hydrogeologic unit.

Basal Sandstone of the Chadron Formation

Water levels for the basal sandstone of the Chadron Formation were measured at 13 sites in October 2013, January 2014, April 2014, July 2014 (**Appendix FF**). The static water level for wells screened in the basal sandstone of the Chadron Formation in the vicinity of the MEA typically ranges from approximately 399 to 680 feet bgs. Groundwater elevations measured during the measurement events ranged from approximately 3,687 to 3,704 feet amsl. Potentiometric surface

maps and groundwater flow directions for the sampling events are depicted on **Figures 2.9-6a through 2.9-6d.** Groundwater in the basal sandstone of the Chadron Formation flows predominantly to the northwest toward the White River drainage at a lateral hydraulic gradient of 0.0004 ft/ft (Aqui-Ver 2011). It does not appear, based on the four consecutive quarterly measurements that there are seasonal or annual changes in the groundwater flow. Regional water level information for the basal sandstone of the Chadron Formation is currently only available in the vicinity of the current production facility.

Risk Conclusions

Strong vertically downward gradients exist at all locations within the MEA, indicating minimal, if any, risk for potential impacts to the Arikaree Group and Brule Formation from the underlying basal sandstone of the Chadron Formation under natural conditions. Observed head differences between the two water-bearing zones at six well pairs (BOW-2010-1 and Monitor-3, BOW-2010-2 and Monitor-4A, BOW-2010-3 and Monitor-8, BOW-2010-4A and Monitor-10, BOW-2010-5 and Monitor-11, and BOW-2010-6 and Monitor-1) ranged from approximately 346 to 518 feet during the October 2013 measurement event.

Available groundwater data for the Arikaree Group and Brule Formation and basal sandstone of the Chadron Formation at the MEA do not indicate any documented flow rate variations or recharge issues that would impact groundwater quality as a result of ISR recovery operations in the basal sandstone of the Chadron Formation. There are no surface water ponds within the MEA license boundary and only limited, intermittent flow in ephemeral drainages. The Arikaree Group and Brule Formation, while considered to be overlying aquifers, are not exceptionally productive in the MEA area.

The presence of high-capacity irrigation wells both within and near the MEA screened within the Arikaree Group and Brule Formation will have a seasonal impact on those aquifers. Agricultural wells near MEA are primarily used for irrigation water between mid-May and early August, with lesser volumes of water extraction lasting into September. These wells are metered, but data are only collected annually; therefore, daily, weekly, and monthly extraction rates are unavailable. Estimated flow rates for wells provided by well users are provided in **Appendix A.**

Water level elevation data was collected from eight shallow monitoring wells (AOW-4, AOW-5, AOW-9, AOW-10, BOW-2010-4A, BOW-2010-5, BOW-9, and BOW-10) at the MEA from December 11, 2013 to October 9, 2014. Water level data were collected using downhole in-situ Troll® dataloggers equipped with pressure transducers. Water levels were collected once per day from each monitoring well over the monitoring period, and are plotted in **Appendix AA-2** (AquiferTek, 2016a).

Results of water level monitoring indicate the operation of irrigation well 732 caused a maximum of 2.2 feet of drawdown in the nearest monitoring well cluster (AOW-9/BOW-9) over a 100-day (3.3 month) irrigation well pumping period. Drawdown in other shallow monitoring wells was not significant and less than 0.5 feet. Drawdown measured in AOW-9 and BOW-9 was very similar, indicating the shallow Arikaree and Brule aquifers are in hydraulic communication as previously noted in the Aqui-Ver, Inc. Report December 2013 (Aqui-Ver, 2013a) (**Appendix AA-1**).

The data collected during the 2014 irrigation season indicates irrigation well 732 pumped 57,742,980 gallons of groundwater over an approximate 100-day (3.3 month) period from late April

to early August 2014. This equates to an average continuous pumping rate of 401 gpm over the 3.3 month operating period. Because the actual operating pumping rate of well 732 is approximately 800 gpm, we can infer well 732 pumped at a rate of 800 gpm for 12 hours each day during operating period. The observed 2014 irrigation operating conditions differed somewhat from the estimated operating conditions used in the impact analysis (Aqui-Ver, 2013a) (well 732 operating 11 hours per day for 5-months, or an average continuous pumping rate of 373 gpm).

The groundwater flow model used in the original December 2013 impact analysis was calibrated by simulating observed changes in water level elevation (drawdown) in shallow monitoring wells AOW-9/BOW-9 during the 2014 irrigation season using the updated irrigation well 732 operating conditions (Aqui-Ver, 2013a).

Aquifer parameters used in the "high transmissivity scenario" of the December 2013 irrigation well impact analysis were used as initial conditions for the model calibration. In order to calibrate the flow model and achieve a reasonable match between observed and simulated drawdown, the specific yield of the shallow Arikaree/Brule aquifer was lowered slightly from 0.15 to 0.010. A summary of calibrated flow model parameters and irrigation well operating conditions is summarized below:

Hydraulic conductivity - 8.2 ft/day.
Transmissivity - 1656 ft2/day (aquifer thickness 202 feet).
The hydraulic gradient – 0.004.
Porosity – 0.15
Specific Yield – 0.10 (adjusted downward from 0.15 to calibrate the model)
Pumping rate – 401 gpm for 3.3 months (100 days).

Results of the flow model calibration are shown in the AquiferTek Report in **Appendix AA-2** (AquiferTek, 2016a). Observed and simulated drawdowns in wells AOW-9/BOW-9 are very similar, and simulated drawdown in other shallow monitoring wells is less than 0.5 feet as observed. Given these results, the model has been adequately calibrated and can be used to make predictions with a reasonable degree of accuracy.

The calibrated groundwater flow model was used to calculate the 30-year capture zone of irrigation well 732. Particle-tracking techniques were used to illustrate the 30-year capture zone of irrigation well 732 to assess whether a hypothetical shallow casing leak from the MEA wellfields could potentially impact the irrigation well.

For purposes of this analysis, a conservative (worse-case) scenario was assumed in which irrigation well 732 pumps the maximum allowable amount of groundwater (251 acre-ft/year, 373 gpm for 5-months) and a hypothetical shallow casing leak occurs at some time along the downgradient portion of the adjacent wellfields at the MEA. These are the same operating conditions assumed in the original December 2013 impact analysis, which are considered to be more conservative than conditions observed during the 2014 growing season (e.g. 3.3 month operating period, 70% of permitted water right).

The revised 30-year capture zone of irrigation well 732 is illustrated in **Appendix AA-2** (AquiferTek, 2016a). Based on the results of this analysis, MEA wellfields are not located within the capture zone of irrigation well 732. A shallow casing leak within the MEA wellfields will not

impact irrigation well 732 at any time in the future given similar operating conditions. This conclusion is identical to the original December 2013 impact analysis **Appendix AA-1**.

Given the location of other irrigation and domestic wells in the area, **Appendix AA-2** (AquiferTek, 2016a), and configuration of the worse-case capture zone, it is reasonable to conclude there are no other wells outside the MEA boundary that will be impacted by a potential release of MEA regulated material to the shallow aquifer. Therefore, the current MEA shallow groundwater monitoring network is adequate to ensure the protection of human health and environment.

Pumping test data show that the basal sandstone of the Chadron Formation is hydraulically isolated from the overlying Arikaree Group and Brule Formation aquifers due to the presence of several hundred feet of claystones, mudstones, and siltstones of the upper Chadron Formation and middle Chadron Formation. Estimated hydraulic conductivity data based on particle size distribution analysis of core samples from the upper confining zone discussed in Section 2.7.2.2 support the effectiveness of these confining units indicated by the pumping test. No agricultural wells are completed in the basal sandstone of the Chadron Formation. Groundwater extraction by agricultural wells completed in the Arikaree Group or Brule Formation will have no influence on the containment of production fluids within the basal sandstone of the Chadron Formation.

2.9.3.3 Groundwater Quality Data for Arikaree Group, Brule, and Chadron Formations

Four quarterly sampling events were conducted, beginning the fourth quarter of 2013 through the third quarter of 2014, at ten Arikaree Group monitoring wells (AOW-1, AOW-3, AOW-4, AOW-5, AOW-6, AOW-7, AOW-8, AOW-9, AOW-10, AOW-11). The analytical results are shown in **Tables 2.9-42** and **2.9-43**.

Four quarterly sampling events were conducted, beginning the fourth quarter of 2013 through the third quarter of 2014, at eleven Brule Formation monitoring wells (BOW-2010-1, BOW-2010-2, BOW-2010-3, BOW-2010-4A, BOW-2010-5, BOW-2010-6, BOW-2010-7, and BOW-2010-8, BOW-9, BOW-10, and BOW-11. The analytical results are shown in **Table 2.9-8** and **2.9-9**.

Four quarterly sampling events were conducted from the fourth quarter of 2011 through the third quarter 2012 at eleven monitoring wells completed in the basal sandstone of the Chadron Formation (Monitor-1, Monitor-2, Monitor-4A, Monitor-5, Monitor-6, Monitor-7, Monitor-8, Monitor-9, Monitor-10, Monitor-11, and CPW-2010-1). The analytical results are reported in **Tables 2.9-10** and **2.9-11**.

The groundwater analytical laboratory analysis results for the Arikaree Group, the Brule Formation and the Basal Sandstone of the Chadron Formation are provided in **Appendix J**. A summary of the data is presented in **Table 2.9-4**.

2.9.4 Baseline Surface Water Monitoring

Surface water sampling in RG 4.14 calls for sampling of surface water passing through the project site or offsite surface waters that may be subject to drainage from potentially contaminated areas or that could be affected by a "tailings impoundment failure". No impoundments are planned at the MEA. The only offsite impoundment in the vicinity is Box Butte Reservoir, discussed below. Grab

samples were collected monthly and analyzed for suspended and dissolved natural uranium, radium-226, and thorium-230 as shown in **Table 2.9-41**.

Lack of water flow in ephemeral drainages in the MEA has prevented collection of surface water samples. Water samples were collected from the Niobrara River, which flows east to west to the south of the MEA license boundary (**Figure 2.7-4**). The results of this sampling program are discussed below. Historical water flow and water quality data were obtain from NDNR, NDEQ, and USGS databases (see discussions below). Water level measurements of the Box Butte Reservoir were obtained from the USBR (see discussions below).

Box Butte Reservoir was not sampled. Box Butte Reservoir could be subject to drainage from potentially contaminated areas by way of the Niobrara River. In fact, any drainage from potentially contamination areas would be detected first in the Niobrara River and at far higher concentrations than the greatly attenuated contaminant levels that would be present in the reservoir itself. For that reason, the Niobrara River samples were collected to establish baseline water quality and to assess the environmental impacts from operations.

In addition, pesticides and herbicides were and are not monitored in surface waters as these contaminants are not relevant to the MEA ISR operation.

2.9.4.1 NDNR Niobrara River Ambient Stream Monitoring Program

Flow Measurements for Niobrara River

The NDNR maintains stream gaging stations on the Niobrara River, with data reported on its web page at http://dnr.ne.gov/docs/hydrologic.htm. Flow data reported in this section are for the section of the Niobrara River in close proximity to the proposed MEA (**Figure 2.7-4**). The description of the stream gaging stations and their locations is presented in **Table 2.9-12.** The stream gaging measurements from 1999 through 2012 for the designated stream gaging stations are summarized in **Table 2.9-13.** The sampling location at Agate is an exception, with data being available from 2006 through 2012. Monthly flow measurements for stream gaging stations in the upper reaches of the Niobrara River for each of the designated years are presented in **Table 2.9-14.** A graph of the average flow in cubic feet per second (cfs) for the four Niobrara River stream gaging stations from 2006 through September 2012 is shown on **Figure 2.9-7.** As seen on **Figure 2.9-7**, flows for the gaging stations above the Niobrara River are fairly consistent over this time period. The year 2006 was used as the starting date because of the lack of flow data at the Agate gaging station prior to 2006. In the Niobrara River west of Valentine, NE, which includes the area of the river in the vicinity of MEA, groundwater is the primary source of flow into the Niobrara River (Alexander et al 2010). In this area of the river, the discharge of the river is steady and persistent, with overbank flooding being uncommon except during winter ice jams (Shaffer 1975). As can be seen on **Figure 2.9-7**, the average flow of the Niobrara River at the Wyoming/Nebraska state line is consistently lower than the average flows at the gaging stations located at Agate and above the Box Butte Reservoir. **Figure 2.9-7** clearly shows the time periods during which water is stored and released from Box Butte Reservoir. These data can be correlated with the flow data presented in **Table 2.9-14.** Peak discharge extremes and minimum discharge flows for the years 1999 through 2010 are presented in **Table 2.9-13**.

Water Quality

The NDNR has not collected water quality data on the Niobrara River in the area of the Marsland project since sampling was shared with the USGS prior to 1998 (Hayden 2011).

2.9.4.2 NDEQ Niobrara River Ambient Stream Monitoring Program

Water quality data for the NDEQ Niobrara River sampling stations were obtained from the NDEQ (Ihrie 2013a). Water quality data presented in this report are for the years 2003 through 2011, and consisted of major ions, physical properties, and metals, but no radiological analyses. Water samples were collected at a sampling station above the Niobrara River (NDEQ sample station SNI4NIOBR402/USGS 06454500) and a sampling point below Box Butte Reservoir (NDEQ sample station SNI4NIOBRA20/USGS 06455500) (**Figure 2.9-8**).

Nebraska Department of Environmental Quality Water Quality Sampling for Niobrara River Above Box Butte Reservoir (SNI4NIOBR402)

Monthly water quality data from the sample location above Box Butte Reservoir (SNI4NIOBR402) are shown in **Tables 2.9-15** through **2.9-25** A summary of the water quality data for 2003 through 2011 in **Tables 2.9-17** through **2.9-25** is presented in **Table 2.9-26**. Water quality samples were analyzed for eight major ions. The dominant cation at the sampling location above Box Butte Reservoir (SNI4IOBR402) was calcium (range of 42.82 to 58.20 mg/L), followed by sodium (range of 21.4 to 40.6 mg/L), magnesium (range of <0.15 to 11.5 mg/L), and chloride (range of 3. 46 to 7. 35 mg/L) (**Table 2.9-26**).

Nutrients such as nitrogen and phosphorus compounds occur naturally in surface water, but elevated concentrations may occur due to agricultural runoff and wastewater discharges and septic systems. There are at least two cattle feeding operations in close proximity to the stretch of the Niobrara River near the MEA project site (NDEQ 2005a). Maximum values for nitrite plus nitrate, total ammonia nitrogen, and total Kjeldahl nitrogen were all less than 2.17 mg/L for the above-referenced NDEQ samples. Thirteen of 152 total phosphorus samples yielded concentrations higher than (maximum of 0.71 mg/L) the EPA recommendation of 0.1 mg/L for avoiding algal blooms.

The average of the dissolved O_2 readings was 8.85 mg/L, ranging from 3.34 to 12.9 mg/L. There were only six readings below 6.0 mg/L and three between 6.1 and 6.3 mg/L, with 148 of the total samples being above 6.5 mg/L. Lower readings appeared to occur during low or high flows.

The NDEQ water quality standards state that, in order for water to support aquatic life, the pH standard unit (su) should be maintained between 6.5 and 9.0 unless the pH values are outside this range due to natural conditions. One of 91 of the pH readings for the Niobrara River (9.92 su) was outside the acceptable range of 6.5 to 9 su. The average of the pH values was 8.09 su and ranged from 7.1 to a maximum value of 9.92 su recorded on May 21, 2007.

Temperature readings averaged 11.13 °C, and ranged from -0.26 to 29.0 °C. Seasonal fluctuations indicate that water temperature is primarily dependent upon the ambient air temperatures.

Turbidity field measurements indicated an average of 27.7 nephelometric turbidity units (NTU), with a range of 0.2 to 233. The majority of the turbidity measurements were30 NTU or less (103 of 13 readings [74 percent]). The majority of the turbidity measures above 30 NTU were during periods of either high flow or low flow conditions. There were only 18 readings above 40 NTU.



Total suspended solids (TSS) measurements ranged from <5 to 297 mg/L, with an average of 24.7 mg/L. The maximum value of 297 mg/L was the only value to exceed 100 mg/L, and the cause of the exceptionally high value is unknown based on available information. Daily readings for the months before and after this high reading were 49.5 and 61 mg/L, respectively. TSS values of 103 of the total number of 138 samples (75 percent) analyzed were 30 mg/L or lower. Specific conductance values ranged from 100 to 539 µmhos/cm, with an average of 386 µmhos/cm. All 91 readings were 314 µmhos/cm and above except for two readings of 244 and 297 µmhos/cm.

The above-mentioned NDEQ water quality data support the classification of the Niobrara River by stream segment in the vicinity of the MEA project site. The Niobrara River segments provide a basic unit for assigning site-specific standards and for applying water quality management programs of the NDEQ. The NDEQ Water Quality Body ID N14-4000 is located to the south of the MEA (**Figure 2.7-3**). This segment is rated as Supported Beneficial Use for aquatic life, agricultural water supply, and aesthetics. However, it is also classified as Impaired for recreational use due to the measured presence of *E. coli* (NDEQ 2010e and 2005a). As a result, the water body category for this segment of the Niobrara River has been established as Category 5 (water bodies where one or more beneficial uses are determined to be impaired by one or more pollutants and all of the Total Maximum Daily Loads [TMDLs] have not been developed) (NDEQ 2010e). A TMDL is the maximum quantity of a pollutant a water body can receive and still meet its appropriate water quality criteria or goal (NDEQ 2010e).

Nebraska Department of Environmental Quality Water Quality Sampling for Niobrara River Below Box Butte Reservoir (SNI4NIOBRA20)

NDEQ water quality data were only available for 2008 for the Niobrara River below Box Butte Reservoir (SNI4NIOBRA20) (**Table 2.9-27**). The ranges for data available for the year 2008 are shown in **Table 2.9-28**. This sampling location is an NDEQ Basin Rotation site that was sampled as part of the 6-year Basin Rotation Cycle. There was no sampling done at the site in 2009, 2010, 2011, and 2012 because sampling is only conducted every 6 years at Basin Rotation sites. Although scheduled for 2014, it may or may not be sampled in 2014, depending on site selections by the NDEQ for the Basin Rotation Cycle (Ihrie 2013b).

Box Butte Reservoir

Box Butte Reservoir is rated as Supported Beneficial Use for recreation, agricultural water supply, and aesthetics, but Impaired Beneficial Use for aquatic life (NDEQ 2010e). The impairment classification is due to a fish consumption advisory for northern pike because of elevated mercury levels identified in tissues. As a result, the water body category for this lake has been established as Category 5 (water bodies where one or more beneficial uses are determined to be impaired by one or more pollutants and all of the TMDLs have not been developed) (NDEQ 2010e).

2.9.4.3 Crow Butte Sampling of the Niobrara River

CBR established two water quality sampling locations on the Niobrara River, with one sampling point (N-1) established upstream (west) of the MEA license boundary and one point (N-2) located downstream (east) of the license boundary (**Figure 2.7-4**). Water quality and sediment samples are collected at N-1 and N-2.

Based on Requests for Additional Information (RAI) by the NRC and further discussions, the downstream sampling location on the Niobrara River was moved approximately 2.3 river miles (3.7 km) upstream to the USGS/NDNR 06454500 and NDEQ SNI4NIOBR402 Gaging Station, which is referred to as the Niobrara River above Box Butte Reservoir for sampling purposes (**Figure 2.7-4**). N-1 and N-2 are located such that potential impacts from either of the two major ephemeral drainages that drain the MEA site from northwest to southeast, and connect to the Niobrara River between N-1 and N-2.

CBR has collected monthly samples for baseline water quality analysis for radiological parameters from September 2013 through August 2014 for sampling locations N1 and N2 (**Table 2.9-29** and **Table 2.9-30**). A summary of the baseline suspended and dissolved radiological parameters is presented in **Table 2.9-31.** The results of the radiological analyses indicated that background levels were low, with the majority of the results at or below the RL (**Table 2.9-31**). The surface water laboratory records are presented in **Appendix W-1**.

2.9.4.4 USBR Box Butte Reservoir Storage Content

The USBR monitors the contents of the Box Butte Reservoir daily (USBR 2011b). Measurements (acre-feet) for the reservoir from 2003 through September 2013 are shown in **Table 2.9-34.** The average values for the content of the reservoir was 9,627 acre-feet between 2003 and September 2013. The minimum and maximum values were 2,352 and 24,942 acre-feet, respectively (see summary values in **Table 2.9-35**). Since the 1950s, groundwater depletions of base flow and numerous farm conservation practices have greatly reduced inflow into the reservoir (USBR 2008).

Box Butte Reservoir is used as a source of irrigation water; consequently, the reservoir storage content (in acre-feet) can vary considerably annually due to the use of the water for irrigation purposes downstream of the reservoir dam. Historically, the reservoir has experienced the highest reservoir elevations during the months of May and June, while September and October exhibit the lowest reservoir elevations following irrigation releases (USBR 2008). As seen in **Table 2.9-34**, the reservoir contained an average of 12,336 and 12,965 acre-feet in May and June 2013, respectively, whereas in August and September, 2013, the reservoir contained an average of 6,541 and 5,295 acre-feet, respectively.

Under an agreement among the Mirage Flats Irrigation District, the NGPC, and the USBR, a minimum pool elevation is maintained at 3,978 acre-feet to support and maintain a viable fishery resource in the reservoir (USBR 2008).

2.9.5 Baseline Vegetation, Food, and Fish Monitoring

Reference is made in this section to "milling" or "mill site" as it applies to RG 4.14. Milling or mill site typically refer to a primary recovery method or facility used to extract uranium from mined operations, e.g., conventional milling. ISR facilities perform uranium "milling" under an expanded NRC definition of by-product material that includes discrete surface wastes resulting from uranium solution extraction processes. Therefore, references to milling or mill site in this section can be extrapolated to uranium *in-situ* operations.

2.9.5.1 Vegetation

RG 4.14 recommends sampling of grazing areas near the site in different sectors that will exhibit the highest predicted air particulate concentrations during the milling operations.

Forage vegetation was sampled as described in **Table 2.9-41** following guidance in RG 4.14. The factors used to select the vegetation sampling locations within the MEA were; the three dominate wind directions, the grazing area availability and private landowner access. The forage vegetation sampling locations are shown on **Figure 2.7-4.** Three samples were collected three times during the grazing season and analyzed for natural uranium, radium-226, thorium-230, lead-210, and polonium-210. Results from the vegetation sampling are shown in **Table 2.9-32.** The analytical data sheets for vegetation sampling are provided in **Appendix Q.**

2.9.5.2 Food

Crops

RG 4.14 recommends that crops raised within ~1.86 miles (3 km) of the mill site be sampled at the time of harvest. The NRC has indicated that other food sources should be explored for sampling, such as private gardens in the area (e.g., sampling a variety of available garden plants). Grab samples should be analyzed for natural uranium, radium-226, thorium-230, lead-210, and polonium-210.

Cultivated fields make up approximately 6.3 percent of the project area as discussed in Section 2.8.5.3. During 2017, CBR will collect preoperational crop samples from available crops raised within 3 km of the MEA as required by RG 4.14. Once received the laboratory results will be added to **Appendix Q.**

Gardens

Seven private gardens were identified within 3 km of the MEA (**Figure 2.7-4).** The garden sample size to meet the LLD in RG 4.14 would require 30 lbs. of produce per sample. Consent was not granted by the private landowners to collect garden samples due to the amount of care required to grow a garden and the large sample size. As a best management practice, CBR collected garden soil samples from all seven of the private gardens. The garden soil sample results are found in **Table 2.9-36**.

Livestock

NRC RG 4.14 recommends sampling and analysis of the edible portions of livestock raised within 3 km of the site at the time of slaughter. Grab samples should be analyzed for natural uranium, radium-226, thorium-230, lead-210, and polonium-210. With the cooperation of a local landowner in March of 2014, animal tissue samples were collected from three locally raised beef cattle at the time of slaughter within 3 km of the MEA. The location of livestock samples are shown on **Figure 2.7-4.** Samples were analyzed for natural uranium, radium-226, thorium-230, lead-210, and polonium-210. **Table 2.9-33** presents the radionuclide analysis for beef samples collected in the MEA. The individual analytical data sheets, analytical QA/QC summary report, and chain of custody record are found in **Appendix DD.**



Game Animals

Although elk and pronghorn have been observed in the MEA, preoperational samples of game animals were not collected due to limited hunting access, limited availability, and movement of the animals which increased the difficulty of obtaining the quantity of sample necessary. The sample size needed to meet the LLD is 30+ lbs.

All land within the MEA permit boundary is owned by private land owners **(Figure 1.3-2).** Although hunting access may be granted by a land owner, CBR has not been granted permission to hunt on land within 3 km of the permit boundary. There is an Open Fields and Waters Hunting Area **(Figure 2.2-2)** 8 km from the MEA, however this hunting area is not within 3 km of the mill site as recommended in NRC RG 4.14.

Contact was made with the Nebraska Game and Parks Commission (NGPC) in an attempt to collect preoperational samples from Elk and Pronghorn through the following programs; Nebraska Game and Parks Commission (NGPC) Hunters Helping the Hungry Program, Depredation Program, and Confiscation Program (Lombard, 2016). No samples were available to CBR through these programs.

The MEA is located within the NGPC pronghorn hunting unit known as Box Butte West. The Box Butte West Unit covers approximately 2,000,000 acres, which makes up less than 2% of the MEA AOR. In 2016, only 59 pronghorn were harvested in the entire Box Butte West unit (Hams, 2017). Attempts to collect pronghorn samples have been unsuccessful.

Elk may compete more with cattle for forage than other big game species, because of similar diets (Nelson 1982). Yet, elk play a subordinate role to cattle, and space competition results in elk movements (Fricke, et al. 2008). Due to this movement, it would be difficult to attribute any radionuclide concentration origins to the MEA. There are a limited number of elk in the Ash Creek Elk Unit which surrounds the MEA (Fricke, et al. 2008). The MEA comprises a very small portion of the larger Ash Creek Elk Unit which ranges from east of Nebraska Highway 71, north of Nebraska Highway 2 and west of U.S. Highway 385. The Ask Creek elk unit averages only 25 elk harvested annually (Hams, 2017). Attempts to collect elk samples have been unsuccessful.

Livestock was determined to be a more relevant food sample as beef consumption in the U.S. is 67 lbs/person annually and the second highest consumer in the world per capita (OECD, 2016). It is also a more relevant food sample because it is the only animal raised within 3 km of the MEA, it is the only animal anticipated to remain on site for an extended period of time and therefore more likely to be in the pathway-to-man. Livestock samples of the edible portions of livestock raised within 3 km of the site at the time of slaughter were collected per RG 4.14.

2.9.5.3 Fish

RG 4.14 requires that fish be collected, if available, from lakes and streams in the project site area that may be subject to seepage or direct surface runoff from potentially contaminated areas or that could be affected by a tailings impoundment failure. Fish should be collected, sampled, and analyzed semiannually for natural uranium, radium-226, thorium-230, lead-210, and polonium-



210. There are no streams or water impoundments located within the MEA license boundary. There are only two dry drainages that cross the license area. Therefore, fish sampling within the MEA license boundary is not feasible.

The nearest permanent stream is the Niobrara River located just to the south of MEA license boundary which flows into Box Butte Reservoir. Given the large sample size required to attain LLDs (14 pounds) and the limited fish population present in the stream, the fish sampling focused on northern pike in the inlet of Box Butte Reservoir. Box Butte Reservoir is overpopulated with northern pike, which allows for a larger bag limit than elsewhere in Nebraska. As the most prevalent species, a popular gamefish and known human food source, sampling the meat of the northern pike is the only feasible approach to assessing potential dietary contribution to humans. Northern pike fish tissue samples were collected from the inlet of the Box Butte Reservoir on May 25, 2014 and September 26, 2014. The samples were analyzed for natural uranium, radium-226, thorium-230, lead-210, and polonium-210 (**Table 2.9-37**).

Collection of fish tissue at N-1 and N-2 **(Figure 2.7-4)** was not feasible due to the small fish population with insufficient fish biomass. Attempting to collect the required amount of fish tissue needed for the analytical laboratory to obtain the required LLD would decimate the limited fish population.

The analytical data sheets and the QA/QC summary reports for the fish tissue samples are shown in **Appendix X**.

As of May 2010, the Nebraska Department of Human and Health Services (NDHHS) with the NDEQ, the NGPC and the Nebraska Department of Agriculture (NDA), have issued fish consumption advisories for warning to limit the consumption of northern pike in Box Butte Reservoir due to elevated mercury concentrations (NDEQ 2011d).

Due to the lack of background data from the study area with which to compare the current findings, radionuclide data interpretation is impracticable at this time, other than that the concentrations are considered low. The radiological results will serve as background information for future sampling events and the development of long-term trends.

2.9.6 Baseline Soil Monitoring

RG 4.14 and NUREG-1569 recommend soil samples be collected as follows:

- Up to 40 surface soil samples collected at 300-meter intervals to a distance of 1,500 meters in each of eight directions from the center of the milling area. Surface soil samples collected to a depth of 5 cm using consistent sampling methods. Sampling conducted once prior to construction and repeated for locations disturbed by excavation, leveling, or contouring. All samples analyzed for radium-226, and 10 percent of the samples analyzed for natural uranium, thorium-230, and lead-210. Soil sampling is conducted at both a 5 cm depth and 15 cm depth for background decommissioning data Acceptance Criterion 2.9.3(2) of NUREG-1569.
- Five or more surface soil samples (to a depth of 5 cm) collected at the same locations used for air particulate samples. Samples collected once prior to construction. Samples analyzed for natural uranium, radium-226, thorium-230, and lead-210.



- Five subsurface samples collected at the center point location and distances of 750 meters in each of four directions. Subsurface soil samples collected to a depth of 1 meter and divided into three equal sections for analysis. Samples collected once prior to construction and repeated for locations disturbed by construction. All samples analyzed for radium-226, and one set of the samples analyzed for natural uranium, thorium-230, and lead-210.

All baseline soil samples were collected as described in RG 4.14 and NUREG 1569. The baseline soil monitoring results are included in the Marsland Expansion Area Baseline Radiological Investigation Report (Tetra Tech 2015) and are presented in **Appendix BB.**

Quality of Soil Measurements

The accuracy of monitoring data is critical to ensure that the soil monitoring program precisely reflects radionuclide concentrations. RG 4.14 specifies the following LLDs:

Radionuclide	LLD µCi/g (dry)	LLD pCi/g (dry)
Natural Uranium	2×10^{-7}	.2 pCi/g
Radium-226	2×10^{-7}	.2 pCi/g
Thorium-230	2×10^{-7}	.2 pCi/g
Lead-210 (dry)	2×10^{-7}	.2 pCi/g

2.9.7 Baseline Sediment Sampling

Sediments of lakes, reservoirs, and flowing bodies of surface water may become contaminated as a result of direct liquid discharges, wet surface deposition, or from runoffs associated with contaminated soils. Because of various chemically and physically binding interactions with radionuclides, sediments serve as integrating media that are important to environmental monitoring.

RG 4.14 recommends that sediment samples be collected from sediments of surface water passing through the project site or offsite surface waters that may be subject to drainage from potentially contaminated areas. The PPMP and operational monitoring plan will be designed to meet the criteria outlined in RG 4.14 (NRC 1980a). Samples are to be collected once following spring runoff and in late summer following a period of extended low flow.

2.9.7.1 Niobrara River Sediments

Sediment sampling in RG 4.14 requires samples from each large onsite body of water or offsite surface waters that may be subject to direct surface drainage from potentially contaminated areas that could be affected by a tailings impoundment failure. There are no onsite surface impoundments, so such sampling is not required. Sediment samples will be collected from the Niobrara River, which could receive surface water runoff by means of ephemeral drainages located on the MEA project site (**Figure 2.7-4**). Sediments of the Niobrara River were sampled at designated upstream and downstream sampling locations (sample points N-1 and N-2) (**Figure 2.7-**

4). Water samples are also collected at these sampling points. The downstream sampling point is located to assess potential impacts from either of the two ephemeral drainages that drain the MEA.

Sediment samples at N-1 and N-2 sampling points were collected on October 25, 2013 and May 2 2014. The radiological sample analytical results for lead-210, radium-226, thorium-230, and natural uranium are shown in **Table 2.9-38**. The analytical data sheets and the QA/QC summary reports for the Niobrara River Sediments are shown in **Appendix W-2**.

2.9.7.2 Ephemeral Drainages

There are two major ephemeral drainages that traverse across the MEA license area north to south. Seven sampling points in the channel bottom were selected on these drainages to measure radiological concentrations in the sediment at stations MED-1 through MED-7 (**Figure 2.7-4).**

The sediments in ephemeral drainages at the designated sampling points were sampled twice, once in the spring and once in late summer. Samples were analyzed for natural uranium, radium-226, thorium-230, and lead-210. The PPMP and operational monitoring program is shown in **Tables 2.9-41 and 5.7-1.**

Sediment sampling at MED-1 through MED-6 was conducted in the fourth quarter of 2013 and the second quarter of 2014. Sediment sampling at MED-7 was conducted in the fourth quarter of 2014 and the second quarter of 2015 (**Table 2.9-39**). Sediment samples were collected in accordance with the SHEQMS Volume VI Environmental Manual (CBR 2010b). The analytical data sheets and the QA/QC summary reports are provided in **Appendix W-2.**

Water was not present in the ephemeral drainage system during Q4 2013 through Q2 2015, therefore no baseline water samples were collected. If water flow becomes available at any time prior to mining at any of the sampling points (MED-1 through MED-7), CBR will collect baseline water samples.

2.9.8 Baseline Direct Radiation Monitoring

2.9.8.1 Survey Intervals

RG 4.14 recommends direct radiation measurements be collected at 150-meter intervals to a distance of 4,921.26 feet (1,500 meters) in each of eight directions from the centerpoint of the milling area or at a point equidistant from the milling area and tailings disposal area. The direct gamma radiation sampling at MEA was designed to meet or exceed this guidance. Because there are no milling or tailings disposal areas, CBR used the satellite facility as the centerpoint.

2.9.8.2 Survey Measurements at Air Particulate Monitoring Stations

The PPMP baseline radiation monitoring program includes routine monitoring of direct radiation levels at the air monitoring stations. The PPMP and operational monitoring plan has been designed to meet the criteria outlined in RG 4.14 (NRC 1980a). As with air particulate and radon-220 monitoring, gamma monitoring began in the fourth quarter of 2011 and was completed in the fourth



quarter of 2012 (five quarters of data). The PPMP and operational monitoring program is shown in **Tables 2.9-41 and 5.7-1**.

Monitoring has been conducted by placing Inlight® Systems Dosimeters, provided by Landauer, Inc., quarterly at the air particulate monitoring sites (**Figure 2.9-2**). The monitors were located approximately 1 meter above ground level. They were exchanged with new monitors quarterly, and the exposed monitors were returned to the vendor for processing. These devices provide an integrated exposure for the period between annealing and processing.

The results of gamma measurements conducted at the air particulate monitoring stations (MAR-1 through MAR-5) for the fourth quarter of 2011 through the fourth quarter 2012 are presented in **Table 2.9-40**. The gross and net measurements for all sampling locations over the entire sampling period ranged from 19.9 to 40.9 (average of 33.3) and 4.5 to 14.5 (average of 8.0) mRems ambient dose equivalent, respectively. The range of the gross and net measurements for MAR-1 through MAR-4 was 19.9 through 40.9 (average of 33.8) and 4.6 to 14.5 (average of 8.5), respectively, compared to MAR-5 with a range of 20.9 through 38.1 (average of 31.8) and 4.5 to 7.7 (average of 6.2), respectively. The gamma laboratory records are provided in **Appendix V-3**.

The average background gamma level in the Western Great Plains has been reported to be 0.014 milli-Roentgens per hour (mR/hr; NRC 1979).

NRC RG 4.14 guidance recommends a combination of direct gamma radiation measurements and exposure measurements made with integrating devices (i.e., OSLDs) during the PPMP.

In addition to the environmental gamma monitors, NRC recommends that the background gamma radiation in the area of the facility be measured with a scintillometer. As per RG 4.14, CBR performed PPMP gamma radiation measurements at 150-meter intervals as discussed above.

Tetra Tech performed two gamma survey approaches: (1) RG 4.14 direct gamma field investigation, and (2) continuous gamma survey field investigation. Both of these approaches used NRC guidance documents for ISR uranium projects. Background radiation, as described in NUREG-1757 Vol. 1, Rev. 2 Consolidated Decommission Guidance and NUREG-1757 Vol. 2, Rev. 1 Characterization, Survey, and Determination of Radiological Criteria, is radiation from cosmic sources, naturally occurring radioactive material (including radon), and global fallout. The results of these surveys are presented in their entirety in **Appendix BB**, MEA Baseline Radiological Investigation Report, and Section 2.2 (Tetra Tech 2015).

2.9.9 Preoperational/Preconstruction Baseline Monitoring Program Summary

The MEA PPMP is summarized on **Table 2.9-41.** It should be noted that the baseline monitoring program did not include radon flux. Radon flux sampling is of use for conventional mills where tailings impoundments are required and must meet radon flux standards as required in 10 CFR 40 Appendix A. As the ISR method does not involve generation of conventional tailings impoundments, radon flux measurements are not applicable to ISR facilities.



This page intentionally blank

Replacement Pages – Section 5

Instructions:

Remove pages 5-1 through 5-6
Replace with this packet 5-1 through 5-6

MEA TR

Reponses to Open Issues

6-29-2017

5 OPERATIONS

CBR operates a commercial-scale in-situ leach uranium mine (the Crow Butte Project) near Crawford, Nebraska. CBR maintains a headquarters in Casper, Wyoming, where site-licensing actions originate. All CBR operations, including the Crow Butte Project operations, are conducted in conformance with applicable laws, regulations, and requirements of the various regulatory agencies. The responsibilities described below have been designed to both ensure compliance and further implement CBR's policy for providing a safe working environment with cost-effective incorporation of the philosophy of maintaining radiation exposures as low as is reasonably achievable (ALARA).

5.1 Corporate Organization and Administrative Procedures

CBR will maintain a performance-based approach to the management of the environment and employee health and safety, including radiation safety. The SHEQMS encompasses licensing, compliance, environmental monitoring, industrial hygiene, and health physics programs under one umbrella, and it includes involvement for all employees from the individual worker to senior management. This SHEQMS will allow CBR to operate efficiently and maintain an effective environment, health, and safety program.

Figure 5.1-1 is a partial organization chart for CBR that illustrates the operation of the CPF and associated operations and identifies the management levels that play a key part in the SHEQMS that will also apply to the satellite facility. The personnel identified are responsible for the development, review, approval, implementation, and adherence to operating procedures, radiation safety programs, environmental and groundwater monitoring programs, as well as routine and non-routine maintenance activities. These individuals may also serve a functional part of the Safety and Environmental Review Panel (SERP) described in Section 5.2.3.

Specific responsibilities in the organization are described below.

5.1.1 Board of Directors

The Board of Directors for Crow Butte Resources, Inc. has the ultimate responsibility and authority for radiation safety and environmental compliance for CBR. The Board of Directors sets corporate policy and provides procedural guidance in these areas. The Board of Directors provides operational direction to the President of CBR.

5.1.2 President

The President is responsible for interpreting and acting upon the Board of Directors' policy and procedural decisions. The President directly supervises the General Manager of US Operations. The President is empowered by the Board of Directors to have the responsibility and authority for the radiation safety and environmental compliance programs. The President is responsible for ensuring that the operations staff is complying with all applicable regulations and permit/license conditions through direct supervision of the General Manager of US Operations.

5.1.3 General Manager of US Operations

The General Manager of US Operations is responsible for managing all US Operations. The General Manager of US Operations is responsible for ensuring that Crow Butte personnel comply with Industrial Safety, Radiation Safety, Environmental Protection Programs, and all relevant state and federal regulations. The General Manager of US Operations has the responsibility and the authority to suspend, postpone or modify, immediately if necessary, any activity that is determined to be a threat to employees, public health, the environment, or potentially a violation of state or federal regulations. The General Manager of US Operations reports directly to the President.

5.1.4 Restoration Manager

The Restoration Manager is responsible for all uranium production and restoration activities at the project site. The Restoration Manager is also responsible for implementing any industrial and radiation safety and environmental protection programs associated with operations and restoration. The Restoration Manager is authorized to immediately implement any action to correct or prevent hazards. The Restoration Manager has the responsibility and the authority to suspend, postpone, or modify, immediately if necessary, any activity that is determined to be a threat to employees, public health, the environment, or potentially a violation of state or federal regulations. The Restoration Manager cannot unilaterally override a decision for suspension, postponement, or modification if that decision is made by the Manager of Safety, Health, Environment and Quality, or the RSO. The Restoration Manager reports directly to the General Manager of US Operations.

5.1.5 Safety, Health, Environment, and Quality Manager

The Manager of Safety, Heath, Environment and Quality is responsible for all health and safety, and environmental programs as stated in the SHEQMS Program and for ensuring that CBR complies with all applicable regulatory requirements. The Manager of Safety, Heath, Environment and Quality reports directly to the Restoration Manager. This position assists in the development and review of radiological and environmental sampling and analysis procedures and is responsible for routine auditing of the programs. The Manager of Safety, Heath, Environment and Quality has no production-related responsibilities. The Manager of Safety, Heath, Environment and Quality also has the responsibility and authority to suspend, postpone, or modify any activity that is determined to be a threat to employees, public health, the environment or potentially a violation of state or federal regulations.

5.1.6 Plant Supervisor

The Plant Supervisor supervises plant operations, including the safe and efficient recovery and processing of uranium oxide while staying within regulatory and technical constraints. The Plant Supervisor is responsible for carrying out any procedures or actions implemented by the Restoration Manager, Manager of SHEQ, or the RSO to correct or prevent radiation safety hazards in the plant. The RSO and the Plant Supervisor or the RSO and the Restoration Manager are responsible for conducting weekly inspections of all facility areas to observe general radiation control practices and review required changes in procedures and equipment. The Plant Supervisor reports directly to the Restoration Manager.

5.1.7 Radiation Safety Officer

The RSO is responsible for the development, administration, and enforcement of all radiation safety programs. The RSO is authorized to conduct inspections and to immediately order any change necessary to preclude or eliminate radiation safety hazards and/or maintain regulatory compliance. The RSO is responsible for the implementation of all on-site environmental programs including emergency procedures. The RSO inspects facilities to verify compliance with all applicable requirements in the areas of radiological health and safety. The RSO works closely with all supervisory personnel to ensure that established programs are maintained. The RSO is also responsible for the collection and interpretation of employee exposure-related monitoring including data from radiological safety. The RSO makes recommendations to improvement any and all radiological safety-related controls. The RSO has no production-related responsibilities. The RSO reports directly to the Restoration Manager and has a secondary reporting requirement to the General Manager of US Operations.

5.1.8 Health Physics Technician

The CBR Health Physics Technician (HPT) assists the RSO with the implementation of the radiological and industrial safety programs. The HPT is responsible for the orderly collection and interpretation of all monitoring data, to include data from radiological safety and environmental programs. The HPT reports directly to the RSO. Such personnel would be familiar with operations and receive the necessary radiation safety training, including hands-on training (e.g., use of survey instruments for monitoring items removed from the restricted area; see Section 5.7.6 for additional discussions).

5.1.9 SHEQ Specialist

The SHEQ Specialist assists in the development and submittal of regulatory permits and license applications. Provides analysis and guidance in the areas of Safety, Health, Environment and Quality and is responsible for assisting site management with coordination of the corrective and preventative action process. The SHEQ Specialist maintains and updates documents associated with the activities relating to the SHEQ system. The SHEQ Specialist reports directly to the SHEQ Manager.

5.1.10 Lab Foreman

The Lab Foreman has direct oversight of the on-site analytical laboratory including implementing laboratory quality assurance procedures. The Lab Foreman is responsible for carrying out any procedures or actions implemented by the Restoration Manager, Manager of SHEQ, or the RSO to correct or prevent radiation safety hazards in the laboratory. The Lab Foreman reports directly to the SHEQ Manager.

5.1.11 Safety Supervisor/Technician

The Safety Supervisor/Technician is responsible for the non-radiation-related health and safety programs. The Safety Supervisor/Technician is authorized to conduct inspections and to immediately order any change necessary to preclude or eliminate safety hazards and/or maintain regulatory compliance. Responsibilities include the development and implementation of health

and safety programs in compliance with Occupational Safety and Health Administration (OSHA) regulations. Responsibilities of the Safety Supervisor/Technician include development of industrial safety and health programs and procedures, coordination with the RSO where industrial and radiological safety concerns are interrelated, safety and health training of new and existing employees, and the maintenance of appropriate records to document compliance with regulations. The Safety Supervisor/Technician may be a qualified HPT and may function in that capacity when needed. The Safety Supervisor/Technician reports directly to the SHEQ Manager.

5.1.12 Qualified Designated Operator

The qualified Designated Operator is responsible for performing daily inspection in the occasional absence of the RSO and the HPT. A qualified Designated Operator will meet the minimum qualifications and perform only those duties as outline in Section 5.5.4.

5.1.13 ALARA Program Responsibilities

The purpose of the ALARA program is to keep exposures to all radioactive materials and other hazardous material as low as possible, and to expose as few personnel as possible. This program takes into account the state of technology and the economics of improvements in relation to benefits to the public health, safety, and other societal and socioeconomic considerations, and in relation to the use of atomic energy in the public interest.

In order for an ALARA program to correctly function, all individuals, including management, supervisors, health physics staff, and workers, must take part in and share responsibility for keeping all exposures ALARA. This policy addresses this need and describes the responsibilities of each level in the organization.

5.1.14 Management Responsibilities

Consistent with RG 8.31 (NRC 2002a), CBR senior management is responsible for the development, implementation, and enforcement of applicable rules, policies, and procedures as directed by regulatory agencies and company policies. These responsibilities include the following:

1. The development of a strong commitment to and continuing support of the implementation and operations of the ALARA program
2. An Annual Audit Program which reviews radiation monitoring results, procedural, and operational methods
3. A continuing evaluation of the Health Physics Program including adequate staffing and support
4. Proper training and discussions that address the ALARA program and its function to all facility employees and, when appropriate, to contractors and visitors.

5.1.14.1 Radiation Safety Officer ALARA Responsibility

The RSO is responsible for ensuring the technical adequacy of the radiation protection program, implementation of proper radiation protection measures, and the overall surveillance and maintenance of the ALARA program. The RSO is assigned the following:

1. The responsibility for the development and administration of the ALARA program
2. Enforcement of regulations and administrative policies that affect any radiological aspect of the SHEQMS
3. Assistance with the review and approval of new equipment, process changes, or operating procedures to ensure that the plans do not adversely affect the radiological aspects of the SHEQMS
4. Maintenance of equipment and surveillance programs to ensure continued implementation of the ALARA program
5. Assistance with conducting an Annual ALARA Audit, as discussed in Section 5.3.2, to determine the effectiveness of the program and make any appropriate recommendations or changes as may be dictated by the ALARA philosophy
6. Annual review of all existing operating procedures involving or potentially involving any handling, processing, or storage of radioactive materials to ensure that the procedures are ALARA and do not violate any newly established radiation protection practices
7. Conductance of (or designate a qualified individual to conduct) daily inspections of pertinent facility areas to confirm that general radiation control practices, hygiene, and housekeeping practices are in line with the ALARA principle

5.1.14.2 Supervisor Responsibility

Supervisors shall be the front line for implementing the ALARA program. Each supervisor shall be trained and instructed in the general radiation safety practices and procedures. Their responsibilities include:

1. Adequate training to implement the general philosophy behind the ALARA program
2. Directing and guiding to subordinates in ways to adhere to the ALARA program
3. Enforcing rules and policies as directed by the SHEQMS, which implement the requirements of regulatory agencies and company management
4. Seeking additional help from management and the RSO should radiological problems be deemed by the supervisor to be outside their sphere of training

5.1.14.3 Worker Responsibility

Because success of both the radiation protection and ALARA programs are contingent upon the cooperation and adherence to those policies by the workers themselves, the facility employees must be responsible for certain aspects of the program in order for the program to accomplish its goal of keeping exposures as low as possible. Worker responsibilities include:

1. Adhering to all rules, notices, and operating procedures established by management and the RSO through the SHEQMS
2. Making suggestions which might improve the radiation protection and ALARA programs
3. Reporting promptly, to immediate supervisor, any malfunction of equipment or violation of procedures which could result in an unacceptable increased radiological hazard
4. Properly using protective equipment
5. Properly performing required contamination surveys

5.1.15 Contractor Management

Like the CPF, CBR will employ contractors to accomplish a variety of tasks at the MEA starting with facility construction and continuing into operations. CBR contractor interactions are governed by the Cameco Resources SHEQ Management System, Contractor Management Program, Document Number CR-CMP. The CMP describes the requirement for managing both long term and short term contractors, including subcontractors at all CBR work sites. The purpose of the contractor management program is to insure a consistent approach to managing contractor activities. The major elements of the program include:

- Development of a Scope of Work that identifies and addresses Safety, Radiation, Environmental, and Quality objectives
- Cameco review of required subcontractor submissions
- Establishment and control of site access
- Training
- Job Hazard Analyses where appropriate
- Communication with the subcontractor
- Documentation
- Change Control
- Emergency preparedness and response
- Roles and responsibilities
- Supervision and Oversight of Contractor Performance
    - Graded approach
    - Inspections and audits
    - Tracking
    - Non-conformances and corrective actions
- Management reviews

The overall objectives of this program are to insure that:

- People and the environment are protected;
- SHEQ risks associated with contractor activities are managed in a risk-informed manner;
- Contractor's work in accordance with Cameco's SHEQ Policy, CBR's integrated SHEQ management system and applicable regulatory requirements; and
- CBR is duly diligent with respect to contractor management.

Replacement Pages – Section 5

Instructions:

Remove pages 5-45 through 5-56
Replace with this packet 5-45 through 5-60

MEA TR

Reponses to Open Issues

6-29-2017

shall be deemed to be in compliance with 10 CFR 20.1208 if the additional dose equivalent to the embryo/fetus does not exceed 0.05 Rem (0.5 mSv) during the remainder of the pregnancy.

Individual Monitoring of External and Internal Occupational Exposure

The dose equivalent to the embryo/fetus is determined by the monitoring of the declared pregnant woman. 10 CFR §20.1502(a)(3) requires monitoring the exposure of a declared pregnant woman when the external dose to the embryo/fetus is likely to receive during the entire pregnancy, from radiation sources external to the body, a DDE in excess of 0.1 Rem (1 mSv). All of the occupational doses in 10 CFR 20.1201 continue to be applicable to the declared pregnant worker as long as the embryo/fetus dose limit is not exceeded. 10 CFR 20.1502(b)(3) requires the monitoring of occupational intake of radioactive material by and assess the committed effective dose equivalent to a declared pregnant woman likely to receive, during the entire pregnancy, a CEDE in excess of 0.1 Rem (1 mSv). Based on this 0.1 Rem threshold, the dose to the embryo/fetus must be determined if the intake is likely to exceed 1 percent of ALI during the entire period of gestation.

Prior to declaration of pregnancy, the woman may not have been subject to monitoring based on the conditions specified in 10 CFR 20.1502. In this case, CBR will estimate the exposure during the period monitoring was not provided, using any combination of surveys or other available data (for example, air monitoring, area monitoring, and bioassay). Exposure calculations will be performed as recommended in RG 8.36 (NRC 1992d).

External Dose to the Embryo/Fetus

The DDE to the declared pregnant woman during the gestation period will be taken as the external dose for the embryo/fetus. The determination of external dose will consider all occupational exposures of the declared pregnant woman since the estimated date of conception and will be based on the methods discussed in Section 5.7.2. External dose to the declared pregnant woman after declaration for the duration of the pregnancy shall be accomplished by personal dosimetry with monthly exchanges.

Internal Dose To The Embryo/Fetus

The internal dose to the embryo/fetus will consider the exposure to the embryo/fetus from radionuclides in the declared pregnant woman and in the embryo/fetus. The dose to the embryo/fetus will include the contribution from any radionuclides in the declared pregnant woman (body burden) from occupational intakes occurring prior to conception.

The intake for the declared pregnant woman will be determined as discussed in Sections 5.7.3.1 and 5.7.3.2.

5.7.5 Bioassay Program

CBR has implemented a urinalysis bioassay program at the Crow Butte Uranium Project facilities that meets the guidelines contained in RG 8.22 (NRC 1988). The primary purpose of the program is to detect uranium intake in employees who are regularly exposed to uranium. The bioassay program consists of the following elements:

1. Prior to assignment to the facility, all new employees are required to submit a baseline urinalysis sample. Upon termination, an exit bioassay is required from all employees.

2. During operations, urine samples are collected from workers quarterly. Employees who have the potential for exposure to dried yellowcake submit bioassay samples monthly or more frequently as determined by the RSO. Samples are analyzed for uranium content by a contract analytical laboratory. Blank and spiked samples are also submitted to the laboratory with employee samples as part of the Quality Assurance program. The measurement sensitivity for the analytical laboratory is 5 µg/L.
3. Action levels for urinalysis are established based upon Table A-1 in RG 8.22.

Elements of the quality assurance requirements for the Bioassay Program are based upon the guidelines contained in RG 8.22. These elements included the following:

1. Each batch of samples submitted to the contract analytical laboratory is accompanied by two blind control samples. The control samples are from persons that have not been occupationally exposed and are spiked to a uranium concentration of 10 to 20 µg/L and 40 to 60 µg/L. The results of analysis for these samples are required to be within ± 30 percent of the spiked value.
2. The contract analytical laboratory spikes 10 to 30 percent of all samples received with known concentrations of uranium and the recovery fraction determined. Results are reported to CBR.

CBR proposes to continue to implement the Bioassay Program described in this section for operations at the satellite facility. The facility and wellfield operators will be included in a personnel dosimetry (exchanged quarterly) and bioassay program, with urine samples collected quarterly. The program will be implemented in accordance with the guidance contained in RG 8.22 and with the instructions currently contained in SHEQMS Volume IV, Health Physics Manual.

5.7.6 Contamination Control Program

The Survey Program for Beta/Gamma Contamination, submitted as a license condition requirement under Crow Butte Source Materials License, SUA-1534 (CBR), will be used for beta/gamma surveys of personnel and equipment exiting restricted areas at the MEA 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.

5.7.6.1 Surface Contamination

CBR will perform surveys for surface contamination in operating and clean areas of the satellite facility in accordance with the guidelines contained in RG 8.30. Surveys for total alpha and beta contamination in clean areas will be conducted weekly. In designated clean areas, such as lunchrooms, offices, change rooms, and respirator cabinets, the target level of contamination is nothing detectable above background. If the total alpha or beta survey indicates contamination that exceeds 250 disintegrations per minute (dpm)/100 cm^2 (25 percent of the removable limit) a smear survey must be performed to assess the level of removable alpha and beta activity. If smear test results indicate removable contamination greater than 250 dpm/100 cm^2, the area will be promptly cleaned and resurveyed. Total surface activity will be measured with an appropriate alpha/beta

survey meter. A Ludlum 2224-1 scaler/ratemeter or a Ludlum model 3030E with a model 43-93 probe or equivalent.

5.7.6.2 Personnel Contamination

All personnel leaving a restricted area will be required to perform and document alpha and beta contamination monitoring. In addition, personnel who could come in contact with potentially contaminated solutions outside a restricted area such as in the wellfield will be required to monitor themselves prior to leaving the area. All personnel receive training in surveys for skin and personal contamination. All contamination on skin and clothing is considered removable, so the limit of 1,000 dpm/100 cm^2 is applied to personnel monitoring. Personnel will also be allowed to conduct contamination monitoring of small, hand-carried items for use in wellfield and controlled areas as long as all surfaces can be reached with the instrument probe and the item does not originate in yellowcake areas. Personnel surveys will be measured with an appropriate alpha/beta survey meter. A Ludlum 2224-1 scaler/ratemeter or a Ludlum model 3030E with a model 43-93 probe or equivalent. All other items are surveyed as described below.

5.7.6.3 Controlled Release Survey Program

The Controlled Release Survey Program (CRSP) will allow for the *controlled* release of equipment, materials, or packages, including items in packages and resin trailers from a restricted area. The CRSP items will be maintained in the control of a CRSP trained and qualified employee until returned to a restricted area, installed, surveyed for unrestricted release by the RSO or a qualified HPT, or disposed of as 11e.(2) byproduct waste.

Non-radiation staff trained and qualified in the CRSP will perform the controlled release surveys. The qualified CRSP employee will be qualified through a combination of education, facility specific experience and training specific to the risks associated with controlled release. The competency of the designee will be evaluated prior to qualification and continued competency will be maintained through refresher training and surveys in the field.

Program Qualifications and Training

Designated non-radiation staff must meet the general qualifications and training and specific CRSP training requirements to be qualified to perform controlled releases within the CRSP. Proficiency must be demonstrated prior to entering the CRSP and annually to maintain qualification.

General Qualifications and Training

- Education: a high school diploma or equivalent
- Six months work experience in a uranium recovery facility, including procedures that involve health physics, industrial safety or industrial hygiene at a uranium recovery facility.
- New Employee Radiation Safety Training

Training

CRSP training will be conducted by an RSO or a qualified HPT. Employees must demonstrate competency with an 80% passing test grade covering the following topics:

- Appropriate Use of the Controlled Release Survey Program
- Contamination Control
- Action Limits
- Allowable Limits
- Survey Locations
- Pre-survey inspections
- Decontamination of Items
- Proper use of survey instruments
    - Alpha Surveys (Ludlum Model 177 and 43-5 probe or equivalent)
    - Beta Surveys (Ludlum Model 2224-1 and 43-93 probe or equivalent)
- Marking and Tagging
- Logging
- Release of resin trailers
- Security
- Recordkeeping

Demonstration of Proficiency

Initial proficiency will be determined by performing a minimum of six (6) controlled release surveys under the supervision of the RSO or a qualified HPT. The supervised surveys will be documented with signatures of the RSO or a qualified HPT and the trainee.

If initial proficiency is not demonstrated, re-evaluation may be allowed by performing additional surveys. The additional controlled release surveys will be supervised by the RSO and proficiency must be demonstrated to the satisfaction of the RSO.

Maintaining Qualification

To maintain designation in the CRSP, annual radiation safety refresher training will be completed along with an 80% passing test grade. A minimum of two (2) supervised controlled release surveys will be performed annually and documented under the direct supervision of the RSO or a qualified HPT.

Training Documentation

Training documentation will include new employee radiation safety training, CRSP training, training tests, evaluation surveys, maintenance surveys and re-evaluation surveys, if necessary. Training documentation will be maintained by the RSO.

Controlled Release of Equipment, Materials or Packages

The elements of the CRSP for controlled release of equipment, materials or packages are presented below.

Applicability	• The Controlled Release Survey Program (CRSP) will allow for the *controlled* release of equipment, materials, or packages, including items in packages and resin trailers from a restricted area. • The CRSP items will be maintained in the control of a CRSP trained and qualified employee until returned to a restricted area, installed, surveyed for unrestricted release by the RSO or a qualified HPT, or disposed of as 11e.(2) byproduct waste. • Not required for small personal items or notebooks.
Appropriate Use	• CRSP will not be used casually – equipment, materials, or packages available outside the restricted area should be accessed even when inconvenient.
Condition of Item	• The surface of each item or package containing an item must be free of surficial dirt, debris, grease, oil, loose paint or other material that could become detached. • When the item is difficult to clean or survey, it must be placed in an appropriately sealed container that can be surveyed for release.
Criteria	• The action limit will be a total activity of 750 dpm/100cm^2 in order to moderate the potential for exceeding the removable release limits located in Table 2 of Regulatory Guide 8.30. • If this action limit is exceeded the item or package will be decontaminated and resurveyed. If the limit is exceeded upon resurvey, the CRSP requires approval from a member of the radiation safety staff prior to removing the item from the restricted area.
Tracking	• Controlled released item(s) or package(s) will be marked/tagged. • Items assigned controlled release status will be logged. • Markings/tags may only be removed when the item or package is returned to a restricted area, or released for unrestricted use by the RSO or a qualified HPT, installed, or properly disposed of as 11e.(2) Byproduct waste.

Controlled Release of Resin Trailers

The elements of the CRSP for Resin Trailers to be released from a satellite facility are presented below.

Appropriate Use	• For the transportation of loaded and unloaded resin between the satellite facility and the Central Processing Plant where they will re-enter a restricted area.
Condition of Trailer	• Pre-trip tractor and trailer inspection • The resin trailer must be free of surficial dirt, debris, grease, oil, loose paint or other material that could become detached.

Criteria	• Pre-trip gamma and alpha surveys • Alpha activity <2200 dpm/100cm^2 above background • If alpha activity is >2200 dpm/100cm^2 above background clean contaminated area(s) and resurvey • If alpha activity cannot be cleaned below this level contact a member of radiation safety staff to perform a smear (removable) survey with the same action level
Tracking	• Transportation Survey Form

Survey equipment is calibrated annually or at the manufacturer's recommended frequency, whichever is more frequent. Surface contamination instruments are checked daily when in use. Alpha/Beta survey meters for personnel surveys are response checked before each use, with other checks performed weekly. For additional information see Section 3.3.

As recommended in RG 8.30, CBR conducts quarterly unannounced spot checks of personnel to verify the effectiveness of the surveys for personnel contamination. A spot check of the employees assigned to the satellite facility will be conducted, concentrating on facility operators and maintenance personnel. The purpose of the surveys is to ensure that employees are adequately surveying and decontaminating themselves prior to exiting the restricted areas.

The contamination control program for the satellite facility will be implemented in accordance with the SHEQMS Volume IV, Health Physics Manual.

5.7.7 Airborne Effluent and Environmental Operational Monitoring Programs

The operational baseline monitoring program is presented in **Table 5.7-1.**

5.7.7.1 Air Particulate Monitoring

Composite airborne particulate samples for natural uranium, radium-226, lead-210, and thorium-230 will be obtained quarterly from air monitoring locations MAR-1 through MAR-6. The quality of sample collection and analysis shall be maintained by adhering to quality control (QC) procedures discussed in Section 5.7.10 and LLD concentration limits discussed in Section 2.9.2.4

The air particulate samplers described in Section 2.9.2 will continue to be used for the operational monitoring program.

5.7.7.2 Radon and Radon Progeny

Satellite Facility

Emissions from the satellite facility will be determined based on the following assumptions and measurements. The total radon emission from the satellite facility will be the sum of the radon released from the tank vents of the tanks with the potential to contain significant quantities of radon plus the ambient radon in the facilities that is vented through the building's exhaust fans.

The satellite facility will use pressurized downflow IX columns, which do not routinely release radon gas except during resin transfer and column backwashing. The design and operation of these systems result in the majority of the radon in the production fluid staying in solution and not being released from the columns. Lucas cells will be used to sample the air in the tank vent and quantify the concentration of radon at each tank vent. The use of scintillation cells for the measurement radon is an approved method, as outlined in Method 115 from 40 CFR 61 Appendix B. While the method describes the use of scintillation cells for underground mining and tailing piles, it can be applied to this application. Measurements of the radon from tank vents will be performed at a minimum of once a quarter.

The amount of radon in the satellite facility air will be determined using Track Etch cups with semi-annual exposures. There will be four sample locations throughout the facility **(Figure 5.7-2).** Each semi-annual sample results from the four locations will be averaged to determine the ambient radon concentration in the facilities air. The rate of radon released from the process facility will be based on the manufactures flowrate for each of the exhaust fans. It will be assumed that the fans are operational 100% of the time which represents the worst case scenario.

A total radon released from the satellite facility will be calculated semi-annually based on the sum of the radon released from the tank vents and the ambient radon released as a result of the building ventilation. This release rate will be reported semiannually in agreement with 10 CFR 40.65.

The radon gas effluent released to the environment from satellite facility will be monitored at the same air monitoring locations (MAR-1 through MAR-6) that were used for baseline determination of radon concentrations as described in Section 2.9.2. Sampling locations are shown on **Figure**

2.9-2. Monitoring will be performed using Track-Etch radon cups. The cups will be exchanged semiannually to achieve the required LLD. SHEQMS Volume IV, Health Physics Manual currently provides the instructions for environmental radon gas monitoring. In addition to the manufacturer's Quality Assurance program, CBR will expose one duplicate radon Track Etch cup per monitoring period. The quality of sample collection and analysis shall be maintained by adhering to QC procedures discussed in Section 5.7.10 and LLD concentration limits discussed in Section 2.9.2.4.

CBR has used MILDOS-AREA to model the dose from facility operations resulting from releases of radon gas (Savignac 2014). MILDOS-AREA outputs are presented in **Appendix M,** and are discussed in Section 7.3.3. In determining the source term for MILDOS-AREA for the satellite facility, radon gas release was estimated at 25 percent of the radon-222 in the production fluid from the wellfields and an additional 10 percent in the IX circuit in the satellite building. The release of radon-222 at this concentration did not result in significant public dose.

Prior to operation, CBR will submit a figure showing the sampling locations of the tank vents and general ventilation discharge points to the NRC for review.

Wellhouses

Radon emissions from wellhouses will be estimated based on the following assumptions and measurements. The concentration of radon in air released from the wellhouse will be based on radon measurements taken within the wellhouse utilizing Track Etch cups with a six month exposure time. The average semi-annual radon concentrations will be used along with the manufacture's rating on the wellhouse exhaust fan to determine the total radon released from the wellhouse. This assumes that all radon in the wellhouse is released into the environment at a rate of the exhaust fan. The exhaust fans in the wellhouses are operated on a continual basis.

A maximum of four production and four restoration wellhouses will be monitored as described above. The average radon emission per wellhouse will be attributed to the remaining operational wellhouses in each group. The emissions from the operational wellhouses will be totaled on a semi-annual basis and reported in the semi-annual report consistent with the requirements of 10 CFR 40.65.

Emissions of particulate radionuclides will be estimated based upon semi-annual isotopic analysis of filters used for semi-annual air particulate in air samples in each of the wellhouses that are monitored for radon. The wellhouse exhaust rate will be based on the manufactures rating on the fans in the wellhouses. The total of all of the operational wellhouses emissions will be reported in the semi-annual report consistent with the requirements of 10 CFR 40.65. No more than four production and four restoration wellhouses will be monitored annually.

Wellfields

Injection wells have sealed wellheads and the potential for radon release is minimal. Potential emission of radon in the wellfield is limited to the production wells; however this source is also minimal. The release of radon from production wells is considered to be negligible. The submersible pumps are positioned just above the production zone of the wellfield. These submersible pumps are extracting production fluids containing dissolved radon from the formation

and transfer these solutions to the nearest wellhouse through a closed poly pipe line under pressure. This production fluid is the source of the radon measured in the wellhouses.

The stagnant nature of the fluid above the pump lacks the turbulence to release a significant amount of radon gas into the well bore above the fluid surface. The stagnant water in the well above the pump is raised or lowered within the well bore by atmospheric conditions or changes in pump flow rates. These minor changes in the water level in the wellbore are the only means to exhaust gases from the production wellhead. Given the small volume of gas and the low concentration of radon in this gas, the radon released from the production wells is minor when compared to the quantity released from the satellite facility and the wellhouses. Because the production fluid is the main source of radon measured in the wellhouses, a separate reporting of radon from the production wells will not be included in the release calculations.

A potential source of radon emitted from the wellheads and piping occurs when the wellheads are opened to the atmosphere to depressurize a wellhead that has become pressurized. Because this situation is transient and very short lived, in addition to being highly localized, emissions from this situation will be measured through the use of grab samples collected with scintillation cells. Sampling of at least one well per quarter will be planned to determine the radon concentration in the gases released during depressurization of the wellhead. These samples will be collected in the airstream being vented from the well. The volume of gas will be calculated based on the casing volume and well pressure. The casing volume will assume the casing diameter and the average length of the casing from ground surface to the top of the screen for each mine unit.

The other potential source of radon release from the wellfields is the unplanned releases of process fluid resulting from spills in the wellfield. The amount of radon released as a result of a spill will be estimated based on the volume of fluid released and an estimate of the radon concentration in that fluid. The concentration of radon in the fluid will be based on the calculations used to determine the radon concentration in production fluid by the program MILDOS. While the quantity of radon released as a result of spills in the wellfields is minor this procedure will represent a conservative estimate of the radon released.

The quantity of radon released from the satellite facility, wellhouses, well venting, and spills will be summarized on a semi-annual basis and reported in the semiannual report consistent with the requirements of 10 CFR 40.65.

5.7.7.3 Surface Soil

Surface soil will be sampled as described in Section 2.9. Surface soil samples will be taken at the monitoring locations (MAR-1 through MAR-6) during operations (Table 5.7-1). Following conclusion of operations, samples will be collected and compared to the results of the PPMP. Samples shall be analyzed for natural uranium, radium-226, and lead-210.

Surface soil will also be sampled at the satellite plant location as described in Section 2.9. Surface soil samples will be taken following conclusion of operations and compared to the results of the PPMP. The quality of sample collection and analysis shall be maintained by adhering to QC procedures and LLD concentration limits discussed in Section 2.9.6.



5.7.7.4 Subsurface Soil

Subsurface soil will be sampled at the facility location as described in Section 2.9. Subsurface soil samples will be taken following conclusion of operations and compared to the results of the PPMP. The quality of samples shall be maintained by following QC procedures discussed in Section 5.7.10 and adhering to the LLD concentration limits discussed in Section 2.9.6.

5.7.7.5 Vegetation

Samples of vegetation will be collected three times during the grazing season at each air monitoring station presented on Figure 2.9.2. These air monitoring locations are located in three different sectors having the highest predicted airborne radionuclide concentrations due to ISR operations, which is a siting criterion for the air monitoring stations. Justification regarding the placement of these air monitoring stations as they apply to recommendations in RG 4.14 is provided in Section 2.9.2. The samples of vegetation will be analyzed for radium-226 and lead-210.

Based on MILDOS-AREA results that show the total effective dose equivalent (TEDE) from all pathways is less than 5% of the applicable radiation protection standard (the modeled dose to potential maximally exposed member of the public is approximately 27 mrem/year), CBR does not believe that the ingestion pathways from grazing animals is a potentially significant pathway exceeding 5% of the applicable radiation protection standard. However, CBR will sample vegetation during the first year of operations for comparison to the baseline data. If analysis and MILDOS-AREA determine that there is not a significant pathway, CBR will propose to modify the monitoring plan to remove the sampling of vegetation or forage from the operational monitoring program. This is consistent with recommendations contained in RG 4.14.

5.7.7.6 Food

Crops

Based on MILDOS-AREA results that show the total effective dose equivalent (TEDE) from all pathways is less than 5% of the applicable radiation protection standard (the modeled dose to potential maximally exposed member of the public is approximately 27 mrem/year), the ingestion pathway from crops would not likely exceed 5% of the applicable radiation protection standard. If the pre-operational crop results described in Section 2.9.5.2 supported by MILDOS-AREA modeling demonstrate no significant exposure pathway, CBR will propose to modify the monitoring plan to remove the sampling of crops from the operational monitoring program. This approach is consistent with the recommendations contained in RG 4.14.

Livestock

CBR commits to collecting livestock samples annually consistent with guidance contained in RG 4.14. Livestock samples will be collected and analyzed for uranium (natural), thorium-230, radium-226, lead-210 and polonium-210. If the analysis of livestock tissue supported by the annual MILDOS-AREA modeling indicates grazing animals demonstrate no significant exposure pathway, CBR will propose to modify the monitoring plan to remove livestock from the operational monitoring program. This approach is consistent with the recommendations contained in RG 4.14, Table 2, footnote "o".

Fish

Due to the arid nature of the area in which the MEA is located, the dry drainages that traverse to MEA license boundary do not support a fish population. The two major ephemeral drainages eventually connect to the Niobrara River, which is the nearest stream with permanent water. The river is located south of the license boundary, flowing west to east. The Box Butte Reservoir is located on the Niobrara River approximately 3.5 miles (5.6 km) from the southeastern corner of the MEA license boundary. The storm water controls (berms) employed at the Marsland operation will prevent the discharge of liquids into the ephemeral drainages. Any spills that could occur would be contained per the site spill control plans, and it is highly unlikely that any liquid spills would ever reach the Niobrara River. However, at certain times of the year, the Niobrara River may gain flow from Brule or Arikaree groundwater. If those sources of groundwater were contaminated, it could impact fish. Therefore operational fish samples will be collected from Box Butte Reservoir per **Table 5.7-1**.

Game Animals

Due to the migratory nature, small herd size and relatively large home range of game animals in relation to the size of the project area, game animals are not a significant pathway to man, which RG 4.14 lists as a criterion for sampling in the operational monitoring program. This will be confirmed through annual MILDOS-AREA modeling.

5.7.7.7 Direct Radiation

Environmental gamma radiation levels will be monitored continuously at the air monitoring stations (MAR-1 through MAR-6) during operations. Gamma radiation will be monitored using environmental dosimeters obtained from an NVLAP certified vendor. Dosimeters will be exchanged quarterly.

5.7.7.8 Sediment

Sediment samples will be collected annually at the sample locations described in Section 2.9 and shown in **Figure 2.7-4**. Samples will be collected as described in Section 2.9.7 and analyzed for natural uranium, radium-226, thorium-230, and lead-210. The quality of sample collection and analysis shall be maintained by adhering to QC procedures as discussed in Section 5.7.10 and LLD concentration limits discussed in Section 2.9.7.1.

5.7.8 Groundwater/Surface Water Monitoring Program

5.7.8.1 Program Description

During operations at the satellite facility, a detailed water sampling program will be conducted to identify any potential impacts to water resources of the area. The CBR operational water monitoring program includes the regional evaluation of groundwater, groundwater within the permit or licensed area, and surface water on a regional and site-specific basis. The quality of sample collection and analysis shall be maintained by adhering to QC procedures discussed in Section 5.7.10.

5.7.8.2 Groundwater Monitoring

The groundwater excursion monitoring program is designed to detect excursions of lixiviant into the ore zone aquifer outside of the wellfield being leached and into the overlying water-bearing strata. Monitor wells will be placed in the basal sandstone of the Chadron Formation and in the overlying Brule and Arikaree aquifers. All monitor wells will be completed by one of the three methods discussed in Section 3.1.2.2, developed prior to recovery solution injection. The development process for monitor wells includes establishing baseline water quality before the initiation of mining operations.

The Pierre Shale below the ore zone is more than 1,200 feet thick and contains no water-bearing strata. Therefore, it is not necessary to monitor any water-bearing strata below the ore zone.

5.7.9 Private Well Monitoring

During operations, on a quarterly basis, all active, operational and accessible private wells located within the MEA license boundary and within 0.62 mile (1 km) of the MEA license boundary will be monitored (**Figures 2.7-6 and 2.9-3**). Groundwater samples are taken in accordance with the instructions contained in SHEQMS Volume VI, Environmental Manual, and samples are analyzed for natural uranium and radium-226. Water well samples will be collected and analyzed as described in Section 2.9.3.1.

5.7.9.1 Monitor Well Baseline Water Quality

After delineation of the production unit boundaries, monitor wells are installed no further than 300 feet from the wellfield boundary and no further than 400 feet apart or as required by the NDEQ. After completion, wells are washed out and developed (by air-lifting or pumping) until pH and specific conductivity appear stable and consistent with the anticipated quality of the area. After development, wells are sampled to obtain baseline water quality data. For baseline sampling, wells are purged before sample collection to ensure that representative water is obtained. All monitor wells, including ore zone and overlying monitor wells, are sampled four times at least 14 days apart. Samples are analyzed for chloride, conductivity, and total alkalinity as specified in License Condition 10.4. Results from the samples are averaged arithmetically to obtain an average baseline value as well as a maximum value for determination of upper control limits for excursion detection. Wells are developed and sampled in accordance with the instructions contained in SHEQMS Volume VI, Environmental Manual.

5.7.9.2 Upper Control Limits and Excursion Monitoring

After baseline water quality is established for the monitor wells for a particular production unit, upper control limits (UCLs) are set for chemical constituents which would indicate a migration of lixiviant from the wellfield. The constituents chosen for indicators of lixiviant migration and for which UCLs are set are chloride, conductivity, and total alkalinity. Chloride was chosen due to its low natural levels in the native groundwater and because chloride is introduced into the lixiviant from the IX process (uranium is exchanged for chloride on the IX resin). Chloride is also a highly mobile constituent in the groundwater and will show up very quickly in the case of a lixiviant migration to a monitor well. Conductivity was chosen because it is an excellent general indicator of overall groundwater quality. Total alkalinity concentrations should be affected during an



excursion, as bicarbonate is the major constituent added to the lixiviant during mining. Water levels are obtained and recorded prior to each well sampling. However, water levels are not used as an excursion indicator. Upper control limits are set at 20 percent above the maximum baseline concentration for the excursion indicator. For excursion indicators with a baseline average below 50 mg/L, the UCL may be determined by adding 5 standard deviations or 15 mg/L to the baseline average for the indicator.

Operational monitoring consists of sampling the monitor wells biweekly and analyzing the samples for the excursion indicators chloride, conductivity, and total alkalinity. License SUA-1534 Condition 11.2 currently requires that monitor wells be sampled no more than 14 days apart except in certain situations. These situations include inclement weather, mechanical failure, holiday scheduling, or other factors that may result in placing an employee at risk or potentially damaging the surrounding environment. In these situations, CBR documents the cause and the duration of any delays. In no event is sampling delayed for more than 5 days.

5.7.9.3 Excursion Verification and Corrective Action

During routine sampling, if two of the three UCL values are exceeded in a monitor well, or if one UCL value is exceeded by 20 percent, the well is resampled within 48 hours and analyzed for the excursion indicators. If the second sample does not exceed the UCLs, a third sample is taken within 48 hours. If neither the second nor third sample results exceeded the UCLs, the first sample is considered in error.

If the second or third sample verifies an exceedance, the well in question is placed on excursion status. Upon verification of the excursion, the NRC Project Manager is notified by telephone or email within 24 hours and notified in writing within 7 days.

If an excursion is verified, the following methods of corrective action are instituted (not necessarily in the order given) dependent upon the circumstances:

- A preliminary investigation is completed to determine the probable cause.
- Production and/or injection rates in the vicinity of the monitor well are adjusted as necessary to increase the net over recovery, thus forming a hydraulic gradient toward the production zone.
- Individual wells are pumped to enhance recovery of mining solutions.

Injection into the wellfield area adjacent to the monitor well may be suspended. Recovery operations continue, thus increasing the overall bleed rate and the recovery of wellfield solutions.

In addition to the above corrective actions, sampling frequency of the monitor well on excursion status is increased to weekly. An excursion is considered concluded when the concentrations of excursion indicators do not exceed the criteria defining an excursion for three consecutive 1-week samples.

Surface Water Monitoring

Whenever sufficient flow is available for sampling in the ephermal drainages, surface water samples will be collected from the main drainage channel as described in Section 2.9. In addition,

a seventh location MED-7 has been added where one of the two ephemeral drainages leaves and then quickly re-enters the license boundary. In the Niobrara River, samples will be collected quarterly and analyzed for dissolved and suspended natural uranium, radium-226, thorium-230, lead-210, and polonium-210. The seven sample locations are shown on **Figure 2.7-4.** The quality of sample collection and analysis shall be maintained by adhering to QC procedures discussed in Section 5.7.10 and LLD concentration limits discussed in Section 2.9.4.5.

Surface water samples will be taken in accordance with the instructions contained in SHEQMS Volume VI, Environmental Manual. Upstream and downstream samples from all locations will be obtained quarterly. Surface water samples are analyzed for the parameters identified in Section 2.9. Surface monitoring results are submitted in the semi-annual environmental and effluent reports submitted to NRC.

5.7.10 Quality Assurance Program

A quality assurance (QA) program is in place at Crow Butte Uranium Project for all relevant operational monitoring and analytical procedures. The objective of the program is to identify any deficiencies in the sampling techniques and measurement processes so that corrective action can be taken and to obtain a level of confidence in the results of the monitoring programs. The QA program provides assurance to both regulatory agencies and the public that the monitoring results are valid.

The QA program addresses the following:

- Formal delineation of organizational structure and management responsibilities. Responsibility for both review/approval of written procedures and monitoring data/reports is provided
- Minimum qualifications and training programs for individuals performing radiological monitoring and those individuals associated with the QA program
- Written procedures for QA activities. These procedures include activities involving sample analysis, calibration of instrumentation, calculation techniques, data evaluation, and data reporting
- QC for onsite analytical instrumentation and sampling. Procedures cover statistical data evaluation, instrument calibration, duplicate sample programs, and spike sample programs. Outside laboratory QA/QC programs are included
- Provisions for periodic management audits to verify that the QA program is effectively implemented; to verify compliance with applicable rules, regulations, and license requirements; and to protect employees by maintaining effluent releases and exposures ALARA.

The SHEQMS developed by CBR is a critical step to ensuring that QA objectives are met. Current procedures exist for a variety of areas, including but not limited to:

1. Environmental monitoring
2. Testing
3. Exposure
4. Equipment operation and maintenance

5. Employee health and safety procedures
6. Incident response procedures



This page intentionally blank

Replacement Pages – Section 6

Instructions:

Remove pages 6-5 through 6-6
Replace with this packet 6-5 through 6-6

MEA TR

Reponses to Open Issues

6-29-2017

During restoration, sampling and analysis will be conducted in accordance with the operational groundwater monitoring program described in Section 5.7.8 and 5.7.10. Consistent with the Class III UIC Permit, the specifics of the restoration monitoring are provided in a restoration plan for each MU or group of MUs for submission to the NDEQ.

6.1.3.1 Establishment of Baseline Water Quality

In addition to pre-operational baseline groundwater monitoring, before mining in each MU, the baseline groundwater quality is determined. The baseline data are established in each MU by assigning and evaluating groundwater quality in "baseline restoration wells". A minimum of one baseline restoration well for each 4 acres, but not fewer than six wells total for each MU, are sampled to establish the MU baseline water quality. A minimum of four samples are collected from each well. The samples are collected at least 14 days apart. The samples are analyzed for the parameters listed in **Table 6.1-1**.

Table 2.7-5 is the restoration tables for MU-1 in the current commercial license area. This is provided as an example of the 11 restoration tables for MU-1 through MU-11. These tables provide the baseline average and the range for all restoration parameters as well as the NDEQ restoration standard approved for that MU in the NOI. Similar tables will be provided for the MEA mine units at the appropriate time to address restoration activities.

6.1.3.2 Establishment of Restoration Goals

The baseline data are used to establish the restoration standards for each MU. As previously noted, the primary goal of restoration is to return the MU to PPMP water quality condition on an MU average. Because ISR operations alter the groundwater geochemistry, it is unlikely that restoration efforts will return the groundwater to the precise water quality that existed before operations.

Restoration goals are established by NDEQ to ensure that, if baseline water quality is not achievable after diligent application of best practicable technology (BPT), the groundwater is suitable for any use for which it was suitable before mining. NRC considers these NDEQ restoration goals as the secondary goals. The NDEQ restoration values are established for each MU and are approved with the NOI to Operate submittals according to the following analyses:

- For parameters that have numerical groundwater standards established in Title 118 (NDEQ 2006). The restoration goal is based on the Title 118 Maximum Contaminant Level (MCL).
- If the baseline concentration exceeds the applicable MCL as noted above, the standard is set as the MU baseline average plus two standard deviations.
- If there is no MCL for an element (e.g., vanadium), the restoration value is based on a wellfield average of the PPMP sampling data. Normal statistical procedures will be used to obtain the average.
- The restoration values for the major cations (calcium, magnesium, potassium, and sodium) allow the concentrations of these cations to vary by as much as one order of magnitude as long as the TDS restoration value is met. The total carbonate restoration criterion allows for the total carbonate to be less than 50 percent of the TDS. The TDS restoration value is set at the baseline MU average plus one standard deviation.



The current NDEQ restoration standards are listed in **Table 6.1-1.**

It is anticipated that the Class III UIC Permit issued for the MEA will have similar requirements. Under the provisions of the performance-based license, the CBR SERP reviews and approves the establishment of restoration standards using the review procedures discussed in Section 5. **Table 6.1-1** lists the 27 parameters used at the Crow Butte Project to determine groundwater quality. The current MCLs from Title 118 are listed as well as the restoration standards from the Class III UIC Permit. The restoration value for each MU is based on the current Title 118 standard at the time the NOI is approved by the NDEQ.

Proposals for Alternate Concentration Limits (ACLs) will include consideration of factors listed under Criterion 5B(6) of 10 CFR Part 40, Appendix A and approval by NRC pursuant to Criterion 5B(5)(c).

6.1.4 Groundwater Restoration Methods

6.1.4.1 Introduction

Restoration activities in the current license area have proven that the groundwater can be restored to the appropriate standards following commercial mining activities. As shown in **Table 1.7-1,** MUs 2 through 6 are currently undergoing restoration, with MU 2 undergoing stability monitoring following active restoration. MU 1 groundwater restoration has been approved by the NDEQ and the NRC. On February 12, 2003, the NRC issued the final approval of groundwater restoration in MU 1 at Crow Butte. This approval was the culmination of 3 years of agency reviews including a license amendment to accept the NDEQ restoration standards as the approved secondary goals. MU 1 consisted of 40 patterns installed in 9.3 acres immediately adjacent to the CPF. Included within the boundaries of MU 1 were five wells originally mined beginning in 1986 as part of the R & D pilot plant operation. Commercial mining activities began in 1991 and were completed in 1994. MU 1 was successfully restored to the approved primary or secondary restoration standards for all parameters.

The approved CBR restoration plan consists of four steps:

1. Groundwater transfer
2. Groundwater sweep
3. Groundwater treatment
4. Wellfield recirculation

A reductant may be added at any time during the restoration stage to lower the oxidation potential of the mining zone. A sulfide or sulfite compound will be added to the injection stream in concentrations sufficient to reduce the mobilized species. Safety and handling issues associated with the use of Na_2S are discussed in Section 3.2.2. Instructions and safety precautions on the use of Na_2S are included in the SHEQMS Volume III Operating Manual (Restoration Reductant [Na_2S]).

Although CBR's CSA Class III UIC Permit requires a minimum of 6 months for stability monitoring of an MU to demonstrate the success of restoration (stabilization), for this license, the specified ore zone monitoring wells will be sampled at a frequency of once each quarter. The

Replacement Pages – Section 6

Instructions:

Remove pages 6-25 through 6-26
Replace with this packet 6-25 through 6-26

MEA TR

Reponses to Open Issues

6-29-2017

6.4 Methodologies for Conducting Post-Reclamation and Decommissioning Radiological Surveys

As discussed in Section 6.2, survey areas will include areas expected to exhibit higher levels of contamination than surrounding areas, including diversion ditches, any surface impoundments, wellfield surfaces (particularly those areas where spills or leaks may have occurred), and structures in process and storage areas, areas around the deep disposal wells, and on-site transportation routes for contaminated material and equipment.

6.4.1 Cleanup Criteria

Surface soils will be cleaned up in accordance with the requirements of 10 CFR Part 40, Appendix A, including a consideration of ALARA goals and the chemical toxicity of uranium.

The proposed limits and ALARA goals for cleanup of soils are summarized in **Table 6.4-1** and described below.

The existing radium-226 criterion in 10 CFR Part 40, Appendix A, was used to derive a dose criterion (Benchmark Approach) for the cleanup of byproduct materials. The Benchmark Dose was modeled using the RESRAD code (Version 7.0). The RESRAD runs are shown and presented in **Appendix N.** The results show that a concentration of 600 pCi/g for natural uranium in the top 15 cm layer of soil for the resident farmer scenario is equivalent to the Benchmark Dose derived from a concentration of 5 pCi/g of radium-226.

ALARA considerations require that an effort be made to reduce contaminants to ALARA levels. The ALARA goals are normally based on a cost-benefit analysis. For the cleanup of gamma-emitting radionuclides, the cost of cleanup becomes excessively high as soil concentrations and/or gamma emission rates become indistinguishable from background.

Cleanup of uranium mill sites has demonstrated that conservatively derived gamma action levels along with appropriate field survey and sampling procedures result in near background radium-226 concentrations for the site. In addition, the presence of a mixture of radium-226 and uranium will tend to drive the cleanup to even lower radium-226 concentrations. It is therefore believed that no specific ALARA goal is required for surface radium-226.

The uranium concentration should be limited to a maximum of 230 pCi/g for all soil depths because of chemical toxicity concerns. Using the most conservative daily limit corresponding to the National Primary Drinking Water Standard, a soil limit of 230 pCi/g corresponds to the EPA intake limit from drinking water with a uranium concentration of 0.06 mg/day.

CBR desires to reduce subsurface concentrations to a maximum of two thirds of the proposed limit of 15 pCi/g radium-226. The subsurface uranium goal has not been reduced because it has not been demonstrated that these levels can be detected with readily available field instruments.

As demonstrated at the CPF the spills of process solutions are not likely to contain substantial amounts of thorium-230. CBR believes that development of soil cleanup criteria for thorium-230 is not appropriate at this time. However, thorium-230 will be radiochemically analyzed in representative soil samples. In the unlikely event that thorium-230 is present in elevated levels,

clean-up criteria for thorium-230 will be developed using the radium-226 Benchmark Approach and submitted to the NRC for approval prior to final site decommissioning.

6.4.2 Surface Soil Cleanup Verification and Sampling Plan

Cleanup of surface soils will be restricted to areas where there are known spills and, potentially, small spills near wellheads. CBR commits to meeting the soil cleanup criteria established in 10 CFR 40 Appendix A, Criterion 6(6). CBR will follow survey methodology as described in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM).

CBR will divide the area systematically into 100 m^2 grid blocks and sample all grid blocks containing gamma count rates exceeding gamma action level (**Appendix N**). The samples will be five-point composites, and analyzed at an offsite analytical laboratory for radium-226 and natural uranium. CBR will sample the remaining grid blocks with average gamma count rates ranking in the top 10 percent.

If any grid blocks within the top 10 percent fail the cleanup criteria, CBR will sample the second 10 percent of grid blocks. This will continue until all grid blocks pass within a 10 percent grouping. To meet the cleanup criterion, each of the sampled grid blocks must satisfy the following inequality:

$$\sum \frac{C_i}{Cc} < 1$$

Where, C_i is the concentration of the constituent and C_c is the concentration of the constituent that is equivalent to the Benchmark Dose.

CBR will remediate the grid blocks failing this inequality or propose alternatives consistent with Appendix A of 10 CFR 40.

After all sampled grids have met the inequality rule; an NRC-approved statistical test will be conducted to demonstrate that the survey method provides for a 95-percent confidence level that cleanup guidelines have been met, as per acceptance criteria 6.4.3 of NUREG-1569 (NRC 2003). An appropriate statistical test for analysis of the survey data as described in NUREG-1575 ("Multi-Agency Radiation Survey and Site Investigation Manual") will be utilized (NRC 2000). If the mean of the sample concentrations is lower than the criterion but the data fail the statistical test, CBR will follow procedures similar to those recommended in NUREG-1575.

6.4.3 Subsurface Soil Cleanup Verification and Sampling Plan

For subsurfaces CBR will adopt different survey and sample protocols, depending on the type and size of excavation. CBR will rely on sampling and analysis of radium-226 and natural uranium over surveying, to verify cleanup of subsurface excavations. The protocols will be submitted to the NRC for approval prior to post-reclamation and decommissioning.

Replacement Pages – Section 7

Remove pages 7-49 through 7-50
Replace with this packet 7-49 through 7-50

MEA TR

Reponses to Open Issues

6-29-2017



- Each resin hauling truck will be equipped with a radio that can communicate with either the CPF or the satellite facility. In the event of an accident and spill, the driver can radio to both sites to obtain help.
- A check-in and check-out procedure will be instituted where the driver will call the receiving facility prior to departure from his location. If the resin shipment fails to appear within a set time, a crew would respond and search for this vehicle. This system will ensure a reasonably quick response time in the case that the driver is incapacitated in the accident.
- Each resin transport vehicle will be equipped with an emergency spill kit that the driver can use to begin containment of any spilled material.
- Both the satellite and central process facilities will be equipped with emergency response packages to quickly respond to a transportation accident.
- Personnel at the satellite and central process facilities, as well as the designated truck drivers, will have specialized training to handle an emergency response to a transportation accident.

7.5.6 Natural Disaster Risk

NUREG/CR-6733 evaluates the potential risks to an ISR facility from natural disasters. Specifically, the risk from an earthquake and a tornado strike were analyzed. NRC determined that the primary hazard from these natural events was from dispersal of yellowcake from a tornado strike and failure of chemical storage facilities and the possible reaction of process chemicals during either event. NUREG/CR-6733 recommended that licensees follow industry best practices during design and construction of chemical facilities. CBR is committed to following these standards.

7.5.6.1 Tornado Risk

NUREG/CR 6733 evaluates tornado risks associated with ISL facilities for the release of radioactive materials or hazardous chemical due to the effects of a tornado. NUREG/CR 6733 ; concluded the risk of a tornado strike on an ISL facility was very low, that structures (e.g. buildings, wellhouses) at ISL facilities were not designed to withstand tornado winds, a conservative assessment of yellowcake dispersal by a tornado resulted in negligible radiological consequence and that no design or operational changes were necessary to mitigate the potential risks.

NUREG/CR 6733 determined that in the event of a tornado strike, chemical storage tanks could fail resulting in the release of chemicals and it was important to locate chemical storage tanks far enough from each other to prevent contact of reactive chemicals in the event of an accident. During the final design phase, CBR will assess the location(s) and construction of chemical storage tanks and containment features in order to reduce the risk of potential leaks caused by tornado damage which may result in harmful chemical reactions. CBR will have separate containment berms around storage tanks to reduce the risk of mixing of incompatible chemicals in the event of a spill.

In Dawes County, eight tornadoes touched down from 2000 to 2017 between the months of May and August (NOAA 2017). None of these tornadoes occurred in the MEA. One magnitude EF1 (Enhanced Fujita scale) tornado occurred June 11, 2013, near the Box Butte Reservoir. Based on local reports several small structures sustained minor damage or were destroyed (The Chadron Record 2013). The other seven tornadoes were a magnitude F0 and/or EF0 (Fujita or Enhanced Fujita scale). According to NOAA, no injuries, deaths, property or crop damage occurred (NOAA



2017). Most tornado events were reported to have taken place in open country, rangeland, and wooded areas. From 2000 to 2017, nearby Sheridan County experienced an F1 and an EF2 tornado causing approximately $175,000 in total property damage. EF0 wind scale ranges from 65-85 mph, EF1 wind scales range from 86-110 mph and EF2 wind scales range from 110-137 mph (NOAA 2017).

Tornadoes are rare in the Marsland Expansion Area. In the USNRC, "Draft Generic Environmental Impact Statement on Uranium Milling" (USNRC 1980), the authors calculated a mean annual frequency of 0.6 for tornadoes in intensity Category I at Rapid City. A tornado in intensity Category I has a rotational speed of 134 meters per second (m/s) and a translational speed of 26 m/s. The annual probability of occurrence at the MEA is calculated at 1.05×10^{-3} with a mean annual frequency of 1.3 (H. Thom 1963).

CBR emergency procedures currently contained in the SHEQMS Volume VIII, Emergency Manual, provide instructions for response and mitigation of natural disasters and spills or radioactive materials. Mitigation of damage due to tornado activity (structure damage, spills, radioactive materials, etc.) is described throughout the SHEQMS Volume VIII, Emergency Manual. CBR's Emergency Manual contains emergency provisions such as notification to personnel of severe weather; evacuation procedures, security plans and threats associated with source material, medical emergencies, damage inspection/assessment and reporting, and cleanup and mitigation of spills of chemicals. In addition, the site's SOPs, training and personnel protective equipment will be available to personnel for response and mitigation of hazardous chemical releases.

7.5.6.2 Seismic Risk

The project area, along with most of the State of Nebraska, is in seismic risk Zone 1. Most of the central United States is within seismic risk Zone 1, and only minor damage is expected from earthquakes that occur within this area. Dawes County-area historical earthquake activity is significantly above Nebraska state average, but it is 85 percent smaller than the overall U.S. average (City-Data 2012). Seismology was discussed in detail in Section 2.6. No historical earthquake events that had recorded magnitudes of 3.5 or above have been reported in or near Dawes County (USA.com 2013).

NUREG/CR-6733 concluded that risk from earthquakes at ISL facilities was no greater than for a tornado strike, and that no design or operational changes were required to mitigate the risk. However, the NRC advised that it was important to located chemical storage tanks far enough from each other to prevent contact of reactive chemicals in the event of an accident.

As stated above for potential tornado strikes, CBR emergency procedures currently contained in the SHEQMS Volume VIII, Emergency Manual, provide instructions for response and mitigation of natural disasters and spills or radioactive materials. CBR will have separate containment berms around storage tanks to reduce the risk of mixing of incompatible chemicals in the event of a spill. In addition, the site's SOPs, training and personnel protective equipment will be available to personnel for response and mitigation of hazardous chemical releases.

Replacement Pages – References

Instructions:

Remove Reference Section (pages 1-30)
Replace with this packet References (pages 1-30)

MEA TR

Reponses to Open Issues

6-29-2017

References

Abegglen, J. 2011. Wildlife Biologist, U.S. Forest Service, Nebraska National Forest. Personal communication with Hayden-Wing Associates. June 7, 2011.

Advameg, Inc. 2010. *Crawford, Nebraska.* [Web Page]. City-Data.com. Located at: http://www.city-data.com/city/Crawford-Nebraska.html. Accessed on: February 25, 2010.

Alexander, J.S., Zelt, R.B., and Schaepe, N.J. 2010. Hydrogeomorphic Segments and Hydraulic Microhabitats of the Niobrara River, Nebraska – With Special Emphasis on the Niobrara National Scenic River, U.S. Geological Survey Scientific Investigations Report 2010-5141, 62 p.

American National Standards Institute. (ANSI). 1999. ANSI/HPS N13.12, *Surface and Volume Radioactivity Standards for Clearance.*

AquiferTek. 2014. Validation of Marsland Expansion Area (MEA) Agricultural Well Impact Analysis, Final Report, November 7, 2014.

AquiferTek. 2015. Aquifer-Tek. Hydraulic Containment of Mining Solutions. B. Lewis, October, 2015.

AquiferTek. 2016a. Aquifer-Tek. Agricultural Well Impact Analysis. B. Lewis, revised (October 2015) Validation of MEA Agricultural Well Impact, May, 2016.

AquiferTek. 2016b. Aquifer-Tek. Drawdown Impact Assessment, Marsland Expansion Area (MEA) B. Lewis, revised May, 2016.

Aqui-Ver, Inc. (Aqui-Ver). 2011. Marsland Hydrologic Testing Report – Test #8. Marsland Expansion Area, Dawes County, NE. Final Report, July 8.

Aqui-Ver, Inc. (Aqui-Ver). 2013a. Marsland Expansion Area (MEA) Agricultural Well Impact Analysis. Letter report from Robert Lewis, Principal Hydrogeologist, Aqui-Ver, Inc., Wheat Ridge, CO to Doug Pavlick, Cameco Resources, Crow Butte Facility, Crawford, NE. December 10.

Aqui-Ver, Inc. (Aqui-Ver). 2013b. Letter Report from Robert L. Lewis, P.G., Principal Hydrogeologist to Doug Pavlick and John Schmuck, Crow Butte Resources, Crawford, NE Regarding Hydraulic containment analysis for the Marsland Expansion Area. May 30.

ARCADIS-US, Inc. (ARCADIS). 2012. Hydrologic and Erosion Study, Marsland Expansion Area. April 12.

ARCADIS-US, Inc. (ARCADIS). 2013. Hydrologic and Flood Study, Marsland Expansion Area. May.

Argonne National Laboratory. (ANL). 1989. *MILDOS-Area: An Enhanced Version of MILDOS For Large-Area Sources,* June 1989.

Argonne National Laboratory. (ANL). 1998. National Assessment Division. MILDOS-AREA User's Guide (Draft). September.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.Bentall, R. and Shaffer, F.B. 1979. Availability of Use of Water in Nebraska, 1975. Lincoln, University of Nebraska, Conservation Survey Division, Nebraska Water Survey Paper 48, 121 p. Referenced in Alexander et al 2010.

Bradley, E. and Rainwater, F. H. 1956. Geology and Groundwater Resources of the Upper Niobrara River Basin, Nebraska and Wyoming with a Section on Chemical Quality of the Groundwater. USGS Water Supply Paper 1368.

Brechignac, F. 2002. *Protection of the environment: how to position radioprotection in an ecological risk assessment perspective.* The Science of the Total Environment: 307 (2003), p. 34-35.

Brown, V.M. and Harrell, J.A. 1991. Megascopic classification of Rocks. Journal of Geological Education. v. 39. p. 379-387.

Burchett, R.R. 1990. Earthquakes in Nebraska. University of Nebraska-Lincoln, Educational Circular No. 4a, 20pp.

Bureau of Economic Analysis (BEA). 2011. Personal Income and Per Capita Income by County for Nebraska 2005-2007. [Web Page]. Located at: http://www.bea.gov/regional/reis/. Accessed on: August 18, 2011.

Bureau of Labor Statistics (BLS). 2011. Labor Force Data by County, Not Seasonally Adjusted, November 2008-December 2009. [Web Page]. Located at: http://www.bls.gov/lau/laucntycur14.txt. Accessed August 18, 2011.

Bureau of Land Management. (BLM). 2009. Assessment and Mitigation of Potential Impacts to Paleontological Resources – Guidelines for Assessment and Mitigation of Potential Impacts to Paleontological Resources. Instructional Memorandum No. 2009-011 Attachment 1. 19 pages.

Bureau of Land Management. (BLM). 1986a. *Visual Resource Inventory.* BLM Manual Handbook 8410-1.

Bureau of Land Management. (BLM). 1986b. *Visual Resource Contrast Rating.* BLM Manual Handbook 8431-1.

Bureau of Land Management. (BLM). 2005. Jonah Infill Drilling Project Air Quality Impact Analysis. Supplemental Draft Environmental Impact Statement. Pinedale and Rock Springs Field Offices. August 2005. DES-05-05.

Bureau of Land Management. (BLM). 2008. Pinedale Field Office Resource Management Plan Final Environmental Impact Statement.

C. W. Fetter, Applied Hydrology, Third Edition, (Englewood Cliffs NJ, Prentice-Hall 1994) p.257-258.

Cady, R. C. and Scherer, O. J. 1946. Geology and Ground-Water Resources of Box Butte County, Nebraska: U.S.G.S Water Supply Paper Number 969. 114 p.

California Environmental Protection Agency Air Resources Board. 2013. EMFAC, [Web Page]. California Environmental Protection Agency Air Resources Board, Located at: http://www.epa.arb.ca.gov/msei/msei.htm. Accessed: August 7, 2013.

Cameco Resources, Crow Butte Operation. (CBR) and Denison Mines (USA) (DUSA) Corporation (CBR and DUSA). 2010. Byproduct Disposal Agreement for Disposal of CBR Byproduct Waste at White Mesa Mill. June 1.

Cameco Resources, Crow Butte Operation. (CBR). 2007. Application for 2007 License Renewal, Crow Butte License Area. October 2007.

Cameco Resources, Crow Butte Operation. (CBR). 2009. Safety, Health, Environment And Quality Management System Volume II, Management Procedures Manual, Chapter SHEQ-20 SHEQ Management System Audits, Section 5 Annual ALARA Audits. December 12.

Cameco Resources, Crow Butte Operation. (CBR). 2010a. Application for amendment of USNRC source materials license SU-1534, Three Crow Expansion Area, Crawford, Nebraska. Technical Report – Volume I.

Cameco Resources, Crow Butte Operation. (CBR). 2010b. Safety, Health, Environment and Quality Management System, Volume VI, Environmental Manual.

Cameco Resources, Crow Butte Operation. (CBR). 2010c. *Safety, Health, Environment and Quality Management System. Volume IV. Health Physics Manual.*

Cameco Resources, Crow Butte Operation. (CBR). 2011. Marsland Expansion Area On-Site Meteorological Monitoring Data. August 24, 2010 through August 29, 2011.

Cameco Resources, Crow Butte Operation. (CBR). 2011. Safety, Health, Environment and Quality Management System Volume IV, Health Physics Manual, Chapter 2, Section 2.9.4 Quality Assurance Audits. February 28.

Cameco Resources, Crow Butte Operation. (CBR). 2012. Letter from Larry Teahon, Manager, Safety, health, Environment and Quality, Crow Butte Operation to Document Control Desk, Deputy Director, Decommissioning and Uranium recovery Licensing Directorate, Division of Waste Management and Environmental Protection, Office of Federal and State Materials and Environmental Management Programs, U.S. Nuclear Regulatory Commission Regarding Evacuation Due to Threatening Wildfires. September 11.

Cameco Resources, Crow Butte Operation. (CBR). 2012. Letter from Scott Bakken, Manager, SHEQ Systems and Compliance, CBR, Crawford, Nebraska to Michael

Linder, Director, Department of Environmental Quality, Lincoln, Nebraska regarding a request for approval of the 2013 surety estimate. September 28.

Cameco Resources, Crow Butte Operation. (CBR). Crow Butte Materials License SUA-1534, Docket No. 40-8943. November 2014.

Caribbean Disaster Emergency Response Agency (CDERA). 2009. CDERA Virtual Disaster Library – *Earthquakes and Seismic Activity*. [Web Page]. Located at: http://www.cdera.org/doccentre/fs_earthquakes.php. Accessed on: December 30, 2009.

Carrier, W. David, III. 2003. Goodbye Hazen; Hello, Kozeny-Carman. Journal of Geotechnical and Geo-environmental Engineering, Vol. 129, No. 11, November 2003, pp. 1054-1056.

Center for Earthquake Research and Information (CERI). 2010. Recent Earthquakes in Central US. [Web Page] Located at: http://folkworm.ceri.memphis.edu/recenteqs/ Accessed on: February 20, 2010.

Center for Nuclear Waste Regulatory Analyses (CNWRA). 2001. NUREG/CR–6733, *A Baseline Risk-Informed, Performance-Based Approach for In Situ Leach Uranium Extraction Licenses*.

Century Geophysical Corporation. 2009. Dipmeter User Guide. [Web Page]. Located at: http://www.centurywirelineservices.com/9411UG.pdf. Accessed on: April 29, 2011.

Chadron State College (CSC). 2010a. *Student Enrollment Information*. [Web Page]. Located at: http://www.csc.edu/ir/enrollment.csc. [225, 2006 and 2007 data]. Accessed on: February 25, 2010.

Chadron State College. (CSC). 2010b. *Enrollment Quick Facts*. [Web Page]. Located at: http://www.csc.edu/ir/quickfacts.csc. [2008 data]. Accessed on: February 25, 2010.

Chapman, S.S., Omernik, J.M., Freeouf, J.A., Huggins, D.G., McCauley, J.R., Freeman, C.C., Steinauer, G., Angelo, R.T., and Schlepp, R.L. 2001. Ecoregions of Nebraska and Kansas. [Web page]. Located at: ftp:/ftp.epa/gov/wed/ecoregions/ks/ksne_front.pdf. Accessed on: February 24, 2011.

City-Data.com (City-Data). 2010. *Crawford, NE (Nebraska) Houses and Residents.* [Web Page]. Located at: http://www.city-data.com/housing/houses-Crawford-Nebraska.html. Accessed on: August 18, 2011.

City-Data.com. (City-Data). 2012. Dawes County, Nebraska (NE). [Web Page]. Located at: http://www.city-data.com/county/Dawes_County-NE.html. Accessed on: March 8, 2013.

Clark, J. 1975. Controls of sedimentation and provenance of sediments in the Oligocene of the central Rocky Mountains *In:* Curtis, B.F., ed., Cenozoic history of the southern Rocky Mountains. Geological Society of America Memoir 144, p. 95-117.

Clark, J., Beerbower, J.R. and Kietzke, K.K. 1967. Oligocene sedimentation, stratigraphy, paleoecology and paleoclimatology in the Big Badlands of South Dakota. Field Museum of Natural History, Fieldiana Geology Memoirs, v. 5, p. 158.

Cobban, W.A., Creataceous Stages, in Creataceous System, McGookey, P.P. et al. eds, In Geologic Atlas of the Rocky Mountains, RMAG. pp 190-195; 1972.

Collings, S.P. and Knode, R.H. 1984. Practical Hydromet '83; 7th Annual Symposium on Uranium and Precious Metals, American Institute of Metallurgical Engineers.

Compressed Gas Association. (CGA). 1993. CGA G-4.4, Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems.

Compressed Gas Association. (CGA). 2000. CGA-G-4.1, *Cleaning Equipment for Oxygen Service*.

Cook, H. J. 1915. Notes on the Geology of Sioux County, Nebraska and Vicinity. Nebraska Geological Survey Bulletin, v. 7. Part 11, 16 pp.

Cooper, H.H., and C.E. Jacob. 1946. A generalized graphical method for evaluating formation constants and summarizing wellfield history, Am. Geophys. Union Trans, Vol. 27, pp.526-534.

Curtis, J. and K. Grimes. 2007: *Wyoming Climate Atlas.* [Web Page]. Located at: http://www.wrds.uwyo.edu/wrds/wsc/climateatlas/. May 2.Accessd on March 19, 2010.

Darton, N. H. 1901. Preliminary description of the geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming: U.S. Geol. Survey 21st Ann. Rept., pt. 4, p. 489-599.

Darton, N. H. 1912. Volcanic Action in the Black Hills of South Dakota. Science N.S., Vol. 36, pp. 602-603.

DeGraw, H.M. 1969. Subsurface Relations of the Cretaceous and Tertiary in Western Nebraska. University of Nebraska, MS Thesis, 137pp.

DeGraw, H.M. 1971. The pre-Oligocene surface in western Nebraska – Its relation to structure and subsequent topographies. In: Stout, T.M. Degraw, H.M., Tanner, L.G., Stanley, K.O., Wayne, W.J., and J.B. Swinehart (eds.), Guidebook to the Late Pliocene and Early Pleistocene of Nebraska. Nebraska Geological Survey. April 1971. p. 13-22.

DeLorme Maps. 2005. Nebraska Atlas and Gazetteer; Third Edition. Yarmouth, Maine.

Diffendal, R.F., Jr. 1982. Regional implications of the geology of the Ogallala Group (Upper Tertiary) of southwestern Morrill County, Nebraska. Geological Society of America Bulletin, v. 93, p. 964-976.

Diffendal, R.F., Jr. 1994. Geomorphic and structural features of the Alliance 1 degree X 2 degree Quadrangle, western Nebraska, discernible from synthetic-aperture radar imagery and digital shaded-relief maps. Rocky Mountain Geology; October 1994; v. 30; no. 2; p. 137-147.

Docekal, J. 1970. Earthquakes of the Stable Interior with Emphasis on the Mid-Continent. University of Nebraska, PhD Thesis.

Driscoll, F.G. 1986. Ground Water and Wells, Second Edition, (St. Paul Minnesota, Johnson Filtration Systems Inc. Chapter 9, Well Hydraulics. p. 205-267

Elsenbud, M. 1987. Environmental radioactivity: from natural, industrial and military sources (3rd ed.). Academic Press Inc., Fl. (as cited by the Government of Ontario in Appendix IV. Fish Tissue Analysis and Work Plan [Web Page]. Located at: http://www.ene.gov.on.ca/envision/techdocs/4022App_IV.htm\. Accessed on: March 26, 2010.

Energy Information Administration. (EIA). 2013a. Domestic Uranium Production Report – Annual. Data for 2010. [Web Page]. Located at: http://www.eia.gov/uranium/production/annual/. Accessed on: June 10, 2013.

Energy Information Administration. (EIA). 2013b. Nuclear and Uranium. Uranium Marketing Annual Report. [Web Page]. Located at: http://www.eia.gov/uranium/marketing/. Accessed on: June 10, 2013.

Energy Laboratories, Inc. (ELI). 2012. Letter from Steve Dobbs, Client Services Supervisor, ELI to Rhonda Grantham, Supervisor Radiation Safety & Regulatory Affairs/RSO, Crow Butte Resources, Inc. Regarding NRC Regulatory Guide 4,14 Lower Limits of Detection for the Marsland Baseline Samples. April 23.

Engberg, R.A. and Spalding, R.F. 1978. Groundwater quality atlas of Nebraska: Lincoln, University of Nebraska—Lincoln, Conservation and Survey Division Resource Atlas No.3, 39 p.

Environmental Protection Agency. (EPA). 1978. *Supplement No. 8 for Compilation of Air Pollutant Emission Factors Third Edition (Including Supplements, 1-7).* Research Triangle Park, North Carolina, May 1978.

Environmental Protection Agency. (EPA). 2000. Stormwater Phase II Final Rule: Small Construction Site Program Overview. EPA 833-F_00-013. Washington, D.C.

Environmental Protection Agency. (EPA). 2002. Onsite Wastewater Treatment Systems Manual. EPA/625/R-00/008. February.

Environmental Protection Agency. (EPA). 2006. Emissions Factors & AP 42, Compilation of Air Pollutant Emission Factors [Web Page]. U.S. Environmental

Protection Agency. Section 13.2.2, Unpaved Roads, November, Located at: http://www.epa.gov/ttnchie1/ap42/. Accessed: August 7, 2013.

Environmental Protection Agency. (EPA). 2007. *Air Quality Monitoring Data Base.* [Web Page]. Located at: http://www.epa.gov/air/data/. Accessed on: March 2, 2007.

Environmental Protection Agency. (EPA). 2010a. Airdata: Access to Air Pollution Data. Monitor Values Report - Criteria Air Pollutants – South Dakota. [Web Page]. Located at: http://epa.gov/air/data/monvals.html?st~SD~South%20Dakota. Accessed on: March 19, 2010.

Environmental Protection Agency. (EPA). 2011. Ecoregions of Kansas and Nebraska. [Web Page]. Located at: http://www.epa.gov/wed/pages/ecoregions/ksne_eco.htm. Accessed on: March 26, 2011.

Environmental Protection Agency. (EPA). 2011a. EPA Memorandum from Gina McCarthy, Assistant Administrator to Air Division Directors, Regions I-10 Regarding Implementation of the Ozone National Ambient Air Quality Standard. September 22. [Table 2.5-19 & 2.5-20].

Environmental Protection Agency. (EPA). 2011b. Emissions Factors & AP 42, Compilation of Air Pollutant Emission Factors [Web Page]. U.S. Environmental Protection Agency. Section 13.2.1, Paved Roads, January, Located at: http://www.epa.gov/ttnchie1/ap42/. Accessed: August 7, 2013.

Environmental Protection Agency. (EPA). 2012. Implementation of the 2008 National Air Quality Standards for Ozone: Nonattainment Area Classifications Approach. Attainment Deadlines and Revocation of the 1997 Ozone Standards for Transportation Conformity Purposes. Federal Register Volume 77, No. 30, pp. 8197-8209. February 14.

Environmental Protection Agency. (EPA). 2013. Water Sense. [Web Page]. Located at:http://www.epa.gov/watersense/pubs/indoor.html. Access on: September 16, 2013.

Environmental Protection Agency. (EPA). 2013. Air and Radiation. National Ambient Air Quality Standards (NAQQS). [Web Page].

Environmental Protection Agency. (EPA). 2013. National Pollutant Discharge Elimination System (NPDES) Construction Site Stormwater Runoff Control. [Web Page]. Located at: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=min_measure&min_measure_id=4. Accessed on: May 09, 2013.

Environmental Simulations, Inc. (ESI). 1999. AquiferWin32/WinFlow/WinTran Version 3.

Evans, J.E. and Terry, D.O., Jr. 1994. The significance of incision and fluvial sedimentation in the Basal White River Group (Eocene-Oligocene), badlands of South Dakota, U.S.A. Sedimentary Geology, v. 90, p. 137-152.

F. G. Driscoll, Ground Water and Wells, Second Edition, (St. Paul Minnesota, Johnson Filtration Systems Inc. 1986) Chapter 9, Well Hydraulics p. 205-267.

Federal Emergency Management Agency. (FEMA). 2011. Map Service Center. [Web Page]. Located at: http://www.msc.fema.gov/webapp/wcs/stores/servlet/FemaWelcomeView?storeId=10001&catalogId=10001&langId=-1. Accessed on: October 7, 2011.

Ferraro, J. 2011. Extension Associate Professor and Herpetologist, School of Natural Resources, University of Nebraska-Lincoln. Personal communication with Hayden-Wing Associates, June 10, 2011.

Ferret Exploration Company of Nebraska. 1987. *Application and Supporting Environmental Report For USNRC Commercial Source Material License.* September 1987.

Ferris, J.G., Knowles, D.B, Brown, R. H., and R.W. Stallman (1962). Theory of Aquifer Tests, U.S. Geological Survey Water Supply. Paper 1536-E, page 174.

Fetter, C.W. 1994. Applied Hydrology, Third Edition, (Englewood Cliffs NJ, Prentice-Hall). p.257-258

Fitzgerald J.P., C.A. Meaney, and D.M. Armstrong. 1994. Mammals of Colorado. Denver Museum of Natural History, Denver, Colorado.

Florida Oceanographic Online (FOO). 2002. Earthquake Magnitude and Intensity Information. [Web Page]. Located at: http://www.floridaoceanographic.org/reference/earthquake.htm. Accessed on: December 30, 2009.

Fogell, D.D. 2010. A field guide to the amphibians and reptiles of Nebraska. University of Nebraska-Lincoln. Conservation and Survey Division, School of Natural Resources. May 2010.

Fricke, Kent A., Cover, Michael A., Hygnstrom, Scott E., Genoways, Hugh H., Groepper, Scott R., 2008. *Historic and Recent Distributions of Elk in Nebraska,* Fall 2008.Gjelsteen, T.W., and S.P. Collings, 1988, Relationship between ground water flow and uranium mineralization in the Chadron Formation, northwest Nebraska: Wyoming Geological Association Guidebook, Thirty-ninth Field Conference, p. 271-284.

Gosselin, D. C., Headrick, J., Chen, X-H., Summerside, S. E. 1996. Regional Analysis of Rural Domestic Well-water Quality -- Hat Creek-White River Drainage Basin; from Domestic Water-well Quality in Rural Nebraska, Nebraska Department of Health.

Graves, Adam, Natalie Graves, Maureen Boyle, and Ashley Howder. 2011. Marsland Expansion Area Uranium Project Cultural Resource Inventory. ARCADIS U.S., Inc., Buffalo, Wyoming. Prepared for Cameco Resources, Crawford, Nebraska. 152 pages plus attachments. April.

Graves, Natalie and Graves, Adam. 2012. Marsland Expansion Area Uranium Project. Prepared for Cameco Resources, Crawford, Nebraska. Addition. 11 pages plus attachments. March.

Graves, Natalie. 2011. Submittal letter to Terry Steinacher, Nebraska State Historical Society for Marsland Expansion Area Uranium Project, Cultural Resource Inventory. April 28.

Gutentag, E.D., Heimes, F.J., Krothe, N.C., Luckey, R.R., Weeks, J.B., 1984. Geohydrology of the High Plains Aquifer in Parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas and Wyoming. USGS Professional Paper 1400-B, p.63.

Haag, Justin. 2012. CSC Information Services. Rapid City Journal. January 10.

Hams, Kit. 2017. Personal communication with Teahon, L. [March 30, 2017 e-mail from Big Game Program Manager, Nebraska Game and Parks Commission, RE: Elk and Pronghorn Harvest in Ash Creek Unit. 1 page.

Hansley, P.L. and Dickinson, K.A. 1990. Uranium Mineralization Favorability in the Oligocene Chadron Formation, Southeaster Wyoming and Northwestern Nebraska. Short Paper of the USGS Uranium Workshop. p. 27-31.

Hansley, P.L., S.P. Collings, I.K. Brownfield, and G.L. Skipp. 1989. Mineralogy of Uranium Ore from the Crow Butte Uranium Deposit, Oligocene Chadron Formation, Northwestern Nebraska. USGS Open File Report 89-225.

Harksen, J.C. and Macdonald, J.R. 1969. Type sections for the Chadron and Brule Formations of the White River Oligocene in the Big Badlands of South Dakota. South Dakota Geological Survey Report of Investigations #99, p. 23.

Harlan, Casey & Associates, Inc. and Resource Technologies Group, Inc., (HCA & RTG) 1993; Hydrogeologic Review and Engineering Design for Proposed Underground Injection Well, Crow Butte Project, Dawes County, Nebraska; May 10, 1993.

Hayden, T. 2011. Supervisor, Nebraska Department of Natural Resources, Bridgeport, NE Personal communication [telephone conversation with Jack Cearley, Project Director, ARCADIS-US, Inc., Highlands Ranch, Co. Regarding availability of water quality data on the Upper Niobrara River]. August 23.

Hayden-Wing Associates (HWA). 2011. Ecological Resources Summary: Technical Report for Cameco Resources – 2011. Marsland Expansion Area Uranium Project, Dawes County, Nebraska. Prepared for Cameco Resources by Hayden-Wing Associates, Laramie, Wyoming.

High Plains Regional Climate Center. (HPRCC). 2011. Historical Climate Data Summaries. [Web Page]. Located at: http://www.hprcc.unl.edu/data/historical/. Accessed on November 9, 2011.

Hoganson, J.W., Murphy, E.C. and Forsman, N.F. 1998. Lithostratigraphy, paleontology, and biochronology of the Chadron, Brule, and Arikaree Formations in North Dakota. *In:* Terry, D. O., Jr., LaGarry, H. E. and Hunt, R. M., eds., Depositional Environments, Lithostratigraphy, and Biostratigraphy of the White River and Arikaree Groups (Late Eocene to Early Miocene, North America): Geological Society of America Special Paper #325, p. 185-196.

Hunt, R.M., Jr. 1981. Geology and vertebrate paleontology of the Agate Fossil Beds National Monument and surrounding region, Sioux County, Nebraska (1972-1978). National Geographic Society Research Reports, v. 13, p. 263-285.

Hunt, R.M., Jr. 1990. Taphonomy and sedimentology of Arikaree (lower Miocene) fluvial, eolian, and lacustrine paleoenvironments, Nebraska and Wyoming: A paleobiota entombed in fine-grained volcaniclastic rocks. *In:* Lockley, M.G., and Rice, A., eds., Volcanism and fossil biotas: Geological Society of America Special Paper 244, p. 69-111.

Ihrie, D. 2011. Personal communication [September 15 email to J. Cearley, ARCADIS-US, Inc., Highlands Ranch, Colorado Regarding Request for Niobrara River Water Quality Data]. Planning Section, Water Division, NDEQ, Lincoln, NE. 2 pages. Referenced in Table F.1-13.

Ihrie, D. 2013a. Personal communication [July 24 email to J. Cearley, ARCADIS-US, Inc., Highlands Ranch, Colorado Regarding Request for Niobrara River Water Quality Data]. Planning Section, Water Division, NDEQ, Lincoln, NE. 9 page.

Ihrie, D. 2013b. Personal communication [July 24 email to J. Cearley, ARCADIS-US, Inc., Highlands Ranch, Colorado Regarding Request for Niobrara River Water Quality Data]. Planning Section, Water Division, NDEQ, Lincoln, NE. 6 pages.

International Commission on Radiological Protection. (ICRP). 1977. Recommendations of the International Commission on Radiation Protection. Publication 26. Pergamon Press, Oxford.

International Commission on Radiological Protection. (ICRP). 1991. Recommendations of the International Commission on Radiation Protection. Publication 60. Annals of the ICRP 21. Pergamon Press, Oxford.

International Commission on Radiological Protection. (ICRP). 2010. Annals of the ICRP, Environmental Protection: Transfer parameters for Reference Animals and Plants. ICRP ref 4871-0544-3078. June.

Jensen, M.E., R. D. Burman, and R. G. Allen. 1990. Evapotranspiration and Irrigation Water Requirements, ASCE manuals and Reports on Engineering Practice NO.70 American Society of Civil Engineers NY 1-332.

Journey to Western Nebraska. 2013. Chadron State Park. [Web Page]. Located at: http://www.westnebraska.com/2012/Chadron-State-Park/. Accessed on: September 12, 2013.

Kelly, Mary. 2010 *Nebraska's Evolving Water Law: Overview of Challenges & Opportunities* Platte Institute for Economic Research. September.

Key to the City. 2011. Marsland, Nebraska. [Web Page]. Located at: http://www.usacitiesonline.com/. Accessed on: August 10, 2011.

LaGarry, H.E. 1998. Lithostratigraphic revision and redescription of the Brule Formation (White River Group) of northwestern Nebraska. *In:* Terry, D. O., Jr., LaGarry, H. E. and Hunt, R. M., eds., Depositional Environments, Lithostratigraphy, and Biostratigraphy of the White River and Arikaree Groups (Late Eocene to Early Miocene, North America): Geological Society of America Special Paper #325, p. 63-91.

LaGarry, H.E., LaGarry, L.A., Terry, D.O. 1996. New vertebrate fauna from the Chamberlain Pass Fm (Eocene), Sioux City, Nebraska. Proceedings, 106th Annual Nebraska Academy of Sciences, Earth Science Section, p. 45.

Larson, E.E. and Evanoff, E. 1998. Tephrostratigraphy and source of the tuffs of the White River sequence. *In:* Terry, D. O., Jr., LaGarry, H. E. and Hunt, R. M., eds., Depositional Environments, Lithostratigraphy, and Biostratigraphy of the White River and Arikaree Groups (Late Eocene to Early Miocene, North America): Geological Society of America Special Paper #325, p. 1-14.

Leftwich, Josh. 2011. Memorandum from Josh Leftwich, Director of Radiation Safety and Licensing, Cameco Resources, Inc. to Ronald Burrows, U.S. Nuclear Regulatory Commission Regarding CBR request to suspend NRC review of the TCEA application due to possible use if pipelines in lieu of full satellite facility. April 14. (ML111160020).

Leftwich, Josh. 2012. Letter from Josh Leftwich, Director of SHEQ, Cameco Resources, Inc. to Andrew Persinko, Deputy Director, Decommissioning & Uranium Recovery License Directorate, Division of Waste Management and Environmental Management Program, U.S. Nuclear Regulatory Commission Regarding Notice of Intent to restart TCEA application process. October 11. (ML12299A211).

Leftwich, Josh. 2013. Letter from Director of SHEQ, Cameco Resources, Inc. to Michael Linder, Director, Nebraska Department of Environmental Quality, Lincoln, Nebraska Regarding 2014 Surety Estimate. cc: Ronald Burrows, Fuel Cycle Licensing Branch, U.S. Nuclear Regulatory Commission. September 30.

Lilligraven, J.A. 1970. Stratigraphy, structure, and vertebrate fossils of the Oligocene Brule Formation, Slim Buttress, northwestern South Dakota. Geological Society of America Bulletin, v. 81, p. 831-850.

Lindeman, G.H. 2011. Personal communication [July 27 email to J. Cearley, ARCADIS U.S., Inc., Highland Ranch, Colorado Regarding Niobrara River Flow Measurements. Nebraska Department of Natural Resources, Lincoln, Nebraska. 1 p.

Lisenbee, A.L. 1988. Tectonic history of the Black Hills uplift. *In:* Wyoming Geological Association Guidebook, 39th Field Conference, pp. 45–52. Located at: http://www.epa.gov/air/criteria.html. Accessed on: May 6, 2013.

Lombard, Teresa. 2016. Personal communication to Larry Teahon. [November 17, 2016 e-mail to Nebraska Game and Parks Commission, Hunters Helping the Hungry Program Coordinator. RE: Wild Game Samples. SHEQ Manager, Crow Butte Resources, Inc., Crawford, Nebraska. 1 page.

Lugn, A. L., 1939. Classification of the Tertiary System in Nebraska. Geological Society of America Bulletin, v. 50, p. 673-696.

MacFadden, B.J. and Hunt, Jr., R. M., 1998. Magnetic Polarity Stratigraphy and Correlation of the Arikaree Group, Arikareean (Late Oligocene-Early Miocene) of Northwestern Nebraska. *In:* Terry, D. O., Jr., LaGarry, H. E. and Hunt, R. M., eds., Depositional Environments, Lithostratigraphy, and Biostratigraphy of the White River and Arikaree Groups (Late Eocene to Early Miocene, North America): Geological Society of America Special Paper #325.

Mayer, W. M., DeOreo, W.B., Opitz, E.M., Kiefer, J.C., Davis, W.Y., Dziegielewski, B., and Nelson, J.O. 1999. Sponsored by American Water Works Association Research Foundation. (AWWARF). Residential End Uses of Water. 310 p.

National Agricultural Statistics Service. (NASS). 2009a. Census of Agriculture Volume 1 Chapter 2: Nebraska County Level Data. Issued February, 2009. [Web Page]. Located at: http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Nebraska/index.asp. Accessed July 2011.

National Agricultural Statistics Service. (NASS). 2009b. Quick Stats Nebraska County Data - Livestock. [Web Page]. Located at: http://www.nass.usda.gov/QuickStats. Accessed on: July 2011.

National Agricultural Statistics Service. (NASS). 2009c. Quick Stats Nebraska County Data-Crops. [Web Page]. Located at: http://www.nass.usda.gov/QuickStats/PullData_US_CNTY.jsp. Accessed on: July 2011.

National Agricultural Statistics Service. (NASS). 2011. QuickStats Ad-hoc Query Tool. [Web Page]. Located at: http://quickstats.nass.usda.gov. Accessed June 2011.

National Agricultural Statistics Service. (NASS). 2013. Census of Agriculture Volume 1 Chapter 2: Nebraska County Level Data. Issued February, 2009. [Web Page]. Located at:

http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Nebraska/index.asp. Accessed on: June 17.

National Agricultural Statistics Service. (NASS). 2016. Quick Stats Nebraska County Data-Crops. [Web Page]. Located at: https://quickstata.nass.usda.gov/data/printable/7035A76A-A444-3105-BF25-E3377F9E2C82. Accessed on: November 17, 2016.

National Climatic Data Center (NCDC). 2011. *Surface Data, Monthly Extremes.* [Web Page]. Located at: http://gis.ncdc.noaa.gov/website/ims-cdo/extmo/viewer.htm?Box=-110.307738654357:41.4493000825986:-102.349767058746:45.2536595444503. Accessed on: July 5, 2011.

National Fire Protection Association (NFPA). 1996. NFPA-50, Standard for Bulk Oxygen Systems at Consumer Sites.

National Land Cover Data (NLCD). 2006. Citation: Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, PE&RS, Vol. 77(9):858-864.

National Oceanic and Atmospheric Administration. (NOAA). 2012. National Climatic Data Center Storm Events Database: Nebraska. 2012. [Web Page]. Located at: http://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=31%2CNEBRASKA. Accessed on: March 07, 2013.

National Park Service. (NPS). 2002. Agate Fossil Beds National Monument, Fish. [Web Page]. Located at: http://www.nps.gov/agfo/naturescience/fish.htm. Accessed on: July 21, 2011.

National Park Service. (NPS). 2010. Mammal Fossils. [Web Page] Located at: http://www.nps.gov/agfo/naturescience/mammalfossils.htm. Accessed on: May 5, 2011.

National Park Service. (NPS). 2013. National Park Service Visitor Summary Report, Total Recreation Visitors for August 2013. [Web Page]. Located at: https://irma.nps.gov/Stats/SSRSReports/System%20Wide%20Reports/YTD%20Report%20(By%20Park-State-Park%20Type-Region)?RptMonth=8/1/2013&RptField=TRV&FeeOption=All. Accessed on: September 3, 2013.

National Renewable Energy Laboratory (NREL). 1990. "Solar Radiation for Flat-Plate Collectors Facing South at a Fixed-Tilt," 30-year (1961-1990) averages for Scottsbluff, Nebraska. [Web Page]. Located at: http://rredc.nrel.gov/solar/old_data/nsrdb/1961-1990/redbook/mon2/24028.txt Accessed on: March 26, 2012.

Natural Resources Conservation Service. (NRCS). 2007. National Cooperative Soil Survey Web Soil Survey. [Web Page]. Located at: http://websoilsurvey.nrcs.usda.gov/app/. Accessed on: January 25, 2007.

Natural Resources Conservation Service. (NRCS). 2009. Soil Survey Geographic (SSURGO) database for Dawes County, Nebraska. Located at: http://SoilDataMart.nrcs.usda.gov. Published: October 20, 2009.

Natural Resources Conservation Service. (NRCS). 2011. Web Soil Survey. [Web Page] Located at: http://websoilsurvey.nrcs.usda.gov. Accessed on: April 26, 2011.

NatureServe. 2010. NatureServe Explorer: An online encyclopedia of life. Version 7.1. NatureService, Arlington, Virginia. [Web Page]. Located at: http://www.natureserve.org. Accessed on: July 18, 2011.

Nebraska Administrative Code. (NAC). 2009a. Title 117 – Nebraska Department of Environmental Quality. Chapter 5 – Stream Classification by Basin. Niobrara River Subbasin N14. March 22.

Nebraska Administrative Code. (NAC). 2009b. Title 117 – Nebraska Department of Environmental Quality. Chapter 6 – Lakes and Impounded Waters. March 22.

Nebraska Board of Educational Land and Funds. (NBELF). 2010. Sixty-Seventh Biennial Report. 2008-2010. September 30.

Nebraska Department of Economic Development. (NDED). 2010. Projected Nebraska Farm and Nonfarm Employment 1998 to 2045. [Web Page]. Located at: http://www.neded.org/files/research/stathand/csecc3.gif. Accessed on: January 15, 2010.

Nebraska Department of Economic Development. (NDED). 2011a. Attendance at Selected Nebraska Attractions, 2011. [Web Page]. Located at: http://industry.visitnebraska.org/pdfs/industry/2011AttractionAttendance.pdf. Accessed on: September 3, 2013.

Nebraska Department of Economic Development. (NDED). 2011b. Tourism and recreation. [Web Page]. Located at: http://www.neded.org/search-ne-ded?q=recreational+area+attendance. Accessed on: November 21, 2011.

Nebraska Department of Education. (NDE). 2011a. Education Directory Search. [Web Page]. Located at: http://educdirsrc.education.ne.gov/default.aspx. Accessed on: November 21, 2011.

Nebraska Department of Education. (NDE). 2011b. 2009-2010 State of the Schools Report. [Web Page]. Located at: http://reportcard.education.ne.gov. Accessed on: June, 2011.

Nebraska Department of Environmental Quality. (NDEQ). 2002. Title 122 *Rules and Regulations for Underground Injection and Mineral Production Wells* (April 2002).

Nebraska Department of Environmental Quality. (NDEQ). 2003. *Environmental Fact Sheet: Establishing Air Quality Regulations in Nebraska.* [Web Page]. Located at: http://www.deq.state.ne.us/. Accessed on: July 5, 2011.

Nebraska Department of Environmental Quality. (NDEQ). 2005a. Total Maximum Daily Loads for the Niobrara River Basin. Perimeter of Concern: E. coli Bacteria. December.

Nebraska Department of Environmental Quality. (NDEQ). 2005b. *Title 119 – Rules and Regulations Pertaining to the Issuance of Permits under the National Pollutant Discharge Elimination System*, May 16, 2005.

Nebraska Department of Environmental Quality. (NDEQ). 2006. *Title 118 – Ground Water Quality Standards and Use Classification*, March 27, 2006.

Nebraska Department of Environmental Quality. (NDEQ). 2010a. Title 119, *Rules and Regulations Pertaining to the Issuance of Permits under the National Pollutant Discharge Elimination System.*

Nebraska Department of Environmental Quality. (NDEQ). 2010b. Title 122, *Rules and Regulations for Underground Injection and Mineral Production Wells.*

Nebraska Department of Environmental Quality. (NDEQ). 2010c. Title 124, *Rules and Regulations for the Design, Operation, and Maintenance of On-site Wastewater Treatment Systems.*

Nebraska Department of Environmental Quality. (NDEQ). 2010d. Title 128, *Nebraska Hazardous Waste Regulations.*

Nebraska Department of Environmental Quality. (NDEQ). 2010e. 2010 Water Quality Integrated Report. April.

Nebraska Department of Environmental Quality. (NDEQ). 2011a. Class III Underground Injection Control (UIC) Permit for North Trend Expansion Area. Effective August 11, 2011.

Nebraska Department of Environmental Quality. (NDEQ). 2011b. Aquifer Exemption Order Granting Approval of CBR Request for Exemption for Portion of Chadron Formation at North Trend Expansion Area. April 7.

Nebraska Department of Environmental Quality. (NDEQ). 2011c. *NDEQ 2010 Ambient Air Monitoring Network Plan and 5 Year Assessment.* [Web Page]. Located at: http://www.deq.state.ne.us/. Accessed on: November 9, 2011.

Nebraska Department of Environmental Quality. (NDEQ). 2011d. 2010 Nebraska Water Monitoring Programs Report. January.

Nebraska Department of Environmental Quality. (NDEQ). 2011e. Ihrie, D. Personal communication [September 15 email to J. Cearley, ARCADIS-US, Inc., Highlands Ranch, Colorado Regarding Request for Niobrara River Water Quality

Data]. Planning Section, Water Division, NDEQ, Lincoln, NE. 1 page.

Nebraska Department of Health and Human Services. (NDHHS). 2010. Nebraska Administrative Code: Title 179. Public Water Systems, Chapter 7, 7-007 Design Standards, 7-007.03 Wells/Groundwater Source(s). April 4.

Nebraska Department of Labor (NDOL). 2010. Labor Force/Work Force Summaries. [Web Page]. Located at: http://www.dol.nebraska.gov/nwd/center.cfm?PRICAT=3&SUBCAT=4F. Accessed on: February 26, 2010.

Nebraska Department of Natural Resources. (NDNR). 2011a. Data Bank. Department of Natural Resources Stream Gaging [Web Page]. Located at: http://dnr.ne.gov/docs/hydrologic.html. Accessed on: July 14, 2011.

Nebraska Department of Natural Resources. (NDNR). 2011b. Summary Report Registered Groundwater Wells by County. [Web Page]. Located at: http://dnrdata.dnr.ne.gov/wellssql/Summary.asp?type=county. Accessed on: August 23, 2011.

Nebraska Department of Natural Resources. (NDNR). 2013a. State of Nebraska Department of Natural Resources Summary of Non-Abandoned Registered Wells on File After Second Quarter 2011. [Web Page]. Located at: http://dnr.ne.gov/GroundWater/ PDF Files/Summary_non-AbandonedRegisteredWells/SecondQuarter/2011.pdf. Accessed on: April 9, 2013.

Nebraska Department of Natural Resources. (NDNR). 2013b. Registered Groundwater Wells Data Retrieval. [Web Page]. Located at: http://dnrdata.dnr.ne.gov/wellscs/Menu.aspx. Accessed on: September 6, 2013.

Nebraska Department of Property Assessment and Taxation. (NDPA&T). 2010. Research Reports [Valuation, Taxes Levied, & Tax Rate Data]. [Web Page]. Located at: http://pat.nol.org/researchReports/map/index.html. Accessed on: February 25, 2010.

Nebraska Department of Revenue Property Assessment Division (NE Revenue). 2010. Reference List of All Individual Taxing Subdivisions & Tax Rates for Tax Year 2010. [Web Page]. Located at: http://www.revenue.ne.gov/PAD/research/valuation/tax_entity_all/taxentity_allcnty2010.pdf. Accessed on: February 26, 2010.

Nebraska Department of Roads. (NDOR). 2010. Annual Average 24-Hour Traffic; Year Ending December 31, 2010. [Web Page]. Located at: http://www.dor.state.ne.us/maps/Statewide%20Traffic%20Flow%20Maps/2010-Statewide-Traffic-Flow-Map.pdf. Accessed on: November 19, 2011.

Nebraska Game and Parks Commission. (NGPC). 2008a. Annual Performance Report: 2008-09. U.S. Department of Interior Fish and Wildlife Service, Sportfish and

Wildlife Restoration Program, Wildlife Surveys and Inventories, Project W-15-R, Segment 65. Nebraska Game and Parks Commission, Wildlife Division, Lincoln, Nebraska.

Nebraska Game and Parks Commission. (NGPC). 2008b. Estimated Current Ranges of Threatened and Endangered Species: List of Species by County. Nebraska Natural Heritage Program and Nebraska Game and Parks Commission, Lincoln, Nebraska.

Nebraska Game and Parks Commission. (NGPC). 2009. Range Maps for Nebraska's Threatened and Endangered Species. Nebraska Game and Parks Commission, Nebraska Natural Heritage Program, Lincoln, Nebraska.

Nebraska Game and Parks Commission. (NGPC). 2010. 2010 Big Game Guide. Nebraska Game and Parks Commission, Lincoln, Nebraska.

Nebraska Game and Parks Commission. (NGPC). 2011a. Nebraska Game and Parks Interactive Map. [Web Page]. Located at: http://mapserver.ngpc.state.ne.us/website/gpc_land/viewer.htm. Accessed on: July 18, 2011.

Nebraska Game and Parks Commission. (NGPC). 2011b. Wildlife Species Guide. Nebraska Game and Parks Commission, Lincoln, Nebraska. [Web Page]. Located at: http://outdoornebraska.ne.gov/wildlife/wildlife_species_guide/NEwildlife.asp. Accessed on: July 14, 2011.

Nebraska Game and Parks Commission. (NGPC). 2011c. 2011 Big Game Guide. Nebraska Game and Parks Commission, Lincoln, Nebraska.

Nebraska Game and Parks Commission. (NGPC). 2011d. Big Game Hunting Guide, Buck Harvest Summary. Nebraska Game and Parks Commission, Lincoln, Nebraska. [Web Page]. Located at: http://outdoornebraska.ne.gov/hunting/guides/biggame/buckharvest.asp. Accessed on: July 14, 2011.

Nebraska Game and Parks Commission. (NGPC). 2011e. Whitetail and Mule Deer Hunting. Nebraska Game and Parks Commission, Lincoln, Nebraska. [Web Page]. Located at: http://outdoornebraska.ne.gov/hunting/guides/biggame/deer/BGdeer.asp. Accessed on: July 14, 2011.

Nebraska Game and Parks Commission. (NGPC). 2011f. Elk Hunting. Nebraska Game and Parks Commission, Lincoln, Nebraska. [Web Page]. Located at: http://outdoornebraska.ne.gov/hunting/guides/biggame/elk/BGelk.asp. Accessed on: July 14, 2011.

Nebraska Game and Parks Commission. (NGPC). 2011g. Bighorn Sheep Hunting. Nebraska Game and Parks Commission, Lincoln, Nebraska. [Web Page]. Located at:

http://outdoornebraska.ne.gov/hunting/guides/biggame/bighorns/BGbighorns.asp. Accessed on: July 14, 2011.

Nebraska Oil and Gas Conservation Commission. (NOGCC). 2011. Nebraska Oil and Gas Conservation Commission. [Web Page]. Located at: http://www.nogcc.ne.gov/ (Well data and publications). Accessed on: October 7, 2011.

Nebraska Oil and Gas Conservation Commission. (NOGCC). 2013a. Email from NOGCC (nogcc@nogcc.ne.gov) to Jack Cearley, Project Director, ARCADIS-US, Inc., Highlands Ranch, CO. Regarding online information request response from NOGCC as to any active producing oil and gas wells in Dawes County, NE. May 23.

Nebraska Oil and Gas Conservation Commission. (NOGCC). 2013b. Well Data – Access 2003 Format (12/20/2012). [Web page]. Located at http://www.nogcc.ne.gov/NOGCCPublications.aspx. Accessed on: May 23.

Nebraska Ornithologists Union. (NOU). 2011. Nebraska Ornithologists' Union. [Web Page]. Located at: http://www.noubirds.org. Accessed on: February 24, 2011.

Nebraska Public Power District. (NPPD). 2012. Community Facts – Crawford Nebraska. [Web Page]. Located at: http://sites.nppd.com/aedc/fastfacts.asp?city=Crawford. Accessed on: April 16, 2012.

Nebraska Revised Statutes. (NRS). 2008. Chapter 46: Irrigation and Regulation of Water. Section 46-602: Registration of water wells; forms; replacement; change in ownership; illegal water well; decommissioning required.

Nebraska State Historical Society. (NSHS). 2012. Letter from Terry Steinacher, H.P. Archaeologist (concurrence by L. Robert Puschendorf, Deputy NeSHPO) to Natalie Graves, Field Director, Project Archaeologist, Regarding Marsland Expansion Addition, Dawes County, NE H.P. #1105-021-01. March.

Nebraska Tourism Statistics. 2012. [Web Page]. Located at: http://industry.visitnebraska.org/index.php?option=com_content&view=article&id=3&Itemid=4. Accessed on: September 13, 2013.

Nebraska, State of. (Nebraska). 2010. Nebraska Energy Statistics – Energy Production in Btu. [Web Page] Located at: http://www.eia.doe.gov/emeu/states/sep_prod/P2/PDF/P2.pdf. Accessed on: May 17, 2011.

Nebraska's Coordinating Commission for Postsecondary Education. (NCCPE). 2005. *2005 Nebraska Higher Education Progress Report for the LR75 Legislative Evaluation Task Force:* Volume *One*. [Web Page] Located at: http://www.ccpe.state.ne.us/publicdoc/ccpe/reports/LR174/2005/default.asp. Accessed on: February 25, 2010.

Neuzil, C.E. 1993. Low Fluid Pressure Within the Pierre Shale: A Transient Response to Erosion, *Water Resour. Res.*, v. *29*(7), pp. 2007–2020.

Neuzil, C.E. and Bredehoeft, J.D. 1980. Measurement of In-Situ Hydraulic Conductivity in the Cretaceous Pierre Shale, 3rd Invitational Well-Testing Symposium, Well Testing in Low Permeability Environments, Proceedings March 26-28, 1908, Berkeley, California, p. 96-102.

Neuzil, C.E., Bredehoeft, J.D. and Wolff, R.G. 1982. Leakage and fracture permeability in the Cretaceous shales confining the Dakota aquifer in South Dakota. *In:* Jorgensen, D.G. and Signor, D.C., eds., Geohydrology of the Dakota aquifer-Proceedings of the First C.V. Theis Conference on Geohydrology, October 5-6, 1982: National Water Well Association, p. 113-120.

Nixon, D.A. 1995. The structure of the Pine Ridge of the tri-state region of Wyoming, Nebraska, and South Dakota and its relationship to the Black Hills Dome. Geological Society of America Abstracts with Programs, 29th annual meeting, p.77.

NOAA. 2017. Storm Events Database. [Web Page]. Located at: https://www.ncdc.noaa.gov/stormevents/listevents.jsp?eventType=%28C%29+Tornado&beginDate_mm=01&beginDate_dd=01&beginDate_yyyy=2000&endDate_mm=04&endDate_dd=27&endDate_yyyy=2017&county=DAWES%3A45&hailfilter=0.00&tornfilter=0&windfilter=000&sort=DT&submitbutton=Search&statefips=31%2CNEBRASKA. Accessed on April 27, 2017.

Nuclear Regulatory Commission. (NRC). 1979. Description of the United States Uranium Resource Areas and Supplement to the Generic Environmental Impact Statement on Uranium Milling, NUREG-0597, June 1979.

Nuclear Regulatory Commission. (NRC). 1980a. Regulatory Guide 4.14. Radiological Effluent and Environmental Monitoring at Uranium Mills. (1980).

Nuclear Regulatory Commission. (NRC). 1980b. NUREG–0706, *Final Generic Environmental Impact Statement on Uranium Milling—Project M–25.* September 1980.

Nuclear Regulatory Commission. (NRC). 1981. MILDOS – A Computer Program for Calculating Environmental Radiation Doses from Uranium Recovery Operations. NUREG/CR-2011 PNL-3767. April 1981.

Nuclear Regulatory Commission. (NRC). 1982. Draft Environmental Statement Related to the Operation of the Teton Project, NUREG-0925, June 1982. Para. 2.3.5.

Nuclear Regulatory Commission. (NRC). 1986. Regulatory Guide 3.56, *General Guidance For Designing, Testing, Operating, and Maintaining Emission Control Devices at Uranium Mills.* May.

Nuclear Regulatory Commission. (NRC). 1987. Regulatory Guide 3.59, *Methods for Estimating Radioactive and Toxic Airborne Source Terms for Uranium Milling Operations*. March 1987.

Nuclear Regulatory Commission. (NRC). 1988. Regulatory Guide 8.22, Bioassay at Uranium Mills. Revision 1, August 1988.

Nuclear Regulatory Commission. (NRC). 1992a. Regulatory Guide 8.34, *Monitoring Criteria and Methods To Calculate Occupational Radiation Doses.* July 1992.

Nuclear Regulatory Commission. (NRC). 1992b. Regulatory Guide 8.25, *Air Sampling in the Workplace.* Revision 1, June 1992.

Nuclear Regulatory Commission. (NRC). 1992c. Regulatory Guide 8.7, *Instructions for Recording and Reporting Occupational Radiation Exposure Data.* Revision 1, June 1992.

Nuclear Regulatory Commission. (NRC). 1992d. Regulatory Guide 8.36, Radiation Dose to the Embryo/Fetus. July, 1992.

Nuclear Regulatory Commission. (NRC). 1993. *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for By-Product, Source or Special Nuclear Material* (April 1993).

Nuclear Regulatory Commission. (NRC). 1996. Regulatory Guide 8.29, *Instructions Concerning Risks from Occupational Radiation Exposure.* Revision 1, February 1996.

Nuclear Regulatory Commission. (NRC). 1997. NUREG—1508, *Final Environmental Impact Statement to Construct and Operate the Crown Point Uranium Solution Mining Project, Crown Point, New Mexico*. 1997.

Nuclear Regulatory Commission. (NRC). 1999a. Regulatory Guide 8.13, *Instruction Concerning Prenatal Radiation Exposure.* Revision 3, June 1999.

Nuclear Regulatory Commission. (NRC). 1999b. Regulatory Guide 8.15, *Acceptable Programs for Respiratory Protection.* Revision 1, October 1999.

Nuclear Regulatory Commission. (NRC). 2000. Multi-Agency Radiation Survey and Site Investigation Manual, NUREG-1575, Rev. 1. August.

Nuclear Regulatory Commission. (NRC). 2001. Regulatory Guide/CR-6733, *A Baseline Risk-Informed, Performance-Based Approach for In Situ Leach Uranium Extraction Licensees.* (September 2001).

Nuclear Regulatory Commission. (NRC). 2002a. Regulatory Guide 8.31, *Information Relevant to Ensuring That Occupational Radiation Exposures at Uranium Recovery Facilities Will Be As Low As Reasonably Achievable.* Revision 1, May 2002.

Nuclear Regulatory Commission. (NRC). 2002b. Regulatory Guide 8.30, *Health Physics Surveys in Uranium Recovery Facilities.* Revision 1, May 2002.

Nuclear Regulatory Commission. (NRC). 2003. NUREG–1569, "Standard Review Plan for *In-Situ* Leach Uranium Extraction License 36 Applications. Final Report." Washington, DC: NRC. June 2003.

Nuclear Regulatory Commission. (NRC). 2004. Multi-Agency Radiological Laboratory Analytical Protocols Manual. NUREG-1576. July 2004.

Nuclear Regulatory Commission. (NRC). 2007a. Renewal Application for 2007 License Renewal, USNRC Source Materials License SUA-1534, Crow Butte License Area November 27. ML073480266/ML073480267.

Nuclear Regulatory Commission. (NRC). 2007b. Application for Amendment of USNRC Source Materials License SUA-1534, North Trend Expansion Area, Crawford, Nebraska, Volume I, Technical Report. May 30. ML071760344.

Nuclear Regulatory Commission. (NRC). 2008. Regulatory Guide 3.11, *Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills.* Revision 3, January 2008.

Nuclear Regulatory Commission. (NRC). 2009. NUREG-1910, Vol. I, *General Environmental Impact Statement for ISL Uranium Milling Facilities*. May 2009.

Nuclear Regulatory Commission. (NRC). 2010. Application for Amendment of USNRC Source Materials License SUA-1534, Three Crow Expansion Area, Crawford, Nebraska, Volume I, Technical Report. August 03. ML1012230171.

Nuclear Regulatory Commission. (NRC). 2011a. Facilities (By NRC Region or State). [Web Page]. Located at: http://www.nrc.gov/info-finder/region-state/ Accessed on: October 7, 2011.

Nuclear Regulatory Commission. (NRC). 2011b. Locations of Fuel Cycle Facilities. [Web Page]. Located at: http://www.nrc.gov/info-finder/materials/fuel-cycle. Accessed on: October 7, 2011.

Nuclear Regulatory Commission. (NRC). 2011c. Regulatory Guide 8.2 *Guide For Administrative Practices In Radiation Monitoring*. Revision 1, May 2011.

Nuclear Regulatory Commission. (NRC). 2012. Letter from Keith I. McConnell, Deputy Director, Decommissioning and Uranium Recovery Licensing Directorate, Division of Waste Management and Environmental Protection, Office of Federal and State Materials and Environmental Management Programs, US Nuclear Regulatory Commission to Thomas P. Young, Vice-President of Operations, Cameco Resources Regarding License Amendment No. 26 Regarding 2011 Surety Update, Crow Butte Resources Inc., Crawford, Nebraska, Source Materials License SUA-1534 (TAC No. J00634). March 6.

Nuclear Regulatory Commission. (NRC). 2012a. Safety Evaluation Report, License Renewal of the Crow Butte Resources ISR Facility, Dawes County, Nebraska, Materials License No. SUA-1534. Docket No. 40-8943. December.

Nuclear Regulatory Commission. (NRC). 2013. Letter from U.S. Nuclear Regulatory Commission to Tribal Historic Preservation Officer Regarding Update of Section 106 Consultation for the Proposed Crow Butte In-Situ Uranium recovery (ISR) License Renewal, North Trend, Marsland and Three Crow Projects. January 3.

Nuclear Regulatory Commission. (NRC). 2013. Major Uranium Recovery Licensing Applications, [Web Page]. Located at: http://www.nrc.gov/materials/uranium-recovery/license-apps/ur-projects-list-public.pdf. Accessed on: May 06, 2013.

On Road Mobile Emission Factors from California ARB EMFAC2002 Scenario Year 2004 (Model Years A11965 to 2004). 2013. [Web Page]. Located at: http://www.google.com/advanced_search?hl=en&authuser=0, exact word search: CE-Emission-Factor-Calcs. Accessed: August 7, 2013.

Organization for Economic Co-operation and Development, (OECD) 2016. Meat consumption (indicator). doi: 10.1787/fa290fd0-en. https://data.oecd.org/agroutput/meat-consumption.htm. Accessed on: 16 May 2017.

Petersan, Donis N. 2005. *Economic Importance of and Economic Impacts Associated with Livestock Production in Dawes County.* Economic Development Department, Nebraska Public Power District.

Petersen, M.D., Frankel, A.D., Harmsen, S.C., Mueller, C.S., Haller, K.M., Wheeler, R.L., Wesson, R.L., Zeng, Y., Boyd, O.S., Perkins, D.M., Luco, N., Field, E.H., Willis, C.J., and Rukstales, K.S. 2008. *Documentation for the 2008 Update of the United States National Seismic Hazard Maps.* United States Geological Survey, Reston, Virginia. Open-File Report 2008 – 1128.

Petrotek 2014. Class I UIC Permit Re-Application, Class I Non-Hazardous Deepwell. Prepared for Crow Butte Resources, Inc. and submitted to the Nebraska Department of Environmental Quality, January 6, 2014.

Petrotek, 2002. Groundwater Pumping Test #4 Data Evaluation Report. Crow Butte Resources, Inc. October 2002.

Petrotek. 2004. Class I UIC Permit Re-Application, Class I Non-Hazardous Deepwell. Prepared for Crow Butte Resources, Inc. and submitted to the Nebraska Department of Environmental Quality, March 15, 2004.

Powertech (USA) Inc. 2009. Dewey-Burdock Project Underground Injection Control Permit Application. Prepared for South Dakota Department of Environmental & Natural Resources. April.

Pure Water Products, LLC. 2013. Reverse Osmosis Rejection Percentages. [Web Page]. Located at: http://www.purewaterproducts.com/articles/ro-rejection-rates/. Accessed on: November 5, 2013. Referenced in Table R.2-1.

Retallack, Greg J. 1983. Late Eocene and Oligocene Paleosols from Badlands National Prk, South Dakota. ISBN 0813721938 p. 82.

Rothe, G.H. 1981. Earthquakes in Nebraska through 1979. Earthquake Notes, V.52, No. 2, pp.59-65.

Rothe, G.H., Lui, C.V., and Steeples, D.W. 1981. Recent Seismicity on the Chadron-Cambridge Arch, South-Central Nebraska. Earthquake Notes, V.52, No. 1, p.61.

Santee Sioux Nation Tribal Historic Preservation Office. Niobrara, Nebraska. Crow Butte Project, Dawes County Crawford, Nebraska. 2013.

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski, Jr., and W. A. Link. 2011. Species List, North American Breeding Bird Survey Route, Crawford. U.S. Geological Survey Patuxent Wildlife Research Center, Laurel, Maryland. [Web Page]. Located at: http://www.mbr-pwrc.usgs.gov/cgi-bin/rtena226.pl?54044. Accessed on: July 21, 2011.

Savignac, N. 2014. MILDOS-AREA Radiation Doses from Cameco Resources Marsland Expansion Area In-Situ Uranium Recovery Operation. October 2014.

Schauster E. R., E. M. Gese, and A. M. Kitchen. 2002. Population ecology of swift foxes (*Vulpes velox*) in southeastern Colorado. Canadian Journal of Zoology 80:307-319.

Schlumberger. 2010. API Unit. [Web Page]. Located at: http://www.glossary.oilfield.slb.com/Display.cfm?Term=API%20unit. Accessed on: March 21, 2010.

Schultz, C. B., 1941. The Pipy Concretions of the Arikaree. Bulletin of the University of Nebraska State Museum, v. 8, p. 69-82.

Schultz, C.B. and Stout, T.M. 1955. Classification of Oligocene Sediments of Nebraska. Bulletin of the University of Nebraska State Museum, v. 4, p 17-52.

Shaffer, F.B. 1975. History of irrigation and characteristics of streamflow in northern Nebraska: USGS Open-File Report 75-01, 114 p. Referenced in: Alexander et al 2010. Sibray, Steven S., 2010. White River Group Paleosols as Source Rocks for Uranium Mineralization in Western Nebraska, The Mountain Geologist, v. 48, no. 1, p. 9-41.

Simley, J.D. and W.J. Carswell, Jr. 2009. The National Map – Hydrography: U.S. Geological Survey Fact Sheet 2009-3054. 4 pp.

Singler, C.R. and Picard, M.D. 1980. Stratigraphic Review of Oligocene Beds in Northern Great Plains Earth Science Bul., WGA,. V.13, No.1, p.1-18.

Snowhite, L. 2011. Letter to Jenny Coughlin, Nebraska Department of Environmental Quality from Lee Snowhite, Senior Engineer, Cameco Resources Regarding Crow Butte Resources, Inc. Pumping Test Plan, Request for Changes. March 21.

Soil Conservation Service (SCS). 1977. Soil Survey of Dawes County Nebraska. United States Department of Agriculture SCS, in cooperation with University of Nebraska Conservation and Survey Division. February 1977.

Souders, V.L., 1981. *Geology and Groundwater Supplies of Southern Dawes and Northern Sheridan Counties, Nebraska.* Conservation and Survey Division Institute of Agriculture and Natural resources, The University of Nebraska Lincoln, p. 1-67.

South Dakota Department of Environment & Natural Resources. (SD DENR). 2011. South Dakota Ambient Air Monitoring Annual Network Plan 2009. [Web Page]. Located at: http://denr.sd.gov/des/aq/aqnews/South%20Dakota%20AP2009.pdf. Accessed on: November 9, 2011.

Stanley, K.O. and Bensen, L.V. 1979. Early diagenesis of High Plains Tertiary vitric and arkosic sandstone, Wyoming and Nebraska. *In:* Scholle, P.A., and Schluger, P.R., eds., *Aspects of diagenesis*: Society of Economic Geologists and Paleontologists Special Publication 26, p. 401-423.

Stephens, R. M. and S. H. Anderson. 2005. Swift fox (*Vulpes velox*): A technical conservation assessment. USDA Forest Service, Rocky Mountain Region. [Web Page]. Located at: http://www.fs.fed.us/r2/projects/scp/assessments/swiftfox.pdf. Accessed on: July 18, 2011.

Stout, T.M., H.M. DeGraw, L.G. Tanner, K.O. Stanley, W.J. Wayne, and J.B. Swinehart. (Stout et al). 1971. Guidebook to the Late Pliocene and Early Pleistocene of Nebraska. Nebraska Geological Society. 113 pp.

Svoboda, R. F., 1951, A Detailed Sedimentation and Petrographic Analysis of the Monroe Cree Formation of the Pine Ridge Area of Northwest Nebraska. [*unpublished* M.S. thesis]: Lincoln Nebraska, University of Nebraska, p. 189.

Swinehart, J.B., Souders, V.L., DeGraw, H.M. and Diffendal, R.F. Jr. 1985. Cenozoic Paleography of Western Nebraska. *In:* Flores, R.M. and Kaplan, S.S., eds., Cenzoic Paleogeography of the West-Central United States: Rocky Mountain Section, SEPM, p.187-206.

Teahon, Larry. 2013a. Personal communication [July 29 telephone conversation with Robin Foulk, District Conservationist, Natural Resources Conservation Service, Chadron Field Office, Chadron, NE, Regarding calculation of livestock water consumption for Dawes County when designing planned grazing system]. SHEQ Manager, Cameco Resources, Crow Butte Operations, Crawford, NE.

Teahon, Larry. 2013b. Personal communication. [September 6 e-mail to John Schmuck, Cameco Resources, Cheyenne, Wyoming. RE: TR RAI # 3 (Development of

New Wells)]. SHEQ Manager, Crow Butte Resources, Inc., Crawford, Nebraska. 1 page.

Tedford, R. H., Swinehart, J. B., Hunt Jr. R. M., Voorhies, M. R. 1985. Uppermost White River and Lowermost Arikaree Rocks and Faunas, White River Valley, Northwestern Nebraska, and Their Correlation with South Dakota. *In*: Martin, J. E., ed., Follisiferous Cenozoic Deposits of Western South Dakota and Northwestern Nebraska: Dakoterra v. 2, pp. 335-352.

Tedford, R.H., Albright, L.B., III, Barnosky, A.D., Ferrusquia-Villafranca, I., Hunt, R. M. Jr., Storer, J.E., Swisher, C.C., Voorhies, M.R., Webb, S.D., and Whistler, D.P. 2004. Mammalian biochronology of the Arikareean through Hemphilian interval (Late Oligocene through Early Pliocene epochs). *In:* Woodburne, M.O. ed., Late Cretaceous and Cenozoic Mammals of North America: Columbia University Press. P. 169-231.

Terry, D. O., Jr. 1991. The study and implications of comparative pedogenesis of sediments from the base of the White River Group, South Dakota [M.S. thesis]: Bowling Green, Ohio, Bowling Green State University, p. 184.

Terry, D. O., Jr. 1998. Lithostratigraphic Revision and Correlation of the Lower Part of the White River Group: South Dakota to Nebraska. *In:* Terry, D. O., Jr., LaGarry, H. E. and Hunt, R. M., eds., Depositional Environments, Lithostratigraphy, and Biostratigraphy of the White River and Arikaree Groups (Late Eocene to Early Miocene, North America): Geological Society of America Special Paper #325, p. 15-37.

Terry, D. O., Jr., and LaGarry, H. E. 1998. The Big Cottonwood Creek Member: A New Member of the Chadron Formation in Northwestern Nebraska; in Terry, D. O., Jr., LaGarry, H. E., and Hunt, R. M., eds., Depositional Environments, Lithostratigraphy, and Biostratigraphy of the White River and Arikaree Groups (Late Eocene to Early Miocene, North America): Geological Society of America Special Paper #325, p. 117-141.

Terry, D.O., Jr. and J.E. Evans. 1994. Pedogenesis and paleoclimatic implications of the Chamberlain Pass Formation, Basal White River Group, Badlands of South Dakota. Paleogeography, Paleoclimatology, Paleoecology. v. 110, p. 197-215.

Tetra Tech. 2015. Marsland Expansion Area Baseline Radiological Investigation Report, Revision 2.

The Chadron Record. 2013. [Web Page]. Tornado leaves trail of damage in rural area. [Web Page]. Located at: http://rapidcityjournal.com/news/local/communities/chadron/ tornado-leaves-trail-of-damage-in-rural-area/article_e74dc3c8-d836-11e2-b5ec-0019bb2963f4.html. Accessed on April 27, 2017.

Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., vol. 16, pp. 519-524.

Troester, B. 2011. Landowner. Personal communication with Hayden-Wing Associates, June 2011.

U.S. Army Corps of Engineers (USACE). 2008. Interim regional supplement to the Corps of Engineers wetland delineation manual: Great Plains region. J. S. Wakeley, R. W. Lichvar, and C. V. Noble, eds. ERDC/EL TR-08-12. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

U.S. Bureau of Reclamation. (USBR). 2008. Reclamation Managing Water in the West. Resource Management Plan, Box Butte Reservoir, Nebraska, Great Plains Region. November.

U.S. Bureau of Reclamation. (USBR). 2011a. Mirage Flats Project. [Web Page]. Located at: http://www.usbr.gov/projects/Project.jsp?proj_Name=Mirage%20Flats%20Project. Accessed on: August 8, 2011.

U.S. Bureau of Reclamation. (USBR). 2011b. Hydromet: ARC050 Database. Water Operations: Reservoirs, Dams & Hydropower. [Web Page]. Located at: http://www.usbr.gov/gp/lakes_reservoirs/. Accessed on: August 8, 2011.

U.S. Census Bureau (USCB). 1990a. 1990 Census of Population and Housing – Population and Housing Counts - Nebraska. CPH-2-29. [Web Page] Located at: http://www.census.gov/prod/cen1990/cph2/cph-2.html. Accessed on: February 25, 2010.

U.S. Census Bureau. (USCB). 1990b. 1990 Census of Housing – General Housing Characteristics - Nebraska. CH-1-29. [Web Page] Located at: http://www.census.gov/prod/cen1990/ch1/ch-1.html. Accessed on: February 25, 2010.

U.S. Census Bureau. (USCB). 2003a. 2000 Census of Population and Housing - Population and Housing Unit Counts - Nebraska. PHC-3-29. Issued September 2003. [Web Page] Located at: http://www.census.gov/prod/cen2000/index.html. Accessed on: February 27, 2010.

U.S. Census Bureau. (USCB). 2003b. 2000 Census of Population and Housing - Population and Housing Unit Counts – South Dakota. PHC-3-43. Issued September 2003. [Web Page] Located at: http://www.census.gov/prod/cen2000/index.html. Accessed on: February 27, 2010.

U.S. Census Bureau. (USCB). 2003c. 2000 Census of Population and Housing – Summary Population and Housing Characteristics - Nebraska. PHC-1-29. Issued September 2003. [Web Page]. Located at: http://www.census.gov/prod/cen2000/index.html. Accessed on: February 27, 2010.

U.S. Census Bureau. (USCB). 2009a. 2008 Population Estimates – County Characteristics. [Web Page]. Located at:

http://www.census.gov/popest/counties/asrh/CC-EST2008-agesex.html. Accessed on: February 27, 2010.

U.S. Census Bureau. (USCB). 2011. Census 2000 Summary File 1 (SF 1) 100-Percent Data, Detailed Tables. [Web Page]. Located at: http://factfinder2.census.gov. Accessed on: September 2011.

U.S. Census Bureau. (USCB). 2012. U.S. Census Bureau Statistical Abstract of the United States: 2012. [Web Page]. Located at: https://www.census.gov/compendia/statab/2012/tables/12s1253.pdf. Accessed on: September 11, 2013.

U.S. Census Bureau. (USCB). 2013. Selected Economic Characteristics, Dawes County, Nebraska, 2007-2011 American Community Survey 5-Year Estimates. [Web Page]. Located at: http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_11_5YR_DP03. Accessed on: September 3, 2013.

U.S. Fish and Wildlife Service (USFWS). 2011a. Birds Protected by the Migratory Bird Treaty Act. U.S. Fish and Wildlife Service, Migratory Bird Program. Updated April 11, 2011. [Web Page]. Located at: http://www.fws.gov/migratorybirds/RegulationsPolicies/mbta/mbtintro.html. Accessed on: July 14, 2011.

U.S. Fish and Wildlife Service. (USFWS). 2011b. Endangered, Threatened, Proposed, and Candidate Species in Nebraska Counties. U.S. Fish and Wildlife Service, Ecological Services, Nebraska Field Office, Grand Island, Nebraska.

U.S. Fish and Wildlife Service. (USFWS). 2011c. Whooping Crane Tracking Project Database. Cooperative Whooping Crane Tracking Project, U.S. Fish and Wildlife Service, Nebraska Field Office, Grand Island, Nebraska.

U.S. Fish and Wildlife Service. (USFWS). 2011d. Endangered and Threatened Wildlife and Plants; Reissuance of Final Rule to Identify the Northern Rocky Mountain Population of Gray Wolf as a Distinct Population Segment and to Revise the List of Endangered and Threatened Wildlife. Federal Register 76(87): 25590-25592.

U.S. Fish and Wildlife Service. (USFWS). 2011e. National Wetlands Inventory. U. S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. [Web Page]. Located at http://www.fws.gov/wetlands/. Accessed on: July 21, 2011.

U.S. Geological Survey. (USGS). 2005. Estimated Use of Water in the United States County-Level Data for 2005. [Web Page]. Located at: http://water.usgs.gov/watuse/data/2005/index.html. Accessed on: April 10, 2013.

U.S. Geological Survey. (USGS). 2009a. [Web Page]. Located at: http://earthquake.usgs.gov/earthquakes/states/nebraska/hazards.php. Accessed on: December 30, 2009.

U.S. Geological Survey. (USGS). 2009b. The Modified Mercalli Intensity Sale. [Web Page]. Located at: http://earthquake.usgs.gov/learn/topics/mercalli.php. Accessed on: December 30, 2009.

U.S. Geological Survey. (USGS). 2009c. *Earthquakes.* [Web Page]. Located at: http://earthquake.usgs.gov/earthquakes/. Accessed on: December 30, 2009.

U.S. Geological Survey. (USGS). 2009d. *Top Earthquake States.* [Web Page]. Located at: U.S. Geological Survey (USGS). 2009a. [Web Page]. Accessed on: December 29, 2009.

U.S. Geological Survey. (USGS). 2009e. *Nebraska Seismicity Map.* [Web Page]. Located at: http://earthquake.usgs.gov/earthquakes/states/nebraska/seismicity.php. Accessed on: December 29, 2009.

U.S. Geological Survey. (USGS). 2009f. *Google Earth Files for Earthquake Catalogs.* [Web Page]. Located at: http://neic.usgs.gov/neis/epic/kml/. Accessed on: December 30, 2009.

U.S. Geological Survey. (USGS). 2009g. Geomorphic Segmentation, Hydraulic Geometry, and Hydraulic Microhabitats of the Niobrara River, Nebraska – Methods and Initial Results.

U.S. Geological Survey. (USGS). 2010. Quaternary Fold and Fault Database for the United States. [Webpage]. Located at: http://earthquake.usgs.gov/hazards/qfaults/. Updated November 3, 2010. Accessed on: October 16, 2013.

U.S. Geological Survey. (USGS). 2011a. Water Resources of the United States. What are Hydrologic Units? October 28, 2011. [Web Page]. Located at: http://water.usgs.gov/GIS/huc.html. Accessed on: August 22, 2011.

U.S. Geological Survey. (USGS). 2011b. Water Resources of the United States. Boundary Descriptions and Names of Regions, Subregions, Accounting Units and Cataloging Units. October 28, 2011. [Web Page]. Located at: http://water.usgs.gov/GIS/huc_name.html#Region10. Accessed on: August 22, 2011.

U.S. Geological Survey. (USGS). 2013. Water Use in the United States. [Web Page]. Located at: http://water.usgs.gov/watuse/. Access on: April 10, 2013.

Universities.com. 2010. Chadron State College. [Web Page]. Located at: http://www.universities.com/edu/Chadron_State_College.html. Accessed on: March 14, 2012.

University of Nebraska Rural Initiative (UNRI). 2008. Nebraska Population Growth Continues to be Concentrated in Metropolitan Counties. 4 pg. [Web Page]. Located at: http://ruralinitiative.nebraska.edu/growth/index.html.

University of Nebraska-Lincoln. 1986. The Groundwater Atlas of Nebraska, Resource Atlas No. 4. Conservation and Survey Division.

USA.com. 2013. Dawes County Natural Disasters and Weather Extremes – Tornado Index. [Web Page]. Located at: http://www.usa.com/dawes-county-ne-natural-disasters-extremes.htm#TornadoIndex. Accessed on: March 07, 2013.

Ux Consulting Company, The (UxC). 2011. *Ux Weekly.* [Web Page]. Located at: http://www.uxc.com/review/uxc Prices.aspx. Accessed on: October 19, 2011.

Vicars, R. G. and Breyer, J. A. 1981. Sedimentary Facies in Air-Fall Pryoclastic Debris, Arikaree Group (Miocene), Northwest Nebraska, U.S.A.: Journal of Sedimentary Petrology, v. 51. p. 0909-0921.

Vogl, B. 2010. Personal communication with Jason Adams [ARCADIS] via phone regarding school capacities. February 26, 2010.

Vondra, C. F. 1958. Depositional history of the Chadron Formation in northwestern Nebraska: Proceedings, 68th Annual Meeting, Nebraska Academy of Sciences Abstracts with Programs, p. 16.

Wachal, D. and K.E. Banks. 2007. Integrating GIS and Erosion Modeling: A Tool for Watershed Management, ESRI 2007 International User Conference, Paper No. UC1038.

Wanless, H. R. 1923. The stratigraphy of the White River beds of South Dakota: Am. Philos. Soc. Proc., v. 62, p. 190-269.

Wellman, S. S. 1964. Stratigraphy of the Lower Miocene Gering Formation, Pine Ridge Area, Northwestern Nebraska: [unpublished M.S. thesis]: Lincoln, University of Nebraska, 35 p.

Western Regional Climate Center (WRCC). 2011. Chadron 1 NW, Nebraska. [Web Page]. Located at: http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ne1575. Accessed on: July 13, 2011.

Wheeler, R. L., and Crone, A. J. 2001. Known and suggested quaternary faulting in the midcontinent United States: Engineering Geology, v. 62. p. 51-78.

Witzel, F. L. 1974. Guidebook and Road Logs for the Geology of Dawes and Northern Sioux Counties, Nebraska [M.S. thesis]: Chadron, Chadron State College, 97 p.

WorleyParsons Resources and Energy. 2010. Regional Pumping Test Plan Crow Butte Marsland Expansion Area. September 27.

Wyoming Department of Administration and Information, Economic Analysis Division. 2009. Wyoming Population Estimates and Forecasts from 2000 to 2030. [Web Page]. Located at: http://eadiv.state.wy.us/pop/wyc&sc30.htm. Accessed on: February 26, 2010.

Wyoming Fuel Company. (WFC). 1983. Crow Butte Project, Dawes County, Nebraska, Application and Supporting Environmental Report for State of Nebraska. Submitted to Nebraska Dept. of Environmental Control.

Wyoming Fuel Company. (WFC). 1983. Application and Supporting Environmental Report for Research and Development Source Material License, February 11, 1983.

Wyoming Fuel Company. (WFC). 1983. Crow Butte Uranium Project, Dawes County Nebraska, Petition for Aquifer Exemption for State of Nebraska Underground Injection Control Program. July 22, 1983.



Response to Request for Additional Information (RAI)
Combined Revisions May 2012 through June 2017

Volume II - Tables and Figures

COPY 1 of 6	Document Control Desk, Director Office of Nuclear Material Safety and Safeguards U.S. Nuclear Regulatory Commission
COPY 2 of 6	Tom Lancaster, Project Manager Office of Nuclear Material Safety and Safeguards U.S. Nuclear Regulatory Commission
COPY 3 of 6	Tom Lancaster, Project Manager Office of Nuclear Material Safety and Safeguards U.S. Nuclear Regulatory Commission
COPY 4 of 6	Tom Lancaster, Project Manager Office of Nuclear Material Safety and Safeguards U.S. Nuclear Regulatory Commission
COPY 5 of 6	Crow Butte Resources, Inc.
COPY 6 of 6	Crow Butte Resources, Inc.

Replacement Pages – Tables

Remove and Replace Revised Tables:

2.6-2 Stratagraphic Section MEA
2.9-32 Vegetation Analysis
2.9-33 Livestock Analysis
2.9-36 Garden Soil Analysis
2.9-37 Radionuclides & Metals in Fish Tissue (Northern Pike)
2.9-38 Radionuclides N-1 N-2
2.9-39 Radionuclides Ephemeral Drainage
2.9-41 Preoperational/Preconstruction Monitoring Program

MEA TR

Reponses to Open Issues

6-29-2017

Table 2.6-2 Representative Stratigraphic Section – Marsland Expansion Area

Elevation (ft amsl)	Average Depth (ft bgs)	Group	Formation & Member (Schultz and Stout 1955)			Formation and Member (Revised)		References (Revised)	Formation & Member (USGS)		Formation & Member (MEA)		
Varying 4,380 -4,080	15 - 135	Arikaree Group	Monroe Creek Formation			Upper Harrison Beds		Swinehart et al. (1985)	Arikaree Group	Harrison Sandstone	Arikaree Group	Upper Harrison Beds	
						Harrison-Monroe Creek Formation				Monroe Creek Sandstone		Harrison – Monroe Creek Formation	
			Gering Formation			Gering Formation				Gering Formation		Gering Formation	
Varying 4,080 -3,620	135 - 460	White River Group	Brule Formation	Whitney Member		Brule Formation	Brown Siltstone Member	LaGarry (1998)	Brule Formation	Whitney Member	White River Group	Brule Formation	Brown Siltstone Member
							Whitney Member						
				Orella Member	Orella D		Orella Member			Orella Member			Whitney Member
					Orella C								
					Orella B								Orella Member
					Orella A		Big Cottonwood Creek Member						
3,620 – 3,480	460 – 600		Chadron Formation	Upper Chadron	Chadron C	Chadron Formation		Terry (1998) Terry and LaGarry (1998)	Chadron Formation			Chadron Formation	Upper Chadron
				Upper/Middle Chadron	Chadron B								
3,480 – 3,230	600 -850			Middle Chadron			Peanut Peak Member	Terry (1998) Terry and LaGarry (1998)					Middle Chadron
					Chadron A								
3,230 -3,180	850 – 1,200			Upper Interior Paleosol		Chamberlain Pass Formation	Upper Interior Paleosol	Terry (1998)					basal sandstone of the Chadron Formation
				basal sandstone of the Chadron Formation			Channel Sandstone	Terry (1998) Terry and LaGarry (1998)					
3,180 – 3,130	1,200 - ? (Bottom not seen in logs)	Montana Group	Pierre Shale	Interior Paleosol		Pierre Shale	Yellow Mounds Paleosol	Retallack (1983) Terry (1998)	Pierre Shale		Montana Group	Pierre Shale	
				Pierre Shale			Pierre Shale	Terry (1998) Terry and LaGarry (1998)					

Notes:

1) The Shultz and Stout conventions for Formation & Member are utilized throughout this document for consistency with historical permitting, with the exception of the Red Clay Horizon, which is referred to as the Upper Interior Paleosol.
2) Topsoil, colluvial and alluvial deposits are not shown, but are Quaternary in age and range in thickness from 0 to 30 ft-bgs.
3) The terms "Arikaree Group", "Arikaree Formation", and "Arikaree Sandstone" are accepted usages by USGS in Nebraska.
4) The terms "Gering Formation" and "Gering Sandstone" are both accepted usages by USGS in Nebraska.
5) Subdivisions of the Chadron Formation are not formally recognized by USGS in Nebraska.
6) ft amsl = feet above mean sea level; ft bgs = feet below ground surface.
7) Elevations are representative averages for MEA only, and based on Log M-1252.

Table 2.9-32 MEA Vegetation Seasonal Radiological Laboratory Analysis

Location ID:		Marsland West						Marsland Middle						Marsland East					
Date Collected:		6/26/2013		7/19/2013		9/13/2013		6/26/2013		7/19/2013		9/13/2013		6/26/2013		7/19/2013		9/13/2013	
	UNITS	RESULTS	RL	RESULTS	RL	RESULTS	RL	RESULTS	RL	RESULTS	RL	RESULTS	RL	RESULTS	RL	RESULTS	RL	RESULTS	RL
RADIONUCLIDES																			
Lead 210	µCi/kg	4.6E-05	4.6E-06	1.0E-04	8.2E-06	1.5E-04	3.3E-06	1.2E-04	5.0E-06	1.1E-05	4.5E-06	9.8E-05	2.8E-06	2.5E-05	2.6E-06	2.7E-05	2.4E-06	7.5E-05	2.5E-06
Lead 210 precision (±)	µCi/kg	4.0E-06		8.0E-06		4.6E-06		6.2E-06		3.1E-06		3.5E-06		2.3E-06		2.2E-06		3.0E-06	
Lead 210 MDC	µCi/kg	4.6E-06		8.2E-06		3.3E-06		5.0E-06		4.5E-06		2.8E-06		2.6E-06		2.4E-06		2.5E-06	
Polonium 210	µCi/kg	4.6E-06	4.4E-06	2.9E-05	2.5E-06	5.9E-05	2.8E-06	2.4E-05	3.1E-06	2.1E-06	1.2E-06	3.5E-05	2.4E-06	2.7E-06	1.3E-06	3.4E-06	1.3E-06	1.4E-05	2.1E-06
Polonium 210 precision (±)	µCi/kg	4.2E-06		7.0E-06		1.0E-05		8.6E-06		1.4E-06		6.7E-06		1.4E-06		1.7E-06		1.6E-06	
Polonium MDC	µCi/kg	4.4E-06		2.5E-06		2.8E-06		3.1E-06		1.2E-06		2.4E-06		1.3E-06		1.3E-06		2.9E-06	
Radium 226	µCi/kg	1.1E-06	1.0E-06	2.7E-06	1.7E-07	4.7E-06	3.1E-07	9.1E-06	9.6E-07	4.0E-07	8.0E-08	2.8E-06	2.5E-07	1.8E-06	4.7E-07	1.8E-06	2.4E-08	2.6E-06	1.8E-07
Radium 226 precision (±)	µCi/kg	6.7E-07		3.0E-07		5.0E-07		1.0E-06		8.9E-08		3.6E-07		3.8E-07		1.2E-08		2.9E-07	
Radium MDC	µCi/kg	1.0E-06		1.7E-07		3.1E-07		9.6E-07		8.0E-08		2.5E-07		4.7E-07		2.4E-08		1.8E-07	
Thorium 230	µCi/kg	4.6E-06	2.2E-06	3.6E-06	1.8E-06	9.3E-06	1.6E-06	7.4E-06	4.9E-06	9.3E-07	7.2E-07	6.2E-06	1.8E-06	1.6E-06	1.5E-06	2.3E-06	1.5E-06	3.1E-06	1.1E-06
Thorium 230 precision (±)	µCi/kg	2.1E-06		1.6E-06		2.4E-06		4.2E-06		5.7E-07		1.9E-06		1.1E-06		1.2E-06		1.2E-06	
Thorium MDC	µCi/kg	2.2E-06		1.8E-06		1.6E-06		4.9E-06		7.2E-07		1.8E-06		1.5E-06		1.5E-06		1.1E-06	
METALS																			
Uranium	mg/kg	0.63 D	0.0031	0.0093	0.00073	0.08	0.02	0.043 D	0.0015	0.0023	0.00040	0.20	0.02	0.0010 D	0.00072	0.0021	0.00030	0.16	0.02
Uranium Activity	µCi/kg	4.2E-04 D	2.1E-06	6.3E-06	4.9E-07	5.0E-05	1.0E-05	2.9E-05 D	9.9E-07	1.6E-06	2.7E-07	1.3E-04	1.0E-05	6.8E-07 D	4.9E-07	1.4E-06	2.0E-07	1.1E-04	1.0E-05

µCi/kg - microcuries per kilogram
mg/g - milligrams per gram
RL - Analyte Reporting Limit
D - RL increased due to sample matrix
LLD - Lower Limit of Detection
MDC - Minimum Detectable Concentration

Table 2.9-33 MEA Radionuclide Analyses for Livestock Samples						
Radionuclide, Total	**Units**	**Reporting Limit (RL)**	**Beef Sample No. 1**	**Beef Sample No. 2**	**Beef Samples No. 3**	**Average Value**
Lead 210	*u*Ci/kg	1.0E-6	8.8E-6	5.0E-6	6.1E-6	6.6E-6
Lead 210 Precision (+)	*u*Ci/kg		4.0E-6	2.5E-6	6.2E-6	
Polonium 210	*u*Ci/kg	1.0E-6	-4.0E-7	-4.0E-7	-9.0E-7	-6.0E-7
Polonium 210 Precision (+)	uCi/kg		6.0E-7	4.0E-7	7.0E-7	
Radium 226	*u*Ci/kg	5.0E-8	1.2E-6	2.0E-7	1.5E-7	5.2E-7
Radium 226 Precision (+)	*u*Ci/kg		4.0E-7	2.0E-7	3.0E-7	
Thorium 230	*u*Ci/kg	2.0E-7	1.0E-7	5.0E-8	1.0E-6	3.8E-7
Thorium 230 Precision (+)	*u*Ci/kg		1.0E-7	9.0E-8	6.0E-7	
Thorium 229 Tracer (30-120)	Percent		95.6	102	107	
Uranium	*u*Ci/kg	2.0E-7	9.0E-7	2.0E-7	<2.0E-7	4.0E-7

Source: Inter-Mountain Labs Sample Analysis Reports presented in Appendix DD.

Table 2.9-36 MEA Garden Soil Radiological Laboratory Analysis

Location ID:		Furman		Metz		Richardson		Tollman		Troester 1		Troester 2		Walters	
Date Collected:		8/1/2013		8/1/2013		8/1/2013		8/15/2013		8/1/2013		8/2/2013		8/1/2013	
	UNITS	RESULTS	RL	RESULTS	RL	RESULTS	RL	RESULTS	RL	RESULTS	RL	RESULTS	RL	RESULTS	RL
RADIONUCLIDES															
Lead 210	pCi/g	1.2	1	1.6	1	1.3	1	1.4	1	1.3	1	0.8	1	1.3	1
Lead 210 precision (±)	pCi/g	0.4		0.4		0.4		0.4		0.4		0.4		0.4	
Polonium 210	pCi/g	<2	2	<2	2	<2	2	<2	2	<2	2	<2	2	<2	2
Polonium 210 precision (±)	pCi/g	NA		NA		NA		NA		NA		NA		NA	
Radium 226	pCi/g	0.6	0.2	0.7	0.2	0.6	0.2	0.8	0.2	0.9	0.2	0.8	0.2	0.3	0.2
Radium 226 precision (±)	pCi/g	0.4		0.4		0.5		0.4		0.4		0.3		0.4	
Thorium 230	pCi/g	0.4	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.4	0.2	0.3	0.2	0.3	0.2
Thorium 230 precision (±)	pCi/g	0.1		0.1		0.1		0.1		0.1		0.1		0.2	
Thorium229 Tracer (30-120)	pCi/g	93.9		97.0		92.3		98.1		105.0		95.0		52.5	
METALS															
Uranium	pCi/g	0.5	0.2	0.5	0.2	0.6	0.2	0.6	0.2	0.8	0.2	0.6	0.2	0.5	0.2

RL - Analyte Reporting Limit

Table 2.9-37 Total Radionuclides and Metals in Tissue of Northern Pike Collected from Inlet of Box Butte Reservoir					
	May 25, 2014		September 26, 2014		
Radionuclide - Total	**Result [a]**	**Units**	**Result [a]**	**Units**	**RL**
Lead 210	2.8E-05	uCi/kg	6.0E-7	uCi/kg	1.0E-06
Lead 210 Precision (+)	1.5E-05	uCi/kg	2.9E-06	uCi/kg	--
Lead 210 MDC	1.0E-06	uCi/kg	1.0E-06	uCi/kg	--
Polonium 210	8.1E-06	uCi/kg	-2.0E-7	uCi/kg	1.0E-06
Polonium 210 Precision (+)	7.0E-06	uCi/kg	8.0E-07	uCi/kg	--
Polonium 210 MDC	1.0E-06	uCi/kg	1.0E-06	uCi/kg	--
Radium 226	4.1E-06	uCi/kg	8.0E-07	uCi/kg	5.0E-08
Radium 226 Precision (+)	2.2E-06	uCi/kg	3.0E-07	uCi/kg	--
Radium 226 MDC	5.0E-08	uCi/kg	5.0E-08	uCi/kg	--
Thorium 230	8.0E-07	uCi/kg	4.0E-07	uCi/kg	2.0E-07
Thorium 230 Precision (+)	1.6E-06	uCi/kg	3.0E-07	uCi/kg	--
Thorium 230 MDC	2.0E-07	uCi/kg	2.0E-07	uCi/kg	--
Metals - Total					--
Uranium, Total	.0031	mg/kg	.0023	mg/kg	0.0003
Uranium Activity	2.1E-6	uCi/kg	1.5E-06	uCi/kg	2.0E-07

[a] Results reported on a wet weight basis (as received) for composite of two or more samples (digestion, radiochemistry).
uCi/kg = microcuries per kilogram.
RL = Analyte reporting limit.
MDC = Minimum detectable concentration.
mg/kg – milligram per kilogram

Table 2.9-38 Radionuclide and Metal Analyses for Niobrara River Sample Locations N-1 and N-2 Sediment Samples

Radionuclide	Units	10/25/2013 (Fall Collection Date)		5/02/2014 (Spring Collection Date)	
		Result	Reporting Limit (RL)	Result	Reporting Limit (RL)
N-1					
RADIONUCLIDES - TOTAL					
Lead-210	µCi/g - dry	1.0E-6	2.0E-7	1.3E-6	2.0E-7
Lead 210 precision (+)	µCi/g - dry	4.0E-7		2.0E-7	
Radium 226	µCi/g - dry	6.0E-7	2.0E-7	7.0E-7	2.0E-7
Radium 226 precision (+)	µCi/g - dry	3.0E-7		3.0E-7	
Thorium 230	µCi/g - dry	3.0E-7	2.0E-7	2.0E-7	2.0E-7
Thorium 230 precision (+)	µCi/g - dry	1.0E-7		1.0E-7	
Thorium 229 Tracer (30-120)	%	51.2		107	
METALS - TOTAL					
Uranium Activity	µCi/g - dry	3.0E-7	2.0E-7	6.0E-7	2.0E-7
N-2					
RADIONUCLIDES - TOTAL					
Lead-210	µCi/g - dry	3.0E-7	2.0E-7	5.0E-7	2.0E-7
Lead 210 precision (+)	µCi/g - dry	1.0E-7		1.0E-7	
Radium 226	µCi/g - dry	4.0E-7	2.0E-7	5.0E-7	2.0E-7
Radium 226 precision (+)	µCi/g - dry	3.0E-7		2.0E-7	
Thorium 230	µCi/g - dry	1.0E-7	2.0E-7	1.0E-7	2.0E-7
Thorium 230 precision (+)	µCi/g - dry	1.0E-7		1.0E-7	
Thorium 229 Tracer (30-120)	%	70.7		93.0	
METALS - TOTAL					
Uranium Activity	µCi/g - dry	2.0E-7	2.0E-7	4.0E-7	2.0E-7

RL - Analyte reporting limit
MDC – Minimum detectable concentration
mg/kg-dry – milligram/kilogram-dry weight
pCi/g-dry – picocuries per gram -dry weight

Table 2.9-39 Radionuclide and Metal Analyses for Marsland Ephemeral Drainage (MED)

Radionuclide	Units	Result	Reporting Limit (RL)		Result	Reporting Limit (RL)
		10/25/2013 (Fall Collection Date)			5/02/2014 (Spring Collection Date)	
MED - 1						
Lead-210	µCi/g-dry	2.1E-6	2.0E-7		3.0E-7	2.0E-7
Lead 210 precision (+)	µCi/g-dry	4.0E-7			1.0E-7	
Radium 226	µCi/g-dry	3.0E-7	2.0E-7		3.0E-7	2.0E-7
Radium 226 precision (+)	µCi/g-dry	3.0E-7			2.0E-7	
Thorium 230	µCi/g-dry	2.0E-7	2.0E-7		1.9E-7	2.0E-7
Thorium 230 precision (+)	µCi/g-dry	1.0E-7			1.0E-7	
Thorium 229 Tracer (30-120)	%	92.8			95.2	
METALS						
Uranium Activity	µCi/g-dry	4.0E-7	2.0E-7		3.0E-7	2.0E-7
MED - 2						
Lead-210	µCi/g-dry	6.0E-7	2.0E-7		1.3E-6	2.0E-7
Lead 210 precision (+)	µCi/g-dry	2.0E-7			2.0E-7	
Radium 226	µCi/g-dry	4.0E-7	2.0E-7		5.0E-7	2.0E-7
Radium 226 precision (+)	µCi/g-dry	3.0E-7			4.0E-7	
Thorium 230	µCi/g-dry	1.9E-7	2.0E-7		4.0E-7	2.0E-7
Thorium 230 precision (+)	µCi/g-dry	1.0E-7			1.0E-7	
Thorium 229 Tracer (30-120)	%	96.6			98.9	
METALS						
Uranium Activity	µCi/g-dry	2.0E-7	2.0E-7		6.0E-7	2.0E-7
MED - 3						
Lead-210	µCi/g-dry	4.0E-7	2.0E-7		1.4E-6	2.0E-7
Lead 210 precision (+)	µCi/g-dry	2.0E-7			2.0E-7	
Radium 226	µCi/g-dry	2.0E-7	2.0E-7		8.0E-7	2.0E-7
Radium 226 precision (+)	µCi/g-dry	3.0E-7			3.0E-7	
Thorium 230	µCi/g-dry	1.0E-7	2.0E-7		3.0E-7	2.0E-7
Thorium 230 precision (+)	µCi/g-dry	1.0E-7			1.0E-7	
Thorium 229 Tracer (30-120)	%	95.6			94.1	
METALS						
Uranium Activity	µCi/g-dry	2.0E-7	2.0E-7		5.0E-7	2.0E-7

Table 2.9-39 Radionuclide and Metal Analyses for Marsland Ephemeral Drainage (MED)

Radionuclide	Units	Result	Reporting Limit (RL)		Result	Reporting Limit (RL)
		10/25/2013 (Fall Collection Date)			5/02/2014 (Spring Collection Date)	
MED - 4						
Lead-210	µCi/g-dry	1.7E-6	2.0E-7		2.1E-6	2.0E-7
Lead 210 precision (+)	µCi/g-dry	4.0E-7			3.0E-7	
Radium 226	µCi/g-dry	7.0E-7	2.0E-7		8.0E-7	2.0E-7
Radium 226 precision (+)	µCi/g-dry	4.0E-7			4.0E-7	
Thorium 230	µCi/g-dry	5.0E-7	2.0E-7		5.0E-7	2.0E-7
Thorium 230 precision (+)	µCi/g-dry	1.0E-7			1.0E-7	
Thorium 229 Tracer (30-120)	%	87.2			90.3	
METALS						
Uranium Activity	µCi/g-dry	5.0E-7	2.0E-7		5.0E-7	2.0E-7
MED - 5						
Lead-210	µCi/g-dry	1.2E-6	2.0E-7		2.0E-6	2.0E-7
Lead 210 precision (+)	µCi/g-dry	3.0E-7			2.0E-7	
Radium 226	µCi/g-dry	6.0E-7	2.0E-7		1.2E-6	2.0E-7
Radium 226 precision (+)	µCi/g-dry	4.0E-7			5.0E-7	
Thorium 230	µCi/g-dry	1.9E-7	2.0E-7		5.0E-7	2.0E-7
Thorium 230 precision (+)	µCi/g-dry	1.0E-7			2.0E-7	
Thorium 229 Tracer (30-120)	%	54			85.4	
METALS						
Uranium Activity	µCi/g-dry	4.0E-7	2.0E-7		6.0E-7	2.0E-7
MED - 6						
Lead-210	µCi/g-dry	9.0E-7	2.0E-7		1.0E-6	2E-7
Lead 210 precision (+)	µCi/g-dry	4.0E-7			2.0E-7	
Radium 226	µCi/g-dry	7.0E-7	2.0E-7		7.0E-7	2E-7
Radium 226 precision (+)	µCi/g-dry	3.0E-7			3.0E-7	
Thorium 230	µCi/g-dry	4.0E-7	2.0E-7		2.0E-7	2E-7
Thorium 230 precision (+)	µCi/g-dry	1.0E-7			1.0E-7	
Thorium 229 Tracer (30-120)	%	93.5	93.5		88.3	
METALS						
Uranium Activity	µCi/g-dry	4.0E-7	2.0E-7		5.0E-7	2.0E-7

Table 2.9-39 Radionuclide and Metal Analyses for Marsland Ephemeral Drainage (MED)

Radionuclide	Units	Result	Reporting Limit (RL)		Result	Reporting Limit (RL)
		10/17/2014 (Fall Collection Date)			4/30/2015 (Spring Collection Date)	
MED-7 [b]						
Lead-210	µCi/g-dry	7.0E-7	2.0E-7		1.8E-6	2.0E-7
Lead 210 precision (+)	µCi/g-dry	1.0E-7			5.0E-7	
Radium 226	µCi/g-dry	6.0E-7	2.0E-7		1.0E-6	2.0E-7
Radium 226 precision (+)	µCi/g-dry	1.0E-7			3.0E-7	
Thorium 230	µCi/g-dry	1.5E-6	2.0E-7		4.0E-7	2.0E-7
Thorium 230 precision (+)	µCi/g-dry	1.7E-6			2.0E-7	
Thorium 229 Tracer (30-120)	%	80.5			38.4	
METALS						
Uranium Activity	µCi/g-dry	7.2E-6	2.0E-7		5.4E-6	2.0E-7

MED - Marsland Ephermeral Drainage
RL - Analyte reporting limit
µCi/g-dry - microcuries/gram-dry weight
[b] New sampling point added after sampling of MED-1 through MED-6 was completed.

Table 2.9-41 Marsland Expansion Area Preoperational/Preconstruction Monitoring Program

	Sample Collection				Sample Analysis	
Type of Sample	**Number**	**Location**	**Method**	**Frequency**	**Frequency**	**Type of Analysis**
Air Particulates	3	On MEA southern boundary	Continuous	Weekly filter change	Quarterly composites of weekly samples	Natural uranium, Ra-226, Th-230, and Pb-210
	1	Nearest Resident	Continuous	Weekly filter change	Quarterly composites of weekly samples	Natural uranium, Ra-226, Th-230, and Pb-210
	1	Control background location west of MEA License Boundary	Continuous	Weekly filter change	Quarterly composites of weekly samples	Natural uranium, Ra-226, Th-230, and Pb-210
Radon Gas	3	On MEA southern boundary	Continuous	Quarterly	Quarterly	Rn-222
	1	Nearest Resident	Continuous	Quarterly	Quarterly	Rn-222
	1	Control background location west of MEA License Boundary	Continuous	Quarterly	Quarterly	Rn-222
Groundwater	1	Wells within MEA license boundary and 2 km radius: • Private Wells • MEA Arikaree Wells • MEA Brule Wells • MEA Ore Zone Wells	Grab	Quarterly	Quarterly	Suspended & Dissolved Natural Uranium, Ra-226, Th-230, Pb-210 & Po-210
Surface Water	2 [a]	Niobrara River (N-1 and N-2) Ephemeral Drainages	Grab	Monthly	Monthly	Suspended & Dissolved Natural Uranium, Ra-226, Th-230
			Grab	Semiannually	Semiannually	Suspended & Dissolved Pb-210 & Po-210
Vegetation	3	Grazing areas near the site in different sectors that will have the highest predicted air particulate concentrations during milling operations	Grab	3 times during grazing season	3 Times	Natural Uranium, Ra-226, Th-230, Pb-210, & Po-210
Food	3	Crops (alternate of garden soil sampling used)	Grab	Time of Harvest or Slaughter	1	Natural Uranium, Ra-226, Th-230, Pb-210, & Po-210
	3	Livestock			1	

Table 2.9-41 Marsland Expansion Area Preoperational/Preconstruction Monitoring Program

	Sample Collection				Sample Analysis	
Type of Sample	**Number**	**Location**	**Method**	**Frequency**	**Frequency**	**Type of Analysis**
Fish	Each Body of Water	Box Butte Reservoir	Grab	Semiannually	2	Natural Uranium, Ra-226, Th-230, Pb-210, & Po-210
Surface Soil [b]	Up to 40	300 meter intervals to a distance of 1500 meters in each of 8 directions from center-point of satellite facility; additional transects through wellfields	Grab	Once prior to construction. Repeat for location disturbed by excavation, leveling or contouring	1	All samples for Ra-226, 10% of samples natural uranium, Th-230 & Pb-210
	5	Same location used for collection of air particulates	Grab	Once prior to construction	1	Natural Uranium, Ra-226, Th-230 & Pb-210
Subsurface Soil [c]	5	At center-point of satellite facility & at distances of 750 meters in each of 4 directions	Grab	Once prior to construction. Repeat for location disturbed by construction	1	Ra-226 (all samples) Natural Uranium, Th-230 & Pb-210 (one set of samples)
Sediment [d]	1 from each stream (2) & ephemeral drainage (7) sampling points	Up and down gradient samples from ephemeral drainages (total of 7 samples) & Niobrara River (N-1 & N-2)	Grab (Composite samples)	Once following spring runoff & late summer following period of extended low flow	2	Natural Uranium, Ra-226, Th-230 & Pb-210
Direct Radiation (Survey)	Up to 80	150 meter intervals to a distance of 1500 meters in each of 8 directions from center-point of satellite facility	Grab	Once prior to construction. Repeat for areas disturbed by site preparation or construction	1	Gamma exposure using sodium iodide scintillometer
Direct Radiation (Continuous)	5	Same location used for collection of air particulates	Grab	Once prior to construction	1	Gamma exposure using a continuous integrating device
Radon Flux [e]	-	-	-	-	-	-

[a] Two samples from the Niobrara River per sampling event and one (1) from each sampling point (total of 7) located on ephemeral streams (**Figure 2.7-4**).

[b] Surface soil samples collected to a depth of 5 cm and 15 cm using a consistent technique.

[c] Subsurface soil samples collected to a depth of 1 meter; samples divided into 3 equal sections for analysis.

[d] Sediment sample locations shown in Figure 2.7-4

[e] Radon Flux measurements are not applicable to ISR facilities.

Replacement Pages – Figures

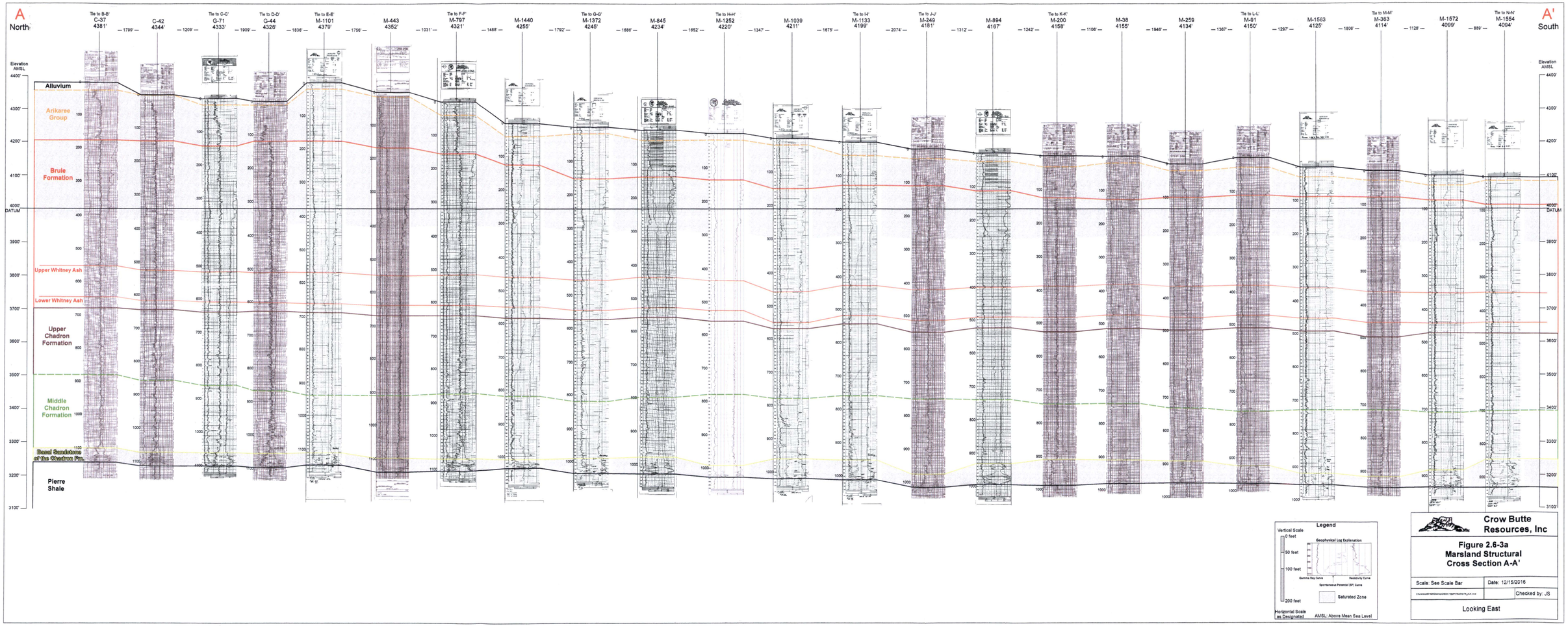
Remove and Replace with Revised Figures:

2.6-3a through 2.6-3n
2.7-4 Sampling Locations
5.1-1 Organizational Chart

MEA TR

Reponses to Open Issues

6-29-2017


A
North
A'
South
Elevation AMSL
4400'
4300'
4200'
4100'
4000'
DATUM
3900'
3800'
3700'
3600'
3500'
3400'
3300'
3200'
3100'
Alluvium
Arikaree Group
Brule Formation
Upper Whitney Ash
Lower Whitney Ash
Upper Chadron Formation
Middle Chadron Formation
Basal Sandstone of the Chadron Fm.
Pierre Shale
Tie to B-B'
C-37
4381'
1799'
C-42
4344'
1209'
Tie to C-C'
G-71
4333'
1909'
Tie to D-D'
G-44
4326'
1836'
Tie to E-E'
M-1101
4379'
1756'
M-443
4352'
1031'
Tie to F-F'
M-797
4321'
1488'
M-1440
4255'
1792'
Tie to G-G'
M-1372
4245'
1686'
M-845
4234'
1652'
Tie to H-H'
M-1252
4220'
1347'
M-1039
4211'
1675'
Tie to I-I'
M-1133
4199'
2074'
Tie to J-J'
M-249
4181'
1312'
M-894
4167'
1242'
Tie to K-K'
M-200
4155'
1106'
M-38
4155'
1946'
M-259
4134'
1367'
Tie to L-L'
M-91
4150'
1297'
M-1563
4125'
1806'
Tie to M-M'
M-363
4114'
1126'
M-1572
4099'
889'
Tie to N-N'
M-1554
4094'
Legend
Vertical Scale
0 feet
50 feet
100 feet
200 feet
Geophysical Log Explanation
Gamma Ray Curve
Resistivity Curve
Spontaneous Potential (SP) Curve
Saturated Zone
Horizontal Scale as Designated
AMSL: Above Mean Sea Level
Crow Butte Resources, Inc
Figure 2.6-3a
Marsland Structural
Cross Section A-A'
Scale: See Scale Bar
Date: 12/15/2016
Checked by: JS
Looking East

B
West

B'
East

C-38
4373'

— 757' —

Tie to A-A'
C-37
4381'

— 742' —

C-36
4393'

Elevation AMSL

4400'
4300'
4200'
4100'
4000' DATUM
3900'
3800'
3700'
3600'
3500'
3400'
3300'
3200'
3100'

Alluvium

Arikaree Group

Brule Formation

Upper Whitney Ash

Lower Whitney Ash

Upper Chadron Formation

Middle Chadron Formation

Basal Sandstone of the Chadron Fm.

Pierre Shale

Legend

Vertical Scale
0 feet
50 feet
100 feet
200 feet

Geophysical Log Explanation

Gamma Ray Curve
Resistivity Curve
Spontaneous Potential (SP) Curve

Saturated Zone

Horizontal Scale as Designated

AMSL: Above Mean Sea Level

Crow Butte Resources, Inc

Figure 2.6-3b
Marsland Structural Cross Section B-B'

Scale: See Scale Bar	Date: 12/12/2016
C:\Users\ksd41420\Desktop\DBOW TEMPT\R-MRCTR_B-B'.mxd	Checked by: JS

Looking North

C
West

C-34
4465'

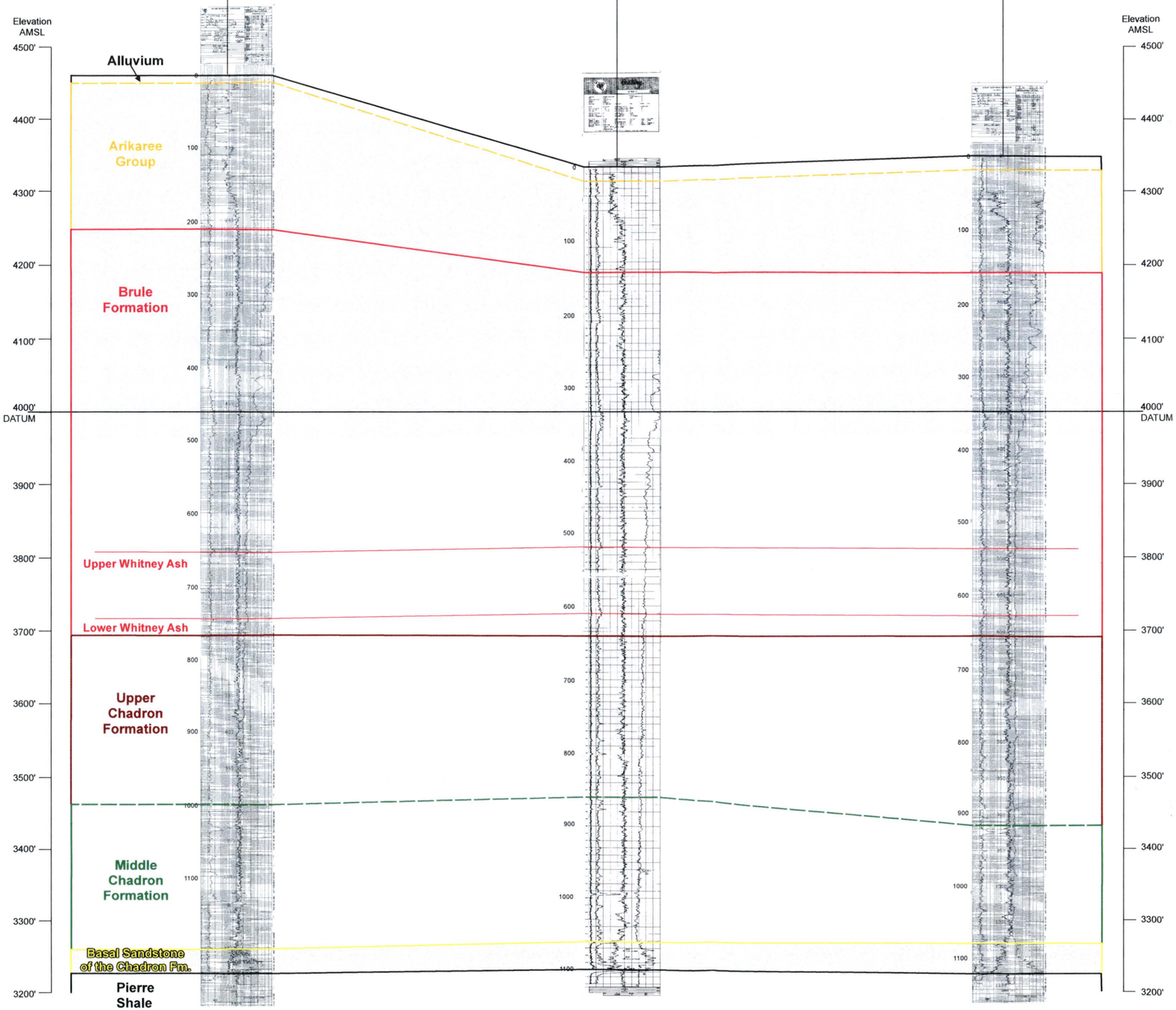
— 2448' —

Tie to A-A'
G-71
4333'

— 675' —

B-76
4347'

C'
East



Legend

Vertical Scale
0 feet
50 feet
100 feet
200 feet

Geophysical Log Explanation

Gamma Ray Curve | Resistivity Curve

Spontaneous Potential (SP) Curve

Saturated Zone

Horizontal Scale as Designated

AMSL: Above Mean Sea Level

Crow Butte Resources, Inc

Figure 2.6-3c
Marsland Structural Cross Section C-C'

Scale: See Scale Bar	Date: 12/12/2016
C:\Users\cab\1428\Desktop\DBOW TEMPITB-MROTR_C-C'.mxd	Checked by: JS

Looking North

D
West

D'
East

G-50
4355'

— 804' —

Tie to A-A'
G-44
4326'

— 610' —

G-65
4340'

Elevation
AMSL

4400'
4300'
4200'
4100'
4000'
DATUM
3900'
3800'
3700'
3600'
3500'
3400'
3300'
3200'
3100'

Alluvium

Arikaree
Group

Brule
Formation

Upper Whitney Ash

Lower Whitney Ash

Upper
Chadron
Formation

Middle
Chadron
Formation

Basal Sandstone
of the Chadron Fm.

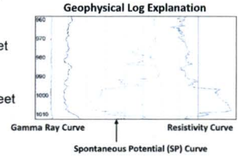
Pierre
Shale

0
100
200
300
400
500
600
700
800
900
1000
1100

Legend

Vertical Scale
0 feet
50 feet
100 feet
200 feet

Geophysical Log Explanation



Gamma Ray Curve
Resistivity Curve
Spontaneous Potential (SP) Curve

Saturated Zone

Horizontal Scale
as Designated

AMSL: Above Mean Sea Level

Crow Butte Resources, Inc

Figure 2.6-3d
Marsland Structural
Cross Section D-D'

Scale: See Scale Bar	Date: 12/12/2016
C:\Users\ka\41429\Desktop\CBOW TEMP\TR-MROTR_D-D'.mxd	Checked by: JS

Looking North

E
West

E'
East

M-49
4400'

— 1830' —

M-53
4330'

— 1949' —

Tie to A-A'
M-1101
4379'

— 1496' —

M-51
4306'

— 1547' —

M-802
4288'

Elevation AMSL

4500'
4400'
4300'
4200'
4100'
4000' DATUM
3900'
3800'
3700'
3600'
3500'
3400'
3300'
3200'

Alluvium

Arikaree Group

Brule Formation

Upper Whitney Ash

Lower Whitney Ash

Upper Chadron Formation

Middle Chadron Formation

Basal Sandstone of the Chadron Fm.

Pierre Shale

Legend

Vertical Scale

0 feet
50 feet
100 feet
200 feet

Geophysical Log Explanation

Gamma Ray Curve
Resistivity Curve
Spontaneous Potential (SP) Curve

Saturated Zone

Horizontal Scale as Designated

AMSL: Above Mean Sea Level

Crow Butte Resources, Inc

Figure 2.6-3e
Marsland Structural Cross Section E-E'

Scale: See Scale Bar	Date: 12/15/2016
C:\Users\kaM.HSR\Desktop\DBOX\ TEMP\3\Att\CCR_E-E'.mxd	Checked by: JS

Looking North

F
West

M-1071
4289'

— 1142' —

Tie to A-A'
M-797
4321'

— 1826' —

M-24
4267'

F'
East

Elevation AMSL

4400'
4300'
4200'
4100'
4000' DATUM
3900'
3800'
3700'
3600'
3500'
3400'
3300'
3200'
3100'

Alluvium

Arikaree Group

Brule Formation

Upper Whitney Ash

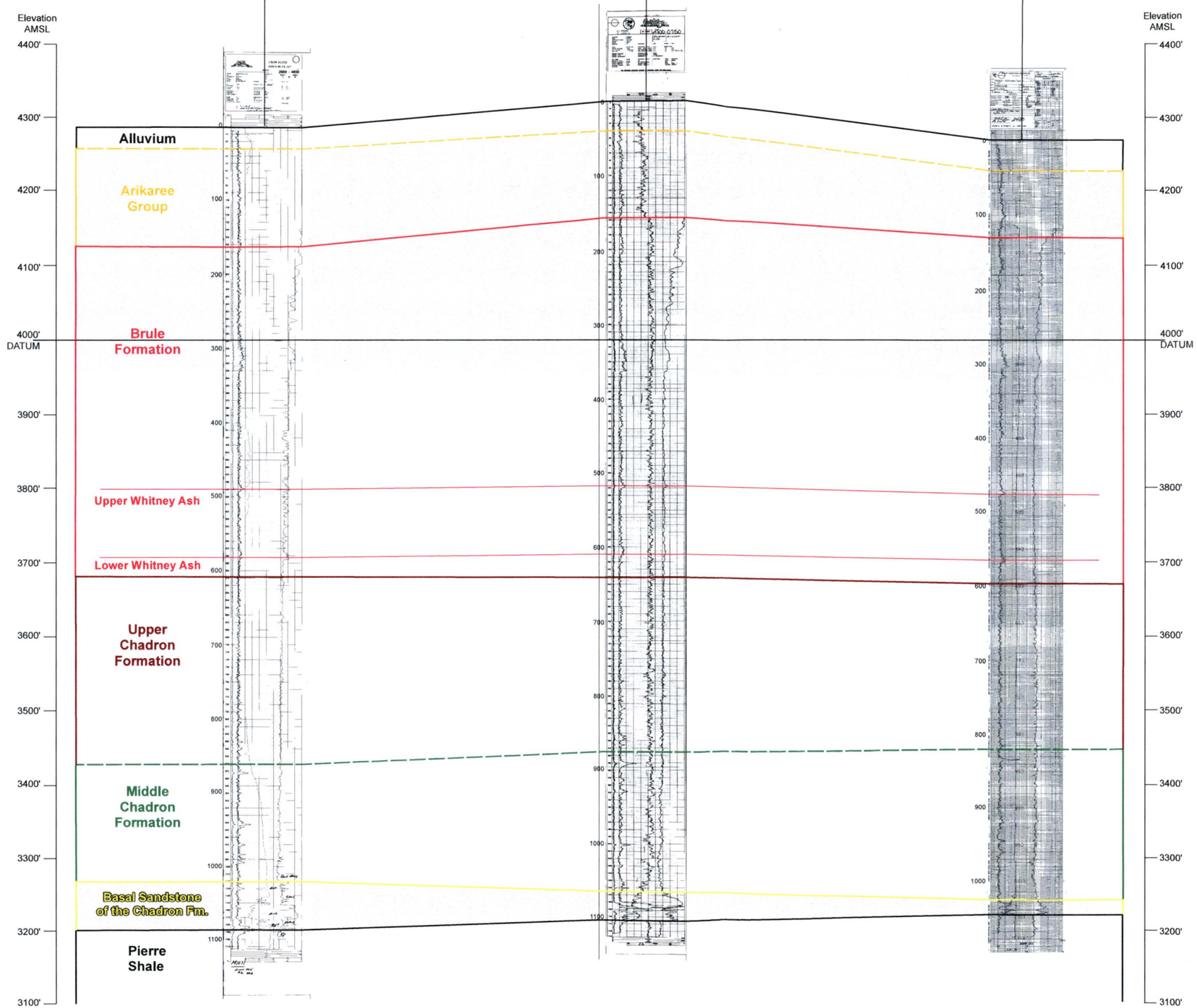
Lower Whitney Ash

Upper Chadron Formation

Middle Chadron Formation

Basal Sandstone of the Chadron Fm.

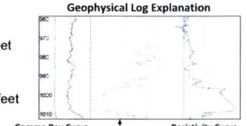
Pierre Shale



Legend

Vertical Scale
0 feet
50 feet
100 feet
200 feet

Geophysical Log Explanation



Gamma Ray Curve
Resistivity Curve
Spontaneous Potential (SP) Curve

Saturated Zone

Horizontal Scale as Designated

AMSL: Above Mean Sea Level

Crow Butte Resources, Inc

Figure 2.6-3f
Marsland Structural Cross Section F-F'

Scale: See Scale Bar	Date: 12/8/2016
C:\Users\kc\04142\Desktop\[CBOW TEMPSTR-MS\CSTR_F-F'.mxd	Checked by: JS

Looking North

G
West

M-77
4336'

— 2715' —

M-704
4304'

— 1700' —

Tie to A-A'
M-1372
4245'

— 2531' —

M-66
4237'

— 744' —

M-3
4249'

G'
East

Elevation
AMSL

4400'
4300'
4200'
4100'
4000'
DATUM
3900'
3800'
3700'
3600'
3500'
3400'
3300'
3200'
3100'

Alluvium

Arikaree
Group

Brule
Formation

Upper Whitney Ash

Lower Whitney Ash

Upper
Chadron
Formation

Middle
Chadron
Formation

Basal Sandstone
of the Chadron Fm.

Pierre
Shale

Legend

Vertical Scale
0 feet
50 feet
100 feet
200 feet

Geophysical Log Explanation

Gamma Ray Curve
Resistivity Curve
Spontaneous Potential (SP) Curve

Saturated Zone

Horizontal Scale
as Designated

AMSL: Above Mean Sea Level

Crow Butte Resources, Inc

Figure 2.6-3g
Marsland Structural
Cross Section G-G'

Scale: See Scale Bar	Date: 12/8/2016
C:\Users\ea\d\14240\Desktop\GB\SW TEMP\TR\HR\CTR_G-G'.mxd	Checked by: JS

Looking North

H
West

H'
East

M-1271
4248'

— 1740' —

Tie to A-A'
M-1252
4220'

— 670' —

M-29
4228'

Elevation
AMSL

4300'
4200'
4100'
4000'
DATUM
3900'
3800'
3700'
3600'
3500'
3400'
3300'
3200'
3100'
3000'

Alluvium

Arikaree
Group

Brule
Formation

Upper Whitney Ash

Lower Whitney Ash

Upper
Chadron
Formation

Middle
Chadron
Formation

Basal Sandstone
of the Chadron Fm.

Pierre
Shale

Legend

Vertical Scale
0 feet
50 feet
100 feet
200 feet

Geophysical Log Explanation

Gamma Ray Curve
Resistivity Curve
Spontaneous Potential (SP) Curve

Saturated Zone

Horizontal Scale
as Designated

AMSL: Above Mean Sea Level

Crow Butte Resources, Inc

Figure 2.6-3h
Marsland Structural
Cross Section H-H'

Scale: See Scale Bar	Date: 12/15/2016
C:\Users\ca841429\Desktop\CBOW TEMP\TR-WELCTR_H-H'.mxd	Checked by: JS

Looking North

West

East

M-31
4243'

— 1395' —

M-47
4182'

— 1603' —

Tie to A-A'
M-1133
4199'

— 2017' —

M-36
4191'

Elevation
AMSL

4300'
4200'
4100'
4000'
DATUM
3900'
3800'
3700'
3600'
3500'
3400'
3300'
3200'
3100'
3000'

Alluvium

Arikaree
Group

Brule
Formation

Upper Whitney Ash

Lower Whitney Ash

Upper
Chadron
Formation

Middle
Chadron
Formation

Basal Sandstone
of the Chadron Fm.

Pierre
Shale

Legend

Vertical Scale
0 feet
50 feet
100 feet
200 feet

Geophysical Log Explanation

Gamma Ray Curve
Resistivity Curve
Spontaneous Potential (SP) Curve

Saturated Zone

Horizontal Scale
as Designated

AMSL: Above Mean Sea Level

Crow Butte Resources, Inc

Figure 2.6-3i
Marsland Structural
Cross Section I-I'

Scale: See Scale Bar | Date: 12/8/2016

C:\Users\ca941420\Desktop\DBOW TEMPITK-MRCSTR_s4.mxd | Checked by: JS

Looking North

J
West

M-35
4205'

— 2132' —

M-196
4186'

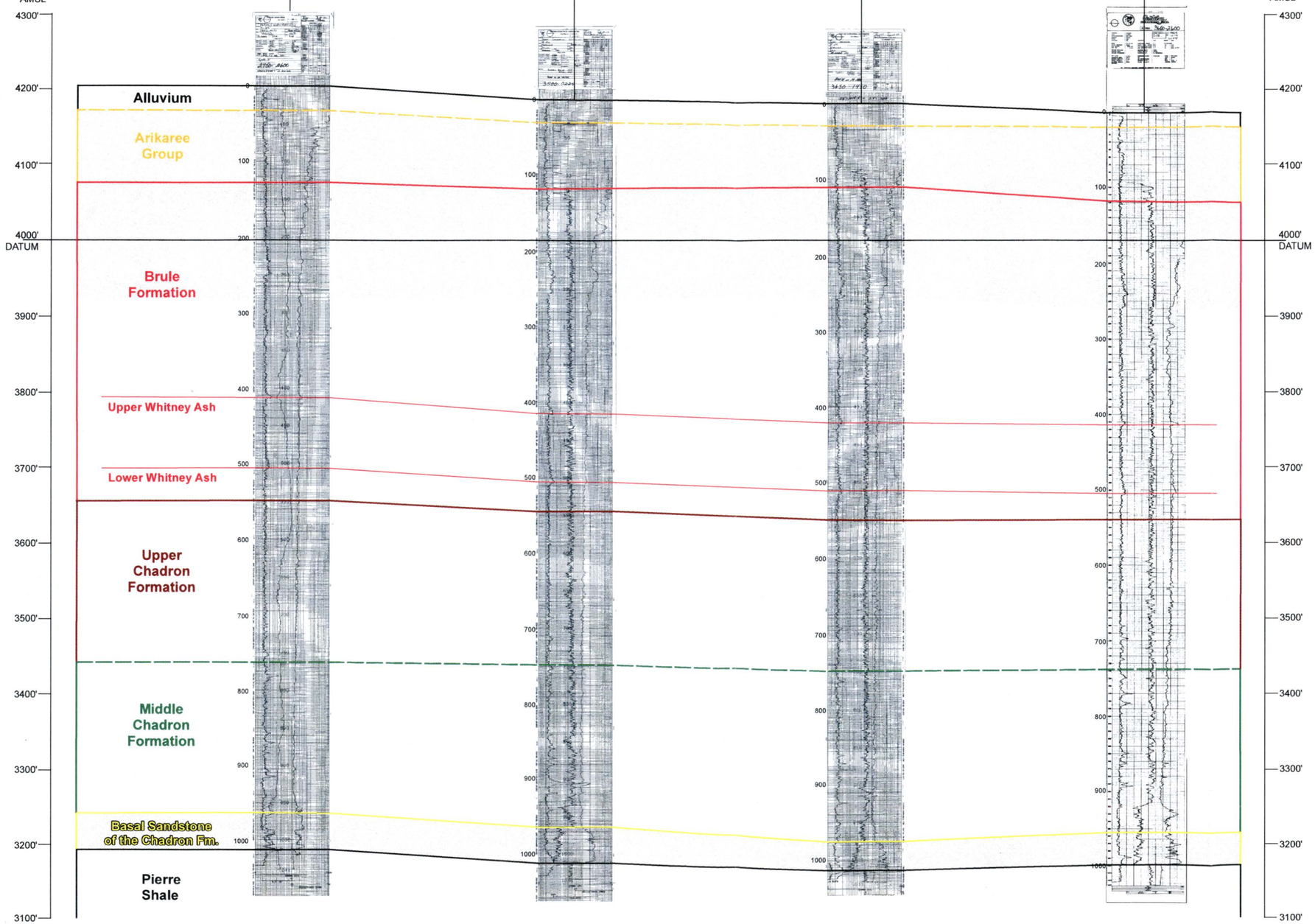
— 1213' —

Tie to A-A'
M-249
4181'

— 1174' —

M-783
4170'

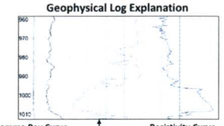
J'
East



Legend

Vertical Scale
0 feet
50 feet
100 feet
200 feet

Geophysical Log Explanation



Gamma Ray Curve
Resistivity Curve
Spontaneous Potential (SP) Curve

Saturated Zone

Horizontal Scale as Designated

AMSL: Above Mean Sea Level

Crow Butte Resources, Inc

Figure 2.6-3j
Marsland Structural Cross Section J-J'

Scale: See Scale Bar	Date: 12/8/2016
C:\Users\kab41420\Desktop\DBOW TEMP\TR-WR\CTR_J-J'.mxd	Checked by: JS

Looking North

K
West

K'
East

M-195
4159'

Tie to A-A'
M-200
4158'

M-256
4151'

--- 1576' ---

--- 808' ---

Elevation
AMSL

4300'
4200'
4100'
4000'
DATUM
3900'
3800'
3700'
3600'
3500'
3400'
3300'
3200'
3100'

Alluvium

Arikaree
Group

Brule
Formation

Upper Whitney Ash

Lower Whitney Ash

Upper
Chadron
Formation

Middle
Chadron
Formation

Basal Sandstone
of the Chadron Fm.

Pierre
Shale

0
100
200
300
400
500
600
700
800
900
1000

Legend

Vertical Scale
0 feet
50 feet
100 feet
200 feet

Geophysical Log Explanation

Gamma Ray Curve
Resistivity Curve
Spontaneous Potential (SP) Curve

Saturated Zone

Horizontal Scale
as Designated

AMSL: Above Mean Sea Level

Crow Butte Resources, Inc

Figure 2.6-3k
Marsland Structural
Cross Section K-K'

Scale: See Scale Bar	Date: 12/8/2016
C:\Users\cab41429\Desktop\DBOW TEMP\TRANSCRIPTS\K-K'.mxd	Checked by: JS

Looking North

L
West

L'
East

M-39
4107'

— 2079' —

Tie to A-A'
M-91
4150'

— 1801' —

M-90
4165'

— 1443' —

M-74
4133'

Elevation
AMSL

4300'
4200'
4100'
4000'
DATUM
3900'
3800'
3700'
3600'
3500'
3400'
3300'
3200'
3100'
3000'

Alluvium

Arikaree
Group

Brule
Formation

Upper Whitney Ash

Lower Whitney Ash

Upper
Chadron
Formation

Middle
Chadron
Formation

Basal Sandstone
of the Chadron Fm.

Pierre
Shale

Legend

Vertical Scale
0 feet
50 feet
100 feet
200 feet

Geophysical Log Explanation

Gamma Ray Curve
Resistivity Curve
Spontaneous Potential (SP) Curve

Saturated Zone

Horizontal Scale
as Designated

AMSL: Above Mean Sea Level

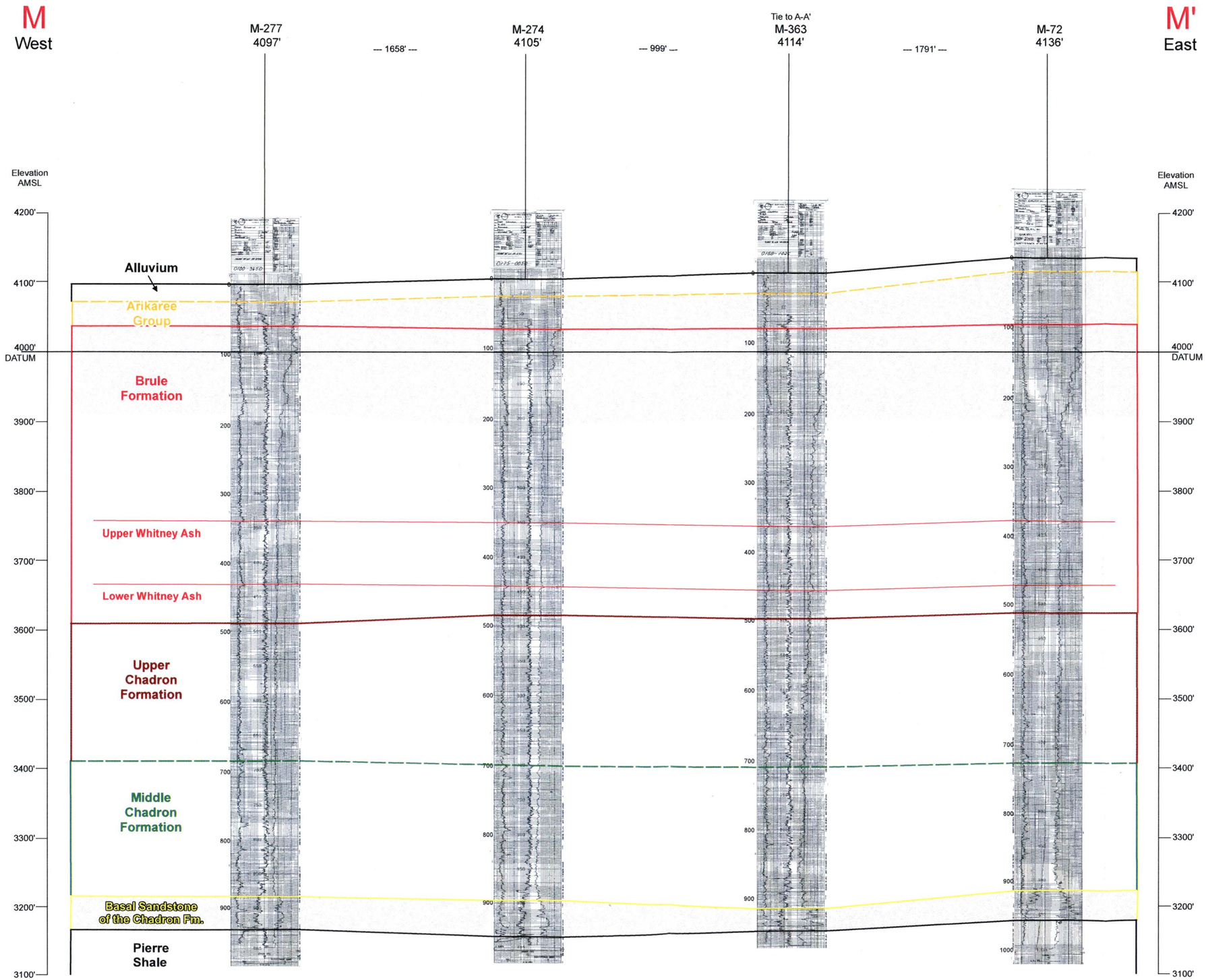
Crow Butte Resources, Inc

Figure 2.6-3l
Marsland Structural
Cross Section L-L'

Scale: See Scale Bar | Date: 12/8/2016

C:\Users\cad4142\Desktop\OBJWT\TEMP\TR-R\RCTR_L-L'.mxd | Checked by: JS

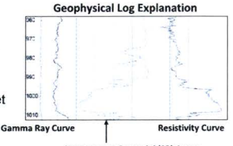
Looking North



Legend

Vertical Scale
0 feet
50 feet
100 feet
200 feet

Geophysical Log Explanation



Saturated Zone

Horizontal Scale as Designated

AMSL: Above Mean Sea Level

Crow Butte Resources, Inc

Figure 2.6-3m
Marsland Structural Cross Section M-M'

Scale: See Scale Bar	Date: 12/8/2016
C:\Users\lcal\841420\Desktop\DBOWTEMP\TR-6\RC\TR_M-M'.mxd	Checked by: JS

Looking North

N
West

N'
East

M-1582
4090'

--- 628' ---

Tie to A-A'
M-1554
4094'

--- 1002' ---

M-1573
4079'

Elevation
AMSL

4300'
4200'
4100'
4000'
DATUM
3900'
3800'
3700'
3600'
3500'
3400'
3300'
3200'
3100'

Alluvium

Arikaree
Group

Brule
Formation

Upper Whitney Ash

Lower Whitney Ash

Upper
Chadron
Formation

Middle
Chadron
Formation

Basal Sandstone
of the Chadron Fm.

Pierre
Shale

0
100
200
300
400
500
600
700
800
900

Legend

Vertical Scale
0 feet
50 feet
100 feet
200 feet

Geophysical Log Explanation

Gamma Ray Curve
Resistivity Curve
Spontaneous Potential (SP) Curve

Saturated Zone

Horizontal Scale
as Designated

AMSL: Above Mean Sea Level

Crow Butte
Resources, Inc

Figure 2.6-3n
Marsland Structural
Cross Section N-N'

Scale: See Scale Bar	Date: 12/8/2016
C:\Users\ca841420\Desktop\DBGW TEMP\TR-W-KOTR_N-N'.mxd	Checked by: JS

Looking North

TR Figure 2.7-4 MEA Surface Water Sampling Locations_rv11062014 final.pdf | Last Saved By: sfox | Last Saved On: 6/14/2017

Richardson
Metz
MED-4
MED-1
MED-5
MED-7
Dooley Spring
Tollman
Veg West
MED-2
MED-6
Walters
Furman
Niobrara River above Box Butte Reservoir
Veg East
MED-3
Troester 2
N-1
Veg Middle
Troester 1
N-2
Box Butte Reservoir
Marsland
DAWES COUNTY
BOX BUTTE COUNTY
Sand
R. 51W
R. 50W
R. 49W
T. 30N
T. 29N
T. 28N

LEGEND

- Proposed Marsland Expansion Area
- 2.25-Mile Area of Review (AOR)
- 3 Kilometer AOR for Crops
- Livestock Sampling Location
- Garden Soil Sampling Location
- Vegetation Sampling Location
- Proposed Marsland Satellite Facility Site
- CBR Surface Water/ Sediment Sampling Location
- Marsland Ephemeral Drainage (MED) Sediment and Surface Runoff Sampling Point
- Crop Sampling Location
- USGS/NDNR 06454500 and NDEQ SNI4NIOBR402 Gaging Station
- Natural Spring
- Reservoir/Lake/Pond
- Perennial River
- Ephemeral Drainage
- Railroad
- StateHighway

Note: Fish sampling for radiological analysis occurs in headwaters of Box Butte Reservoir.

N

0 0.5 1

Miles

PROJECTION: NAD 1983, STATE PLANE NEBRASKA NORTH, FIPS 2600
SOURCES: US TOPO MAPS, SERVICED BY ESRI ARCGIS ONLINE

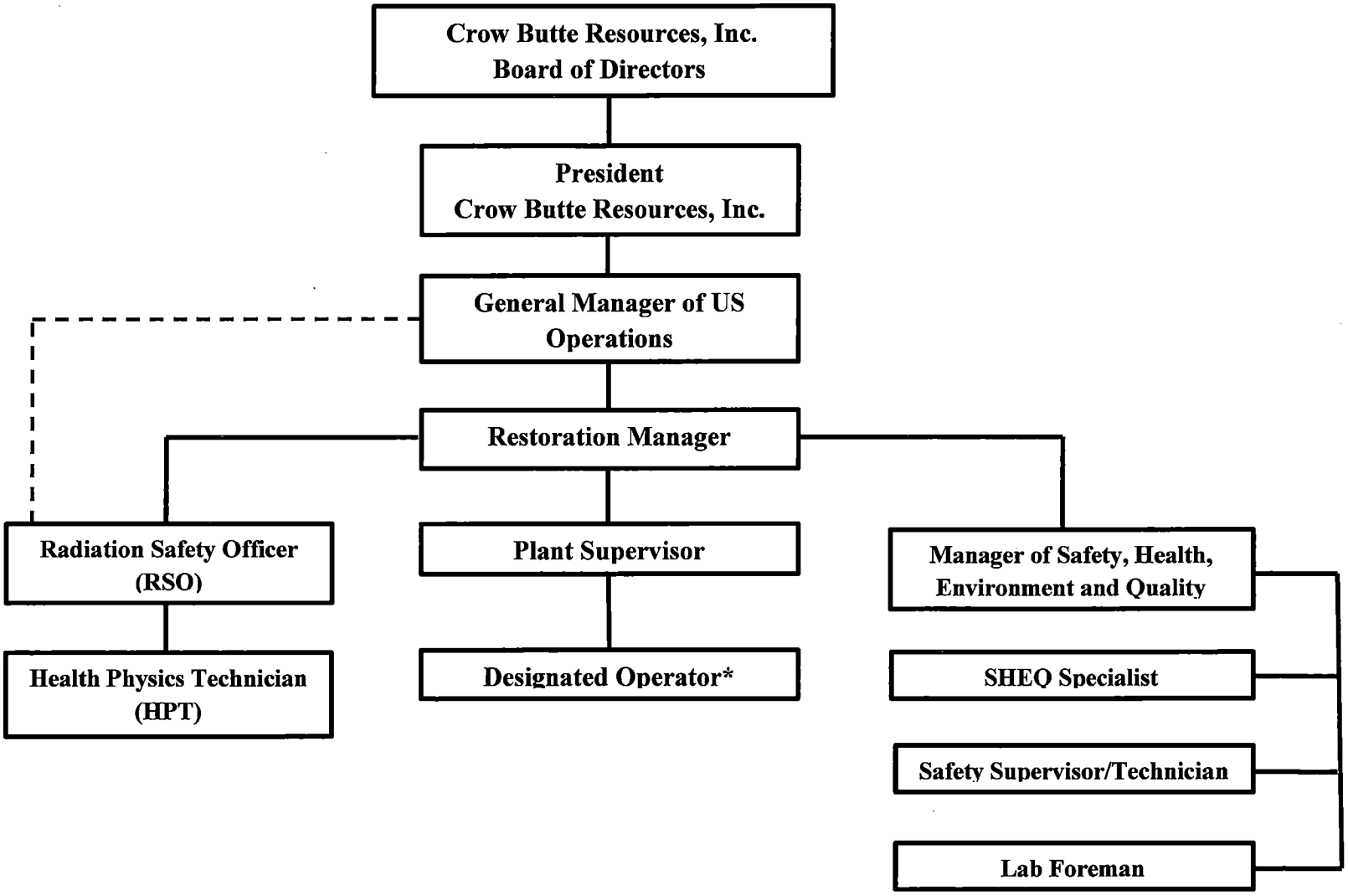
CROW BUTTE RESOURCES, INC.

FIGURE 2.7-4
SAMPLING LOCATIONS

PROJECT: CO001636 MAPPED BY: JC CHECKED BY: JEC

ARCADIS
630 Plaza Drive, Ste. 100
Highlands Ranch, CO 80129
P: 720-344-3500 F: 720-344-3535
www.arcadis-us.com

Figure 5.1-1: Crow Butte Resources Organizational Chart



*Qualifications for Designated Operator described in Marsland Expansion Area Technical Report, Section 5.5.4

CROW BUTTE RESOURCES, INC.

Technical Report
Marsland Expansion Area



Response to Request for Additional Information (RAI)
Combined Revisions May 2012 through June 2017

Volume III - Appendices A-J

COPY 1 of 6	Document Control Desk, Director Office of Nuclear Material Safety and Safeguards U.S. Nuclear Regulatory Commission
COPY 2 of 6	Tom Lancaster, Project Manager Office of Nuclear Material Safety and Safeguards U.S. Nuclear Regulatory Commission
COPY 3 of 6	Tom Lancaster, Project Manager Office of Nuclear Material Safety and Safeguards U.S. Nuclear Regulatory Commission
COPY 4 of 6	Tom Lancaster, Project Manager Office of Nuclear Material Safety and Safeguards U.S. Nuclear Regulatory Commission
COPY 5 of 6	Crow Butte Resources, Inc.
COPY 6 of 6	Crow Butte Resources, Inc.

Additional Pages – Appendix E

Instructions:

Retain all of Appendix E (Do Not Remove E-1 or E-2)

Add this additional packet of Well Completion Reports (Deep Brule Wells) to the end of Appendix E-2

MEA TR

Reponses to Open Issues

6-29-2017

8180856

Nebraska Department of Environmental Quality **Permit No. NE0220824**

Well Completion Report

Company: Crow Butte Resources. Inc.
Project: Crow Butte
Well Type: Production/Injection ____ Monitor X
Well No. DBOW 1
Ground Elevation: 4260 ft.
Wellhead Elevation: 4261 ft.
Drilling Contractor: Single Water Service
Driller: Tucker Baughman
Mud Products: 7 Bags Super Gel
Bit Size: 8 Inch
Drilling Begun: 8/16/2016
Drilling Completed On: 8/24/2016
Completed Formation: Brule
Depth Drilled: 600 ft.
Casing Diameter: 4.95 inch O.D.
Casing Type: White Certalok
Casing Depth: 459 ft.
Basket Depth: N/A ft.
Packer Type: Johnson K-packer
Packer Depth: 455 ft.
Centralizer Depths: 20, 40, 100, 160, 220, 280, 340, 400 Ft

Screen Size: 3 inch by .020 inch
Gravel Size:
Screened Interval(s): 465 ft. - 505 ft.
ft. - ft.
555 ft. - 565 ft.
ft. - ft.
Completed Formation Upper Boundary: 465 ft.
Lower Boundary: 565 ft.
Cement Contractor: Crow Butte Resources
Operator: Klein
Estimated Cement Volume: 17.7 bbls.
Actual Cement Volume Used: 24.8 bbls.
Cement Density: 12.9 lbs/gal
Water Volume Used: 17.8 bbls.
Cement Type/Class: I/II API
Additives: 500 lbs. Salt 500 lbs. Bentonite
Cement Circulated to Surface: 1/2 bbls.
Density At Surface: 11.2 lbs/gal
Logging Contractor: Century Geophysical Corp.
Operator: Klein
Unit No.: 2008
Probe No.: 9057C
Log Type: Gamma, SP, Resistance, Deviation
Well Deviation: 12.7 ft. at 265 degrees
Remarks: #N/A

This report was filled out by: Skip Chubb
Representing: Single Water Service
On:

Certification:

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this form and all its attachments and that, based on inquiry of those individuals immediately responsible for obtaining information, I believe the information is true, accurate, and complete. Further, I certify awareness that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

By: Skip Chubb Title :

Skip L. Chubb Date: September 22, 2016

6180857

Nebraska Department of Environmental Quality **Permit No. NE0220824**

Well Completion Report

Company: Crow Butte Resources. Inc.
Project: Crow Butte
Well Type: Production/Injection ____ Monitor X
Well No. DBOW 2
Ground Elevation: 4330 ft.
Wellhead Elevation: 4331 ft.
Drilling Contractor: Single Water Service
Driller: Tucker Baughman
Mud Products: 4 Bags Super Gel
Bit Size: 8 Inch
Drilling Begun: 8/22/2016
Drilling Completed On: 8/25/2016
Completed Formation: Brule
Depth Drilled: 660 ft.
Casing Diameter: 4.95 inch O.D.
Casing Type: White Certalok
Casing Depth: 519 ft.
Basket Depth: N/A ft.
Packer Type: Johnson K-packer
Packer Depth: 510 ft.
Centralizer Depths: 20, 40, 100, 160, 220, 280, 340, 400, 460 Ft

Screen Size: 3 inch by .020 inch
Gravel Size:
Screened Interval(s): 530 ft. - 550 ft.
ft. - ft.
620 ft. - 630 ft.
ft. - ft.
Completed Formation Upper Boundary: 530 ft.
Lower Boundary: 630 ft.
Cement Contractor: Crow Butte Resources
Operator: Klein
Estimated Cement Volume: 20.0 bbls.
Actual Cement Volume Used: 28.0 bbls.
Cement Density: 13.1 lbs/gal
Water Volume Used: 20.1 bbls.
Cement Type/Class: I/II API
Additives: 500 lbs. Salt 500 lbs. Bentonite
Cement Circulated to Surface: 1/2 bbls.
Density At Surface: 11.3 lbs/gal
Logging Contractor: Century Geophysical Corp.
Operator: Klein
Unit No.: 2008
Probe No.: 9057C
Log Type: Gamma, SP, Resistance, Deviation
Well Deviation: 10.6 ft. at 119 degrees
Remarks: #N/A

This report was filled out by: Skip Chubb
Representing: Single Water Service
On:

Certification:

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this form and all its attachments and that, based on inquiry of those individuals immediately responsible for obtaining information, I believe the information is true, accurate, and complete. Further, I certify awareness that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

By: Skip Chubb Title :

Skip L. Chubb Date: September 22, 2016

6180858

Nebraska Department of Environmental Quality **Permit No. NE0220824**

Well Completion Report

Company: Crow Butte Resources. Inc. Project: Crow Butte

Well Type: Production/Injection ____ Monitor X Well No. DBOW 3

Ground Elevation: 4350 ft. Wellhead Elevation: 4351 ft.

Drilling Contractor: Single Water Service Driller: Tucker Baughman

Mud Products: Bags Super Gel

Bit Size: 8 Inch

Drilling Begun: 8/23/2016 Drilling Completed On: 9/1/2016

Completed Formation: Brule Depth Drilled: 660 ft.

Casing Diameter: 4.95 inch O.D. Casing Type: White Certalok

Casing Depth: 499 ft. Basket Depth: N/A ft.

Packer Type: Johnson K-packer Packer Depth: 490 ft.

Centralizer Depths: 20, 40, 100, 160, 220, 280, 340, 400, 460 Ft

Screen Size: 3 inch by .020 inch

Screened Interval(s): 500 ft. - 520 ft. 610 ft. - 630 ft.

530 ft. - 570 ft. ft. - ft.

Completed Formation Upper Boundary: 500 ft. Lower Boundary: 630 ft.

Cement Contractor: Crow Butte Resources Operator: Klein

Estimated Cement Volume: 19.2 bbls. Actual Cement Volume Used: 26.9 bbls.

Cement Density: 12.3 lbs/gal Water Volume Used: 19.3 bbls.

Cement Type/Class: I/II API Additives: 500 lbs. Salt 500 lbs. Bentonite

Cement Circulated to Surface: 3 bbls. Density At Surface: 11.7 lbs/gal

Logging Contractor: Century Geophysical Corp. Operator: Klein

Unit No.: 2008 Probe No.: 9057C

Log Type: Gamma, SP, Resistance, Deviation

Well Deviation: 21.8 ft. at 0 degrees

Remarks: #N/A

This report was filled out by: Skip Chubb

Representing: Single Water Service

On:

Certification:

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this form and all its attachments and that, based on inquiry of those individuals immediately responsible for obtaining information, I believe the information is true, accurate, and complete. Further, I certify awareness that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

By: Skip Chubb Title :

Skip L. Chubb Date: September 22, 2016

6181859

Nebraska Department of Environmental Quality **Permit No. NE0220824**

Well Completion Report

Company: Crow Butte Resources. Inc.
Project: Crow Butte
Well Type: Production/Injection ___ Monitor X
Well No. DBOW 4
Ground Elevation: 4161 ft.
Wellhead Elevation: 4162 ft.
Drilling Contractor: Single Water Service
Driller: Tucker Baughman
Mud Products: 4 Bags Super Gel
Bit Size: 8 Inch
Drilling Begun: 8/31/2016
Drilling Completed On: 9/9/2016
Completed Formation: Brule
Depth Drilled: 520 ft.
Casing Diameter: 4.95 inch O.D.
Casing Type: White Certalok
Casing Depth: 379 ft.
Basket Depth: N/A ft.
Packer Type: Johnson K-packer
Packer Depth: 370 ft.
Centralizer Depths: 20, 40, 100, 160, 220, 280, 340 Ft

Screen Size: 3 inch by .020 inch
Gravel Size:
Screened Interval(s): 380 ft. - 440 ft.
ft. - ft.
450 ft. - 490 ft.
ft. - ft.
Completed Formation Upper Boundary: 380 ft.
Lower Boundary: 490 ft.
Cement Contractor: Crow Butte Resources
Operator: Klein
Estimated Cement Volume: 14.6 bbls.
Actual Cement Volume Used: 20.5 bbls.
Cement Density: 12.9 lbs/gal
Water Volume Used: 14.7 bbls.
Cement Type/Class: I/II API
Additives: 500 lbs. Salt 500 lbs. Bentonite
Cement Circulated to Surface: 3 bbls.
Density At Surface: 12.3 lbs/gal
Logging Contractor: Century Geophysical Corp.
Operator: Klein
Unit No.: 2008
Probe No.: 9057C
Log Type: Gamma, SP, Resistance, Deviation
Well Deviation: 8.6 ft. at 280.8 degrees
Remarks: #N/A

This report was filled out by: Skip Chubb
Representing: Single Water Service
On:

Certification:

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this form and all its attachments and that, based on inquiry of those individuals immediately responsible for obtaining information, I believe the information is true, accurate, and complete. Further, I certify awareness that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

By: Skip Chubb Title :

Skip L. Chubb Date: September 22, 2016

6180860

Nebraska Department of Environmental Quality **Permit No. NE0220824**

Well Completion Report

Company: Crow Butte Resources. Inc.
Project: Crow Butte
Well Type: Production/Injection ___ Monitor X
Well No. DBOW 5
Ground Elevation: 4124 ft.
Wellhead Elevation: 4125 ft.
Drilling Contractor: Single Water Service
Driller: Tucker Baughman
Mud Products: 6 Bags Super Gel
Bit Size: 8 Inch
Drilling Begun: 9/8/2016
Drilling Completed On: 9/15/2016
Completed Formation: Brule
Depth Drilled: 500 ft.
Casing Diameter: 4.95 inch O.D.
Casing Type: White Certalok
Casing Depth: 319 ft.
Basket Depth: N/A ft.
Packer Type: Johnson K-packer
Packer Depth: 315 ft.
Centralizer Depths: 20, 40, 100, 160, 220, 280 Ft

Screen Size: 3 inch by .020 inch
Gravel Size:
Screened Interval(s): 325 ft. - 385 ft.
ft. - ft.
435 ft. - 460 ft.
ft. - ft.
Completed Formation Upper Boundary: 325 ft.
Lower Boundary: 460 ft.
Cement Contractor: Crow Butte Resources
Operator: Klein
Estimated Cement Volume: 12.3 bbls.
Actual Cement Volume Used: 17.2 bbls.
Cement Density: 12.3 lbs/gal
Water Volume Used: 12.4 bbls.
Cement Type/Class: I/II API
Additives: 500 lbs. Salt 500 lbs. Bentonite
Cement Circulated to Surface: 3 bbls.
Density At Surface: 12 lbs/gal
Logging Contractor: Century Geophysical Corp.
Operator: Klein
Unit No.: 2008
Probe No.: 9057C
Log Type: Gamma, SP, Resistance, Deviation
Well Deviation: 6.8 ft. at 10.2 degrees
Remarks: #N/A

This report was filled out by: Skip Chubb
Representing: Single Water Service
On:

Certification:

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this form and all its attachments and that, based on inquiry of those individuals immediately responsible for obtaining information, I believe the information is true, accurate, and complete. Further, I certify awareness that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

By: Skip Chubb Title :

Skip L. Chubb Date: September 22, 2016

8/8081

Nebraska Department of Environmental Quality **Permit No. NE0220824**

Well Completion Report

Company: Crow Butte Resources. Inc.
Project: Crow Butte
Well Type: Production/Injection ____ Monitor X
Well No. DBOW 6
Ground Elevation: 4099 ft.
Wellhead Elevation: 4100 ft.
Drilling Contractor: Single Water Service
Driller: Tucker Baughman
Mud Products: 1 Bags Super Gel
Bit Size: 8 Inch
Drilling Begun: 9/7/2016
Drilling Completed On: 9/14/2016
Completed Formation: Brule
Depth Drilled: 480 ft.
Casing Diameter: 4.95 inch O.D.
Casing Type: White Certalok
Casing Depth: 299 ft.
Basket Depth: N/A ft.
Packer Type: Johnson K-packer
Packer Depth: 290 ft.
Centralizer Depths: 20, 40, 100, 160, 220, 280 Ft

Screen Size: 3 inch by .020 inch
Screened Interval(s): 300 ft. - 350 ft. 430 ft. - 450 ft.
380 ft. - 400 ft. ft. - ft.
Completed Formation Upper Boundary: 300 ft.
Lower Boundary: 450 ft.
Cement Contractor: Crow Butte Resources
Operator: Klein
Estimated Cement Volume: 11.6 bbls.
Actual Cement Volume Used: 16.2 bbls.
Cement Density: 12.6 lbs/gal
Water Volume Used: 11.6 bbls.
Cement Type/Class: I/II API
Additives: 500 lbs. Salt 500 lbs. Bentonite
Cement Circulated to Surface: 2 bbls.
Density At Surface: 12.2 lbs/gal
Logging Contractor: Century Geophysical Corp.
Operator: Klein
Unit No.: 2008
Probe No.: 9057C
Log Type: Gamma, SP, Resistance, Deviation
Well Deviation: 21.1 ft. at 201.6 degrees
Remarks: #N/A

This report was filled out by: Skip Chubb
Representing: Single Water Service
On:

Certification:

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this form and all its attachments and that, based on inquiry of those individuals immediately responsible for obtaining information, I believe the information is true, accurate, and complete. Further, I certify awareness that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

By: Skip Chubb Title :

Skip L. Chubb Date: September 22, 2016

6180802

Nebraska Department of Environmental Quality **Permit No. NE0220824**

Well Completion Report

Company: Crow Butte Resources. Inc. Project: Crow Butte

Well Type: Production/Injection ____ Monitor X Well No. DBOW 7

Ground Elevation: 4246 ft. Wellhead Elevation: 4247 ft.

Drilling Contractor: Single Water Service Driller: Tucker Baughman

Mud Products: Bags Super Gel

Bit Size: 8 Inch

Drilling Begun: 8/15/2016 Drilling Completed On: 8/18/2016

Completed Formation: Brule Depth Drilled: 600 ft.

Casing Diameter: 4.95 inch O.D. Casing Type: White Certalok

Casing Depth: 479 ft. Basket Depth: N/A ft.

Packer Type: Johnson K-packer Packer Depth: 470 ft.

Centralizer Depths: 20, 40, 100, 160, 220, 280, 340, 400, 460 Ft

Screen Size: 3 inch by .020 inch

Screened Interval(s): 480 ft. - 500 ft. 550 ft. - 580 ft.

510 ft. - 540 ft. ft. - ft.

Completed Formation Upper Boundary: 480 ft. Lower Boundary: 580 ft.

Cement Contractor: Crow Butte Resources Operator: Klein

Estimated Cement Volume: 18.5 bbls. Actual Cement Volume Used: 25.8 bbls.

Cement Density: 11.8 lbs/gal Water Volume Used: 18.5 bbls.

Cement Type/Class: I/II API Additives: 500 lbs. Salt 500 lbs. Bentonite

Cement Circulated to Surface: 1 bbls. Density At Surface: 10.7 lbs/gal

Logging Contractor: Century Geophysical Corp. Operator: Klein

Unit No.: 2008 Probe No.: 9057C

Log Type: Gamma, SP, Resistance, Deviation

Well Deviation: 8.4 ft. at 320.3 degrees

Remarks: #N/A

This report was filled out by: Skip Chubb

Representing: Single Water Service

On:

Certification:

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this form and all its attachments and that, based on inquiry of those individuals immediately responsible for obtaining information, I believe the information is true, accurate, and complete. Further, I certify awareness that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

By: Skip Chubb Title :

Skip L. Chubb Date: September 22, 2016

6180863

Nebraska Department of Environmental Quality **Permit No. NE0220824**

Well Completion Report

Company: Crow Butte Resources. Inc.
Project: Crow Butte
Well Type: Production/Injection ____ Monitor X
Well No. DBOW 8
Ground Elevation: 4365 ft.
Wellhead Elevation: 4366 ft.
Drilling Contractor: Single Water Service
Driller: Tucker Baughman
Mud Products: 7 Bags Super Gel
Bit Size: 8 Inch
Drilling Begun: 8/16/2016
Drilling Completed On: 8/30/2016
Completed Formation: Brule
Depth Drilled: ~~680~~ ft.
Casing Diameter: 4.95 inch O.D.
Casing Type: White Certalok
Casing Depth: 509 ft.
Basket Depth: N/A ft.
Packer Type: Johnson K-packer
Packer Depth: 501 ft.
Centralizer Depths: 20, 40, 100, 160, 220, 280, 340, 400, 460 Ft

Screen Size: 3 inch by .020 inch
Screened Interval(s): 511 ft. - 531 ft. 581 ft. - 601 ft.
541 ft. - 561 ft. ft. - ft.
Completed Formation Upper Boundary: 511 ft.
Lower Boundary: 601 ft.
Cement Contractor: Crow Butte Resources
Operator: Klein
Estimated Cement Volume: 19.6 bbls.
Actual Cement Volume Used: 27.5 bbls.
Cement Density: 12 lbs/gal
Water Volume Used: 19.7 bbls.
Cement Type/Class: I/II API
Additives: 500 lbs. Salt 500 lbs. Bentonite
Cement Circulated to Surface: 1/2 bbls.
Density At Surface: 10.8 lbs/gal
Logging Contractor: Century Geophysical Corp.
Operator: Klein
Unit No.: 2008
Probe No.: 9057C
Log Type: Gamma, SP, Resistance, Deviation
Well Deviation: 34.5 ft. at 233.3 degrees
Remarks: #N/A

This report was filled out by: Skip Chubb
Representing: Single Water Service
On:

Certification:

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this form and all its attachments and that, based on inquiry of those individuals immediately responsible for obtaining information, I believe the information is true, accurate, and complete. Further, I certify awareness that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

By: Skip Chubb Title :

Skip L. Chubb Date: September 22, 2016

6130844

Nebraska Department of Environmental Quality **Permit No. NE0220824**

Well Completion Report

Company: Crow Butte Resources. Inc.
Project: Crow Butte
Well Type: Production/Injection ____ Monitor X
Well No. DBOW 9
Ground Elevation: 4146 ft.
Wellhead Elevation: 4147 ft.
Drilling Contractor: Single Water Service
Driller: Tucker Baughman
Mud Products: 6 Bags Super Gel
Bit Size: 8 Inch
Drilling Begun: 9/6/2016
Drilling Completed On: 9/13/2016
Completed Formation: Brule
Depth Drilled: 520 ft.
Casing Diameter: 4.95 inch O.D.
Casing Type: White Certalok
Casing Depth: 379 ft.
Basket Depth: N/A ft.
Packer Type: Johnson K-packer
Packer Depth: 375 ft.
Centralizer Depths: 20, 40, 100, 160, 220, 280, 340 Ft

Screen Size: 3 inch by .020 inch
Screened Interval(s): 385 ft. - 405 ft. ft. - ft.
455 ft. - 480 ft. ft. - ft.
Completed Formation Upper Boundary: 385 ft. Lower Boundary: 480 ft.
Cement Contractor: Crow Butte Resources
Operator: Klein
Estimated Cement Volume: 14.6 bbls.
Actual Cement Volume Used: 20.5 bbls.
Cement Density: 12.5 lbs/gal
Water Volume Used: 14.7 bbls.
Cement Type/Class: I/II API
Additives: 500 lbs. Salt 500 lbs. Bentonite
Cement Circulated to Surface: 1/2 bbls.
Density At Surface: 11.7 lbs/gal
Logging Contractor: Century Geophysical Corp.
Operator: Klein
Unit No.: 2008
Probe No.: 9057C
Log Type: Gamma, SP, Resistance, Deviation
Well Deviation: 1.6 ft. at 129.9 degrees
Remarks: #N/A

This report was filled out by: Skip Chubb
Representing: Single Water Service
On:

Certification:

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this form and all its attachments and that, based on inquiry of those individuals immediately responsible for obtaining information, I believe the information is true, accurate, and complete. Further, I certify awareness that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

By: Skip Chubb Title :

Skip L. Chubb Date: September 22, 2016

6180805

Nebraska Department of Environmental Quality **Permit No. NE0220824**

Well Completion Report

Company: Crow Butte Resources. Inc.
Project: Crow Butte
Well Type: Production/Injection ___ Monitor X
Well No. DBOW 10
Ground Elevation: 4196 ft.
Wellhead Elevation: 4197 ft.
Drilling Contractor: Single Water Service
Driller: Tucker Baughman
Mud Products: 7 Bags Super Gel
Bit Size: 8 Inch
Drilling Begun: 9/6/2016
Drilling Completed On: 9/12/2016
Completed Formation: Brule
Depth Drilled: 580 ft.
Casing Diameter: 4.95 inch O.D.
Casing Type: White Certalok
Casing Depth: 399 ft.
Basket Depth: N/A ft.
Packer Type: Johnson K-packer
Packer Depth: 390 ft.
Centralizer Depths: 20, 40, 100, 160, 220, 280, 340 Ft

Screen Size: 3 inch by .020 inch
Gravel Size:
Screened Interval(s): 400 ft. - 480 ft.
ft. - ft.
510 ft. - 530 ft.
ft. - ft.
Completed Formation Upper Boundary: 400 ft.
Lower Boundary: 530 ft.
Cement Contractor: Crow Butte Resources
Operator: Klein
Estimated Cement Volume: 15.4 bbls.
Actual Cement Volume Used: 21.5 bbls.
Cement Density: 12.5 lbs/gal
Water Volume Used: 15.5 bbls.
Cement Type/Class: I/II API
Additives: 500 lbs. Salt 500 lbs. Bentonite
Cement Circulated to Surface: 1 bbls.
Density At Surface: 12 lbs/gal
Logging Contractor: Century Geophysical Corp.
Operator: Klein
Unit No.: 2008
Probe No.: 9057C
Log Type: Gamma, SP, Resistance, Deviation
Well Deviation: 12.5 ft. at 339.3 degrees
Remarks: #N/A

This report was filled out by: Skip Chubb
Representing: Single Water Service
On:

Certification:

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this form and all its attachments and that, based on inquiry of those individuals immediately responsible for obtaining information, I believe the information is true, accurate, and complete. Further, I certify awareness that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

By: Skip Chubb Title :

Skip L. Chubb Date: September 22, 2016



Response to Request for Additional Information (RAI)
Combined Revisions May 2012 through June 2017

Volume IV - Appendices K-HH

COPY 1 of 6	Document Control Desk, Director Office of Nuclear Material Safety and Safeguards U.S. Nuclear Regulatory Commission
COPY 2 of 6	Tom Lancaster, Project Manager Office of Nuclear Material Safety and Safeguards U.S. Nuclear Regulatory Commission
COPY 3 of 6	Tom Lancaster, Project Manager Office of Nuclear Material Safety and Safeguards U.S. Nuclear Regulatory Commission
COPY 4 of 6	Tom Lancaster, Project Manager Office of Nuclear Material Safety and Safeguards U.S. Nuclear Regulatory Commission
COPY 5 of 6	Crow Butte Resources, Inc.
COPY 6 of 6	Crow Butte Resources, Inc.

Replacement Pages – Appendix Q

Instructions:

Remove and Replace all of Appendix Q

MEA TR

Reponses to Open Issues

6-29-2017

Appendix Q

MEA Baseline Crop and Vegetation Sampling Analytical Data

ANALYTICAL SUMMARY REPORT

April 12, 2017

Crow Butte Resources
86 Crow Butte Rd
Crawford, NE 69339

Work Order: C13060954

Project Name: Vegetation Baseline Sampling

Energy Laboratories, Inc. Casper WY received the following 6 samples for Crow Butte Resources on 6/26/2013 for analysis.

Lab ID	Client Sample ID	Collect Date	Receive Date	Matrix	Test
C13060954-001	Three Crow West Site	06/26/13 0:00	06/26/13	Vegetation	Uranium, Total Digestion, Radiochemistry Lead 210 Polonium 210 Radium 226 Thorium, Isotopic
C13060954-002	Three Crow Middle Site	06/26/13 0:00	06/26/13	Vegetation	Same As Above
C13060954-003	Three Crow East Site	06/26/13 0:00	06/26/13	Vegetation	Same As Above
C13060954-004	Marsland West Site	06/26/13 0:00	06/26/13	Vegetation	Same As Above
C13060954-005	Marsland Middle Site	06/26/13 0:00	06/26/13	Vegetation	Same As Above
C13060954-006	Marsland East Site	06/26/13 0:00	06/26/13	Vegetation	Same As Above

The results as reported relate only to the item(s) submitted for testing. The analyses presented in this report were performed at Energy Laboratories, Inc., 2393 Salt Creek Hwy., Casper, WY 82601, unless otherwise noted. Any exceptions or problems with the analyses are noted in the Laboratory Analytical Report, the QA/QC Summary Report, or the Case Narrative.

If you have any questions regarding these test results, please call.

Report Approved By:

Randy Horton, Project Manager

Digitally signed by
Randy Horton
Date: 2017.04.12 15:45:14 -06:00

CLIENT: Crow Butte Resources
Project: Vegetation Baseline Sampling
Work Order: C13060954

Revised Date: 04/12/17
Report Date: 09/17/13

CASE NARRATIVE

REVISED/SUPPLEMENTAL REPORT R2
The attached analytical report has been revised from a previously submitted report due to the request by Larry Teahon on 3-27-17 for the addition of RLs on all samples. The data presented here is from that addition. The report has been revised and replaces any previously issued report in its entirety.

REVISED/SUPPLEMENTAL REPORT R1
The attached analytical report has been revised from a previously submitted report due to the request by Larry Teahon on 11-15-2016 for the re-report of specified analyses that were reported as ND or less than detection limit with actual responses for samples Marsland West Site (004), Marsland Middle Site (005) and Marsland East Site (006). The data presented here is from that request. The report has been revised and replaces any previously issued report in its entirety.

pH COMMENTS
Per NELAC rule, pH is considered a field parameter with a holding time of 15 minutes. Due to this rule, all pH analyses will be flagged with an H.

RADIOCHEMISTRY ANALYSIS
Per client request, results less than MDC (or precision if no MDC), are reported as <MDC (or <precision). Actual instrument results are available by request.

ORIGINAL SAMPLE SUBMITTAL(S)
All original sample submittals have been returned with the data package.

SAMPLE TEMPERATURE COMPLIANCE: 4°C (±2°C)
Temperature of samples received may not be considered properly preserved by accepted standards. Samples that are hand delivered immediately after collection shall be considered acceptable if there is evidence that the chilling process has begun.

GROSS ALPHA ANALYSIS
Method 900.0 for gross alpha and gross beta is intended as a drinking water method for low TDS waters. Data provided by this method for non potable waters should be viewed as inconsistent.

SOIL/SOLID SAMPLES
All samples reported on an as received basis unless otherwise indicated.

SUBCONTRACTING ANALYSIS
Subcontracting of sample analyses to an outside laboratory may be required. If so, ENERGY LABORATORIES will utilize its branch laboratories or qualified contract laboratories for this service. Any such laboratories will be indicated within the Laboratory Analytical Report.

BRANCH LABORATORY LOCATIONS
eli-b - Energy Laboratories, Inc. - Billings, MT
eli-g - Energy Laboratories, Inc. - Gillette, WY
eli-h - Energy Laboratories, Inc. - Helena, MT
eli-r - Energy Laboratories, Inc. - Rapid City, SD
eli-cs - Energy Laboratories, Inc. - College Station, TX

CERTFICATIONS:
USEPA: WY00002, Radiochemical WY00937; FL-DOH NELAC: E87641, Radiochemical E871017; California: 02118CA; Oregon: WY200001, Radiochemical WY200002; Utah: WY00002; Virginia: 00057; Washington: C836

ISO 17025 DISCLAIMER:
The results of this Analytical Report relate only to the items submitted for analysis.

ENERGY LABORATORIES, INC. - CASPER,WY certifies that certain method selections contained in this report meet requirements as set forth by the above accrediting authorities. Some results requested by the client may not be covered under these certifications. All analysis data to be submitted for regulatory enforcement should be certified in the sample state of origin. Please verify ELI's certification coverage by visiting www.energylab.com

ELI appreciates the opportunity to provide you with this analytical service. For additional information and services visit our web page www.energylab.com.

RA226 ANALYSIS
USNRC Regulatory Guide 4.14 provides guidance on Minimum Detectable Concentrations (MDC) that should be achieved in

CLIENT: Crow Butte Resources
Project: Vegetation Baseline Sampling
Work Order: C13060954

Revised Date: 04/12/17
Report Date: 09/17/13

CASE NARRATIVE

samples for this radionuclide. The sample-specific MDC for this sample could not be achieved due to significant matrix interferences, restricting the volume of sample to be used in the analysis. Please consult with your local regulatory agency prior to using these results for compliance purposes.

LABORATORY ANALYTICAL REPORT

Prepared by Casper, WY Branch

Client: Crow Butte Resources
Project: Vegetation Baseline Sampling
Lab ID: C13060954-001
Client Sample ID: Three Crow West Site

Revised Date: 04/12/17
Report Date: 09/17/13
Collection Date: 06/26/13
DateReceived: 06/26/13
Matrix: Vegetation

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
RADIONUCLIDES							
Lead 210	3.4E-04	uCi/kg		7.1E-06		E909.0	08/04/13 20:50 / eli-cs
Lead 210 precision (±)	1.2E-05	uCi/kg				E909.0	08/04/13 20:50 / eli-cs
Lead 210 MDC	7.1E-06	uCi/kg				E909.0	08/04/13 20:50 / eli-cs
Polonium 210	1.6E-04	uCi/kg		5.6E-06		E912.0	08/09/13 10:33 / plj
Polonium 210 precision (±)	3.9E-05	uCi/kg				E912.0	08/09/13 10:33 / plj
Polonium 210 MDC	5.6E-06	uCi/kg				E912.0	08/09/13 10:33 / plj
Radium 226	3.6E-06	uCi/kg		4.8E-07		E903.0	08/06/13 03:23 / lmc
Radium 226 precision (±)	6.6E-07	uCi/kg				E903.0	08/06/13 03:23 / lmc
Radium 226 MDC	4.8E-07	uCi/kg				E903.0	08/06/13 03:23 / lmc
Thorium 230	1.1E-05	uCi/kg		8.7E-06		E908.0	08/01/13 09:13 / dmf
Thorium 230 precision (±)	7.0E-06	uCi/kg				E908.0	08/01/13 09:13 / dmf
Thorium 230 MDC	8.7E-06	uCi/kg				E908.0	08/01/13 09:13 / dmf
Uranium	0.020	mg/kg	D	0.0044		SW6020	08/08/13 01:42 / clm
Uranium, Activity	1.4E-05	uCi/kg	D	3.0E-06		SW6020	08/08/13 01:42 / clm

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MDC - Minimum detectable concentration
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
D - RL increased due to sample matrix.

LABORATORY ANALYTICAL REPORT

Prepared by Casper, WY Branch

Client: Crow Butte Resources
Project: Vegetation Baseline Sampling
Lab ID: C13060954-002
Client Sample ID: Three Crow Middle Site

Revised Date: 04/12/17
Report Date: 09/17/13
Collection Date: 06/26/13
DateReceived: 06/26/13
Matrix: Vegetation

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
RADIONUCLIDES							
Lead 210	1.4E-04	uCi/kg		5.8E-06		E909.0	08/10/13 08:36 / eli-cs
Lead 210 precision (±)	7.1E-06	uCi/kg				E909.0	08/10/13 08:36 / eli-cs
Lead 210 MDC	5.8E-06	uCi/kg				E909.0	08/10/13 08:36 / eli-cs
Polonium 210	1.9E-05	uCi/kg		4.9E-06		E912.0	08/09/13 10:33 / plj
Polonium 210 precision (±)	8.4E-06	uCi/kg				E912.0	08/09/13 10:33 / plj
Polonium 210 MDC	4.9E-06	uCi/kg				E912.0	08/09/13 10:33 / plj
Radium 226	1.7E-06	uCi/kg		1.6E-06		E903.0	09/05/13 20:49 / trs
Radium 226 precision (±)	1.0E-06	uCi/kg				E903.0	09/05/13 20:49 / trs
Radium 226 MDC	1.6E-06	uCi/kg				E903.0	09/05/13 20:49 / trs
Thorium 230	1.3E-05	uCi/kg		7.3E-06		E908.0	08/09/13 08:58 / dmf
Thorium 230 precision (±)	6.6E-06	uCi/kg				E908.0	08/09/13 08:58 / dmf
Thorium 230 MDC	7.3E-06	uCi/kg				E908.0	08/09/13 08:58 / dmf
Uranium	0.015	mg/kg	D	0.0048		SW6020	08/08/13 01:23 / clm
Uranium, Activity	9.9E-06	uCi/kg	D	3.2E-06		SW6020	08/08/13 01:23 / clm

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MDC - Minimum detectable concentration
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
D - RL increased due to sample matrix.

LABORATORY ANALYTICAL REPORT

Prepared by Casper, WY Branch

Client: Crow Butte Resources
Project: Vegetation Baseline Sampling
Lab ID: C13060954-003
Client Sample ID: Three Crow East Site

Revised Date: 04/12/17
Report Date: 09/17/13
Collection Date: 06/26/13
DateReceived: 06/26/13
Matrix: Vegetation

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
RADIONUCLIDES							
Lead 210	3.6E-05	uCi/kg		3.6E-06		E909.0	08/25/13 18:48 / eli-cs
Lead 210 precision (±)	3.1E-06	uCi/kg				E909.0	08/25/13 18:48 / eli-cs
Lead 210 MDC	3.6E-06	uCi/kg				E909.0	08/25/13 18:48 / eli-cs
Polonium 210	3.9E-06	uCi/kg		2.3E-06		E912.0	09/06/13 12:31 / plj
Polonium 210 precision (±)	2.4E-06	uCi/kg				E912.0	09/06/13 12:31 / plj
Polonium 210 MDC	2.3E-06	uCi/kg				E912.0	09/06/13 12:31 / plj
Radium 226	2.8E-07	uCi/kg		1.7E-07		E903.0	09/16/13 12:14 / trs
Radium 226 precision (±)	1.4E-07	uCi/kg				E903.0	09/16/13 12:14 / trs
Radium 226 MDC	1.7E-07	uCi/kg				E903.0	09/16/13 12:14 / trs
Thorium 230	2.8E-06	uCi/kg		2.4E-06		E908.0	09/06/13 12:33 / dmf
Thorium 230 precision (±)	1.8E-06	uCi/kg				E908.0	09/06/13 12:33 / dmf
Thorium 230 MDC	2.4E-06	uCi/kg				E908.0	09/06/13 12:33 / dmf
Uranium	0.0014	mg/kg	D	0.0014		SW6020	09/11/13 04:14 / clm
Uranium, Activity	9.7E-07	uCi/kg	D	9.6E-07		SW6020	09/11/13 04:14 / clm

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MDC - Minimum detectable concentration
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
D - RL increased due to sample matrix.

LABORATORY ANALYTICAL REPORT

Prepared by Casper, WY Branch

Client: Crow Butte Resources
Project: Vegetation Baseline Sampling
Lab ID: C13060954-004
Client Sample ID: Marsland West Site

Revised Date: 04/12/17
Report Date: 09/17/13
Collection Date: 06/26/13
DateReceived: 06/26/13
Matrix: Vegetation

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
RADIONUCLIDES							
Lead 210	4.6E-05	uCi/kg		4.6E-06		E909.0	08/26/13 00:27 / eli-cs
Lead 210 precision (±)	4.0E-06	uCi/kg				E909.0	08/26/13 00:27 / eli-cs
Lead 210 MDC	4.6E-06	uCi/kg				E909.0	08/26/13 00:27 / eli-cs
Polonium 210	4.6E-06	uCi/kg		4.4E-06		E912.0	08/22/13 09:29 / plj
Polonium 210 precision (±)	4.2E-06	uCi/kg				E912.0	08/22/13 09:29 / plj
Polonium 210 MDC	4.4E-06	uCi/kg				E912.0	08/22/13 09:29 / plj
Radium 226	1.1E-06	uCi/kg		1.0E-06		E903.0	09/05/13 20:49 / trs
Radium 226 precision (±)	6.7E-07	uCi/kg				E903.0	09/05/13 20:49 / trs
Radium 226 MDC	1.0E-06	uCi/kg				E903.0	09/05/13 20:49 / trs
Thorium 230	4.6E-06	uCi/kg		2.2E-06		E908.0	09/06/13 12:33 / dmf
Thorium 230 precision (±)	2.1E-06	uCi/kg				E908.0	09/06/13 12:33 / dmf
Thorium 230 MDC	2.2E-06	uCi/kg				E908.0	09/06/13 12:33 / dmf
Uranium	0.63	mg/kg	D	0.0031		SW6020	08/10/13 04:52 / clm
Uranium, Activity	4.2E-04	uCi/kg	D	2.1E-06		SW6020	08/10/13 04:52 / clm

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MDC - Minimum detectable concentration
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
D - RL increased due to sample matrix.

LABORATORY ANALYTICAL REPORT

Prepared by Casper, WY Branch

Client: Crow Butte Resources
Project: Vegetation Baseline Sampling
Lab ID: C13060954-005
Client Sample ID: Marsland Middle Site

Revised Date: 04/12/17
Report Date: 09/17/13
Collection Date: 06/26/13
DateReceived: 06/26/13
Matrix: Vegetation

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
RADIONUCLIDES							
Lead 210	1.2E-04	uCi/kg		5.0E-06		E909.0	08/30/13 05:06 / eli-cs
Lead 210 precision (±)	6.2E-06	uCi/kg				E909.0	08/30/13 05:06 / eli-cs
Lead 210 MDC	5.0E-06	uCi/kg				E909.0	08/30/13 05:06 / eli-cs
Polonium 210	2.4E-05	uCi/kg		3.1E-06		E912.0	08/22/13 11:36 / plj
Polonium 210 precision (±)	8.6E-06	uCi/kg				E912.0	08/22/13 11:36 / plj
Polonium 210 MDC	3.1E-06	uCi/kg				E912.0	08/22/13 11:36 / plj
Radium 226	9.1E-06	uCi/kg		9.6E-07		E903.0	09/05/13 20:49 / trs
Radium 226 precision (±)	1.0E-06	uCi/kg				E903.0	09/05/13 20:49 / trs
Radium 226 MDC	9.6E-07	uCi/kg				E903.0	09/05/13 20:49 / trs
Thorium 230	7.4E-06	uCi/kg		4.9E-06		E908.0	08/27/13 09:12 / dmf
Thorium 230 precision (±)	4.2E-06	uCi/kg				E908.0	08/27/13 09:12 / dmf
Thorium 230 MDC	4.9E-06	uCi/kg				E908.0	08/27/13 09:12 / dmf
Uranium	0.043	mg/kg	D	0.0015		SW6020	08/22/13 00:10 / clm
Uranium, Activity	2.9E-05	uCi/kg	D	9.9E-07		SW6020	08/22/13 00:10 / clm

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MDC - Minimum detectable concentration
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
D - RL increased due to sample matrix.

LABORATORY ANALYTICAL REPORT

Prepared by Casper, WY Branch

Client: Crow Butte Resources
Project: Vegetation Baseline Sampling
Lab ID: C13060954-006
Client Sample ID: Marsland East Site

Revised Date: 04/12/17
Report Date: 09/17/13
Collection Date: 06/26/13
DateReceived: 06/26/13
Matrix: Vegetation

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
RADIONUCLIDES							
Lead 210	2.5E-05	uCi/kg		2.6E-06		E909.0	08/30/13 06:15 / eli-cs
Lead 210 precision (±)	2.3E-06	uCi/kg				E909.0	08/30/13 06:15 / eli-cs
Lead 210 MDC	2.6E-06	uCi/kg				E909.0	08/30/13 06:15 / eli-cs
Polonium 210	2.7E-06	uCi/kg		1.3E-06		E912.0	09/06/13 12:31 / plj
Polonium 210 precision (±)	1.4E-06	uCi/kg				E912.0	09/06/13 12:31 / plj
Polonium 210 MDC	1.3E-06	uCi/kg				E912.0	09/06/13 12:31 / plj
Radium 226	1.8E-06	uCi/kg		4.7E-07		E903.0	09/05/13 20:49 / trs
Radium 226 precision (±)	3.8E-07	uCi/kg				E903.0	09/05/13 20:49 / trs
Radium 226 MDC	4.7E-07	uCi/kg				E903.0	09/05/13 20:49 / trs
Thorium 230	1.6E-06	uCi/kg		1.5E-06		E908.0	09/06/13 12:33 / dmf
Thorium 230 precision (±)	1.1E-06	uCi/kg				E908.0	09/06/13 12:33 / dmf
Thorium 230 MDC	1.5E-06	uCi/kg				E908.0	09/06/13 12:33 / dmf
Uranium	0.0010	mg/kg	D	0.00072		SW6020	08/22/13 00:16 / clm
Uranium, Activity	6.8E-07	uCi/kg	D	4.9E-07		SW6020	08/22/13 00:16 / clm

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MDC - Minimum detectable concentration
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
D - RL increased due to sample matrix.

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 09/17/13
Work Order: C13060954

Client: Crow Butte Resources
Project: Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8										Batch: R176967
Lab ID: LRB		Method Blank				Run: ICPMS2-C_130809A				08/09/13 15:34
Uranium		ND	mg/L	1E-05						
Lab ID: LFB		Laboratory Fortified Blank				Run: ICPMS2-C_130809A				08/09/13 15:37
Uranium		0.0541	mg/L	0.00030	108	85	115			

Qualifiers:

RL - Analyte reporting limit.
MDC - Minimum detectable concentration
ND - Not detected at the reporting limit.

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 09/17/13
Work Order: C13060954

Client: Crow Butte Resources
Project: Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E903.0										Batch: R177979
Lab ID: C13060954-002AMS		Sample Matrix Spike				Run: BERTHOLD 770-1_130819C				09/05/13 20:49
Radium 226		0.00028	uCi/kg		77	70	130			
Lab ID: C13060954-002AMSD		Sample Matrix Spike Duplicate				Run: BERTHOLD 770-1_130819C				09/05/13 20:49
Radium 226		0.00035	uCi/kg		96	70	130	22	14.5	R
- The RPD for the MSD is high. The individual spike recoveries are within range, the MB is acceptable, and the LCS is acceptable therefore the batch is approved.										
Lab ID: LCS-38491		Laboratory Control Sample				Run: BERTHOLD 770-1_130819C				09/05/13 20:49
Radium 226		2.2E-05	uCi/kg		99	80	120			
Lab ID: MB-38491	3	Method Blank				Run: BERTHOLD 770-1_130819C				09/05/13 20:49
Radium 226		-1E-07	uCi/kg							U
Radium 226 precision (±)		1E-07	uCi/kg							
Radium 226 MDC		1E-07	uCi/kg							

Qualifiers:

RL - Analyte reporting limit.
MDC - Minimum detectable concentration
U - Not detected at minimum detectable concentration
ND - Not detected at the reporting limit.
R - RPD exceeds advisory limit.

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 09/17/13
Work Order: C13060954

Client: Crow Butte Resources
Project: Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E903.0										Batch: R176864
Lab ID: C13060245-004AMS		Sample Matrix Spike				Run: BERTHOLD 770-2_130726A				08/06/13 01:47
Radium 226		3.0E-05	uCi/kg		76	70	130			
Lab ID: C13060245-004AMSD		Sample Matrix Spike Duplicate				Run: BERTHOLD 770-2_130726A				08/06/13 01:47
Radium 226		3.4E-05	uCi/kg		88	70	130	11	20.9	
Lab ID: LCS-38250		Laboratory Control Sample				Run: BERTHOLD 770-2_130726A				08/06/13 01:47
Radium 226		2.4E-05	uCi/kg		104	80	120			
Lab ID: MB-38250	3	Method Blank				Run: BERTHOLD 770-2_130726A				08/06/13 01:47
Radium 226		2E-07	uCi/kg							U
Radium 226 precision (±)		2E-07	uCi/kg							
Radium 226 MDC		4E-07	uCi/kg							
Lab ID: C13060245-002AMS		Sample Matrix Spike				Run: BERTHOLD 770-2_130726A				08/06/13 01:47
Radium 226		0.00018	uCi/kg		110	70	130			
Lab ID: C13060245-002AMSD		Sample Matrix Spike Duplicate				Run: BERTHOLD 770-2_130726A				08/06/13 03:23
Radium 226		0.00017	uCi/kg		100	70	130	3.6	16.6	
Lab ID: LCS-38143		Laboratory Control Sample				Run: BERTHOLD 770-2_130726A				08/06/13 03:23
Radium 226		2.4E-05	uCi/kg		108	80	120			
Lab ID: MB-38143	3	Method Blank				Run: BERTHOLD 770-2_130726A				08/06/13 03:23
Radium 226			uCi/kg							U
Radium 226 precision (±)		2E-07	uCi/kg							
Radium 226 MDC		4E-07	uCi/kg							
Lab ID: C13060954-001AMS		Sample Matrix Spike				Run: BERTHOLD 770-2_130726A				08/06/13 03:23
Radium 226		6.6E-05	uCi/kg		94	70	130			
Lab ID: C13060954-001AMSD		Sample Matrix Spike Duplicate				Run: BERTHOLD 770-2_130726A				08/06/13 03:23
Radium 226		6.7E-05	uCi/kg		96	70	130	1.2	21.3	
Lab ID: LCS-38401		Laboratory Control Sample				Run: BERTHOLD 770-2_130726A				08/06/13 03:23
Radium 226		2.5E-05	uCi/kg		110	80	120			
Lab ID: MB-38401	3	Method Blank				Run: BERTHOLD 770-2_130726A				08/06/13 03:23
Radium 226		-1E-07	uCi/kg							U
Radium 226 precision (±)		2E-07	uCi/kg							
Radium 226 MDC		4E-07	uCi/kg							

Qualifiers:

RL - Analyte reporting limit.
MDC - Minimum detectable concentration
ND - Not detected at the reporting limit.
U - Not detected at minimum detectable concentration

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 09/17/13
Work Order: C13060954

Client: Crow Butte Resources
Project: Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E903.0										Batch: 38587
Lab ID: C13060954-003ADUP	3	Sample Duplicate				Run: BERTHOLD 770-2_130909A			09/16/13 12:14	
Radium 226		3.3E-07	uCi/kg					16	104.9	
Radium 226 precision (±)		1.5E-07	uCi/kg							
Radium 226 MDC		1.7E-07	uCi/kg							
Lab ID: C13060954-003AMS		Sample Matrix Spike				Run: BERTHOLD 770-2_130909A			09/16/13 12:14	
Radium 226		8.9E-06	uCi/kg		81	70	130			
Lab ID: MB-RA226-6829	3	Method Blank				Run: BERTHOLD 770-2_130909A			09/16/13 12:14	
Radium 226		0.06	pCi/L							U
Radium 226 precision (±)		0.2	pCi/L							
Radium 226 MDC		0.4	pCi/L							
Lab ID: LCS-RA226-6829		Laboratory Control Sample				Run: BERTHOLD 770-2_130909A			09/16/13 12:14	
Radium 226		24	pCi/L		107	80	120			

Qualifiers:

RL - Analyte reporting limit.
MDC - Minimum detectable concentration
ND - Not detected at the reporting limit.
U - Not detected at minimum detectable concentration

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 09/17/13
Work Order: C13060954

Client: Crow Butte Resources
Project: Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E908.0										Batch: R176643
Lab ID: LCS-38401		Laboratory Control Sample				Run: ALPHANALYST_130729A				08/01/13 09:13
Thorium 230		1.9E-05	uCi/kg		96	80	120			
Lab ID: MB-38401	3	Method Blank				Run: ALPHANALYST_130729A				08/01/13 09:13
Thorium 230		2E-07	uCi/kg							U
Thorium 230 precision (±)		2E-07	uCi/kg							
Thorium 230 MDC		4E-07	uCi/kg							
Lab ID: C13070822-001AMS		Sample Matrix Spike				Run: ALPHANALYST_130729A				08/01/13 09:14
Thorium 230		14.2	pCi/g-dry		108	70	130			
Lab ID: C13070822-001AMSD		Sample Matrix Spike Duplicate				Run: ALPHANALYST_130729A				08/01/13 09:14
Thorium 230		11.6	pCi/g-dry		87	70	130	20	43.2	
Lab ID: LCS-38440		Laboratory Control Sample				Run: ALPHANALYST_130729A				08/01/13 09:14
Thorium 230		0.4	pCi/g-dry		92	80	120			
Lab ID: MB-38440	3	Method Blank				Run: ALPHANALYST_130729A				08/01/13 09:14
Thorium 230		0.006	pCi/g-dry							U
Thorium 230 precision (±)		0.006	pCi/g-dry							
Thorium 230 MDC		0.01	pCi/g-dry							
Method: E908.0										Batch: R177035
Lab ID: LCS-38491		Laboratory Control Sample				Run: ALPHANALYST_130806A				08/09/13 08:58
Thorium 230		1.7E-05	uCi/kg		82	80	120			
Lab ID: MB-38491	3	Method Blank				Run: ALPHANALYST_130806A				08/09/13 08:59
Thorium 230		2E-07	uCi/kg							U
Thorium 230 precision (±)		3E-07	uCi/kg							
Thorium 230 MDC		5E-07	uCi/kg							
Lab ID: C13070974-002AMS		Sample Matrix Spike				Run: ALPHANALYST_130806A				08/09/13 08:59
Thorium 230		12.4	pCi/g-dry		104	70	130			
Lab ID: C13070974-002AMSD		Sample Matrix Spike Duplicate				Run: ALPHANALYST_130806A				08/09/13 08:59
Thorium 230		14.8	pCi/g-dry		122	70	130	18	44.5	
Lab ID: LCS-38488		Laboratory Control Sample				Run: ALPHANALYST_130806A				08/09/13 08:59
Thorium 230		0.4	pCi/g-dry		103	80	120			
Lab ID: MB-38488	3	Method Blank				Run: ALPHANALYST_130806A				08/09/13 08:59
Thorium 230		0.004	pCi/g-dry							U
Thorium 230 precision (±)		0.006	pCi/g-dry							
Thorium 230 MDC		0.01	pCi/g-dry							

Qualifiers:

RL - Analyte reporting limit.
MDC - Minimum detectable concentration
ND - Not detected at the reporting limit.
U - Not detected at minimum detectable concentration

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 09/17/13
Work Order: C13060954

Client: Crow Butte Resources
Project: Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E908.0										Batch: R177665
Lab ID: MB-38587	3	Method Blank				Run: ALPHANALYST_130819A				08/27/13 09:12
Thorium 230		4E-07	uCi/kg							U
Thorium 230 precision (±)		3E-07	uCi/kg							
Thorium 230 MDC		4E-07	uCi/kg							
Lab ID: C13060954-006AMS		Sample Matrix Spike				Run: ALPHANALYST_130819A				08/27/13 09:12
Thorium 230		0.00010	uCi/kg		95	70	130			
Lab ID: C13060954-006AMSD		Sample Matrix Spike Duplicate				Run: ALPHANALYST_130819A				08/27/13 09:12
Thorium 230		0.00011	uCi/kg		102	70	130	0.0	49.8	
Lab ID: MB-38681	3	Method Blank				Run: ALPHANALYST_130819A				08/27/13 09:12
Thorium 230		2E-07	uCi/kg							U
Thorium 230 precision (±)		3E-07	uCi/kg							
Thorium 230 MDC		6E-07	uCi/kg							
Lab ID: LCS-38681		Laboratory Control Sample				Run: ALPHANALYST_130819A				08/27/13 09:12
Thorium 230		1.6E-05	uCi/kg		84	80	120			
Method: E908.0										Batch: R178018
Lab ID: C13060954-006AMS		Sample Matrix Spike				Run: ALPHANALYST_130819C				09/06/13 12:33
Thorium 230		0.00011	uCi/kg		103	70	130			
Lab ID: C13060954-006AMSD		Sample Matrix Spike Duplicate				Run: ALPHANALYST_130819C				09/06/13 12:34
Thorium 230		0.00010	uCi/kg		96	70	130	7.4	33.5	
Lab ID: MB-38681	3	Method Blank				Run: ALPHANALYST_130819C				09/06/13 12:34
Thorium 230		2E-07	uCi/kg							U
Thorium 230 precision (±)		1E-07	uCi/kg							
Thorium 230 MDC		2E-07	uCi/kg							
Lab ID: LCS-38681		Laboratory Control Sample				Run: ALPHANALYST_130819C				09/06/13 12:34
Thorium 230		2.0E-05	uCi/kg		103	80	120			

Qualifiers:

RL - Analyte reporting limit.
MDC - Minimum detectable concentration
ND - Not detected at the reporting limit.
U - Not detected at minimum detectable concentration

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 09/17/13
Work Order: C13060954

Client: Crow Butte Resources
Project: Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E909.0										Batch: T_19228
Lab ID: LCS-19228		Laboratory Control Sample				Run: SUB-T52216				08/04/13 18:31
Lead 210		0.00048	uCi/kg		92	80	120			
Lab ID: MB-19228	3	Method Blank				Run: SUB-T52216				08/04/13 19:41
Lead 210		5E-06	uCi/kg							U
Lead 210 precision (±)		1E-05	uCi/kg							
Lead 210 MDC		2E-05	uCi/kg							
Lab ID: C13060954-001AMS		Sample Matrix Spike				Run: SUB-T52216				08/04/13 21:59
Lead 210		0.00047	uCi/kg		90	70	130			
Lab ID: C13060954-001AMSD		Sample Matrix Spike Duplicate				Run: SUB-T52216				08/04/13 23:09
Lead 210		0.00048	uCi/kg		94	70	130	1.3	15.6	
Method: E909.0										Batch: T_19256
Lab ID: LCS-19256		Laboratory Control Sample				Run: SUB-T52308				08/10/13 06:18
Lead 210		0.00097	uCi/kg		86	80	120			
Lab ID: MB-19256	3	Method Blank				Run: SUB-T52308				08/10/13 07:27
Lead 210		1E-05	uCi/kg							U
Lead 210 precision (±)		4E-05	uCi/kg							
Lead 210 MDC		7E-05	uCi/kg							
Lab ID: C13060954-002AMS		Sample Matrix Spike				Run: SUB-T52308				08/10/13 09:46
Lead 210		0.00022	uCi/kg		90	70	130			
Lab ID: C13060954-002AMSD		Sample Matrix Spike Duplicate				Run: SUB-T52308				08/10/13 10:55
Lead 210		0.00020	uCi/kg		70	70	130	8.7	18	
Method: E909.0										Batch: T_19369
Lab ID: LCS-19369		Laboratory Control Sample				Run: SUB-T52581				08/25/13 15:02
Lead 210		0.00044	uCi/kg		98	80	120			
Lab ID: MB-19369	3	Method Blank				Run: SUB-T52581				08/25/13 16:55
Lead 210		-1E-06	uCi/kg							U
Lead 210 precision (±)		1E-05	uCi/kg							
Lead 210 MDC		2E-05	uCi/kg							
Lab ID: C13060954-003AMS		Sample Matrix Spike				Run: SUB-T52581				08/25/13 20:41
Lead 210		0.00014	uCi/kg		106	70	130			
Lab ID: C13060954-003AMSD		Sample Matrix Spike Duplicate				Run: SUB-T52581				08/25/13 22:34
Lead 210		0.00015	uCi/kg		116	70	130	8.2	17.6	

Qualifiers:

RL - Analyte reporting limit.
MDC - Minimum detectable concentration
ND - Not detected at the reporting limit.
U - Not detected at minimum detectable concentration

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 09/17/13
Work Order: C13060954

Client: Crow Butte Resources
Project: Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: **E909.0**										Batch: T_19411
Lab ID: **LCS-19411**		Laboratory Control Sample				Run: SUB-T52648				08/30/13 02:47
Lead 210		0.00049	uCi/kg		94	80	120			
Lab ID: **MB-19411**	3	Method Blank				Run: SUB-T52648				08/30/13 03:56
Lead 210		-3E-06	uCi/kg							U
Lead 210 precision (±)		2E-05	uCi/kg							
Lead 210 MDC		3E-05	uCi/kg							
Lab ID: **C13060954-006AMS**		Sample Matrix Spike				Run: SUB-T52648				08/30/13 07:24
Lead 210		7.1E-05	uCi/kg		92	70	130			
Lab ID: **C13060954-006AMSD**		Sample Matrix Spike Duplicate				Run: SUB-T52648				08/30/13 08:34
Lead 210		7.5E-05	uCi/kg		104	70	130	6.6	19	

Qualifiers:

RL - Analyte reporting limit.
MDC - Minimum detectable concentration
ND - Not detected at the reporting limit.
U - Not detected at minimum detectable concentration

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 09/17/13
Work Order: C13060954

Client: Crow Butte Resources
Project: Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: SW6020									Analytical Run: ICPMS2-C_130808B	
Lab ID: ICV		Initial Calibration Verification Standard							08/08/13 08:28	
Uranium		0.0519	mg/L	0.00030	104	90	110			
Lab ID: ICSA		Interference Check Sample A							08/08/13 08:30	
Uranium		1.38E-05	mg/L	0.00030						
Lab ID: ICSAB		Interference Check Sample AB							08/08/13 08:32	
Uranium		2.10E-06	mg/L	0.00030						
Method: SW6020									Batch: 38401	
Lab ID: MB-38401		Method Blank				Run: ICPMS2-C_130808B			08/08/13 01:37	
Uranium		9E-05	mg/kg	3E-05						
Lab ID: LCS2-38401		Laboratory Control Sample				Run: ICPMS2-C_130808B			08/08/13 01:39	
Uranium		0.054	mg/kg	0.00030	109	70	130			
Lab ID: C13060954-001ADIL		Serial Dilution				Run: ICPMS2-C_130808B			08/08/13 01:44	
Uranium		0.019	mg/kg	0.022					20	N
Lab ID: C13060954-001AMS		Sample Matrix Spike				Run: ICPMS2-C_130808B			08/08/13 01:46	
Uranium		0.84	mg/kg	0.0044	167	75	125			S
Lab ID: C13060954-001AMSD		Sample Matrix Spike Duplicate				Run: ICPMS2-C_130808B			08/08/13 01:47	
Uranium		0.85	mg/kg	0.0044	169	75	125	0.8	20	S
Method: SW6020									Batch: 38491	
Lab ID: MB-38491		Method Blank				Run: ICPMS2-C_130808B			08/08/13 01:18	
Uranium		6E-05	mg/kg	3E-05						
Lab ID: LCS2-38491		Laboratory Control Sample				Run: ICPMS2-C_130808B			08/08/13 01:19	
Uranium		0.046	mg/kg	0.00030	93	70	130			
Lab ID: C13060954-002ADIL		Serial Dilution				Run: ICPMS2-C_130808B			08/08/13 01:24	
Uranium		0.014	mg/kg	0.024					20	N
Lab ID: C13060954-002AMS		Sample Matrix Spike				Run: ICPMS2-C_130808B			08/08/13 01:26	
Uranium		0.98	mg/kg	0.0048	91	75	125			
Lab ID: C13060954-002AMSD		Sample Matrix Spike Duplicate				Run: ICPMS2-C_130808B			08/08/13 01:34	
Uranium		0.95	mg/kg	0.0048	88	75	125	2.5	20	

Qualifiers:

RL - Analyte reporting limit.
MDC - Minimum detectable concentration

S - Spike recovery outside of advisory limits.

ND - Not detected at the reporting limit.
N - The analyte concentration was not sufficiently high to calculate a RPD for the serial dilution test.

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 09/17/13
Work Order: C13060954

Client: Crow Butte Resources
Project: Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: SW6020									Analytical Run: ICPMS2-C_130809A	
Lab ID: ICV		Initial Calibration Verification Standard							08/09/13 15:08	
Uranium		0.0512	mg/L	0.00030	102	90	110			
Lab ID: ICSA		Interference Check Sample A							08/09/13 15:12	
Uranium		8.90E-06	mg/L	0.00030						
Lab ID: ICSAB		Interference Check Sample AB							08/09/13 15:15	
Uranium		1.90E-06	mg/L	0.00030						
Method: SW6020									Batch: 38587	
Lab ID: MB-38587		Method Blank				Run: ICPMS2-C_130809A			08/10/13 04:36	
Uranium		ND	mg/kg	3E-05						
Lab ID: LCS2-38587		Laboratory Control Sample				Run: ICPMS2-C_130809A			08/10/13 04:39	
Uranium		0.052	mg/kg	0.00030	105	70	130			
Lab ID: C13060954-003ADIL		Serial Dilution				Run: ICPMS2-C_130809A			08/10/13 04:49	
Uranium		0.018	mg/kg	0.014				20		N
Lab ID: C13060954-004AMS		Sample Matrix Spike				Run: ICPMS2-C_130809A			08/10/13 04:55	
Uranium		0.62	mg/kg	0.0031		75	125			A
Lab ID: C13060954-004AMSD		Sample Matrix Spike Duplicate				Run: ICPMS2-C_130809A			08/10/13 04:58	
Uranium		0.00081	mg/kg	0.0031		75	125	20		A

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

A - The analyte level was greater than four times the spike level. In accordance with the method % recovery is not calculated.

MDC - Minimum detectable concentration

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 09/17/13
Work Order: C13060954

Client: Crow Butte Resources
Project: Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: SW6020									Analytical Run: ICPMS2-C_130821A	
Lab ID: ICV		Initial Calibration Verification Standard							08/21/13 12:52	
Uranium		0.0509	mg/L	0.00030	102	90	110			
Lab ID: ICSA		Interference Check Sample A							08/21/13 12:55	
Uranium		1.01E-05	mg/L	0.00030						
Lab ID: ICSAB		Interference Check Sample AB							08/21/13 12:59	
Uranium		1.50E-06	mg/L	0.00030						
Method: SW6020									Batch: 38681	
Lab ID: MB-38681		Method Blank				Run: ICPMS2-C_130821A			08/22/13 00:00	
Uranium		0.0003	mg/kg	3E-05						
Lab ID: LCS2-38681		Laboratory Control Sample				Run: ICPMS2-C_130821A			08/22/13 00:04	
Uranium		0.050	mg/kg	0.00030	100	70	130			
Lab ID: C13060954-005ADIL		Serial Dilution				Run: ICPMS2-C_130821A			08/22/13 00:13	
Uranium		0.056	mg/kg	0.0073				25	20	R
Lab ID: C13060954-006AMS		Sample Matrix Spike				Run: ICPMS2-C_130821A			08/22/13 00:32	
Uranium		0.16	mg/kg	0.00072	66	75	125			S
Lab ID: C13060954-006AMSD		Sample Matrix Spike Duplicate				Run: ICPMS2-C_130821A			08/22/13 00:36	
Uranium		0.16	mg/kg	0.00072	69	75	125	4.3	20	S
Method: SW6020									Analytical Run: ICPMS2-C_130910A	
Lab ID: ICV		Initial Calibration Verification Standard							09/10/13 14:05	
Uranium		0.0514	mg/L	0.00030	103	90	110			
Lab ID: ICSA		Interference Check Sample A							09/10/13 14:08	
Uranium		1.43E-05	mg/L	0.00030						
Lab ID: ICSAB		Interference Check Sample AB							09/10/13 14:11	
Uranium		2.70E-06	mg/L	0.00030						
Method: SW6020									Batch: 38587	
Lab ID: MB-38587		Method Blank				Run: ICPMS2-C_130910A			09/11/13 03:36	
Uranium		ND	mg/kg	3E-05						
Lab ID: LCS2-38587		Laboratory Control Sample				Run: ICPMS2-C_130910A			09/11/13 03:39	
Uranium		0.051	mg/kg	0.00030	104	70	130			
Lab ID: C13060954-003AMS		Sample Matrix Spike				Run: ICPMS2-C_130910A			09/11/13 03:52	
Uranium		0.61	mg/kg	0.0028	128	75	125			S
Lab ID: C13060954-003AMSD		Sample Matrix Spike Duplicate				Run: ICPMS2-C_130910A			09/11/13 03:55	
Uranium		0.61	mg/kg	0.0028	130	75	125	1.5	20	S

Qualifiers:

RL - Analyte reporting limit.
MDC - Minimum detectable concentration
S - Spike recovery outside of advisory limits.
ND - Not detected at the reporting limit.
R - RPD exceeds advisory limit.

Work Order Receipt Checklist

Crow Butte Resources

C13060954

Login completed by: Tessa Parke
Date Received: 6/26/2013
Reviewed by: BL2000\kmiller
Received by: dw
Reviewed Date: 6/27/2013
Carrier name: Hand Del

Shipping container/cooler in good condition?	Yes ☑	No ☐	Not Present ☐
Custody seals intact on all shipping container(s)/cooler(s)?	Yes ☐	No ☐	Not Present ☑
Custody seals intact on all sample bottles?	Yes ☐	No ☐	Not Present ☑
Chain of custody present?	Yes ☑	No ☐	
Chain of custody signed when relinquished and received?	Yes ☑	No ☐	
Chain of custody agrees with sample labels?	Yes ☑	No ☐	
Samples in proper container/bottle?	Yes ☑	No ☐	
Sample containers intact?	Yes ☑	No ☐	
Sufficient sample volume for indicated test?	Yes ☑	No ☐	
All samples received within holding time? (Exclude analyses that are considered field parameters such as pH, DO, Res Cl, Sulfite, Ferrous Iron, etc.)	Yes ☑	No ☐	
Temp Blank received in all shipping container(s)/cooler(s)?	Yes ☐	No ☐	Not Applicable ☑
Container/Temp Blank temperature:	N/A°C		
Water - VOA vials have zero headspace?	Yes ☐	No ☐	No VOA vials submitted ☑
Water - pH acceptable upon receipt?	Yes ☐	No ☐	Not Applicable ☑

Standard Reporting Procedures:

Lab measurement of analytes considered field parameters that require analysis within 15 minutes of sampling such as pH, Dissolved Oxygen and Residual Chlorine, are qualified as being analyzed outside of recommended holding time.

Solid/soil samples are reported on a wet weight basis (as received) unless specifically indicated. If moisture corrected, data units are typically noted as –dry. For agricultural and mining soil parameters/characteristics, all samples are dried and ground prior to sample analysis.

Contact and Corrective Action Comments:

None

Chain of Custody and Analytical Request Record

PLEASE PRINT- Provide as much information as possible.

Company Name: Crow Butte Resources, Inc.	Project Name, Vegetation Baseline Sampling, Marsland	Sample Origin State: NE	EPA/State Compliance: Yes x☐ No ☐
Report Mail Address: P.O. Box 169 Crawford, NE 69339	Contact Name: Larry Teahon Phone/Fax: 308-665-2341	Email: daxmynus@msn.com	Sampler: (Please Print) Brooke Bass
Invoice Address: P.O. Box 169 Crawford, NE 69339	Invoice Contact & Phone: Larry Teahon 308-665-2215 ext 114	Purchase Order: 1125	Quote/Bottle Order:

Special Report/Formats – ELI must be notified prior to sample submittal for the following:

☐ DW ☐ A2LA
☐ GSA ☐ EDD/EDT (Electronic Data)
☐ POTW/WWTP Format: _____
☐ State: _____ ☐ LEVEL IV
☐ Other: _____ ☐ NELAC

Number of Containers
Sample Type: A W S V B O
Air Water Soils/Solids Vegetation Bioassay Other

ANALYSIS REQUESTED

SEE ATTACHED

Normal Turnaround (TAT)

RUSH

Contact ELI prior to RUSH sample submittal for charges and scheduling – See Instruction Page

Comments: Analyze and report as per Reg Guide 4.14 standards.

Shipped by: Hand

Cooler ID(s):

Receipt Temp: NA °C

On Ice: Yes No

Custody Seal Y N
Intact Y N
Signature Match Y N

	SAMPLE IDENTIFICATION (Name, Location, Interval, etc.)	Collection Date	Collection Time	MATRIX	Th230, Pb210, Ra226, Po210, U-nat
1	Three Crow west site	6/26/13		V	X
2	Three Crow middle site	6/26/13		V	X
3	Three Crow east site	6/26/13		V	X
4					
5					
6					

LABORATORY USE ONLY

C1306 0951

Custody Record MUST be Signed

Relinquished by (print): Walt Nelson	Date/Time: 6/26/13 3:19pm	Signature:
Relinquished by (print):	Date/Time:	Signature:
Sample Disposal: Return to Client: No	Lab Disposal: YES	

Received by (print):	Date/Time:	Signature:
Received by (print):	Date/Time:	Signature:
Received by Laboratory:	Date/Time: 6-26-13	Signature: 1510

In certain circumstances, samples submitted to Energy Laboratories, Inc. may be subcontracted to other certified laboratories in order to complete the analysis requested. This serves as notice of this possibility. All sub-contract data will be clearly notated on your analytical report.

Chain of Custody and Analytical Request Record

PLEASE PRINT- Provide as much information as possible.

Company Name: Crow Butte Resources, Inc.	Project Name, Vegetation Baseline Sampling, Marsland	Sample Origin State: NE	EPA/State Compliance: Yes x☐ No ☐
Report Mail Address: P.O. Box 169 Crawford, NE 69339	Contact Name: Larry Teahon Phone/Fax: 308-665-2341	Email: daxmynus@msn.com	Sampler: (Please Print) Brooke Bass
Invoice Address: P.O. Box 169 Crawford, NE 69339	Invoice Contact & Phone: Larry Teahon 308-665-2215 ext 114	Purchase Order: 1125	Quote/Bottle Order:

Special Report/Formats – ELI must be notified prior to sample submittal for the following:

☐ DW ☐ GSA ☐ POTW/WWTP ☐ State: _____ ☐ Other: _____
☐ A2LA ☐ EDD/EDT(Electronic Data) Format:_____ ☐ LEVEL IV ☐ NELAC

RUSH — Contact ELI prior to RUSH sample submittal for charges and scheduling – See Instruction Page

Comments: Analyze and report as per Reg Guide 4.14 standards.

Shipped by:

Cooler ID(s):

Receipt Temp _____ °C

On Ice: Yes No

Custody Seal Intact Y N

Signature Match Y N

	SAMPLE IDENTIFICATION (Name, Location, Interval, etc.)	Collection Date	Collection Time	MATRIX (Number of Containers; Sample Type: A W S V B O; Air Water Soils/Solids Vegetation Bioassay Other)	ANALYSIS REQUESTED: Th230, Pb210, Ra226, Po210, U-nat	SEE ATTACHED	Normal Turnaround (TAT)
1	Marsland west site	6/26/13		V	X		
2	Marsland middle site	6/26/13		V	X		
3	Marsland east site	6/26/13		V	X		
4							
5							
6							

LABORATORY USE ONLY

C13060954

Custody Record MUST be Signed

Relinquished by (print): Walter D. Wilson	Date/Time: 6/26/13 3:40pm	Signature: Walter D. Wilson	Received by (print): / Date/Time: / Signature:
Relinquished by (print):	Date/Time:	Signature:	Received by (print): / Date/Time: / Signature:
Sample Disposal: Return to Client: No	Lab Disposal: YES		Received by Laboratory: C. Williams 6-26-13 1510

In certain circumstances, samples submitted to Energy Laboratories, Inc. may be subcontracted to other certified laboratories in order to complete the analysis requested. This serves as notice of this possibility. All sub-contract data will be clearly notated on your analytical report.

ANALYTICAL SUMMARY REPORT

April 12, 2017

Crow Butte Resources
86 Crow Butte Rd
Crawford, NE 69339

Work Order: C13070769

Project Name: Marsland Vegetation Baseline Sampling

Energy Laboratories, Inc. Casper WY received the following 3 samples for Crow Butte Resources on 7/19/2013 for analysis.

Lab ID	Client Sample ID	Collect Date	Receive Date	Matrix	Test
C13070769-001	Marsland West Site	07/19/13 0:00	07/19/13	Vegetation	Uranium, Total Digestion, Radiochemistry Lead 210 Polonium 210 Radium 226 Thorium, Isotopic
C13070769-002	Marsland Middle Site	07/19/13 0:00	07/19/13	Vegetation	Same As Above
C13070769-003	Marsland East Site	07/19/13 0:00	07/19/13	Vegetation	Same As Above

The results as reported relate only to the item(s) submitted for testing. The analyses presented in this report were performed at Energy Laboratories, Inc., 2393 Salt Creek Hwy., Casper, WY 82601, unless otherwise noted. Any exceptions or problems with the analyses are noted in the Laboratory Analytical Report, the QA/QC Summary Report, or the Case Narrative.

If you have any questions regarding these test results, please call.

Report Approved By:

Randy Horton, Project Manager

Digitally signed by
Randy Horton
Date: 2017.04.12 16:01:00 -06:00

CLIENT: Crow Butte Resources
Project: Marsland Vegetation Baseline Sampling
Work Order: C13070769

Revised Date: 04/12/17
Report Date: 10/17/13

CASE NARRATIVE

REVISED/SUPPLEMENTAL REPORT 3
The attached analytical report has been revised from a previously submitted report due to the request by Larry Teahon on 3-27-17 for the addition of RLs on all samples. The data presented here is from that addition. The report has been revised and replaces any previously issued report in its entirety.

REVISED/SUPPLEMENTAL REPORT 2
The attached analytical report has been revised from a previously submitted report due to the request by Larry Teahon on 11-15-2016 for the re-report of specified analyses that were reported as ND or less than detection limit.with actual responses for samples Marsland West Site (001), Marsland Middle Site (002) and Marsland East Site (003). The data presented here is from that request. The report has been revised and replaces any previously issued report in its entirety.

REVISED/SUPPLEMENTAL REPORT 1
The attached analytical report has been revised from a previously submitted report due to the request by Walter Nelson on October 16, 2014 for the reporting format for Ra226 results on sample -003. The data presented here is from that correction. The report has been revised and replaces any previously issued report in its entirety.

BRANCH LABORATORY SUBCONTRACT ANALYSIS
Tests associated with analyst identified as ELI-CS were subcontracted to Energy Laboratories, 415 Graham Rd., College Station, TX, EPA Number TX01520.

pH COMMENTS
Per NELAC rule, pH is considered a field parameter with a holding time of 15 minutes. Due to this rule, all pH analyses will be flagged with an H.

RADIOCHEMISTRY ANALYSIS
Per client request, results less than MDC (or precision if no MDC), are reported as <MDC (or <precision). Actual instrument results are available by request.

ORIGINAL SAMPLE SUBMITTAL(S)
All original sample submittals have been returned with the data package.

SAMPLE TEMPERATURE COMPLIANCE: 4°C (±2°C)
Temperature of samples received may not be considered properly preserved by accepted standards. Samples that are hand delivered immediately after collection shall be considered acceptable if there is evidence that the chilling process has begun.

GROSS ALPHA ANALYSIS
Method 900.0 for gross alpha and gross beta is intended as a drinking water method for low TDS waters. Data provided by this method for non potable waters should be viewed as inconsistent.

SOIL/SOLID SAMPLES
All samples reported on an as received basis unless otherwise indicated.

SUBCONTRACTING ANALYSIS
Subcontracting of sample analyses to an outside laboratory may be required. If so, ENERGY LABORATORIES will utilize its branch laboratories or qualified contract laboratories for this service. Any such laboratories will be indicated within the Laboratory Analytical Report.

BRANCH LABORATORY LOCATIONS
eli-b - Energy Laboratories, Inc. - Billings, MT
eli-g - Energy Laboratories, Inc. - Gillette, WY
eli-h - Energy Laboratories, Inc. - Helena, MT
eli-r - Energy Laboratories, Inc. - Rapid City, SD
eli-cs - Energy Laboratories, Inc. - College Station, TX

CERTFICATIONS:
USEPA: WY00002, Radiochemical WY00937; FL-DOH NELAC: E87641, Radiochemical E871017; California: 02118CA; Oregon: WY200001, Radiochemical WY200002; Utah: WY00002; Virginia: 00057; Washington: C836

ISO 17025 DISCLAIMER:
The results of this Analytical Report relate only to the items submitted for analysis.

ENERGY LABORATORIES, INC. - CASPER,WY certifies that certain method selections contained in this report meet

CLIENT: Crow Butte Resources
Project: Marsland Vegetation Baseline Sampling
Work Order: C13070769

Revised Date: 04/12/17
Report Date: 10/17/13

CASE NARRATIVE

requirements as set forth by the above accrediting authorities. Some results requested by the client may not be covered under these certifications. All analysis data to be submitted for regulatory enforcement should be certified in the sample state of origin. Please verify ELI's certification coverage by visiting www.energylab.com

ELI appreciates the opportunity to provide you with this analytical service. For additional information and services visit our web page www.energylab.com.

LABORATORY ANALYTICAL REPORT

Prepared by Casper, WY Branch

Client: Crow Butte Resources
Project: Marsland Vegetation Baseline Sampling
Lab ID: C13070769-001
Client Sample ID: Marsland West Site

Revised Date: 04/12/17
Report Date: 10/17/13
Collection Date: 07/19/13
DateReceived: 07/19/13
Matrix: Vegetation

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
RADIONUCLIDES							
Lead 210	1.0E-04	uCi/kg		8.2E-06		E909.0	10/02/13 04:39 / eli-cs
Lead 210 precision (±)	8.0E-06	uCi/kg				E909.0	10/02/13 04:39 / eli-cs
Lead 210 MDC	8.2E-06	uCi/kg				E909.0	10/02/13 04:39 / eli-cs
Polonium 210	2.9E-05	uCi/kg		2.5E-06		E912.0	10/09/13 12:51 / dmf
Polonium 210 precision (±)	7.0E-06	uCi/kg				E912.0	10/09/13 12:51 / dmf
Polonium 210 MDC	2.5E-06	uCi/kg				E912.0	10/09/13 12:51 / dmf
Radium 226	2.7E-06	uCi/kg		1.7E-07		E903.0	10/01/13 08:17 / trs
Radium 226 precision (±)	3.0E-07	uCi/kg				E903.0	10/01/13 08:17 / trs
Radium 226 MDC	1.7E-07	uCi/kg				E903.0	10/01/13 08:17 / trs
Thorium 230	3.6E-06	uCi/kg		1.8E-06		E908.0	10/02/13 08:54 / dmf
Thorium 230 precision (±)	1.6E-06	uCi/kg				E908.0	10/02/13 08:54 / dmf
Thorium 230 MDC	1.8E-06	uCi/kg				E908.0	10/02/13 08:54 / dmf
Uranium	0.0093	mg/kg	D	0.00073		SW6020	09/19/13 02:22 / clm
Uranium, Activity	6.3E-06	uCi/kg	D	4.9E-07		SW6020	09/19/13 02:22 / clm

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MDC - Minimum detectable concentration
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
D - RL increased due to sample matrix.

LABORATORY ANALYTICAL REPORT

Prepared by Casper, WY Branch

Client: Crow Butte Resources
Project: Marsland Vegetation Baseline Sampling
Lab ID: C13070769-002
Client Sample ID: Marsland Middle Site

Revised Date: 04/12/17
Report Date: 10/17/13
Collection Date: 07/19/13
DateReceived: 07/19/13
Matrix: Vegetation

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
RADIONUCLIDES							
Lead 210	1.1E-05	uCi/kg		4.5E-06		E909.0	10/02/13 08:08 / eli-cs
Lead 210 precision (±)	3.1E-06	uCi/kg				E909.0	10/02/13 08:08 / eli-cs
Lead 210 MDC	4.5E-06	uCi/kg				E909.0	10/02/13 08:08 / eli-cs
Polonium 210	2.1E-06	uCi/kg		1.2E-06		E912.0	10/09/13 12:51 / dmf
Polonium 210 precision (±)	1.4E-06	uCi/kg				E912.0	10/09/13 12:51 / dmf
Polonium 210 MDC	1.2E-06	uCi/kg				E912.0	10/09/13 12:51 / dmf
Radium 226	4.0E-07	uCi/kg		8.0E-08		E903.0	10/01/13 08:17 / trs
Radium 226 precision (±)	8.9E-08	uCi/kg				E903.0	10/01/13 08:17 / trs
Radium 226 MDC	8.0E-08	uCi/kg				E903.0	10/01/13 08:17 / trs
Thorium 230	9.3E-07	uCi/kg		7.2E-07		E908.0	10/02/13 08:54 / dmf
Thorium 230 precision (±)	5.7E-07	uCi/kg				E908.0	10/02/13 08:54 / dmf
Thorium 230 MDC	7.2E-07	uCi/kg				E908.0	10/02/13 08:54 / dmf
Uranium	0.0023	mg/kg	D	0.00040		SW6020	09/19/13 02:41 / clm
Uranium, Activity	1.6E-06	uCi/kg	D	2.7E-07		SW6020	09/19/13 02:41 / clm

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MDC - Minimum detectable concentration
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
D - RL increased due to sample matrix.

LABORATORY ANALYTICAL REPORT

Prepared by Casper, WY Branch

Client: Crow Butte Resources
Project: Marsland Vegetation Baseline Sampling
Lab ID: C13070769-003
Client Sample ID: Marsland East Site

Revised Date: 04/12/17
Report Date: 10/17/13
Collection Date: 07/19/13
DateReceived: 07/19/13
Matrix: Vegetation

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
RADIONUCLIDES							
Lead 210	2.7E-05	uCi/kg		2.4E-06		E909.0	10/14/13 20:12 / eli-cs
Lead 210 precision (±)	2.2E-06	uCi/kg				E909.0	10/14/13 20:12 / eli-cs
Lead 210 MDC	2.4E-06	uCi/kg				E909.0	10/14/13 20:12 / eli-cs
Polonium 210	3.4E-06	uCi/kg		1.3E-06		E912.0	10/07/13 12:22 / dmf
Polonium 210 precision (±)	1.7E-06	uCi/kg				E912.0	10/07/13 12:22 / dmf
Polonium 210 MDC	1.3E-06	uCi/kg				E912.0	10/07/13 12:22 / dmf
Radium 226	-3.1E-08	uCi/kg	U	2.4E-08		E903.0	10/11/13 01:38 / trs
Radium 226 precision (±)	1.2E-08	uCi/kg				E903.0	10/11/13 01:38 / trs
Radium 226 MDC	2.4E-08	uCi/kg				E903.0	10/11/13 01:38 / trs
Thorium 230	2.3E-06	uCi/kg		1.5E-06		E908.0	10/08/13 09:07 / dmf
Thorium 230 precision (±)	1.2E-06	uCi/kg				E908.0	10/08/13 09:07 / dmf
Thorium 230 MDC	1.5E-06	uCi/kg				E908.0	10/08/13 09:07 / dmf
Uranium	0.0021	mg/kg		0.00030		SW6020	10/03/13 22:07 / clm
Uranium, Activity	1.4E-06	uCi/kg		2.0E-07		SW6020	10/03/13 22:07 / clm

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MDC - Minimum detectable concentration
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.
U - Not detected at minimum detectable concentration

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 10/17/13
Work Order: C13070769

Client: Crow Butte Resources
Project: Marsland Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E903.0										Batch: 39034
Lab ID: C13070769-001ADUP	3	Sample Duplicate				Run: BERTHOLD 770-1_130925A				10/01/13 08:17
Radium 226		2.6E-06	uCi/kg					5.0	31.8	
Radium 226 precision (±)		2.8E-07	uCi/kg							
Radium 226 MDC		1.5E-07	uCi/kg							
Lab ID: C13070769-002AMS		Sample Matrix Spike				Run: BERTHOLD 770-1_130925A				10/01/13 08:17
Radium 226		1.5E-05	uCi/kg		103	70	130			
Lab ID: LCS-39034		Laboratory Control Sample				Run: BERTHOLD 770-1_130925A				10/01/13 08:17
Radium 226		2.7E-05	uCi/kg		117	80	120			
Lab ID: MB-39034	3	Method Blank				Run: BERTHOLD 770-1_130925A				10/01/13 08:17
Radium 226		2E-07	uCi/kg							U
Radium 226 precision (±)		2E-07	uCi/kg							
Radium 226 MDC		3E-07	uCi/kg							
Method: E903.0										Batch: 39214
Lab ID: C13080395-001ADUP	3	Sample Duplicate				Run: BERTHOLD 770-1_131002B				10/11/13 01:38
Radium 226		1.3E-05	uCi/kg					4.7	12.6	
Radium 226 precision (±)		1.6E-07	uCi/kg							
Radium 226 MDC		2.8E-08	uCi/kg							
Lab ID: C13080395-002AMS		Sample Matrix Spike				Run: BERTHOLD 770-1_131002B				10/11/13 01:38
Radium 226		9.3E-06	uCi/kg		80	70	130			
Lab ID: LCS-39214		Laboratory Control Sample				Run: BERTHOLD 770-1_131002B				10/11/13 01:38
Radium 226		2.7E-05	uCi/kg		119	80	120			
Lab ID: MB-39214	3	Method Blank				Run: BERTHOLD 770-1_131002B				10/11/13 01:38
Radium 226		-1E-07	uCi/kg							U
Radium 226 precision (±)		1E-07	uCi/kg							
Radium 226 MDC		1E-07	uCi/kg							

Qualifiers:

RL - Analyte reporting limit.
MDC - Minimum detectable concentration
ND - Not detected at the reporting limit.
U - Not detected at minimum detectable concentration

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 10/17/13
Work Order: C13070769

Client: Crow Butte Resources
Project: Marsland Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E908.0										Batch: 39034
Lab ID: C13070769-001ADUP	3	Sample Duplicate				Run: ALPHANALYST_130930A				10/02/13 08:54
Thorium 230		5.2E-06	uCi/kg					36	89	
Thorium 230 precision (±)		1.9E-06	uCi/kg							
Thorium 230 MDC		1.6E-06	uCi/kg							
Lab ID: C13070769-002AMS		Sample Matrix Spike				Run: ALPHANALYST_130930A				10/02/13 08:54
Thorium 230		9.9E-05	uCi/kg		103	70	130			
Lab ID: MB-39034	3	Method Blank				Run: ALPHANALYST_130930A				10/02/13 08:54
Thorium 230		2E-07	uCi/kg							U
Thorium 230 precision (±)		1E-07	uCi/kg							
Thorium 230 MDC		2E-07	uCi/kg							
Lab ID: LCS-39034		Laboratory Control Sample				Run: ALPHANALYST_130930A				10/02/13 08:54
Thorium 230		1.9E-05	uCi/kg		98	80	120			
Method: E908.0										Batch: 39214
Lab ID: C13070769-003AMS		Sample Matrix Spike				Run: ALPHANALYST_131003A				10/08/13 09:07
Thorium 230		8.1E-05	uCi/kg		107	70	130			
Lab ID: C13070769-003AMSD		Sample Matrix Spike Duplicate				Run: ALPHANALYST_131003A				10/08/13 09:07
Thorium 230		7.7E-05	uCi/kg		102	70	130	5.0	31.3	
Lab ID: MB-39214	3	Method Blank				Run: ALPHANALYST_131003A				10/08/13 09:07
Thorium 230		1E-07	uCi/kg							U
Thorium 230 precision (±)		1E-07	uCi/kg							
Thorium 230 MDC		2E-07	uCi/kg							
Lab ID: LCS-39214		Laboratory Control Sample				Run: ALPHANALYST_131003A				10/08/13 09:07
Thorium 230		2.0E-05	uCi/kg		106	80	120			

Qualifiers:

RL - Analyte reporting limit.
MDC - Minimum detectable concentration
ND - Not detected at the reporting limit.
U - Not detected at minimum detectable concentration

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 10/17/13
Work Order: C13070769

Client: Crow Butte Resources
Project: Marsland Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E909.0										Batch: T_19549
Lab ID: LCS-19549		Laboratory Control Sample				Run: SUB-T53230				10/02/13 02:21
Lead 210		0.00050	uCi/kg		100	80	120			
Lab ID: MB-19549	3	Method Blank				Run: SUB-T53230				10/02/13 03:30
Lead 210		3E-06	uCi/kg							U
Lead 210 precision (±)		2E-05	uCi/kg							
Lead 210 MDC		3E-05	uCi/kg							
Lab ID: C13070769-001AMS		Sample Matrix Spike				Run: SUB-T53230				10/02/13 05:49
Lead 210		0.00021	uCi/kg		86	70	130			
Lab ID: C13070769-001AMSD		Sample Matrix Spike Duplicate				Run: SUB-T53230				10/02/13 06:58
Lead 210		0.00021	uCi/kg		87	70	130	1.5	19.7	
Method: E909.0										Batch: T_19682
Lab ID: LCS-19682		Laboratory Control Sample				Run: SUB-T53440				10/14/13 17:53
Lead 210		0.00045	uCi/kg		86	80	120			
Lab ID: MB-19682	3	Method Blank				Run: SUB-T53440				10/14/13 19:02
Lead 210		-9E-07	uCi/kg							U
Lead 210 precision (±)		1E-05	uCi/kg							
Lead 210 MDC		2E-05	uCi/kg							
Lab ID: C13080395-002AMS		Sample Matrix Spike				Run: SUB-T53440				10/14/13 23:40
Lead 210		0.00022	uCi/kg		87	70	130			
Lab ID: C13080395-002AMSD		Sample Matrix Spike Duplicate				Run: SUB-T53440				10/15/13 00:49
Lead 210		0.00023	uCi/kg		97	70	130	3.1	15.5	

Qualifiers:

RL - Analyte reporting limit.
MDC - Minimum detectable concentration
ND - Not detected at the reporting limit.
U - Not detected at minimum detectable concentration

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 10/17/13
Work Order: C13070769

Client: Crow Butte Resources
Project: Marsland Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: SW6020									Analytical Run: ICPMS2-C_130918A	
Lab ID: ICV		Initial Calibration Verification Standard							09/18/13 13:37	
Uranium		0.0506	mg/L	0.00030	101	90	110			
Lab ID: ICSA		Interference Check Sample A							09/18/13 13:40	
Uranium		8.40E-06	mg/L	0.00030						
Lab ID: ICSAB		Interference Check Sample AB							09/18/13 13:44	
Uranium		5.00E-07	mg/L	0.00030						
Method: SW6020									Batch: 39034	
Lab ID: MB-39034		Method Blank				Run: ICPMS2-C_130918A			09/19/13 02:12	
Uranium		3E-05	mg/kg	3E-05						
Lab ID: LCS2-39034		Laboratory Control Sample				Run: ICPMS2-C_130918A			09/19/13 02:15	
Uranium		0.026	mg/kg	0.00030	51	70	130			S
Lab ID: C13070769-001ADIL		Serial Dilution				Run: ICPMS2-C_130918A			09/19/13 02:25	
Uranium		0.0089	mg/kg	0.0036					20	N
Lab ID: C13070769-002AMS		Sample Matrix Spike				Run: ICPMS2-C_130918A			09/19/13 02:44	
Uranium		0.82	mg/kg	0.0040	122	75	125			
Lab ID: C13070769-002AMSD		Sample Matrix Spike Duplicate				Run: ICPMS2-C_130918A			09/19/13 02:47	
Uranium		0.82	mg/kg	0.0040	122	75	125	0.0	20	

Qualifiers:

RL - Analyte reporting limit.

MDC - Minimum detectable concentration

S - Spike recovery outside of advisory limits.

ND - Not detected at the reporting limit.

N - The analyte concentration was not sufficiently high to calculate a RPD for the serial dilution test.

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 10/17/13
Work Order: C13070769

Client: Crow Butte Resources
Project: Marsland Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: **SW6020**									Analytical Run: ICPMS2-C_131003A	
Lab ID: **ICV**		Initial Calibration Verification Standard							10/03/13 12:27	
Uranium		0.0509	mg/L	0.00030	102	90	110			
Lab ID: **ICSAB**		Interference Check Sample AB							10/03/13 12:30	
Uranium		1.37E-05	mg/L	0.00030						
Lab ID: **ICSA**		Interference Check Sample A							10/03/13 12:34	
Uranium		2.70E-06	mg/L	0.00030						
Method: **SW6020**									Batch: 39214	
Lab ID: **MB-39214**		Method Blank				Run: ICPMS2-C_131003A			10/03/13 21:22	
Uranium		0.0002	mg/kg	3E-05						
Lab ID: **LCS2-39214**		Laboratory Control Sample				Run: ICPMS2-C_131003A			10/03/13 21:25	
Uranium		0.035	mg/kg	0.00030	70	70	130			
Lab ID: **C13070769-003ADIL**		Serial Dilution				Run: ICPMS2-C_131003A			10/03/13 21:48	
Uranium		0.0019	mg/kg	0.0015					20	N
Lab ID: **C13080395-002AMS**		Sample Matrix Spike				Run: ICPMS2-C_131003A			10/03/13 21:58	
Uranium		0.81	mg/kg	0.0042	113	75	125			
Lab ID: **C13080395-002AMSD**		Sample Matrix Spike Duplicate				Run: ICPMS2-C_131003A			10/03/13 22:01	
Uranium		0.81	mg/kg	0.0042	113	75	125	0.3	20	

Qualifiers:

RL - Analyte reporting limit.
MDC - Minimum detectable concentration

ND - Not detected at the reporting limit.
N - The analyte concentration was not sufficiently high to calculate a RPD for the serial dilution test.

Work Order Receipt Checklist

Crow Butte Resources

C13070769

Login completed by: Kerri Schroeder
Date Received: 7/19/2013
Reviewed by: BL2000\kmiller
Received by: dw
Reviewed Date: 7/22/2013
Carrier name: Hand Del

Shipping container/cooler in good condition?	Yes ☑	No ☐	Not Present ☐
Custody seals intact on all shipping container(s)/cooler(s)?	Yes ☐	No ☐	Not Present ☑
Custody seals intact on all sample bottles?	Yes ☐	No ☐	Not Present ☑
Chain of custody present?	Yes ☑	No ☐	
Chain of custody signed when relinquished and received?	Yes ☑	No ☐	
Chain of custody agrees with sample labels?	Yes ☑	No ☐	
Samples in proper container/bottle?	Yes ☑	No ☐	
Sample containers intact?	Yes ☑	No ☐	
Sufficient sample volume for indicated test?	Yes ☑	No ☐	
All samples received within holding time? (Exclude analyses that are considered field parameters such as pH, DO, Res Cl, Sulfite, Ferrous Iron, etc.)	Yes ☑	No ☐	
Temp Blank received in all shipping container(s)/cooler(s)?	Yes ☐	No ☐	Not Applicable ☑
Container/Temp Blank temperature:	N/A°C		
Water - VOA vials have zero headspace?	Yes ☐	No ☐	No VOA vials submitted ☑
Water - pH acceptable upon receipt?	Yes ☐	No ☐	Not Applicable ☑

Standard Reporting Procedures:

Lab measurement of analytes considered field parameters that require analysis within 15 minutes of sampling such as pH, Dissolved Oxygen and Residual Chlorine, are qualified as being analyzed outside of recommended holding time.

Solid/soil samples are reported on a wet weight basis (as received) unless specifically indicated. If moisture corrected, data units are typically noted as –dry. For agricultural and mining soil parameters/characteristics, all samples are dried and ground prior to sample analysis.

Contact and Corrective Action Comments:

None

Chain of Custody and Analytical Request Record

PLEASE PRINT- Provide as much information as possible.

Company Name: Crow Butte Resources, Inc.	Project Name, Vegetation Baseline Sampling, Marsland	Sample Origin State: NE	EPA/State Compliance: Yes x☐ No ☐
Report Mail Address: P.O. Box 169 Crawford, NE 69339	Contact Name: Larry Teahon Phone/Fax: 308-665-2341	Email: daxmynus@msn.com	Sampler: (Please Print) Brooke Bass
Invoice Address: P.O. Box 169 Crawford, NE 69339	Invoice Contact & Phone: Larry Teahon 308-665-2215 ext 114	Purchase Order: 1125	Quote/Bottle Order:

Special Report/Formats – ELI must be notified prior to sample submittal for the following:

☐ DW ☐ GSA ☐ POTW/WWTP ☐ State: _____ ☐ Other: _____

☐ A2LA ☐ EDD/EDT(Electronic Data) Format:_____ ☐ LEVEL IV ☐ NELAC

Number of Containers
Sample Type: A W S V B O
Air Water Soils/Solids Vegetation Bioassay Other

ANALYSIS REQUESTED

SEE ATTACHED

Normal Turnaround (TAT)

RUSH

Contact ELI prior to RUSH sample submittal for charges and scheduling – See Instruction Page

Comments: Analyze and report as per Reg Guide 4.14 standards.

Shipped by: Hand

Cooler ID(s):

Receipt Temp °C

On Ice: Yes No

Custody Seal Y N
Intact Y N
Signature Match Y N

	SAMPLE IDENTIFICATION (Name, Location, Interval, etc.)	Collection Date	Collection Time	MATRIX	Th230, Pb210, Ra226, Po210, U-nat
1	Marsland west site	7/19/13		V	X
2	Marsland middle site	7/19/13		V	X
3	Marsland east site	7/19/13		V	X
4					
5					
6					

LABORATORY USE ONLY

C13070769

Custody Record MUST be Signed

Relinquished by (print): Rhonda Pelton	Date/Time: 7-19-13 1427	Signature: Rhonda Pelton	Received by (print):	Date/Time:	Signature:
Relinquished by (print):	Date/Time:	Signature:	Received by (print):	Date/Time:	Signature:
Sample Disposal: Return to Client: No	Lab Disposal: YES		Received by Laboratory: CW Ellis	Date/Time: 7-19-13 1427	Signature:

In certain circumstances, samples submitted to Energy Laboratories, Inc. may be subcontracted to other certified laboratories in order to complete the analysis requested. This serves as notice of this possibility. All sub-contract data will be clearly notated on your analytical report.

ENERGY LABORATORIES
Trust our People. Trust our Data.
www.energylab.com
Billings, MT 800.735.4489 • Casper, WY 888.235.0515
Gillette, WY 866.686.7175 • Helena, MT 877.472.0711

ANALYTICAL SUMMARY REPORT

April 12, 2017

Crow Butte Resources
86 Crow Butte Rd
Crawford, NE 69339

Work Order: C13090529

Project Name: Marsland Vegetation Baseline Sampling

Energy Laboratories, Inc. Casper WY received the following 3 samples for Crow Butte Resources on 9/13/2013 for analysis.

Lab ID	Client Sample ID	Collect Date	Receive Date	Matrix	Test
C13090529-001	Marsland West Site	09/13/13 10:24	09/13/13	Vegetation	Uranium, Total Percent Moisture Digestion, Total Metals Digestion, Radiochemistry Lead 210 Polonium 210 Radium 226 Thorium, Isotopic
C13090529-002	Marsland Middle Site	09/13/13 11:08	09/13/13	Vegetation	Same As Above
C13090529-003	Marsland East Site	09/13/13 11:47	09/13/13	Vegetation	Same As Above

The results as reported relate only to the item(s) submitted for testing. The analyses presented in this report were performed at Energy Laboratories, Inc., 2393 Salt Creek Hwy., Casper, WY 82601, unless otherwise noted. Any exceptions or problems with the analyses are noted in the Laboratory Analytical Report, the QA/QC Summary Report, or the Case Narrative.

If you have any questions regarding these test results, please call.

Report Approved By: Randy Horton, Project Manager

Digitally signed by
Randy Horton
Date: 2017.04.12 16:14:46 -06:00

CLIENT: Crow Butte Resources
Project: Marsland Vegetation Baseline Sampling
Work Order: C13090529

Revised Date: 04/12/17
Report Date: 01/06/14

CASE NARRATIVE

REVISED/SUPPLEMENTAL REPORT 3
The attached analytical report has been revised from a previously submitted report due to the request by Larry Teahon on 3-27-17 for the addition of RLs on all samples. The data presented here is from that addition. The report has been revised and replaces any previously issued report in its entirety.

REVISED/SUPPLEMENTAL REPORT 2
The attached analytical report has been revised from a previously submitted report due to the request by Larry Teahon on 11-15-2016 for the re-report of specified analyses that were reported as ND or less than detection limit with actual responses for samples Marsland West Site (001), Marsland Middle Site (002) and Marsland East Site (003). The data presented here is from that request. The report has been revised and replaces any previously issued report in its entirety.

REVISED/SUPPLEMENTAL REPORT
The attached analytical report has been revised from a previously submitted report due to the request by Walt Nelson on January 15, 2014 for the reanalysis of Polonium 210 on sample -003. The sample was recounted to meet the required MDC. The report has been revised and replaces any previously issued report in its entirety.

BRANCH LABORATORY SUBCONTRACT ANALYSIS
Tests associated with analyst identified as ELI-CS were subcontracted to Energy Laboratories, 415 Graham Rd., College Station, TX, EPA Number TX01520.

Ph COMMENTS
Per NELAC rule, Ph is considered a field parameter with a holding time of 15 minutes. Due to this rule, all Ph analyses will be flagged with an H.

RADIOCHEMISTRY ANALYSIS
Per client request, results less than MDC (or precision if no MDC), are reported as <MDC (or <precision). Actual instrument results are available by request.

ORIGINAL SAMPLE SUBMITTAL(S)
All original sample submittals have been returned with the data package.

SAMPLE TEMPERATURE COMPLIANCE: 4°C (±2°C)
Temperature of samples received may not be considered properly preserved by accepted standards. Samples that are hand delivered immediately after collection shall be considered acceptable if there is evidence that the chilling process has begun.

GROSS ALPHA ANALYSIS
Method 900.0 for gross alpha and gross beta is intended as a drinking water method for low TDS waters. Data provided by this method for non potable waters should be viewed as inconsistent.

SOIL/SOLID SAMPLES
All samples reported on an as received basis unless otherwise indicated.

SUBCONTRACTING ANALYSIS
Subcontracting of sample analyses to an outside laboratory may be required. If so, ENERGY LABORATORIES will utilize its branch laboratories or qualified contract laboratories for this service. Any such laboratories will be indicated within the Laboratory Analytical Report.

BRANCH LABORATORY LOCATIONS
eli-b - Energy Laboratories, Inc. - Billings, MT
eli-g - Energy Laboratories, Inc. - Gillette, WY
eli-h - Energy Laboratories, Inc. - Helena, MT
eli-r - Energy Laboratories, Inc. - Rapid City, SD
eli-cs - Energy Laboratories, Inc. - College Station, TX

CERTFICATIONS:
USEPA: WY00002, Radiochemical WY00937; FL-DOH NELAC: E87641, Radiochemical E871017; California: 02118CA; Oregon: WY200001, Radiochemical WY200002; Utah: WY00002; Virginia: 00057; Washington: C836

ISO 17025 DISCLAIMER:
The results of this Analytical Report relate only to the items submitted for analysis.

ENERGY LABORATORIES, INC. - CASPER,WY certifies that certain method selections contained in this report meet

CLIENT: Crow Butte Resources
Project: Marsland Vegetation Baseline Sampling
Work Order: C13090529

Revised Date: 04/12/17
Report Date: 01/06/14

CASE NARRATIVE

requirements as set forth by the above accrediting authorities. Some results requested by the client may not be covered under these certifications. All analysis data to be submitted for regulatory enforcement should be certified in the sample state of origin. Please verify ELI's certification coverage by visiting www.energylab.com

ELI appreciates the opportunity to provide you with this analytical service. For additional information and services visit our web page www.energylab.com.

LABORATORY ANALYTICAL REPORT

Prepared by Casper, WY Branch

Client: Crow Butte Resources
Project: Marsland Vegetation Baseline Sampling
Lab ID: C13090529-001
Client Sample ID: Marsland West Site

Revised Date: 04/12/17
Report Date: 01/06/14
Collection Date: 09/13/13 10:24
DateReceived: 09/13/13
Matrix: Vegetation

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL CHARACTERISTICS							
Moisture	51.1	%		0.1		D2974	09/20/13 14:33 / rw
RADIONUCLIDES							
Lead 210	1.5E-04	uCi/kg		3.3E-06		E909.0	12/21/13 19:32 / eli-cs
Lead 210 precision (±)	4.6E-06	uCi/kg				E909.0	12/21/13 19:32 / eli-cs
Lead 210 MDC	3.3E-06	uCi/kg				E909.0	12/21/13 19:32 / eli-cs
Polonium 210	5.9E-05	uCi/kg		2.8E-06		E912.0	12/30/13 10:20 / dmf
Polonium 210 precision (±)	1.0E-05	uCi/kg				E912.0	12/30/13 10:20 / dmf
Polonium 210 MDC	2.8E-06	uCi/kg				E912.0	12/30/13 10:20 / dmf
Radium 226	4.7E-06	uCi/kg		3.1E-07		E903.0	12/16/13 13:26 / lmc
Radium 226 precision (±)	5.0E-07	uCi/kg				E903.0	12/16/13 13:26 / lmc
Radium 226 MDC	3.1E-07	uCi/kg				E903.0	12/16/13 13:26 / lmc
Thorium 230	9.3E-06	uCi/kg		1.6E-06		E908.0	12/19/13 14:58 / dmf
Thorium 230 precision (±)	2.4E-06	uCi/kg				E908.0	12/19/13 14:58 / dmf
Thorium 230 MDC	1.6E-06	uCi/kg				E908.0	12/19/13 14:58 / dmf
Uranium	0.08	mg/kg		0.02		SW6020	09/27/13 12:18 / cp
Uranium, Activity	5.0E-05	uCi/kg		1.0E-05		SW6020	09/27/13 12:18 / cp

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MDC - Minimum detectable concentration
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

LABORATORY ANALYTICAL REPORT

Prepared by Casper, WY Branch

Client: Crow Butte Resources
Project: Marsland Vegetation Baseline Sampling
Lab ID: C13090529-002
Client Sample ID: Marsland Middle Site

Revised Date: 04/12/17
Report Date: 01/06/14
Collection Date: 09/13/13 11:08
DateReceived: 09/13/13
Matrix: Vegetation

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL CHARACTERISTICS							
Moisture	63.1	%		0.1		D2974	09/20/13 14:39 / rw
RADIONUCLIDES							
Lead 210	9.8E-05	uCi/kg		2.8E-06		E909.0	12/21/13 21:48 / eli-cs
Lead 210 precision (±)	3.5E-06	uCi/kg				E909.0	12/21/13 21:48 / eli-cs
Lead 210 MDC	2.8E-06	uCi/kg				E909.0	12/21/13 21:48 / eli-cs
Polonium 210	3.5E-05	uCi/kg		2.4E-06		E912.0	12/30/13 10:20 / dmf
Polonium 210 precision (±)	6.7E-06	uCi/kg				E912.0	12/30/13 10:20 / dmf
Polonium 210 MDC	2.4E-06	uCi/kg				E912.0	12/30/13 10:20 / dmf
Radium 226	2.8E-06	uCi/kg		2.5E-07		E903.0	12/16/13 13:26 / lmc
Radium 226 precision (±)	3.6E-07	uCi/kg				E903.0	12/16/13 13:26 / lmc
Radium 226 MDC	2.5E-07	uCi/kg				E903.0	12/16/13 13:26 / lmc
Thorium 230	6.2E-06	uCi/kg		1.8E-06		E908.0	12/19/13 14:58 / dmf
Thorium 230 precision (±)	1.9E-06	uCi/kg				E908.0	12/19/13 14:58 / dmf
Thorium 230 MDC	1.8E-06	uCi/kg				E908.0	12/19/13 14:58 / dmf
Uranium	0.20	mg/kg		0.02		SW6020	09/27/13 12:22 / cp
Uranium, Activity	1.3E-04	uCi/kg		1.0E-05		SW6020	09/27/13 12:22 / cp

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MDC - Minimum detectable concentration
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

LABORATORY ANALYTICAL REPORT

Prepared by Casper, WY Branch

Client: Crow Butte Resources
Project: Marsland Vegetation Baseline Sampling
Lab ID: C13090529-003
Client Sample ID: Marsland East Site

Revised Date: 04/12/17
Report Date: 01/06/14
Collection Date: 09/13/13 11:47
DateReceived: 09/13/13
Matrix: Vegetation

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL CHARACTERISTICS							
Moisture	53.9	%		0.1		D2974	09/20/13 14:45 / rw
RADIONUCLIDES							
Lead 210	7.5E-05	uCi/kg		2.5E-06		E909.0	12/22/13 09:03 / eli-cs
Lead 210 precision (±)	3.0E-06	uCi/kg				E909.0	12/22/13 09:03 / eli-cs
Lead 210 MDC	2.5E-06	uCi/kg				E909.0	12/22/13 09:03 / eli-cs
Polonium 210	1.4E-05	uCi/kg		2.1E-06		E912.0	01/22/14 09:08 / plj
Polonium 210 precision (±)	3.9E-06	uCi/kg				E912.0	01/22/14 09:08 / plj
Polonium 210 MDC	2.1E-06	uCi/kg				E912.0	01/22/14 09:08 / plj
Radium 226	2.6E-06	uCi/kg		1.8E-07		E903.0	12/30/13 11:35 / lmc
Radium 226 precision (±)	2.9E-07	uCi/kg				E903.0	12/30/13 11:35 / lmc
Radium 226 MDC	1.8E-07	uCi/kg				E903.0	12/30/13 11:35 / lmc
Thorium 230	3.1E-06	uCi/kg		1.1E-06		E908.0	12/20/13 14:56 / dmf
Thorium 230 precision (±)	1.2E-06	uCi/kg				E908.0	12/20/13 14:56 / dmf
Thorium 230 MDC	1.1E-06	uCi/kg				E908.0	12/20/13 14:56 / dmf
Uranium	0.16	mg/kg		0.02		SW6020	09/27/13 12:27 / cp
Uranium, Activity	1.1E-04	uCi/kg		1.0E-05		SW6020	09/27/13 12:27 / cp

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
MDC - Minimum detectable concentration
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 01/06/14
Work Order: C13090529

Client: Crow Butte Resources
Project: Marsland Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E903.0										Batch: 40051
Lab ID: C13090529-003AMS		Sample Matrix Spike				Run: BERTHOLD 770-1_131220A				12/30/13 11:35
Radium 226		2.1E-05	uCi/kg		95	70	130			
Lab ID: C13090529-003AMSD		Sample Matrix Spike Duplicate				Run: BERTHOLD 770-1_131220A				12/30/13 11:35
Radium 226		2.1E-05	uCi/kg		99	70	130	3.2	17.3	
Lab ID: LCS-40051		Laboratory Control Sample				Run: BERTHOLD 770-1_131220A				12/30/13 11:35
Radium 226		2.4E-05	uCi/kg		105	80	120			
Lab ID: MB-40051	3	Method Blank				Run: BERTHOLD 770-1_131220A				12/30/13 11:35
Radium 226			uCi/kg							U
Radium 226 precision (±)		1E-07	uCi/kg							
Radium 226 MDC		2E-07	uCi/kg							
Method: E903.0										Batch: 39979
Lab ID: C13090529-002AMS		Sample Matrix Spike				Run: G542M_131211A				12/16/13 13:26
Radium 226		2.4E-05	uCi/kg		104	70	130			
Lab ID: C13090529-002AMSD		Sample Matrix Spike Duplicate				Run: G542M_131211A				12/16/13 13:26
Radium 226		2.4E-05	uCi/kg		103	70	130	1.1	18.3	
Lab ID: LCS-39979		Laboratory Control Sample				Run: G542M_131211A				12/16/13 13:26
Radium 226		2.5E-05	uCi/kg		109	80	120			
Lab ID: MB-39979	3	Method Blank				Run: G542M_131211A				12/16/13 13:26
Radium 226		2E-07	uCi/kg							U
Radium 226 precision (±)		2E-07	uCi/kg							
Radium 226 MDC		3E-07	uCi/kg							

Qualifiers:

RL - Analyte reporting limit.
MDC - Minimum detectable concentration
ND - Not detected at the reporting limit.
U - Not detected at minimum detectable concentration

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 01/06/14
Work Order: C13090529

Client: Crow Butte Resources
Project: Marsland Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E908.0										Batch: 39979
Lab ID: C13090529-002AMS		Sample Matrix Spike				Run: ALPHANALYST_131216A				12/19/13 14:58
Thorium 230		0.00018	uCi/kg		98	70	130			
Lab ID: C13090529-002AMSD		Sample Matrix Spike Duplicate				Run: ALPHANALYST_131216A				12/19/13 14:58
Thorium 230		0.00017	uCi/kg		96	70	130	2.7	26.8	
Lab ID: LCS-39979		Laboratory Control Sample				Run: ALPHANALYST_131216A				12/19/13 14:58
Thorium 230		1.8E-05	uCi/kg		94	80	120			
Lab ID: MB-39979	3	Method Blank				Run: ALPHANALYST_131216A				12/19/13 14:58
Thorium 230		2E-07	uCi/kg							
Thorium 230 precision (±)		1E-07	uCi/kg							
Thorium 230 MDC		1E-07	uCi/kg							
Method: E908.0										Batch: 40051
Lab ID: C13090529-003AMS		Sample Matrix Spike				Run: ALPHANALYST_131218B				12/20/13 14:56
Thorium 230		0.00016	uCi/kg		96	70	130			
Lab ID: C13090529-003AMSD		Sample Matrix Spike Duplicate				Run: ALPHANALYST_131218B				12/20/13 14:56
Thorium 230		0.00015	uCi/kg		92	70	130	4.7	26.7	
Lab ID: LCS-40051		Laboratory Control Sample				Run: ALPHANALYST_131218B				12/20/13 14:56
Thorium 230		2.0E-05	uCi/kg		102	80	120			
Lab ID: MB-40051	3	Method Blank				Run: ALPHANALYST_131218B				12/20/13 14:56
Thorium 230		2E-07	uCi/kg							
Thorium 230 precision (±)		1E-07	uCi/kg							
Thorium 230 MDC		2E-07	uCi/kg							

Qualifiers:

RL - Analyte reporting limit.
MDC - Minimum detectable concentration
ND - Not detected at the reporting limit.

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 01/06/14
Work Order: C13090529

Client: Crow Butte Resources
Project: Marsland Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: **E909.0**										Batch: T_20175
Lab ID: **LCS-20175**		Laboratory Control Sample				Run: SUB-T54588				12/21/13 15:02
Lead 210		0.00047	uCi/kg		86	80	120			
Lab ID: **MB-20175**	3	Method Blank				Run: SUB-T54588				12/21/13 17:17
Lead 210		1E-05	uCi/kg							U
Lead 210 precision (±)		9E-06	uCi/kg							
Lead 210 MDC		1E-05	uCi/kg							
Lab ID: **C13090529-002AMS**		Sample Matrix Spike				Run: SUB-T54588				12/22/13 00:03
Lead 210		0.00019	uCi/kg		97	70	130			
Lab ID: **C13090529-002AMSD**		Sample Matrix Spike Duplicate				Run: SUB-T54588				12/22/13 02:18
Lead 210		0.00020	uCi/kg		100	70	130	1.4	14.9	
Method: **E909.0**										Batch: T_20225
Lab ID: **LCS-20225**		Laboratory Control Sample				Run: SUB-T54588				12/22/13 04:33
Lead 210		0.00046	uCi/kg		89	80	120			
Lab ID: **MB-20225**	3	Method Blank				Run: SUB-T54588				12/22/13 06:48
Lead 210		2E-06	uCi/kg							U
Lead 210 precision (±)		9E-06	uCi/kg							
Lead 210 MDC		1E-05	uCi/kg							
Lab ID: **C13090529-003AMS**		Sample Matrix Spike				Run: SUB-T54588				12/22/13 11:18
Lead 210		0.00015	uCi/kg		95	70	130			
Lab ID: **C13090529-003AMSD**		Sample Matrix Spike Duplicate				Run: SUB-T54588				12/22/13 13:33
Lead 210		0.00014	uCi/kg		74	70	130	12	15.2	

Qualifiers:

RL - Analyte reporting limit.
MDC - Minimum detectable concentration
ND - Not detected at the reporting limit.
U - Not detected at minimum detectable concentration

QA/QC Summary Report

Prepared by Casper, WY Branch

Revised Date: 04/12/17
Report Date: 01/06/14
Work Order: C13090529

Client: Crow Butte Resources
Project: Marsland Vegetation Baseline Sampling

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: SW6020									Analytical Run: ICPMS4-C_130926A	
Lab ID: ICSA		Interference Check Sample A							09/26/13 18:28	
Uranium		6.75E-05	mg/L	0.00030						
Lab ID: ICSAB		Interference Check Sample AB							09/26/13 18:32	
Uranium		2.20E-05	mg/L	0.00030						
Lab ID: ICV		Initial Calibration Verification Standard							09/27/13 00:25	
Uranium		0.0493	mg/L	0.00030	99	90	110			
Method: SW6020									Batch: 39183	
Lab ID: MB-39183		Method Blank				Run: ICPMS4-C_130926A			09/27/13 11:32	
Uranium		ND	mg/kg	0.01						
Lab ID: LFB-39183		Laboratory Fortified Blank				Run: ICPMS4-C_130926A			09/27/13 11:36	
Uranium		25	mg/kg	1.0	101	80	120			
Lab ID: LCS3-39183		Laboratory Control Sample				Run: ICPMS4-C_130926A			09/27/13 11:40	
Uranium		120	mg/kg	1.0	119	80	120			
Lab ID: C13090528-001BDIL		Serial Dilution				Run: ICPMS4-C_130926A			09/27/13 11:53	
Uranium		0.0716	mg/kg	0.74					10	
Lab ID: C13090529-003BMS3		Sample Matrix Spike				Run: ICPMS4-C_130926A			09/27/13 12:31	
Uranium		24.3	mg/kg	0.15	98	75	125			
Lab ID: C13090529-003BMSD		Sample Matrix Spike Duplicate				Run: ICPMS4-C_130926A			09/27/13 12:35	
Uranium		25.5	mg/kg	0.15	102	75	125	4.6	20	

Qualifiers:

RL - Analyte reporting limit.
MDC - Minimum detectable concentration
ND - Not detected at the reporting limit.

Work Order Receipt Checklist

Crow Butte Resources

C13090529

Login completed by: Kerri Schroeder
Date Received: 9/13/2013

Reviewed by: BL2000\khelm
Received by: ckw

Reviewed Date: 9/16/2013
Carrier name: Hand Del

Shipping container/cooler in good condition?	Yes ☐	No ☐	Not Present ☑
Custody seals intact on all shipping container(s)/cooler(s)?	Yes ☐	No ☐	Not Present ☑
Custody seals intact on all sample bottles?	Yes ☐	No ☐	Not Present ☑
Chain of custody present?	Yes ☑	No ☐	
Chain of custody signed when relinquished and received?	Yes ☑	No ☐	
Chain of custody agrees with sample labels?	Yes ☑	No ☐	
Samples in proper container/bottle?	Yes ☑	No ☐	
Sample containers intact?	Yes ☑	No ☐	
Sufficient sample volume for indicated test?	Yes ☑	No ☐	
All samples received within holding time? (Exclude analyses that are considered field parameters such as pH, DO, Res Cl, Sulfite, Ferrous Iron, etc.)	Yes ☑	No ☐	
Temp Blank received in all shipping container(s)/cooler(s)?	Yes ☐	No ☐	Not Applicable ☑
Container/Temp Blank temperature:	N/A°C		
Water - VOA vials have zero headspace?	Yes ☐	No ☐	No VOA vials submitted ☑
Water - pH acceptable upon receipt?	Yes ☐	No ☐	Not Applicable ☑

Standard Reporting Procedures:

Lab measurement of analytes considered field parameters that require analysis within 15 minutes of sampling such as pH, Dissolved Oxygen and Residual Chlorine, are qualified as being analyzed outside of recommended holding time.

Solid/soil samples are reported on a wet weight basis (as received) unless specifically indicated. If moisture corrected, data units are typically noted as –dry. For agricultural and mining soil parameters/characteristics, all samples are dried and ground prior to sample analysis.

Contact and Corrective Action Comments:

None

Chain of Custody and Analytical Request Record

PLEASE PRINT- Provide as much information as possible.

Company Name: Crow Butte Resources, Inc.	Project Name, Vegetation Baseline Sampling, Marsland	Sample Origin State: NE	EPA/State Compliance: Yes x☐ No ☐
Report Mail Address: P.O. Box 169 Crawford, NE 69339	Contact Name: Larry Teahon Phone/Fax: 308-665-2341	Email: daxmynus@msn.com	Sampler: (Please Print) Brooke Bass
Invoice Address: P.O. Box 169 Crawford, NE 69339	Invoice Contact & Phone: Larry Teahon 308-665-2215 ext 114	Purchase Order: 1125	Quote/Bottle Order:

Special Report/Formats – ELI must be notified prior to sample submittal for the following:

☐ DW ☐ A2LA
☐ GSA ☐ EDD/EDT (Electronic Data)
☐ POTW/WWTP Format: _____
☐ State: _____ ☐ LEVEL IV
☐ Other: _____ ☐ NELAC

ANALYSIS REQUESTED

SAMPLE IDENTIFICATION (Name, Location, Interval, etc.)	Collection Date	Collection Time	MATRIX	Number of Containers; Sample Type: A W S V B O; Air Water Soils/Solids Vegetation Bioassay Other	Th230, Pb210, Ra226, Po210, U-nat	SEE ATTACHED	Normal Turnaround (TAT)	RUSH
1 Marsland west site	9/13/13	10:24	V	X				
2 Marsland middle site	9/13/13	11:08	V	X				
3 Marsland east site	9/13/13	11:47	V	X				
4								
5								
6								

Contact ELI prior to RUSH sample submittal for charges and scheduling – See Instruction Page

Comments: Analyze and report as per Reg Guide 4.14 standards.

Shipped by: Hand
Cooler ID(s): Client
Receipt Temp: 11/14 °C
On Ice: Yes (No)
Custody Seal Intact: Y (N)
Signature Match: Y N

LABORATORY USE ONLY

C13090529

Custody Record MUST be Signed

Relinquished by (print):	Date/Time:	Signature:	Received by (print):	Date/Time:	Signature:
Rhonda Felton	9-13-13 1530	Rhonda Felton			
Relinquished by (print):	Date/Time:	Signature:	Received by (print):	Date/Time:	Signature:
			Received by Laboratory:	9/13/13 1530	Signature:

Sample Disposal: Return to Client: No Lab Disposal: YES

In certain circumstances, samples submitted to Energy Laboratories, Inc. may be subcontracted to other certified laboratories in order to complete the analysis requested. This serves as notice of this possibility. All sub-contract data will be clearly notated on your analytical report.

Replacement Pages – Appendix W-2 (Located in Appendix Tab 'W')

Instructions:

Retain Appendix W-1 (Do Not Remove W-1)

Remove and Replace Appendix W-2

MEA TR

Reponses to Open Issues

6-29-2017

W-2

Niobrara River and Ephemeral Drainages Sediment Laboratory Records

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Date: 11/28/2016

CLIENT: Cameco Resources, Crow Butte Operation
Project: Marsland Sediment Samples
Lab Order: S1405089

CASE NARRATIVE

Report ID: S1405089002
(Replaces S1405089001)

Samples MED-1, MED-2, MED-3, MED-4, MED-5, MED-6, N1, and N2 were received on May 6, 2014.

All samples were received and analyzed within the EPA recommended holding times, except those noted below in this case narrative. Samples were analyzed using the methods outlined in the following references:

"Standard Methods For The Examination of Water and Wastewater", approved method versions
Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, 3rd Edition
40 CFR Parts 136 and 141
40 CFR Part 50, Appendices B, J, L, and O
Methods indicated in the Methods Update Rule published in the Federal Register Friday, May 18, 2012
ASTM approved and recognized standards

All Quality Control parameters met the acceptance criteria defined by EPA and Inter-Mountain Laboratories except as indicated in this case narrative.

The precision is reported as counting error per MARLAP recommendations Vol. 13 2004.

Report S1405089002 replaces Report S1405089001. The report was revised to display values below the reporting limit.

Reviewed by:

Wade Nieuwsma, Assistant Laboratory Manager

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Sample Analysis Report

Company: Cameco Resources, Crow Butte Operation
PO Box 169
Crawford, NE 69339

Date Reported 11/28/2016
Report ID S1405089002
(Replaces S1405089001)

ProjectName: Marsland Sediment Samples
Lab ID: S1405089-001
ClientSample ID: MED-1
COC: WEB

WorkOrder: S1405089
CollectionDate: 5/2/2014
DateReceived: 5/6/2014 11:57:00 AM
FieldSampler:
Matrix: Sediment

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	0.3	pCi/g		0.2	OTW01	05/20/2014 1134	MB
Lead 210 Precision (±)	0.1	pCi/g			OTW01	05/20/2014 1134	MB
Radium 226	0.3	pCi/g		0.2	EPA 901.1 Mod.	06/14/2014 1120	MB
Radium 226 Precision (±)	0.2	pCi/g			EPA 901.1 Mod.	06/14/2014 1120	MB
Thorium 230	0.19	pCi/g		0.2	ACW10	05/23/2014 920	MB
Thorium230 Precision (±)	0.1	pCi/g			ACW10	05/23/2014 920	MB
Thorium229 Tracer (30-120)	95.2	%			ACW10	05/23/2014 920	MB
Metals - Total							
Uranium	0.3	pCi/g		0.2	EPA 200.8	05/14/2014 1204	MS

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank
E	Value above quantitation range
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits
C	Calculated Value
G	Analyzed at IML Gillette laboratory
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
X	Matrix Effect

Reviewed by:
Wade Nieuwsma, Assistant Laboratory Manager

Sample Analysis Report

Company: Cameco Resources, Crow Butte Operation
PO Box 169
Crawford, NE 69339

Date Reported 11/28/2016
Report ID S1405089002
(Replaces S1405089001)

ProjectName: Marsland Sediment Samples
Lab ID: S1405089-002
ClientSample ID: MED-2
COC: WEB

WorkOrder: S1405089
CollectionDate: 5/2/2014
DateReceived: 5/6/2014 11:57:00 AM
FieldSampler:
Matrix: Sediment

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	1.3	pCi/g		0.2	OTW01	05/20/2014 1134	MB
Lead 210 Precision (±)	0.2	pCi/g			OTW01	05/20/2014 1134	MB
Radium 226	0.5	pCi/g		0.2	EPA 901.1 Mod.	06/14/2014 1120	MB
Radium 226 Precision (±)	0.4	pCi/g			EPA 901.1 Mod.	06/14/2014 1120	MB
Thorium 230	0.4	pCi/g		0.2	ACW10	05/23/2014 920	MB
Thorium230 Precision (±)	0.1	pCi/g			ACW10	05/23/2014 920	MB
Thorium229 Tracer (30-120)	98.9	%			ACW10	05/23/2014 920	MB
Metals - Total							
Uranium	0.6	pCi/g		0.2	EPA 200.8	05/14/2014 1224	MS

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank
E	Value above quantitation range
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits
C	Calculated Value
G	Analyzed at IML Gillette laboratory
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
X	Matrix Effect

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Sample Analysis Report

Company: Cameco Resources, Crow Butte Operation
PO Box 169
Crawford, NE 69339

Date Reported 11/28/2016
Report ID S1405089002
(Replaces S1405089001)

ProjectName: Marsland Sediment Samples
Lab ID: S1405089-003
ClientSample ID: MED-3
COC: WEB

WorkOrder: S1405089
CollectionDate: 5/2/2014
DateReceived: 5/6/2014 11:57:00 AM
FieldSampler:
Matrix: Sediment

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	1.4	pCi/g		0.2	OTW01	05/20/2014 1134	MB
Lead 210 Precision (±)	0.2	pCi/g			OTW01	05/20/2014 1134	MB
Radium 226	0.8	pCi/g		0.2	EPA 901.1 Mod.	06/14/2014 1120	MB
Radium 226 Precision (±)	0.3	pCi/g			EPA 901.1 Mod.	06/14/2014 1120	MB
Thorium 230	0.3	pCi/g		0.2	ACW10	05/23/2014 920	MB
Thorium230 Precision (±)	0.1	pCi/g			ACW10	05/23/2014 920	MB
Thorium229 Tracer (30-120)	94.1	%			ACW10	05/23/2014 920	MB
Metals - Total							
Uranium	0.5	pCi/g		0.2	EPA 200.8	05/14/2014 1241	MS

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank
E	Value above quantitation range
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits
C	Calculated Value
G	Analyzed at IML Gillette laboratory
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
X	Matrix Effect

Reviewed by:
Wade Nieuwsma, Assistant Laboratory Manager

Inter-Mountain Labs
1673 Terra Avenue; Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Sample Analysis Report

Company:	Cameco Resources, Crow Butte Operation PO Box 169 Crawford, NE 69339	**Date Reported** **Report ID**	11/28/2016 S1405089002 (Replaces S1405089001)
ProjectName:	Marsland Sediment Samples	**WorkOrder:**	S1405089
Lab ID:	S1405089-004	**CollectionDate:**	5/2/2014
ClientSample ID:	MED-4	**DateReceived:**	5/6/2014 11:57:00 AM
COC:	WEB	**FieldSampler:**	
		Matrix:	Sediment

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	2.1	pCi/g		0.2	OTW01	05/20/2014 1134	MB
Lead 210 Precision (±)	0.3	pCi/g			OTW01	05/20/2014 1134	MB
Radium 226	0.8	pCi/g		0.2	EPA 901.1 Mod.	06/14/2014 1120	MB
Radium 226 Precision (±)	0.4	pCi/g			EPA 901.1 Mod.	06/14/2014 1120	MB
Thorium 230	0.5	pCi/g		0.2	ACW10	05/23/2014 920	MB
Thorium230 Precision (±)	0.1	pCi/g			ACW10	05/23/2014 920	MB
Thorium229 Tracer (30-120)	90.3	%			ACW10	05/23/2014 920	MB
Metals - Total							
Uranium	0.5	pCi/g		0.2	EPA 200.8	05/14/2014 1246	MS

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank
E	Value above quantitation range
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits
C	Calculated Value
G	Analyzed at IML Gillette laboratory
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
X	Matrix Effect

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Sample Analysis Report

Company: Cameco Resources, Crow Butte Operation
PO Box 169
Crawford, NE 69339

Date Reported 11/28/2016
Report ID S1405089002
(Replaces S1405089001)

ProjectName: Marsland Sediment Samples
Lab ID: S1405089-005
ClientSample ID: MED-5
COC: WEB

WorkOrder: S1405089
CollectionDate: 5/2/2014
DateReceived: 5/6/2014 11:57:00 AM
FieldSampler:
Matrix: Sediment

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	2.0	pCi/g		0.2	OTW01	05/20/2014 1134	MB
Lead 210 Precision (±)	0.2	pCi/g			OTW01	05/20/2014 1134	MB
Radium 226	1.2	pCi/g		0.2	EPA 901.1 Mod.	06/14/2014 1120	MB
Radium 226 Precision (±)	0.5	pCi/g			EPA 901.1 Mod.	06/14/2014 1120	MB
Thorium 230	0.5	pCi/g		0.2	ACW10	05/23/2014 920	MB
Thorium230 Precision (±)	0.2	pCi/g			ACW10	05/23/2014 920	MB
Thorium229 Tracer (30-120)	85.4	%			ACW10	05/23/2014 920	MB
Metals - Total							
Uranium	0.6	pCi/g		0.2	EPA 200.8	05/14/2014 1252	MS

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank
E	Value above quantitation range
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits
C	Calculated Value
G	Analyzed at IML Gillette laboratory
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
X	Matrix Effect

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Sample Analysis Report

Company: Cameco Resources, Crow Butte Operation
PO Box 169
Crawford, NE 69339

Date Reported 11/28/2016
Report ID S1405089002
(Replaces S1405089001)

ProjectName: Marsland Sediment Samples
Lab ID: S1405089-006
ClientSample ID: MED-6
COC: WEB

WorkOrder: S1405089
CollectionDate: 5/2/2014
DateReceived: 5/6/2014 11:57:00 AM
FieldSampler:
Matrix: Sediment

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	1.0	pCi/g		0.2	OTW01	05/20/2014 1134	MB
Lead 210 Precision (±)	0.2	pCi/g			OTW01	05/20/2014 1134	MB
Radium 226	0.7	pCi/g		0.2	EPA 901.1 Mod.	06/14/2014 1120	MB
Radium 226 Precision (±)	0.3	pCi/g			EPA 901.1 Mod.	06/14/2014 1120	MB
Thorium 230	0.2	pCi/g		0.2	ACW10	05/23/2014 1328	MB
Thorium230 Precision (±)	0.1	pCi/g			ACW10	05/23/2014 1328	MB
Thorium229 Tracer (30-120)	88.3	%			ACW10	05/23/2014 1328	MB
Metals - Total							
Uranium	0.5	pCi/g		0.2	EPA 200.8	05/14/2014 1257	MS

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank
E	Value above quantitation range
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits
C	Calculated Value
G	Analyzed at IML Gillette laboratory
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
X	Matrix Effect

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Sample Analysis Report

Company:	Cameco Resources, Crow Butte Operation PO Box 169 Crawford, NE 69339	**Date Reported** **Report ID**	11/28/2016 S1405089002 (Replaces S1405089001)
ProjectName:	Marsland Sediment Samples	**WorkOrder:**	S1405089
Lab ID:	S1405089-007	**CollectionDate:**	5/2/2014
ClientSample ID:	N1	**DateReceived:**	5/6/2014 11:57:00 AM
COC:	WEB	**FieldSampler:**	
		Matrix:	Sediment

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	1.3	pCi/g		0.2	OTW01	05/20/2014 1134	MB
Lead 210 Precision (±)	0.2	pCi/g			OTW01	05/20/2014 1134	MB
Radium 226	0.7	pCi/g		0.2	EPA 901.1 Mod.	06/14/2014 1120	MB
Radium 226 Precision (±)	0.3	pCi/g			EPA 901.1 Mod.	06/14/2014 1120	MB
Thorium 230	0.2	pCi/g		0.2	ACW10	05/23/2014 1328	MB
Thorium230 Precision (±)	0.1	pCi/g			ACW10	05/23/2014 1328	MB
Thorium229 Tracer (30-120)	107	%			ACW10	05/23/2014 1328	MB
Metals - Total							
Uranium	0.6	pCi/g		0.2	EPA 200.8	05/14/2014 1302	MS

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank	C	Calculated Value
E	Value above quantitation range	G	Analyzed at IML Gillette laboratory
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by another laboratory	M	Value exceeds Monthly Ave or MCL or is less than LCL
ND	Not Detected at the Reporting Limit	O	Outside the Range of Dilutions
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Sample Analysis Report

Company: Cameco Resources, Crow Butte Operation
PO Box 169
Crawford, NE 69339

Date Reported 11/28/2016
Report ID S1405089002
(Replaces S1405089001)

ProjectName: Marsland Sediment Samples
Lab ID: S1405089-008
ClientSample ID: N2
COC: WEB

WorkOrder: S1405089
CollectionDate: 5/2/2014
DateReceived: 5/6/2014 11:57:00 AM
FieldSampler:
Matrix: Sediment

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	0.5	pCi/g		0.2	OTW01	05/20/2014 1345	MB
Lead 210 Precision (±)	0.1	pCi/g			OTW01	05/20/2014 1345	MB
Radium 226	0.5	pCi/g		0.2	EPA 901.1 Mod.	06/14/2014 1120	MB
Radium 226 Precision (±)	0.2	pCi/g			EPA 901.1 Mod.	06/14/2014 1120	MB
Thorium 230	0.1	pCi/g		0.2	ACW10	05/23/2014 1328	MB
Thorium230 Precision (±)	0.1	pCi/g			ACW10	05/23/2014 1328	MB
Thorium229 Tracer (30-120)	93.0	%			ACW10	05/23/2014 1328	MB
Metals - Total							
Uranium	0.4	pCi/g		0.2	EPA 200.8	05/14/2014 1308	MS

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank
E	Value above quantitation range
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits
C	Calculated Value
G	Analyzed at IML Gillette laboratory
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
X	Matrix Effect

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Work Order: S1405089
Project: Marsland Sediment Samples

Date: 11/28/2016
Report ID: S1405089002
(Replaces S1405089001)

Lead 210 in Soil Sample Type **MBLK** Units: pCi/g

MB14-133 (05/20/14 11:34)	RunNo: 107987	PrepDate: 05/15/14 0:00			BatchID R107987		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	ND	1					

Lead 210 in Soil Sample Type **LCS** Units: pCi/g

LCS14-133 (05/20/14 11:34)	RunNo: 107987	PrepDate: 05/15/14 0:00			BatchID R107987		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	15	1	11.9		123	50 - 150	

Lead 210 in Soil Sample Type **MS** Units: pCi/g

TAPMS (05/20/14 11:34)	RunNo: 107987	PrepDate: 05/15/14 0:00			BatchID R107987		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	14	1	12.4	1	106	50 - 150	

Lead 210 in Soil Sample Type **MSD** Units: pCi/g

TAPMSD (05/20/14 11:34)	RunNo: 107987	PrepDate: 05/15/14 0:00			BatchID R107987		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Lead 210	15	1	14	4.16	110	30	

Radium By Gamma Spectroscopy in Soil Sample Type **MBLK** Units: pCi/g

MB (06/14/14 11:20)	RunNo: 109199						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Radium 226	ND	0.2					

Radium By Gamma Spectroscopy in Soil Sample Type **LCS** Units: pCi/g

LCS (06/14/14 11:20)	RunNo: 109199						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Radium 226	527	0.2	534		98.8	70 - 130	

Radium By Gamma Spectroscopy in Soil Sample Type **DUP** Units: pCi/g

S1405089-001AD (06/14/14 11:20)	RunNo: 109199						
Analyte	Result	RL	Ref Samp	%RPD	%REC	% RPD Limits	Qual
Radium 226	0.3	0.2	ND			30	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
G	Analyzed at IML Gillette laboratory	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit	O	Outside the Range of Dilutions
R	RPD outside accepted recovery limits	S	Spike Recovery outside accepted recovery limits
X	Matrix Effect		

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Date: 11/28/2016
Work Order: S1405089
Report ID: S1405089002 (Replaces S1405089001)
Project: Marsland Sediment Samples

Thorium 230 in Soil Sample Type **MBLK** Units: pCi/g

MB14-134 (05/23/14 09:20)	RunNo: 108084	PrepDate: 05/13/14 0:00			BatchID R108084		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Thorium230	ND	0.2					

Thorium 230 in Soil Sample Type **LCS** Units: pCi/g

LCS14-134 (05/23/14 09:20)	RunNo: 108084	PrepDate: 05/13/14 0:00			BatchID R108084		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Thorium230	12.4	0.2	12.5		98.9	50 - 150	

Thorium 230 in Soil Sample Type **LCSD** Units: pCi/g

LCS14-134 DUP (05/23/14 09:20)	RunNo: 108084	PrepDate: 05/13/14 0:00			BatchID R108084		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Thorium230	13.8	0.2	12.4	11.4	110	30	

Total (3050) Metals by EPA 200.8 - Soil Sample Type **MBLK** Units: pCi/g

MBLK (05/14/14 11:42)	RunNo: 107639						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	ND	0.2					

Total (3050) Metals by EPA 200.8 - Soil Sample Type **LCS** Units: pCi/g

LCS (05/14/14 11:37)	RunNo: 107639						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	69.8	0.2	67.7		103	85 - 115	

Total (3050) Metals by EPA 200.8 - Soil Sample Type **MS** Units: pCi/g

S1405089-001AS (05/14/14 12:15)	RunNo: 107639						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	745	0.2	745	0.3	100	70 - 130	

Total (3050) Metals by EPA 200.8 - Soil Sample Type **MSD** Units: pCi/g

S1405089-001AMSD (05/14/14 12:19)	RunNo: 107639						
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Uranium	746	0.2	745	0.209	100	20	

Total (3050) Metals by EPA 200.8 - Soil Sample Type **DUP** Units: pCi/g

S1405089-001AD (05/14/14 12:09)	RunNo: 107639						
Analyte	Result	RL	Ref Samp	%RPD	%REC	% RPD Limits	Qual
Uranium	0.3	0.2	0.3	0.893		20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
G	Analyzed at IML Gillette laboratory	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit	O	Outside the Range of Dilutions
R	RPD outside accepted recovery limits	S	Spike Recovery outside accepted recovery limits
X	Matrix Effect		

Inter-Mountain Labs
Sheridan, WY and Gillette, WY

CHAIN OF CUSTODY RECORD

Page 1 of 1

All shaded fields must be completed.
This is a legal document; any misrepresentation may be construed as fraud.

#WEB

Client Name	Project Identification	Sampler (Signature/Attestation of Authenticity)	Telephone #
Cameco Resources, Crow Butte	Marsland SedimentSamples		308-665-2215x117

Report Address	Contact Name
PO Box 169 Crawford, Ne 69339	Walt Nelson Email: Walter_Nelson@cameco.com Phone: 308-665-2215x117

Invoice Address	Purchase Order #	Quote #
Same		

ITEM	LAB ID (Lab Use Only)	DATE SAMPLED	TIME	SAMPLE IDENTIFICATION	Matrix	# of Containers	U Ra226 Pb210	Th230							REMARKS
1	A1405089-001	05/02/14		MED-1	SL	1	x	x							Detection limits per Reg. Guide 4.14 standards for preoperational sediment sampling.
2	-002	05/02/14		MED-2	SL	1	x	x							
3	-003	05/02/14		MED-3	SL	1	x	x							
4	-004	05/02/14		MED-4	SL	1	x	x							
5	-005	05/02/14		MED-5	SL	1	x	x							
6	-006	05/02/14		MED-6	SL	1	x	x							
7	-007	05/02/14		N1	SL	1	x	x							
8	-008	05/02/14		N2	SL	1	x	x							
9															
10															
11															
12															
13															
14															

LAB COMMENTS	Relinquished By (Signature/Printed)	DATE	TIME	Received By (Signature/Printed)	DATE	TIME
	Walter D. Nelson	5/6/14	11:00	Action Couriers	5/6/14	11:00
				Kathy Boyd	5.6.14	11:57

SHIPPING INFO	MATRIX CODES		TURN AROUND TIMES	COMPLIANCE INFORMATION	ADDITIONAL REMARKS
☐ UPS	Water	WT	Check desired service:	Compliance Monitoring ? Y / N	
☐ FedEx	Soil	SL	☒ Standard turnaround	Program (SDWA, NPDES,...)	
☐ USPS	Solid	SD	☐ RUSH - 5 Working Days	PWSID / Permit #	
☐ Hand Carried	Filter	FT	☐ URGENT - < 2 Working Days	Chlorinated? Y / N	
☐ Other	Other	OT	*Rush & Urgent Surcharges will be applied*	Sample Disposal: Lab x Client	

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Date: 11/28/2016

CLIENT: Cameco Resources, Crow Butte Operation
Project: Marsland Sediment Samples
Lab Order: S1311292

CASE NARRATIVE

Report ID: S1311292002
(Replaces S1311292001)

Samples MED-1, MED-2, MED-3, MED-4, MED-5, MED-6, N1, and N2 were received on November 19, 2013.

All samples were received and analyzed within the EPA recommended holding times, except those noted below in this case narrative. Samples were analyzed using the methods outlined in the following references:

"Standard Methods For The Examination of Water and Wastewater", approved method versions
Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, 3rd Edition
40 CFR Parts 136 and 141
40 CFR Part 50, Appendices B, J, L, and O
Methods indicated in the Methods Update Rule published in the Federal Register Friday, May 18, 2012
ASTM approved and recognized standards

All Quality Control parameters met the acceptance criteria defined by EPA and Inter-Mountain Laboratories except as indicated in this case narrative.

The precision is reported as counting error per MARLAP recommendations Vol. 13 2004.

Report S1311292002 replaces Report S1311292001. The report was revised to display values below the reporting limit.

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Sample Analysis Report

Company:	Cameco Resources, Crow Butte Operation PO Box 169 Crawford, NE 69339	**Date Reported** **Report ID**	11/28/2016 S1311292002 (Replaces S1311292001)
ProjectName:	Marsland Sediment Samples	**WorkOrder:**	S1311292
Lab ID:	S1311292-001	**CollectionDate:**	10/25/2013
ClientSample ID:	MED-1	**DateReceived:**	11/19/2013 1:34:00 PM
COC:	WEB	**FieldSampler:**	WN
		Matrix:	Sediment

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	2.1E-6	µCi/g		2.0E-7	OTW01	12/18/2013 955	SH
Lead 210 Precision (±)	4.0E-7	µCi/g			OTW01	12/18/2013 955	SH
Radium 226	3.0E-7	µCi/g		2.0E-7	EPA 901.1 Mod.	12/19/2013 1640	SH
Radium 226 Precision (±)	3.0E-7	µCi/g			EPA 901.1 Mod.	12/19/2013 1640	SH
Thorium 230	2.0E-7	µCi/g		2.0E-7	ACW10	12/16/2013 1048	MB
Thorium230 Precision (±)	1.0E-7	µCi/g			ACW10	12/16/2013 1048	MB
Thorium229 Tracer (30-120)	92.8	%			ACW10	12/16/2013 1048	MB
Metals - Total							
Uranium	4.0E-7	µCi/g		2.0E-7	EPA 200.8	12/02/2013 1718	MS

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank	C	Calculated Value
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	L	Analyzed by another laboratory
M	Value exceeds Monthly Ave or MCL or is less than LCL	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	S	Spike Recovery outside accepted recovery limits
X	Matrix Effect		

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Sample Analysis Report

Company: Cameco Resources, Crow Butte Operation
PO Box 169
Crawford, NE 69339

Date Reported 11/28/2016
Report ID S1311292002
(Replaces S1311292001)

ProjectName: Marsland Sediment Samples
Lab ID: S1311292-002
ClientSample ID: MED-2
COC: WEB

WorkOrder: S1311292
CollectionDate: 10/25/2013
DateReceived: 11/19/2013 1:34:00 PM
FieldSampler: WN
Matrix: Sediment

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	6.0E-7	µCi/g		2.0E-7	OTW01	01/24/2014 1058	SH
Lead 210 Precision (±)	2.0E-7	µCi/g			OTW01	01/24/2014 1058	SH
Radium 226	4.0E-7	µCi/g		2.0E-7	EPA 901.1 Mod.	12/19/2013 1700	SH
Radium 226 Precision (±)	3.0E-7	µCi/g			EPA 901.1 Mod.	12/19/2013 1700	SH
Thorium 230	1.9E-7	µCi/g		2.0E-7	ACW10	12/16/2013 1048	MB
Thorium230 Precision (±)	1.0E-7	µCi/g			ACW10	12/16/2013 1048	MB
Thorium229 Tracer (30-120)	96.6	%			ACW10	12/16/2013 1048	MB
Metals - Total							
Uranium	2.0E-7	µCi/g		2.0E-7	EPA 200.8	12/02/2013 1741	MS

These results apply only to the samples tested. **RL - Reporting Limit**

Qualifiers:

B	Analyte detected in the associated Method Blank
E	Value above quantitation range
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
X	Matrix Effect
C	Calculated Value
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Sample Analysis Report

Company: Cameco Resources, Crow Butte Operation
PO Box 169
Crawford, NE 69339

Date Reported 11/28/2016
Report ID S1311292002
(Replaces S1311292001)

ProjectName: Marsland Sediment Samples
Lab ID: S1311292-003
ClientSample ID: MED-3
COC: WEB

WorkOrder: S1311292
CollectionDate: 10/25/2013
DateReceived: 11/19/2013 1:34:00 PM
FieldSampler: WN
Matrix: Sediment

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	4.0E-7	µCi/g		2.0E-7	OTW01	01/24/2014 1058	SH
Lead 210 Precision (±)	2.0E-7	µCi/g			OTW01	01/24/2014 1058	SH
Radium 226	2.0E-7	µCi/g		2.0E-7	EPA 901.1 Mod.	12/19/2013 1721	SH
Radium 226 Precision (±)	3.0E-7	µCi/g			EPA 901.1 Mod.	12/19/2013 1721	SH
Thorium 230	1.0E-7	µCi/g		2.0E-7	ACW10	12/16/2013 1048	MB
Thorium230 Precision (±)	1.0E-7	µCi/g			ACW10	12/16/2013 1048	MB
Thorium229 Tracer (30-120)	95.6	%			ACW10	12/16/2013 1048	MB
Metals - Total							
Uranium	2.0E-7	µCi/g		2.0E-7	EPA 200.8	12/02/2013 1757	MS

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank
E	Value above quantitation range
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
X	Matrix Effect
C	Calculated Value
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Sample Analysis Report

Company: Cameco Resources, Crow Butte Operation
PO Box 169
Crawford, NE 69339

Date Reported 11/28/2016
Report ID S1311292002
(Replaces S1311292001)

ProjectName: Marsland Sediment Samples
Lab ID: S1311292-004
ClientSample ID: MED-4
COC: WEB

WorkOrder: S1311292
CollectionDate: 10/25/2013
DateReceived: 11/19/2013 1:34:00 PM
FieldSampler: WN
Matrix: Sediment

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	1.7E-6	µCi/g		2.0E-7	OTW01	12/18/2013 1215	SH
Lead 210 Precision (±)	4.0E-7	µCi/g			OTW01	12/18/2013 1215	SH
Radium 226	7.0E-7	µCi/g		2.0E-7	EPA 901.1 Mod.	12/19/2013 1742	SH
Radium 226 Precision (±)	4.0E-7	µCi/g			EPA 901.1 Mod.	12/19/2013 1742	SH
Thorium 230	5.0E-7	µCi/g		2.0E-7	ACW10	12/16/2013 1048	MB
Thorium230 Precision (±)	1.0E-7	µCi/g			ACW10	12/16/2013 1048	MB
Thorium229 Tracer (30-120)	87.2	%			ACW10	12/16/2013 1048	MB
Metals - Total							
Uranium	5.0E-7	µCi/g		2.0E-7	EPA 200.8	12/02/2013 1802	MS

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank
E	Value above quantitation range
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
X	Matrix Effect
C	Calculated Value
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Sample Analysis Report

Company:	Cameco Resources, Crow Butte Operation PO Box 169 Crawford, NE 69339	**Date Reported** **Report ID**	11/28/2016 S1311292002 (Replaces S1311292001)
ProjectName:	Marsland Sediment Samples	**WorkOrder:**	S1311292
Lab ID:	S1311292-005	**CollectionDate:**	10/25/2013
ClientSample ID:	MED-5	**DateReceived:**	11/19/2013 1:34:00 PM
COC:	WEB	**FieldSampler:**	WN
		Matrix:	Sediment

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	1.2E-6	µCi/g		2.0E-7	OTW01	12/18/2013 1215	SH
Lead 210 Precision (±)	3.0E-7	µCi/g			OTW01	12/18/2013 1215	SH
Radium 226	6.0E-7	µCi/g		2.0E-7	EPA 901.1 Mod.	12/19/2013 1803	SH
Radium 226 Precision (±)	4.0E-7	µCi/g			EPA 901.1 Mod.	12/19/2013 1803	SH
Thorium 230	1.9E-7	µCi/g		2.0E-7	ACW10	12/16/2013 1048	MB
Thorium230 Precision (±)	1.0E-7	µCi/g			ACW10	12/16/2013 1048	MB
Thorium229 Tracer (30-120)	54.0	%			ACW10	12/16/2013 1048	MB
Metals - Total							
Uranium	4.0E-7	µCi/g		2.0E-7	EPA 200.8	12/02/2013 1808	MS

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank
E	Value above quantitation range
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
X	Matrix Effect
C	Calculated Value
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Sample Analysis Report

Company: Cameco Resources, Crow Butte Operation
PO Box 169
Crawford, NE 69339

Date Reported 11/28/2016
Report ID S1311292002
(Replaces S1311292001)

ProjectName: Marsland Sediment Samples
Lab ID: S1311292-006
ClientSample ID: MED-6
COC: WEB

WorkOrder: S1311292
CollectionDate: 10/25/2013
DateReceived: 11/19/2013 1:34:00 PM
FieldSampler: WN
Matrix: Sediment

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	9.0E-7	µCi/g		2.0E-7	OTW01	12/18/2013 1215	SH
Lead 210 Precision (±)	4.0E-7	µCi/g			OTW01	12/18/2013 1215	SH
Radium 226	7.0E-7	µCi/g		2.0E-7	EPA 901.1 Mod.	12/19/2013 1823	SH
Radium 226 Precision (±)	3.0E-7	µCi/g			EPA 901.1 Mod.	12/19/2013 1823	SH
Thorium 230	4.0E-7	µCi/g		2.0E-7	ACW10	01/07/2014 1223	MB
Thorium230 Precision (±)	1.0E-7	µCi/g			ACW10	01/07/2014 1223	MB
Thorium229 Tracer (30-120)	93.5	%			ACW10	01/07/2014 1223	MB
Metals - Total							
Uranium	4.0E-7	µCi/g		2.0E-7	EPA 200.8	12/02/2013 1813	MS

These results apply only to the samples tested. **RL - Reporting Limit**

Qualifiers:

B	Analyte detected in the associated Method Blank
E	Value above quantitation range
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
X	Matrix Effect
C	Calculated Value
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Sample Analysis Report

Company:	Cameco Resources, Crow Butte Operation PO Box 169 Crawford, NE 69339	**Date Reported** **Report ID**	11/28/2016 S1311292002 (Replaces S1311292001)
ProjectName:	Marsland Sediment Samples	**WorkOrder:**	S1311292
Lab ID:	S1311292-007	**CollectionDate:**	10/25/2013
ClientSample ID:	N1	**DateReceived:**	11/19/2013 1:34:00 PM
COC:	WEB	**FieldSampler:**	WN
		Matrix:	Sediment

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	1.0E-6	µCi/g		2.0E-7	OTW01	12/18/2013 1215	SH
Lead 210 Precision (±)	4.0E-7	µCi/g			OTW01	12/18/2013 1215	SH
Radium 226	6.0E-7	µCi/g		2.0E-7	EPA 901.1 Mod.	12/19/2013 1844	SH
Radium 226 Precision (±)	3.0E-7	µCi/g			EPA 901.1 Mod.	12/19/2013 1844	SH
Thorium 230	3.0E-7	µCi/g		2.0E-7	ACW10	12/17/2013 1013	MB
Thorium230 Precision (±)	1.0E-7	µCi/g			ACW10	12/17/2013 1013	MB
Thorium229 Tracer (30-120)	51.2	%			ACW10	12/17/2013 1013	MB
Metals - Total							
Uranium	3.0E-7	µCi/g		2.0E-7	EPA 200.8	12/02/2013 1819	MS

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank	C	Calculated Value
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	L	Analyzed by another laboratory
M	Value exceeds Monthly Ave or MCL or is less than LCL	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	S	Spike Recovery outside accepted recovery limits
X	Matrix Effect		

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Sample Analysis Report

Company: Cameco Resources, Crow Butte Operation
PO Box 169
Crawford, NE 69339

Date Reported 11/28/2016
Report ID S1311292002
(Replaces S1311292001)

ProjectName: Marsland Sediment Samples
Lab ID: S1311292-008
ClientSample ID: N2
COC: WEB

WorkOrder: S1311292
CollectionDate: 10/25/2013
DateReceived: 11/19/2013 1:34:00 PM
FieldSampler: WN
Matrix: Sediment

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	3.0E-7	µCi/g		2.0E-7	OTW01	01/24/2014 1311	SH
Lead 210 Precision (±)	1.0E-7	µCi/g			OTW01	01/24/2014 1311	SH
Radium 226	4.0E-7	µCi/g		2.0E-7	EPA 901.1 Mod.	12/19/2013 1905	SH
Radium 226 Precision (±)	3.0E-7	µCi/g			EPA 901.1 Mod.	12/19/2013 1905	SH
Thorium 230	1.0E-7	µCi/g		2.0E-7	ACW10	12/17/2013 1013	MB
Thorium230 Precision (±)	1.0E-7	µCi/g			ACW10	12/17/2013 1013	MB
Thorium229 Tracer (30-120)	70.7	%			ACW10	12/17/2013 1013	MB
Metals - Total							
Uranium	2.0E-7	µCi/g		2.0E-7	EPA 200.8	12/02/2013 1824	MS

These results apply only to the samples tested. **RL - Reporting Limit**

Qualifiers:

B	Analyte detected in the associated Method Blank	C	Calculated Value
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	L	Analyzed by another laboratory
M	Value exceeds Monthly Ave or MCL or is less than LCL	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	S	Spike Recovery outside accepted recovery limits
X	Matrix Effect		

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Work Order: S1311292
Project: Marsland Sediment Samples

Date: 11/28/2016
Report ID: S1311292002
(Replaces S1311292001)

Lead 210 in Soil Sample Type **MBLK** Units: pCi/g

MB13-337 (12/18/13 09:55)	RunNo: 103174	PrepDate: 12/04/13 0:00			BatchID: R103174		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	ND	1					

MB13-337 (12/19/13 12:26)	RunNo: 103174	PrepDate: 12/04/13 0:00			BatchID: R103174		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	ND	1					

MB13-336 (12/20/13 12:28)	RunNo: 103248	PrepDate: 12/05/13 0:00			BatchID: 7727		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	ND	1					

MB14-016 (01/24/14 10:58)	RunNo: 104103	PrepDate: 01/21/14 0:00			BatchID: 7727		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	ND	1					

Lead 210 in Soil Sample Type **LCS** Units: pCi/g

LCS13-337 (12/18/13 09:55)	RunNo: 103174	PrepDate: 12/04/13 0:00			BatchID: R103174		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	13	1	12.1		107	50 - 150	

LCS13-336 (12/19/13 14:36)	RunNo: 103248	PrepDate: 12/05/13 0:00			BatchID: 7727		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	13	1	12.1		109	50 - 150	

LCS14-016 (01/24/14 10:58)	RunNo: 104103	PrepDate: 01/21/14 0:00			BatchID: 7727		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	15	1	12		126	50 - 150	

Lead 210 in Soil Sample Type **MS** Units: pCi/g

TAP WATER MS (12/18/13 09:55)	RunNo: 103174	PrepDate: 12/04/13 0:00			BatchID: R103174		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	12	1	12.4	ND	97.0	50 - 150	

TAP WATER MS (12/19/13 14:36)	RunNo: 103248	PrepDate: 12/05/13 0:00			BatchID: 7727		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	14	1	12.4	ND	112	50 - 150	

TAP WATER MS (01/24/14 10:58)	RunNo: 104103	PrepDate: 01/21/14 0:00			BatchID: 7727		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	7	1	12.3	ND	60.2	50 - 150	

Lead 210 in Soil Sample Type **MSD** Units: pCi/g

TAP WATER MSD (12/18/13 09:55)	RunNo: 103174	PrepDate: 12/04/13 0:00			BatchID: R103174		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Lead 210	15	1	12	20.9	117	30	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by another laboratory	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	R	RPD outside accepted recovery limits
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Work Order: S1311292
Project: Marsland Sediment Samples

Date: 11/28/2016
Report ID: S1311292002
(Replaces S1311292001)

Lead 210 in Soil Sample Type **MSD** Units: pCi/g

TAP WATER MSD (12/19/13 14:36)	RunNo: 103248	PrepDate: 12/05/13 0:00			BatchID: 7727		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Lead 210	15	1	14	5.42	118	30	

TAP WATER MSD (01/24/14 10:58)	RunNo: 104103	PrepDate: 01/21/14 0:00			BatchID: 7727		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Lead 210	7	1	7	0.0161	60.2	30	

Radium By Gamma Spectroscopy in Soil Sample Type **MBLK** Units: pCi/g

MB13-353 (12/19/13 15:16)	RunNo: 103246						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Radium 226	ND	0.2					

Radium By Gamma Spectroscopy in Soil Sample Type **LCS** Units: pCi/g

LCS13-353 (12/19/13 15:37)	RunNo: 103246						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Radium 226	527	0.2	534		98.8	70 - 130	

Radium By Gamma Spectroscopy in Soil Sample Type **DUP** Units: pCi/g

S1311251-001ADUP (12/19/13 21:51)	RunNo: 103246	PrepDate: 11/21/13 0:00			BatchID: R103246		
Analyte	Result	RL	Ref Samp	%RPD	%REC	% RPD Limits	Qual
Radium 226	ND	1	ND			30	

S1311292-008BDUP (12/19/13 22:12)	RunNo: 103246	PrepDate: 11/27/13 0:00			BatchID: R103246		
Analyte	Result	RL	Ref Samp	%RPD	%REC	% RPD Limits	Qual
Radium 226	ND	0.2	0.4			30	

S1311293-007BDUP (12/19/13 22:33)	RunNo: 103246	PrepDate: 11/27/13 0:00			BatchID: R103246		
Analyte	Result	RL	Ref Samp	%RPD	%REC	% RPD Limits	Qual
Radium 226	0.5	0.2	0.8	28.2		30	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by another laboratory	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	R	RPD outside accepted recovery limits
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Work Order: S1311292
Project: Marsland Sediment Samples

Date: 11/28/2016
Report ID: S1311292002
(Replaces S1311292001)

Thorium 230 in Soil Sample Type **MBLK** Units: pCi/g

MB13-338 (12/13/13 12:05)	RunNo: 103171	PrepDate: 12/04/13 0:00			BatchID: R103171		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Thorium230	ND	0.2					

MB13-357 (01/07/14 08:03)	RunNo: 103560	PrepDate: 12/23/13 0:00			BatchID: R103560		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Thorium230	ND	0.2					

Thorium 230 in Soil Sample Type **LCS** Units: pCi/g

LCS13-338 (12/13/13 12:05)	RunNo: 103171	PrepDate: 12/04/13 0:00			BatchID: R103171		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Thorium230	12.0	0.2	12.5		96.0	50 - 150	

LCS13-357 (01/07/14 08:03)	RunNo: 103560	PrepDate: 12/23/13 0:00			BatchID: R103560		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Thorium230	14.5	0.2	12.5		116	50 - 150	

Thorium 230 in Soil Sample Type **LCSD** Units: pCi/g

LCS13-338 DUP (12/13/13 12:05)	RunNo: 103171	PrepDate: 12/04/13 0:00			BatchID: R103171		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Thorium230	13.0	0.2	12.0	8.20	104	30	

LCS13-357 DUP (01/07/14 08:03)	RunNo: 103560	PrepDate: 12/23/13 0:00			BatchID: R103560		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Thorium230	12.6	0.2	14.5	13.4	101	30	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by another laboratory	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	R	RPD outside accepted recovery limits
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Date: 11/28/2016
Work Order: S1311292
Report ID: S1311292002 (Replaces S1311292001)
Project: Marsland Sediment Samples

Total (3050) Metals by EPA 200.8 - Soil Sample Type **MBLK** Units: pCi/g

MBLK (12/02/13 14:50)	RunNo: 102549						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	ND	0.2					

Total (3050) Metals by EPA 200.8 - Soil Sample Type **LCS** Units: pCi/g

LCS (12/02/13 14:45)	RunNo: 102549						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	67.6	0.2	67.7		99.8	85 - 115	

Total (3050) Metals by EPA 200.8 - Soil Sample Type **MS** Units: pCi/g

S1311292-001BS (12/02/13 17:29)	RunNo: 102549						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	735	0.2	745	0.4	98.7	70 - 130	

S1311293-003BS (12/02/13 19:02)	RunNo: 102549						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	709	0.2	745	0.5	95.2	70 - 130	

S1311295-006BS (12/02/13 20:21)	RunNo: 102549						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	733	0.2	745	2.8	98.0	70 - 130	

Total (3050) Metals by EPA 200.8 - Soil Sample Type **MSD** Units: pCi/g

S1311292-001BMSD (12/02/13 17:36)	RunNo: 102549						
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Uranium	716	0.2	735	2.61	96.1	20	

S1311293-003BMSD (12/02/13 19:06)	RunNo: 102549						
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Uranium	709	0.2	709	0.0711	95.1	20	

S1311295-006BMSD (12/02/13 20:26)	RunNo: 102549						
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Uranium	733	0.2	733	0.00615	98.0	20	

Total (3050) Metals by EPA 200.8 - Soil Sample Type **DUP** Units: pCi/g

S1311292-001BD (12/02/13 17:24)	RunNo: 102549						
Analyte	Result	RL	Ref Samp	%RPD	%REC	% RPD Limits	Qual
Uranium	0.4	0.2	0.4	2.56		20	

S1311293-003BD (12/02/13 18:45)	RunNo: 102549						
Analyte	Result	RL	Ref Samp	%RPD	%REC	% RPD Limits	Qual
Uranium	0.5	0.2	0.5	2.60		20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by another laboratory	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	R	RPD outside accepted recovery limits
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Date: 11/28/2016
Work Order: S1311292
Report ID: S1311292002
Project: Marsland Sediment Samples
(Replaces S1311292001)

Total (3050) Metals by EPA 200.8 - Soil Sample Type **DUP** Units: pCi/g

S1311295-006BD (12/02/13 20:16) RunNo: 102549

Analyte	Result	RL	Ref Samp	%RPD	%REC	% RPD Limits	Qual
Uranium	2.9	0.2	2.8	1.04		20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by another laboratory	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	R	RPD outside accepted recovery limits
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

Inter-Mountain Labs
Sheridan, WY and Gillette, WY

CHAIN OF CUSTODY RECORD

Page 1 of 1

All shaded fields must be completed.
This is a legal document; any misrepresentation may be construed as fraud.

#WEB

Client Name	Project Identification	Sampler (Signature/Attestation of Authenticity)	Telephone #
Cameco Resources, Crow Butte	Marsland SedimentSamples		308-665-2215x117

Report Address	Contact Name	Email	Phone	Purchase Order #	Quote #
PO Box 169 Crawford, Ne 69339	Walt Nelson	Walter.Nelson@cameco.com	308-665-2215x117		

Invoice Address: Same

ITEM	LAB ID (Lab Use Only)	DATE SAMPLED	TIME SAMPLED	SAMPLE IDENTIFICATION	Matrix	# of Containers	U, Ra226, Po210	Th230	REMARKS
1	[illegible]	10/25/13		MED-1	SL	1	x	x	Detection limits per Reg.
2	[illegible]	10/25/13		MED-2	SL	1	x	x	Guide 4.14 standards for
3	[illegible]	10/25/13		MED-3	SL	1	x	x	preoperational sediment
4	[illegible]	10/25/13		MED-4	SL	1	x	x	sampling.
5	[illegible]	10/25/13		MED-5	SL	1	x	x	
6	[illegible]	10/25/13		MED-6	SL	1	x	x	
7	[illegible]	10/25/13		N1	SL	1	x	x	
8	[illegible]	10/25/13		N2	SL	1	x	x	
9									
10									
11									
12									
13									
14									

LAB COMMENTS	Relinquished By (Signature/Printed)	DATE	TIME	Received By (Signature/Printed)	DATE	TIME
	Walter Nelson Walter Nelson	11/18/13	11:00	UPS		
				Lay Hs	11-19-13	13:34

SHIPPING INFO	MATRIX CODES		TURN AROUND TIMES	COMPLIANCE INFORMATION	ADDITIONAL REMARKS
☐ UPS	Water	WT	Check desired service	Compliance Monitoring ? Y / N	
☐ FedEx	Soil	SL	☒ Standard turnaround	Program (SDWA, NPDES,...)	
☐ USPS	Solid	SD	☐ RUSH - 5 Working Days	PWSID / Permit #	
☐ Hand Carried	Filter	FT	☐ URGENT - < 2 Working Days	Chlorinated? Y / N	
☐ Other	Other	OT	*Rush & Urgent Surcharges will be applied*	Sample Disposal: Lab x Client	

Inter-Mountain Labs

Sheridan, WY and Gillette, WY

CHAIN OF CUSTODY RECORD -

All shaded fields must be completed.

This is a legal document; any misrepresentation may be construed as fraud.

#WEB

Client Name	Project Identification	Sampler (Signature/Attestation of Authenticity)	Telephone #
Cameco Resources, Crow Butte	Marsland SedimentSamples		308-665-2215x117

Report Address	Contact Name
PO Box 169 Crawford, Ne 69339	Walt Nelson Email Walter_Nelson@cameco.com Phone 308-665-2215x117

Invoice Address	Purchase Order #	Quote #
Same		

ITEM	LAB ID (Lab Use Only)	DATE SAMPLED	TIME SAMPLED	SAMPLE IDENTIFICATION	Matrix	# of Containers	U, Ra226, Pb210	Th230							REMARKS
1	91505077	04/30/15		MED-7	SL	1	x	x							Detection limits per Reg.
2															Guide 4.14 standards for
3															preoperational sediment
4															sampling.
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															

ANALYSES / PARAMETERS

LAB COMMENTS	Relinquished By (Signature/Printed)	DATE	TIME	Received By (Signature/Printed)	DATE	TIME
	Larry Teahon	5/1/15		UPS	5/1/15	
				Kathy Boyd	5.6.15	10:52

SHIPPING INFO	MATRIX CODES		TURN AROUND TIMES	COMPLIANCE INFORMATION	ADDITIONAL REMARKS
☒ UPS	Water	WT	**Check desired service**	Compliance Monitoring ? Y / N	
☐ FedEx	Soil	SL	☒ Standard turnaround	Program (SDWA, NPDES,...)	
☐ USPS	Solid	SD	☐ **RUSH - 5 Working Days**	PWSID / Permit #	
☐ Hand Carried	Filter	FT	☐ **URGENT - < 2 Working Days**	Chlorinated? Y / N	
☐ Other	Other	OT	***Rush & Urgent Surcharges will be applied***	Sample Disposal: Lab x Client	

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Date: 6/30/2015

CLIENT: Cameco Resources, Crow Butte Operation
Project: Marsland Sediment Samples
Lab Order: S1505077

CASE NARRATIVE

Report ID: S1505077001

Sample MED-7 was received on May 6, 2015.

All samples were received and analyzed within the EPA recommended holding times, except those noted below in this case narrative. Samples were analyzed using the methods outlined in the following references:

"Standard Methods For The Examination of Water and Wastewater", approved method versions
Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, 3rd Edition
40 CFR Parts 136 and 141
40 CFR Part 50, Appendices B, J, L, and O
Methods indicated in the Methods Update Rule published in the Federal Register Friday, May 18, 2012
ASTM approved and recognized standards

All Quality Control parameters met the acceptance criteria defined by EPA and Inter-Mountain Laboratories except as indicated in this case narrative.

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Sample Analysis Report

Company: Cameco Resources, Crow Butte Operation
PO Box 169
Crawford, NE 69339

Date Reported 6/30/2015
Report ID S1505077001

ProjectName: Marshland Sediment Samples
Lab ID: S1505077-001
ClientSample ID: MED-7
COC: WEB

WorkOrder: S1505077
CollectionDate: 4/30/2015
DateReceived: 5/6/2015 10:52:00 AM
FieldSampler:
Matrix: Sediment

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	1.8E-6	µCi/g		2.0E-7	OTW01	06/08/2015 1559	MB
Lead 210 Precision (±)	5.0E-7	µCi/g			OTW01	06/08/2015 1559	MB
Radium 226	1.0E-6	µCi/g		2.0E-7	E901.1 Mod.	06/20/2015 1927	MB
Radium 226 Precision (±)	3.0E-7	µCi/g			E901.1 Mod.	06/20/2015 1927	MB
Thorium 230	4.0E-7	µCi/g		2.0E-7	ACW10	06/26/2015 845	MB
Thorium230 Precision (±)	2.0E-7	µCi/g			ACW10	06/26/2015 845	MB
Thorium229 Tracer (30-120)	38.4	%			ACW10	06/26/2015 845	MB
Metals - Total							
Uranium	5.4E-6	µCi/g		2.0E-7	EPA 200.8	05/21/2015 1623	MS

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank
E	Value above quantitation range
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
X	Matrix Effect
C	Calculated Value
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits

Reviewed by: Tom Patten
Tom Patten, Laboratory Manager

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Work Order: S1505077
Project: Marsland Sediment Samples

Date: 6/30/2015
Report ID: S1505077001

Lead 210 in Soil Sample Type **MBLK** Units: pCi/g

MB-477 (06/08/15 15:59)	RunNo: 121931	PrepDate: 05/25/15 0:00			BatchID: 10126		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	ND	1					

Lead 210 in Soil Sample Type **LCS** Units: pCi/g

LCS-477 (06/08/15 13:52)	RunNo: 121931	PrepDate: 05/25/15 0:00			BatchID: 10126		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	16	1	12.9		121	73 - 150	

Lead 210 in Soil Sample Type **MS** Units: pCi/g

MS-477 (06/08/15 13:52)	RunNo: 121931	PrepDate: 05/25/15 0:00			BatchID: 10126		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	15	1	12.9	ND	118	80 - 137	

Lead 210 in Soil Sample Type **MSD** Units: pCi/g

MSD-477 (06/08/15 13:52)	RunNo: 121931	PrepDate: 05/25/15 0:00			BatchID: 10126		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Lead 210	16	1	15	6.67	126	20	

Radium By Gamma Spectroscopy in Soil Sample Type **MBLK** Units: pCi/g

MB-10309 (06/20/15 18:45)	RunNo: 122532	PrepDate: 05/14/15 13:12			BatchID: 10309		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Radium 226	ND	0.2					

Radium By Gamma Spectroscopy in Soil Sample Type **LCS** Units: pCi/g

LCS-10309 (06/20/15 19:05)	RunNo: 122532	PrepDate: 05/14/15 13:12			BatchID: 10309		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Radium 226	510	0.2	534		95.5	70 - 130	

Thorium 230 in Soil Sample Type **MBLK** Units: pCi/g

MB-448 (06/26/15 08:45)	RunNo: 122908	PrepDate: 06/15/15 0:00			BatchID: R122908		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Thorium230	ND	0.2					

Thorium 230 in Soil Sample Type **LCS** Units: pCi/g

LCS448 (06/25/15 09:47)	RunNo: 122908	PrepDate: 06/15/15 0:00			BatchID: R122908		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Thorium230	12.9	0.2	12.5		103	64.6 - 147	

Thorium 230 in Soil Sample Type **LCSD** Units: pCi/g

LCSD-448 (06/25/15 09:47)	RunNo: 122908	PrepDate: 06/15/15 0:00			BatchID: R122908		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Thorium230	10.9	0.2	12.9	16.7	87.5	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by a contract laboratory	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	R	RPD outside accepted recovery limits
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Work Order: S1505077
Project: Marshland Sediment Samples

Date: 6/30/2015
Report ID: S1505077001

Total (3050) Metals by EPA 200.8 - Soil Sample Type **MBLK** Units: pCi/g

MBLK (05/21/15 13:29) RunNo: 121108

Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	ND	0.2					

Total (3050) Metals by EPA 200.8 - Soil Sample Type **LCS** Units: pCi/g

LCS (05/21/15 13:24) RunNo: 121108

Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	67.4	0.2	67.7		99.6	85 - 115	

Total (3050) Metals by EPA 200.8 - Soil Sample Type **MS** Units: pCi/g

S1505077-001AS (05/21/15 16:44) RunNo: 121108

Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	6660	0.2	6910	5.4	96.4	70 - 130	

Total (3050) Metals by EPA 200.8 - Soil Sample Type **MSD** Units: pCi/g

S1505077-001AMSD (05/21/15 16:49) RunNo: 121108

Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Uranium	6670	0.2	6660	0.103	96.5	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by a contract laboratory	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	R	RPD outside accepted recovery limits
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

Inter-Mountain Labs
Sheridan, WY and Gillette, WY

CHAIN OF CUSTODY RECORD -

All shaded fields must be completed.
This is a legal document; any misrepresentation may be construed as fraud.

#WEB

Client Name	Project Identification	Sampler (Signature/Attestation of Authenticity)	Telephone #
Cameco Resources, Crow Butte	Marsland SedimentSamples		308-665-2215x117

Report Address	Contact Name
PO Box 169 Crawford, Ne 69339	Walt Nelson Email Walter_Nelson@cameco.com Phone 308-665-2215x117

Invoice Address	Purchase Order #	Quote #
Same		

ITEM	LAB ID (Lab Use Only)	DATE SAMPLED	TIME	SAMPLE IDENTIFICATION	Matrix	# of Containers	U, Ra226, Pb210	Th230	REMARKS
1	S1410414-001	10/17/14		MED-7	SL	1	x	x	Detection limits per Reg. Guide 4.14 standards for preoperational sediment sampling.
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									

ANALYSES / PARAMETERS

LAB COMMENTS	Relinquished By (Signature/Printed)	DATE	TIME	Received By (Signature/Printed)	DATE	TIME
	Brooke Bass Brooke Bass	10/27/14	0905	Action Cargo	1045	10/27/14
				Kathy Bopp	10:28.14	10:43

SHIPPING INFO	MATRIX CODES		TURN AROUND TIMES	COMPLIANCE INFORMATION	ADDITIONAL REMARKS
☐ UPS	Water	WT	Check desired service	Compliance Monitoring ? Y / N	
☐ FedEx	Soil	SL	☒ Standard turnaround	Program (SDWA, NPDES,...)	
☐ USPS	Solid	SD	☐ RUSH - 5 Working Days	PWSID / Permit #	
☐ Hand Carried	Filter	FT	☐ URGENT - < 2 Working Days	Chlorinated? Y / N	
☐ Other	Other	OT	*Rush & Urgent Surcharges will be applied*	Sample Disposal: Lab x Client	

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Date: 12/15/2014

CLIENT: Cameco Resources, Crow Butte Operation
Project: Marsland Sediment Samples
Lab Order: S1410414

CASE NARRATIVE

Report ID: S1410414001

Sample MED-7 was received on October 28, 2014.

All samples were received and analyzed within the EPA recommended holding times, except those noted below in this case narrative. Samples were analyzed using the methods outlined in the following references:

"Standard Methods For The Examination of Water and Wastewater", approved method versions
Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, 3rd Edition
40 CFR Parts 136 and 141
40 CFR Part 50, Appendices B, J, L, and O
Methods indicated in the Methods Update Rule published in the Federal Register Friday, May 18, 2012
ASTM approved and recognized standards

All Quality Control parameters met the acceptance criteria defined by EPA and Inter-Mountain Laboratories except as indicated in this case narrative.

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Sample Analysis Report

Company: Cameco Resources, Crow Butte Operation
PO Box 169
Crawford, NE 69339

Date Reported 12/15/2014
Report ID S1410414001

ProjectName: Marsland Sediment Samples
Lab ID: S1410414-001
ClientSample ID: MED-7
COC: WEB

WorkOrder: S1410414
CollectionDate: 10/17/2014
DateReceived: 10/28/2014
FieldSampler:
Matrix: Sediment

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	0.7	pCi/g		0.2	OTW01	11/11/2014 1704	MB
Lead 210 Precision (±)	0.1	pCi/g			OTW01	11/11/2014 1704	MB
Radium 226	0.6	pCi/g		0.2	SM 7500 Ra-B	11/12/2014 1310	MB
Radium 226 Precision (±)	0.1	pCi/g			SM 7500 Ra-B	11/12/2014 1310	MB
Thorium 230	1.5	pCi/g		0.2	ACW10	12/09/2014 810	MB
Thorium230 Precision (±)	1.7	pCi/g			ACW10	12/09/2014 810	MB
Thorium229 Tracer (30-120)	80.5	%			ACW10	12/09/2014 810	MB
Metals - Total							
Uranium	7.2	pCi/g		0.2	EPA 200.8	10/31/2014 1625	MS

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank
E	Value above quantitation range
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
X	Matrix Effect
C	Calculated Value
H	Holding times for preparation or analysis exceeded
L	Analyzed by a contract laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Work Order: S1410414
Project: Marsland Sediment Samples

Date: 12/15/2014
Report ID: S1410414001

Lead 210 in Soil Sample Type **MBLK** Units: pCi/g

MB-421 (11/11/14 17:04)	RunNo: 114837	PrepDate: 11/03/14 0:00			BatchID: R114837		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	ND	1					

MB-421 (11/11/14 17:04)	RunNo: 114837	PrepDate: 11/03/14 0:00			BatchID: R114837		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	ND	1					

Lead 210 in Soil Sample Type **LCS** Units: pCi/g

LCS-421 (11/11/14 17:04)	RunNo: 114837	PrepDate: 11/03/14 0:00			BatchID: R114837		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	15	1	11.8		129	80 - 145	

Lead 210 in Soil Sample Type **MS** Units: pCi/g

TAPMS-421 (11/11/14 17:04)	RunNo: 114837	PrepDate: 11/03/14 0:00			BatchID: R114837		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	15	1	12.5	ND	115	73.8 - 150	

Lead 210 in Soil Sample Type **MSD** Units: pCi/g

TAPMSD-421 (11/11/14 17:04)	RunNo: 114837	PrepDate: 11/03/14 0:00			BatchID: R114837		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Lead 210	13	1	15	16.0	97.2	20	

Radium 226 by SM 7500 Sample Type **MBLK** Units: pCi/L

MB-1361 (11/12/14 13:10)	RunNo: 114899	PrepDate: 10/29/14 10:00			BatchID: 9186		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Radium 226	ND	0.2					

Radium 226 by SM 7500 Sample Type **LCS** Units: pCi/L

LCS-1361 (11/12/14 13:10)	RunNo: 114899	PrepDate: 10/29/14 10:00			BatchID: 9186		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Radium 226	8.4	0.2	10		83.4	80 - 120	

Radium 226 by SM 7500 Sample Type **MS** Units: pCi/L

TAPMS-1361 (11/12/14 13:10)	RunNo: 114899	PrepDate: 10/29/14 10:00			BatchID: 9186		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Radium 226	8.9	0.2	10	ND	88.9	72.4 - 124	

Radium 226 by SM 7500 Sample Type **MSD** Units: pCi/L

TAPMSD-1361 (11/12/14 13:10)	RunNo: 114899	PrepDate: 10/29/14 10:00			BatchID: 9186		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Radium 226	9.8	0.2	8.9	9.91	98.2	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by a contract laboratory	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	R	RPD outside accepted recovery limits
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Work Order: S1410414
Project: Marsland Sediment Samples
Date: 12/15/2014
Report ID: S1410414001

Thorium 230 in Soil Sample Type **MBLK** Units: pCi/g

MB-392 (12/09/14 08:10)	RunNo: 115898	PrepDate: 11/25/14 0:00			BatchID: R115898		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Thorium230	ND	0.2					

Thorium 230 in Soil Sample Type **LCS** Units: pCi/g

LCS-392 (12/04/14 09:58)	RunNo: 115898	PrepDate: 11/25/14 0:00			BatchID: R115898		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Thorium230	12.5	0.2	12.5		100	63 - 144	

Thorium 230 in Soil Sample Type **LCSD** Units: pCi/g

LCSD-392 (12/04/14 09:58)	RunNo: 115898	PrepDate: 11/25/14 0:00			BatchID: R115898		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Thorium230	11.8	0.2	12.5	5.68	94.7	20	

Total (3050) Metals by EPA 200.8 - Soil Sample Type **MBLK** Units: pCi/g

MBLK (10/31/14 12:41)	RunNo: 114452						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	ND	0.2					

Total (3050) Metals by EPA 200.8 - Soil Sample Type **LCS** Units: pCi/g

LCS (10/31/14 12:36)	RunNo: 114452						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	68.3	0.2	67.7		101	85 - 115	

Total (3050) Metals by EPA 200.8 - Soil Sample Type **MS** Units: pCi/g

S1410334-001AS (10/31/14 14:11)	RunNo: 114452						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	8300	0.2	8190	21.5	101	70 - 130	

S1410334-011AS (10/31/14 15:32)	RunNo: 114452						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	8060	0.2	8190	2.3	98.4	70 - 130	

Total (3050) Metals by EPA 200.8 - Soil Sample Type **MSD** Units: pCi/g

S1410334-001AMSD (10/31/14 14:16)	RunNo: 114452						
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Uranium	8190	0.2	8300	1.43	99.7	20	

S1410334-011AMSD (10/31/14 15:47)	RunNo: 114452						
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Uranium	7970	0.2	8060	1.19	97.2	20	

Total (3050) Metals by EPA 200.8 - Soil Sample Type **DUP** Units: pCi/g

S1410334-001AD (10/31/14 14:05)	RunNo: 114452						
Analyte	Result	RL	Ref Samp	%RPD	%REC	% RPD Limits	Qual
Uranium	20.9	0.2	21.5	2.70		20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by a contract laboratory	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	R	RPD outside accepted recovery limits
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Work Order: S1410414
Project: Marsland Sediment Samples

Date: 12/15/2014
Report ID: S1410414001

Total (3050) Metals by EPA 200.8 - Soil Sample Type **DUP** Units: pCi/g

S1410334-011AD (10/31/14 15:26)	RunNo: 114452						
Analyte	Result	RL	Ref Samp	%RPD	%REC	% RPD Limits	Qual
Uranium	2.3	0.2	2.3	0.612		20	

S1410334-015AD (10/31/14 16:14)	RunNo: 114452						
Analyte	Result	RL	Ref Samp	%RPD	%REC	% RPD Limits	Qual
Uranium	2.8	0.2	2.7	2.60		20	

S1410334-005AD (10/31/14 17:29)	RunNo: 114452						
Analyte	Result	RL	Ref Samp	%RPD	%REC	% RPD Limits	Qual
Uranium	22.3	0.2	22.2	0.517		20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by a contract laboratory	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	R	RPD outside accepted recovery limits
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

Replacement Pages – Appendix X

Instructions:

Remove and Replace all of Appendix X

MEA TR

Reponses to Open Issues

6-29-2017

Appendix X

Niobrara River Fish Tissue Laboratory Records

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Date: 9/30/2014

CLIENT: Cameco Resources, Crow Butte Operation
Project: Spring Box Butte Sample
Lab Order: S1408283

CASE NARRATIVE

Report ID: S1408283001

Sample Spring Box Butte Fish Tissue was received on August 15, 2014.

All samples were received and analyzed within the EPA recommended holding times, except those noted below in this case narrative. Samples were analyzed using the methods outlined in the following references:

"Standard Methods For The Examination of Water and Wastewater", approved method versions
Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, 3rd Edition
40 CFR Parts 136 and 141
40 CFR Part 50, Appendices B, J, L, and O
Methods indicated in the Methods Update Rule published in the Federal Register Friday, May 18, 2012
ASTM approved and recognized standards

All Quality Control parameters met the acceptance criteria defined by EPA and Inter-Mountain Laboratories except as indicated in this case narrative.

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Sample Analysis Report

Company: Cameco Resources, Crow Butte Operation
PO Box 169
Crawford, NE 69339

Date Reported 1/27/2015
Report ID S1408283004
(Replaces S1408283003)

ProjectName: Spring Box Butte Sample
Lab ID: S1408283-001
ClientSample ID: Spring Box Butte Fish Tissue
COC: WEB

WorkOrder: S1408283
CollectionDate: 5/25/2014
DateReceived: 8/15/2014 11:31:00 AM
FieldSampler:
Matrix: Fish Tissue

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	2.8E-5	µCi/kg		1.0E-6	OTW01	09/13/2014 1255	MB
Lead 210 Precision (±)	1.5E-5	µCi/kg			OTW01	09/13/2014 1255	MB
Polonium 210	8.1E-6	µCi/kg		1.0E-6	OTW01	09/22/2014 1709	MB
Polonium 210 Precision (±)	7.0E-6	µCi/kg			OTW01	09/22/2014 1709	MB
Radium 226	4.1E-6	µCi/kg		5.0E-8	SM 7500 Ra-B	09/22/2014 1343	MB
Radium 226 Precision (±)	2.2E-6	µCi/kg			SM 7500 Ra-B	09/22/2014 1343	MB
Thorium 230	8.0E-7	µCi/kg		2.0E-7	ACW10	09/19/2014 1311	MB
Thorium230 Precision (±)	1.6E-6	µCi/kg			ACW10	09/19/2014 1311	MB
Thorium229 Tracer (30-120)	56.5	%			ACW10	09/19/2014 1311	MB
Uranium	2.1E-6	µCi/kg		2.0E-7	EPA 200.8	09/25/2014 1313	MS
Metals - Total							
Uranium	0.0031	mg/Kg		0.0003	EPA 200.8	09/25/2014 000	MS

These results apply only to the samples tested. **RL - Reporting Limit**

Qualifiers:

B	Analyte detected in the associated Method Blank	C	Calculated Value
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	L	Analyzed by a contract laboratory
M	Value exceeds Monthly Ave or MCL or is less than LCL	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	S	Spike Recovery outside accepted recovery limits
X	Matrix Effect		

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Work Order: S1408283
Project: Spring Box Butte Sample

Date: 9/30/2014
Report ID: S1408283001

Pb210 in Animals Sample Type **MBLK** Units: pCi/Kg

MB-408 (09/13/14 12:55)	RunNo: 113035	PrepDate: 09/12/14 0:00				BatchID: R113035		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits		Qual
Lead 210	ND	1						

Pb210 in Animals Sample Type **LCS** Units: pCi/Kg

LCS-408 (09/23/14 09:41)	RunNo: 113035	PrepDate: 09/12/14 0:00				BatchID: R113035		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits		Qual
Lead 210	14	1	11.8		117	50 - 150		

Pb210 in Animals Sample Type **MS** Units: pCi/Kg

TAPMS-408 (09/23/14 09:41)	RunNo: 113035	PrepDate: 09/12/14 0:00				BatchID: R113035		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits		Qual
Lead 210	14	1	12.3	ND	105	50 - 150		

Pb210 in Animals Sample Type **MSD** Units: pCi/Kg

TAPMSD-408 (09/23/14 09:41)	RunNo: 113035	PrepDate: 09/12/14 0:00			BatchID: R113035		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Lead 210	13	1	14	3.69	93.8	20	

Po210 in Animal Sample Type **MBLK** Units: pCi/Kg

MB-408 (09/22/14 17:09)	RunNo: 113043	PrepDate: 09/12/14 0:00				BatchID: R113043		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits		Qual
Polonium 210	ND	1						

Po210 in Animal Sample Type **LCS** Units: pCi/Kg

LCS-408 (09/22/14 16:07)	RunNo: 113043	PrepDate: 09/12/14 0:00				BatchID: R113043		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits		Qual
Polonium 210	14	1	12.9		105	59.4 - 129		

Po210 in Animal Sample Type **MS** Units: pCi/Kg

TAPMS-408 (09/22/14 16:07)	RunNo: 113043	PrepDate: 09/12/14 0:00				BatchID: R113043		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits		Qual
Polonium 210	12	1	12.3	ND	101	58.7 - 143		

Po210 in Animal Sample Type **MSD** Units: pCi/Kg

TAPMSD-408 (09/22/14 16:07)	RunNo: 113043	PrepDate: 09/12/14 0:00			BatchID: R113043		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Polonium 210	12	1	12	1.89	99.0	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by a contract laboratory	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	R	RPD outside accepted recovery limits
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Date: 9/30/2014
Work Order: S1408283
Report ID: S1408283001
Project: Spring Box Butte Sample

Radium 226 in Animal Sample Type **MBLK** Units: pCi/Kg

MB2-1341 (09/22/14 13:43)	RunNo: 112982	PrepDate: 09/17/14 0:00			BatchID: R112982		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Radium 226	ND	0.2					

Radium 226 in Animal Sample Type **LCS** Units: pCi/Kg

LCS-1341 (09/22/14 10:24)	RunNo: 112982	PrepDate: 09/17/14 0:00			BatchID: R112982		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Radium 226	4.6	0.2	5		92.7	80 - 120	

Radium 226 in Animal Sample Type **MS** Units: pCi/Kg

TAPMS-1341 (09/22/14 10:24)	RunNo: 112982	PrepDate: 09/17/14 0:00			BatchID: R112982		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Radium 226	4.6	0.2	5	0.2	87.7	73.8 - 120	

Radium 226 in Animal Sample Type **MSD** Units: pCi/Kg

TAPMSD-1341 (09/22/14 10:24)	RunNo: 112982	PrepDate: 09/17/14 0:00			BatchID: R112982		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Radium 226	4.9	0.2	4.6	6.36	93.6	0	

Thorium 230 in Animal Sample Type **MBLK** Units: pCi/Kg

MB-374 (09/19/14 13:11)	RunNo: 112897	PrepDate: 09/16/14 0:00			BatchID: R112897		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Thorium230	ND	0.2					

Thorium 230 in Animal Sample Type **LCS** Units: pCi/Kg

LCS-374 (09/19/14 13:11)	RunNo: 112897	PrepDate: 09/16/14 0:00			BatchID: R112897		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Thorium230	13.4	0.2	12.5		107	66.4 - 143	

Thorium 230 in Animal Sample Type **DUP** Units: pCi/Kg

LCSD-374 (09/19/14 13:11)	RunNo: 112897	PrepDate: 09/16/14 0:00			BatchID: R112897		
Analyte	Result	RL	Ref Samp	%RPD	%REC	% RPD Limits	Qual
Thorium230	12.2	0.2	13.4	9.06		20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by a contract laboratory	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	R	RPD outside accepted recovery limits
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Work Order: S1408283
Project: Spring Box Butte Sample

Date: 9/30/2014
Report ID: S1408283001

Total (3050) Metals by EPA 200.8 Sample Type **MBLK** Units: pCi/Kg

MBLK (09/25/14 12:46)	RunNo: 113135						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	ND	0.2					

Total (3050) Metals by EPA 200.8 Sample Type **LCS** Units: pCi/Kg

LCS (09/25/14 12:41)	RunNo: 113135						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	70.4	0.2	67.7		104	85 - 115	

Total (3050) Metals by EPA 200.8 Sample Type **MS** Units: pCi/Kg

S1408283-001AS (09/25/14 13:24)	RunNo: 113135						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	3750	0.2	3720	2.1	101	70 - 130	

Total (3050) Metals by EPA 200.8 Sample Type **MSD** Units: pCi/Kg

S1408283-001AMSD (09/25/14 13:29)	RunNo: 113135						
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Uranium	3780	0.2	3750	0.755	102	20	

Total (3050) Metals by EPA 200.8 Sample Type **DUP** Units: pCi/Kg

S1408283-001AD (09/25/14 13:18)	RunNo: 113135						
Analyte	Result	RL	Ref Samp	%RPD	%REC	% RPD Limits	Qual
Uranium	2.1	0.2	2.1	0.829		20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by a contract laboratory	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	R	RPD outside accepted recovery limits
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

Inter-Mountain Labs

Sheridan, WY and Gillette, WY

CHAIN OF CUSTODY RECORD

Page 1 of 1

All shaded fields must be completed.

This is a legal document; any misrepresentation may be construed as fraud.

#WEB

Client Name	Project Identification	Sampler (Signature/Attestation of Authenticity)	Telephone #
Cameco Resources, Crow Butte	Spring Box Butte Fish Sample		308-665-2215x117

Report Address	Contact Name	Email	Phone
PO Box 169 Crawford, Ne 69339	Walt Nelson	Walter_Nelson@cameco.com	308-665-2215x117

Invoice Address	Purchase Order #	Quote #
Same		

ITEM	LAB ID (Lab Use Only)	DATE SAMPLED	TIME SAMPLED	SAMPLE IDENTIFICATION	Matrix	# of Containers	ANALYSES / PARAMETERS: U-nat, Ra226, Pb210	ANALYSES / PARAMETERS: Th230, Po210	REMARKS
1	S406285-01	05/25/14		Spring Box Butte Fish Tissue	SD	1 cooler	x	x	Detection limits per Reg. Guide 4.14 standards for preoperational fish sampling. U=2x10-7ucl/kg Th=2x10-7ucl/kg Ra=5x10-8uci/kg Po=1x10-6ucl/kg Pb=1x10-6ucl/kg
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									Approximately 4 lbs. frozen fish tissue.
12									
13									
14									

LAB COMMENTS	Relinquished By (Signature/Printed)	DATE	TIME	Received By (Signature/Printed)	DATE	TIME
	Brad Bass Brad Bass	8-14-14	10:10	Action Cargo	8-14-14	10:10
				Kay Lutes	8-15-14	11:31

SHIPPING INFO	MATRIX CODES		TURN AROUND TIMES	COMPLIANCE INFORMATION	ADDITIONAL REMARKS
☐ UPS	Water	WT	Check desired service	Compliance Monitoring ? Y / N	
☐ FedEx	Soil	SL	☒ Standard turnaround	Program (SDWA, NPDES,...)	
☐ USPS	Solid	SD	☐ RUSH - 5 Working Days	PWSID / Permit #	
☐ Hand Carried	Filter	FT	☐ URGENT - < 2 Working Days	Chlorinated? Y / N	
☐ Other	Other	OT	*Rush & Urgent Surcharges will be applied*	Sample Disposal: Lab x Client	

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Date: 11/28/2016

CLIENT: Cameco Resources, Crow Butte Operation
Project: Fall Box Butte Fish Sample
Lab Order: S1410151

CASE NARRATIVE

Report ID: S1410151004
(Replaces S1410151003)

Sample Fall Box Butte Fish Tissue was received on October 8, 2014.

All samples were received and analyzed within the recommended holding times, except those noted below in this case narrative. Samples were analyzed using the methods outlined in the following references:

NRC radiological air particulate filters, animal, vegetation, soil and sediment samples may be composited by date and location per client's monitoring program requirements. Highly carbonaceous samples may require ashing. Samples are subjected to a modified USEPA SW-846 Method 3050B mineral acid digestion as appropriate. Analysis of the resulting solutions and digestates is performed using approved TNI, USEPA, and industry recognized analytical techniques. Where client-provided air volumes corresponding to the air filter composites exist, aqueous digestate results are converted to radiological particulate concentrations in air (e.g. µCi/mL). Quality control parameters acceptance criteria are defined by USEPA programs, and in USNRC Regulatory Guide 4.14 (Radiological Effluent and Environmental Monitoring at Uranium Mills), USNRC Regulatory Guide 4.15 (Quality Assurance for Radiological Monitoring Programs – Effluent Streams and the Environment), the TNI Standard EL-V1-2009, and Inter-Mountain Labs internal quality procedures.

All Quality Control parameters met the acceptance criteria defined by EPA, NRC guidance, and Inter-Mountain Laboratories except as indicated in this case narrative.

The precision is reported as counting error per MARLAP recommendations Vol. 13 2004.

Report S1410151004 replaces Report S1410151003. The report was revised to display values below the reporting limit.

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Inter-Mountain Labs
Your Environmental Monitoring Partner
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Sample Analysis Report

Company: Cameco Resources, Crow Butte Operation
PO Box 169
Crawford, NE 69339

Date Reported 11/28/2016
Report ID S1410151004
(Replaces S1410151003)

ProjectName: Fall Box Butte Fish Sample
Lab ID: S1410151-001
ClientSample ID: Fall Box Butte Fish Tissue
COC: WEB

WorkOrder: S1410151
CollectionDate: 9/26/2014
DateReceived: 10/8/2014
FieldSampler:
Matrix: Fish Tissue

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	6.0E-7	µCi/kg		1.0E-6	OTW01	11/04/2014 842	MB
Lead 210 Precision (±)	2.9E-6	µCi/kg			OTW01	11/04/2014 842	MB
Polonium 210	-2.0E-7	µCi/kg		1.0E-6	OTW01	10/31/2014 1639	MB
Polonium 210 Precision (±)	8.0E-7	µCi/kg			OTW01	10/31/2014 1639	MB
Radium 226	8.0E-7	µCi/kg		5.0E-8	SM 7500 Ra-B	11/05/2014 1249	MB
Radium 226 Precision (±)	3.0E-7	µCi/kg			SM 7500 Ra-B	11/05/2014 1249	MB
Thorium 230	4.0E-7	µCi/kg		2.0E-7	ACW10	11/03/2014 1010	MB
Thorium230 Precision (±)	3.0E-7	µCi/kg			ACW10	11/03/2014 1010	MB
Thorium229 Tracer (30-120)	85.7	%			ACW10	11/03/2014 1010	MB
Uranium	1.5E-6	µCi/kg		2.0E-7	EPA 200.8	10/27/2014 2003	MS
Uranium	0.0023	mg/Kg		0.0003	EPA 200.8	10/27/2014 000	MS

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank
E	Value above quantitation range
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
X	Matrix Effect
C	Calculated Value
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945
Your Environmental Monitoring Partner

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Work Order: S1410151
Project: Fall Box Butte Fish Sample

Date: 11/28/2016
Report ID: S1410151004
(Replaces S1410151003)

Pb210 in Animals Sample Type **MBLK** Units: pCi/Kg

MB-419 (11/04/14 08:42)	RunNo: 114590	PrepDate: 10/28/14 0:00			BatchID: R114590		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	ND	1					

Pb210 in Animals Sample Type **LCS** Units: pCi/Kg

LCS-419 (11/04/14 08:42)	RunNo: 114590	PrepDate: 10/28/14 0:00			BatchID: R114590		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	13	1	11.8		110	79.4 - 145	

Pb210 in Animals Sample Type **MS** Units: pCi/Kg

TAPMS-419 (11/04/14 08:42)	RunNo: 114590	PrepDate: 10/28/14 0:00			BatchID: R114590		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	14	1	12.5	ND	110	80 - 129	

Pb210 in Animals Sample Type **MSD** Units: pCi/Kg

TAPMSD-419 (11/04/14 08:42)	RunNo: 114590	PrepDate: 10/28/14 0:00			BatchID: R114590		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Lead 210	13	1	14	6.11	104	20	

Po210 in Animal Sample Type **MBLK** Units: pCi/Kg

MB-419 (10/31/14 16:39)	RunNo: 114597	PrepDate: 10/30/14 0:00			BatchID: R114597		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Polonium 210	ND	1					

Po210 in Animal Sample Type **LCS** Units: pCi/Kg

LCS-419 (10/31/14 16:39)	RunNo: 114597	PrepDate: 10/30/14 0:00			BatchID: R114597		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Polonium 210	8	1	10.1		79.4	50 - 150	

Po210 in Animal Sample Type **MS** Units: pCi/Kg

TAPMS-419 (10/31/14 16:39)	RunNo: 114597	PrepDate: 10/30/14 0:00			BatchID: R114597		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Polonium 210	14	1	12.5	ND	111	60.9 - 134	

Po210 in Animal Sample Type **MSD** Units: pCi/Kg

TAPMSD-419 (10/31/14 16:39)	RunNo: 114597	PrepDate: 10/30/14 0:00			BatchID: R114597		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Polonium 210	11	1	14	22.9	88.6	30	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by another laboratory	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	R	RPD outside accepted recovery limits
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Date: 11/28/2016
Work Order: S1410151
Report ID: S1410151004 (Replaces S1410151003)
Project: Fall Box Butte Fish Sample

Radium 226 in Animal Sample Type **MBLK** Units: pCi/L

MB-1359 (11/05/14 12:49)	RunNo: 114701	PrepDate: 10/29/14 0:00			BatchID: 9162		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Radium 226	ND	0.05					

Radium 226 in Animal Sample Type **LCS** Units: pCi/L

LCS-1359 (11/05/14 10:39)	RunNo: 114701	PrepDate: 10/29/14 0:00			BatchID: 9162		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Radium 226	5.1	0.05	5		102	56.9 - 139	

Radium 226 in Animal Sample Type **MS** Units: pCi/L

TAPMS-1359 (11/05/14 10:39)	RunNo: 114701	PrepDate: 10/29/14 0:00			BatchID: 9162		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Radium 226	4.6	0.05	5	0.07	91.1	79.6 - 122	

Radium 226 in Animal Sample Type **MSD** Units: pCi/L

TAPMSD-1359 (11/05/14 10:39)	RunNo: 114701	PrepDate: 10/29/14 0:00			BatchID: 9162		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Radium 226	4.5	0.05	4.6	2.12	89.2	0	

Thorium 230 in Animal Sample Type **MBLK** Units: pCi/Kg

MB-385 (11/03/14 10:10)	RunNo: 114525	PrepDate: 10/28/14 0:00			BatchID: R114525		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Thorium230	ND	0.2					

Thorium 230 in Animal Sample Type **LCS** Units: pCi/Kg

LCS-385 (11/03/14 10:10)	RunNo: 114525	PrepDate: 10/28/14 0:00			BatchID: R114525		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Thorium230	13.4	0.2	12.5		108	50 - 143	

Thorium 230 in Animal Sample Type **DUP** Units: pCi/Kg

LCSD-385 (11/03/14 10:10)	RunNo: 114525	PrepDate: 10/28/14 0:00			BatchID: R114525		
Analyte	Result	RL	Ref Samp	%RPD	%REC	% RPD Limits	Qual
Thorium230	12.9	0.2	13.4	4.45		30	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by another laboratory	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	R	RPD outside accepted recovery limits
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Date: 11/28/2016
Work Order: S1410151
Report ID: S1410151004 (Replaces S1410151003)
Project: Fall Box Butte Fish Sample

Total (3050) Metals by EPA 200.8 Sample Type **MBLK** Units: pCi/Kg

MBLK (10/27/14 12:53) RunNo: 114262

Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	ND	0.2					

Total (3050) Metals by EPA 200.8 Sample Type **LCS** Units: pCi/Kg

LCS (10/27/14 12:48) RunNo: 114262

Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	68.9	0.2	67.7		102	85 - 115	

Total (3050) Metals by EPA 200.8 Sample Type **MS** Units: pCi/Kg

S1410151-001AS (10/27/14 20:24) RunNo: 114262 PrepDate: 10/14/14 14:13 BatchID: 9036

Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	2490	0.2	2480	1.5	101	70 - 130	

Total (3050) Metals by EPA 200.8 Sample Type **MSD** Units: pCi/Kg

S1410151-001AMSD (10/27/14 20:29) RunNo: 114262 PrepDate: 10/14/14 14:13 BatchID: 9036

Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Uranium	2480	0.2	2490	0.454	100	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by another laboratory	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	R	RPD outside accepted recovery limits
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

Inter-Mountain Labs
Sheridan, WY and Gillette, WY

CHAIN OF CUSTODY RECORD

Page 1 of 1

All shaded fields must be completed.
This is a legal document; any misrepresentation may be construed as fraud.

#WEB

Client Name	Project Identification	Sampler (Signature/Attestation of Authenticity)	Telephone #
Cameco Resources, Crow Butte	Fall Box Butte Fish Sample		308-665-2215x117

Report Address	Contact Name	Email	Phone
PO Box 169 Crawford, Ne 69339	Walt Nelson	Walter.Nelson@cameco.com	308-665-2215x117

Invoice Address	Purchase Order #	Quote #
Same		

ITEM	LAB ID (Lab Use Only)	DATE SAMPLED	TIME	SAMPLE IDENTIFICATION	Matrix	# of Containers	U-nat, Ra226, Pb210	Th230, Po210							REMARKS
1		09/26/14		Fall Box Butte Fish Tissue	SD	1 cooler	x	x							Detection limits per Reg.
2															Guide 4.14 standards for
3															preoperational fish
4															sampling.
5															U=2x10-7ucl/kg
6															Th=2x10-7ucl/kg
															Ra=5x10-8ucl/kg
8															Po=1x10-6ucl/kg
9															Pb=1x10-6ucl/kg
10															
11															Approximately 7 lbs.
12															frozen fish tissue.
13															3.3 Kg
14															

LAB COMMENTS	Relinquished By (Signature/Printed)	DATE	TIME	Received By (Signature/Printed)	DATE	TIME
	[illegible]	10/1/14	10:00	Action Cargo	10/1/14	10:00
				Kathy Poop	10.8.14	10:44

SHIPPING INFO	MATRIX CODES		TURN AROUND TIMES	COMPLIANCE INFORMATION	ADDITIONAL REMARKS
☐ UPS	Water	WT	Check desired service:	Compliance Monitoring ? Y / N	
☐ FedEx	Soil	SL	☒ Standard turnaround	Program (SDWA, NPDES,...)	
☐ USPS	Solid	SD	☐ RUSH - 5 Working Days	PWSID / Permit #	
☐ Hand Carried	Filter	FT	☐ URGENT - < 2 Working Days	Chlorinated? Y / N	
☐ Other	Other	OT	*Rush & Urgent Surcharges will be applied*	Sample Disposal: Lab ☒ Client	

Replacement Pages – Appendix DD

Instructions:

Remove and Replace all of Appendix DD

MEA TR

Reponses to Open Issues

6-29-2017

Appendix DD

Livestock Analytical Data

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Date: 11/28/2016

CLIENT: Cameco Resources, Crow Butte Operation
Project: Marsland Beef Samples
Lab Order: S1404031

CASE NARRATIVE

Report ID: S1404031003
(Replaces S1404031002)

Samples Marsland Beef Sample #1, Marsland Beef Sample #2, and Marsland Beef Sample #3 were received on April 1, 2014.

All samples were received and analyzed within the recommended holding times, except those noted below in this case narrative. Samples were analyzed using the methods outlined in the following references:

NRC radiological air particulate filters, animal, vegetation, soil and sediment samples may be composited by date and location per client's monitoring program requirements. Highly carbonaceous samples may require ashing. Samples are subjected to a modified USEPA SW-846 Method 3050B mineral acid digestion as appropriate. Analysis of the resulting solutions and digestates is performed using approved TNI, USEPA, and industry recognized analytical techniques. Where client-provided air volumes corresponding to the air filter composites exist, aqueous digestate results are converted to radiological particulate concentrations in air (e.g. µCi/mL). Quality control parameters acceptance criteria are defined by USEPA programs, and in USNRC Regulatory Guide 4.14 (Radiological Effluent and Environmental Monitoring at Uranium Mills), USNRC Regulatory Guide 4.15 (Quality Assurance for Radiological Monitoring Programs – Effluent Streams and the Environment), the TNI Standard EL-V1-2009, and Inter-Mountain Labs internal quality procedures.

All Quality Control parameters met the acceptance criteria defined by EPA, NRC guidance, and Inter-Mountain Laboratories except as indicated in this case narrative.

The precision is reported as counting error per MARLAP recommendations Vol. 13 2004.

Report S1404031003 replaces Report S1404031002. The report was revised to display values below the reporting limit.

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Sample Analysis Report

Company: Cameco Resources, Crow Butte Operation
PO Box 169
Crawford, NE 69339

Date Reported 11/28/2016
Report ID S1404031003
(Replaces S1404031002)

ProjectName: Marsland Beef Samples
Lab ID: S1404031-001
ClientSample ID: Marsland Beef Sample #1
COC: WEB

WorkOrder: S1404031
CollectionDate: 3/28/2014
DateReceived: 4/1/2014 10:40:00 AM
FieldSampler:
Matrix: Animal

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	8.8E-6	µCi/kg		1.0E-6	OTW01	04/28/2014 1117	MB
Lead 210 Precision (±)	4.0E-6	µCi/kg			OTW01	04/28/2014 1117	MB
Polonium 210	-4.0E-7	µCi/kg		1.0E-6	OTW01	04/28/2014 1434	MB
Polonium 210 Precision (±)	6.0E-7	µCi/kg			OTW01	04/28/2014 1434	MB
Radium 226	1.2E-6	µCi/kg		5.0E-8	SM 7500 Ra-B	04/28/2014 1533	MB
Radium 226 Precision (±)	4.0E-7	µCi/kg			SM 7500 Ra-B	04/28/2014 1533	MB
Thorium 230	1.0E-7	µCi/kg		2.0E-7	ACW10	05/02/2014 1353	KK
Thorium230 Precision (±)	1.0E-7	µCi/kg			ACW10	05/02/2014 1353	KK
Thorium229 Tracer (30-120)	95.6	%			ACW10	05/02/2014 1353	KK
Uranium	9.0E-7	µCi/kg		2.0E-7	EPA 200.8	04/23/2014 132	MS

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank
E	Value above quantitation range
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
X	Matrix Effect
C	Calculated Value
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Sample Analysis Report

Company: Cameco Resources, Crow Butte Operation
PO Box 169
Crawford, NE 69339

Date Reported 11/28/2016
Report ID S1404031003
(Replaces S1404031002)

ProjectName: Marsland Beef Samples
Lab ID: S1404031-002
ClientSample ID: Marsland Beef Sample #2
COC: WEB

WorkOrder: S1404031
CollectionDate: 3/28/2014
DateReceived: 4/1/2014 10:40:00 AM
FieldSampler:
Matrix: Animal

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	5.0E-6	µCi/kg		1.0E-6	OTW01	04/28/2014 1117	MB
Lead 210 Precision (±)	2.5E-6	µCi/kg			OTW01	04/28/2014 1117	MB
Polonium 210	-4.0E-7	µCi/kg		1.0E-6	OTW01	04/28/2014 1434	MB
Polonium 210 Precision (±)	4.0E-7	µCi/kg			OTW01	04/28/2014 1434	MB
Radium 226	2.0E-7	µCi/kg		5.0E-8	SM 7500 Ra-B	04/28/2014 1533	MB
Radium 226 Precision (±)	2.0E-7	µCi/kg			SM 7500 Ra-B	04/28/2014 1533	MB
Thorium 230	5.0E-8	µCi/kg		2.0E-7	ACW10	05/02/2014 1353	KK
Thorium230 Precision (±)	9.0E-8	µCi/kg			ACW10	05/02/2014 1353	KK
Thorium229 Tracer (30-120)	102	%			ACW10	05/02/2014 1353	KK
Uranium	2.0E-7	µCi/kg		2.0E-7	EPA 200.8	04/23/2014 204	MS

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank
E	Value above quantitation range
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
X	Matrix Effect
C	Calculated Value
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Sample Analysis Report

Company: Cameco Resources, Crow Butte Operation
PO Box 169
Crawford, NE 69339

Date Reported 11/28/2016
Report ID S1404031003
(Replaces S1404031002)

ProjectName: Marsland Beef Samples
Lab ID: S1404031-003
ClientSample ID: Marsland Beef Sample #3
COC: WEB

WorkOrder: S1404031
CollectionDate: 3/28/2014
DateReceived: 4/1/2014 10:40:00 AM
FieldSampler:
Matrix: Animal

Comments

Analyses	Result	Units	Qual	RL	Method	Date Analyzed/Init	
Radionuclides - Total							
Lead 210	6.1E-6	µCi/kg		1.0E-6	OTW01	04/28/2014 1117	MB
Lead 210 Precision (±)	6.2E-6	µCi/kg			OTW01	04/28/2014 1117	MB
Polonium 210	-9.0E-7	µCi/kg		1.0E-6	OTW01	04/28/2014 1434	MB
Polonium 210 Precision (±)	7.0E-7	µCi/kg			OTW01	04/28/2014 1434	MB
Radium 226	1.5E-7	µCi/kg		5.0E-8	SM 7500 Ra-B	04/28/2014 1533	MB
Radium 226 Precision (±)	3.0E-7	µCi/kg			SM 7500 Ra-B	04/28/2014 1533	MB
Thorium 230	1.0E-6	µCi/kg		2.0E-7	ACW10	05/02/2014 1353	KK
Thorium230 Precision (±)	6.0E-7	µCi/kg			ACW10	05/02/2014 1353	KK
Thorium229 Tracer (30-120)	107	%			ACW10	05/02/2014 1353	KK
Uranium	ND	µCi/kg		2.0E-7	EPA 200.8	04/23/2014 209	MS

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank	C	Calculated Value
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	L	Analyzed by another laboratory
M	Value exceeds Monthly Ave or MCL or is less than LCL	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	S	Spike Recovery outside accepted recovery limits
X	Matrix Effect		

Reviewed by: _____
Wade Nieuwsma, Assistant Laboratory Manager

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Work Order: S1404031
Project: Marsland Beef Samples

Date: 11/28/2016
Report ID: S1404031003
(Replaces S1404031002)

Pb210 in Animals Sample Type **MBLK** Units: pCi/Kg

MB14-112 (04/28/14 09:14)	RunNo: 107237	PrepDate: 04/23/14 0:00			BatchID: 8140		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	ND	1					

Pb210 in Animals Sample Type **LCS** Units: pCi/Kg

LCS14-112 (04/28/14 09:14)	RunNo: 107237	PrepDate: 04/23/14 0:00			BatchID: 8140		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	14	1	12		116	50 - 150	

Pb210 in Animals Sample Type **MS** Units: pCi/Kg

TAP MS (04/28/14 09:14)	RunNo: 107237	PrepDate: 04/23/14 0:00			BatchID: 8140		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Lead 210	15	1	12.5	1	113	50 - 150	

Pb210 in Animals Sample Type **MSD** Units: pCi/Kg

TAP MSD (04/28/14 09:14)	RunNo: 107237	PrepDate: 04/23/14 0:00			BatchID: 8140		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Lead 210	17	1	15	10.3	126	20	

Po210 in Animal Sample Type **MBLK** Units: pCi/Kg

MB14-112 (04/28/14 13:31)	RunNo: 107198	PrepDate: 04/23/14 0:00			BatchID: 8140		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Polonium 210	ND	1					

Po210 in Animal Sample Type **LCS** Units: pCi/Kg

LCS14-112 (04/28/14 13:31)	RunNo: 107198	PrepDate: 04/23/14 0:00			BatchID: 8140		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Polonium 210	3	1	3.07		89.2	50 - 150	

Po210 in Animal Sample Type **MS** Units: pCi/Kg

TAP MS (04/28/14 14:34)	RunNo: 107198	PrepDate: 04/23/14 0:00			BatchID: 8140		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Polonium 210	12	1	12.5	ND	97.9	50 - 150	

Po210 in Animal Sample Type **MSD** Units: pCi/Kg

TAP MSD (04/28/14 14:34)	RunNo: 107198	PrepDate: 04/23/14 0:00			BatchID: 8140		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Polonium 210	13	1	12	4.25	102	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by another laboratory	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	R	RPD outside accepted recovery limits
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Date: 11/28/2016
Work Order: S1404031
Report ID: S1404031003 (Replaces S1404031002)
Project: Marsland Beef Samples

Radium 226 in Animal — Sample Type **MBLK** — Units: pCi/Kg

MB14-111 (04/28/14 15:33)	RunNo: 107123	PrepDate: 04/22/14 0:00			BatchID: 8140		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Radium 226	ND	0.05					

Radium 226 in Animal — Sample Type **LCS** — Units: pCi/Kg

LCS14-111 (04/28/14 13:19)	RunNo: 107123	PrepDate: 04/22/14 0:00			BatchID: 8140		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Radium 226	4.9	0.05	5		98.6	87.4 - 111	

Radium 226 in Animal — Sample Type **MS** — Units: pCi/Kg

TAP MS (04/28/14 13:19)	RunNo: 107123	PrepDate: 04/22/14 0:00			BatchID: 8140		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Radium 226	5.0	0.05	5	ND	99.5	70.8 - 130	

Radium 226 in Animal — Sample Type **MSD** — Units: pCi/Kg

TAP MSD (04/28/14 13:19)	RunNo: 107123	PrepDate: 04/22/14 0:00			BatchID: 8140		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Radium 226	5.3	0.05	5.0	6.30	106	20	

Thorium 230 in Animal — Sample Type **MBLK** — Units: pCi/Kg

MB14-111 (05/02/14 13:53)	RunNo: 107266	PrepDate: 04/21/14 0:00			BatchID: 8140		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Thorium230	0.0 ± 0.0	0.2					

Thorium 230 in Animal — Sample Type **LCS** — Units: pCi/Kg

LCS14-111 (05/01/14 09:35)	RunNo: 107266	PrepDate: 04/21/14 0:00			BatchID: 8140		
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Thorium230	13.3	0.2	12.5		106	50 - 150	

Thorium 230 in Animal — Sample Type **LCSD** — Units: pCi/Kg

LCS14-111 DUP (05/01/14 09:35)	RunNo: 107266	PrepDate: 04/21/14 0:00			BatchID: 8140		
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Thorium230	11.5	0.2	13.3	13.6	91.8	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by another laboratory	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	R	RPD outside accepted recovery limits
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

ANALYTICAL QC SUMMARY REPORT

CLIENT: Cameco Resources, Crow Butte Operation
Work Order: S1404031
Project: Marsland Beef Samples

Date: 11/28/2016
Report ID: S1404031003
(Replaces S1404031002)

Total (3050) Metals by EPA 200.8 Sample Type **MBLK** Units: pCi/Kg

MBLK (04/22/14 15:02)	RunNo: 106807						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	ND	0.2					

Total (3050) Metals by EPA 200.8 Sample Type **LCS** Units: pCi/Kg

LCS (04/22/14 14:57)	RunNo: 106807						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	68.8	0.2	67.7		102	85 - 115	

Total (3050) Metals by EPA 200.8 Sample Type **MS** Units: pCi/Kg

S1404031-001AS (04/23/14 01:54)	RunNo: 106807						
Analyte	Result	RL	Spike	Ref Samp	%REC	% Rec Limits	Qual
Uranium	574	0.2	602	0.9	95.2	70 - 130	

Total (3050) Metals by EPA 200.8 Sample Type **MSD** Units: pCi/Kg

S1404031-001AMSD (04/23/14 01:59)	RunNo: 106807						
Analyte	Result	RL	Conc	%RPD	%REC	% RPD Limits	Qual
Uranium	578	0.2	574	0.859	96.0	20	

Total (3050) Metals by EPA 200.8 Sample Type **DUP** Units: pCi/Kg

S1404031-001AD (04/23/14 01:49)	RunNo: 106807						
Analyte	Result	RL	Ref Samp	%RPD	%REC	% RPD Limits	Qual
Uranium	0.9	0.2	0.9	2.64		20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
L	Analyzed by another laboratory	ND	Not Detected at the Reporting Limit
O	Outside the Range of Dilutions	R	RPD outside accepted recovery limits
S	Spike Recovery outside accepted recovery limits	X	Matrix Effect

Inter-Mountain Labs
Sheridan, WY and Gillette, WY

CHAIN OF CUSTODY RECORD

Page 1 of 1

All shaded fields must be completed.
This is a legal document; any misrepresentation may be construed as fraud.

#WEB

Client Name	Project Identification	Sampler (Signature/Attestation of Authenticity)	Telephone #
Cameco Resources, Crow Butte	Marsland Beef Samples		308-665-2215x117

Report Address	Contact Name	
PO Box 169 Crawford, Ne 69339	Walt Nelson	
	Email	Walter.Nelson@cameco.com
Invoice Address	Phone	308-665-2215x117
Same	Purchase Order #	Quote #

ITEM	LAB ID (Lab Use Only)	DATE SAMPLED	TIME SAMPLED	SAMPLE IDENTIFICATION	Matrix	# of Containers	U-nat, Ra226, Pb210	Th230, Po210						REMARKS
1	S140-003-001	03/28/14		Marsland Beef Sample #1	SD	1 cooler	x	x		13.6	Kg			Detection limits per Reg.
2	002	03/28/14		Marsland Beef Sample #2	SD	1 cooler	x	x		20.8	Kg			Guide 4.14 standards for
3	003	03/28/14		Marsland Beef Sample #3	SD	1 cooler	x	x		12.0	Kg			preoperational food
4														sampling.
5														U=2x10-7ucl/kg
6														Th=2x10-7ucl/kg
7														Ra=5x10-8ucl/kg
8														Po=1x10-6ucl/kg
9														Pb=1x10-6ucl/kg
10														
11														
12														Each sample has been
13														shipped in a separate
14														cooler.

LAB COMMENTS	Relinquished By (Signature/Printed)	DATE	TIME	Received By (Signature/Printed)	DATE	TIME
	Walter D. Nelson Walter D. Nelson	3/31/14	12:00	Action Cargo	3/31/14	12:00
				Mark Brown	4/1/14	10:40

SHIPPING INFO	MATRIX CODES		TURN AROUND TIMES	COMPLIANCE INFORMATION	ADDITIONAL REMARKS
☐ UPS	Water	WT	Check desired service	Compliance Monitoring ? Y / N	
☐ FedEx	Soil	SL	☒ Standard turnaround	Program (SDWA, NPDES,...)	
☐ USPS	Solid	SD	☐ RUSH - 5 Working Days	PWSID / Permit #	
☐ Hand Carried	Filter	FT	☐ URGENT - < 2 Working Days	Chlorinated? Y / N	
☐ Other	Other	OT	*Rush & Urgent Surcharges will be applied*	Sample Disposal: Lab X Client	

Replacement Pages – Appendix EE

Instructions:

Remove and Replace all of Appendix EE

MEA TR

Reponses to Open Issues

6-29-2017

Appendix EE

Kozeny-Carmen Calculations

Analysis of K results				
Formation	**Geomean of K (cm/sec)**	**STD**	**Coeff of Variation**	**# of Samples**
Arikaree	1.4E-04	9.3E-04	6.69	10
Brule	8.9E-05	6.1E-05	0.69	13
Upper Chadron	5.1E-05	8.2E-06	0.16	3
Middle Chadron	2.2E-05	8.3E-06	0.37	2
Upper + Middle Chadron	3.7E-05	1.7E-05	0.47	5
Basal Sandstone	7.5E-05	N/A	N/A	1
Pierre	2.5E-06	1.3E-06	0.54	7

Note:
While values have been calculated for the Pierre Shale using Kozeny-Carman, those values are not valid due to high levels of clay present and have not been included in the application.

Porosity	0.438	
Kozeny-Carman Coeff	4.8	Range 4.5 to 5.1
Shape Factor	6.5	Range 6 to 8.4

Rounded 6.1 - 6.6
Medium angular 7.4 - 7.5
Very Angular 7.7 - 8.4

Effective Grain Size (cm)	0.006494829
Intrinsic Permeability (cm2)	5.5E-08
Rho (g/cm3)	1.03
Viscosity (dyne-sec/cm2)	0.016
Gravitational Const (cm/sec2)	980
Hydraulic Conductivity K (cm/sec)	3.5E-03

$$\text{Intrinsic Permeability} = \frac{\text{Porosity}^3}{\left(\frac{K\text{-}C\ \text{coefficient}}{\left(\frac{\text{Shape Factor}}{\text{Effective Grain Size}}\right)^2} \times (1 - \text{Porosity})^2\right)}$$

$$\text{Hydraulic Conductivity (K)} = \frac{\text{Intrinsic Permeability} \times \text{Density} \times \text{Gravity}}{\text{Viscosity}}$$

		Arikaree		Arikaree		Arikaree		Arikaree		Arikaree		Arikaree		Arikaree		Arikaree		Arikaree	
	Porosity	0.35		0.35		0.35		0.35		0.35		0.35		0.35		0.35		0.35	
		M-533C Run 1, Sample 1		M-533C Run 1, Sample 2		M-1635C Run 1, Sample 1		M-1635C Run 1, Sample 2		M-1912C Run 1, Sample 1		M-1912C Run 2, Sample 1		M-1956C Run 1, Sample 1		M-1956C Run 3, Sample 1		M-2169C Run 1, Sample 1		M-2169C Run 2, Sample 3	
Sieves Size/Number	Sieve Size (mm)	Retained (%)		Retained (%)		Retained (%)		Retained (%)		Retained (%)		Retained (%)		Retained (%)		Retained (%)		Retained (%)		Retained (%)	
	6.35107	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
	4.75683	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
	3.36359	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
	2.00000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
Medium Sand	1.18921	3.42	2.110	0.00	0.000	0.00	0.000	0.00	0.000	0.82	0.506	0.74	0.457	1.37	0.845	0.00	0.000	0.00	0.000	0.00	0.000
	0.84090	2.47	2.389	0.00	0.000	0.00	0.000	0.00	0.000	0.69	0.668	2.75	2.661	1.79	1.731	0.00	0.000	0.00	0.000	0.00	0.000
	0.70711	1.42	1.810	0.00	0.000	0.00	0.000	0.00	0.000	0.32	0.408	0.96	1.224	1.31	1.670	0.01	0.018	0.00	0.000	0.00	0.000
	0.59460	2.07	3.137	0.00	0.000	0.00	0.000	0.00	0.000	0.35	0.531	0.89	1.350	2.02	3.061	0.14	0.212	0.00	0.000	0.00	0.000
	0.50000	3.50	6.307	0.00	0.000	0.00	0.000	0.00	0.000	0.56	1.010	1.17	2.109	3.82	6.883	0.39	0.703	0.00	0.000	0.00	0.000
	0.42045	5.55	11.892	0.00	0.000	0.00	0.000	0.00	0.000	1.11	2.381	1.33	2.851	6.67	14.289	0.46	0.986	0.00	0.000	0.00	0.000
Fine Sand	0.35355	6.39	16.280	0.00	0.007	0.00	0.000	0.00	0.000	1.76	4.488	0.98	2.498	8.24	20.989	0.27	0.688	0.00	0.000	0.00	0.000
	0.29730	11.20	33.927	0.11	0.333	0.00	0.000	0.00	0.000	4.49	13.615	1.10	3.334	15.19	46.034	0.19	0.576	0.00	0.008	0.00	0.000
	0.25000	10.90	39.258	0.41	1.477	0.00	0.005	0.00	0.004	6.17	22.245	1.17	4.216	14.79	53.294	0.25	0.901	0.06	0.213	0.00	0.003
	0.21022	10.80	46.250	0.83	3.555	0.08	0.343	0.09	0.377	8.16	34.937	2.13	9.126	13.69	58.657	0.78	3.341	0.32	1.371	0.07	0.308
	0.17678	9.65	49.136	1.24	6.315	0.67	3.413	0.88	4.485	9.53	48.523	3.87	19.714	10.59	53.962	1.77	9.015	0.85	4.330	0.73	3.716
	0.14865	7.85	47.525	1.75	10.597	1.98	11.993	2.96	17.936	10.31	62.421	6.15	37.250	7.02	42.492	3.04	18.410	1.60	9.690	2.55	15.435
	0.12500	5.92	42.614	2.41	17.351	3.41	24.558	5.43	39.122	10.51	75.660	8.05	57.974	4.36	31.379	4.33	31.178	2.43	17.499	4.98	35.840
	0.10511	4.21	36.033	3.35	28.677	5.23	44.785	8.03	68.789	10.00	85.591	9.01	77.152	2.69	23.019	5.74	49.142	3.54	30.310	7.70	65.890
#200	0.08839	2.94	29.919	4.59	46.718	7.43	75.648	10.41	105.930	8.75	89.034	8.83	89.901	1.72	17.500	7.32	74.513	5.07	51.615	10.09	102.761
	0.07433	2.12	25.652	5.84	70.675	9.08	109.920	11.81	142.906	6.87	83.211	7.73	93.576	1.08	13.065	8.67	104.935	6.71	81.221	11.09	134.281
Silt	0.06250	1.60	23.019	6.64	95.545	9.18	132.135	11.41	164.155	4.77	68.695	6.16	88.664	0.62	8.918	9.27	133.403	7.79	112.116	10.19	146.715
	0.05256	1.23	21.040	6.82	116.682	7.90	135.202	9.55	163.507	2.95	50.514	4.63	79.238	0.34	5.815	8.89	152.114	7.92	135.531	8.29	141.949
	0.04419	0.95	19.322	6.51	132.429	6.22	126.570	7.16	145.756	1.73	35.222	3.46	70.406	0.22	4.474	7.85	159.705	7.37	149.956	6.38	129.735
	0.03716	0.74	17.895	5.84	141.253	4.87	117.828	5.21	126.106	1.11	26.871	2.74	66.293	0.18	4.352	6.58	159.169	6.51	157.492	5.02	121.373
	0.03125	0.58	16.677	5.09	146.381	3.96	113.920	3.91	112.527	0.83	23.890	2.34	67.315	0.15	4.312	5.41	155.600	5.65	162.520	4.11	118.153
	0.02503	0.60	20.919	5.57	194.231	4.21	146.852	3.82	133.302	0.92	32.108	2.67	93.133	0.17	5.926	5.49	191.461	6.07	211.711	4.26	148.493
	0.02005	0.49	21.321	4.80	208.899	3.69	160.642	2.89	125.865	0.88	38.331	2.44	106.222	0.18	7.831	4.19	182.371	4.94	215.038	3.36	146.174
	0.01563	0.47	25.812	4.61	253.218	3.96	217.583	2.52	138.518	0.97	53.325	2.50	137.361	0.19	10.432	3.60	197.762	4.56	250.525	3.06	168.016
	0.01105	0.56	41.039	5.64	413.391	5.59	409.855	2.77	203.177	1.28	93.899	3.19	233.885	0.23	16.852	3.74	274.158	5.32	390.020	3.52	257.905
	0.00781	0.48	49.729	5.27	546.082	5.31	550.399	2.25	233.314	1.09	113.043	2.85	295.408	0.21	21.752	2.78	288.097	4.59	475.721	2.95	305.565
	0.00500	0.52	79.319	6.26	955.037	5.67	865.297	2.39	364.885	1.06	161.853	3.12	476.135	0.26	39.651	2.64	402.806	5.01	764.497	3.15	480.387
Clay	0.00195	0.80	232.691	10.50	3054.588	7.19	2092.322	3.82	1112.089	1.22	355.216	4.56	1326.981	0.47	136.678	3.67	1067.795	8.07	2348.189	5.08	1477.277
	0.00098	0.39	262.463	4.34	2921.239	2.79	1878.529	1.80	1212.444	0.49	330.098	1.77	1191.737	0.32	215.311	1.71	1151.118	3.87	2605.438	2.41	1621.546
	0.00049	0.20	269.006	1.49	2004.438	1.43	1924.326	0.80	1076.981	0.27	363.529	0.65	874.681	0.13	174.819	0.76	1022.507	1.61	2166.330	0.95	1277.512
	0.00038	0.02	45.195	0.11	248.614	0.14	316.517	0.07	162.846	0.03	63.337	0.05	119.823	0.00	0.000	0.07	153.705	0.14	316.486	0.08	176.223
		Sum(fi/(dli^0.404	1539.687		11617.733		9458.645		5855.019		2335.161		5632.654		1045.993		5986.360		10657.807		7075.259
		Deff (mm)	0.0649	Deff (mm)	0.0086	Deff (mm)	0.0106	Deff (mm)	0.0171	Deff (mm)	0.0428	Deff (mm)	0.0178	Deff (mm)	0.0956	Deff (mm)	0.0167	Deff (mm)	0.0094	Deff (mm)	0.0141
		K (cm/sec)	**1.3E-03**	**K (cm/sec)**	**2.3E-05**	**K (cm/sec)**	**3.5E-05**	**K (cm/sec)**	**9.2E-05**	**K (cm/sec)**	**5.8E-04**	**K (cm/sec)**	**1.0E-04**	**K (cm/sec)**	**2.9E-03**	**K (cm/sec)**	**8.8E-05**	**K (cm/sec)**	**2.8E-05**	**K (cm/sec)**	**6.3E-05**
		K (ft/day)	3.77	K (ft/day)	0.07	K (ft/day)	0.10	K (ft/day)	0.26	K (ft/day)	1.64	K (ft/day)	0.28	K (ft/day)	8.18	K (ft/day)	0.25	K (ft/day)	0.08	K (ft/day)	0.18
		K (m/day)	1.15	K (m/day)	0.02	K (m/day)	0.03	K (m/day)	0.08	K (m/day)	0.50	K (m/day)	0.09	K (m/day)	2.49	K (m/day)	0.08	K (m/day)	0.02	K (m/day)	0.05
		D10 (mm)	0.0649	D10 (mm)	0.0086	D10 (mm)	0.0106	D10 (mm)	0.0171	D10 (mm)	0.0428	D10 (mm)	0.0178	D10 (mm)	0.0956	D10 (mm)	0.0167	D10 (mm)	0.0094	D10 (mm)	0.0141
		K Hazen (cm/sec	4.22E-03	K Hazen (cm/sec	7.41E-05	K Hazen (cm/sec	1.12E-04	K Hazen (cm/sec	2.92E-04	K Hazen (cm/sec	1.83E-03	K Hazen (cm/sec	3.15E-04	K Hazen (cm/sec	9.14E-03	K Hazen (cm/sec	2.79E-04	K Hazen (cm/sec	8.80E-05	K Hazen (cm/sec	2.00E-04
		K (ft/day)	11.96	K (ft/day)	0.21	K (ft/day)	0.32	K (ft/day)	0.83	K (ft/day)	5.20	K (ft/day)	0.89	K (ft/day)	25.91	K (ft/day)	0.79	K (ft/day)	0.25	K (ft/day)	0.57
		K Hazen (cm/sec	2.18E-03	K Hazen (cm/sec	3.82E-05	K Hazen (cm/sec	5.77E-05	K Hazen (cm/sec	1.50E-04	K Hazen (cm/sec	9.46E-04	K Hazen (cm/sec	1.63E-04	K Hazen (cm/sec	4.72E-03	K Hazen (cm/sec	1.44E-04	K Hazen (cm/sec	4.54E-05	K Hazen (cm/sec	1.03E-04
		K (ft/day)	6.17	K (ft/day)	0.11	K (ft/day)	0.16	K (ft/day)	0.43	K (ft/day)	2.68	K (ft/day)	0.46	K (ft/day)	13.37	K (ft/day)	0.41	K (ft/day)	0.13	K (ft/day)	0.29
Sand (%)		90.37		20.53		27.88		39.61		80.39		56.86		96.33		33.36		20.58		37.21	
Silt (%)		8.22		63.04		60.57		53.90		17.60		36.10		2.75		60.43		65.73		54.28	
Clay (%)		1.41		16.44		11.55		6.50		2.01		7.03		0.92		6.21		13.69		8.51	

Analysis of K results

Formation	Geomean of K (cm/sec)	STD	# of Samples
Arikaree	1.4E-04	9.3E-04	10

Porosity 0.438
Kozeny-Carman Coeff 4.8 Range 4.5 to 5.1
Shape Factor 6.5 Range 6 to 8.4 Rounded 6.1 - 6.6
Medium angular 7.4 - 7.5
Very Angular 7.7 - 8.4

Effective Grain Size (cm) 0.00152912
Intrinsic Permeability (cm2) 3.1E-09
Rho (g/cm3) 1.03
Viscosity (dyne-sec/cm2) 0.016
Gravitational Const (cm/sec2) 980
Hydraulic Conductivity K (cm/sec) 1.9E-04

$$\text{Intrinsic Permeability} = \frac{\text{Porosity}^3}{\left(\frac{\text{K-C coefficient}}{\text{Shape Factor}} \times \left(\frac{\text{Effective Grain Size}}{\text{Shape Factor}}\right)^2 \times (1 - \text{Porosity})\right)}$$

$$\text{Hydraulic Conductivity (K)} = \frac{\text{Intrinsic Permeability} \times \text{Density} \times \text{Gravity}}{\text{Viscosity}}$$

		Brule		Brule		Brule		Brule		Brule		Brule		Brule		Brule		Brule		Brule		Brule	
	Porosity	0.35		0.35		0.35		0.35		0.35		0.35		0.35		0.35		0.35		0.35		0.35	
		M-533C Run 3, Sample 1		M-533C Run 3, Sample 2		M-1635C Run 2, Sample 1		M-1635C Run 2, Sample 2		M-1912C Run 3, Sample 1		M-1912C Run 3, Sample 2		M-1956C Run 4, Sample 1		M-1956C Run 4, Sample 2		M-1956C Run 5, Sample 1		M-1956C Run 5, Sample 2		M-2169C Run 3, Sample 1	
Sieves Size/Number	Sieve Size (mm)	Retained (%)		Retained (%)		Retained (%)		Retained (%)		Retained (%)		Retained (%)		Retained (%)		Retained (%)		Retained (%)		Retained (%)		Retained (%)	
	6.35107	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
	4.75683	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
	3.36359	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
	2.00000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
Medium Sand	1.18921	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.02	0.013	0.00	0.000	0.03	0.015	0.00	0.000	0.00	0.000	0.30	0.185	0.00	0.000
	0.84090	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.35	0.339	0.00	0.000	0.30	0.290	0.00	0.000	0.00	0.000	0.96	0.920	0.00	0.000
	0.70711	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.41	0.523	0.00	0.000	0.19	0.242	0.00	0.000	0.00	0.000	0.36	0.459	0.00	0.000
	0.59460	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.78	1.183	0.00	0.000	0.34	0.516	0.00	0.000	0.00	0.000	0.50	0.758	0.00	0.000
	0.50000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	1.28	2.307	0.00	0.000	0.64	1.154	0.00	0.000	0.00	0.000	0.75	1.352	0.00	0.000
	0.42045	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	1.58	3.387	0.00	0.000	0.72	1.544	0.00	0.000	0.00	0.000	0.89	1.908	0.00	0.000
Fine Sand	0.35355	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	1.38	3.517	0.00	0.000	0.48	1.224	0.00	0.000	0.00	0.000	0.81	2.064	0.00	0.000
	0.29730	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	1.89	5.727	0.00	0.000	0.46	1.394	0.00	0.000	0.00	0.000	1.32	4.000	0.00	0.000
	0.25000	0.00	0.002	0.00	0.001	0.00	0.000	0.00	0.001	1.77	6.377	0.01	0.033	0.47	1.694	0.00	0.000	0.00	0.006	1.42	5.116	0.00	0.000
	0.21022	0.03	0.111	0.02	0.094	0.00	0.018	0.03	0.124	2.28	9.767	0.21	0.901	0.97	4.157	0.02	0.086	0.07	0.283	1.86	7.968	0.00	0.021
	0.17678	0.23	1.172	0.32	1.628	0.11	0.560	0.39	1.986	3.12	15.892	1.09	5.558	1.90	9.682	0.32	1.630	0.48	2.445	2.47	12.582	0.13	0.662
	0.14865	0.75	4.544	1.46	8.834	0.66	3.997	1.67	10.111	4.20	25.436	2.62	15.884	3.20	19.388	1.54	9.329	1.31	7.933	3.17	19.199	0.79	4.785
	0.12500	1.43	10.302	3.09	22.230	1.41	10.153	3.49	25.124	5.30	38.165	4.42	31.861	4.74	34.147	3.30	23.768	1.85	13.320	3.67	26.428	1.80	12.963
	0.10511	2.30	19.701	4.89	41.829	2.24	19.179	5.56	47.591	6.58	56.337	6.73	57.596	6.58	56.361	5.27	45.131	2.13	18.234	4.09	35.019	2.90	24.833
#200	0.08839	3.43	34.934	6.98	71.093	3.58	36.445	7.91	80.503	8.00	81.441	9.53	97.015	8.47	86.262	7.51	76.468	2.72	27.686	4.65	47.339	4.30	43.781
	0.07433	4.80	58.127	9.24	111.860	5.73	69.358	10.20	123.429	9.15	110.753	12.01	145.401	9.81	118.791	9.69	117.314	3.98	48.168	5.35	64.759	6.04	73.119
Silt	0.06250	6.25	89.991	10.99	158.164	8.34	120.030	11.70	168.339	9.44	135.859	13.01	187.288	10.00	143.979	10.90	156.904	5.62	80.872	5.98	86.066	7.67	110.401
	0.05256	7.61	130.282	11.49	196.606	10.60	181.389	11.70	200.155	8.62	147.505	11.91	203.843	9.08	155.441	10.80	184.847	6.92	118.399	6.34	108.493	8.62	147.526
	0.04419	8.79	178.925	10.69	217.502	12.00	244.157	10.40	211.541	7.06	143.643	9.35	190.230	7.55	153.677	9.50	193.328	7.52	152.983	6.40	130.219	8.74	177.850
	0.03716	9.40	227.506	8.91	215.589	11.70	283.046	8.38	202.670	5.39	130.392	6.59	159.345	6.03	145.936	7.74	187.281	7.36	178.027	6.10	147.573	8.10	195.979
	0.03125	9.40	270.505	6.97	200.586	10.20	293.395	6.39	183.750	4.08	117.356	4.53	130.435	4.83	138.987	6.13	176.358	6.89	198.157	5.62	161.657	7.16	205.977
	0.02503	11.00	383.827	6.52	227.538	10.00	348.777	5.85	203.975	3.90	136.021	4.03	140.701	4.86	169.574	5.99	208.957	7.90	275.494	6.38	222.523	7.75	270.336
	0.02005	9.01	392.374	4.48	194.828	6.66	289.905	3.93	171.020	2.85	124.056	2.87	125.057	3.68	160.252	4.42	192.436	6.75	293.780	5.50	239.414	6.28	273.398
	0.01563	7.36	404.531	3.45	189.361	4.67	256.564	2.97	163.121	2.36	129.653	2.36	129.788	3.10	170.379	3.66	201.114	6.26	343.867	5.15	282.938	5.59	307.146
	0.01105	6.32	463.531	3.10	227.050	3.67	269.051	2.65	194.217	2.31	169.345	2.30	168.787	3.08	225.888	3.57	261.770	7.04	516.033	5.57	408.346	5.90	432.587
	0.00781	3.60	373.275	1.98	205.017	2.16	223.865	1.73	179.247	1.58	163.750	1.59	164.958	2.15	222.918	2.46	255.006	5.65	585.488	4.05	419.752	4.43	459.187
	0.00500	2.68	409.129	1.66	253.065	1.80	274.665	1.49	227.296	1.36	207.521	1.42	216.902	1.92	293.094	2.16	329.661	5.73	874.224	3.55	541.707	4.28	653.174
Clay	0.00195	3.23	840.255	2.09	904.651	2.48	721.607	1.96	570.137	1.66	483.002	1.87	544.670	2.50	727.719	2.84	826.514	8.36	2437.979	4.08	1187.174	5.97	1737.308
	0.00098	1.58	1064.178	1.08	726.405	1.30	875.198	1.03	693.225	0.82	552.038	0.95	640.221	1.22	821.670	1.41	949.435	3.76	2530.975	1.76	1184.898	2.52	1686.748
	0.00049	0.70	942.289	0.56	752.787	0.63	847.681	0.55	739.824	0.44	592.020	0.52	700.388	0.61	821.101	0.69	928.590	1.56	2098.715	0.87	1170.621	0.94	1264.951
	0.00038	0.06	140.218	0.05	124.215	0.06	133.374	0.05	119.776	0.04	99.463	0.05	117.670	0.06	131.166	0.06	144.704	0.14	316.435	0.08	185.369	0.08	171.825
				6539.709		4750.934		5502.415		4517.161		3692.789		4174.529		4818.643		5470.632		11119.503		6706.814		8264.558
		Deff (mm)		0.0153	Deff (mm)	0.0210	Deff (mm)	0.0182	Deff (mm)	0.0221	Deff (mm)	0.0271	Deff (mm)	0.0240	Deff (mm)	0.0208	Deff (mm)	0.0183	Deff (mm)	0.0090	Deff (mm)	0.0149	Deff (mm)	0.0121
		K (cm/sec)		7.4E-05	K (cm/sec)	1.4E-04	K (cm/sec)	1.0E-04	K (cm/sec)	1.5E-04	K (cm/sec)	2.3E-04	K (cm/sec)	1.8E-04	K (cm/sec)	1.4E-04	K (cm/sec)	1.1E-04	K (cm/sec)	2.6E-05	K (cm/sec)	4.6E-05	K (cm/sec)	3.5E-05
		K (ft/day)		0.21	K (ft/day)	0.40	K (ft/day)	0.30	K (ft/day)	0.44	K (ft/day)	0.66	K (ft/day)	0.51	K (ft/day)	0.39	K (ft/day)	0.30	K (ft/day)	0.07	K (ft/day)	0.20	K (ft/day)	0.13
		K (m/day)		0.06	K (m/day)	0.12	K (m/day)	0.09	K (m/day)	0.13	K (m/day)	0.20	K (m/day)	0.16	K (m/day)	0.12	K (m/day)	0.09	K (m/day)	0.02	K (m/day)	0.06	K (m/day)	0.04
		D10 (mm)		0.0153	D10 (mm)	0.0210	D10 (mm)	0.0182	D10 (mm)	0.0221	D10 (mm)	0.0271	D10 (mm)	0.0240	D10 (mm)	0.0208	D10 (mm)	0.0183	D10 (mm)	0.0090	D10 (mm)	0.0149	D10 (mm)	0.0121
		K Hazen (cm/sec)		2.34E-04	K Hazen (cm/sec)	4.43E-04	K Hazen (cm/sec)	3.30E-04	K Hazen (cm/sec)	4.90E-04	K Hazen (cm/sec)	7.33E-04	K Hazen (cm/sec)	5.74E-04	K Hazen (cm/sec)	4.31E-04	K Hazen (cm/sec)	3.34E-04	K Hazen (cm/sec)	8.09E-05	K Hazen (cm/sec)	2.22E-04	K Hazen (cm/sec)	1.46E-04
		K (ft/day)		0.66	K (ft/day)	1.26	K (ft/day)	0.94	K (ft/day)	1.39	K (ft/day)	2.08	K (ft/day)	1.63	K (ft/day)	1.22	K (ft/day)	0.95	K (ft/day)	0.23	K (ft/day)	0.63	K (ft/day)	0.42
		K Hazen (cm/sec)		1.21E-04	K Hazen (cm/sec)	2.29E-04	K Hazen (cm/sec)	1.70E-04	K Hazen (cm/sec)	2.53E-04	K Hazen (cm/sec)	3.78E-04	K Hazen (cm/sec)	2.96E-04	K Hazen (cm/sec)	2.22E-04	K Hazen (cm/sec)	1.72E-04	K Hazen (cm/sec)	4.17E-05	K Hazen (cm/sec)	1.15E-04	K Hazen (cm/sec)	7.55E-05
		K (ft/day)		0.34	K (ft/day)	0.65	K (ft/day)	0.48	K (ft/day)	0.72	K (ft/day)	1.07	K (ft/day)	0.84	K (ft/day)	0.63	K (ft/day)	0.49	K (ft/day)	0.12	K (ft/day)	0.33	K (ft/day)	0.21
Sand (%)		12.97		26.00		13.73		29.24		48.09		36.63		39.31		27.65		12.54		32.57		15.97		25.72
Silt (%)		81.45		70.23		81.80		67.17		48.95		59.98		56.30		67.34		73.63		60.64		74.53		64.33
Clay (%)		5.57		3.77		4.47		3.59		2.96		3.40		4.39		5.00		13.84		6.79		9.51		9.95

	Brule		Brule	
	M-2169C Run 4, Sample 1		M-2169C Run 5, Sample 1	
Sieves Size/Number	Retained (%)		Retained (%)	
	0.00		0.00	
	0.00	0.000	0.00	0.000
	0.00	0.000	0.00	0.000
	0.00	0.000	0.00	0.000
	0.00	0.000	1.72	1.062
	0.05	0.046	4.90	4.741
	0.15	0.191	1.67	2.130
	0.28	0.425	1.86	2.820
	0.33	0.595	1.99	3.588
	0.24	0.514	1.73	3.709
	0.18	0.459	1.32	3.384
	0.40	1.212	1.94	5.879
	0.69	2.486	1.71	6.162
	1.21	5.184	1.60	6.855
	1.91	9.729	1.70	8.660
	2.69	16.292	2.19	13.265
	3.29	23.692	2.70	19.445
	3.88	33.221	3.05	26.117
	4.70	47.848	3.46	35.227
	5.72	69.238	4.13	49.996
	6.60	94.980	4.92	70.816
	7.00	119.787	5.52	94.468
	6.92	140.799	5.73	116.596
	6.41	155.072	5.41	130.890
	5.75	165.396	4.83	138.944
	6.37	222.174	5.28	184.171
	5.34	232.449	4.42	192.417
	4.99	274.148	4.14	227.468
	5.73	420.076	4.75	348.258
	4.62	478.828	3.88	402.165
	4.60	701.931	3.98	607.371
	4.08	1187.174	5.97	1737.308
	2.56	1723.487	2.54	1710.159
	1.00	1345.541	1.00	1345.649
	0.08	189.891	0.08	189.906
		8311.745		7651.720
	Deff (mm)	0.0120	Deff (mm)	0.0131
	K (cm/sec)	4.6E-05	K (cm/sec)	5.4E-05
	K (ft/day)	0.13	K (ft/day)	0.15
	K (m/day)	0.04	K (m/day)	0.05
	D10 (mm)	0.0120	D10 (mm)	0.0131
	K Hazen (cm/sec)	1.45E-04	K Hazen (cm/sec)	1.71E-04
	K (ft/day)	0.41	K (ft/day)	0.48
	K Hazen (cm/sec)	7.47E-05	K Hazen (cm/sec)	8.81E-05
	K (ft/day)	0.21	K (ft/day)	0.25
		37.67		
		52.86		
		9.46		

Analysis of K results

Formation	Geomean of K (cm/sec)	STD	# of Samples
Brule	8.9E-05	6.1E-05	13

Porosity	0.438
Kozeny-Carman Coeff	4.8 Range 4.5 to 5.1
Shape Factor	6.5 Range 6 to 8.4

Rounded 6.1 - 6.6
Medium angular 7.4 - 7.5
Very Angular 7.7 - 8.4

Effective Grain Size (cm)	0.001164539
Intrinsic Permeability (cm2)	1.8E-09
Rho (g/cm3)	1.03
Viscosity (dyne-sec/cm2)	0.016
Gravitational Const (cm/sec2)	980
Hydraulic Conductivity K (cm/sec)	1.1E-04

$$\text{Intrinsic Permeability} = \frac{\text{Porosity}^3}{\left(\frac{\text{K-C}}{\text{coefficient}} \times \left(\frac{\text{Shape Factor}}{\text{Effective Grain Size}}\right)^2 \times (1 - \text{Porosity})^2\right)}$$

$$\text{Hydraulic Conductivity (K)} = \frac{\text{Intrinsic Permeability} \times \text{Density} \times \text{Gravity}}{\text{Viscosity}}$$

		Upper Chadron		Upper Chadron		Upper Chadron	
	Porosity	0.35		0.35		0.35	
		M-1635C Run 3, Sample 1		**M-1454c Run 1**		**M-1624c Run 1**	
Sieves Size/Number	Sieve Size (mm)	Retained (%)		Retained (%)		Retained (%)	
	6.35107	0.00		0.00		0.00	
	4.75683	0.00	0.000	0.00	0.000	0.00	0.000
	3.36359	0.00	0.000	0.00	0.000	0.00	0.000
	2.00000	0.00	0.000	0.00	0.000	0.00	0.000
Medium Sand	1.18921	0.00	0.000	3.58	2.211	0.81	0.500
	0.84090	0.17	0.164	11.00	10.646	2.66	2.573
	0.70711	0.40	0.510	3.31	4.223	0.89	1.135
	0.59460	0.56	0.849	2.42	3.671	0.81	1.228
	0.50000	0.77	1.388	2.14	3.860	1.05	1.892
	0.42045	0.93	1.993	1.85	3.967	1.28	2.743
Fine Sand	0.35355	0.79	2.013	1.22	3.111	1.16	2.956
	0.29730	1.07	3.243	1.34	4.062	1.72	5.211
	0.25000	1.05	3.783	1.13	4.073	1.76	6.340
	0.21022	1.53	6.555	1.36	5.829	2.25	9.636
	0.17678	2.36	12.021	1.63	8.306	2.84	14.462
	0.14865	3.19	19.320	1.89	11.451	3.32	20.102
	0.12500	3.54	25.492	2.06	14.841	3.52	25.341
	0.10511	3.66	31.338	2.23	19.102	3.69	31.586
#200	0.08839	4.02	40.926	2.62	26.684	4.10	41.728
	0.07433	4.75	57.498	3.31	40.083	4.77	57.723
Silt	0.06250	5.53	79.591	4.09	58.889	5.44	78.273
	0.05256	5.99	102.505	4.59	78.579	5.83	99.738
	0.04419	6.12	124.524	4.73	96.280	5.87	119.403
	0.03716	5.98	144.672	4.54	109.879	5.54	133.989
	0.03125	5.68	163.386	4.23	121.725	5.02	144.359
	0.02503	6.54	228.108	4.87	169.928	5.58	194.567
	0.02005	5.53	240.725	4.23	184.208	4.69	204.100
	0.01563	5.10	280.197	3.98	218.751	4.33	237.824
	0.01105	5.70	417.885	4.53	332.241	4.81	352.534
	0.00781	4.47	463.291	3.67	380.528	3.79	392.699
	0.00500	4.37	666.848	3.77	575.520	3.77	575.123
Clay	0.00195	6.15	1789.526	5.78	1682.536	5.38	1565.017
	0.00098	2.77	1864.904	2.69	1811.769	2.34	1574.950
	0.00049	1.18	1587.771	1.08	1453.795	0.93	1251.016
	0.00038	0.10	226.065	0.09	203.540	0.08	178.539
			8587.092	Sum(fi/(dli^0.404*	7644.287		7327.286
		Deff (mm)	0.0116	Deff (mm)	0.0131	Deff (mm)	0.0136
		K (cm/sec)	**4.3E-05**	**K (cm/sec)**	**5.4E-05**	**K (cm/sec)**	**5.9E-05**
		K (ft/day)	0.12	K (ft/day)	0.15	K (ft/day)	0.17
		K (m/day)	0.04	K (m/day)	0.05	K (m/day)	0.05
		D10 (mm)	0.0116	D10 (mm)	0.0131	D10 (mm)	0.0136
		K Hazen (cm/sec)	1.36E-04	K Hazen (cm/sec)	1.71E-04	K Hazen (cm/sec)	1.86E-04
		K (ft/day)	0.38	K (ft/day)	0.49	K (ft/day)	0.53
		K Hazen (cm/sec)	7.00E-05	K Hazen (cm/sec)	8.83E-05	K Hazen (cm/sec)	9.61E-05
		K (ft/day)	0.20	K (ft/day)	0.25	K (ft/day)	0.27

Sand (%)	28.79	43.11	36.62
Silt (%)	61.01	47.25	54.65
Clay (%)	10.20	9.64	8.73

Analysis of K results			
Formation	**Geomean of K (cm/sec)**	**STD**	**# of Samples**
Upper Chadron	5.1E-05	8.2E-06	3

Porosity	0.438	
Kozeny-Carman Coeff	4.8	Range 4.5 to 5.1
Shape Factor	6.5	Range 6 to 8.4

Rounded 6.1 - 6.6
Medium angular 7.4 - 7.5
Very Angular 7.7 - 8.4

Effective Grain Size (cm)	0.0007421
Intrinsic Permeability (cm2)	7.2E-10
Rho (g/cm3)	1.03
Viscosity (dyne-sec/cm2)	0.016
Gravitational Const (cm/sec2)	980
Hydraulic Conductivity K (cm/sec)	4.6E-05

$$\text{Intrinsic Permeability} = \frac{\text{Porosity}^3}{\left(\frac{\text{K-C coefficient}}{\text{Shape Factor}} \times \left(\frac{\text{Shape Factor}}{\text{Effective Grain Size}}\right)^2 \times (1 - \text{Porosity})^2\right)}$$

$$\text{Hydraulic Conductivity (K)} = \frac{\text{Intrinsic Permeability} \times \text{Density} \times \text{Gravity}}{\text{Viscosity}}$$

		Middle Chadron		Middle Chadron	
	Porosity	0.35		0.35	
		M-1451c Run 2		**M-1624c Run 2**	
Sieves Size/Number	Sieve Size (mm)	Retained (%)		Retained (%)	
	6.35107	0.00		0.00	
	4.75683	0.00	0.000	0.00	0.000
	3.36359	0.00	0.000	0.00	0.000
	2.00000	0.00	0.000	0.00	0.000
Medium Sand	1.18921	0.00	0.000	2.23	1.377
	0.84090	1.24	1.200	8.51	8.234
	0.70711	2.40	3.061	4.07	5.191
	0.59460	1.92	2.911	4.04	6.126
	0.50000	1.42	2.560	3.97	7.158
	0.42045	1.60	3.430	3.55	7.611
Fine Sand	0.35355	1.64	4.180	2.54	6.474
	0.29730	2.63	7.970	3.04	9.214
	0.25000	2.46	8.864	2.40	8.649
	0.21022	2.67	11.439	2.31	9.898
	0.17678	2.82	14.365	2.24	11.412
	0.14865	2.77	16.777	2.14	12.963
	0.12500	2.49	17.931	1.98	14.260
	0.10511	2.26	19.351	1.83	15.671
#200	0.08839	2.26	23.008	1.79	18.226
	0.07433	2.41	29.172	1.85	22.397
Silt	0.06250	2.55	36.701	1.93	27.781
	0.05256	2.63	45.007	2.00	34.230
	0.04419	2.80	56.972	2.13	43.345
	0.03716	3.04	73.546	2.28	55.167
	0.03125	3.28	94.350	2.43	69.908
	0.02503	4.40	153.467	3.22	112.324
	0.02005	4.43	192.841	3.24	141.058
	0.01563	4.61	253.276	3.39	186.273
	0.01105	5.86	429.615	4.36	319.687
	0.00781	5.69	589.737	4.35	450.912
	0.00500	7.07	1078.859	5.63	859.231
Clay	0.00195	13.10	3811.835	10.80	3142.990
	0.00098	5.63	3790.401	4.44	2989.622
	0.00049	1.79	2408.567	1.22	1641.807
	0.00038	0.13	293.884	0.08	174.092
			13475.274	Sum(fi/(dli^0.404*	10413.286
		Deff (mm)	0.0074	Deff (mm)	0.0096
		K (cm/sec)	**1.7E-05**	**K (cm/sec)**	**2.9E-05**
		K (ft/day)	0.05	K (ft/day)	0.08
		K (m/day)	0.02	K (m/day)	0.03
		D10 (mm)	0.0074	D10 (mm)	0.0096
		K Hazen (cm/sec)	5.51E-05	K Hazen (cm/sec)	9.22E-05
		K (ft/day)	0.16	K (ft/day)	0.26
		K Hazen (cm/sec)	2.84E-05	K Hazen (cm/sec)	4.76E-05
		K (ft/day)	0.08	K (ft/day)	0.13

Sand (%)	32.99	48.50
Silt (%)	46.36	34.96
Clay (%)	20.65	16.54

Analysis of K results			
Formation	**Geomean of K (cm/sec)**	**STD**	**# of Samples**
Middle Chadron	2.2E-05	8.29E-06	2

Porosity	0.438
Kozeny-Carman Coeff	4.8
Shape Factor	6.5
Effective Grain Size (cm)	0.000232359
Intrinsic Permeability (cm2)	7.1E-11
Rho (g/cm3)	1.03
Viscosity (dyne-sec/cm2)	0.016
Gravitational Const (cm/sec2)	980
Hydraulic Conductivity K (cm/sec)	4.5E-06

$$\text{Intrinsic Permeability} = \frac{\text{Porosity}^3}{\left(\frac{\text{K-C}}{\text{coefficient}} \times \left(\frac{\text{Shape Factor}}{\text{Effective Grain Size}}\right)^2 \times (1 - \text{Porosity})^2\right)}$$

$$\text{Hydraulic Conductivity (K)} = \frac{\text{Intrinsic Permeability} \times \text{Density} \times \text{Gravity}}{\text{Viscosity}}$$

				Rerun	
		Basal Sandstone/Pierre Shale		Basal Sandstone/Pierre Shale	
	Porosity	0.35		0.35	
		M-1912C Run 4, Sample 2		M-1912C Run 4, Sample 2R2	
Sieves Size/Number	Sieve Size (mm)	Retained (%)		Retained (%)	
	6.35107	0.00		0.00	
	4.75683	0.00	0.000	0.00	0.000
	3.36359	0.00	0.000	0.00	0.000
	2.00000	0.00	0.000	0.00	0.000
Medium Sand	1.18921	0.00	0.000	25.71	15.870
	0.84090	0.00	0.000	25.10	24.283
	0.70711	0.00	0.000	9.82	12.523
	0.59460	0.00	0.000	6.77	10.265
	0.50000	0.00	0.000	4.24	7.644
	0.42045	0.00	0.000	2.66	5.702
Fine Sand	0.35355	0.00	0.000	1.46	3.721
	0.29730	0.00	0.000	1.33	4.030
	0.25000	0.00	0.000	0.82	2.955
	0.21022	0.00	0.000	0.70	2.999
	0.17678	0.00	0.000	0.59	3.005
	0.14865	0.00	0.000	0.48	2.907
	0.12500	0.00	0.000	0.40	2.881
	0.10511	0.00	0.000	0.37	3.168
#200	0.08839	0.00	0.000	0.35	3.563
	0.07433	0.00	0.000	0.33	3.995
Silt	0.06250	0.00	0.000	0.31	4.462
	0.05256	0.00	0.000	0.30	5.134
	0.04419	0.00	0.000	0.30	6.104
	0.03716	0.00	0.000	0.31	7.500
	0.03125	0.00	0.000	0.33	9.492
	0.02503	0.00	0.000	0.48	16.742
	0.02005	0.10	4.177	0.56	24.377
	0.01563	2.33	127.940	0.63	34.613
	0.01105	5.79	424.246	0.94	68.914
	0.00781	7.14	739.608	1.36	140.957
	0.00500	12.59	1921.642	2.38	363.180
Clay	0.00195	39.38	11458.186	6.53	1900.098
	0.00098	23.99	16148.973	3.35	2255.390
	0.00049	8.14	10946.796	1.02	1372.480
	0.00038	0.56	1265.254	0.07	158.245
			43036.821		6477.198
		Deff (mm)	0.0023	Deff (mm)	0.0154
		K (cm/sec)	**1.7E-06**	**K (cm/sec)**	**7.5E-05**
		K (ft/day)	0.00	K (ft/day)	0.21
		K (m/day)	0.00	K (m/day)	0.07
		D10 (mm)	0.0023	D10 (mm)	0.0154
		K Hazen (cm/sec)	5.40E-06	K Hazen (cm/sec)	2.38E-04
		K (ft/day)	0.02	K (ft/day)	0.68
		K Hazen (cm/sec)	2.79E-06	K Hazen (cm/sec)	1.23E-04
		K (ft/day)	0.01	K (ft/day)	0.35

Sand (%)	0.00	81.13
Silt (%)	27.94	7.90
Clay (%)	72.06	10.97

Analysis of K results			
Formation	**Geomean of K (cm/sec)**	**STD**	**# of Samples**
Basal Sandstone	7.5E-05	N/A	1

Note : While values have been calculated for the Pierre Shale using Kozeny-Carman, those values are not valid due to high levels of clay present and have not been included in the application.

Porosity	0.438		
Kozeny-Carman Coeff	4.8	Range 4.5 to 5.1	
Shape Factor	6.5	Range 6 to 8.4	Rounded 6.1 - 6.6 Medium angular 7.4 - 7.5 Very Angular 7.7 - 8.4

		Range 4.5 to 5.1	
		Range 6 to 8.4	Rounded 6.1 - 6.6 Medium angular 7.4 - 7.5 Very Angular 7.7 - 8.4

Effective Grain Size (cm)	0.000242738
Intrinsic Permeability (cm2)	7.7E-11
Rho (g/cm3)	1.03
Viscosity (dyne-sec/cm2)	0.016
Gravitational Const (cm/sec2)	980
Hydraulic Conductivity K (cm/sec)	4.9E-06

$$\text{Intrinsic Permeability} = \frac{\text{Porosity}^3}{\left(\text{K-C}_{\text{coefficient}} \times \left(\frac{\text{Shape Factor}}{\text{Effective Grain Size}}\right)^2 \times (1 - \text{Porosity})^2\right)}$$

$$\text{Hydraulic Conductivity (K)} = \frac{\text{Intrinsic Permeability} \times \text{Density} \times \text{Gravity}}{\text{Viscosity}}$$

		Pierre Shale		Pierre Shale		Pierre Shale		Pierre Shale		Pierre Shale		Pierre Shale		Pierre Shale	
	Porosity	0.35		0.35		0.35		0.35		0.35		0.35		0.35	
		M-533C Run 5, Sample 1		M-1635C Run 6, Sample 1		M-1912C Run 4, Sample 1		M-1956C Run 6, Sample 1		M-2169C Run 7, Sample 1		M-1451c Run 4		M-1624c Run 5	
Sieves Size/Number	Sieve Size (mm)	Retained (%)		Retained (%)		Retained (%)		Retained (%)		Retained (%)		Retained (%)		Retained (%)	
	6.35107	0.00		0.00		0.00		0.00		0.00		0.00		0.00	
	4.75683	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
	3.36359	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
	2.00000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
Medium Sand	1.18921	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
	0.84090	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
	0.70711	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
	0.59460	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
	0.50000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
	0.42045	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
Fine Sand	0.35355	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
	0.29730	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
	0.25000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
	0.21022	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
	0.17678	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
	0.14865	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.01	0.035
	0.12500	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.08	0.597
	0.10511	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.033	0.24	2.054
#200	0.08839	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.08	0.845	0.39	3.968
	0.07433	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.36	4.358	0.56	6.775
Silt	0.06250	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.77	11.083	0.70	10.070
	0.05256	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	1.14	19.509	0.81	13.855
	0.04419	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	1.55	31.539	0.99	20.134
	0.03716	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	2.10	50.806	1.31	31.677
	0.03125	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	2.87	82.559	1.80	51.752
	0.02503	0.00	0.000	0.00	0.000	0.00	0.000	0.02	0.663	0.02	0.802	4.78	166.726	3.15	109.815
	0.02005	0.09	3.875	0.00	0.000	0.00	0.000	1.49	64.894	1.86	80.989	5.62	244.650	4.11	178.824
	0.01563	2.33	128.038	0.06	3.518	0.22	12.085	4.74	260.551	6.16	338.525	6.45	354.378	5.11	280.609
	0.01105	7.27	533.099	2.68	196.589	5.93	434.660	6.64	487.048	8.34	611.597	9.67	708.960	8.22	602.340
	0.00781	9.81	1016.966	6.89	714.511	8.65	896.346	9.84	1019.345	11.30	1171.499	10.90	1129.760	10.20	1056.658
	0.00500	15.30	2335.220	14.41	2198.624	14.00	2135.927	16.41	2503.863	17.70	2701.691	14.30	2182.201	14.49	2211.573
Clay	0.00195	35.61	10361.055	41.62	12111.541	37.09	10793.190	36.32	10567.955	35.11	10216.148	25.10	7303.818	28.69	8347.045
	0.00098	20.30	13669.860	23.61	15897.619	22.80	15347.046	17.51	11787.899	14.40	9697.428	10.40	7002.024	13.59	9151.743
	0.00049	8.56	11520.485	9.87	13274.738	10.40	13991.113	6.51	8764.120	4.73	6366.257	3.62	4871.109	5.15	6926.297
	0.00038	0.72	1628.008	0.85	1922.627	0.92	2079.379	0.52	1176.136	0.36	814.053	0.28	633.001	0.42	949.009
		Sum(fi/(dli^0.404*	41196.606		46319.766		45689.746		36632.474		31998.990		24797.358		29954.830
		Deff (mm)	0.0024	Deff (mm)	0.0022	Deff (mm)	0.0022	Deff (mm)	0.0027	Deff (mm)	0.0031	Deff (mm)	0.0040	Deff (mm)	0.0033
		K (cm/sec)	**1.9E-06**	**K (cm/sec)**	**1.5E-06**	**K (cm/sec)**	**1.5E-06**	**K (cm/sec)**	**2.4E-06**	**K (cm/sec)**	**3.1E-06**	**K (cm/sec)**	**5.1E-06**	**K (cm/sec)**	**3.5E-06**
		K (ft/day)	0.01	K (ft/day)	0.00	K (ft/day)	0.00	K (ft/day)	0.01	K (ft/day)	0.01	K (ft/day)	0.01	K (ft/day)	0.01
		K (m/day)	0.00	K (m/day)	0.00	K (m/day)	0.00	K (m/day)	0.00	K (m/day)	0.00	K (m/day)	0.00	K (m/day)	0.00
		D10 (mm)	0.0024	D10 (mm)	0.0022	D10 (mm)	0.0022	D10 (mm)	0.0027	D10 (mm)	0.0031	D10 (mm)	0.0040	D10 (mm)	0.0033
		K Hazen (cm/sec)	5.89E-06	K Hazen (cm/sec)	4.66E-06	K Hazen (cm/sec)	4.79E-06	K Hazen (cm/sec)	7.45E-06	K Hazen (cm/sec)	9.77E-06	K Hazen (cm/sec)	1.63E-05	K Hazen (cm/sec)	1.11E-05
		K (ft/day)	0.02	K (ft/day)	0.01	K (ft/day)	0.01	K (ft/day)	0.02	K (ft/day)	0.03	K (ft/day)	0.05	K (ft/day)	0.03
		K Hazen (cm/sec)	3.04E-06	K Hazen (cm/sec)	2.40E-06	K Hazen (cm/sec)	2.47E-06	K Hazen (cm/sec)	3.84E-06	K Hazen (cm/sec)	5.04E-06	K Hazen (cm/sec)	8.39E-06	K Hazen (cm/sec)	5.75E-06
		K (ft/day)	0.01	K (ft/day)	0.01	K (ft/day)	0.01	K (ft/day)	0.01	K (ft/day)	0.01	K (ft/day)	0.02	K (ft/day)	0.02

Sand (%)		0.00		0.00		0.00		0.00		0.00		0.45		1.28	
Silt (%)		34.81		24.05		28.79		39.14		45.40		60.15		50.88	
Clay (%)		65.19		75.95		71.21		60.86		54.60		39.40		47.85	

Analysis of K results			
Formation	**Geomean of K (cm/sec)**	**STD**	**# of Samples**
Pierre Shale	2.5E-06	1.32E-06	7

Replacement Pages – Appendix HH (New Appendix)

Instructions:

Insert new Appendix HH (at the end of Volume IV)

MEA TR

Reponses to Open Issues

6-29-2017

Appendix HH

Deep Brule Monitor Well Installation Program



Final Report
Deep Brule Monitor Well Installation Program
Marsland Expansion Area
Dawes County, Nebraska

Prepared for:

Crow Butte Resources, Inc.

May 3, 2017

Reported by:

James Shriver

Senior Geologist

Cameco Resources

Smith Ranch-Highland Operation

PO Box 120

Glenrock, Wyoming 82637

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY 2
2.0 PROGRAM BACKGROUND 3
3.0 PROGRAM DESCRIPTION 3
4.0 PROGRAM RESULTS 5
5.0 REFERENCES 8

FIGURES

Figure 1 Marsland Expansion Area Location Map
Figure 2 MEA Bedrock Geology and Representative Stratigraphic Section
Figure 3 MEA Stratigraphic Column and Monitor Well Formation Targets
Figure 4 Photographs of Drill Cuttings Samples: DBOW4 Well
Figure 5 MEA DBOW Well Location Map
Figure 6 MEA DBOW Well Locations and Cross Section Index Map
Figure 7 MEA Structural Cross Section AA-AA'
Figure 8 Well Log Comparison Diagrams DBOW1-DBOW3
Figure 9 Well Log Comparison Diagrams DBOW4-DBOW6
Figure 10 Well Log Comparison Diagrams DBOW7-DBOW9
Figure 11 Well Log Comparison Diagram DBOW10
Figure 12 Photograph of Airlifting: DBOW2 Well
Figure 13 Photograph of Airlifting: DBOW3 Well
Figure 14 Photograph of Airlifting: DBOW8 Well
Figure 14 Photograph of Airlifting: DBOW10 Well

TABLES

Table 1 Deep Brule Observation / Monitor Well Summary
Table 2 Deep Brule Observation / Monitor Well Water Levels

ATTACHMENTS

Attachment A - Deep Brule Well Registration Forms - Nebraska Department of Natural Resources

1.0 EXECUTIVE SUMMARY

Crow Butte Resources Inc. (CBR) conducted the first phase of a monitor well installation program in 2016 at the Marsland Expansion Area (MEA), located in Dawes County, Nebraska. Ten wells were installed in the lower (deep) Brule Formation with completion depths ranging from 450 to 630 feet. The well completions and well development were the first phase of the monitor well program and are the subject of this report. Additional program phases, if warranted are to monitor water quality and water levels for one year and to conduct pumping tests to assess any hydrologic connections between the MEA mining zone and the lower Brule.

The monitor well program was proposed by CBR as a result of its revision of the boundary between the Brule and Chadron Formations; the formational boundary was lowered by approximately 280 feet at MEA. Additional characterization of the lower Brule was necessary to address open issues in permitting including potential reclassification of the first overlying aquifer to the mining zone at MEA, and other related regulatory requirements and subsequent revisions to permit applications.

The first phase of the MEA monitor well program resulted in the following conclusions regarding the characterization of the lower Brule Formation:

- Geophysical and geologic sample logging and well development results demonstrate that the lower Brule Formation is composed of non-aquifer sediments and that it does not produce water in usable, significant or economic amounts and cannot be classified as an aquifer.
- Additional testing which includes water quality, water level measurements and pumping tests is not recommended.
- The first overlying aquifer to the mining zone at MEA should remain the Brown Siltstone Member of the upper Brule Formation.

2.0 PROGRAM BACKGROUND

The Marsland Expansion Area (MEA) project is in the permitting stage of development. CBR currently has an application to the U.S. Nuclear Regulatory Commission (NRC) for the MEA license amendment, an Aquifer Exemption Permit (AEP) application to the Nebraska Department of Environmental Quality (NDEQ) and various other required permit applications. CBR revised the Marsland AEP application with changes to the Brule and Chadron Formation geology after reviewing work completed by Swinehart et al. (1985) and LaGarry (1998). The revised AEP reflected changes in the boundary between the Brule and Chadron Formations which was lowered by approximately 280 feet. Along with the revisions to the AEP, CBR proposed to install monitor wells in the lower portion of the Brule, monitor water quality and water levels for one year and to conduct pumping tests to assess any hydrologic connections between the mining zone and the lower Brule (CBR 2016).

Discussions between CBR and the NRC regarding open issues with the MEA license amendment application Technical Report included the topic of additional characterization of the lower Brule Formation (NRC 2016). The NRC summarized, that if an *aquifer* (defined in 10 CFR 40 Appendix A as "...a geologic formation, group of formations, or part of a formation capable of yielding a significant amount of ground water to wells or springs.") deeper than the previously identified aquifer in the Brown Siltstone Member, is determined to represent the first overlying aquifer of the Brule Formation, additional testing and characterization would be required and incorporated into the license application.

CBR implemented the MEA lower (deep) Brule monitor well program with the installation phase being the subject of this report. The field results in this report are to provide additional information about the newly recognized portion of the Brule, and to address the NRC open issue and its potential regulatory requirements. If the lower Brule is determined to be an aquifer by regulatory agency definition, recommendations would be made to conduct the next phase of the program of additional testing.

3.0 PROGRAM DESCRIPTION

Location and General Geology

Situated in northwest Nebraska in the southern portion of Dawes County, the MEA is approximately 11.1 miles south-southeast of the CBR Central Processing Facility and approximately 4.6 miles northeast of the community of Marsland (Figure 1).

Figure 2 presents the bedrock geology at Marsland and a site specific representative stratigraphic column. The stratigraphic sequence at MEA in descending order is alluvial sediments; the Arikaree Group consisting of the Upper Harrison Beds, Harrison-Monroe Creek Formation and Gering Formation; the Brule Formation (which includes the Brown Siltstone, Whitney and Orella Members) the Upper Chadron Formation, Middle Chadron Formation and basal sandstone of the Chadron Formation. The Orella Member of the Brule Formation may have only minimal presence at the MEA as it is not clearly distinguished by drill cuttings or by geophysical log signature. The basal sandstone of the Chadron Formation is the mining zone aquifer at MEA and is underlain by the Pierre Shale. Regional and site specific subsurface geology and stratigraphy is detailed in Section 2.5 of the Technical Report as part of the NRC license amendment (CBR 2015).

As previously described, the boundary between the Brule and the underlying Chadron Formation was lowered by approximately 280 feet at MEA. The revised bottom of the Brule Formation is based on literature review which identifies volcanic ash marker beds (Upper and Lower Whitney Ash) noted in geophysical logs at Marsland, and lithologic changes observed in drill cuttings below the Lower Whitney Ash where the brown and tan siltstones of the lower Brule show a color change towards the brown and green claystones of the Upper Chadron Formation.

The targeted interval to be screened in the monitor well program is the lower portion of the Brule Formation which includes the Whitney Member and the Orella Member, although the Orella may be only minimally present at the MEA. Previously installed Brule monitor wells were screened within sandstone lenses of the Brown Siltstone Member of the upper Brule Formation.

As shown in Figure 3, the MEA stratigraphic column includes the initial interpreted base of the Brule Formation where a distinct grain size change occurs, and the revised base of the Brule occurring below the Lower Whitney Ash. Figure 3 also includes an illustration of the target formation depths of the lower (deep) Brule monitor wells (DBOW), the previously installed shallow Arikaree wells (AOW), the BOW wells which were screened in water bearing sand horizons of the upper Brule, and the monitor wells which were installed and screened in the mining zone aquifer in the basal sandstone of the Chadron Formation.

Well Planning and Installation

Ten DBOW monitor wells were to be drilled (piloted), geophysically logged, reamed, cased, cemented, screens installed and developed by airlifting; monitor well names were designated DBOW1 through DBOW10 (Deep Brule Observation Well). Wells were to be constructed, tested and initially developed using methods described in Sections 3.1.2 of the MEA Technical Report (TR), (CBR 2015).

Monitor well locations were staked in close proximity to BOW wells; target total depths (TD's) were based on revised MEA regional cross sections (TR Figures 2.6-3a through 2.6-3n), interpretation of geophysical logs from nearby exploration drill holes and monitor wells and by

description of cuttings sampled during the drilling of the pilot hole. Screen intervals were to be set in the newly recognized portions of the lower Brule.

The well installation program started on August 11, 2016. During the initial pilot drilling of the DBOW wells, drill cuttings were sampled every 5 feet and laid out for description. Lithologic changes were noted to occur below the Lower Whitney Ash at base of the Brule, where the brown and tan clay rich siltstones change toward the tan/brown and green claystones of the Upper Chadron Formation. The boundary between the Lower Whitney and the underlying Orella Member was not distinguishable by log signature or drill cuttings as they are similar in nature, however the overall lithology change occurring at the Upper Chadron was evident. An example is shown in Figure 4; photographs of the drill cuttings from well DBOW4 show a lithologic change around 510 feet in depth where green clay is noted to occur. The lithologic change is consistent with the interpreted revised base of the Brule shown in revised cross sections in the MEA TR.

The pilot holes were then geophysically logged, reamed, cased and cemented, cement was drilled out and screen assemblies were set. The drill rig was utilized to airlift the wells using an air compressor for a minimum of 3.5 hours and water volumes were measured at the surface to estimate rate of flow from the well. The last DBOW well was installed and initially developed on September 15, 2016. All well sites were reclaimed and seeded during the fall of 2016.

Well locations were resurveyed by GPS, registration forms were completed and submitted to the Nebraska Department of Natural Resources (Attachment A) and well completion reports were sent to the NDEQ.

4.0 PROGRAM RESULTS

The completed DBOW well locations are shown in Figure 5. The completed well depths range from 450 to 630 feet and a summary of the DBOW well information including location data and screened intervals is presented in Table 1.

A structural north-south cross section across the MEA project area includes 8 of the 10 newly installed DBOW wells, selected basal Chadron sandstone monitor (Monitor) wells, exploration drill hole and upper Brule (BOW) monitor wells (Figures 6 and 7). The cross section shows the consistency of the presence of the Upper and Lower Whitney Ash marker beds across the MEA and confirm the placement of the DBOW wells in lower Brule.

Diagrams comparing geophysical logs of all DBOW wells, their associated BOW wells and nearby basal Chadron sandstone monitor wells or exploration drill holes (which were used to help determine the target depth of the DBOW wells) are shown in Figures 8 through 11.

Geophysical and Drill Cuttings Logs

The geophysical logs shown in the cross sections and in the well cluster diagrams indicate a lack of aquifer potential in the lower Brule. The resistivity and SP curves throughout the lower Brule have relatively low activity with little character and do not demonstrate the presence of sandstones such as the log signatures in the overlying Arikaree Group sandstones, the sandstone horizons in the upper Brule and the basal sandstone of the Chadron Formation. The small and thin resistivity / SP gamma kicks that do occur in the lower Brule are associated with the Upper and Lower Whitney Ash beds, which are composed of silt & clay size particles.

Drill cuttings samples recovered from the lower Brule consist predominantly of siltstone, silty claystone and clay rich siltstone but only occasionally possess small amounts of sand sized material. This is in contrast to drill cuttings from the Arikaree Group, the upper Brule sandstones and the basal sandstone of the Chadron which do reveal the presence of sand bodies and are consistent with the interpretation of the geophysical logs.

The poor water-bearing potential of the lower Brule as observed in drill cuttings is consistent with the results of core material testing. Laboratory grain size analysis conducted on 2 core samples within the lower Brule, M-1956C Run 5 Samples 1 and 2 (PTS 2013) resulted in average grain size of 0.052 and 0.029 mm (both classified as silt).

Well Development

Initial well capacities measured during development by airlifting of the DBOW wells further validate the poor water-bearing potential of the lower Brule Formation. Initial well development on the drill rig by airlifting using compressed air was conducted on all wells for a minimum of 3.5 hours following installation of each screen assembly. The initial flow rate / well capacity estimates made during airlifting resulted in a maximum of 0.15 gallons per minute (gpm) (reported as <0.2 gpm to the Nebraska Department of Natural Resources) for wells DBOW2 and DBOW3. Photographs extracted from videos taken during well airlifting are presented in Figures 12 through 15 and display the insignificant amounts of water availability at the time of well development.

The small amounts of water produced from the wells during airlifting demonstrate that no usable quantities exist within the lower Brule.

Following mechanical integrity testing, the DBOW wells were evacuated of water using a wireline / slimline pump assembly. Field conductivity / pH measurements were taken on the extracted water and the elevated readings indicated the presence of drilling mud filtrate and cement thus requiring further well development. Submersible pumps were then installed in each of the wells and static water levels were measured in December 2016. Water levels for each of the DBOW wells are shown in Table 2. The wells were pumped until dry (approximately one casing volume) on several occasions from December 2016 through April, 2017 in an attempt to continue well development. The results of continued conductivity and pH measurements of the extracted water

revealed that the values were slowly dropping but were still elevated and had yet to stabilize several months after well completion.

Two wells (DBOW 3 and DBOW 6) were evacuated and water levels were measured during the recovery cycle for each well. The maximum recovery rate calculated was 0.08 gpm for DBOW 3 and 0.28 gpm for DBOW6; both wells took more than 1 week to return to initial water level.

The extremely low well recovery rates further indicate a formation with very low hydraulic conductivity, which is consistent with previous lab testing. Falling Head Permeameter testing of a core sample from the lower Brule (M-2169c Run 5 sample 1) measured hydraulic conductivity of 1.31×10^{-7} cm/sec. (PTS 2014).

The low recovery rates confirm that the DBOW monitor wells completed in the lower Brule Formation do not produce water in usable, significant or economic quantities and therefore the lower Brule cannot be determined to be an aquifer at the MEA.

Summary

- Geophysical and geologic sample logging and well development results of the DBOW monitor well installation program demonstrate that the lower Brule Formation is not an aquifer and additional testing and characterization is not recommended.
- The first overlying aquifer of the mining zone at the MEA should remain the Brown Siltstone Member of the upper Brule Formation.

5.0 REFERENCES

CBR, 2015. Crow Butte Resources, Inc. Revised Marsland Expansion Area Technical Report, Incorporating all Responses to the Request for Additional Information, Amendment to Source Material License – SUA-1534, November 12, 2015, ADAMS Accession No. ML15328A422 (Package).

CBR, 2016. Letter from Wade Beins, Crow Butte Resources, Inc. to M. Link, Nebraska Department of Environmental Quality, Marsland Permitting Revision, April 20, 2016, ADAMS Accession No. ML16118A326

LaGarry, Hanna E., 1998. Lithostratigraphic Revision and Redescription of the Brule Formation (White River Group) of northwestern Nebraska in Geologic Society of America Special Paper 325.

NRC, 2016. Letter from Tom Lancaster, U.S. NRC, to L. Teahon, Cameco Resources, Crow Butte Operation, Summary of June 14, 2016 Teleconference Regarding Open Issues, Crow Butte Resources, Inc., Marsland Expansion Area License Amendment (CAC No. J00683), July 5, 2016.

PTS, 2013. PTS Laboratories, Inc., File No. 43570 Physical Properties Data - Marsland Core, 10/10/2013.

PTS, 2014. PTS Laboratories, Inc., File No. 44735 Physical Properties Data - Hydraulic Conductivity, 12/11/2014.

Swinehart James B., Souders Vernon L., Degraw, Harold M., Diffendal Jr., Robert F., 1985. Cenozoic Paleogeography of Western Nebraska in Rocky Mountain SEPM Rocky Mountain Paleogeography Symposium 3, Cenozoic Paleogeography of West-central United States. Denver, Colorado.

Tables

Table 1
Deep Brule Observation / Monitor Well Summary
Marsland Expansion Area
Dawes County, Nebraska

Well ID	Easting*	Northing	Elevation GL	TOC Height	TOC Elevation	Qtr-Qtr	Section	Township (N)	Range (W)	Formation	Date Completed	Casing Depth	K-Packer Depth	Top of Screen	Bottom of Screen	Top of Screen	Bottom of Screen	Top of Screen	Bottom of Screen
DBOW1	1,121,472	446,312	4259.7	0.7	4260.4	SWSW	1	29	51	Lower Brule	8/24/2016	459	455	465	505	555	565		
DBOW2	1,121,278	450,084	4330.3	0.6	4330.9	NWNW	1	29	51	Lower Brule	8/25/2016	519	510	530	550	620	630		
DBOW3	1,117,047	450,929	4350.3	0.7	4351.0	NENW	2	29	51	Lower Brule	9/1/2016	499	490	500	520	530	570	610	630
DBOW4	1,124,577	434,792	4161.0	0.7	4161.7	NENE	24	29	51	Lower Brule	9/9/2016	379	370	380	440	450	490		
DBOW5	1,129,422	432,057	4123.7	0.9	4124.6	NESE	19	29	50	Lower Brule	9/15/2016	319	315	325	385	435	460		
DBOW6	1,131,480	429,004	4098.8	0.9	4099.7	NENW	29	29	50	Lower Brule	9/14/2016	299	290	300	350	380	400	430	450
DBOW7	1,122,420	442,889	4246.9	0.6	4247.5	NESW	12	29	51	Lower Brule	8/19/2016	479	470	480	500	510	540	550	580
DBOW8	1,120,622	456,167	4365.6	0.5	4366.1	NENE	35	30	51	Lower Brule	8/30/2016	509	501	511	531	541	561	581	601
DBOW9	1,128,050	436,427	4146.1	0.6	4146.7	NWSE	18	29	50	Lower Brule	9/13/2016	379	375	385	405	455	480		
DBOW10	1,126,717	440,765	4195.9	0.6	4196.5	SWSW	7	29	50	Lower Brule	9/12/2016	399	390	400	480	510	530		

* NAD27 State Plane Nebraska North FIPS 2601
Elevations and surface coordinates are measured in feet.
TOC: Top of Casing

Table 2

Deep Brule Observation / Monitor Well Water Levels

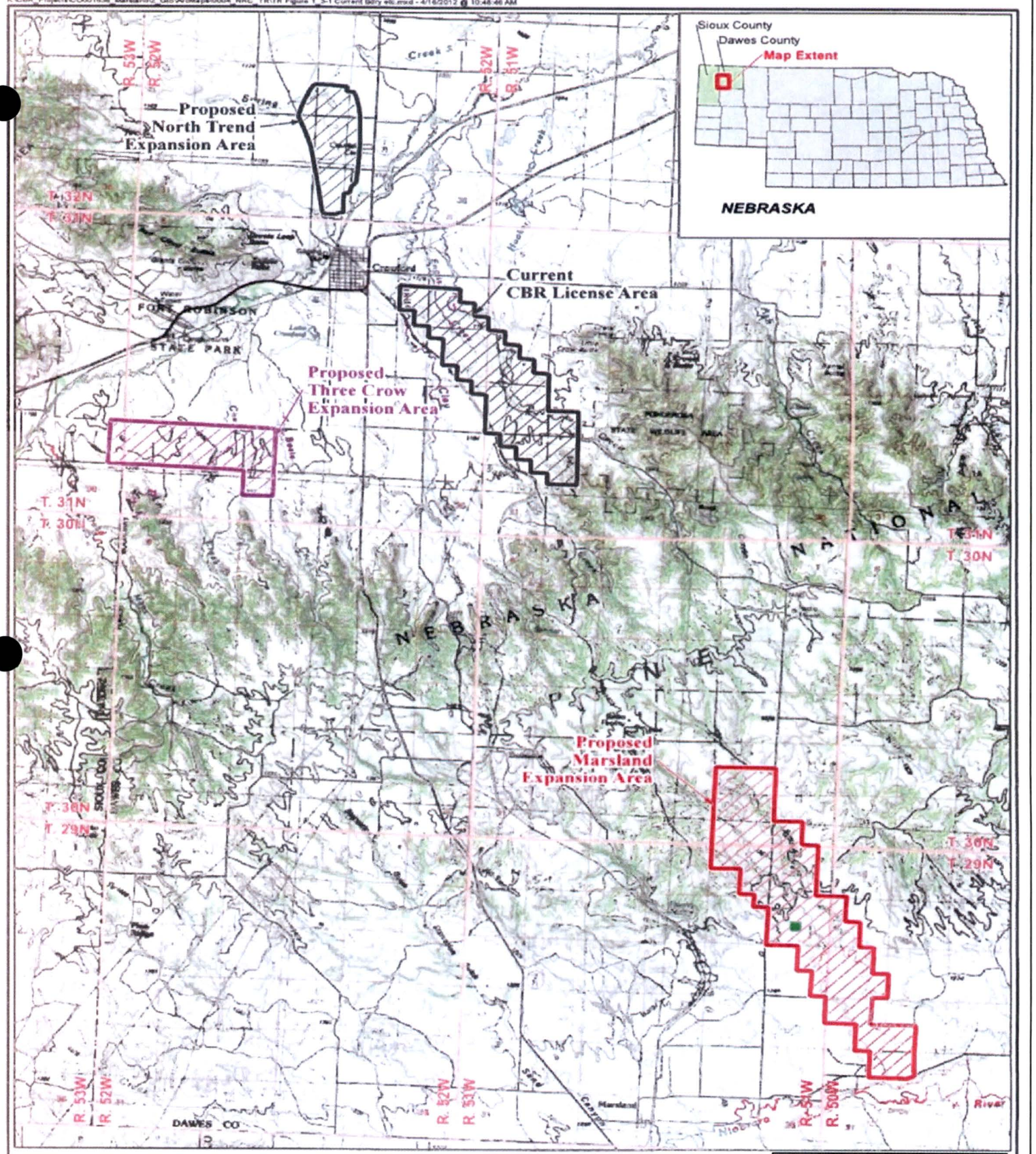
Marsland Expansion Area

Dawes County, Nebraska

Well ID	Elevation GL	Date	Water Level	Water Level Elevation
DBOW1	4259.7	12/8/2016	120.5	4139.3
DBOW2	4330.3	12/8/2016	156.7	4173.7
DBOW3	4350.3	12/7/2016	136.6	4213.8
DBOW4	4161.0	12/8/2016	91.6	4069.4
DBOW5	4123.7	12/8/2016	69.6	4054.1
DBOW6	4098.8	12/8/2016	46.0	4052.8
DBOW7	4246.9	12/8/2016	151.9	4095.0
DBOW8	4365.6	12/7/2016	72.1	4293.5
DBOW9	4146.1	12/6/2016	70.8	4075.3
DBOW10	4195.9	12/6/2016	111.9	4084.1

Levels are measured in feet.

Figures

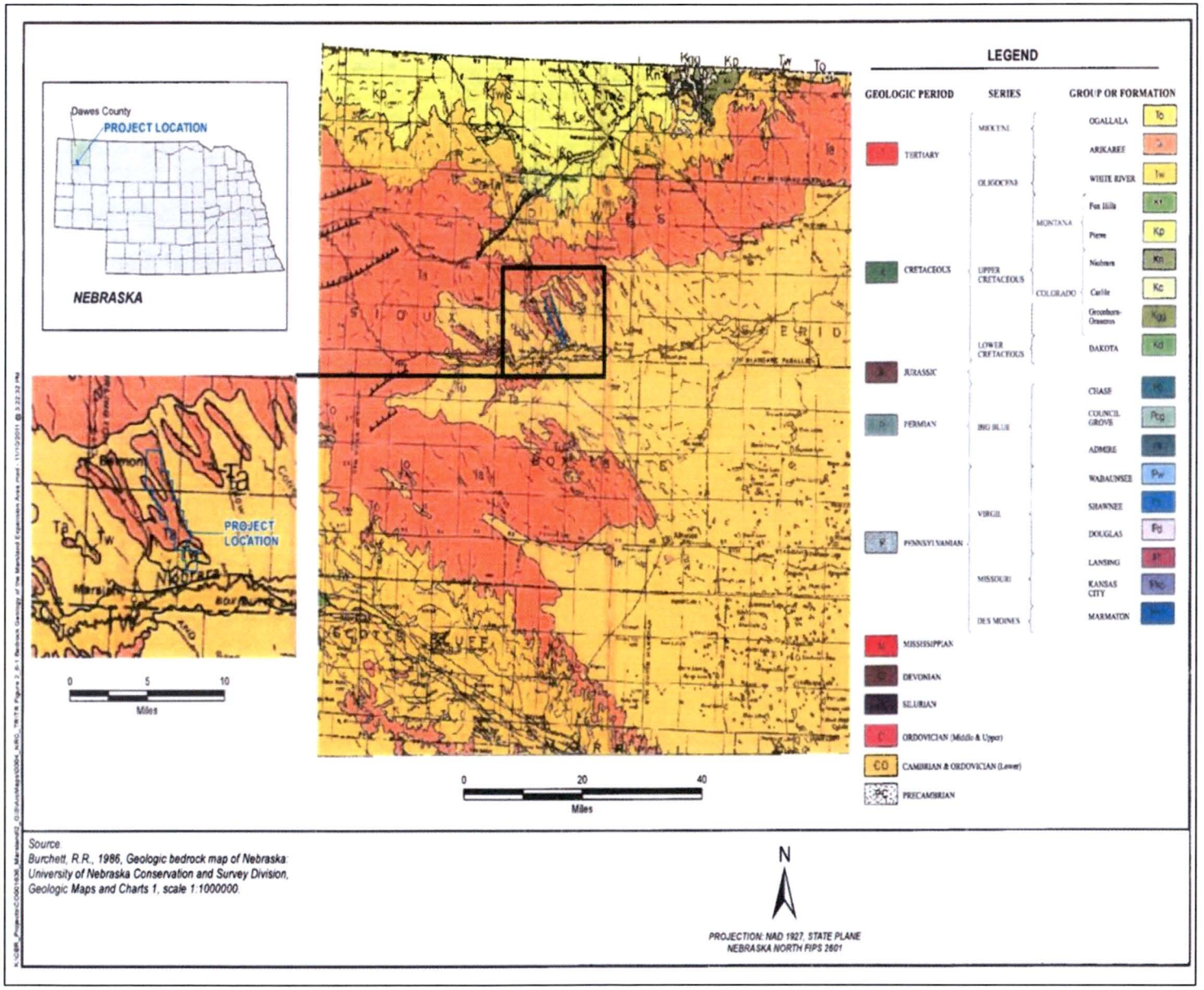


Crow Butte Resources, Inc

Figure 1
Marsland Expansion Area
Location Map

Scale: See Scale Bar	Date: 12/30/2016

Figure 2 Bedrock Geology and Representative Stratigraphic Section – Marsland Expansion Area



Group	Formation & Member (MEA)	
Arikaree Group		Upper Harrison Beds
		Harrison – Monroe Creek Formation
		Gering Formation
White River Group	Brule Formation	Brown Siltstone Member
		Whitney Member
		Orella Member
	Chadron Formation	Upper Chadron
		Middle Chadron
		basal sandstone of the Chadron Formation
Montana Group	Pierre Shale	

Figure 3 Marsland Expansion Area Stratigraphic Column and Monitor Well Formation Targets

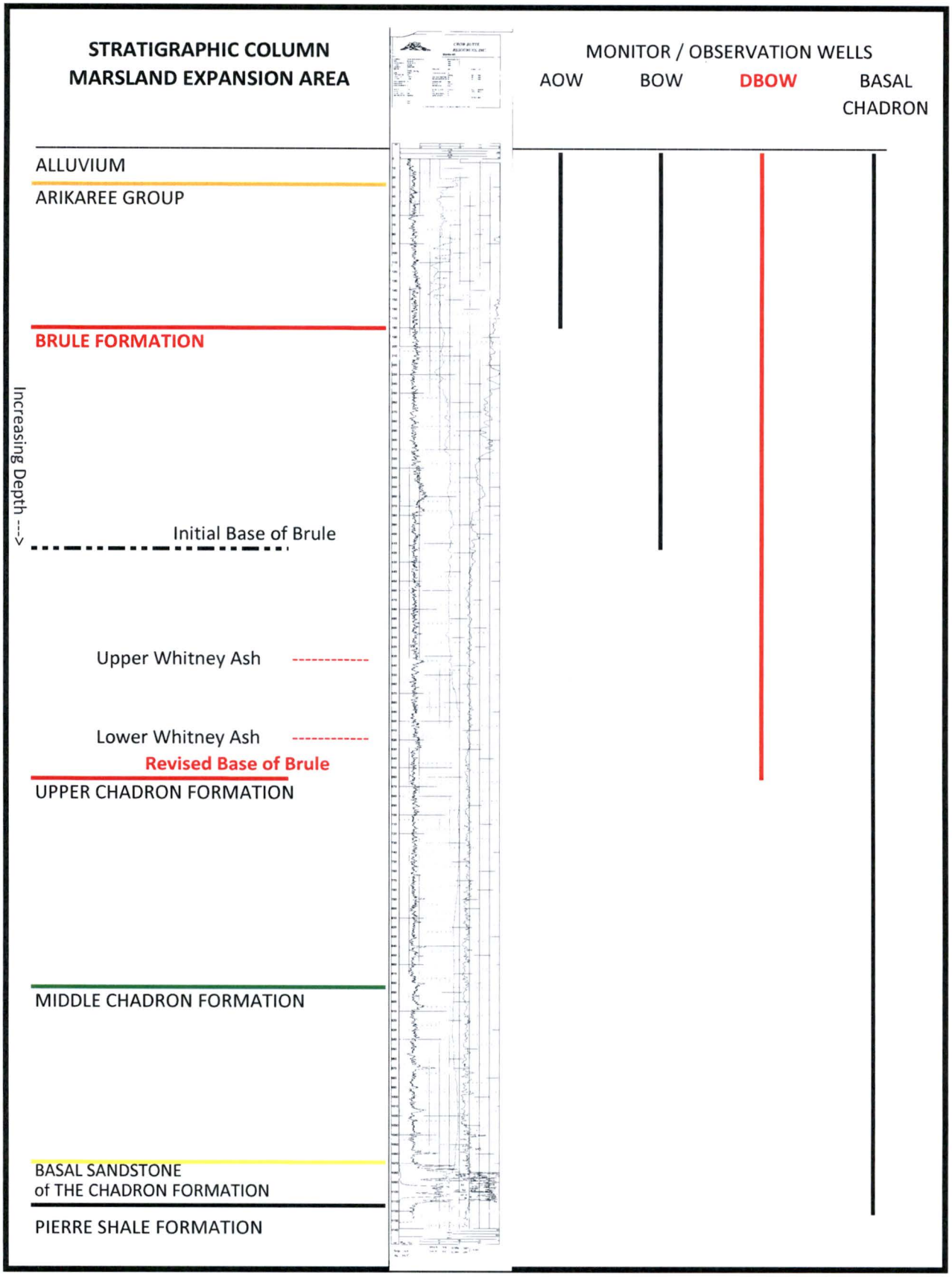


Figure 4
Drill Cuttings Samples: DBOW4 Well

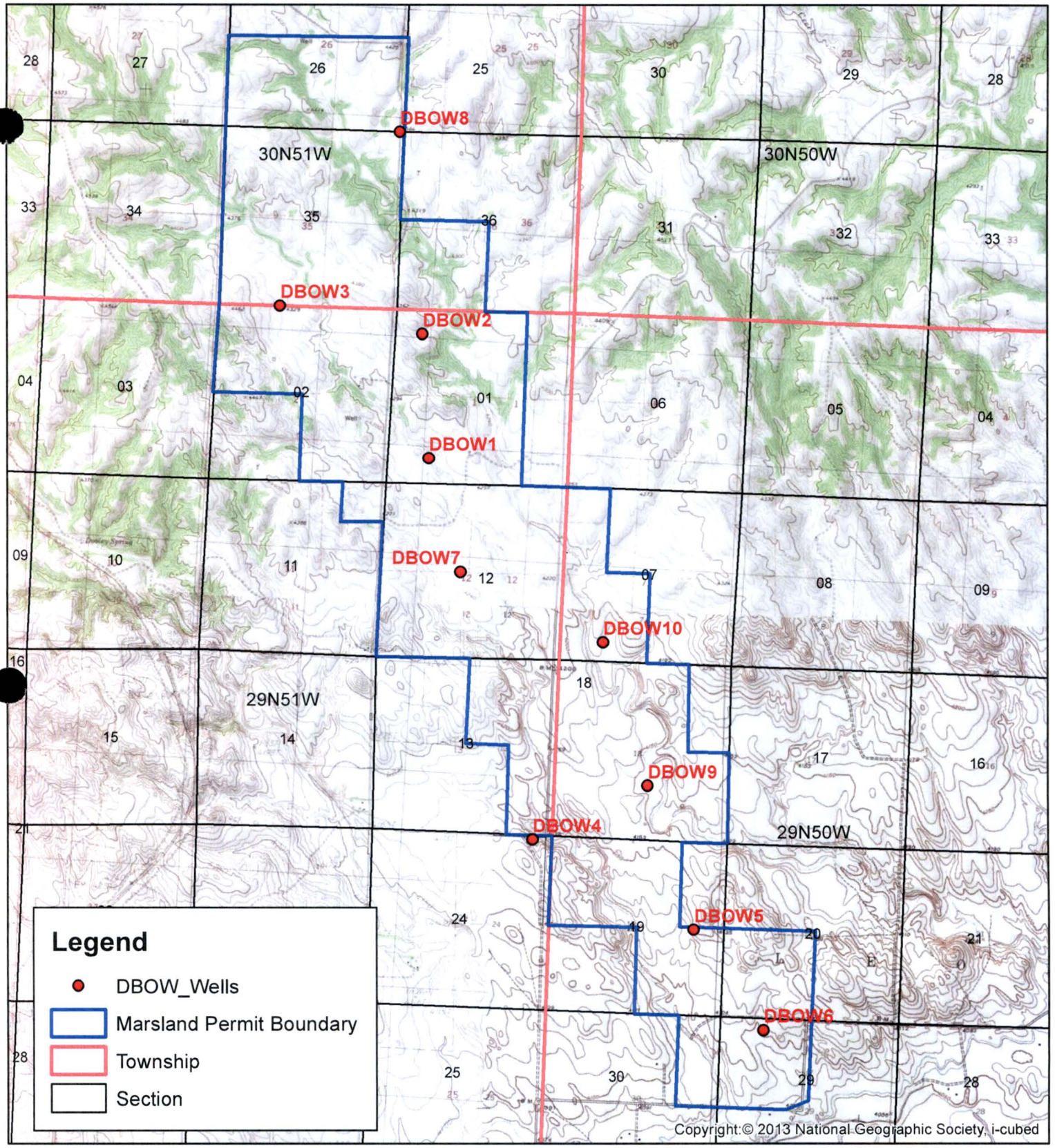
Cuttings Sampled every 5 Feet

Sample Depth
0-100'
100-200'
200-300'
300-400'
400-500'
500-520'





510-520'
Green Clay Observed:
Upper Chadron Formation



REVISIONS		
NO.	DATE	BY

Crow Butte Resources, Inc.

Figure 5
Marsland Expansion Area
DBOW Well Locations

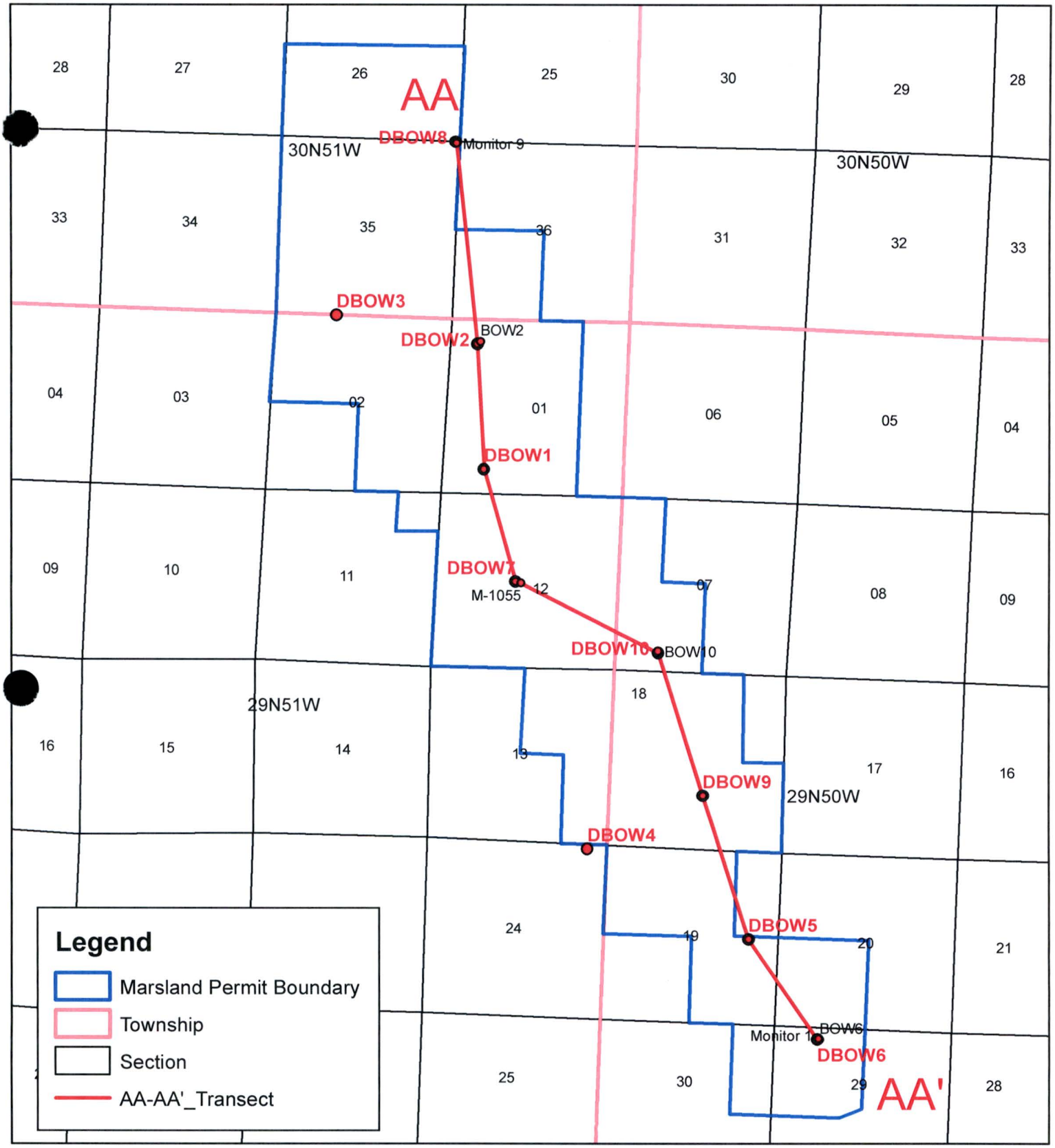
N

SIZE	DATE	DEPARTMENT	COORDINATE SYSTEM	REV
	12/30/2016		NAD27 State Plane Nebraska North FIPS 2601	

GEOL. BY: JB DATE: XXXX
ENG. BY: XXXX DATE: XXXX
DRAFT BY: XXXX DATE: XXXX

DRAWING LOCATION: C:\Users\ca041426\Desktop\DBOW TEMP\X-Sections\Marsland DBOW Monitor wells 2016.mxd

Miles
0 0.25 0.5 1 1.5 2



REVISIONS		
NO.	DATE	BY

Crow Butte Resources, Inc.

Figure 6
Marsland Expansion Area
DBOW Well Locations
Cross Section AA-AA'

N

SIZE:
DATE: 12/30/2016
DEPARTMENT:
COORDINATE SYSTEM: NAD27 State Plane Nebraska North FIPS 2601
REV:

GEOL. BY: XXXX DATE: XXXX
ENG. BY: XXXX DATE: XXXX
DRAFT BY: XXXX DATE: XXXX

DRAWING LOCATION: C:\Users\ca041426\Desktop\DBOW TEMP\X-Sections\Marsland DBOW Monitor wells Cross Section Index Map.mxd

0 0.25 0.5 1 1.5 2 Miles

M-347C | BOW1 | DBOW1 | AOW1 | MONITOR 4A | BOW2 | DBOW2 | MONITOR 8 | BOW3 | DBOW3 | AOW3

Depth Feet

0
100
200
300
400
500
600
700
800
900
1000
1100

Alluvium

Arikaree Group

Brule Fm.

Upper Whitney Ash

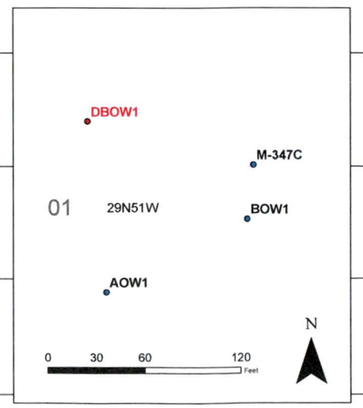
Lower Whitney Ash

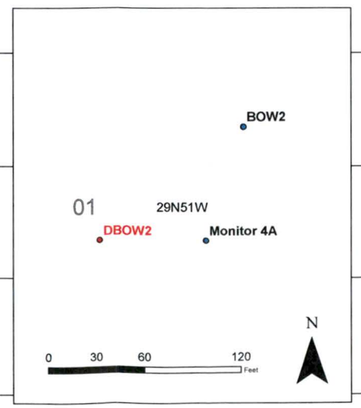
Upper Chadron Fm.

Middle Chadron Fm.

Basal 33 of the Chadron Fm.

Pierre Shale





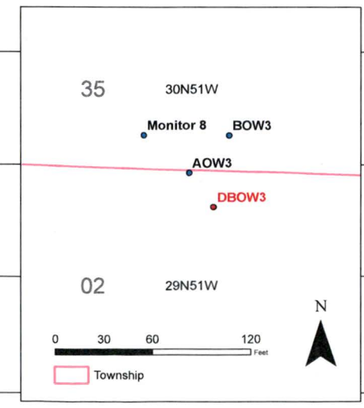


Figure 8 Well Log Comparison Diagrams DBOW1 - DBOW3

MONITOR 10 | BOW4A | DBOW4 | AOW4

MONITOR 11 | BOW5 | DBOW5 | AOW5

MONITOR 1 | BOW6 | DBOW6 | AOW6

Depth Feet

0 Alluvium

Arikaree Group

100 Brule Fm.

200

300

400 Upper Whitney Ash

500 Lower Whitney Ash

Upper Chadron Fm.

600

700

Middle Chadron Fm.

800

900 Basal 4.5 ft. of the Chadron Fm.

1000 Pierre Shale

1100

Depth Feet

0

100

200

300

400

500

600

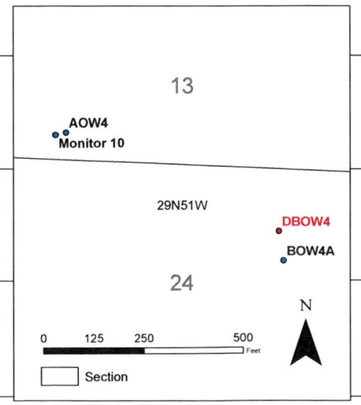
700

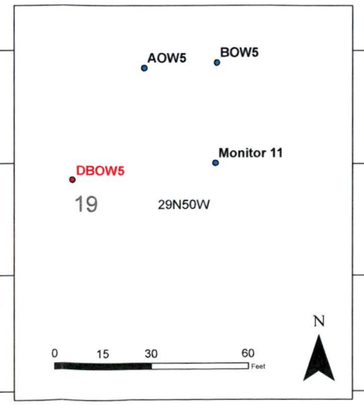
800

900

1000

1100





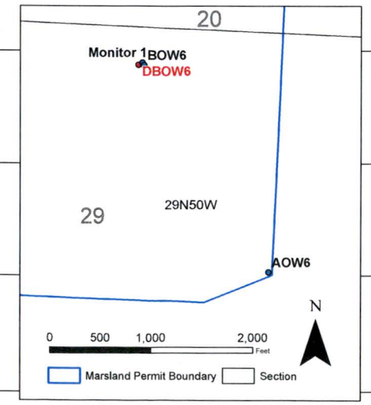


Figure 9 Well Log Comparison Diagrams DBOW4 - DBOW6

M-1055 | BOW7 | DBOW7 | AOW7

MONITOR 9 | BOW8 | DBOW8 | AOW8

M-888 | BOW9 | DBOW9 | AOW9

Depth Feet

0
100
200
300
400
500
600
700
800
900
1000
1100

Alluvium

Arikaree Group

Brule Fm.

Upper Whitney Ash

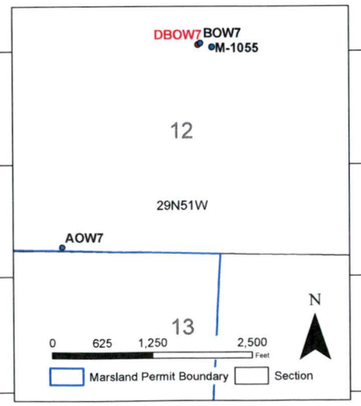
Lower Whitney Ash

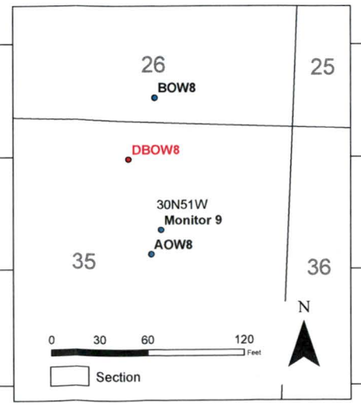
Upper Chadron Fm.

Middle Chadron Fm.

Basal 88 of the Chadron Fm.

Pierre Shale





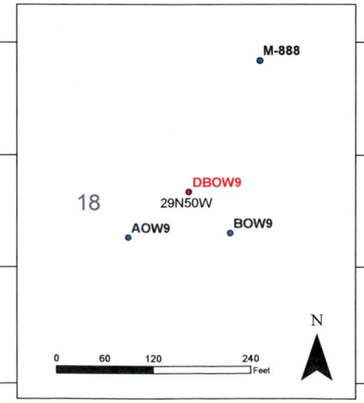


Figure 10 Well Log Comparison Diagrams DBOW7 - DBOW9

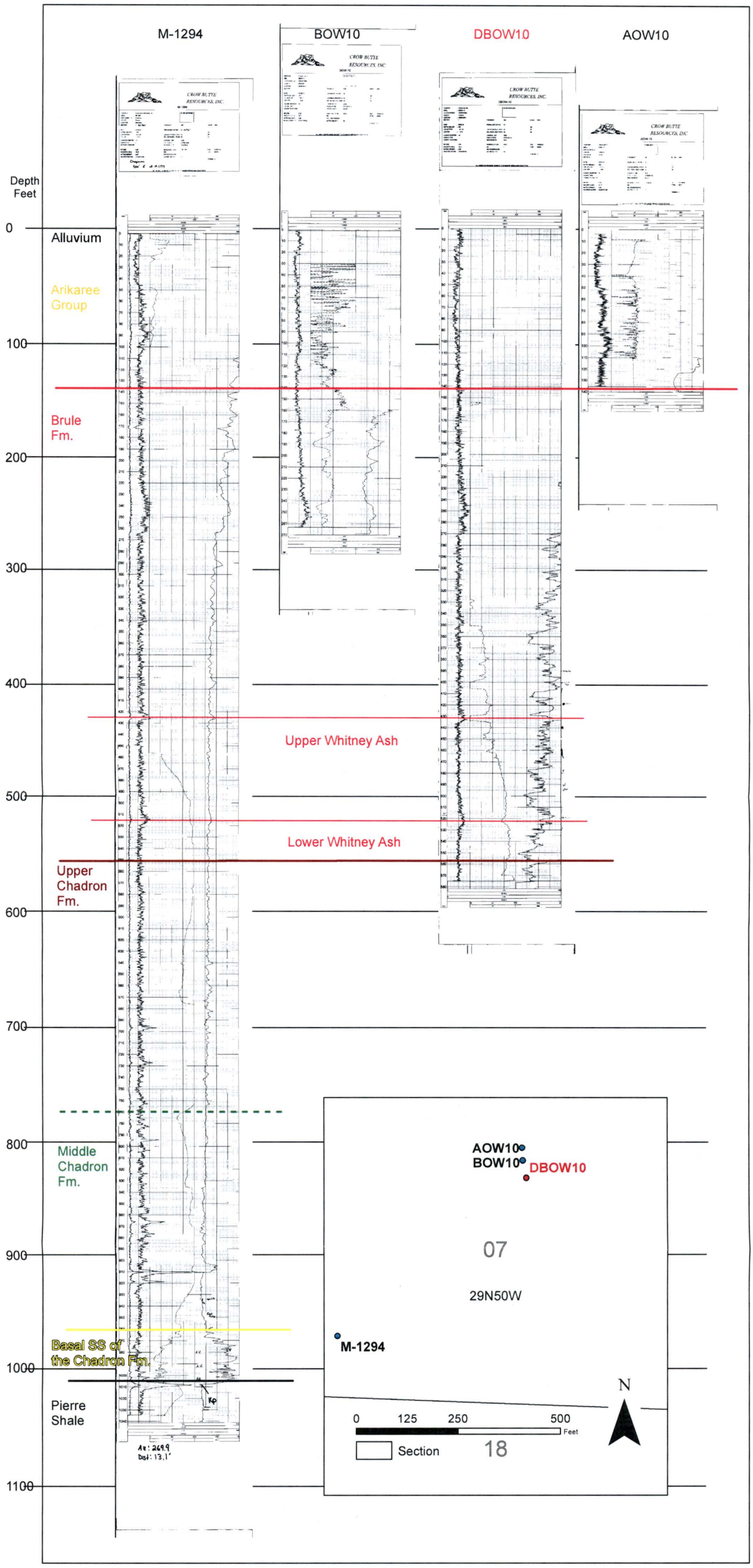


Figure 11 Well Log Comparison Diagram DBOW10

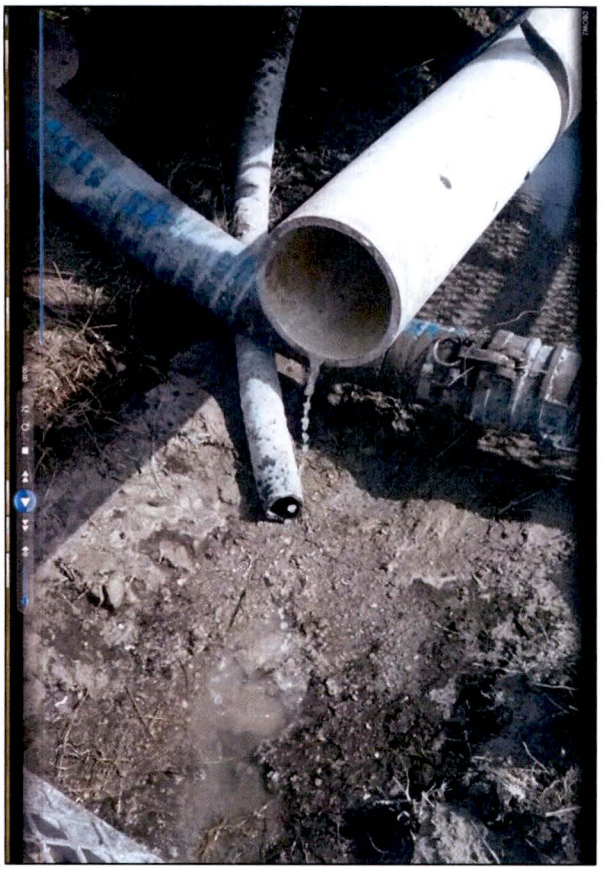


Figure 12 DBOW2 Airlifting @ <0.2 GPM

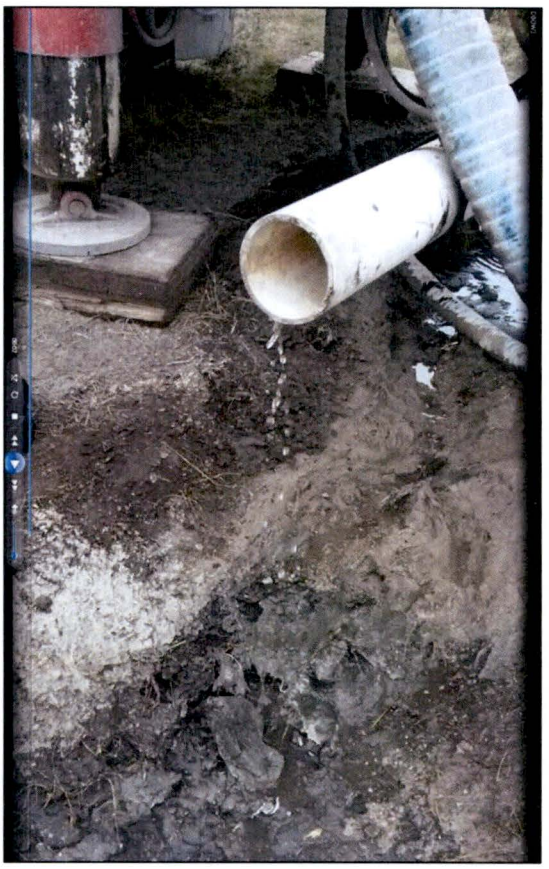


Figure 13 DBOW3 Airlifting @ <0.2 GPM

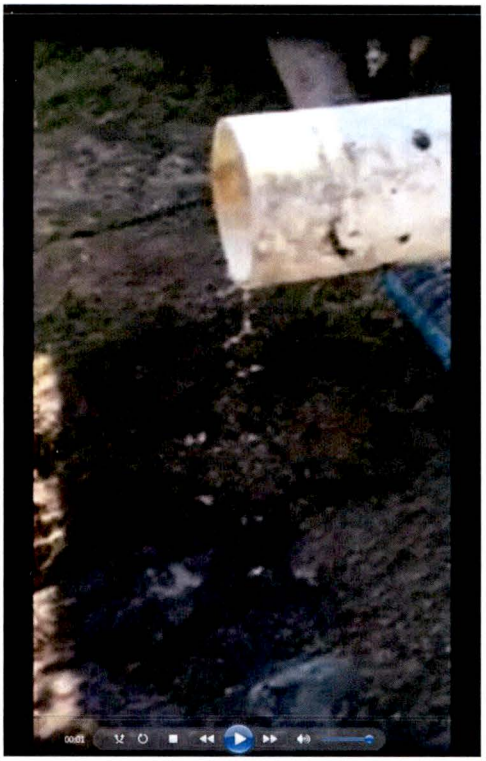


Figure 14 DBOW8 Airlifting @ <0.1 GPM

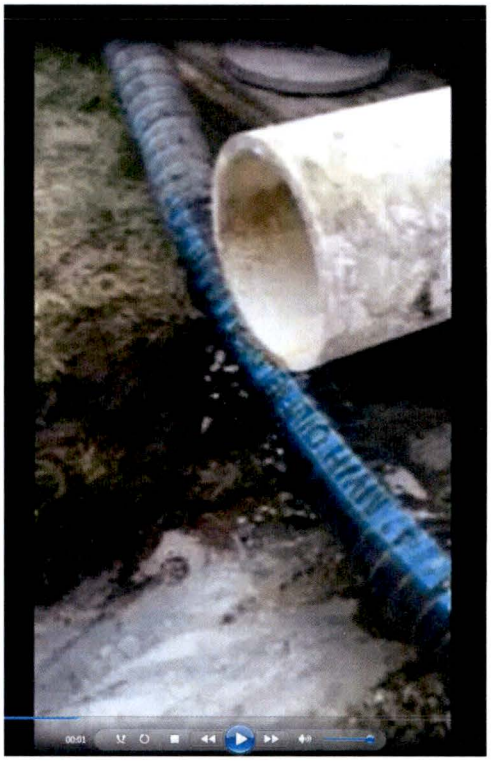


Figure 15 DBOW10 Airlifting @ <0.1 GPM

Attachment A

Deep Brule Well Registration Forms - Nebraska Department of Natural Resources

Sept 2015
DNR Form 667

Submit to:
Department of Natural Resources
301 Centennial Mall South
P.O. Box 94676
Lincoln, Nebraska 68509-4676
Phone (402) 471.2363

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION MODIFICATION
OWNER USE ONLY

FOR DEPARTMENT USE ONLY

Date Filed 4/25/17 Owner Code No. 49185 Registration No. G-180856

04252017 - 245402 -MOD F (2) UPPER NIOBRARA - WHITE NRD
WELL ID

ALL ITEMS IN SECTION 1 AND SIGNATURE IN SECTION 3 ARE REQUIRED

SECTION 1: ☐ **Check here if:** This form is also to be used to change the ownership of this well.

A. Well Owner's First Name _____ Last Name _____
OR Company Name Crow Butte Resources
Attention Name Bob Tiensvold
Address 86 Crow Butte Road
City Crawford State NE Zip 69339 Telephone (308) 665-2215
Email _____

THIS COPY IS FOR YOUR RECORDS

B. Well Registration No. G-180856 DBOW 1 (Only one number per form)

C. State Reason for Change: Static water level

CORRECTIONS NEEDED Complete only those items being modified

SECTION 2:

A. If location of well needs to be corrected, fully complete the Legal description of the well including GPS Coordinates (latitude and longitude). Footage may be provided. **(1 & 2 REQUIRED)**

1. Well location: ____ ¼ of the ____ ¼ of Section ____, Township ____ North, Range ____ East/West, ____ County.
2. Latitude Degree: ____ Minute: ____ Second: ____ Longitude Degree: ____ Minute: ____ Second: ____ (NAD 83)
3. The well is ____ feet from the (North or South) section line and ____ feet from the (East/West) section line.
   (circle one) (circle one)

B. Location of water use (give complete legal description) _____

For Irrigation Wells: Number of acres irrigated: _____

If the location of use is different than what is currently registered, and/or the number of acres irrigated is more than what is currently registered, and you are located in an area that has stays or a moratorium on newly irrigated acres, you **MUST** obtain the written approval of the Natural Resources District **PRIOR TO FILING THIS FORM**. This approval can be the submission of a separate Natural Resources District Approval form by the NRD.

(Natural Resources District) (Signature of NRD Staff) (Date)

C. Pump information.

1. Pumping rate: _____ gallons per minute.
2. Drop Pipe diameter: _____ Inches. 3. Length of drop pipe: _____ feet.
4. Pumping equipment installed: (m)____/(d)____/(y)____. 5. Brand/Type: _____
6. Static Water Level: _____ feet.
7. Pumping water level: _____ feet.
8. Amount of time pumped: _____

RECEIVED
APR 25 2017
DEPARTMENT OF NATURAL RESOURCES

D. Change of use, complete items 1, 2 and 3. Identify use from this Listing: Dewatering (over 90 days), Domestic, Ground Heat Exchanger, Ground Water Source Heat Pump, Industrial, Injection, Irrigation, Livestock, Monitoring, Observation, Public Water Supply (with spacing (46-638), Public Water Supply (without spacing), Recovery, Other(if well use falls in this category – add specific use).

1. Well was used for: _____ (if necessary, please provide updated pump information)
2. New well use is: _____
3. Date of Change: _____

E. Active to Inactive (please check A or B) with or without pump

On _____, 20___, the water well is ____a) altered from active to inactive by removing the _____inch pump and pumping column and properly capping the water well according to state standards or ____b) no longer in use but pump still in place with a water tight seal according to state standards. (§46-1207.02)

F. I certify that the well has been modified according to information given in section 2 C, E, or J, such that it will pump 50 gallons per minute or less. Pumping Rate: _____

Change to use (Check one of the following): ☐ Livestock ☐ Monitoring ☐ Observation

☐ nonconsumptive or de-minimus use approved by the applicable natural resources district. State use: _____

G. Wells in a Series.

1. Is this well a part of a series? _____ Yes.
2. How many total wells in the series? _____
3. If one or more of the wells in the series is currently registered, give all well registration numbers: _____

H. Well Construction Information.

1. Total well depth: _____ feet.
2. Static water level: 112 _____ feet.
3. Pumping water level: _____ feet.
4. Well Construction began: (m)_____/(d)_____/(y)_____
5. Well Construction completed: (m)_____/(d)_____/(y)_____
6. Bore hole diameter in inches: Top____ Bottom _____
7. Casing and Screen Joints are: Welded_____, Glued_____, Threaded_____, Other_____
8. Total Estimate Capacity of Well _____ gallons per minute (to be used to determine sustainability of aquifer)

I. Replacement and decommissioned/modified well information.

Department of Natural Resources Decommission/Modification Certification form or Notice of Decommissioning form is Required for replacement wells

1. Is this well a replacement well? ____Yes ____No
2. Registration number of original well: _____ If original well is not registered, date well construction completed (m)___/(d___/(y)___
3. Original well last operated (m)___/(d)_____/(y)_____
4. Completion of original well decommission/modification on (m)___/(d____/(y)____
5. Complete location of water use of original well: _____

J. Well Construction Modification.

1. Total well depth: _____ feet.
2. Static water level: _____ feet.
3. Pumping water level: _____ feet
4. Well Modification began: (m)_____/(d)_____/(y)____
5. Well Modification completed: (m)_____/(d)_____/(y)___
6. Casing diameter in inches: Top____ Bottom _____
7. Casing and Screen Joints are: Welded____, Glued_____, Threaded_____, Other_____
8. Total Estimate Capacity of Well _____ gallons per minute (to be used to determine sustainability of aquifer)

SECTION 3:

I hereby certify that the information provided on this form is true and accurate to the best of my knowledge.

Bob Pa — 4/20/2017

Water Well Owner's Signature — Date

The Department reserves the right to request verification of information provided.

Mail to
Department of Natural Resources
PO Box 94676
Lincoln, NE 68509-4676
Phone (402)471-2363

January 2011
DNR WWR

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION

Please indicate NA for items unknown

FOR DEPARTMENT USE ONLY

Date Filed 10/24/16 Owner Code No. 49185 Registration No. 6180856

10242016 - 245402 -WWR(S) Receipt R27310 UNW NRD
Well ID

1. a. Well Owner's First Name _____ Last Name _____

   OR Company Name Crow Butte Resources

   b. Attention Name _____

   c. Street Address 86 Crow Butte Road

   Address 2/PO Address PO Box 169

   City Crawford State NE Zip 69339 Telephone (308) 665-2215

2. a. Contractor's License No 39561 Contractor's Name Skip L. Chubb

   Contractor's Email Address NA

   b. Drilling Firm Name Single Water Services, LLC

   Address PO Box 1625

   City Glenrock State WY Zip 82637 Telephone (307) 267-4415

   Drilling Firm's Email Address NA

3. a. Well location SW ¼ of the SW ¼ of Section 1, Township 29 North, Range 51 E ☐ W ☑, Dawes County

   Latitude Degree 42 Minute 30 Second 42.829

   Longitude Degree 103 Minute 15 Second 34.431

   GPS Required

   Location of well for a pit is the location of the pump

   b. Natural Resources District Upper Niobrara / White River NRD

   c. The well is: 740 feet from the (N ☐ S ☑) section line and 1250 feet from the (E ☐ W ☑) section line

   d. Street address and subdivision, if applicable _____

   e. Location of water use (give legal descriptions) _____

   f. If for irrigation, the land to be irrigated is _____ acres.

   Location of water use is required on all wells

   g. Well reference letter(s), if applicable DBOW1 HHSS PWSID _____

4. Permits

   Management Area Permit Number _____
   Geothermal Permit Number _____
   Municipal Permit Number _____
   Well Spacing Permit Number _____
   HHSS _____
   Surface Water Permit Number _____
   Industrial Permit Number _____
   Transfer Out-Of-State Permit Number _____
   Conduct Permit Number _____
   Other Permit Number _____
   NDEQ _____

5. Purpose of well (indicate one)

   ☐ Aquaculture ☐ Commercial/Industrial ☐ Dewatering (over 90 days)
   ☐ Domestic ☐ Ground Heat Exchanger ☐ Groundwater Source Heat Pump ☐ Irrigation ☐ Injection
   ☐ Livestock ☑ Monitoring ☐ Observation ☐ Pit (for irrigation) ☐ Public Water Supply (with spacing (46-638))
   ☐ Public Water Supply (without spacing) ☐ Recovery ☐ Other _____
   (further description of use can be provided under other) (indicate use)

6. Wells in a Series.

   a. Is this well a part of a series? ☐ Yes go to part b of this section ☑ No go to part 7 of this application (Y/N **required**)

   b. If one or more of the wells in the series is currently registered, give well registration number _____

   c. How many wells in the series are you registering at this time? _____ d. How many total wells in the series? _____

6180856

7. Replacement and decommissioned/modified well information.
   a. Is this well a replacement well? ☐ Yes ☑ No go to part 8 of this application
   b. Registration number of original well _____ If not registered, date original well was constructed (m)___/(d___/(y)____
   c. Original well last operated (m)___/(d)___/(y)____ d. Replacement well is _____ feet from original well.
   e. Location of water use of original well _____
   Please Select One:
   f.1. ☐ Original water well decommissioned on (m)___/(d___/(y)___ **OR**
   2. ☐ I hereby certify that the original water well will be decommissioned within 180 days after such construction of the replacement water well. **OR**
   3. ☐ I hereby certify that the original water well will be modified and equipped to pump 50 gallons per minute or less within 180 days after such construction of the replacement water well. It will be used for one of the following: a. ☐ Livestock b. ☐ Monitoring c. ☐ Observation d. ☐ nonconsumptive or de minimus use approved by the applicable natural resources district. State use: _____
   If 3d is chosen. NRD signature is required. (Signature can be submitted on NRD Approval form to DNR prior to registration)
   NRD signature _____ Date _____ **OR**
   4. ☐ Owners CERTIFICATION OF INTENT to Decommission or Modify the original well form is submitted by landowner. (Must be submitted before registering well)

8. Pump Information. (Pump information is required if registering a pit)
   a. Is pump installed at this time ☐ Yes ☑ No
   Is pump installed by well owner in section 1? ☐ Yes ☐ No
   Is pump installed by contractor in section 2? ☐ Yes ☐ No
   Is this a free flowing well ☐ Yes(no pump to be installed) ☐ No
   If pump installed by pump installer, please fill out license number below
   b. Pump Installer's License No. _____ Pump Installer's Name _____
   Pump Installer's Email Address _____
   Pump Installer's Firm Name _____
   Pump Installer's Firm Address _____
   City _____ State _____ Zip _____ Telephone _____
   Pump Installer's Firm Email Address _____
   c. Measured Pumping rate _____ gallons per minute d. Pumping water level _____ feet
   e. Drop pipe diameter _____ inches f. Length of drop pipe _____ feet
   g. Pumping equipment installed (m)___/(d___/(y)___
   h. Pump Brand _____
   i. This well is designed and constructed to pump 50 gpm or less ☑ Yes ☐ No **(8I is required on ALL wells)**

9. Well Construction Information.
   a. Total well depth 565 feet. b. Static water level 167 feet. **(required)**
   c. Well Construction Began (m) 8 /(d) 16 /(y) 2016 d.. Well Construction Completed (m) 8 /(d) 24 /(y) 2016

Wells drilled prior to stays or moratoriums require NRD signature	**NRD signature** _____ Date _____ (Signature can be submitted on NRD Approval form to DNR prior to registration)

   e. Bore hole diameter in inches Top 8 Bottom 8
   f. Casing and Screen Joints are Welded ☐ Glued ☑ Threaded ☐ Other Spline & Groove
   g. Capacity of Well 0.1 gallons per minute (to be used to determine sustainability of aquifer)
   h. Pumping water level at this capacity _____ feet

6181856

10. Well Construction (Casing & Screen)- c, d, e, & f measurements should be in inches to three decimal places (From not less than zero)

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							
0	459	Casing	4.320	4.950	0.297		PVC	Certa-Lok
459	465	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank
465	505	Screen	3.000	3.500	0.250	0.020	PVC	Johnson
505	555	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank
555	565	Screen	3.000	3.500	0.250	0.020	PVC	Johnson

Additional information for Double cased or Nested wells:

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							

11. Grout and Gravel Pack (must start at zero)

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout: *See **Desc**
From	To				
0	459	Grout	Neat Cement		17.6 bbls of Cement Slurry
459	565	Gravel Pack	Natural Formation Gravel Pack	2.82 Cubic Yards	

Desc: Description of gravel pack i.e. engineered gravel pack, or gravel pit description (¼ down), or brand nam e (Best Sand), natural formation, drilling cuttings, soil backfill
Quantity #cubic yards, #tons, #sacks, - (for drilling cuttings and soil backfill estimate quantity) Calculation assistance available on web
Volume & Type: #gallons of a slurry, #barrels of a slurry, #sacks used in the slurry, #bags of non-slurry bentonite (chip-pellet –granular)
Additional information for Double cased or Nested wells:

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout *See **Desc**
From	To				

6/80856

12. Geologic Materials Logged (must start at zero) - **Use only options provided below for Type, Hardness and Color**

From	To	Type	Hardness	Color	Other/Drilling Action
0	10	Top Soil	Unconsolidated	Brown	
10	40	Other - Quaternary Alluvium	Unconsolidated	Tan	
40	260	Sand with Silt/Clay	Dense/Stiff	Brown	
260	420	Siltstone	Dense/Stiff	Brown	
420	590	Clay	Dense/Stiff	Brown	
590	600	Clay	Dense/Stiff	Tan, Green	

Type		Hardness	Color	
Clay	Sand fine-med	Cemented	Black	Pepper
Clay Stone	Sand med-coarse	Consolidated	Blue	Red
Cobbles	Sand with grave	Dense/Stiff	Brown	Tan
Fine Sand	Sandstone	Hard	Gray	White
Gravel S	hale	Soft	Green	Yellow
Limestone Silt		Unconsolidated	Orange	
Loss Circulation	Siltstone	Very Hard		
Ochre (weathered shale)	Top Soil			
Sandy Clay	Other			
Sand with Clay/Silt				

(Additional sheets may be submitted)

13. I hereby certify that the information provided on this registration is true and accurate to the best of my knowledge.

Skip L. Chubb 9/22/16

Water Well Contractor's Signature Date
(not required for pits)

Well Owner's Signature Date
(if Contractor is unknown or Deceased or for pits)
(Not required if signed by Contractor)

Please note this document contains four pages.

Sections 9F, 9G, 10, 11 & 12 are not required if registering a pit.

Owner Registering well drilled prior to 2002: Minimum Required Sections - 1, 3(a,b,c,e,f), 5, 6, 7, 8(a,g,i), 9d

Sept 2015
DNR Form 667

Submit to:
Department of Natural Resources
301 Centennial Mall South
P.O. Box 94676
Lincoln, Nebraska 68509-4676
Phone (402) 471 2363

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION MODIFICATION
OWNER USE ONLY

FOR DEPARTMENT USE ONLY

Date Filed 4/25/17 Owner Code No. 49185 Registration No. G-180857

04252017 - 245403 -MOD F (2) UPPER NIOBRARA-WHITE NRD
WELL ID

ALL ITEMS IN SECTION 1 AND SIGNATURE IN SECTION 3 ARE REQUIRED

SECTION 1: ☐ **Check here if:** This form is also to be used to change the ownership of this well.

A. Well Owner's First Name _____ Last Name _____
OR Company Name Crow Butte Resources
Attention Name Bob Tiensvold
Address 86 Crow Butte Road
City Crawford State NE Zip 69339 Telephone (308) 665-2215
Email _____

THIS COPY IS FOR YOUR RECORDS

B. Well Registration No. G-180857 DBOW 2 (Only one number per form)

C. State Reason for Change: Static water level

CORRECTIONS NEEDED Complete only those items being modified

SECTION 2:

A. If location of well needs to be corrected, fully complete the Legal description of the well including GPS Coordinates (latitude and longitude). Footage may be provided. **(1 & 2 REQUIRED)**

1. Well location: ____¼ of the ____ ¼ of Section ____, Township ____ North, Range ___ East/West, _____ County.
2. Latitude Degree:____ Minute:____ Second:___.___ Longitude Degree:____ Minute:____ Second:___.___ (NAD 83)
3. The well is _____ feet from the (North or South) section line and _____ feet from the (East/West) section line.
(circle one) (circle one)

B. Location of water use (give complete legal description)_____

For Irrigation Wells: Number of acres irrigated:_____

If the location of use is different than what is currently registered, and/or the number of acres irrigated is more than what is currently registered, and you are located in an area that has stays or a moratorium on newly irrigated acres, you **MUST** obtain the written approval of the Natural Resources District **PRIOR TO FILING THIS FORM.** This approval can be the submission of a separate Natural Resources District Approval form by the NRD.

_____ _____ _____
(Natural Resources District) (Signature of NRD Staff) (Date)

C. Pump information.

1. Pumping rate:_____ gallons per minute.
2. Drop Pipe diameter:_____ Inches. 3. Length of drop pipe:_____ feet.
4. Pumping equipment installed: (m)____/(d)____/(y)____. 5. Brand/Type:_____
6. Static Water Level:_____ feet:
7. Pumping water level:_____ feet.
8. Amount of time pumped:_____

RECEIVED
APR 25 2017
DEPARTMENT OF NATURAL RESOURCES

D. Change of use, complete items 1, 2 and 3. Identify use from this Listing: Dewatering (over 90 days), Domestic, Ground Heat Exchanger, Ground Water Source Heat Pump, Industrial, Injection, Irrigation, Livestock, Monitoring, Observation, Public Water Supply (with spacing (46-638), Public Water Supply (without spacing), Recovery, Other(if well use falls in this category – add specific use).

1. Well was used for: _____ (if necessary, please provide updated pump information)
2. New well use is: _____
3. Date of Change: _____

E. Active to Inactive (please check A or B) with or without pump

On _____, 20___, the water well is ____a) altered from active to inactive by removing the _____inch pump and pumping column and properly capping the water well according to state standards or ____b) no longer in use but pump still in place with a water tight seal according to state standards. (§46-1207.02)

F. I certify that the well has been modified according to information given in section 2 C, E, or J, such that it will pump 50 gallons per minute or less. Pumping Rate: _____

Change to use (Check one of the following): ☐ Livestock ☐ Monitoring ☐ Observation

☐ nonconsumptive or de minimus use approved by the applicable natural resources district. State use: _____

G. Wells in a Series.

1. Is this well a part of a series? _____ Yes.
2. How many total wells in the series? _____
3. If one or more of the wells in the series is currently registered, give all well registration numbers: _____

H. Well Construction Information.

1. Total well depth: _____ feet.
2. Static water level: 157 feet.
3. Pumping water level: _____ feet
4. Well Construction began: (m)____/(d)____/(y)____
5. Well Construction completed: (m)____/(d)____/(y)____
6. Bore hole diameter in inches: Top____ Bottom ____
7. Casing and Screen Joints are: Welded____, Glued____, Threaded____, Other____
8. Total Estimate Capacity of Well ____ gallons per minute (to be used to determine sustainability of aquifer)

I. Replacement and decommissioned/modified well information.

Department of Natural Resources Decommission/Modification Certification form or Notice of Decommissioning form is Required for replacement wells

1. Is this well a replacement well? ____Yes ____No
2. Registration number of original well: _____ If original well is not registered, date well construction completed (m)___/(d___/(y)___
3. Original well last operated (m)___/(d)____/(y)____
4. Completion of original well decommission/modification on (m)___/(d____/(y)____
5. Complete location of water use of original well: _____

J. Well Construction Modification.

1. Total well depth: _____ feet.
2. Static water level: _____ feet.
3. Pumping water level: _____ feet
4. Well Modification began: (m)____/(d)____/(y)____
5. Well Modification completed: (m)____/(d)____/(y)____
6. Casing diameter in inches: Top____ Bottom ____
7. Casing and Screen Joints are: Welded____, Glued____, Threaded____, Other____
8. Total Estimate Capacity of Well ____ gallons per minute (to be used to determine sustainability of aquifer)

SECTION 3:

I hereby certify that the information provided on this form is true and accurate to the best of my knowledge.

Bob Dr — Water Well Owner's Signature

4/20/2017 — Date

The Department reserves the right to request verification of information provided.

Mail to
Department of Natural Resources
PO Box 94676
Lincoln, NE 68509-4676
Phone (402)471-2363

January 2011
DNR WWR

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION

Please indicate NA for items unknown

FOR DEPARTMENT USE ONLY

Date Filed 10/24/16 Owner Code No. 49185 Registration No. 6180857

10/24/2016 - 245403 -WWR A(S) Receipt R27310 UNW NRD
Well ID

1. a. Well Owner's First Name _____ Last Name _____

OR Company Name Crow Butte Resources

b. Attention Name _____

c. Street Address 86 Crow Butte Road

Address 2/PO Address PO Box 169

City Crawford State NE Zip 69339 Telephone (308) 665-2215

2. a. Contractor's License No 39561 Contractor's Name Skip L. Chubb

Contractor's Email Address NA

b. Drilling Firm Name Single Water Services, LLC

Address PO Box 1625

City Glenrock State WY Zip 82637 Telephone (307) 267-4415

Drilling Firm's Email Address NA

3. a. Well location NW ¼ of the NW ¼ of Section 1, Township 29 North, Range 51 E ☐ W ☑, Dawes County

Latitude Degree 42 Minute 31 Second 19.964

Longitude Degree 103 Minute 15 Second 38.980

GPS Required

Location of well for a pit is the location of the pump

b. Natural Resources District Upper Niobrara / White River NRD

c. The well is: 740 feet from the (N ☑ S ☐) section line and 815 feet from the (E ☐ W ☑) section line

d. Street address and subdivision, if applicable _____

e. Location of water use (give legal descriptions) _____

f. If for irrigation, the land to be irrigated is _____ acres.

Location of water use is required on all wells

g. Well reference letter(s), if applicable DBOW 2 HHSS PWSID _____

4. Permits

Management Area Permit Number _____
Geothermal Permit Number _____
Municipal Permit Number _____
Well Spacing Permit Number _____
HHSS _____

Surface Water Permit Number _____
Industrial Permit Number _____
Transfer Out-Of-State Permit Number _____
Conduct Permit Number _____
Other Permit Number _____
NDEQ _____

5. Purpose of well (indicate one)

☐ Aquaculture ☐ Commercial/Industrial ☐ Dewatering (over 90 days)
☐ Domestic ☐ Ground Heat Exchanger ☐ Groundwater Source Heat Pump ☐ Irrigation ☐ Injection
☐ Livestock ☑ Monitoring ☐ Observation ☐ Pit (for irrigation) ☐ Public Water Supply (with spacing (46-638))
☐ Public Water Supply (without spacing) ☐ Recovery ☐ Other _____
(further description of use can be provided under other) (indicate use)

6. Wells in a Series.

a. Is this well a part of a series? ☐ Yes go to part b of this section ☑ No go to part 7 of this application (Y/N **required**)

b. If one or more of the wells in the series is currently registered, give well registration number _____

c. How many wells in the series are you registering at this time? _____ d. How many total wells in the series? _____

6181857

7. Replacement and decommissioned/modified well information.
   a. Is this well a replacement well? ☐ Yes ☑ No go to part 8 of this application
   b. Registration number of original well _____ If not registered, date original well was constructed (m)___/(d___/(y)____
   c. Original well last operated (m)____/(d)____/(y)____ d. Replacement well is _____ feet from original well.
   e. Location of water use of original well _____

   Please Select One:

   f.1. ☐ Original water well decommissioned on (m)___/(d___/(y)___ **OR**

   2. ☐ I hereby certify that the original water well will be decommissioned within 180 days after such construction of the replacement water well. **OR**

   3. ☐ I hereby certify that the original water well will be modified and equipped to pump 50 gallons per minute or less within 180 days after such construction of the replacement water well. It will be used for one of the following: a. ☐ Livestock b. ☐ Monitoring c. ☐ Observation d. ☐ nonconsumptive or de minimus use approved by the applicable natural resources district. State use: _____

   If 3d is chosen. NRD signature is required. (Signature can be submitted on NRD Approval form to DNR prior to registration)

   NRD signature_____ Date _____ **OR**

   4. ☐ Owners CERTIFICATION OF INTENT to Decommission or Modify the original well form is submitted by landowner. (Must be submitted before registering well)

8. Pump Information. (Pump information is required if registering a pit)
   a. Is pump installed at this time ☐ Yes ☑ No
      Is pump installed by well owner in section 1? ☐ Yes ☐ No
      Is pump installed by contractor in section 2? ☐ Yes ☐ No
      Is this a free flowing well ☐ Yes(no pump to be installed) ☐ No

   If pump installed by pump installer, please fill out license number below

   b. Pump Installer's License No._____ Pump Installer's Name_____
      Pump Installer's Email Address_____
      Pump Installer's Firm Name_____
      Pump Installer's Firm Address_____
      City _____ State _____ Zip_____ Telephone _____
      Pump Installer's Firm Email Address_____
   c. Measured Pumping rate _____ gallons per minute d. Pumping water level _____ feet
   e. Drop pipe diameter _____ inches f. Length of drop pipe _____ feet
   g. Pumping equipment installed (m)___/(d___/(y)___
   h. Pump Brand_____
   i. This well is designed and constructed to pump 50 gpm or less ☑ Yes ☐ No **(8I is required on ALL wells)**

9. Well Construction Information.
   a. Total well depth 630 feet. b. Static water level 248 feet. **(required)**
   c. Well Construction Began (m) 8 /(d) 22 /(y) 2016 d.. Well Construction Completed (m) 8 /(d) 30 /(y) 2016

   Wells drilled prior to stays or moratoriums require NRD signature **NRD signature**_____ Date _____ (Signature can be submitted on NRD Approval form to DNR prior to registration)

   e. Bore hole diameter in inches Top 8 Bottom 8
   f. Casing and Screen Joints are Welded ☐ Glued ☐ Threaded ☑ Other Spline & Groove
   g. Capacity of Well 0.2 gallons per minute (to be used to determine sustainability of aquifer)
   h. Pumping water level at this capacity _____ feet

618085 1

10. Well Construction (Casing & Screen)- c, d, e, & f measurements should be in inches to three decimal places (From not less than zero)

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							
0	519	Casing	4.320	4.950	0.297		PVC	Certa-Lok
519	530	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank
530	550	Screen	3.000	3.500	0.250	0.020	PVC	Johnson
550	620	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank
620	630	Screen	3.000	3.500	0.250	0.020	PVC	Johnson

Additional information for Double cased or Nested wells:

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							

11. Grout and Gravel Pack (must start at zero)

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout *See **Desc**
From	To				
0	519	Grout	Neat Cement		19.9 bbls of Cement Slurry
519	630	Gravel Pack	Natural Formation Gravel Pack	4.26 Cubic Yards	

Desc: Description of gravel pack i.e. engineered gravel pack, or gravel pit description (¼ down), or brand nam e (Best Sand), natural formation, drilling cuttings, soil backfill
Quantity #cubic yards, #tons, #sacks, - (for drilling cuttings and soil backfill estimate quantity) Calculation assistance available on web
Volume & Type: #gallons of a slurry, #barrels of a slurry, #sacks used in the slurry, #bags of non-slurry bentonite (chip-pellet –granular)
Additional information for Double cased or Nested wells:

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout *See **Desc**
From	To				

6180857

12. Geologic Materials Logged (must start at zero) - **Use only options provided below for Type, Hardness and Color**

From	To	Type	Hardness	Color	Other/Drilling Action
0	10	Top Soil	Unconsolidated	Brown	
10	25	Other - Quaternary Alluvium	Unconsolidated	Tan	
25	330	Siltstone	Dense/Stiff	Brown	
330	400	Sand with Clay/Silt	Dense/Stiff	Brown	
400	635	Clay	Dense/Stiff	Brown	
635	660	Clay	Dense/Stiff	Brown, Green	

Type		Hardness	Color	
Clay	Sand fine-med	Cemented	Black	Pepper
Clay Stone	Sand med-coarse	Consolidated	Blue	Red
Cobbles	Sand with grave	Dense/Stiff	Brown	Tan
Fine Sand	Sandstone	Hard	Gray	White
Gravel S	hale	Soft	Green	Yellow
Limestone Silt		Unconsolidated	Orange	
Loss Circulation	Siltstone	Very Hard		
Ochre (weathered shale)	Top Soil			
Sandy Clay	Other			
Sand with Clay/Silt				

(Additional sheets may be submitted)

13. I hereby certify that the information provided on this registration is true and accurate to the best of my knowledge.

Skip L. Chubb 9/22/14

Water Well Contractor's Signature Date
(not required for pits)

Well Owner's Signature Date
(if Contractor is unknown or Deceased or for pits)
(Not required if signed by Contractor)

Please note this document contains four pages.

Sections 9F, 9G, 10, 11 & 12 are not required if registering a pit.

Owner Registering well drilled prior to 2002: Minimum Required Sections - 1, 3(a,b,c,e,f), 5, 6, 7, 8(a,g,i), 9d

Sept 2015
DNR Form 667

Submit to:
Department of Natural Resources
301 Centennial Mall South
P.O. Box 94676
Lincoln, Nebraska 68509-4676
Phone (402) 471 2363

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION MODIFICATION
OWNER USE ONLY

FOR DEPARTMENT USE ONLY

Date Filed 4/25/17 Owner Code No. 49185 Registration No. G-180858

04252017 - 245404 -MOD F(2) UPPER NIOBRARA - WHITE NRD
WELL ID

ALL ITEMS IN SECTION 1 AND SIGNATURE IN SECTION 3 ARE REQUIRED

SECTION 1: ☐ **Check here if:** This form is also to be used to change the ownership of this well.

A. Well Owner's First Name _____ Last Name _____
OR Company Name Crow Butte Resources
Attention Name Bob Tiensvold
Address 86 Crow Butte Road
City Crawford State NE Zip 69339 Telephone (308) 665-2215
Email _____

THIS COPY IS FOR YOUR RECORDS

B. Well Registration No. G-180858 DBOW 3 (Only one number per form)

C. State Reason for Change: Static water level

CORRECTIONS NEEDED **Complete only those items being modified**

SECTION 2:

A. If location of well needs to be corrected, fully complete the Legal description of the well including GPS Coordinates (latitude and longitude). Footage may be provided. **(1 & 2 REQUIRED)**

1. Well location: _____ ¼ of the _____ ¼ of Section _____, Township _____ North, Range ___ East/West, _____ County.
2. Latitude Degree: _____ Minute: _____ Second: ___.___ Longitude Degree: _____ Minute: _____ Second: ___.___ (NAD 83)
3. The well is _____ feet from the (North or South) section line and _____ feet from the (East/West) section line.
(circle one) (circle one)

B. Location of water use (give complete legal description) _____

For Irrigation Wells: Number of acres irrigated: _____

If the location of use is different than what is currently registered, and/or the number of acres irrigated is more than what is currently registered, and you are located in an area that has stays or a moratorium on newly irrigated acres, you **MUST** obtain the written approval of the Natural Resources District **PRIOR TO FILING THIS FORM.** This approval can be the submission of a separate Natural Resources District Approval form by the NRD.

_____ _____ _____
(Natural Resources District) (Signature of NRD Staff) (Date)

C. Pump information.

1. Pumping rate: _____ gallons per minute.
2. Drop Pipe diameter: _____ Inches.
3. Length of drop pipe: _____ feet.
4. Pumping equipment installed: (m)____/(d)____/(y)____.
5. Brand/Type: _____
6. Static Water Level: _____ feet.
7. Pumping water level: _____ feet.
8. Amount of time pumped: _____.

RECEIVED
APR 25 2017
DEPARTMENT OF NATURAL RESOURCES

D. Change of use, complete items 1, 2 and 3. Identify use from this Listing: Dewatering (over 90 days), Domestic, Ground Heat Exchanger, Ground Water Source Heat Pump, Industrial, Injection, Irrigation, Livestock, Monitoring, Observation, Public Water Supply (with spacing (46-638), Public Water Supply (without spacing), Recovery, Other(if well use falls in this category – add specific use).

1. Well was used for: _____ (if necessary, please provide updated pump information)
2. New well use is: _____
3. Date of Change: _____

E. Active to Inactive (please check A or B) with or without pump

On _____, 20___, the water well is ____a) altered from active to inactive by removing the _____inch pump and pumping column and properly capping the water well according to state standards or ____b) no longer in use but pump still in place with a water tight seal according to state standards. (§46-1207.02)

F. I certify that the well has been modified according to information given in section 2 C, E, or J, such that it will pump 50 gallons per minute or less. Pumping Rate: _____

Change to use (Check one of the following): ☐ Livestock ☐ Monitoring ☐ Observation

☐ nonconsumptive or de minimus use approved by the applicable natural resources district. State use: _____

G. Wells in a Series.

1. Is this well a part of a series? _____ Yes.
2. How many total wells in the series? _____
3. If one or more of the wells in the series is currently registered, give all well registration numbers: _____

H. Well Construction Information.

1. Total well depth: _____ feet.
2. Static water level: 137 feet.
3. Pumping water level: _____ feet
4. Well Construction began: (m)____/(d)____/(y)____
5. Well Construction completed: (m)____/(d)____/(y)____
6. Bore hole diameter in inches: Top____ Bottom ____
7. Casing and Screen Joints are: Welded____, Glued____, Threaded____, Other____
8. Total Estimate Capacity of Well ____ gallons per minute (to be used to determine sustainability of aquifer)

I. Replacement and decommissioned/modified well information.

Department of Natural Resources Decommission/Modification Certification form or Notice of Decommissioning form is Required for replacement wells

1. Is this well a replacement well? ____Yes ____No
2. Registration number of original well: _____ If original well is not registered, date well construction completed (m)___/(d___/(y)___
3. Original well last operated (m)___/(d)____/(y)____
4. Completion of original well decommission/modification on (m)___/(d___/(y)___
5. Complete location of water use of original well: _____

J. Well Construction Modification.

1. Total well depth: _____ feet.
2. Static water level: _____ feet.
3. Pumping water level: _____ feet
4. Well Modification began: (m)____/(d)____/(y)____
5. Well Modification completed: (m)____/(d)____/(y)____
6. Casing diameter in inches: Top____ Bottom ____
7. Casing and Screen Joints are: Welded____, Glued____, Threaded____, Other____
8. Total Estimate Capacity of Well ____ gallons per minute (to be used to determine sustainability of aquifer)

SECTION 3:

I hereby certify that the information provided on this form is true and accurate to the best of my knowledge.

Bob [signature] — Water Well Owner's Signature

4/20/2017 — Date

The Department reserves the right to request verification of information provided.

Mail to
Department of Natural Resources
PO Box 94676
Lincoln, NE 68509-4676
Phone (402)471-2363

January 2011
DNR WWR

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION

Please indicate NA for items unknown

FOR DEPARTMENT USE ONLY

Date Filed 10/24/16 Owner Code No. 49185 Registration No. 6180858

10242016 - 245404 - WWR (S) Receipt 1227310 UNW NRD
Well ID

1. a. Well Owner's First Name _____ Last Name _____

OR Company Name Crow Butte Resources

b. Attention Name _____

c. Street Address 86 Crow Butte Road

Address 2/PO Address PO Box 169

City Crawford State NE Zip 69339 Telephone (308) 665-2215

2. a. Contractor's License No 39561 Contractor's Name Skip L. Chubb

Contractor's Email Address NA

b. Drilling Firm Name Single Water Services, LLC

Address PO Box 1625

City Glenrock State WY Zip 82637 Telephone (307) 267-4415

Drilling Firm's Email Address NA

3. a. Well location NE ¼ of the NW ¼ of Section 2, Township 29 North, Range 51 E ☐ W ☑, Dawes County

Latitude Degree 42 Minute 31 Second 26.709

Longitude Degree 103 Minute 16 Second 35.825

GPS Required

Location of well for a pit is the location of the pump

b. Natural Resources District Upper Niobrara / White River NRD

c. The well is: 15 feet from the (N ☑ S ☐) section line and 1830 feet from the (E ☐ W ☑) section line

d. Street address and subdivision, if applicable _____

e. Location of water use (give legal descriptions) _____

f. If for irrigation, the land to be irrigated is _____ acres.

Location of water use is required on all wells

g. Well reference letter(s), if applicable DBOW 3 HHSS PWSID _____

4. Permits

Management Area Permit Number _____
Geothermal Permit Number _____
Municipal Permit Number _____
Well Spacing Permit Number _____
HHSS _____

Surface Water Permit Number _____
Industrial Permit Number _____
Transfer Out-Of-State Permit Number _____
Conduct Permit Number _____
Other Permit Number _____
NDEQ _____

5. Purpose of well (indicate one)

☐ Aquaculture ☐ Commercial/Industrial ☐ Dewatering (over 90 days)
☐ Domestic ☐ Ground Heat Exchanger ☐ Groundwater Source Heat Pump ☐ Irrigation ☐ Injection
☐ Livestock ☑ Monitoring ☐ Observation ☐ Pit (for irrigation) ☐ Public Water Supply (with spacing (46-638))
☐ Public Water Supply (without spacing) ☐ Recovery ☐ Other _____
(further description of use can be provided under other) (indicate use)

6. Wells in a Series.

a. Is this well a part of a series? ☐ Yes go to part b of this section ☑ No go to part 7 of this application (Y/N required)

b. If one or more of the wells in the series is currently registered, give well registration number _____

c. How many wells in the series are you registering at this time? _____ d. How many total wells in the series? _____

6180858

7. Replacement and decommissioned/modified well information.
   a. Is this well a replacement well? ☐ Yes ☑ No go to part 8 of this application
   b. Registration number of original well _____ If not registered, date original well was constructed (m)___/(d___/(y)____
   c. Original well last operated (m)___/(d)___/(y)____ d. Replacement well is _____ feet from original well.
   e. Location of water use of original well _____
   Please Select One:
   f.1. ☐ Original water well decommissioned on (m)___/(d___/(y)___ **OR**
   2. ☐ I hereby certify that the original water well will be decommissioned within 180 days after such construction of the replacement water well. **OR**
   3. ☐ I hereby certify that the original water well will be modified and equipped to pump 50 gallons per minute or less within 180 days after such construction of the replacement water well. It will be used for one of the following: a. ☐ Livestock b. ☐ Monitoring c. ☐ Observation d. ☐ nonconsumptive or de minimus use approved by the applicable natural resources district. State use: _____
   If 3d is chosen. NRD signature is required. (Signature can be submitted on NRD Approval form to DNR prior to registration)
   NRD signature_____ Date _____ **OR**
   4. ☐ Owners CERTIFICATION OF INTENT to Decommission or Modify the original well form is submitted by landowner. (Must be submitted before registering well)

8. Pump Information. (Pump information is required if registering a pit)
   a. Is pump installed at this time ☐ Yes ☑ No
   Is pump installed by well owner in section 1? ☐ Yes ☐ No
   Is pump installed by contractor in section 2? ☐ Yes ☐ No
   Is this a free flowing well ☐ Yes(no pump to be installed) ☐ No
   If pump installed by pump installer, please fill out license number below
   b. Pump Installer's License No._____ Pump Installer's Name_____
   Pump Installer's Email Address_____
   Pump Installer's Firm Name_____
   Pump Installer's Firm Address_____
   City _____ State _____ Zip_____ Telephone _____
   Pump Installer's Firm Email Address_____
   c. Measured Pumping rate _____ gallons per minute d. Pumping water level _____ feet
   e. Drop pipe diameter _____ inches f. Length of drop pipe _____ feet
   g. Pumping equipment installed (m)___/(d___/(y)___
   h. Pump Brand_____
   i. This well is designed and constructed to pump 50 gpm or less ☑ Yes ☐ No **(8I is required on ALL wells)**

9. Well Construction Information.
   a. Total well depth 630 feet. b. Static water level 155 feet. **(required)**
   c. Well Construction Began (m) 8 /(d) 23 /(y) 2016 d.. Well Construction Completed (m) 9 /(d) 1 /(y) 2016

Wells drilled prior to stays or moratoriums require NRD signature	**NRD signature**_____ Date _____ (Signature can be submitted on NRD Approval form to DNR prior to registration)

   e. Bore hole diameter in inches Top 8 Bottom 8
   f. Casing and Screen Joints are Welded ☐ Glued ☐ Threaded ☑ Other Spline & Groove
   g. Capacity of Well 0.2 gallons per minute (to be used to determine sustainability of aquifer)
   h. Pumping water level at this capacity _____ feet

6180858

10. Well Construction (Casing & Screen)- c, d, e, & f measurements should be in inches to three decimal places (From not less than zero)

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							
0	499	Casing	4.320	4.950	0.297		PVC	Certa-Lok
499	500	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank
500	520	Screen	3.000	3.500	0.250	0.020	PVC	Johnson
520	530	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank
530	570	Screen	3.000	3.500	0.250	0.020	PVC	Johnson
570	610	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank

Additional information for Double cased or Nested wells:

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							
610	630	Screen	3.000	3.500	0.250	0.020	PVC	Johnson

11. Grout and Gravel Pack (must start at zero)

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout *See **Desc**
From	To				
0	499	Grout	Neat Cement		13.3 bbls of Cement Slurry
499	630	Gravel Pack	Natural Formation Gravel Pack	5.03 Cubic Yards	

Desc: Description of gravel pack i.e. engineered gravel pack, or gravel pit description (¼ down), or brand nam e (Best Sand), natural formation, drilling cuttings, soil backfill
Quantity #cubic yards, #tons, #sacks, - (for drilling cuttings and soil backfill estimate quantity) Calculation assistance available on web
Volume & Type: #gallons of a slurry, #barrels of a slurry, #sacks used in the slurry, #bags of non-slurry bentonite (chip-pellet –granular)
Additional information for Double cased or Nested wells:

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout *See **Desc**
From	To				

8181858

12. Geologic Materials Logged (must start at zero) - **Use only options provided below for Type, Hardness and Color**

From	To	Type	Hardness	Color	Other/Drilling Action
0	5	Top Soil	Unconsolidated	Brown	
5	20	Other - Quaternary Alluvium	Unconsolidated	Tan	
20	75	Sandstone	Unconsolidated	Tan	
75	290	Siltstone	Dense/Stiff	Brown	
290	380	Sand with Clay/Silt	Dense/Stiff	Brown	
380	430	Clay	Dense/Stiff	Brown	
430	500	Siltstone	Dense/Stiff	Brown	
500	655	Clay	Dense/Stiff	Gray	
655	660	Caly	Dense/Stiff	Gray, Green	

Type		Hardness	Color	
Clay	Sand fine-med	Cemented	Black	Pepper
Clay Stone	Sand med-coarse	Consolidated	Blue	Red
Cobbles	Sand with grave	Dense/Stiff	Brown	Tan
Fine Sand	Sandstone	Hard	Gray	White
Gravel S	hale	Soft	Green	Yellow
Limestone Silt		Unconsolidated	Orange	
Loss Circulation	Siltstone	Very Hard		
Ochre (weathered shale)	Top Soil			
Sandy Clay	Other			
Sand with Clay/Silt				

(Additional sheets may be submitted)

13. I hereby certify that the information provided on this registration is true and accurate to the best of my knowledge.

Water Well Contractor's Signature 9/22/14 Date
(not required for pits)

Well Owner's Signature Date
(if Contractor is unknown or Deceased or for pits)
(Not required if signed by Contractor)

Please note this document contains four pages.

Sections 9F, 9G, 10, 11 & 12 are not required if registering a pit.

Owner Registering well drilled prior to 2002: Minimum Required Sections - 1, 3(a,b,c,e,f), 5, 6, 7, 8(a,g,i), 9d

Sept 2015
DNR Form 667

Submit to:
Department of Natural Resources
301 Centennial Mall South
P.O. Box 94676
Lincoln, Nebraska 68509-4676
Phone (402) 471 2363

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION MODIFICATION
OWNER USE ONLY

FOR DEPARTMENT USE ONLY

Date Filed 4/25/17 Owner Code No. 49185 Registration No. G-180859

04252017 - 245405 -MOD F (2) UPPER NIOBRARA - WHITE NRD
WELL ID

ALL ITEMS IN SECTION 1 AND SIGNATURE IN SECTION 3 ARE REQUIRED

SECTION 1: ☐ **Check here if:** This form is also to be used to change the ownership of this well.

A. Well Owner's First Name _____ Last Name _____
OR Company Name Crow Butte Resources THIS COPY IS
Attention Name Bob Tiensvold FOR YOUR RECORDS
Address 86 Crow Butte Road
City Crawford State NE Zip 69339 Telephone (308) 665-2215
Email _____

B. Well Registration No. G-180859 DBOW4 (Only one number per form)

C. State Reason for Change: Static water level

CORRECTIONS NEEDED Complete only those items being modified

SECTION 2:

A. If location of well needs to be corrected, fully complete the Legal description of the well including GPS Coordinates (latitude and longitude). Footage may be provided. **(1 & 2 REQUIRED)**

1. Well location: _____¼ of the _____ ¼ of Section _____, Township _____ North, Range ___ East/West, _____ County.
2. Latitude Degree:_____ Minute:_____ Second:___.___ Longitude Degree:_____ Minute:_____ Second:___.___ (NAD 83)
3. The well is _____ feet from the (North or South) section line and _____ feet from the (East/West) section line.
(circle one) (circle one)

B. Location of water use (give complete legal description) _____

For Irrigation Wells: Number of acres irrigated: _____

If the location of use is different than what is currently registered, and/or the number of acres irrigated is more than what is currently registered, and you are located in an area that has stays or a moratorium on newly irrigated acres, you **MUST** obtain the written approval of the Natural Resources District **PRIOR TO FILING THIS FORM.** This approval can be the submission of a separate Natural Resources District Approval form by the NRD.

_____ _____ _____
(Natural Resources District) (Signature of NRD Staff) (Date)

C. Pump information.

1. Pumping rate: _____ gallons per minute.
2. Drop Pipe diameter: _____ Inches. 3. Length of drop pipe: _____ feet.
4. Pumping equipment installed: (m)_____/(d)_____/(y)_____. 5. Brand/Type: _____
6. Static Water Level: _____ feet.
7. Pumping water level: _____ feet.
8. Amount of time pumped: _____.

RECEIVED
APR 25 2017
DEPARTMENT OF
NATURAL RESOURCES

D. Change of use, complete items 1, 2 and 3. Identify use from this Listing: Dewatering (over 90 days), Domestic, Ground Heat Exchanger, Ground Water Source Heat Pump, Industrial, Injection, Irrigation, Livestock, Monitoring, Observation, Public Water Supply (with spacing (46-638), Public Water Supply (without spacing), Recovery, Other(if well use falls in this category – add specific use).

1. Well was used for: _____ (if necessary, please provide updated pump information)
2. New well use is: _____
3. Date of Change: _____

E. Active to Inactive (please check A or B) with or without pump

On _____, 20___, the water well is ____a) altered from active to inactive by removing the _____inch pump and pumping column and properly capping the water well according to state standards or ____b) no longer in use but pump still in place with a water tight seal according to state standards. (§46-1207.02)

F. I certify that the well has been modified according to information given in section 2 C, E, or J, such that it will pump 50 gallons per minute or less. Pumping Rate: _____

Change to use (Check one of the following): ☐ Livestock ☐ Monitoring ☐ Observation

☐ nonconsumptive or de minimus use approved by the applicable natural resources district. State use: _____

G. Wells in a Series.

1. Is this well a part of a series? _____ Yes.
2. How many total wells in the series? _____
3. If one or more of the wells in the series is currently registered, give all well registration numbers: _____

H. Well Construction Information.

1. Total well depth: _____ feet.
2. Static water level: 92 feet.
3. Pumping water level: _____ feet
4. Well Construction began: (m)____/(d)____/(y)____
5. Well Construction completed: (m)____/(d)____/(y)____
6. Bore hole diameter in inches: Top____ Bottom ____
7. Casing and Screen Joints are: Welded____, Glued____, Threaded____, Other____
8. Total Estimate Capacity of Well ____ gallons per minute (to be used to determine sustainability of aquifer)

I. Replacement and decommissioned/modified well information.

Department of Natural Resources Decommission/Modification Certification form or Notice of Decommissioning form is Required for replacement wells

1. Is this well a replacement well? ____Yes ____No
2. Registration number of original well: _____ If original well is not registered, date well construction completed (m)____/(d____/(y)____
3. Original well last operated (m)____/(d)____/(y)____
4. Completion of original well decommission/modification on (m)____/(d____/(y)____
5. Complete location of water use of original well: _____

J. Well Construction Modification.

1. Total well depth: _____ feet.
2. Static water level: _____ feet.
3. Pumping water level: _____ feet
4. Well Modification began: (m)____/(d)____/(y)____
5. Well Modification completed: (m)____/(d)____/(y)____
6. Casing diameter in inches: Top____ Bottom ____
7. Casing and Screen Joints are: Welded____, Glued____, Threaded____, Other____
8. Total Estimate Capacity of Well ____ gallons per minute (to be used to determine sustainability of aquifer)

SECTION 3:

I hereby certify that the information provided on this form is true and accurate to the best of my knowledge.

Bob Dunn — Water Well Owner's Signature

4/20/2017 — Date

The Department reserves the right to request verification of information provided.

Mail to
Department of Natural Resources
PO Box 94676
Lincoln, NE 68509-4676
Phone (402)471-2363

January 2011
DNR WWR

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION

Please indicate NA for items unknown

FOR DEPARTMENT USE ONLY

Date Filed 10/24/16 Owner Code No. 49185 Registration No. 6180859

10242016 - 24540S -WWR A(S) Receipt R27310 UNW NRD

Well ID

1. a. Well Owner's First Name _____ Last Name _____

OR Company Name Crow Butte Resources

b. Attention Name _____

c. Street Address 86 Crow Butte Road

Address 2/PO Address PO Box 169

City Crawford State NE Zip 69339 Telephone (308) 665-2215

2. a. Contractor's License No 39561 Contractor's Name Skip L. Chubb

Contractor's Email Address NA

b. Drilling Firm Name Single Water Services, LLC

Address PO Box 1625

City Glenrock State WY Zip 82637 Telephone (307) 267-4415

Drilling Firm's Email Address NA

3. a. Well location NE ¼ of the NE ¼ of Section 24, Township 29 North, Range 51 E ☐ W ☑, Dawes County

Latitude Degree 42 Minute 28 Second 49.863

Longitude Degree 103 Minute 14 Second 47.109

GPS Required

Location of well for a pit is the location of the pump

b. Natural Resources District Upper Niobrara / White River NRD

c. The well is: 190 feet from the (N ☑ S ☐) section line and 570 feet from the (E ☑ W ☐) section line

d. Street address and subdivision, if applicable _____

e. Location of water use (give legal descriptions) _____

f. If for irrigation, the land to be irrigated is _____ acres.

Location of water use is required on all wells

g. Well reference letter(s), if applicable DBOW 4 HHSS PWSID _____

4. Permits

Management Area Permit Number _____
Geothermal Permit Number _____
Municipal Permit Number _____
Well Spacing Permit Number _____
HHSS _____

Surface Water Permit Number _____
Industrial Permit Number _____
Transfer Out-Of-State Permit Number _____
Conduct Permit Number _____
Other Permit Number _____
NDEQ _____

5. Purpose of well (indicate one)

☐ Aquaculture ☐ Commercial/Industrial ☐ Dewatering (over 90 days)
☐ Domestic ☐ Ground Heat Exchanger ☐ Groundwater Source Heat Pump ☐ Irrigation ☐ Injection
☐ Livestock ☑ Monitoring ☐ Observation ☐ Pit (for irrigation) ☐ Public Water Supply (with spacing (46-638))
☐ Public Water Supply (without spacing) ☐ Recovery ☐ Other _____
(further description of use can be provided under other) (indicate use)

6. Wells in a Series.

a. Is this well a part of a series? ☐ Yes go to part b of this section ☑ No go to part 7 of this application (Y/N **required**)

b. If one or more of the wells in the series is currently registered, give well registration number _____

c. How many wells in the series are you registering at this time? _____ d. How many total wells in the series? _____

6780859

7. Replacement and decommissioned/modified well information.
   a. Is this well a replacement well? ☐ Yes ☑ No go to part 8 of this application
   b. Registration number of original well _____ If not registered, date original well was constructed (m)___/(d___/(y)____
   c. Original well last operated (m)___/(d)___/(y)____ d. Replacement well is _____ feet from original well.
   e. Location of water use of original well _____
   Please Select One:
   f.1. ☐ Original water well decommissioned on (m)___/(d___/(y)___ **OR**
   2. ☐ I hereby certify that the original water well will be decommissioned within 180 days after such construction of the replacement water well. **OR**
   3. ☐ I hereby certify that the original water well will be modified and equipped to pump 50 gallons per minute or less within 180 days after such construction of the replacement water well. It will be used for one of the following: a. ☐ Livestock b. ☐ Monitoring c. ☐ Observation d. ☐ nonconsumptive or de minimus use approved by the applicable natural resources district. State use: _____
   If 3d is chosen. NRD signature is required. (Signature can be submitted on NRD Approval form to DNR prior to registration)
   NRD signature_____ Date _____ **OR**
   4. ☐ Owners CERTIFICATION OF INTENT to Decommission or Modify the original well form is submitted by landowner. (Must be submitted before registering well)

8. Pump Information. (Pump information is required if registering a pit)
   a. Is pump installed at this time ☐ Yes ☑ No
   Is pump installed by well owner in section 1? ☐ Yes ☐ No
   Is pump installed by contractor in section 2? ☐ Yes ☐ No
   Is this a free flowing well ☐ Yes(no pump to be installed) ☐ No
   If pump installed by pump installer, please fill out license number below
   b. Pump Installer's License No._____ Pump Installer's Name_____
   Pump Installer's Email Address_____
   Pump Installer's Firm Name_____
   Pump Installer's Firm Address_____
   City _____ State _____ Zip_____ Telephone _____
   Pump Installer's Firm Email Address_____
   c. Measured Pumping rate _____ gallons per minute d. Pumping water level _____ feet
   e. Drop pipe diameter _____ inches f. Length of drop pipe _____ feet
   g. Pumping equipment installed (m)___/(d___/(y)___
   h. Pump Brand_____
   i. This well is designed and constructed to pump 50 gpm or less ☑ Yes ☐ No **(8I is required on ALL wells)**

9. Well Construction Information.
   a. Total well depth 490 feet. b. Static water level 102 feet. **(required)**
   c. Well Construction Began (m) 8 /(d) 31 /(y) 2016 d.. Well Construction Completed (m) 9 /(d) 9 /(y) 2016

Wells drilled prior to stays or moratoriums require NRD signature	**NRD signature**_____ Date _____ (Signature can be submitted on NRD Approval form to DNR prior to registration)

   e. Bore hole diameter in inches Top 8 Bottom 8
   f. Casing and Screen Joints are Welded ☐ Glued ☐ Threaded ☑ Other Spline & Groove
   g. Capacity of Well 0.1 gallons per minute (to be used to determine sustainability of aquifer)
   h. Pumping water level at this capacity _____ feet

6180859

10. Well Construction (Casing & Screen)- c, d, e, & f measurements should be in inches to three decimal places (From not less than zero)

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							
0	379	Casing	4.320	4.950	0.297		PVC	Certa-Lok
379	380	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank
380	440	Screen	3.000	3.500	0.250	0.020	PVC	Johnson
440	450	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank
450	490	Screen	3.000	3.500	0.250	0.020	PVC	Johnson

Additional information for Double cased or Nested wells:

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							

11. Grout and Gravel Pack (must start at zero)

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout *See **Desc**
From	To				
0	379	Grout	Neat Cement		10.1 bbls of Cement Slurry
379	490	Gravel Pack	Natural Formation Gravel Pack	4.26 Cubic Yards	

Desc: Description of gravel pack i.e. engineered gravel pack, or gravel pit description (¼ down), or brand nam e (Best Sand), natural formation, drilling cuttings, soil backfill
Quantity #cubic yards, #tons, #sacks, - (for drilling cuttings and soil backfill estimate quantity) Calculation assistance available on web
Volume & Type: #gallons of a slurry, #barrels of a slurry, #sacks used in the slurry, #bags of non-slurry bentonite (chip-pellet –granular)
Additional information for Double cased or Nested wells:

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout *See **Desc**
From	To				

6181859

12. Geologic Materials Logged (must start at zero) - **Use only options provided below for Type, Hardness and Color**

From	To	Type	Hardness	Color	Other/Drilling Action
0	5	Top Soil	Unconsolidated	Brown	
5	30	Sandstone	Unconsolidated	Tan	
35	160	Siltstone	Dense/Stiff	Brown	
160	240	Sand with Clay/Silt	Dense/Stiff	Tan	
240	300	Siltstone	Dense/Stiff	Brown	
300	510	Clay	Dense/Stiff	Brown	
510	520	Clay	Dense/Stiff	Brown,Green	

Type		Hardness	Color	
Clay	Sand fine-med	Cemented	Black	Pepper
Clay Stone	Sand med-coarse	Consolidated	Blue	Red
Cobbles	Sand with grave	Dense/Stiff	Brown	Tan
Fine Sand	Sandstone	Hard	Gray	White
Gravel S	hale	Soft	Green	Yellow
Limestone Silt		Unconsolidated	Orange	
Loss Circulation	Siltstone	Very Hard		
Ochre (weathered shale)	Top Soil			
Sandy Clay	Other			
Sand with Clay/Silt				

(Additional sheets may be submitted)

13. I hereby certify that the information provided on this registration is true and accurate to the best of my knowledge.

Skip L. Clark 9/22/16

Water Well Contractor's Signature (not required for pits) Date

Well Owner's Signature (if Contractor is unknown or Deceased or for pits) (Not required if signed by Contractor) Date

Please note this document contains four pages.

Sections 9F, 9G, 10, 11 & 12 are not required if registering a pit.

Owner Registering well drilled prior to 2002: Minimum Required Sections - 1, 3(a,b,c,e,f), 5, 6, 7, 8(a,g,i), 9d

Sept 2015
DNR Form 667

Submit to:
Department of Natural Resources
301 Centennial Mall South
P.O. Box 94676
Lincoln, Nebraska 68509-4676
Phone (402) 471 2363

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION MODIFICATION
OWNER USE ONLY

FOR DEPARTMENT USE ONLY

Date Filed 4/25/17 Owner Code No. 49185 Registration No. G-180860

04252017 - 245406 -MOD F (2) UPPER NIOBRARA-WHITE NRD
WELL ID

ALL ITEMS IN SECTION 1 AND SIGNATURE IN SECTION 3 ARE REQUIRED

SECTION 1: ☐ **Check here if:** This form is also to be used to change the ownership of this well.

A. Well Owner's First Name _____ Last Name _____ THIS COPY IS
OR Company Name Crow Butte Resources FOR YOUR RECORDS
Attention Name Bob Tiensvold
Address 86 Crow Butte Road
City Crawford State NE Zip 69339 Telephone (308) 665-2215
Email _____

B. Well Registration No. G-180860 DBOU 5 (Only one number per form)

C. State Reason for Change: Static water level

CORRECTIONS NEEDED Complete only those items being modified

SECTION 2:

A. If location of well needs to be corrected, fully complete the Legal description of the well including GPS Coordinates (latitude and longitude). Footage may be provided. **(1 & 2 REQUIRED)**

1. Well location: ____¼ of the ____¼ of Section ____, Township ____ North, Range ___ East/West, _____ County.
2. Latitude Degree:____ Minute:____ Second:___.___ Longitude Degree:____ Minute:____ Second:___.___ (NAD 83)
3. The well is _____ feet from the (North or South) section line and _____ feet from the (East/West) section line.
(circle one) (circle one)

B. Location of water use (give complete legal description)_____

For Irrigation Wells: Number of acres irrigated:_____

If the location of use is different than what is currently registered, and/or the number of acres irrigated is more than what is currently registered, and you are located in an area that has stays or a moratorium on newly irrigated acres, you **MUST** obtain the written approval of the Natural Resources District **PRIOR TO FILING THIS FORM.** This approval can be the submission of a separate Natural Resources District Approval form by the NRD.

_____ _____ _____
(Natural Resources District) (Signature of NRD Staff) (Date)

C. Pump information.

1. Pumping rate:_____ gallons per minute.
2. Drop Pipe diameter:_____ Inches. 3. Length of drop pipe:_____ feet.
4. Pumping equipment installed: (m)____/(d)____/(y)____. 5. Brand/Type:_____
6. Static Water Level:_____ feet.
7. Pumping water level:_____ feet.
8. Amount of time pumped:_____.

RECEIVED
APR 25 2017
DEPARTMENT OF NATURAL RESOURCES

D. Change of use, complete items 1, 2 and 3. Identify use from this Listing: Dewatering (over 90 days), Domestic, Ground Heat Exchanger, Ground Water Source Heat Pump, Industrial, Injection, Irrigation, Livestock, Monitoring, Observation, Public Water Supply (with spacing (46-638), Public Water Supply (without spacing), Recovery, Other(if well use falls in this category – add specific use).

1. Well was used for: _____ (if necessary, please provide updated pump information)
2. New well use is: _____
3. Date of Change: _____

E. Active to Inactive (please check A or B) with or without pump

On _____, 20___, the water well is ____a) altered from active to inactive by removing the _____inch pump and pumping column and properly capping the water well according to state standards or ____b) no longer in use but pump still in place with a water tight seal according to state standards. (§46-1207.02).

F. I certify that the well has been modified according to information given in section 2 C, E, or J, such that it will pump 50 gallons per minute or less. Pumping Rate: _____

Change to use (Check one of the following): ☐ Livestock ☐ Monitoring ☐ Observation

☐ nonconsumptive or de minimus use approved by the applicable natural resources district. State use: _____

G. Wells in a Series.

1. Is this well a part of a series? _____ Yes.
2. How many total wells in the series? _____
3. If one or more of the wells in the series is currently registered, give all well registration numbers: _____

H. Well Construction Information.

1. Total well depth: _____ feet.
2. Static water level: 70 _____ feet.
3. Pumping water level: _____ feet
4. Well Construction began: (m)_____/(d)_____/(y)_____
5. Well Construction completed: (m)_____/(d)_____/(y)_____
6. Bore hole diameter in inches: Top____ Bottom _____
7. Casing and Screen Joints are: Welded_____, Glued_____, Threaded_____, Other_____
8. Total Estimate Capacity of Well _____ gallons per minute (to be used to determine sustainability of aquifer)

I. Replacement and decommissioned/modified well information.

Department of Natural Resources Decommission/Modification Certification form or Notice of Decommissioning form is Required for replacement wells

1. Is this well a replacement well? ____Yes ____No
2. Registration number of original well: _____ If original well is not registered, date well construction completed (m)___/(d___/(y)___
3. Original well last operated (m)___/(d)_____/(y)_____
4. Completion of original well decommission/modification on (m)___/(d____/(y)____
5. Complete location of water use of original well: _____

J. Well Construction Modification.

1. Total well depth: _____ feet.
2. Static water level: _____ feet.
3. Pumping water level: _____ feet
4. Well Modification began: (m)_____/(d)_____/(y)_____
5. Well Modification completed: (m)_____/(d)_____/(y)____
6. Casing diameter in inches: Top____ Bottom _____
7. Casing and Screen Joints are: Welded____, Glued_____, Threaded_____, Other_____
8. Total Estimate Capacity of Well _____ gallons per minute (to be used to determine sustainability of aquifer)

SECTION 3:

I hereby certify that the information provided on this form is true and accurate to the best of my knowledge.

Bob Dr — Water Well Owner's Signature

4/20/2017 — Date

The Department reserves the right to request verification of information provided.

Mail to
Department of Natural Resources
PO Box 94676
Lincoln, NE 68509-4676
Phone (402)471-2363

January 2011
DNR WWR

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION

Please indicate NA for items unknown

FOR DEPARTMENT USE ONLY

Date Filed 10/24/16 Owner Code No. 49185 Registration No. 61808600

10/24/2016 - 245406 -WWR(5) Receipt 627310 UNW NRD

Well ID

1. a. Well Owner's First Name _____ Last Name _____

   OR Company Name Crow Butte Resources

   b. Attention Name _____

   c. Street Address 86 Crow Butte Road

   Address 2/PO Address PO Box 169

   City Crawford State NE Zip 69339 Telephone (308) 665-2215

2. a. Contractor's License No 39561 Contractor's Name Skip L. Chubb

   Contractor's Email Address NA

   b. Drilling Firm Name Single Water Services, LLC

   Address PO Box 1625

   City Glenrock State WY Zip 82637 Telephone (307) 267-4415

   Drilling Firm's Email Address NA

3. a. Well location NE ¼ of the SE ¼ of Section 19, Township 29 North, Range 50 E ☐ W ☑, Dawes County

   Latitude Degree 42 Minute 28 Second 25.076

   Longitude Degree 103 Minute 13 Second 41.126

   GPS Required

   Location of well for a pit is the location of the pump

   b. Natural Resources District Upper Niobrara / White River NRD

   c. The well is: 2600 feet from the (N ☐ S ☑) section line and 875 feet from the (E ☑ W ☐) section line

   d. Street address and subdivision, if applicable _____

   e. Location of water use (give legal descriptions) _____

   f. If for irrigation, the land to be irrigated is _____ acres.

   Location of water use is required on all wells

   g. Well reference letter(s), if applicable DBOW 5 HHSS PWSID _____

4. Permits

   Management Area Permit Number _____
   Geothermal Permit Number _____
   Municipal Permit Number _____
   Well Spacing Permit Number _____
   HHSS _____
   Surface Water Permit Number _____
   Industrial Permit Number _____
   Transfer Out-Of-State Permit Number _____
   Conduct Permit Number _____
   Other Permit Number _____
   NDEQ _____

5. Purpose of well (indicate one)

   ☐ Aquaculture ☐ Commercial/Industrial ☐ Dewatering (over 90 days)
   ☐ Domestic ☐ Ground Heat Exchanger ☐ Groundwater Source Heat Pump ☐ Irrigation ☐ Injection
   ☐ Livestock ☑ Monitoring ☐ Observation ☐ Pit (for irrigation) ☐ Public Water Supply (with spacing (46-638))
   ☐ Public Water Supply (without spacing) ☐ Recovery ☐ Other _____
   (further description of use can be provided under other) (indicate use)

6. Wells in a Series.

   a. Is this well a part of a series? ☐ Yes go to part b of this section ☑ No go to part 7 of this application (Y/N **required**)

   b. If one or more of the wells in the series is currently registered, give well registration number _____

   c. How many wells in the series are you registering at this time? _____ d. How many total wells in the series? _____

6180860

7. Replacement and decommissioned/modified well information.
   a. Is this well a replacement well? ☐ Yes ☑ No go to part 8 of this application
   b. Registration number of original well _____ If not registered, date original well was constructed (m)___/(d___/(y)____
   c. Original well last operated (m)___/(d)___/(y)____ d. Replacement well is _____ feet from original well.
   e. Location of water use of original well _____
   Please Select One:
   f.1. ☐ Original water well decommissioned on (m)___/(d___/(y)___ **OR**
   2. ☐ I hereby certify that the original water well will be decommissioned within 180 days after such construction of the replacement water well. **OR**
   3. ☐ I hereby certify that the original water well will be modified and equipped to pump 50 gallons per minute or less within 180 days after such construction of the replacement water well. It will be used for one of the following: a. ☐ Livestock b. ☐ Monitoring c. ☐ Observation d. ☐ nonconsumptive or de minimus use approved by the applicable natural resources district. State use: _____
   If 3d is chosen. NRD signature is required. (Signature can be submitted on NRD Approval form to DNR prior to registration)
   NRD signature_____ Date _____ **OR**
   4. ☐ Owners CERTIFICATION OF INTENT to Decommission or Modify the original well form is submitted by landowner. (Must be submitted before registering well)

8. Pump Information. (Pump information is required if registering a pit)
   a. Is pump installed at this time ☐ Yes ☑ No
   Is pump installed by well owner in section 1? ☐ Yes ☐ No
   Is pump installed by contractor in section 2? ☐ Yes ☐ No
   Is this a free flowing well ☐ Yes(no pump to be installed) ☐ No
   If pump installed by pump installer, please fill out license number below
   b. Pump Installer's License No._____ Pump Installer's Name_____
   Pump Installer's Email Address_____
   Pump Installer's Firm Name_____
   Pump Installer's Firm Address_____
   City _____ State _____ Zip_____ Telephone _____
   Pump Installer's Firm Email Address_____
   c. Measured Pumping rate _____ gallons per minute d. Pumping water level _____ feet
   e. Drop pipe diameter _____ inches f. Length of drop pipe _____ feet
   g. Pumping equipment installed (m)___/(d___/(y)___
   h. Pump Brand_____
   i. This well is designed and constructed to pump 50 gpm or less ☑ Yes ☐ No **(8I is required on ALL wells)**

9. Well Construction Information.
   a. Total well depth 460 feet. b. Static water level 71 feet. **(required)**
   c. Well Construction Began (m) 9 /(d) 8 /(y) 2016 d.. Well Construction Completed (m) 9 /(d) 15 /(y) 2016

Wells drilled prior to stays or moratoriums require NRD signature	**NRD signature**_____ Date _____ (Signature can be submitted on NRD Approval form to DNR prior to registration)

   e. Bore hole diameter in inches Top 8 Bottom 8
   f. Casing and Screen Joints are Welded ☐ Glued ☐ Threaded ☑ Other Spline & Groove
   g. Capacity of Well 0.1 gallons per minute (to be used to determine sustainability of aquifer)
   h. Pumping water level at this capacity _____ feet

6180840

10. Well Construction (Casing & Screen)- c, d, e, & f measurements should be in inches to three decimal places (From not less than zero)

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							
0	319	Casing	4.320	4.950	0.297		PVC	Certa-Lok
319	325	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank
325	385	Screen	3.000	3.500	0.250	0.020	PVC	Johnson
385	435	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank
435	460	Screen	3.000	3.500	0.250	0.020	PVC	Johnson

Additional information for Double cased or Nested wells:

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							

11. Grout and Gravel Pack (must start at zero)

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout *See **Desc**
From	To				
0	319	Grout	Neat Cement		12.2 bbls of Cement Slurry
319	460	Gravel Pack	Natural Formation Gravel Pack	3.75 Cubic Yards	

Desc: Description of gravel pack i.e. engineered gravel pack, or gravel pit description (¼ down), or brand nam e (Best Sand), natural formation, drilling cuttings, soil backfill
Quantity #cubic yards, #tons, #sacks, - (for drilling cuttings and soil backfill estimate quantity) Calculation assistance available on web
Volume & Type: #gallons of a slurry, #barrels of a slurry, #sacks used in the slurry, #bags of non-slurry bentonite (chip-pellet –granular)
Additional information for Double cased or Nested wells:

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout *See **Desc**
From	To				

6180840

12. Geologic Materials Logged (must start at zero) - **Use only options provided below for Type, Hardness and Color**

From	To	Type	Hardness	Color	Other/Drilling Action
0	5	Top Soil	Unconsolidated	Brown	
5	25	Other - Quaternary Alluvium	Unconsolidated	Tan	
25	40	Limestone Silt	Hard	Gray	
40	190	Siltstone	Dense/Stiff	Brown	
190	220	Sandstone	Unconsolidated	Tan	
220	420	Siltstone	Dense/Stiff	Brown	
420	500	Caly	Dense/Stiff	Brown	

Type		Hardness	Color	
Clay	Sand fine-med	Cemented	Black	Pepper
Clay Stone	Sand med-coarse	Consolidated	Blue	Red
Cobbles	Sand with grave	Dense/Stiff	Brown	Tan
Fine Sand	Sandstone	Hard	Gray	White
Gravel S	hale	Soft	Green	Yellow
Limestone Silt		Unconsolidated	Orange	
Loss Circulation	Siltstone	Very Hard		
Ochre (weathered shale)	Top Soil			
Sandy Clay	Other			
Sand with Clay/Silt				

(Additional sheets may be submitted)

13. I hereby certify that the information provided on this registration is true and accurate to the best of my knowledge.

Skip L. Chubb 9/22/14

Water Well Contractor's Signature Date
(not required for pits)

Well Owner's Signature Date
(if Contractor is unknown or Deceased or for pits)
(Not required if signed by Contractor)

Please note this document contains four pages.

Sections 9F, 9G, 10, 11 & 12 are not required if registering a pit.

Owner Registering well drilled prior to 2002: Minimum Required Sections - 1, 3(a,b,c,e,f), 5, 6, 7, 8(a,g,i), 9d

Sept 2015
DNR Form 667

Submit to:
Department of Natural Resources
301 Centennial Mall South
P.O. Box 94676
Lincoln, Nebraska 68509-4676
Phone (402) 471 2363

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION MODIFICATION
OWNER USE ONLY

FOR DEPARTMENT USE ONLY

Date Filed 4/25/17 Owner Code No. 49185 Registration No. G-180861

04252017 - 245407 -MOD F(2) UPPER NIOBRARA-WHITE NRD
WELL ID

ALL ITEMS IN SECTION 1 AND SIGNATURE IN SECTION 3 ARE REQUIRED

SECTION 1: ☐ **Check here if:** This form is also to be used to change the ownership of this well.

A. Well Owner's First Name _____ Last Name _____
OR Company Name Crow Butte Resources
Attention Name Bob Tiensvold
Address 86 Crow Butte Road
City Crawford State NE Zip 69339 Telephone (308) 665-2215
Email _____

THIS COPY IS FOR YOUR RECORDS

B. Well Registration No. G-180861 DBOD 6 (Only one number per form)

C. State Reason for Change: Static water level

CORRECTIONS NEEDED Complete only those items being modified

SECTION 2:

A. If location of well needs to be corrected, fully complete the Legal description of the well including GPS Coordinates (latitude and longitude). Footage may be provided. **(1 & 2 REQUIRED)**

1. Well location: ____¼ of the ____¼ of Section ____, Township ____ North, Range ___ East/West, _____ County.
2. Latitude Degree:____ Minute:____ Second:___.___ Longitude Degree:____ Minute:____ Second:___.___ (NAD 83)
3. The well is _____ feet from the (North or South) section line and _____ feet from the (East/West) section line.
(circle one) (circle one)

B. Location of water use (give complete legal description)_____

For Irrigation Wells: Number of acres irrigated:_____

If the location of use is different than what is currently registered, and/or the number of acres irrigated is more than what is currently registered, and you are located in an area that has stays or a moratorium on newly irrigated acres, you **MUST** obtain the written approval of the Natural Resources District **PRIOR TO FILING THIS FORM**. This approval can be the submission of a separate Natural Resources District Approval form by the NRD.

_____ _____ _____
(Natural Resources District) (Signature of NRD Staff) (Date)

C. Pump information.

1. Pumping rate:_____ gallons per minute.
2. Drop Pipe diameter:_____ Inches. 3. Length of drop pipe:_____ feet.
4. Pumping equipment installed: (m)____/(d)____/(y)____. 5. Brand/Type:_____
6. Static Water Level:_____ feet.
7. Pumping water level:_____ feet.
8. Amount of time pumped:_____.

RECEIVED
APR 25 2017
DEPARTMENT OF NATURAL RESOURCES

D. Change of use, complete items 1, 2 and 3. Identify use from this Listing: Dewatering (over 90 days), Domestic, Ground Heat Exchanger, Ground Water Source Heat Pump, Industrial, Injection, Irrigation, Livestock, Monitoring, Observation, Public Water Supply (with spacing (46-638), Public Water Supply (without spacing), Recovery, Other(if well use falls in this category – add specific use).

1. Well was used for: _____ (if necessary, please provide updated pump information)
2. New well use is: _____
3. Date of Change: _____

E. Active to Inactive (please check A or B) with or without pump

On _____, 20___, the water well is ____a) altered from active to inactive by removing the _____inch pump and pumping column and properly capping the water well according to state standards or ____b) no longer in use but pump still in place with a water tight seal according to state standards. (§46-1207.02)

F. I certify that the well has been modified according to information given in section 2 C, E, or J, such that it will pump 50 gallons per minute or less. Pumping Rate: _____

Change to use (Check one of the following): ☐ Livestock ☐ Monitoring ☐ Observation

☐ nonconsumptive or de minimus use approved by the applicable natural resources district. State use: _____

G. Wells in a Series.

1. Is this well a part of a series?_____ Yes.
2. How many total wells in the series?_____
3. If one or more of the wells in the series is currently registered, give all well registration numbers: _____

H. Well Construction Information.

1. Total well depth: _____ feet.
2. Static water level: 46 feet.
3. Pumping water level: _____ feet
4. Well Construction began: (m)____/(d)____/(y)____
5. Well Construction completed: (m)____/(d)____/(y)____
6. Bore hole diameter in inches: Top____ Bottom ____
7. Casing and Screen Joints are: Welded_____, Glued_____, Threaded_____, Other_____
8. Total Estimate Capacity of Well _____ gallons per minute (to be used to determine sustainability of aquifer)

I. Replacement and decommissioned/modified well information.

Department of Natural Resources Decommission/Modification Certification form or Notice of Decommissioning form is Required for replacement wells

1. Is this well a replacement well? ____Yes ____No
2. Registration number of original well:_____ If original well is not registered, date well construction completed (m)____/(d____/(y)____
3. Original well last operated (m)____/(d)____/(y)____
4. Completion of original well decommission/modification on (m)____/(d____/(y)____
5. Complete location of water use of original well: _____

J. Well Construction Modification.

1. Total well depth: _____ feet.
2. Static water level: _____ feet.
3. Pumping water level: _____ feet
4. Well Modification began: (m)____/(d)____/(y)____
5. Well Modification completed: (m)____/(d)____/(y)____
6. Casing diameter in inches: Top____ Bottom ____
7. Casing and Screen Joints are: Welded____, Glued_____, Threaded_____, Other_____
8. Total Estimate Capacity of Well _____ gallons per minute (to be used to determine sustainability of aquifer)

SECTION 3:

I hereby certify that the information provided on this form is true and accurate to the best of my knowledge.

Bob Dr — Water Well Owner's Signature

4/20/2017 — Date

The Department reserves the right to request verification of information provided.

Mail to
Department of Natural Resources
PO Box 94676
Lincoln, NE 68509-4676
Phone (402)471-2363

January 2011
DNR WWR

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION

Please indicate NA for items unknown

FOR DEPARTMENT USE ONLY

Date Filed 10/24/16 Owner Code No. 49185 Registration No. 61808b1

10242016 - 245407 -WWR(CS) Receipt 227310 UNW NRD

Well ID

1. a. Well Owner's First Name _____ Last Name _____

OR Company Name Crow Butte Resources

b. Attention Name _____

c. Street Address 86 Crow Butte Road

Address 2/PO Address PO Box 169

City Crawford State NE Zip 69339 Telephone (308) 665-2215

2. a. Contractor's License No 39561 Contractor's Name Skip L. Chubb

Contractor's Email Address NA

b. Drilling Firm Name Single Water Services, LLC

Address PO Box 1625

City Glenrock State WY Zip 82637 Telephone (307) 267-4415

Drilling Firm's Email Address NA

3. a. Well location NE ¼ of the NW ¼ of Section 29, Township 29 North, Range 50 E ☐ W ☑, Dawes County

Latitude Degree 42 Minute 27 Second 55.673

Longitude Degree 103 Minute 13 Second 12.109

GPS Required

Location of well for a pit is the location of the pump

b. Natural Resources District Upper Niobrara / White River NRD

c. The well is: 380 feet from the (N ☑ S ☐) section line and 1310 feet from the (E ☐ W ☑) section line

d. Street address and subdivision, if applicable _____

e. Location of water use (give legal descriptions) _____

f. If for irrigation, the land to be irrigated is _____ acres.

Location of water use is required on all wells

g. Well reference letter(s), if applicable DBOW6 HHSS PWSID _____

4. Permits

Management Area Permit Number _____
Geothermal Permit Number _____
Municipal Permit Number _____
Well Spacing Permit Number _____
HHSS _____

Surface Water Permit Number _____
Industrial Permit Number _____
Transfer Out-Of-State Permit Number _____
Conduct Permit Number _____
Other Permit Number _____
NDEQ _____

5. Purpose of well (indicate one)

☐ Aquaculture ☐ Commercial/Industrial ☐ Dewatering (over 90 days)
☐ Domestic ☐ Ground Heat Exchanger ☐ Groundwater Source Heat Pump ☐ Irrigation ☐ Injection
☐ Livestock ☑ Monitoring ☐ Observation ☐ Pit (for irrigation) ☐ Public Water Supply (with spacing (46-638))
☐ Public Water Supply (without spacing) ☐ Recovery ☐ Other _____
(further description of use can be provided under other) (indicate use)

6. Wells in a Series.

a. Is this well a part of a series? ☐ Yes go to part b of this section ☑ No go to part 7 of this application (Y/N **required**)

b. If one or more of the wells in the series is currently registered, give well registration number _____

c. How many wells in the series are you registering at this time? _____ d. How many total wells in the series? _____

618086 1

7. Replacement and decommissioned/modified well information.
   a. Is this well a replacement well? ☐ Yes ☑ No go to part 8 of this application
   b. Registration number of original well _____ If not registered, date original well was constructed (m)___/(d___/(y)____
   c. Original well last operated (m)____/(d)____/(y)____ d. Replacement well is _____ feet from original well.
   e. Location of water use of original well _____

   Please Select One:

   f.1. ☐ Original water well decommissioned on (m)___/(d___/(y)___ **OR**
   2. ☐ I hereby certify that the original water well will be decommissioned within 180 days after such construction of the replacement water well. **OR**
   3. ☐ I hereby certify that the original water well will be modified and equipped to pump 50 gallons per minute or less within 180 days after such construction of the replacement water well. It will be used for one of the following: a. ☐ Livestock b. ☐ Monitoring c. ☐ Observation d. ☐ nonconsumptive or de minimus use approved by the applicable natural resources district. State use: _____

      If 3d is chosen. NRD signature is required. (Signature can be submitted on NRD Approval form to DNR prior to registration)

      NRD signature_____ Date _____ **OR**
   4. ☐ Owners CERTIFICATION OF INTENT to Decommission or Modify the original well form is submitted by landowner. (Must be submitted before registering well)

8. Pump Information. (Pump information is required if registering a pit)
   a. Is pump installed at this time ☐ Yes ☑ No

      Is pump installed by well owner in section 1? ☐ Yes ☐ No

      Is pump installed by contractor in section 2? ☐ Yes ☐ No

      Is this a free flowing well ☐ Yes(no pump to be installed) ☐ No

   If pump installed by pump installer, please fill out license number below

   b. Pump Installer's License No._____ Pump Installer's Name_____

      Pump Installer's Email Address_____

      Pump Installer's Firm Name_____

      Pump Installer's Firm Address_____

      City _____ State _____ Zip_____ Telephone _____

      Pump Installer's Firm Email Address_____

   c. Measured Pumping rate _____ gallons per minute d. Pumping water level _____ feet
   e. Drop pipe diameter _____ inches f. Length of drop pipe _____ feet
   g. Pumping equipment installed (m)___/(d___/(y)___
   h. Pump Brand_____
   i. This well is designed and constructed to pump 50 gpm or less ☑ Yes ☐ No **(8I is required on ALL wells)**

9. Well Construction Information.
   a. Total well depth 450 feet. b. Static water level 50 feet. **(required)**
   c. Well Construction Began (m) 9 /(d) 7 /(y) 2016 d.. Well Construction Completed (m) 9 /(d) 14 /(y) 2016

   Wells drilled prior to stays or moratoriums require NRD signature — **NRD signature**_____ Date _____ (Signature can be submitted on NRD Approval form to DNR prior to registration)

   e. Bore hole diameter in inches Top 8 Bottom 8
   f. Casing and Screen Joints are Welded ☐ Glued ☐ Threaded ☑ Other Spline & Groove
   g. Capacity of Well 0.1 gallons per minute (to be used to determine sustainability of aquifer)
   h. Pumping water level at this capacity _____ feet

6-180841

10. Well Construction (Casing & Screen)- c, d, e, & f measurements should be in inches to three decimal places (From not less than zero)

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							
0	299	Casing	4.320	4.950	0.297		PVC	Certa-Lok
299	300	Screen Blank	3.000	3.500	0.250		PVC	Certainteed Screen Blank
300	350	Screen	3.000	3.500	0.250	0.020	PVC	Johnson
350	380	Screen Blank	3.000	3.500	0.250		PVC	Certainteed Screen Blank
380	400	Screen	3.000	3.500	0.250	0.020	PVC	Johnson
400	430	Screen Blank	3.000	3.500	0.250			Certainteed Screen Blank

Additional information for Double cased or Nested wells:

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							
430	450	Screen	3.000	3.500	0.250	0.020	PVC	Johnson

11. Grout and Gravel Pack (must start at zero)

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout *See **Desc**
From	To				
0	299	Grout	Neat Cement		11.5 bbls of Cement Slurry
299	450	Gravel Pack	Natural Formation Gravel Pack	5.79 Cubic Yards	

Desc: Description of gravel pack i.e. engineered gravel pack, or gravel pit description (¼ down), or brand nam e (Best Sand), natural formation, drilling cuttings, soil backfill
Quantity #cubic yards, #tons, #sacks, - (for drilling cuttings and soil backfill estimate quantity) Calculation assistance available on web
Volume & Type: #gallons of a slurry, #barrels of a slurry, #sacks used in the slurry, #bags of non-slurry bentonite (chip-pellet –granular)
Additional information for Double cased or Nested wells:

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout *See **Desc**
From	To				

8-180841

12. Geologic Materials Logged (must start at zero) - **Use only options provided below for Type, Hardness and Color**

From	To	Type	Hardness	Color	Other/Drilling Action
0	10	Top Soil	Unconsolidated	Brown	
10	20	Other - Quaternary Alluvium	Unconsolidated	Brown	
20	30	Sandstone	Unconsolidated	Brown	
30	40	Siltstone	Dense/Stiff	Tan	
40	55	Limestone Silt	Hard	White	
55	170	Siltstone	Dense/Stiff	Brown	
170	210	Sand with Clay/Silt	Unconsolidated	Tan	
210	285	Siltsone	Dense/Stiff	Brown	
285	460	Clay	Dense/Stiff	Brown	
460	480	Caly	Dense/Stiff	Brown, Green	

Type		Hardness	Color	
Clay	Sand fine-med	Cemented	Black	Pepper
Clay Stone	Sand med-coarse	Consolidated	Blue	Red
Cobbles	Sand with grave	Dense/Stiff	Brown	Tan
Fine Sand	Sandstone	Hard	Gray	White
Gravel S	hale	Soft	Green	Yellow
Limestone Silt		Unconsolidated	Orange	
Loss Circulation	Siltstone	Very Hard		
Ochre (weathered shale)	Top Soil			
Sandy Clay	Other			
Sand with Clay/Silt				

(Additional sheets may be submitted)

13. I hereby certify that the information provided on this registration is true and accurate to the best of my knowledge.

Skip L. Clubb 9/22/14

Water Well Contractor's Signature (not required for pits) Date

Well Owner's Signature (if Contractor is unknown or Deceased or for pits) (Not required if signed by Contractor) Date

Please note this document contains four pages.

ections 9F, 9G, 10, 11 & 12 are not required if registering a pit.

Owner Registering well drilled prior to 2002: Minimum Required Sections - 1, 3(a,b,c,e,f), 5, 6, 7, 8(a,g,i), 9d

Sept 2015
DNR Form 667

Submit to:
Department of Natural Resources
301 Centennial Mall South
P.O. Box 94676
Lincoln, Nebraska 68509-4676
Phone (402) 471 2363

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION MODIFICATION
OWNER USE ONLY

FOR DEPARTMENT USE ONLY

Date Filed 4/25/17 Owner Code No. 49185 Registration No. G-180862

04252017 - 245408 -MOD F(2) UPPER NIOBRARA-WHITE NRD
WELL ID

ALL ITEMS IN SECTION 1 AND SIGNATURE IN SECTION 3 ARE REQUIRED

SECTION 1: ☐ **Check here if:** This form is also to be used to change the ownership of this well.

A. Well Owner's First Name _____ Last Name _____
OR Company Name Crow Butte Resources THIS COPY IS
Attention Name Bob Tiensvold FOR YOUR RECORDS
Address 86 Crow Butte Road
City Crawford State NE Zip 69339 Telephone (308) 665-2215
Email _____

B. Well Registration No. G-180862 D BOL 7 (Only one number per form)

C. State Reason for Change: Static water level

CORRECTIONS NEEDED **Complete only those items being modified**

SECTION 2:

A. If location of well needs to be corrected, fully complete the Legal description of the well including GPS Coordinates (latitude and longitude). Footage may be provided. **(1 & 2 REQUIRED)**

1. Well location: ____ ¼ of the ____ ¼ of Section ____, Township ____ North, Range ___ East/West, _____ County.
2. Latitude Degree:____ Minute:____ Second:___.___ Longitude Degree:____ Minute:____ Second:___.___ (NAD 83)
3. The well is _____ feet from the (North or South) section line and _____ feet from the (East/West) section line.
(circle one) (circle one)

B. Location of water use (give complete legal description)_____

For Irrigation Wells: Number of acres irrigated:_____

If the location of use is different than what is currently registered, and/or the number of acres irrigated is more than what is currently registered, and you are located in an area that has stays or a moratorium on newly irrigated acres, you **MUST** obtain the written approval of the Natural Resources District **PRIOR TO FILING THIS FORM.** This approval can be the submission of a separate Natural Resources District Approval form by the NRD.

_____ _____ _____
(Natural Resources District) (Signature of NRD Staff) (Date)

C. Pump information.

1. Pumping rate:_____ gallons per minute.
2. Drop Pipe diameter:_____ Inches.
3. Length of drop pipe:_____ feet.
4. Pumping equipment installed: (m)____/(d)____/(y)____.
5. Brand/Type:_____
6. Static Water Level:_____ feet.
7. Pumping water level:_____ feet.
8. Amount of time pumped:_____.

RECEIVED
APR 25 2017
DEPARTMENT OF NATURAL RESOURCES

D. Change of use, complete items 1, 2 and 3. Identify use from this Listing: Dewatering (over 90 days), Domestic, Ground Heat Exchanger, Ground Water Source Heat Pump, Industrial, Injection, Irrigation, Livestock, Monitoring, Observation, Public Water Supply (with spacing (46-638), Public Water Supply (without spacing), Recovery, Other(if well use falls in this category – add specific use).

1. Well was used for: _____ (if necessary, please provide updated pump information)
2. New well use is: _____
3. Date of Change: _____

E. Active to Inactive (please check A or B) with or without pump

On _____, 20___, the water well is ____a) altered from active to inactive by removing the _____inch pump and pumping column and properly capping the water well according to state standards or ____b) no longer in use but pump still in place with a water tight seal according to state standards. (§46-1207.02)

F. I certify that the well has been modified according to information given in section 2 C, E, or J, such that it will pump 50 gallons per minute or less. Pumping Rate: _____

Change to use (Check one of the following): ☐ Livestock ☐ Monitoring ☐ Observation

☐ nonconsumptive or de minimus use approved by the applicable natural resources district. State use: _____

G. Wells in a Series.

1. Is this well a part of a series? _____ Yes.
2. How many total wells in the series? _____
3. If one or more of the wells in the series is currently registered, give all well registration numbers: _____

H. Well Construction Information.

1. Total well depth: _____ feet.
2. Static water level: 152 feet.
3. Pumping water level: _____ feet
4. Well Construction began: (m)____/(d)____/(y)____
5. Well Construction completed: (m)____/(d)____/(y)____
6. Bore hole diameter in inches: Top____ Bottom ____
7. Casing and Screen Joints are: Welded_____, Glued_____, Threaded_____, Other_____
8. Total Estimate Capacity of Well _____ gallons per minute (to be used to determine sustainability of aquifer)

I. Replacement and decommissioned/modified well information.

Department of Natural Resources Decommission/Modification Certification form or Notice of Decommissioning form is Required for replacement wells

1. Is this well a replacement well? ____Yes ____No
2. Registration number of original well: _____ If original well is not registered, date well construction completed (m)___/(d___/(y)___
3. Original well last operated (m)___/(d)____/(y)____
4. Completion of original well decommission/modification on (m)___/(d____/(y)____
5. Complete location of water use of original well: _____

J. Well Construction Modification.

1. Total well depth: _____ feet.
2. Static water level: _____ feet.
3. Pumping water level: _____ feet
4. Well Modification began: (m)____/(d)____/(y)____
5. Well Modification completed: (m)____/(d)____/(y)____
6. Casing diameter in inches: Top____ Bottom ____
7. Casing and Screen Joints are: Welded____, Glued_____, Threaded_____, Other_____
8. Total Estimate Capacity of Well _____ gallons per minute (to be used to determine sustainability of aquifer)

SECTION 3:

I hereby certify that the information provided on this form is true and accurate to the best of my knowledge.

Bob Dr — Water Well Owner's Signature

4/20/2017 — Date

The Department reserves the right to request verification of information provided.

Mail to
Department of Natural Resources
PO Box 94676
Lincoln, NE 68509-4676
Phone (402)471-2363

January 2011
DNR WWR

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION

Please indicate NA for items unknown

FOR DEPARTMENT USE ONLY

Date Filed 10/24/16 Owner Code No. 49185 Registration No. 6180862

10242016 - 245408 -WWR(S) Receipt R27310 UNW NRD

Well ID

1. a. Well Owner's First Name _____ Last Name _____

OR Company Name Crow Butte Resources

b. Attention Name _____

c. Street Address 86 Crow Butte Road

Address 2/PO Address PO Box 169

City Crawford State NE Zip 69339 Telephone (308) 665-2215

2. a. Contractor's License No 39561 Contractor's Name Skip L. Chubb

Contractor's Email Address NA

b. Drilling Firm Name Single Water Services, LLC

Address PO Box 1625

City Glenrock State WY Zip 82637 Telephone (307) 267-4415

Drilling Firm's Email Address NA

3. a. Well location NE ¼ of the SW ¼ of Section 12, Township 29 North, Range 51 E ☐ W ☑, Dawes County

Latitude Degree 42 Minute 30 Second 09.361

Longitude Degree 103 Minute 15 Second 20.032

GPS Required

Location of well for a pit is the location of the pump

b. Natural Resources District Upper Niobrara / White River NRD

c. The well is: 2650 feet from the (N ☑ S ☐) section line and 2400 feet from the (E ☐ W ☑) section line

d. Street address and subdivision, if applicable _____

e. Location of water use (give legal descriptions) _____

f. If for irrigation, the land to be irrigated is _____ acres.

Location of water use is required on all wells

g. Well reference letter(s), if applicable DBOW 7 HHSS PWSID _____

4. Permits

Management Area Permit Number _____
Geothermal Permit Number _____
Municipal Permit Number _____
Well Spacing Permit Number _____
HHSS _____

Surface Water Permit Number _____
Industrial Permit Number _____
Transfer Out-Of-State Permit Number _____
Conduct Permit Number _____
Other Permit Number _____
NDEQ _____

5. Purpose of well (indicate one)

☐ Aquaculture ☐ Commercial/Industrial ☐ Dewatering (over 90 days)
☐ Domestic ☐ Ground Heat Exchanger ☐ Groundwater Source Heat Pump ☐ Irrigation ☐ Injection
☐ Livestock ☑ Monitoring ☐ Observation ☐ Pit (for irrigation) ☐ Public Water Supply (with spacing (46-638))
☐ Public Water Supply (without spacing) ☐ Recovery ☐ Other _____
(further description of use can be provided under other) (indicate use)

6. Wells in a Series.

a. Is this well a part of a series? ☐ Yes go to part b of this section ☑ No go to part 7 of this application (Y/N **required**)

b. If one or more of the wells in the series is currently registered, give well registration number _____

c. How many wells in the series are you registering at this time? _____ d. How many total wells in the series? _____

6180802

7. Replacement and decommissioned/modified well information.

a. Is this well a replacement well? ☐ Yes ☑ No go to part 8 of this application

b. Registration number of original well _____ If not registered, date original well was constructed (m)___/(d___/(y)____

c. Original well last operated (m)___/(d)___/(y)____ d. Replacement well is _____ feet from original well.

e. Location of water use of original well _____

Please Select One:

f.1. ☐ Original water well decommissioned on (m)___/(d___/(y)___ **OR**

2. ☐ I hereby certify that the original water well will be decommissioned within 180 days after such construction of the replacement water well. **OR**

3. ☐ I hereby certify that the original water well will be modified and equipped to pump 50 gallons per minute or less within 180 days after such construction of the replacement water well. It will be used for one of the following: a. ☐ Livestock b. ☐ Monitoring c. ☐ Observation d. ☐ nonconsumptive or de minimus use approved by the applicable natural resources district. State use: _____

If 3d is chosen. NRD signature is required. (Signature can be submitted on NRD Approval form to DNR prior to registration)

NRD signature_____ Date _____ **OR**

4. ☐ Owners CERTIFICATION OF INTENT to Decommission or Modify the original well form is submitted by landowner. (Must be submitted before registering well)

8. Pump Information. (Pump information is required if registering a pit)

a. Is pump installed at this time ☐ Yes ☑ No

Is pump installed by well owner in section 1? ☐ Yes ☐ No

Is pump installed by contractor in section 2? ☐ Yes ☐ No

Is this a free flowing well ☐ Yes(no pump to be installed) ☐ No

If pump installed by pump installer, please fill out license number below

b. Pump Installer's License No._____ Pump Installer's Name_____

Pump Installer's Email Address_____

Pump Installer's Firm Name_____

Pump Installer's Firm Address_____

City _____ State _____ Zip_____ Telephone _____

Pump Installer's Firm Email Address_____

c. Measured Pumping rate _____ gallons per minute d. Pumping water level _____ feet

e. Drop pipe diameter _____ inches f. Length of drop pipe _____ feet

g. Pumping equipment installed (m)___/(d___/(y)___

h. Pump Brand_____

i. This well is designed and constructed to pump 50 gpm or less ☑ Yes ☐ No **(8I is required on ALL wells)**

9. Well Construction Information.

a. Total well depth 580 feet. b. Static water level 217 feet. **(required)**

c. Well Construction Began (m) 8 /(d) 15 /(y) 2016 d.. Well Construction Completed (m) 8 /(d) 19 /(y) 2016

Wells drilled prior to stays or moratoriums require NRD signature **NRD signature**_____ Date _____ (Signature can be submitted on NRD Approval form to DNR prior to registration)

e. Bore hole diameter in inches Top 8 Bottom 8

f. Casing and Screen Joints are Welded ☐ Glued ☐ Threaded ☑ Other Spline & Groove

g. Capacity of Well 0.1 gallons per minute (to be used to determine sustainability of aquifer)

h. Pumping water level at this capacity _____ feet

6180842

10. Well Construction (Casing & Screen)- c, d, e, & f measurements should be in inches to three decimal places (From not less than zero)

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							
0	479	Casing	4.320	4.950	0.297		PVC	Certa-Lok
479	480	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank
480	500	Screen	3.000	3.500	0.250	0.020	PVC	Johnson
500	510	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank
510	540	Screen	3.000	3.500	0.250	0.020	PVC	Johnson
540	550	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank

Additional information for Double cased or Nested wells:

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							
550	580	Screen	3.000	3.500	0.250	0.020	PVC	Johnson

11. Grout and Gravel Pack (must start at zero)

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout *See **Desc**
From	To				
0	479	Grout	Neat Cement		12.8 bbls of Cement Slurry
479	580	Gravel Pack	Natural Formation Gravel Pack	3.87 Cubic Yards	

Desc: Description of gravel pack i.e. engineered gravel pack, or gravel pit description (¼ down), or brand nam e (Best Sand), natural formation, drilling cuttings, soil backfill
Quantity #cubic yards, #tons, #sacks, - (for drilling cuttings and soil backfill estimate quantity) Calculation assistance available on web
Volume & Type: #gallons of a slurry, #barrels of a slurry, #sacks used in the slurry, #bags of non-slurry bentonite (chip-pellet –granular)
Additional information for Double cased or Nested wells:

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout *See **Desc**
From	To				

6180812

12. Geologic Materials Logged (must start at zero) - **Use only options provided below for Type, Hardness and Color**

From	To	Type	Hardness	Color	Other/Drilling Action
0	5	Top Soil	Unconsolidated	Brown	
5	20	Other - Quaternary Alluvium	Unconsolidated	Tan	
20	60	Sandstone	Dense/Stiff	Gray	
60	140	Siltstone	Dense/Stiff	Tan	
140	160				Lost Circulation
160	280	Siltstone	Dense/Stiff	Brown	
280	345	Clay	Dense/Stiff	Brown	
345	590	Sandy Clay	Dense/Stiff	Brown	
590	600	Clay	Dense/Stiff	Brown, Green	

Type		Hardness	Color	
Clay	Sand fine-med	Cemented	Black	Pepper
Clay Stone	Sand med-coarse	Consolidated	Blue	Red
Cobbles	Sand with grave	Dense/Stiff	Brown	Tan
Fine Sand	Sandstone	Hard	Gray	White
Gravel S	hale	Soft	Green	Yellow
Limestone Silt		Unconsolidated	Orange	
Loss Circulation	Siltstone	Very Hard		
Ochre (weathered shale)	Top Soil			
Sandy Clay	Other			
Sand with Clay/Silt				

(Additional sheets may be submitted)

13. I hereby certify that the information provided on this registration is true and accurate to the best of my knowledge.

Skip L. Clark 9/22/16

Water Well Contractor's Signature Date
(not required for pits)

Well Owner's Signature Date
(if Contractor is unknown or Deceased or for pits)
(Not required if signed by Contractor)

Please note this document contains four pages.

Sections 9F, 9G, 10, 11 & 12 are not required if registering a pit.

Owner Registering well drilled prior to 2002: Minimum Required Sections - 1, 3(a,b,c,e,f), 5, 6, 7, 8(a,g,i), 9d

Sept 2015
DNR Form 667

Submit to:
Department of Natural Resources
301 Centennial Mall South
P.O. Box 94676
Lincoln, Nebraska 68509-4676
Phone (402) 471 2363

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION MODIFICATION
OWNER USE ONLY

FOR DEPARTMENT USE ONLY

Date Filed 4/25/17 Owner Code No. 49185 Registration No. G-180863

04252017 - 245409 -MOD F (2) UPPER NIOBRARA-WHITE NRD
WELL ID

ALL ITEMS IN SECTION 1 AND SIGNATURE IN SECTION 3 ARE REQUIRED

SECTION 1: ☐ **Check here if:** This form is also to be used to change the ownership of this well.

THIS COPY IS FOR YOUR RECORDS

A. Well Owner's First Name _____ Last Name _____
OR Company Name Crow Butte Resources
Attention Name Bob Tiensvold
Address 86 Crow Butte Road
City Crawford State NE Zip 69339 Telephone (308) 665-2215
Email _____

B. Well Registration No. G-180863 DBOLD & (Only one number per form)

C. State Reason for Change: Static water level

CORRECTIONS NEEDED Complete only those items being modified.

SECTION 2:

A. If location of well needs to be corrected, fully complete the Legal description of the well including GPS Coordinates (latitude and longitude). Footage may be provided. **(1 & 2 REQUIRED)**

1. Well location: _____ ¼ of the _____ ¼ of Section _____, Township _____ North, Range ___ East/West, _____ County.
2. Latitude Degree: _____ Minute: _____ Second: ___.___ Longitude Degree: _____ Minute: _____ Second: ___.___ (NAD 83)
3. The well is _____ feet from the (North or South) section line and _____ feet from the (East/West) section line.
(circle one) (circle one)

B. Location of water use (give complete legal description) _____

For Irrigation Wells: Number of acres irrigated: _____

If the location of use is different than what is currently registered, and/or the number of acres irrigated is more than what is currently registered, and you are located in an area that has stays or a moratorium on newly irrigated acres, you **MUST** obtain the written approval of the Natural Resources District **PRIOR TO FILING THIS FORM.** This approval can be the submission of a separate Natural Resources District Approval form by the NRD.

_____ _____ _____
(Natural Resources District) (Signature of NRD Staff) (Date)

C. Pump information.

1. Pumping rate: _____ gallons per minute.
2. Drop Pipe diameter: _____ Inches. 3. Length of drop pipe: _____ feet.
4. Pumping equipment installed: (m)____/(d)____/(y)_____. 5. Brand/Type: _____
6. Static Water Level: _____ feet.
7. Pumping water level: _____ feet.
8. Amount of time pumped: _____

RECEIVED
APR 25 2017
DEPARTMENT OF NATURAL RESOURCES

D. Change of use, complete items 1, 2 and 3. Identify use from this Listing: Dewatering (over 90 days), Domestic, Ground Heat Exchanger, Ground Water Source Heat Pump, Industrial, Injection, Irrigation, Livestock, Monitoring, Observation, Public Water Supply (with spacing (46-638), Public Water Supply (without spacing), Recovery, Other(if well use falls in this category – add specific use).

1. Well was used for: _____ (if necessary, please provide updated pump information)
2. New well use is: _____
3. Date of Change: _____

E. Active to Inactive (please check A or B) with or without pump

On _____, 20___, the water well is ____a) altered from active to inactive by removing the _____inch pump and pumping column and properly capping the water well according to state standards or ____b) no longer in use but pump still in place with a water tight seal according to state standards. (§46-1207.02)

F. I certify that the well has been modified according to information given in section 2 C, E, or J, such that it will pump 50 gallons per minute or less. Pumping Rate: _____

Change to use (Check one of the following): ☐ Livestock ☐ Monitoring ☐ Observation

☐ nonconsumptive or de minimus use approved by the applicable natural resources district. State use: _____

G. Wells in a Series.

1. Is this well a part of a series? _____ Yes.
2. How many total wells in the series? _____
3. If one or more of the wells in the series is currently registered, give all well registration numbers: _____

H. Well Construction Information.

1. Total well depth: _____ feet.
2. Static water level: 72 _____ feet.
3. Pumping water level: _____ feet
4. Well Construction began: (m)_____/(d)_____/(y)_____
5. Well Construction completed: (m)_____/(d)_____/(y)_____
6. Bore hole diameter in inches: Top____ Bottom _____
7. Casing and Screen Joints are: Welded_____, Glued_____, Threaded_____, Other_____
8. Total Estimate Capacity of Well _____ gallons per minute (to be used to determine sustainability of aquifer)

I. Replacement and decommissioned/modified well information.

Department of Natural Resources Decommission/Modification Certification form or Notice of Decommissioning form is Required for replacement wells

1. Is this well a replacement well? ____Yes ____No
2. Registration number of original well: _____ If original well is not registered, date well construction completed (m)____/(d____/(y)____
3. Original well last operated (m)____/(d)_____/(y)_____
4. Completion of original well decommission/modification on (m)____/(d_____/(y)_____
5. Complete location of water use of original well: _____

J. Well Construction Modification.

1. Total well depth: _____ feet.
2. Static water level: _____ feet.
3. Pumping water level: _____ feet
4. Well Modification began: (m)_____/(d)_____/(y)____
5. Well Modification completed: (m)_____/(d)_____/(y)____
6. Casing diameter in inches: Top____ Bottom _____
7. Casing and Screen Joints are: Welded____, Glued_____, Threaded_____, Other_____
8. Total Estimate Capacity of Well _____ gallons per minute (to be used to determine sustainability of aquifer)

SECTION 3:

I hereby certify that the information provided on this form is true and accurate to the best of my knowledge.

Bob Dr — Water Well Owner's Signature

4/20/2017 — Date

The Department reserves the right to request verification of information provided.

Mail to
Department of Natural Resources
PO Box 94676
Lincoln, NE 68509-4676
Phone (402)471-2363

January 2011
DNR WWR

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION

Please indicate NA for items unknown

FOR DEPARTMENT USE ONLY

Date Filed 10/24/16 Owner Code No. 49185 Registration No. 6180863

10242016 - 245409 -WWR A(S) Receipt R27310 UNW NRD

Well ID

1. a. Well Owner's First Name _____ Last Name _____

OR Company Name Crow Butte Resources

b. Attention Name _____

c. Street Address 86 Crow Butte Road

Address 2/PO Address PO Box 169

City Crawford State NE Zip 69339 Telephone (308) 665-2215

2. a. Contractor's License No 39561 Contractor's Name Skip L. Chubb

Contractor's Email Address NA

b. Drilling Firm Name Single Water Services, LLC

Address PO Box 1625

City Glenrock State WY Zip 82637 Telephone (307) 267-4415

Drilling Firm's Email Address NA

3. a. Well location NE ¼ of the NE ¼ of Section 35, Township 30 North, Range 51 E ☐ W ☑, Dawes County

Latitude Degree 42 Minute 32 Second 19.782

Longitude Degree 103 Minute 15 Second 50.832

GPS Required

Location of well for a pit is the location of the pump

b. Natural Resources District Upper Niobrara / White River NRD

c. The well is: 120 feet from the (N ☑ S ☐) section line and 105 feet from the (E ☑ W ☐) section line

d. Street address and subdivision, if applicable _____

e. Location of water use (give legal descriptions) _____

f. If for irrigation, the land to be irrigated is _____ acres.

Location of water use is required on all wells

g. Well reference letter(s), if applicable DBOW 8 HHSS PWSID _____

4. Permits

Management Area Permit Number _____
Geothermal Permit Number _____
Municipal Permit Number _____
Well Spacing Permit Number _____
HHSS _____

Surface Water Permit Number _____
Industrial Permit Number _____
Transfer Out-Of-State Permit Number _____
Conduct Permit Number _____
Other Permit Number _____
NDEQ _____

5. Purpose of well (indicate one)

☐ Aquaculture ☐ Commercial/Industrial ☐ Dewatering (over 90 days)
☐ Domestic ☐ Ground Heat Exchanger ☐ Groundwater Source Heat Pump ☐ Irrigation ☐ Injection
☐ Livestock ☑ Monitoring ☐ Observation ☐ Pit (for irrigation) ☐ Public Water Supply (with spacing (46-638))
☐ Public Water Supply (without spacing) ☐ Recovery ☐ Other _____
(further description of use can be provided under other) (indicate use)

6. Wells in a Series.

a. Is this well a part of a series? ☐ Yes go to part b of this section ☑ No go to part 7 of this application (Y/N required)

b. If one or more of the wells in the series is currently registered, give well registration number _____

c. How many wells in the series are you registering at this time? _____ d. How many total wells in the series? _____

6180863

7. Replacement and decommissioned/modified well information.

a. Is this well a replacement well? ☐ Yes ☑ No go to part 8 of this application

b. Registration number of original well _____ If not registered, date original well was constructed (m)___/(d___/(y)____

c. Original well last operated (m)___/(d)___/(y)____ d. Replacement well is _____ feet from original well.

e. Location of water use of original well _____

Please Select One:

f.1. ☐ Original water well decommissioned on (m)___/(d___/(y)___ **OR**

2. ☐ I hereby certify that the original water well will be decommissioned within 180 days after such construction of the replacement water well. **OR**

3. ☐ I hereby certify that the original water well will be modified and equipped to pump 50 gallons per minute or less within 180 days after such construction of the replacement water well. It will be used for one of the following: a. ☐ Livestock b. ☐ Monitoring c. ☐ Observation d. ☐ nonconsumptive or de minimus use approved by the applicable natural resources district. State use: _____

If 3d is chosen. NRD signature is required. (Signature can be submitted on NRD Approval form to DNR prior to registration)

NRD signature_____ Date _____ **OR**

4. ☐ Owners CERTIFICATION OF INTENT to Decommission or Modify the original well form is submitted by landowner. (Must be submitted before registering well)

8. Pump Information. (Pump information is required if registering a pit)

a. Is pump installed at this time ☐ Yes ☑ No

Is pump installed by well owner in section 1? ☐ Yes ☐ No

Is pump installed by contractor in section 2? ☐ Yes ☐ No

Is this a free flowing well ☐ Yes(no pump to be installed) ☐ No

If pump installed by pump installer, please fill out license number below

b. Pump Installer's License No._____ Pump Installer's Name_____

Pump Installer's Email Address_____

Pump Installer's Firm Name_____

Pump Installer's Firm Address_____

City _____ State _____ Zip_____ Telephone _____

Pump Installer's Firm Email Address_____

c. Measured Pumping rate _____ gallons per minute d. Pumping water level _____ feet

e. Drop pipe diameter _____ inches f. Length of drop pipe _____ feet

g. Pumping equipment installed (m)___/(d___/(y)___

h. Pump Brand_____

i. This well is designed and constructed to pump 50 gpm or less ☑ Yes ☐ No **(8I is required on ALL wells)**

9. Well Construction Information.

a. Total well depth 601 feet. b. Static water level 161 feet. **(required)**

c. Well Construction Began (m) 8 /(d) 16 /(y) 2016 d.. Well Construction Completed (m) 8 /(d) 31 /(y) 2016

Wells drilled prior to stays or moratoriums require NRD signature **NRD signature**_____ Date _____ (Signature can be submitted on NRD Approval form to DNR prior to registration)

e. Bore hole diameter in inches Top 8 Bottom 8

f. Casing and Screen Joints are Welded ☐ Glued ☐ Threaded ☑ Other Spline & Groove

g. Capacity of Well 0.1 gallons per minute (to be used to determine sustainability of aquifer)

h. Pumping water level at this capacity _____ feet

6180263

10. Well Construction (Casing & Screen)- c, d, e, & f measurements should be in inches to three decimal places (From not less than zero)

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							
0	509	Casing	4.320	4.950	0.297		PVC	Certa-Lok
509	511	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank
511	531	Screen	3.000	3.500	0.250	0.020	PVC	Johnson
531	541	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank
541	561	Screen	3.000	3.500	0.250	0.020	PVC	Johnson
561	581	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank

Additional information for Double cased or Nested wells:

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							
581	601	Screen	3.000	3.500	0.250	0.020	PVC	Johnson

11. Grout and Gravel Pack (must start at zero)

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout *See **Desc**
From	To				
0	509	Grout	Neat Cement		19.5 bbls of Cement Slurry
509	601	Gravel Pack	Natural Formation Gravel Pack	2.45 Cubic Yards	

Desc: Description of gravel pack i.e. engineered gravel pack, or gravel pit description (¼ down), or brand nam e (Best Sand), natural formation, drilling cuttings, soil backfill

Quantity #cubic yards, #tons, #sacks, - (for drilling cuttings and soil backfill estimate quantity) Calculation assistance available on web

Volume & Type: #gallons of a slurry, #barrels of a slurry, #sacks used in the slurry, #bags of non-slurry bentonite (chip-pellet –granular)

Additional information for Double cased or Nested wells:

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout *See **Desc**
From	To				

A180863

12. Geologic Materials Logged (must start at zero) - **Use only options provided below for Type, Hardness and Color**

From	To	Type	Hardness	Color	Other/Drilling Action
0	5	Top Soil	Unconsolidated	Brown	
5	20	Other - Quaternary Alluvium	Unconsolidated	Tan	
20	65	Sandstone	Dense/Stiff	Brown	
65	80	Siltstone	Dense/Stiff	Gray	
80	320	Siltsone	Dense/Stiff	Brown	
320	600	Siltstone	Dense/Stiff	Brown	
600	670	Clay	Dense/Stiff	Brown	
670	680	Clay	Dense/Stiff	Brown, Green	

Type		Hardness	Color	
Clay	Sand fine-med	Cemented	Black	Pepper
Clay Stone	Sand med-coarse	Consolidated	Blue	Red
Cobbles	Sand with grave	Dense/Stiff	Brown	Tan
Fine Sand	Sandstone	Hard	Gray	White
Gravel S	hale	Soft	Green	Yellow
Limestone Silt		Unconsolidated	Orange	
Loss Circulation	Siltstone	Very Hard		
Ochre (weathered shale)	Top Soil			
Sandy Clay	Other			
Sand with Clay/Silt				

(Additional sheets may be submitted)

13. I hereby certify that the information provided on this registration is true and accurate to the best of my knowledge.

Shiyo L. Chubb 9/22/16

Water Well Contractor's Signature Date
(not required for pits)

Well Owner's Signature Date
(if Contractor is unknown or Deceased or for pits)
(Not required if signed by Contractor)

Please note this document contains four pages.

Sections 9F, 9G, 10, 11 & 12 are not required if registering a pit.

Owner Registering well drilled prior to 2002: Minimum Required Sections - 1, 3(a,b,c,e,f), 5, 6, 7, 8(a,g,i), 9d

Sept 2015
DNR Form 667

Submit to:
Department of Natural Resources
301 Centennial Mall South
P.O. Box 94676
Lincoln, Nebraska 68509-4676
Phone (402) 471 2363

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION MODIFICATION
OWNER USE ONLY

FOR DEPARTMENT USE ONLY

Date Filed 4/25/17 Owner Code No. 49185 Registration No. G-180864

04252017 - 245410 -MOD F (2) UPPER NIOBRARA-WHITE NRD
WELL ID

ALL ITEMS IN SECTION 1 AND SIGNATURE IN SECTION 3 ARE REQUIRED

SECTION 1: ☐ **Check here if:** This form is also to be used to change the ownership of this well.

A. Well Owner's First Name _____ Last Name _____ THIS COPY IS

OR Company Name Crow Butte Resources FOR YOUR RECORDS

Attention Name Bob Tiensvold

Address 86 Crow Butte Road

City Crawford State NE Zip 69339 Telephone (308) 665-2215

Email _____

B. Well Registration No. G-180864 DBOW 9 (Only one number per form)

C. State Reason for Change: Static water level

CORRECTIONS NEEDED **Complete only those items being modified**

SECTION 2:

A. If location of well needs to be corrected, fully complete the Legal description of the well including GPS Coordinates (latitude and longitude). Footage may be provided. **(1 & 2 REQUIRED)**

1. Well location: _____ ¼ of the _____ ¼ of Section _____, Township _____ North, Range ___ East/West, _____ County.
2. Latitude Degree:_____ Minute:_____ Second:___.___ Longitude Degree:_____ Minute:_____ Second:___.___ (NAD 83)
3. The well is _____ feet from the (North or South) section line and _____ feet from the (East/West) section line.
(circle one) (circle one)

B. Location of water use (give complete legal description)_____

For Irrigation Wells: Number of acres irrigated:_____

If the location of use is different than what is currently registered, and/or the number of acres irrigated is more than what is currently registered, and you are located in an area that has stays or a moratorium on newly irrigated acres, you **MUST** obtain the written approval of the Natural Resources District **PRIOR TO FILING THIS FORM**. This approval can be the submission of a separate Natural Resources District Approval form by the NRD.

_____ _____ _____
(Natural Resources District) (Signature of NRD Staff) (Date)

C. Pump information.

1. Pumping rate:_____ gallons per minute.
2. Drop Pipe diameter:_____ Inches. 3. Length of drop pipe:_____ feet.
4. Pumping equipment installed: (m)____/(d)____/(y)____. 5. Brand/Type:_____
6. Static Water Level:_____ feet.
7. Pumping water level:_____ feet.
8. Amount of time pumped:_____

RECEIVED
APR 25 2017
DEPARTMENT OF
NATURAL RESOURCES

D. Change of use, complete items 1, 2 and 3. Identify use from this Listing: Dewatering (over 90 days), Domestic, Ground Heat Exchanger, Ground Water Source Heat Pump, Industrial, Injection, Irrigation, Livestock, Monitoring, Observation, Public Water Supply (with spacing (46-638), Public Water Supply (without spacing), Recovery, Other(if well use falls in this category – add specific use).

1. Well was used for:
(if necessary, please provide updated pump information)
2. New well use is:_____
3. Date of Change:_____

E. Active to Inactive (please check A or B) with or without pump

On _____, 20___, the water well is ____a) altered from active to inactive by removing the _____inch pump and pumping column and properly capping the water well according to state standards or ____b) no longer in use but pump still in place with a water tight seal according to state standards. (§46-1207.02)

F. I certify that the well has been modified according to information given in section 2 C, E, or J, such that it will pump 50 gallons per minute or less. Pumping Rate:_____

Change to use (Check one of the following): ☐ Livestock ☐ Monitoring ☐ Observation

☐ nonconsumptive or de minimus use approved by the applicable natural resources district. State use:_____

G. Wells in a Series.

1. Is this well a part of a series?_____ Yes.
2. How many total wells in the series?_____
3. If one or more of the wells in the series is currently registered, give all well registration numbers:_____

H. Well Construction Information.

1. Total well depth: _____ feet.
2. Static water level: 71 feet.
3. Pumping water level: _____ feet
4. Well Construction began: (m)____/(d)____/(y)____
5. Well Construction completed: (m)____/(d)____/(y)____
6. Bore hole diameter in inches: Top____ Bottom ____
7. Casing and Screen Joints are: Welded_____, Glued_____, Threaded_____, Other_____
8. Total Estimate Capacity of Well _____ gallons per minute (to be used to determine sustainability of aquifer)

I. Replacement and decommissioned/modified well information.

Department of Natural Resources Decommission/Modification Certification form or Notice of Decommissioning form is Required for replacement wells

1. Is this well a replacement well? ____Yes ____No
2. Registration number of original well:_____ If original well is not registered, date well construction completed (m)___/(d___/(y)___
3. Original well last operated (m)___/(d)____/(y)____
4. Completion of original well decommission/modification on (m)___/(d____/(y)____
5. Complete location of water use of original well: _____

J. Well Construction Modification.

1. Total well depth: _____ feet.
2. Static water level: _____ feet.
3. Pumping water level: _____ feet
4. Well Modification began: (m)____/(d)____/(y)____
5. Well Modification completed: (m)____/(d)____/(y)____
6. Casing diameter in inches: Top____ Bottom ____
7. Casing and Screen Joints are: Welded____, Glued_____, Threaded_____, Other_____
8. Total Estimate Capacity of Well _____ gallons per minute (to be used to determine sustainability of aquifer)

SECTION 3:

I hereby certify that the information provided on this form is true and accurate to the best of my knowledge.

Bob Dr
Water Well Owner's Signature

4/20/2017
Date

The Department reserves the right to request verification of information provided.

Mail to:
Department of Natural Resources
PO Box 94676
Lincoln, NE 68509-4676
Phone (402)471-2363

January 2011
DNR WWR

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION

Please indicate NA for items unknown

FOR DEPARTMENT USE ONLY

Date Filed 10/24/16 Owner Code No. 49185 Registration No. 6180864

10242016 - 245410 -WWR(S) Receipt RZ7310 UNW NRD

Well ID

1. a. Well Owner's First Name _____ Last Name _____

OR Company Name Crow Butte Resources THIS COPY IS

b. Attention Name _____ FOR YOUR RECORDS

c. Street Address 86 Crow Butte Road

Address 2/PO Address PO Box 169

City Crawford State NE Zip 69339 Telephone (308) 665-2215

2. a. Contractor's License No 39561 Contractor's Name Skip L. Chubb

Contractor's Email Address NA

b. Drilling Firm Name Single Water Services, LLC

Address PO Box 1625

City Glenrock State WY Zip 82637 Telephone (307) 267-4415

Drilling Firm's Email Address NA

3. a. Well location NW ¼ of the SE ¼ of Section 18, Township 29 North, Range 50 E ☐ W ☑, Dawes County

Latitude Degree 42 Minute 29 Second 07.497

Longitude Degree 103 Minute 14 Second 01.308

GPS Required

Location of well for a pit is the location of the pump

b. Natural Resources District Upper Niobrara / White River NRD

c. The well is: 1610 feet from the (N ☐ S ☑) section line and 2370 feet from the (E ☑ W ☐) section line

d. Street address and subdivision, if applicable _____

e. Location of water use (give legal descriptions) _____

f. If for irrigation, the land to be irrigated is _____ acres.

Location of water use is required on all wells

g. Well reference letter(s), if applicable DBOW 9 HHSS PWSID _____

4. Permits

Management Area Permit Number _____
Geothermal Permit Number _____
Municipal Permit Number _____
Well Spacing Permit Number _____
HHSS _____

Surface Water Permit Number _____
Industrial Permit Number _____
Transfer Out-Of-State Permit Number _____
Conduct Permit Number _____
Other Permit Number _____
NDEQ _____

5. Purpose of well (indicate one)

☐ Aquaculture ☐ Commercial/Industrial ☐ Dewatering (over 90 days)
☐ Domestic ☐ Ground Heat Exchanger ☐ Groundwater Source Heat Pump ☐ Irrigation ☐ Injection
☐ Livestock ☑ Monitoring ☐ Observation ☐ Pit (for irrigation) ☐ Public Water Supply (with spacing (46-638))
☐ Public Water Supply (without spacing) ☐ Recovery ☐ Other _____
(further description of use can be provided under other) (indicate use)

6. Wells in a Series.

a. Is this well a part of a series? ☐ Yes go to part b of this section ☑ No go to part 7 of this application (Y/N **required**)

b. If one or more of the wells in the series is currently registered, give well registration number _____

c. How many wells in the series are you registering at this time? _____ d. How many total wells in the series? _____

6180864

7. Replacement and decommissioned/modified well information.
   a. Is this well a replacement well? ☐ Yes ☑ No go to part 8 of this application
   b. Registration number of original well _____ If not registered, date original well was constructed (m)___/(d___/(y)____
   c. Original well last operated (m)___/(d)___/(y)____ d. Replacement well is _____ feet from original well.
   e. Location of water use of original well _____

   Please Select One:

   f.1. ☐ Original water well decommissioned on (m)___/(d___/(y)___ **OR**

   2. ☐ I hereby certify that the original water well will be decommissioned within 180 days after such construction of the replacement water well. **OR**

   3. ☐ I hereby certify that the original water well will be modified and equipped to pump 50 gallons per minute or less within 180 days after such construction of the replacement water well. It will be used for one of the following: a. ☐ Livestock b. ☐ Monitoring c. ☐ Observation d. ☐ nonconsumptive or de minimus use approved by the applicable natural resources district. State use: _____

      If 3d is chosen. NRD signature is required. (Signature can be submitted on NRD Approval form to DNR prior to registration)

      NRD signature_____ Date _____ **OR**

   4. ☐ Owners CERTIFICATION OF INTENT to Decommission or Modify the original well form is submitted by landowner. (Must be submitted before registering well)

8. Pump Information. (Pump information is required if registering a pit)
   a. Is pump installed at this time ☐ Yes ☑ No

      Is pump installed by well owner in section 1? ☐ Yes ☐ No

      Is pump installed by contractor in section 2? ☐ Yes ☐ No

      Is this a free flowing well ☐ Yes(no pump to be installed) ☐ No

   If pump installed by pump installer, please fill out license number below

   b. Pump Installer's License No._____ Pump Installer's Name_____

      Pump Installer's Email Address_____

      Pump Installer's Firm Name_____

      Pump Installer's Firm Address_____

      City _____ State _____ Zip_____ Telephone _____

      Pump Installer's Firm Email Address_____

   c. Measured Pumping rate _____ gallons per minute d. Pumping water level _____ feet

   e. Drop pipe diameter _____ inches f. Length of drop pipe _____ feet

   g. Pumping equipment installed (m)___/(d___/(y)___

   h. Pump Brand_____

   i. This well is designed and constructed to pump 50 gpm or less ☑ Yes ☐ No **(8I is required on ALL wells)**

9. Well Construction Information.
   a. Total well depth 480 feet. b. Static water level 94 feet. **(required)**

   c. Well Construction Began (m) 9 /(d) 6 /(y) 2016 d.. Well Construction Completed (m) 9 /(d) 13 /(y) 2016

   Wells drilled prior to stays or moratoriums require NRD signature **NRD signature**_____ Date _____ (Signature can be submitted on NRD Approval form to DNR prior to registration)

   e. Bore hole diameter in inches Top 8 Bottom 8

   f. Casing and Screen Joints are Welded ☐ Glued ☐ Threaded ☑ Other Spline & Groove

   g. Capacity of Well 0.1 gallons per minute (to be used to determine sustainability of aquifer)

   h. Pumping water level at this capacity _____ feet

0100804

10. Well Construction (Casing & Screen)- c, d, e, & f measurements should be in inches to three decimal places (From not less than zero)

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							
0	379	Casing	4.320	4.950	0.297		PVC	Certa-Lok
379	385	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank
385	405	Screen	3.000	3.500	0.250	0.020	PVC	Johnson
405	455	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank
455	480	Screen	3.000	3.500	0.250	0.020	PVC	Johnson

Additional information for Double cased or Nested wells:

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							

11. Grout and Gravel Pack (must start at zero)

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout *See **Desc**
From	To				
0	379	Grout	Neat Cement		14.5 bbls of Cement Slurry
379	480	Gravel Pack	Natural Formation Gravel Pack	3.87 Cubic Yards	

Desc: Description of gravel pack i.e. engineered gravel pack, or gravel pit description (¼ down), or brand nam e (Best Sand), natural formation, drilling cuttings, soil backfill
Quantity #cubic yards, #tons, #sacks, - (for drilling cuttings and soil backfill estimate quantity) Calculation assistance available on web
Volume & Type: #gallons of a slurry, #barrels of a slurry, #sacks used in the slurry, #bags of non-slurry bentonite (chip-pellet –granular)
Additional information for Double cased or Nested wells:

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout *See **Desc**
From	To				

6180864

12. Geologic Materials Logged (must start at zero) - **Use only options provided below for Type, Hardness and Color**

From	To	Type	Hardness	Color	Other/Drilling Action
0	10	Top Soil	Unconsolidated	Brown	
10	35	Other - Quaternary Alluvium	Unconsolidated	Tan	
35	85	Sandstone	Unconsolidated	Brown	
85	95	Clay	Dense/Stiff	Brown	
95	120	Gravel	Unconsolidated	Brown	
120	235	Sandstone	Dense/Stiff	Brown	
235	510	Siltsone	Dense/Stiff	Brown	
510	520	Siltstone	Dense/Stiff	Brown, Green	

Type		Hardness	Color	
Clay	Sand fine-med	Cemented	Black	Pepper
Clay Stone	Sand med-coarse	Consolidated	Blue	Red
Cobbles	Sand with grave	Dense/Stiff	Brown	Tan
Fine Sand	Sandstone	Hard	Gray	White
Gravel S	hale	Soft	Green	Yellow
Limestone Silt		Unconsolidated	Orange	
Loss Circulation	Siltstone	Very Hard		
Ochre (weathered shale)	Top Soil			
Sandy Clay	Other			
Sand with Clay/Silt				

(Additional sheets may be submitted)

13. I hereby certify that the information provided on this registration is true and accurate to the best of my knowledge.

Skip L. Chubb 9/22/16
Water Well Contractor's Signature Date
(not required for pits)

Well Owner's Signature Date
(if Contractor is unknown or Deceased or for pits)
(Not required if signed by Contractor)

Please note this document contains four pages.

Sections 9F, 9G, 10, 11 & 12 are not required if registering a pit.

Owner Registering well drilled prior to 2002: Minimum Required Sections - 1, 3(a,b,c,e,f), 5, 6, 7, 8(a,g,i), 9d

Sept 2015
DNR Form 667

Submit to:
Department of Natural Resources
301 Centennial Mall South
P.O. Box 94676
Lincoln, Nebraska 68509-4676
Phone (402) 471 2363

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION MODIFICATION
OWNER USE ONLY

FOR DEPARTMENT USE ONLY

Date Filed 4/25/17 Owner Code No. 49185 Registration No. G-180865

04252017 - 245411 -MOD F (2) UPPER NIOBRARA-WHITE NRD
WELL ID

ALL ITEMS IN SECTION 1 AND SIGNATURE IN SECTION 3 ARE REQUIRED

SECTION 1: ☐ **Check here if:** This form is also to be used to change the ownership of this well.

A. Well Owner's First Name _____ Last Name _____
OR Company Name Crow Butte Resources
Attention Name Bob Tiensvold
Address 86 Crow Butte Road
City Crawford State NE Zip 69339 Telephone (308) 665-2215
Email _____

THIS COPY IS FOR YOUR RECORDS

B. Well Registration No. G-180865 DBOU ID (Only one number per form)

C. State Reason for Change: Static water level

CORRECTIONS NEEDED Complete only those items being modified

SECTION 2:

A. If location of well needs to be corrected, fully complete the Legal description of the well including GPS Coordinates (latitude and longitude). Footage may be provided. **(1 & 2 REQUIRED)**

1. Well location: _____ ¼ of the _____ ¼ of Section _____, Township _____ North, Range ___ East/West, _____ County.
2. Latitude Degree:_____ Minute:_____ Second:___.___ Longitude Degree:_____ Minute:_____ Second:___.___ (NAD 83)
3. The well is _____ feet from the (North or South) section line and _____ feet from the (East/West) section line.
(circle one) (circle one)

B. Location of water use (give complete legal description)_____

For Irrigation Wells: Number of acres irrigated:_____

If the location of use is different than what is currently registered, and/or the number of acres irrigated is more than what is currently registered, and you are located in an area that has stays or a moratorium on newly irrigated acres, you **MUST** obtain the written approval of the Natural Resources District **PRIOR TO FILING THIS FORM.** This approval can be the submission of a separate Natural Resources District Approval form by the NRD.

_____ _____ _____
(Natural Resources District) (Signature of NRD Staff) (Date)

C. Pump information.

1. Pumping rate:_____ gallons per minute.
2. Drop Pipe diameter:_____ Inches. 3. Length of drop pipe:_____ feet.
4. Pumping equipment installed: (m)____/(d)____/(y)____. 5. Brand/Type:_____
6. Static Water Level:_____ feet.
7. Pumping water level:_____ feet.
8. Amount of time pumped:_____

RECEIVED
APR 25 2017
DEPARTMENT OF NATURAL RESOURCES

D. Change of use, complete items 1, 2 and 3. Identify use from this Listing: Dewatering (over 90 days), Domestic, Ground Heat Exchanger, Ground Water Source Heat Pump, Industrial, Injection, Irrigation, Livestock, Monitoring, Observation, Public Water Supply (with spacing (46-638), Public Water Supply (without spacing), Recovery, Other(if well use falls in this category – add specific use).

1. Well was used for:_____ (if necessary, please provide updated pump information)
2. New well use is:_____
3. Date of Change:_____

E. Active to Inactive (please check A or B) with or without pump

On _____, 20___, the water well is ____a) altered from active to inactive by removing the _____inch pump and pumping column and properly capping the water well according to state standards or ____b) no longer in use but pump still in place with a water tight seal according to state standards. (§46-1207.02)

F. I certify that the well has been modified according to information given in section 2 C, E, or J, such that it will pump 50 gallons per minute or less. Pumping Rate:_____

Change to use (Check one of the following): ☐ Livestock ☐ Monitoring ☐ Observation

☐ nonconsumptive or de minimus use approved by the applicable natural resources district. State use:_____

G. Wells in a Series.

1. Is this well a part of a series?_____ Yes.
2. How many total wells in the series?_____
3. If one or more of the wells in the series is currently registered, give all well registration numbers:_____

_____

H. Well Construction Information.

1. Total well depth: _____ feet.
2. Static water level: 120 feet.
3. Pumping water level: _____ feet
4. Well Construction began: (m)____/(d)____/(y)_____
5. Well Construction completed: (m)____/(d)____/(y)_____
6. Bore hole diameter in inches: Top____ Bottom _____
7. Casing and Screen Joints are: Welded_____, Glued_____, Threaded_____, Other_____
8. Total Estimate Capacity of Well _____ gallons per minute (to be used to determine sustainability of aquifer)

I. Replacement and decommissioned/modified well information.

Department of Natural Resources Decommission/Modification Certification form or Notice of Decommissioning form is Required for replacement wells

1. Is this well a replacement well? ____Yes ____No
2. Registration number of original well:_____ If original well is not registered, date well construction completed (m)____/(d____/(y)____
3. Original well last operated (m)____/(d)_____/(y)_____
4. Completion of original well decommission/modification on (m)____/(d____/(y)____
5. Complete location of water use of original well: _____

J. Well Construction Modification.

1. Total well depth:_____ feet.
2. Static water level: _____ feet.
3. Pumping water level: _____ feet
4. Well Modification began: (m)____/(d)____/(y)____
5. Well Modification completed: (m)____/(d)____/(y)____
6. Casing diameter in inches: Top____ Bottom _____
7. Casing and Screen Joints are: Welded____, Glued_____, Threaded_____, Other_____
8. Total Estimate Capacity of Well _____ gallons per minute (to be used to determine sustainability of aquifer)

SECTION 3:

I hereby certify that the information provided on this form is true and accurate to the best of my knowledge.

Bob Dr — Water Well Owner's Signature

4/20/2017 — Date

The Department reserves the right to request verification of information provided.

Mail to
Department of Natural Resources
PO Box 94676
Lincoln, NE 68509-4676
Phone (402)471-2363

January 2011
DNR WWR

STATE OF NEBRASKA
DEPARTMENT OF NATURAL RESOURCES
WATER WELL REGISTRATION

Please indicate NA for items unknown

FOR DEPARTMENT USE ONLY

Date Filed 10/24/16 Owner Code No. 49185 Registration No. 6180805

10242016 - 245411 -WWR(S) Receipt 1227310 UNW NRD

Well ID

1. a. Well Owner's First Name _____ Last Name _____

OR Company Name Crow Butte Resources

b. Attention Name _____

c. Street Address 86 Crow Butte Road

Address 2/PO Address PO Box 169

City Crawford State NE Zip 69339 Telephone (308) 665-2215

2. a. Contractor's License No 39561 Contractor's Name Skip L. Chubb

Contractor's Email Address NA

b. Drilling Firm Name Single Water Services, LLC

Address PO Box 1625

City Glenrock State WY Zip 82637 Telephone (307) 267-4415

Drilling Firm's Email Address NA

3. a. Well location SW ¼ of the SW ¼ of Section 7, Township 29 North, Range 50 E ☐ W ☑, Dawes County

Latitude Degree 42 Minute 29 Second 49.933

Longitude Degree 103 Minute 14 Second 21.676

GPS Required

Location of well for a pit is the location of the pump

b. Natural Resources District Upper Niobrara / White River NRD

c. The well is: 545 feet from the (N ☐ S ☑) section line and 1040 feet from the (E ☐ W ☑) section line

d. Street address and subdivision, if applicable _____

e. Location of water use (give legal descriptions) _____

f. If for irrigation, the land to be irrigated is _____ acres.

Location of water use is required on all wells

g. Well reference letter(s), if applicable DBOW 10 HHSS PWSID _____

4. Permits

Management Area Permit Number _____
Geothermal Permit Number _____
Municipal Permit Number _____
Well Spacing Permit Number _____
HHSS _____

Surface Water Permit Number _____
Industrial Permit Number _____
Transfer Out-Of-State Permit Number _____
Conduct Permit Number _____
Other Permit Number _____
NDEQ _____

5. Purpose of well (indicate one)

☐ Aquaculture ☐ Commercial/Industrial ☐ Dewatering (over 90 days)
☐ Domestic ☐ Ground Heat Exchanger ☐ Groundwater Source Heat Pump ☐ Irrigation ☐ Injection
☐ Livestock ☑ Monitoring ☐ Observation ☐ Pit (for irrigation) ☐ Public Water Supply (with spacing (46-638))
☐ Public Water Supply (without spacing) ☐ Recovery ☐ Other _____
(further description of use can be provided under other) (indicate use)

6. Wells in a Series.

a. Is this well a part of a series? ☐ Yes go to part b of this section ☑ No go to part 7 of this application (Y/N **required**)

b. If one or more of the wells in the series is currently registered, give well registration number _____

c. How many wells in the series are you registering at this time? _____ d. How many total wells in the series? _____

6180865

7. Replacement and decommissioned/modified well information.
   a. Is this well a replacement well? ☐ Yes ☑ No go to part 8 of this application
   b. Registration number of original well _____ If not registered, date original well was constructed (m)___/(d___/(y)____
   c. Original well last operated (m)___/(d)___/(y)____ d. Replacement well is _____ feet from original well.
   e. Location of water use of original well _____

   Please Select One:

   f.1. ☐ Original water well decommissioned on (m)___/(d___/(y)___ **OR**

   2. ☐ I hereby certify that the original water well will be decommissioned within 180 days after such construction of the replacement water well. **OR**

   3. ☐ I hereby certify that the original water well will be modified and equipped to pump 50 gallons per minute or less within 180 days after such construction of the replacement water well. It will be used for one of the following: a. ☐ Livestock b. ☐ Monitoring c. ☐ Observation d. ☐ nonconsumptive or de minimus use approved by the applicable natural resources district. State use: _____

   If 3d is chosen. NRD signature is required. (Signature can be submitted on NRD Approval form to DNR prior to registration)

   NRD signature _____ Date _____ **OR**

   4. ☐ Owners CERTIFICATION OF INTENT to Decommission or Modify the original well form is submitted by landowner. (Must be submitted before registering well)

8. Pump Information. (Pump information is required if registering a pit)
   a. Is pump installed at this time ☐ Yes ☑ No
      Is pump installed by well owner in section 1? ☐ Yes ☐ No
      Is pump installed by contractor in section 2? ☐ Yes ☐ No
      Is this a free flowing well ☐ Yes(no pump to be installed) ☐ No

   If pump installed by pump installer, please fill out license number below

   b. Pump Installer's License No._____ Pump Installer's Name_____
      Pump Installer's Email Address_____
      Pump Installer's Firm Name_____
      Pump Installer's Firm Address_____
      City _____ State _____ Zip_____ Telephone _____
      Pump Installer's Firm Email Address_____
   c. Measured Pumping rate _____ gallons per minute d. Pumping water level _____ feet
   e. Drop pipe diameter _____ inches f. Length of drop pipe _____ feet
   g. Pumping equipment installed (m)___/(d___/(y)___
   h. Pump Brand_____
   i. This well is designed and constructed to pump 50 gpm or less ☑ Yes ☐ No **(8I is required on ALL wells)**

9. Well Construction Information.
   a. Total well depth 530 feet. b. Static water level 116 feet. **(required)**
   c. Well Construction Began (m) 9 /(d) 6 /(y) 2016 d.. Well Construction Completed (m) 9 /(d) 12 /(y) 2016

   Wells drilled prior to stays or moratoriums require NRD signature — **NRD signature** _____ Date _____ (Signature can be submitted on NRD Approval form to DNR prior to registration)

   e. Bore hole diameter in inches Top 8 Bottom 8
   f. Casing and Screen Joints are Welded ☐ Glued ☐ Threaded ☑ Other Spline & Groove
   g. Capacity of Well 0.1 gallons per minute (to be used to determine sustainability of aquifer)
   h. Pumping water level at this capacity _____ feet

6178086

10. Well Construction (Casing & Screen)- c, d, e, & f measurements should be in inches to three decimal places (From not less than zero)

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							
0	399	Casing	4.320	4.950	0.297		PVC	Certa-Lok
399	400	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank
400	480	Screen	3.000	3.500	0.250	0.020	PVC	Johnson
480	510	Casing	3.000	3.500	0.250		PVC	Certainteed Screen Blank
510	530	Screen	3.000	3.500	0.250	0.020	PVC	Johnson

Additional information for Double cased or Nested wells:

a		b	c	d	e	f	g	h
Placement Depth in Feet		Casing or Screen or Open Hole	Inside Diameter	Outside Diameter	Wall Thickness	Screen Slot Size	Type of Material	Trade Name
From	To							

11. Grout and Gravel Pack (must start at zero)

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout *See **Desc**
From	To				
0	399	Grout	Neat Cement		10.6 bbls of Cement Slurry
399	530	Gravel Pack	Natural Formation Gravel Pack	5.03 Cubic Yards	

Desc: Description of gravel pack i.e. engineered gravel pack, or gravel pit description (¼ down), or brand nam e (Best Sand), natural formation, drilling cuttings, soil backfill
Quantity #cubic yards, #tons, #sacks, - (for drilling cuttings and soil backfill estimate quantity) Calculation assistance available on web
Volume & Type: #gallons of a slurry, #barrels of a slurry, #sacks used in the slurry, #bags of non-slurry bentonite (chip-pellet –granular)
Additional information for Double cased or Nested wells:

Placement Depth in Feet		Grout/Gravel/ Open Hole	Material Description *See **Desc** for gravel	Quantity gravel *See **Desc**	Volume & Type Grout *See **Desc**
From	To				

6188805

12. Geologic Materials Logged (must start at zero) - **Use only options provided below for Type, Hardness and Color**

From	To	Type	Hardness	Color	Other/Drilling Action
0	20	Top Soil	Unconsolidated	Brown	
20	30	Other - Quaternary Alluvium	Unconsolidated	Tan	
30	120	Sandstone	Unconsolidated	Brown	
120	220	Sand with Clay/Silt	Consolidated	Brown	
220	280	Clay	Dense/Stiff	Brown	
280	560	Siltstone	Dense/Stiff	Brown	
560	580	Clay	Dense/Stiff	Brown, Green	

Type		Hardness	Color	
Clay	Sand fine-med	Cemented	Black	Pepper
Clay Stone	Sand med-coarse	Consolidated	Blue	Red
Cobbles	Sand with grave	Dense/Stiff	Brown	Tan
Fine Sand	Sandstone	Hard	Gray	White
Gravel S	hale	Soft	Green	Yellow
Limestone Silt		Unconsolidated	Orange	
Loss Circulation	Siltstone	Very Hard		
Ochre (weathered shale)	Top Soil			
Sandy Clay	Other			
Sand with Clay/Silt				

(Additional sheets may be submitted)

13. I hereby certify that the information provided on this registration is true and accurate to the best of my knowledge.

Water Well Contractor's Signature (not required for pits) — Date

Well Owner's Signature (if Contractor is unknown or Deceased or for pits) (Not required if signed by Contractor) — Date

Please note this document contains four pages.

Sections 9F, 9G, 10, 11 & 12 are not required if registering a pit.

Owner Registering well drilled prior to 2002: Minimum Required Sections - 1, 3(a,b,c,e,f), 5, 6, 7, 8(a,g,i), 9d

REDLINE CHANGES

Redline Changes – Section 2

MEA TR

Reponses to Open Issues

6-29-2017

2.6 Geology and Seismology

This section describes the regional and local geology and seismology of the MEA area. The geology of the CPF, NTEA, and TCEA has been discussed in previous license applications submitted to the NRC. Detailed information contained in those reports (e.g., laboratory results and field data that describe formation characteristics [lithology, mineralogy, permeability] for the Pierre Shale, Chadron Formation, and the Brule Formation at the CPF), also applies in a general sense to the MEA. These data, in addition to new information from exploratory drilling/logging activities within the MEA, are used to describe the geology and seismology in this section.

2.6.1 Geology and Seismology

2.6.1.1 Regional Setting

As shown on **Figure 4.2-1**, the centerpoint proposed MEA satellite building is approximately 15.1 miles (24.3 km) south-southeast to the centerpoint of the City of Crawford, Nebraska in Sections 26 35, and 36 Township 30 North, Range 51 West; Sections 1, 2, 11, 12, and 13 Township 29 North, Range 51 West; and Sections 7, 18, 19, 20, 29, and 30 Township 29 North, Range 50 West. The City of Crawford is 25 miles (40.2 km) west of Chadron, Nebraska and 70 miles (112.6 km) north of Scottsbluff, Nebraska. The City of Crawford is 21 miles (33.8 km) south of the South Dakota state line and 33 miles (53.1 km) east of the Wyoming state line. The Marsland area is located near the northern limits of the High Plains section of the Great Plains physiographic province. Topography of the Marsland area includes gently sloping, rolling hills with outlying, broad ridges dissected by intermittent and perennial streams. The most prominent physiographic feature in the region is the Pine Ridge Escarpment, which rises roughly 300 to 900 feet above the basal plain and bounds three sides of the Crawford Basin. Colluvial and alluvial deposits originating from this escarpment cover the license area. The elevation of the MEA ranges from 3,880 to 4,400 feet above mean sea level (amsl).

Regional Stratigraphy

Table 2.6-1 summarizes the regional stratigraphic section for northwest Nebraska that includes the White River Group (Brule Formation through basal sandstone of the Chadron Formation). A geologic map of bedrock in northwestern Nebraska is shown on **Figure 2.6-1**. The bedrock map depicts the occurrence of the Miocene Ogallala Group, Miocene Arikaree Group, the Eocene-Oligocene White River Group, and Upper Cretaceous strata belonging to the Montana Group and Colorado Group. The Upper Cretaceous Pierre Shale, the unconformably overlying White River Group (Brule Formation, Chadron Formation, and Chamberlain Pass Formation), and the Arikaree Group outcrop in the vicinity of the City of Crawford and MEA (**Figure 2.6-1**, see inset). In general, the stratigraphic nomenclature of Schultz and Stout (1955) is used in this application for consistency with historical permitting.

MEA Stratigraphy

The local stratigraphy at the MEA consists of the following geological units in descending order: alluvial sediments, Upper Harrison Beds, ~~Monroe Creek -~~Harrison-Monroe Creek -Formation, Gering Formation, Brule Formation, Upper Chadron Formation, ~~Upper/Middle Chadron Formation,~~ Middle Chadron Formation, basal sandstone of the Chadron Formation, and Pierre Shale. The channel sandstone facies of the basal sandstone of the Chadron Formation represents

respectively. Lithologic observations of outcrops in the northern MEA and Pine Ridge area north of MEA, drill cuttings, and interpretation of geophysical logs indicate that the Gering Formation makes up the majority of the stratigraphic thickness of the Arikaree Group at MEA.

The unconformable contact between the Brule and Gering Formations is readily observed when coarse sediments of the Gering Formation are in contact with the finer grained Brule Formation. When the sediments of the Gering Formation are fine grained, the contact is more difficult to discern based on observations of drill cuttings.

White River Group (Eocene-Oligocene)

At the MEA, the Eocene-Oligocene White River Group consists of the Chadron Formation overlain by the Brule Formation (**Table 2.6-2**). Strata assigned to this group were deposited within fluvial, lacustrine, and eolian environments (Terry and LaGarry 1998). In northwest Nebraska, the White River Group rests unconformably on weathered Pierre Shale. The bulk of the White River Group consists of airfall and reworked volcaniclastics derived from sources in Nevada and Utah (Larson and Evanoff 1998; Terry and LaGarry 1998).

There have been various interpretations of the history of stratigraphic nomenclature for the White River Group of Nebraska and South Dakota as described by Harksen and Macdonald (1969). The following stratigraphic nomenclature retains the formal and informal members based on nomenclature by Schultz and Stout (1955), but also includes more recent nomenclature (Terry and LaGarry 1998; Terry 1998; LaGarry 1998; Hoganson et al. 1998).

Brule Formation

The Oligocene Brule Formation represents the youngest unit within the White River Group present in the subsurface of the MEA. The Brule Formation conformably overlies the Chadron Formation and is unconformably overlain by the Arikaree Group (**Figure 2.6-1**). The Brule Formation was originally subdivided by Swinehart et al. (1985) and later revised by LaGarry (1998) into three members, from youngest to oldest: the Brown Siltstone Member, the Whitney Member, and underlying Orella Member (**Table 2.6-2**).

The Brown Siltstone Member consists of pale brown and brown, nodular, cross bedded eolian volcaniclastic siltstones and sandy siltstones. The contact with the underlying Whitney Member varies from a gradational contact to a sharp disconformity where the "brown siltstone" fills valleys incised into the older strata of the Whitney Member. Thick, fine to medium grained sandstones appear near the base of the Brown Siltstone Member. These sandstones are present across the MEA. ~~As observed in drill cuttings,~~ Tthe Whitney Member consists mostly of pale brown, massive, typically nodular eolian siltstones with rare thin interbeds of brown and bluish-green sandstone, and volcanic ash. The basal 10 meters of the Whitney Member consist of white or green laminated fluvial siltstones and thin sheet sandstones. The contact between the Whitney Member and the underlying Orella Member is intertonguing. The Orella Member consists of pale brown, brown, and brownish-orange volcaniclastic overbank clayey siltstones and silty claystones, brown and bluish-green overbank sheet sandstones, and thin volcanic ashes. At the MEA, the Brule Formation is predominated by the Brown Siltstone and Whitney Members while the presence of the Orella Member is minimal as determined by cuttings, descriptions and geophysical log interpretation. Further discussion of the interpretation of the base of the Brule Formation follows later in this section. The overall thickness of the Brule Formation within the MEA ranges from

approximately 350 to 550 feet. In approximately the northern third of the MEA, the Brule Formation is generally 475 feet thick or more, and thins southward to a thickness generally between 350 and 450 feet. An isopach map of the undifferentiated Brule Formation is shown on **Figure 2.6-7. Figure 2.6-10** illustrates the elevation of the top of the Brule Formation across the MEA.

The contact between the Brule Formation and underlying Chadron Formation is difficult to identify in some places, as the contact between the two formations is intertonguing (LaGarry 1998). Regionally, the contact is recognized as the lithologic change from thinly interbedded and less pedogenically modified brown, orange, and tan volcaniclastic clayey siltstones and sheet sandstones of the Orella Member to pedogenically modified green, red, and pink volcaniclastic silty claystones of Big Cottonwood Creek Member in the upper Chadron Formation (Terry and LaGarry 1998).

On geophysical logs, the Brown Siltstone Member is characterized by rapidly fluctuating geophysical log curves, or "log chatter" (**Figure 2.6-5**). This response is recognized in resistivity curves, and to a lesser extent in SP curves, throughout the MEA. Such fluctuations result from resistivity contrasts between the thinly interbedded siltstones and sandstones. Because the sandstones are porous and constitute a part of the regional aquifer, the contacts with the interbedded, dry siltstones are sharp and easily recognized on logs (Gutentag et al. 1984). These interbedded sandstones and siltstones are present across the entire MEA project area, and represent the base of the first overlying aquifer above the production zone. **Figures 2.6-7** and **2.6-10** depict the thickness and elevation of the top of the Brule Formation across the MEA, respectively.

The contact between the interbedded siltstones and sandstone of the Brown Siltstone Member and the underlying Whitney and Orella Members is distinguished on geophysical logs by a change from highly variable log readings (i.e., "log chatter") to relatively flat or straight curves (i.e., the shale baseline) on both resistivity and SP logs (**Figure 2.6-5**).

Two lithified volcanic ash horizons (tuffs) within the Whitney Member are identified in the MEA drill logs and are designated the Upper and Lower Whitney ash zones. Geophysical log signatures of the Whitney ash zones typically show increased resistivity as well as elevated natural gamma levels, most likely due to the presence of uranium within the volcanic ash (Swinehart et al. 1985; LaGarry 1998). These ash zone tuffs were deposited over a wide area and have been correlated throughout the MEA (**Figures 2.6-3a through 2.6-3n**). A detailed analysis of the lower Brule Formation (Whitney Member) is discussed in **Appendix HH**. The Orella Member as described previously is difficult to distinguish by drill cuttings or by log signature and may have minimal presence at the MEA.

The contact between the lower Brule Formation and the upper Chadron Formation is difficult to identify on geophysical logs because of intertonguing of the siltstones and silty claystones ~~thin sandstones~~. As a result, the formation contact appears deeper on some geophysical logs and varies locally on the Brule Formation isopach map (**Figure 2.6-7).** Observed lithologic changes from brown and tan siltstones towards green and gray silty-claystones in drill cuttings have been used to assist in identifying this contact (**Appendix HH**). **Figure 2.6-3a** through **2.6-3n** depict the subsurface geology of the Brule Formation within the MEA.

Chadron Formation (Eocene-Oligocene)

The Eocene-Oligocene Chadron Formation is in the lower part of the White River Group (**Table 2.6-2**). The Chadron Formation unconformably overlies the Cretaceous Pierre Shale. From top to bottom, the Chadron Formation historically consists of the following stratigraphic units: Big Cottonwood Creek Member (herein referred to as the informal upper Chadron and upper/middle Chadron to be consistent with historical permitting), Peanut Peak Member (herein referred to as the informal middle Chadron to also be consistent with historical permitting), and basal sandstone of the Chadron Formation (also known formally as the Chamberlain Pass Formation). The basal sandstone of the Chadron Formation represents the production zone and target of ISR mining within the MEA. **Figures 2.6-3a** through **2.6-3n** depict the subsurface geology of the Chadron Formation within the MEA. **Figure 2.6-11** illustrates the elevation of the top of the Chadron Formation across the MEA. A unit locally referred to as the upper/middle Chadron has been observed in regional outcrops and in the subsurface at other CBR operations (e.g., North Trend Expansion Area); however, this unit has been determined to be absent at MEA based on geophysical logs and observations of cores and drill cuttings, and is not discussed in this application.

Upper Chadron

The upper Chadron is the youngest subdivision of the Chadron Formation recognized at MEA (**Table 2.6-2**). Descriptions of the upper Chadron at Toadstool Park (approximately 22 miles [35.4 km] northwest of MEA) indicate that the unit is composed primarily of volcaniclastic overbank silty claystones interbedded with tabular and lenticular channel sandstones, lacustrine limestones, pedogenic calcretes, marls, volcanic ashes, and gypsum (Terry and LaGarry 1998). Drill cuttings, cores, and geophysical logs from MEA support these observations, except the presence of limestones which have not been observed. At MEA, the upper part of the upper Chadron is light green-gray bentonitic clay grading downward to green and frequently red clay, though thin interbedded sheet sandstones also occur. This observation is consistent with Terry and LaGarry's (1998) observation of thin (0.1 to 0.15 meter) sandstones at Toadstool Park. Water has not been observed in upper Chadron sandstones at MEA. Tuffs in the Toadstool Park area that occur in the upper Chadron were dated by 40Ar/39Ar methods as late Eocene (~34 million years ago [Ma]) in age (Terry and LaGarry 1998). Based on geophysical data, the upper Chadron is continuous across the MEA. The available data suggest that the upper Chadron ranges in stratigraphic thickness from approximately 190 to 250 feet and averages about 220 feet across the MEA (**Figure 2.6-3a** through **Figure 2.6-3n**).

As supported by observations at the MEA, the lower boundary of this unit is an intertonguing contact with the underlying middle Chadron (Terry and LaGarry 1998; **Table 2.6-2**). The upper boundary is recognized by a lithologic change from thinly bedded and less pedogenically modified brown, orange, and tan volcaniclastic clayey siltstones, sheet sandstones, and channel sandstones of the overlying Orella Member of the Brule Formation to more pedogenically modified green, red, and pink volcaniclastic silty claystones of the upper Chadron (Terry and LaGarry 1998; **Table 2.6-2**).

Three core samples (M-1454C, Run 1; M-1624C, Run 1; and M-1635C Run 3, Sample 1) were collected from the upper Chadron by CBR at boreholes M-1454C, M1624C, and M-1635C (**Figure 2.6-4; Appendix G-1** and **G-2**). X-ray diffraction (XRD) analyses of upper Chadron core samples indicate varied mineralogical compositions. Sample M-1454C Run 1 was primarily composed of calcite, montmorillonite, and quartz with minor amounts of plagioclase, potassium feldspar, and illite/mica. The samples from M-1635C and M-1624C were both primarily composed of montmorillonite, calcite, quartz, and plagioclase with minor amounts of illite/mica and potassium feldspar.

Particle size distribution analysis of the three upper Chadron core samples produced median grain sizes between 0.056 and 0.040 millimeter (mm), which are within the silt size range. The weight percent of sand in these samples ranged from 28.79 (M-1635C) to 43.11 (M-1454C). The sample from M-1454C contained significant proportions of medium sand (24.31 weight percent). The weight percent of clay in the upper Chadron samples ranged from 8.73 percent (M-1624C) to 10.20 percent (M-1635C). M-1454C Run 1, M-1624C Run 1, and M-1635C Run 3 Sample 1 give median grain sizes of 0.056 millimeter (mm; fine sand), 0.049 mm (silt), and 0.040 mm (silt) respectively. All samples are dominated by silt-sized grains; however, M-1454C Run 1, contained more medium sand than M-1624C or M-1635C which increased the median grain size. M-1454C Run 1 contained 47.25 percent silt and 9.64 percent clay. M-1624C Run 1 contained 54.65 percent silt and 8.73 percent clay. M-1635C Run 3 Sample 1 contained 61.01 percent silt and 10.20 percent clay. All three upper Chadron core samples contained greater than 50 percent combined silt and clay-sized particles, and because greater than 67 percent of the silt+clay component was silt in each sample, they are classified as siltstones (Brown and Harrell 1991). Hydraulic properties of the upper Chadron based on grain size analysis of core samples are discussed in Section 2.7.2.3 (confining layers).

Typical gamma ray (GR), SP, and resistivity log signatures for the upper Chadron exhibit curves representative of the relatively flat shale baseline (**Figure 2.6-5**). Fluctuations are present among upper Chadron log curves, representing interbedded siltstones, silty claystones, silty sandstones, limestones, and volcanic ash deposits that occur less commonly than in the overlying Brule Formation. Logging tools/procedures and other tests are described in Section 3.1.2.4.

Middle Chadron

The middle Chadron is a variegated clay-rich interval that may be red, grey, grey-green, or bluish-green in color with interbedded bentonitic clay and sands. A light green-gray "sticky" clay within this unit serves as an excellent marker bed in drill cuttings and has been observed in virtually all regional test holes within the MEA, TCEA, NTEA, and the CPF. The middle Chadron unconformably overlies the basal sandstone of the Chadron Formation (Chamberlain Pass Formation) in South Dakota and Nebraska (Terry 1998; **Table 2.6-2**). As described above, this unit is overlain by the upper Chadron at the MEA (**Table 2.6-2**). The middle Chadron differs from the overlying upper Chadron in that the middle Chadron is composed of bluish-green, smectite-rich mudstone and claystone is less variegated in color; and contains less silt (Terry 1998). The predominantly clay lithology of the middle Chadron represents a distinct and rapid facies change from the underlying basal sandstone of the Chadron Formation. The available data suggest that the middle Chadron typically ranges in thickness from approximately 150 to 290 feet and averages about 180 feet across the MEA.

vicinity of the MEA can best be observed in geophysical logs from four of the six nearby abandoned oil and gas wells (Hollibaugh 1, Chicoine 1A, Royal 1, and Smith 1-A), and two CBR deep disposal wells (DDW#1, DDW#2), which were completed through the entire thickness of the unit. Based on observations from oil and gas exploration logging, the thickness of the Pierre Shale in the vicinity of the MEA ranges from approximately 769 to 1,000 ft KB.

Oil & Gas Exploration Wells	Township, Range, Section	Total Depth (ft KB)	Pierre Shale Depth (ft KB)	Niobrara FM Depth (ft KB)	Thickness of Pierre Shale	Distance from Permit Boundary (miles)
Hollibaugh 1	T29N, R51W, Section 12	3,295	1,040	1,915	875	Inside Permit Boundary
Chicoine 1A	T30N, R50W, Section 30	3,050	1,258	2,144	886	1.15 (east)
Royal 1	T30N, R51W, Section 23	3,956	1,200	2,200	1,000	~ 0.5 (north)
Smith 1-A	T29N, R50W, Section 29	2,901	947	1,716	769	~ 0.25 (east)

Source: NOGCC 2011, Petrotek 2015

Based on observations from CBR disposal well logs, the thickness of the Pierre Shale in the vicinity of the DDW's range from approximately 1,369 to 1,550 ft KB.

Deep Disposal Wells	Township, Range, Section	Total Depth (ft KB)	Pierre Shale Depth (ft KB)	Niobrara FM Depth (ft KB)	Thickness of Pierre Shale	Distance from Permit Boundary (miles)
DDW#1	T31N R52W Section 19	3,880	764	2,133	1,369	7.8
DDW#2	T31N R52W Section 13	3,803	511	2061	1,550	11.9

Source: Petrotek 2015

Stratigraphy of Units Below the Pierre Shale

Underlying the Pierre Shale is a thick sequence of Mississippian through Cretaceous age strata that unconformably overlie Precambrian granite (**Table 2.6-1**). Together with the Pierre Shale, the underlying Niobrara Formation, Carlile Shale, Greenhorn Limestone, and Graneros Shale compose a composite lower confining interval approximately 2,500 feet thick which immediately underlies the basal sandstone of the Chadron Formation. With exception of the hydrocarbon-bearing "D", "G", and "J" sandstones of the Dakota Group (occasionally interbedded with the Graneros and Huntsman Shales; **Table 2.6-1**), there do not appear to be significant sandstone units within this thick sequence of low-permeability strata.



- Alluvium
- Arikaree Group
- Brule Formation (first overlying aquifer in Brown Siltstone Member)
- Chadron Formation (Upper Confining Unit including the combined upper and middle Chadron Basal sandstone of the Chadron Formation (Mining Unit)
- Pierre Shale (Lower Confining Unit)

With regard to the CPF, NTEA, TCEA, and MEA in particular, two groundwater sources are of interest in the Crow Butte and surrounding area. These are the Brule Formation sand and the basal sandstone of the Chadron Formation. The basal sandstone of the Chadron Formation contains the uranium mineralization at the CPF, NTEA, TCEA, and MEA.

2.7.2.1 Groundwater Occurrence and Flow Direction

In the vicinity of the MEA, water has been observed in the alluvium, Arikaree Group, Brule Formation, and basal sandstone of the Chadron Formation. Alluvial deposits are discontinuous at MEA and have not been shown to contain usable amounts of water. Of the wells identified in **Table 2.7-9**, none are known to be completed within alluvial deposits, and those that are shallow enough (e.g., less than 50 feet) are understood to be completed within bedrock aquifers. Additionally, except during large storms that produce surface runoff, water within the alluvium is expected to recharge to underlying porous units of the Arikaree Group. Similarly, in areas where the Arikaree Group is deeply dissected by erosion, the Arikaree Group is not typically considered to be a reliable water source; however, within the MEA, the Arikaree Group is locally used for domestic and livestock purposes.

The Arikaree Group and Brule Formation within the MEA meet the NDEQ definition (Nebraska Administrative Code Title 122, Chapter 1, Part 006) of an aquifer: "a geological formation, group of formations, or part of a formation that is capable of yielding a useable amount of water to a well, spring, or other point of discharge." For the purposes of permitting at MEA, alluvium is not considered an aquifer. Likewise, although thin sandstones are present within the upper Chadron Formation, drill cuttings, cores, and geophysical logs have not indicated a potential for the existence ~~presence~~ of water bearing units within any portions of the upper Chadron or middle Chadron Formation at the MEA. As described in Section 2.7.2.3 (confining layer), the upper Chadron and middle Chadron Formation constitute the confining unit between the basal sandstone of the Chadron Formation and overlying aquifers of the Brule Formation and Arikaree Group. Aquifer properties of the basal sandstone of the Chadron Formation are discussed in Section 2.7.2.2 in relation to aquifer pumping tests conducted in 2011.

Hydraulic conductivities for the Arikaree Group and Brule Formation were estimated using particle grain-size distribution data from core samples. Results of the particle size distribution analyses indicate sediments variably dominated by sands, silts, and clays. Hydraulic conductivity estimates were developed using the Kozeny-Carman equation, which is appropriate for sands and silts, but not for cohesive clayey soils with a high degree of plasticity. Published literature validates the use of the Kozeny-Carman equation for fine grained non-plastic silts (Carrier 2003). For samples that have high plasticity, hydraulic conductivity values are likely overestimated. Therefore, the Kozeny-Carman equation provides a conservative estimate of hydraulic conductivity. Additionally, Falling Head Permeameter Tests were completed on one Brule Formation core sample (M-2169C, Run 5, Sample 1) and one Upper Chadron Formation core (M-1635C, Run 3,

At the base of the Brown Siltstone Member is a channel sandstone that has incised into the underlying Whitney Member and constitutes the first overlying aquifer above the production zone. This 10 to 35 foot thick sandstone is present across the entire MEA, as observed in drill cuttings and geophysical logs. Other sand-rich horizons that may produce water within the Brule Formation are also present above this lower sandstone, but are limited in lateral extent and do not extend across the entire MEA. **Figures 2.9-5a through 2.9-5d** shows the potentiometric surface as determined by groundwater level gauging of the 11 water wells that are completed in the Brule Formation. Because the Brule Formation potentiometric surface extends upward into the Arikaree Group, it can be assumed that the entire thickness of the overlying Brule Formation is saturated where local aquifer properties permit the flow of groundwater. That said, not all stratigraphic horizons of the Brule Formation are capable of producing water in useable quantities **(Appendix HH)**.

A total of 13 core samples have been collected from the Brule Formation for grain size analysis, from units demonstrating a range in visually observed textural composition (mudstones to sandstones). However, grain size analysis of core samples collected from the Brule Formation indicate that all 13 samples are dominated by silt-sized particles. The two samples with the highest weight percent of sand (39.31 percent [M-1956C Run 4 Sample 1; 48.09 percent [M-1912C Run 3 Sample 1]) have calculated hydraulic conductivity values of 1.4×10^{-4} cm/sec and 2.3×10^{-4} cm/sec, respectively. By comparison, the geometric mean of all samples collected from the Brule Formation is 8.9×10^{-5} cm/sec. Based on grain size distributions, average intrinsic permeability of Brule Formation core samples is estimated to be approximately 4.2×10^{-7} cm^2.

Falling Head Permeameter Testing (ASTM D5084) of core sample (M-2169C, Run 5, Sample 1) from the Brule Formation returned an average measured hydraulic conductivity value of 1.31×10^{-7} cm/s. The same core sample (M-2169C, Run 5, Sample 1); using the Kozeny-Carman equation to calculate hydraulic conductivity based on particle grain size, results in an estimate of 5.4×10^{-5} cm/s. The difference between the two results is most likely due to the presence of high plasticity clay-sized particles that can result in an over estimated hydraulic conductivity value when calculated using the Kozeny-Carman equation.

The coefficient of variation (standard deviation divided by geometric mean) for all Brule Formation samples calculated using Kozeny-Carman are an order of magnitude less than for all Arikaree Group samples. This may represent a higher level of lithologic heterogeneity within the Arikaree Group and higher potential for local barriers to groundwater flow to be present.

Baseline groundwater monitoring for private water supply wells and CBR monitor wells (water levels and water quality) is presented in Section 2.9.3.

Basal Sandstone of the Chadron Formation

Discussions of the groundwater conditions for the basal sandstone of the Chadron Formation are presented below in Sections 2.7.2.2 and 2.7.2.3.

2.7.2.2 Aquifer Testing and Hydraulic Parameter Identification Information

Prior to initiation of ISR mining activities, the NDEQ regulations require hydrologic testing and baseline water quality sampling. During the initial permitting and development activities within

- Adequate confinement exists between the overlying Brule Formation and the basal sandstone of the Chadron Formation, as evidenced by no discernible drawdown in the Brule Formation observation wells.
- The hydrologic properties of the basal sandstone of the Chadron Formation have been adequately characterized within the majority of the proposed MEA to proceed with Class III UIC permitting and an NRC License Amendment Application for the MEA.

These conclusions indicate that, though variance in thickness and hydraulic conductivity may impact mining operations (e.g., well spacing, completion interval, and injection/production rates), it is not anticipated to impact regulatory issues.

Based on conclusions drawn from the geophysical and geologic sample logging and well development results, the lower Brule Formation is composed of non-aquifer sediments and it does not produce water in usable, significant or economic amounts and cannot be classified as an aquifer. Therefore, additional testing such as water quality, water level measurements and pumping tests were not recommended (**Appendix HH**). The first overlying aquifer to the mining zone at MEA should remain the Brown Siltstone Member of the upper Brule Formation.

2.7.2.3 Hydrologic Conceptual Model for the Marsland Expansion Area

Tables 2.6-1 and 2.6-2 present the regional and local stratigraphic columns in the vicinity of MEA. As discussed above in Section 2.7.2.1, aquifers within the stratigraphic section present at the MEA include permeable intervals of the Arikaree Group, permeable intervals in the Brown Siltstone Member of the shallow Brule Formation, and the deeper confined basal sandstone of the Chadron Formation. Discussions below describe the upper and lower confining units and the hydrologic conditions for the water-bearing intervals present at the MEA.

Confining Layers

Upper confinement for the basal sandstone of the Chadron Formation within the MEA is represented by 360 to 450 feet of smectite-rich mudstone and siltstones of the upper Chadron and middle Chadron (**Figures 2.6-3a** through **2.6-3n and 2.6-8**). Particle grain-size analyses of five core samples from the upper confining layer within the MEA indicate the samples were predominately siltstone. (**Appendix G-1 and G-2**). All MEA core samples were laboratory tested using ASTM D4464 methods for determining particle-size distributions by laser light scattering. The procedure is a modification of ASTM D4464-85 used to measure particle sizes of catalytic material. The procedure has been extended to include measurement of unconsolidated soils and sediments, and is recognized as an alternative to ASTM D422 (hydrometer) and the pipette method. X-Ray Diffraction (XRD) analyses indicate that the chemical compositions of core samples from the middle Chadron are highly similar to the Pierre Shale (e.g., predominantly mixed-layered illite/smectite or montmorillonite with quartz), which would be expected if the Pierre Shale was a contributing source of materials for the overlying middle Chadron (**Appendix G-1**).

The estimated hydraulic conductivities for the upper confining units were developed using the Kozeny-Carman method (**Appendix EE)** based on particle grain-size distribution data from the five core samples collected from the upper Chadron and middle Chadron. Use of the Kozeny-Carman method is acceptable for developing hydraulic conductivity estimates for sands and silts, but not for cohesive clayey soils with a high degree of plasticity. Results of the particle size

- Results of the May 2011 aquifer pumping test demonstrate no discernible drawdown in the overlying Brule Formation observation wells screened throughout the MEA (see Section 2.7.2.2).
- Large differences in observed hydraulic head (330 to 500 feet) between the Brule Formation and the basal sandstone of the Chadron Formation indicate strong vertically downward gradients and minimal risk of naturally occurring impacts to the overlying Brule Formation (see Section 2.7.2.1).
- Significant historical differences exist in geochemical groundwater characteristics between the basal sandstone of the Chadron Formation and the Brule Formation (Section 2.9.3.3).
- Site-specific XRD analyses, particle grain-size distribution analyses, and geophysical logging confirm the presence of a thick (between 360 and 450 feet), laterally continuous upper confining layer consisting of low permeability mudstone and claystone, and a thick (more than 750 feet), regionally extensive lower confining layer composed of very low permeability black marine shale (see Section 2.7.2.3).
- Falling Head Permeameter testing of two core samples M-2169C, Run 5, Sample 1 (Brule Formation) and M-1635C, Run 3 (Chadron Formation), measured hydraulic conductivities of 1.31×10^{-7} and 1.32×10^{-7} cm/s, respectively.
- Analyses of particle size distribution results using the Kozeny-Carman equation suggests a conservative maximum hydraulic conductivity of 5.9×10^{-5} cm/s for core samples from the upper confining layer and an average estimated hydraulic conductivity of 3.7×10^{-5} cm/s. Actual hydraulic conductivities are expected to be at least one to two orders of magnitude lower as demonstrated by Falling Head Permeameter Testing of the core samples.
- Hydraulic resistance to vertical flow is expected to be high due to the significant thickness of the upper confining zone within the MEA.
- The vertical hydraulic conductivity across the upper and lower confining layers is likely to be even lower than 10^{-5} cm/sec due to vertical anisotropy (see Section 2.7.2.3).

2.7.2.4 Description of the Proposed Mining Operation and Relationship to Site Geology and Hydrology

The basal sandstone of the Chadron Formation is currently mined using ISR techniques within the mine units of the current Crow Butte operations and represents the production zone and target of solution mining in the MEA. Ore-grade uranium deposits underlying the MEA are located in the basal sandstone of the Chadron Formation (**Figure 1.4-1**). The ore body located within the MEA is a stacked roll-front system, which occurs at the boundary between the up-dip and oxidized part of a sandstone body and the reduced part of the sandstone body. Stratigraphic thickness of the unit within the MEA ranges from approximately 20 to ~~110~~ 90 feet, with an average thickness of approximately 55 feet.

The unit occurs at depths ranging from about 850 to 1,200 feet bgs within the MEA (**Figures 2.6-3a** through **2.6-3n** and **2.6-12**). The competent upper confining layer consists of the overlying middle Chadron and upper Chadron, which are composed of predominantly clay, claystone, and siltstone. Based on extensive exploration hole data collected to date (more than 1,650 drill

dominated by smooth brome (*Bromus inermus*). Overall biodiversity in these areas is lower than in areas of mixed-grass prairie. While non-native grasses are common throughout the project area, the southern portion of the project area had sections that were particularly dominated by these species. The degraded rangeland vegetation type comprises 14.0 percent of the project area (**Table 2.8-2**; **Figure 2.8-1**).

Mixed Conifer

Mixed-conifer forests are concentrated along drainages in the northern third of the project area, often expanding out onto nearby hills and plains (**Figure 2.8-1**). This vegetation type is dominated by Ponderosa pine, with chokecherry (*Prunus virginiana*), skunkbush sumac (*Rhus trilobata*), and snowberry (*Symphoricarpus albus*) common in the understory. A combination of native and non-native grasses were common, with smooth brome (*Bromus inermus*) being particularly abundant in low-lying areas. Pussytoes was a commonly observed forb. Mixed-conifer forests comprise 9.1 percent of the project area, making this the most common of the forested vegetation types (**Table 2.8-2**).

Cultivated

Cultivated fields make up approximately 6.3 percent of the project area and include crops such as alfalfa (*Medicago sativa*), wheat (*Triticum* spp.), oats (*Avena* spp.), corn (*Zea mays*), ~~barley (*Hordeum* spp.), and rye (*Secale cereale*)~~. According to the Nebraska Agricultural Statics Service, corn, wheat and alfalfa made up the majority of crops grown in Dawes County from 2013-2015 (NASS 2016). In an environment not altered by humans, areas occupied by this vegetation type would most likely be occupied by mixed-grass prairie.

Drainages

Drainages in the south end of the project area are well drained and usually dry, covering 2.9 percent of the project area (**Table 2.8-2**; **Figure 2.8-1**). The vegetation composition in these intermittent tributaries to the Niobrara River is similar to that of surrounding grassland, though the vegetation is generally more robust. Meadow death camas *(Zigadenus venenosus)*, wild onion (*Allium sp.),* and monkeyflower (*Mimulus sp.)* were observed in these areas. In the north side of the project area, conifers dominate the overstory of drainages with smooth brome in the understory. Standing water was only observed in the northern portion of the survey area, mostly in the area mapped as deciduous streambank forest. The weed houndstongue (*Cynoglossum officinale*) was observed in low densities.

Deciduous Streambank Forest

Deciduous stands found along ephemeral streams make up a very small portion of the project area, totaling less than 1 percent (**Table 2.8-2**; **Figure 2.8-1**). The most common overstory species observed within this habitat type include eastern cottonwood (*Populus deltoides*), boxelder (*Acer negundo*), and willow (*Salix sp.*). Snowberry was the dominant shrub, with Kentucky bluegrass, smallwing sedge (*Carex microptera), Rumex sp.*, and annual mustards (*Brassicaceae sp.*) common in the understory.

Structure Biotopes

The term "structure biotopes" refers to man-made features, with the exception of cultivated land. Common examples include roads, highways, buildings, farmlands, cities, and industry

Dissolved uranium values for the TCEA tended to be somewhat higher than those for the NTEA and MEA.

Concentrations of dissolved radium-226 from private wells in the NTEA, TCEA, and MEA compared as follows:

NTEA	<0.2 to 1.3 x 10^{-9} µCi/mL
TCEA	1E-10 to 1.5E-9 µCi/mL
MEA	<1.3E-10 to 9.5E-9 µCi/mL

The non-radiological analytical results were at levels consistent with what would be expected for background concentrations for the area (**Tables 2.9-4** and **2.9-6**). Concentrations of the parameters for the private wells versus CBR monitor wells completed in the Brule Formation are comparable, with some parameters for the private wells having somewhat lower average values than for the CBR monitor wells (e.g., dissolved sodium, sulfate, chloride, and conductivity; **Table 2.9-4**). The average values for sodium and sulfate for the private wells versus CBR Brule Formation monitor wells was 19.8 versus 104 mg/L and 10.2 versus 26.2 mg/L, respectively. The average values for sodium and sulfate for the Brule Formation monitor wells versus the CBR basal sandstone of the Chadron Formation monitor wells was 104 versus 394 mg/L and 26.2 versus 172 mg/L, respectively.

Overall, similar trends in the NTEA and TCEA were seen for the same MEA water-bearing units.

2.9.3.2 CBR Groundwater Monitor Wells

Arikaree Group and Brule Formation

Ten Arikaree Group monitoring wells (AOW-1, AOW-3 through AOW-11) were installed in 2013. Well AOW-2 was not installed. There are 11 active monitoring wells screened in the Brule Formation (BOW-2010-1, BOW-2010-2, BOW-2010-3, BOW-2010-4A, BOW-2010-5, BOW-2010-6, BOW-2010-7, BOW-2010-8, BOW-9, BOW-10 and BOW-11). Three of these wells (BOW-9, BOW-10, and BOW-11) were screened in the Brule Formation in September 2013. The Walters Drillers Pond-720 (Walters-2) and Walters Drillers Pond-721 (Walters-1) wells have been employed as monitoring wells for the Brule Formation, but these wells will not be part of future monitoring, specifically for the Brule Formation, because these wells are screened across the Arikaree and Brule Formations. In September 2013, ten wells were screened in the Arikaree Group. The primary purpose of the Arikaree and Brule monitor wells is to further the site-specific understanding of the hydrologic characteristics of the Arikaree Group and Brule Formation. Installation and subsequent monitoring of water levels and water quality is intended to provide more information about potentiometric surfaces of groundwater within aquifers, identify the potential for seasonal or annual flow variations, and provide data by which the hydrologic connectivity between the aquifers, or lack thereof, can be determined. The locations of CBR's Arikaree and Brule monitor wells within the MEA are shown on **Figure 2.7-8**. A report on wells installed in the lower portion of the Brule Formation is found in **Appendix HH**.

Well BOW-2010-4 is not being used for baseline monitoring, and plans are to abandon this well in the future. During reaming of this well for casing, the driller lost a bit that he was unable to retrieve. Unsuccessful attempts made to convert the well to a shallow monitor well resulted in the well being considered unacceptable for baseline monitoring. A new replacement well (BOW-2010-4A) was



2.9.5.1 Vegetation

RG 4.14 recommends sampling of grazing areas near the site in different sectors that will exhibit the highest predicted air particulate concentrations during the milling operations.

Forage vegetation was sampled as described in **Table 2.9-41** following guidance in RG 4.14. The factors used to select the vegetation sampling locations within the MEA were; the three dominate wind directions, the grazing area availability and private landowner access. The forage vegetation sampling locations are shown on **Figure 2.7-4.** Three samples were collected three times during the grazing season and analyzed for natural uranium, radium-226, thorium-230, lead-210, and polonium-210. Results from the vegetation sampling are shown in **Table 2.9-32**. The analytical data sheets for vegetation sampling are provided in **Appendix Q.**

2.9.5.2 Food

Crops

RG 4.14 recommends that crops raised within ~1.86 miles (3 km) of the mill site be sampled at the time of harvest. The NRC has indicated that other food sources should be explored for sampling, such as private gardens in the area (e.g., sampling a variety of available garden plants). Grab samples should be analyzed for natural uranium, radium-226, thorium-230, lead-210, and polonium-210.

Cultivated fields make up approximately 6.3 percent of the project area as discussed in Section 2.8.5.3. During 2017, CBR will collect preoperational crop samples from available crops raised within 3 km of the MEA as required by RG 4.14. Once received the laboratory results will be added to **Appendix Q.**

Gardens

Seven private gardens were identified within 3 km of the MEA (**Figure 2.7-4).** The garden sample size to meet the LLD in RG 4.14 would require 30 lbs. of produce per sample. Consent was not granted by the private landowners to collect garden samples due to the amount of care required to grow a garden and the large sample size. As a best management practice, CBR collected garden soil samples from all seven of the private gardens. The garden soil sample results are found in **Table 2.9-36.**

~~An alternative approach to estimating baseline radionuclide concentrations in vegetables was selected to protect the private owner's crops. Because the quantity of vegetables required to meet LLDs is very large, and in many instances would decimate a private garden owner's crop, an alternative approach to estimating baseline radionuclide concentrations in vegetables was used. This approach relies heavily on the approach developed by Powertech for use at the Dewey Burdock site (ML11208B714).~~

~~The PPMP baseline plan employed a ~1.86 mile (3 km) area around the license boundary to identify gardens for soil sampling. Seven garden/crop locations were selected (**Figure 2.7-4**) and soil samples were taken from the vegetable gardens rather than the vegetables. To estimate the radionuclide concentrations, Equation 1, Section 5 (Equation 5.5) of NUREG-5512 was used to calculate the vegetable concentration factors.~~

~~Csvhj = 1000 (MLv + Bjv) Wv {ACsj, tgv}/Csj (Equation 1)~~

~~Where:~~

~~Csvhj = concentration factor for radionuclide j in plant v at harvest from an initial unit concentration of parent radionuclide i in soil (pCi/kg wet-weight plant per pCi/g dry-weight soil)~~

~~Bjv = concentration factor for uptake of radionuclide j from the soil in plant v (pCi/kg dry-weight plant per pCi/g dry-weight soil)~~

~~MLv = plant soil mass-loading factor for re-suspension of soil to plant v (pCi/kg dry-weight plant per pCi/g dry-weight soil)~~

~~Wv = dry to wet-weight conversion factor (unitless)~~

~~{ACsj, tgv} = decay operator notation used to develop the concentration of radionuclide j in soil at the end of the crop growing period t0' (pCi/g dry-weight)~~

~~C'j = concentration of radionuclide j in soil during the growing period (pCi/g dry-weight)~~

~~C'j(O) = initial concentration of radio nuclide j in soil during the growing period (pCi/g dry-weight)~~

~~tgv = growing period for food crop (days)~~

~~1000 = unit conversion factor (g/kg)~~

~~RG 4.14 specifies analysis of natural uranium, thorium-230, radium-226, lead-210, and polonium-210 in vegetables. With the exception of polonium-210, these radionuclides have long half-lives when compared to the growing season. For that reason, the decay correction can be ignored. For polonium-210, CBR will assume that the initial soil concentration and the soil concentration during the growing season remain identical. Thus, Equation 1 is simplified to Equation 2:~~

~~*Csvhj = 1000 (MLv + Bjv) Wv (Equation 2)*~~

~~Based upon Equation 2, **Table 2.9-36** presents both the parameters that will be used to estimate wet-weight vegetable concentrations from dry-weight soil concentrations and the average value for each plant type and each radionuclide in pCi/kg wet-plant weight from the seven gardens sampled. The locations of the gardens are shown in **Figure 2.7-4**. The Garden Soil Analysis in **Appendix CC** contains a table that compiles the analytical data, the laboratory data, the laboratory reports, and a Polonium LLD evaluation for soil.~~

~~.~~

~~Vegetation samples were collected in accordance with the Safety Health Environment and Quality Management System (SHEQMS) Volume VI Environmental Manual (CBR 2010b).~~

Livestock

NRC RG 4.14 recommends sampling and analysis of the edible portions of livestock raised within 3 km of the site at the time of slaughter. Grab samples should be analyzed for natural uranium, radium-226, thorium-230, lead-210, and polonium-210. With the cooperation of a local landowner in March of 2014, animal tissue samples were collected from three locally raised beef cattle at the

Game Animals

- Although elk and pronghorn have been observed in the MEA, preoperational samples of game animals were not collected due to limited hunting access, limited availability, and movement of the animals which increased the difficulty of obtaining the quantity of sample necessary. The sample size needed to meet the LLD is 30+ lbs.

~~No preoperational samples of game animals were collected due to the following considerations:~~All land within the MEA permit boundary is owned by private land owners **(Figure 1.3-2).** Although hunting access may be granted by a land owner,~~Hunting access is limited by private landowners~~ CBR has not been granted permission to hunt on land within 3 km of the permit boundary. There is an Open Fields and Waters Hunting Area **(Figure 2.2-2)** 8 km from the MEA, however this hunting area is not within 3 km of the mill site as recommended in NRC RG 4.14.

- ~~There are a limited number of game animals in the licensed area.~~
- ~~Due to the migratory nature of game animals, it would be difficult to attribute any radionuclide concentration origins to the site.~~

Contact was made with the Nebraska Game and Parks Commission (NGPC) in an attempt to collect preoperational samples from Elk and Pronghorn through the following programs; -Nebraska Game and Parks Commission (NGPC) Hunters Helping the Hungry Program, Depredation Program, and Confiscation Program (Lombard, 2016). No samples were available to CBR through these programs.

The MEA is located within the NGPC pronghorn hunting unit known as Box Butte West. The Box Butte West Unit covers approximately 2,000,000 acres, which makes up less than 2% of the MEA AOR. In 2016, only 59 pronghorn were harvested in the entire Box Butte West unit (Hams, 2017). Attempts to collect pronghorn samples have been unsuccessful.

Elk may compete more with cattle for forage than other big game species, because of similar diets (Nelson 1982). Yet, elk play a subordinate role to cattle, and space competition results in elk movements (Fricke, et al. 2008). Due to this movement, it would be difficult to attribute any radionuclide concentration origins to the MEA. There are a limited number of elk in the Ash Creek Elk Unit which surrounds the MEA (Fricke, et al. 2008). The MEA comprises a very small portion of the larger Ash Creek Elk Unit which ranges from east of Nebraska Highway 71, north of Nebraska Highway 2 and west of U.S. Highway 385. The Ask Creek elk unit averages only 25 elk harvested annually (Hams, 2017). Attempts to collect elk samples have been unsuccessful.

Livestock was determined to be a more relevant food sample as beef consumption in the U.S. is 67 lbs/person annually and the second highest consumer in the world per capita (OECD, 2016). It is also a more relevant food sample because it is the only animal raised within 3 km of the MEA, it is the only animal anticipated to remain on site for an extended period of time and therefore more likely to be in the pathway-to-man. Livestock samples of the edible portions of livestock raised within 3 km of the site at the time of slaughter were collected per RG 4.14.

~~Livestock is the primary food source in the MEA and more likely to be in the pathway-to-man. Therefore, livestock was determined to be a better food sample.~~



2.9.5.3 Fish

RG 4.14 requires that fish be collected, if available, from lakes and streams in the project site area that may be subject to seepage or direct surface runoff from potentially contaminated areas or that could be affected by a tailings impoundment failure. Fish should be collected, sampled, and analyzed semiannually for natural uranium, radium-226, thorium-230, lead-210, and polonium-210. There are no streams or water impoundments located within the MEA license boundary. There are only two dry drainages that cross the license area. Therefore, fish sampling within the MEA license boundary is not feasible.

The nearest permanent stream is the Niobrara River located just to the south of MEA license boundary which flows into Box Butte Reservoir. Given the large sample size required to attain LLDs (14 pounds) and the limited fish population present in the stream, the fish sampling focused on northern pike in the inlet of Box Butte Reservoir. Box Butte Reservoir is overpopulated with northern pike, which allows for a larger bag limit than elsewhere in Nebraska. As the most prevalent species, a popular gamefish and known human food source, sampling the meat of the northern pike is the only feasible approach to assessing potential dietary contribution to humans. Northern pike fish tissue samples were collected from the inlet of the Box Butte Reservoir on May 25, 2014 and September 26, 2014. The samples were analyzed for natural uranium, radium-226, thorium-230, lead-210, and polonium-210 (**Table 2.9-37**).

Collection of fish tissue at N-1 and N-2 **(Figure 2.7-4)** was not feasible due to the small fish population with insufficient fish biomass. Attempting to collect the required amount of fish tissue needed for the analytical laboratory to obtain the required LLD would decimate the limited fish population.

The analytical data sheets and the QA/QC summary reports for the fish tissue samples are shown in **Appendix X**.

As of May 2010, the Nebraska Department of Human and Health Services (NDHHS) with the NDEQ, the NGPC and the Nebraska Department of Agriculture (NDA), have issued fish consumption advisories for warning to limit the consumption of northern pike in Box Butte Reservoir due to elevated mercury concentrations (NDEQ 2011d).

Due to the lack of background data from the study area with which to compare the current findings, radionuclide data interpretation is impracticable at this time, other than that the concentrations are considered low. The radiological results will serve as background information for future sampling events and the development of long-term trends.

2.9.6 Baseline Soil Monitoring

RG 4.14 and NUREG-1569 recommend~~s~~ soil samples be collected as follows:

- Up to 40 surface soil samples collected at 300-meter intervals to a distance of 1,500 meters in each of eight directions from the center of the milling area. Surface soil samples collected to a depth of 5 cm using consistent sampling methods. Sampling conducted once prior to construction and repeated for locations disturbed by excavation, leveling, or contouring. All samples analyzed for radium-226, and 10 percent of the samples analyzed for natural uranium, thorium-230, and lead-210. Soil sampling is conducted at both a 5 cm

depth and 15 cm depth for background decommissioning data Acceptance Criterion 2.9.3(2) of NUREG-1569.

•

- Five or more surface soil samples (to a depth of 5 cm) collected at the same locations used for air particulate samples. Samples collected once prior to construction. Samples analyzed for natural uranium, radium-226, thorium-230, and lead-210.
- Five subsurface samples collected at the center point location and distances of 750 meters in each of four directions. Subsurface soil samples collected to a depth of 1 meter and divided into three equal sections for analysis. Samples collected once prior to construction and repeated for locations disturbed by construction. All samples analyzed for radium-226, and one set of the samples analyzed for natural uranium, thorium-230, and lead-210.

All baseline soil samples were collected as described in RG 4.14 and NUREG 1569. The baseline soil monitoring results are included in the Marsland Expansion Area Baseline Radiological Investigation Report (Tetra Tech 2015) and are presented in **Appendix BB.**

Quality of Soil Measurements

The accuracy of monitoring data is critical to ensure that the soil monitoring program precisely reflects radionuclide concentrations. RG 4.14 specifies the following LLDs:

Radionuclide	**LLD µCi/g (dry)**	**LLD pCi/g (dry)**
Natural Uranium	2×10^{-7}	.2 pCi/g
Radium-226	2×10^{-7}	.2 pCi/g
Thorium-230	2×10^{-7}	.2 pCi/g
Lead-210 (dry)	2×10^{-7}	.2 pCi/g

2.9.7 Baseline Sediment Sampling

Sediments of lakes, reservoirs, and flowing bodies of surface water may become contaminated as a result of direct liquid discharges, wet surface deposition, or from runoffs associated with contaminated soils. Because of various chemically and physically binding interactions with radionuclides, sediments serve as integrating media that are important to environmental monitoring.

RG 4.14 recommends that sediment samples be collected from sediments of surface water passing through the project site or offsite surface waters that may be subject to drainage from potentially contaminated areas. The PPMP and operational monitoring plan will be designed to meet the criteria outlined in RG 4.14 (NRC 1980a). Samples are to be collected once following spring runoff and in late summer following a period of extended low flow.

2.9.7.1 Niobrara River Sediments

Sediment sampling in RG 4.14 requires samples from each large onsite body of water or offsite surface waters that may be subject to direct surface drainage from potentially contaminated areas that could be affected by a tailings impoundment failure. ~~—~~There are no onsite surface impoundments, so such sampling is not required. Sediment samples will be collected from the Niobrara River, which could receive surface water runoff by means of ephemeral drainages located on the MEA project site (**Figure 2.7-4**). Sediments of the Niobrara River were sampled at designated upstream and downstream sampling locations (sample points N-1 and N-2) (**Figure 2.7-4**). Water samples are also collected at these sampling points. The downstream sampling point is located to assess potential impacts from either of the two ephemeral drainages that drain the MEA.

Sediment samples at N-1 and N-2 sampling points were collected on October 25, 2013 and May 2 2014. The radiological sample analytical results for lead-210, radium-226, thorium-230, and natural uranium are shown in **Table 2.9-38**. The analytical data sheets and the QA/QC summary reports for the Niobrara River Sediments are shown in **Appendix W-2**.

2.9.7.2 Ephemeral Drainages

There are two major ephemeral drainages that traverse across the MEA license area north to south. Seven sampling points in the channel bottom were selected on these drainages to measure radiological concentrations in the sediment at stations MED-1 through MED-7 (**Figure 2.7-4).**

The sediments in ephemeral drainages at the designated sampling points were sampled twice, once in the spring and once in late summer. ~~—~~Samples were analyzed for natural uranium, radium-226, thorium-230, and lead-210. The PPMP and operational monitoring program is shown in **Tables 2.9-41 and 5.7-1.**

Sediment sampling at MED-1 through MED-6 was conducted in the fourth quarter of 2013 and the second quarter of 2014. Sediment sampling at MED-7 was conducted in the fourth quarter of 2014 and the second quarter of 2015 (**Table 2.9-39)**.

Sediment samples were collected in accordance with the SHEQMS Volume VI Environmental Manual (CBR 2010b). The analytical data sheets and the QA/QC summary reports are provided in **Appendix W-2.**

Water was not present in the ephemeral drainage system during Q4 2013 through Q2 2015, therefore no baseline water samples were collected. If water flow becomes available at any time prior to mining at any of the sampling points (MED-1 through MED-7), CBR will collect baseline water samples. ~~in the ephemeral drainages at sampling the points MED-1 through MED-7.~~

2.9.8 Baseline Direct Radiation Monitoring

2.9.8.1 Survey Intervals

RG 4.14 recommends direct radiation measurements be collected at 150-meter intervals to a distance of 4,921.26 feet (1,500 meters) in each of eight directions from the centerpoint of the

Redline Changes – Section 5

MEA TR

Reponses to Open Issues

6-29-2017

5 OPERATIONS

CBR operates a commercial-scale in-situ leach uranium mine (the Crow Butte Project) near Crawford, Nebraska. CBR maintains a headquarters in Casper, Wyoming, where site-licensing actions originate. All CBR operations, including the Crow Butte Project operations, are conducted in conformance with applicable laws, regulations, and requirements of the various regulatory agencies. The responsibilities described below have been designed to both ensure compliance and further implement CBR's policy for providing a safe working environment with cost-effective incorporation of the philosophy of maintaining radiation exposures as low as is reasonably achievable (ALARA).

~~Required NRC licenses and amendments, as well as surety agreements, are issued in the name of Crow Butte Resources, Inc. All CBR operations conform to applicable laws, regulations, and requirements of the various regulatory agencies. The responsibilities described below have been designed to ensure compliance and further implement CBR policy of providing a safe working environment through cost-effective maintenance of radiation exposures ALARA.~~

5.1 Corporate Organization and Administrative Procedures

CBR will maintain a performance-based approach to the management of the environment and employee health and safety, including radiation safety. The SHEQMS encompasses licensing, compliance, environmental monitoring, industrial hygiene, and health physics programs under one umbrella, and it includes involvement for all employees from the individual worker to senior management. This SHEQMS will allow CBR to operate efficiently and maintain an effective environment, health, and safety program.

Figure 5.1-1 is a partial organization chart for CBR that illustrates the operation of the CPF and associated operations and identifies the management levels that play a key part in the SHEQMS that will also apply to the satellite facility. The personnel identified are responsible for the development, review, approval, implementation, and adherence to operating procedures, radiation safety programs, environmental and groundwater monitoring programs, as well as routine and non-routine maintenance activities. These individuals may also serve a functional part of the Safety and Environmental Review Panel (SERP) described in Section 5.2.3.

Specific responsibilities in the organization are described below.

5.1.1 Board of Directors

The Board of Directors for Crow Butte Resources, Inc. has the ultimate responsibility and authority for radiation safety and environmental compliance for CBR. The Board of Directors sets corporate policy and provides procedural guidance in these areas. The Board of Directors provides operational direction to the President of CBR.

5.1.2 President

The President is responsible for interpreting and acting upon the Board of Directors' policy and procedural decisions. The President directly supervises the General Manager of US Operations. The President is empowered by the Board of Directors to have the responsibility and authority for the radiation safety and environmental compliance programs. The President is responsible for



ensuring that the operations staff is complying with all applicable regulations and permit/license conditions through direct supervision of the General Manager of US Operations.

5.1.3 General Manager of US Operations

The General Manager of US Operations is responsible for managing all US Operations. The General Manager of US Operations is responsible for ensuring that Crow Butte personnel comply with Industrial Safety, Radiation Safety, Environmental Protection Programs, and all relevant state and federal regulations. The General Manager of US Operations has the responsibility and the authority to suspend, postpone or modify, immediately if necessary, any activity that is determined to be a threat to employees, public health, the environment, or potentially a violation of state or federal regulations. The General Manager of US Operations reports directly to the President.

5.1.4 Restoration Manager

The Restoration Manager is responsible for all uranium production and restoration activities at the project site. The Restoration Manager is also responsible for implementing any industrial and radiation safety and environmental protection programs associated with operations and restoration. The Restoration Manager is authorized to immediately implement any action to correct or prevent hazards. The Restoration Manager has the responsibility and the authority to suspend, postpone, or modify, immediately if necessary, any activity that is determined to be a threat to employees, public health, the environment, or potentially a violation of state or federal regulations. The Restoration Manager cannot unilaterally override a decision for suspension, postponement, or modification if that decision is made by the Manager of Safety, Health, Environment and Quality, or the RSO. The Restoration Manager reports directly to the General Manager of US Operations.

~~### 5.1.4 Mine Manager~~

~~The Mine Manager is responsible for all uranium production activity at the project site. The Mine Manager is also responsible for implementing any industrial and radiation safety and environmental protection programs associated with operations. The Mine Manager is authorized to immediately implement any action to correct or prevent hazards. The Mine Manager has the responsibility and the authority to suspend, postpone, or modify, immediately if necessary, any activity that is determined to be a threat to employees, public health, the environment, or potentially a violation of state or federal regulations. The Mine Manager cannot unilaterally override a decision for suspension, postponement, or modification if that decision is made by the Manager of Safety, Health, Environment and Quality, or the RSO. The Mine Manager reports directly to the General Manager of US Operations.~~

5.1.5 Safety, Health, Environment, and Quality Manager

The Manager of Safety, Heath, Environment and Quality is responsible for all health and safety, and environmental programs as stated in the SHEQMS Program and for ensuring that CBR complies with all applicable regulatory requirements. The Manager of Safety, Heath, Environment and Quality reports directly to the ~~Mine~~Restoration Manager. This position assists in the development and review of radiological and environmental sampling and analysis procedures and is responsible for routine auditing of the programs. The Manager of Safety, Heath, Environment and Quality has no production-related responsibilities. The Manager of Safety, Heath, Environment and Quality also has the responsibility and authority to suspend, postpone, or modify

any activity that is determined to be a threat to employees, public health, the environment or potentially a violation of state or federal regulations.

5.1.6 Plant Supervisor

The Plant Supervisor supervises plant operations, including the safe and efficient recovery and processing of uranium oxide while staying within regulatory and technical constraints. The Plant Supervisor is responsible for carrying out any procedures or actions implemented by the Restoration Manager, Manager of SHEQ, or the RSO to correct or prevent radiation safety hazards in the plant. The RSO and the Plant Supervisor or the RSO and the Restoration Manager are responsible for conducting weekly inspections of all facility areas to observe general radiation control practices and review required changes in procedures and equipment. The Plant Supervisor reports directly to the Restoration Manager.

~~5.1.6~~5.1.7 Radiation Safety Officer

The RSO is responsible for the development, administration, and enforcement of all radiation safety programs. The RSO is authorized to conduct inspections and to immediately order any change necessary to preclude or eliminate radiation safety hazards and/or maintain regulatory compliance. The RSO is responsible for the implementation of all on-site environmental programs including emergency procedures. The RSO inspects facilities to verify compliance with all applicable requirements in the areas of radiological health and safety. The RSO works closely with all supervisory personnel to ensure that established programs are maintained. The RSO is also responsible for the collection and interpretation of employee exposure-related monitoring including data from radiological safety. The RSO makes recommendations to improvement any and all radiological safety-related controls. The RSO has no production-related responsibilities. The RSO reports directly to the Restoration Manager and has a secondary reporting requirement to the ~~President.~~General Manager of US Operations.

~~5.1.7~~5.1.8 Health Physics Technician

The CBR Health Physics Technician (HPT) assists the RSO with the implementation of the radiological and industrial safety programs. The HPT is responsible for the orderly collection and interpretation of all monitoring data, to include data from radiological safety and environmental programs. The HPT reports directly to the RSO. Such personnel would be familiar with operations and receive the necessary radiation safety training, including hands-on training (e.g., use of survey instruments for monitoring items removed from the restricted area; see Section 5.7.6 for additional discussions).

5.1.9 SHEQ Specialist

The SHEQ Specialist assists in the development and submittal of regulatory permits and license applications. Provides analysis and guidance in the areas of Safety, Health, Environment and Quality and is responsible for assisting site management with coordination of the corrective and preventative action process. The SHEQ Specialist maintains and updates documents associated with the activities relating to the SHEQ system. The SHEQ Specialist reports directly to the SHEQ Manager.

5.1.10 Lab Foreman

The Lab Foreman has direct oversight of the on-site analytical laboratory including implementing laboratory quality assurance procedures. The Lab Foreman is responsible for carrying out any procedures or actions implemented by the Restoration Manager, Manager of SHEQ, or the RSO to correct or prevent radiation safety hazards in the laboratory. The Lab Foreman reports directly to the SHEQ Manager.

5.1.11 Safety Supervisor/Technician

The Safety Supervisor/Technician is responsible for the non-radiation-related health and safety programs. The Safety Supervisor/Technician is authorized to conduct inspections and to immediately order any change necessary to preclude or eliminate safety hazards and/or maintain regulatory compliance. Responsibilities include the development and implementation of health and safety programs in compliance with Occupational Safety and Health Administration (OSHA) regulations. Responsibilities of the Safety Supervisor/Technician include development of industrial safety and health programs and procedures, coordination with the RSO where industrial and radiological safety concerns are interrelated, safety and health training of new and existing employees, and the maintenance of appropriate records to document compliance with regulations. The Safety Supervisor/Technician may be a qualified HPT and may function in that capacity when needed. The Safety Supervisor/Technician reports directly to the SHEQ Manager.

5.1.12 Qualified Designated Operator

The qualified Designated Operator is responsible for performing daily inspection in the occasional absence of the RSO and the HPT. A qualified Designated Operator will meet the minimum qualifications and perform only those duties as outline in Section 5.5.4.

~~5.1.8~~5.1.13 ALARA Program Responsibilities

The purpose of the ALARA program is to keep exposures to all radioactive materials and other hazardous material as low as possible, and to expose as few personnel as possible. This program takes into account the state of technology and the economics of improvements in relation to benefits to the public health, safety, and other societal and socioeconomic considerations, and in relation to the use of atomic energy in the public interest.

In order for an ALARA program to correctly function, all individuals, including management, supervisors, health physics staff, and workers, must take part in and share responsibility for keeping all exposures ALARA. This policy addresses this need and describes the responsibilities of each level in the organization.

~~5.1.9~~5.1.14 Management Responsibilities

Consistent with RG 8.31 (NRC 2002a), CBR senior management is responsible for the development, implementation, and enforcement of applicable rules, policies, and procedures as directed by regulatory agencies and company policies. These responsibilities include the following:



2. During operations, urine samples are collected from workers quarterly. Employees who have the potential for exposure to dried yellowcake submit bioassay samples monthly or more frequently as determined by the RSO. Samples are analyzed for uranium content by a contract analytical laboratory. Blank and spiked samples are also submitted to the laboratory with employee samples as part of the Quality Assurance program. The measurement sensitivity for the analytical laboratory is 5 µg/L.
3. Action levels for urinalysis are established based upon Table A-1 in RG 8.22.

Elements of the quality assurance requirements for the Bioassay Program are based upon the guidelines contained in RG 8.22. These elements included the following:

1. Each batch of samples submitted to the contract analytical laboratory is accompanied by two blind control samples. The control samples are from persons that have not been occupationally exposed and are spiked to a uranium concentration of 10 to 20 µg/L and 40 to 60 µg/L. The results of analysis for these samples are required to be within ± 30 percent of the spiked value.
2. The contract analytical laboratory spikes 10 to 30 percent of all samples received with known concentrations of uranium and the recovery fraction determined. Results are reported to CBR.

CBR proposes to continue to implement the Bioassay Program described in this section for operations at the satellite facility. The facility and wellfield operators will be included in a personnel dosimetry (exchanged quarterly) and bioassay program, with urine samples collected quarterly. The program will be implemented in accordance with the guidance contained in RG 8.22 and with the instructions currently contained in SHEQMS Volume IV, Health Physics Manual.

5.7.6 Contamination Control Program

The Survey Program for Beta/Gamma Contamination, submitted as a license condition requirement under Crow Butte Source Materials License, SUA-1534 (CBR), will be used for beta/gamma surveys of personnel and equipment exiting restricted areas at the MEA 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.

~~5.7.5.1~~5.7.6.1 Surface Contamination

CBR will perform surveys for surface contamination in operating and clean areas of the satellite facility in accordance with the guidelines contained in RG 8.30. Surveys for total alpha and beta contamination in clean areas will be conducted weekly. In designated clean areas, such as lunchrooms, offices, change rooms, and respirator cabinets, the target level of contamination is nothing detectable above background. If the total alpha or beta survey indicates contamination that exceeds 250 disintegrations per minute (dpm)/100 cm^2 (25 percent of the removable limit) a smear survey must be performed to assess the level of removable alpha and beta activity. If smear test results indicate removable contamination greater than 250 dpm/100 cm^2, the area will be promptly cleaned and resurveyed. Total surface activity will be measured with an appropriate alpha/beta

~~5.7.6~~5.7.7 Airborne Effluent and Environmental Operational Monitoring Programs

The operational baseline monitoring program is presented in **Table 5.7-1**.

~~5.7.6.1~~5.7.7.1 Air Particulate Monitoring

Composite airborne particulate samples for natural uranium, radium-226, lead-210, and thorium-230 will be obtained quarterly from air monitoring locations MAR-1 through MAR-6. The quality of sample collection and analysis shall be maintained by adhering to quality control (QC) procedures discussed in Section 5.7.~~9~~10 and LLD concentration limits discussed in Section 2.9.2.4

The air particulate samplers described in Section 2.9.2 will continue to be used for the operational monitoring program.

~~5.7.6.2~~5.7.7.2 Radon and Radon Progeny

Satellite Facility

Emissions from the satellite facility will be determined based on the following assumptions and measurements. The total radon emission from the satellite facility will be the sum of the radon released from the tank vents of the tanks with the potential to contain significant quantities of radon plus the ambient radon in the facilities that is vented through the building's exhaust fans.

The satellite facility ~~would~~will use pressurized downflow IX columns, which do not routinely release radon gas except during resin transfer and column backwashing. The design and operation of these systems result in the majority of the radon in the production fluid staying in solution and not being released from the columns. Lucas cells will be used to sample the air in the tank vent and quantify the concentration of radon at each tank vent. The use of scintillation cells for the measurement radon is an approved method, as outlined in Method 115 from 40 CFR 61 Appendix B. While the method describes the use of scintillation cells for underground mining and tailing piles, it can be applied to this application. Measurements of the radon from tank vents will be performed at a minimum of once a quarter.

The amount of radon in the satellite facility air will be determined using Track Etch cups with semi-annual exposures. There will be four sample locations throughout the facility **(Figure 5.7-2).** Each semi-annual sample results from the four locations will be averaged to determine the ambient radon concentration in the facilities air. The rate of radon released from the process facility will be based on the manufactures flowrate for each of the exhaust fans. It will be assumed that the fans are operational 100% of the time which represents the worst case scenario.

A total radon released from the satellite facility will be calculated semi-annually based on the sum of the radon released from the tank vents and the ambient radon released as a result of the building ventilation. This release rate will be reported semiannually in agreement with 10 CFR 40.65.

The radon gas effluent released to the environment from satellite facility will be monitored at the same air monitoring locations (MAR-1 through MAR-6) that were used for baseline determination

of radon concentrations as described in Section 2.9.2. Sampling locations are shown on **Figure 2.9-2**. Monitoring will be performed using Track-Etch radon cups. The cups will be exchanged semiannually to achieve the required LLD. SHEQMS Volume IV, Health Physics Manual currently provides the instructions for environmental radon gas monitoring. In addition to the manufacturer's Quality Assurance program, CBR will expose one duplicate radon Track Etch cup per monitoring period. The quality of sample collection and analysis shall be maintained by adhering to QC procedures discussed in Section ~~5.7.9~~5.7.10 and LLD concentration limits discussed in Section 2.9.2.4.

~~Monitoring of radon gas releases from the satellite facility building and ventilation discharge points is not deemed to be practicable. Section 3.3 of RG 8.37 indicates that, where monitoring effluent points is not practicable, an estimate can be made of the magnitude of these releases, with such estimated releases used in demonstrating compliance with the annual dose limit. In 10 CFR 20.1302, allowance is made for demonstrating by measurement or calculation that the TEDE to the individual likely to receive the highest dose from licensed operations does not exceed the annual dose limit of 100 mRem.The satellite facility would use pressurized downflow IX columns, which do not routinely release radon gas except during resin transfer and column backwashing. The design and operation of these systems result in the majority of the radon in the production fluid staying in solution and not being released from the columns. Radon may be released from occasional venting of process vessels and tanks, small leaks in IX equipment, and during maintenance of equipment. Therefore, releases via the vent stacks would not have a consistent concentration of radon or flow rate, making it impracticable to try to use such data for public exposure estimates.~~

CBR has used MILDOS-AREA to model the dose from facility operations resulting from releases of radon gas (Savignac 2014). MILDOS-AREA outputs are presented in **Appendix M,** and are discussed in Section 7.3.3. In determining the source term for MILDOS-AREA for the satellite facility, radon gas release was estimated at 25 percent of the radon-222 in the production fluid from the wellfields and an additional 10 percent in the IX circuit in the satellite building. The release of radon-222 at this concentration did not result in significant public dose.

~~Environmental monitoring and estimated release of radon from process operations will be reported in the semi-annual reports required by 10 CFR § 40.65 and License SUA-1534 License Condition Number 12.1.~~Prior to operation, CBR will submit a figure showing the sampling locations of the tank vents and general ventilation discharge points to the NRC for review.

Wellhouses

Radon emissions from wellhouses will be estimated based on the following assumptions and measurements. The concentration of radon in air released from the wellhouse will be based on radon measurements taken within the wellhouse utilizing Track Etch cups with a six month exposure time. The average semi-annual radon concentrations will be used along with the manufacture's rating on the wellhouse exhaust fan to determine the total radon released from the wellhouse. This assumes that all radon in the wellhouse is released into the environment at a rate of the exhaust fan. The exhaust fans in the wellhouses are operated on a continual basis.

A maximum of four production and four restoration wellhouses will be monitored as described above. The average radon emission per wellhouse will be attributed to the remaining operational

wellhouses in each group. The emissions from the operational wellhouses will be totaled on a semi-annual basis and reported in the semi-annual report consistent with the requirements of 10 CFR 40.65.

Emissions of particulate radionuclides will be estimated based upon semi-annual isotopic analysis of filters used for semi-annual air particulate in air samples in each of the wellhouses that are monitored for radon. The wellhouse exhaust rate will be based on the manufactures rating on the fans in the wellhouses. The total of all of the operational wellhouses emissions will be reported in the semi-annual report consistent with the requirements of 10 CFR 40.65. No more than four production and four restoration wellhouses will be monitored annually.

Wellfields

Injection wells have sealed wellheads and the potential for radon release is minimal. Potential emission of radon in the wellfield is limited to the production wells; however this source is also minimal. The release of radon from production wells is considered to be negligible. The submersible pumps are positioned just above the production zone of the wellfield. These submersible pumps are extracting production fluids containing dissolved radon from the formation and transfer these solutions to the nearest wellhouse through a closed poly pipe line under pressure. This production fluid is the source of the radon measured in the wellhouses.

The stagnant nature of the fluid above the pump lacks the turbulence to release a significant amount of radon gas into the well bore above the fluid surface. The stagnant water in the well above the pump is raised or lowered within the well bore by atmospheric conditions or changes in pump flow rates. These minor changes in the water level in the wellbore are the only means to exhaust gases from the production wellhead. Given the small volume of gas and the low concentration of radon in this gas, the radon released from the production wells is minor when compared to the quantity released from the satellite facility and the wellhouses. Because the production fluid is the main source of radon measured in the wellhouses, a separate reporting of radon from the production wells will not be included in the release calculations.

A potential source of radon emitted from the wellheads and piping occurs when the wellheads are opened to the atmosphere to depressurize a wellhead that has become pressurized. Because this situation is transient and very short lived, in addition to being highly localized, emissions from this situation will be measured through the use of grab samples collected with scintillation cells. Sampling of at least one well per quarter will be planned to determine the radon concentration in the gases released during depressurization of the wellhead. These samples will be collected in the airstream being vented from the well. The volume of gas will be calculated based on the casing volume and well pressure. The casing volume will assume the casing diameter and the average length of the casing from ground surface to the top of the screen for each mine unit.

The other potential source of radon release from the wellfields is the unplanned releases of process fluid resulting from spills in the wellfield. The amount of radon released as a result of a spill will be estimated based on the volume of fluid released and an estimate of the radon concentration in that fluid. The concentration of radon in the fluid will be based on the calculations used to determine the radon concentration in production fluid by the program MILDOS. While the quantity of radon released as a result of spills in the wellfields is minor this procedure will represent a conservative estimate of the radon released.

The quantity of radon released from the satellite facility, wellhouses, well venting, and spills will be summarized on a semi-annual basis and reported in the semiannual report consistent with the requirements of 10 CFR 40.65.

~~5.7.6.3~~5.7.7.3 Surface Soil

Surface soil will be sampled as described in Section 2.9. Surface soil samples will be taken at the monitoring locations (MAR-1 through MAR-6) during operations (Table 5.7-1). Following conclusion of operations, samples will be collected and compared to the results of the PPMP. Samples shall be analyzed for natural uranium, radium-226, ~~thorium-230,~~ and lead-210.

Surface soil will also be sampled at the satellite plant location as described in Section 2.9. Surface soil samples will be taken following conclusion of operations and compared to the results of the PPMP. The quality of sample collection and analysis shall be maintained by adhering to QC procedures and LLD concentration limits discussed in Section 2.9.6.

~~5.7.6.4~~5.7.7.4 Subsurface Soil

Subsurface soil will be sampled at the facility location as described in Section 2.9. Subsurface soil samples will be taken following conclusion of operations and compared to the results of the PPMP. The quality of samples shall be maintained by following QC procedures discussed in Section ~~5.7.9~~5.7.10 and adhering to the LLD concentration limits discussed in Section 2.9.6.

~~5.7.6.5~~5.7.7.5 Vegetation

Samples of vegetation will be collected three times during the grazing season at each air monitoring station presented on Figure 2.9.2. These air monitoring locations are located in three different sectors having the highest predicted airborne radionuclide concentrations due to ISR operations, which is a siting criterion for the air monitoring stations. Justification regarding the placement of these air monitoring stations as they apply to recommendations in RG 4.14 is provided in Section 2.9.2. The samples of vegetation will be analyzed for radium-226 and lead-210.

Based on MILDOS-AREA results that show the total effective dose equivalent (TEDE) from all pathways is less than 5% of the applicable radiation protection standard (the modeled dose to potential maximally exposed member of the public is approximately 27 mrem/year), CBR does not believe that the ingestion pathways from grazing animals is a potentially significant pathway exceeding 5% of the applicable radiation protection standard. However, CBR will sample vegetation during the first year of operations for comparison to the baseline data. If analysis and MILDOS-AREA determine that there is not a significant pathway, CBR will propose to modify the monitoring plan to remove the sampling of vegetation or forage from the operational monitoring program. This is consistent with recommendations contained in RG 4.14.~~Operational Environmental Monitoring Approach~~

~~At the existing Crow Butte Operation and its Smith Ranch Highland operation in Wyoming, Cameco provided long-term data and demonstrated to the NRC that annual vegetation sampling~~

~~and surface soil sampling at the air monitor locations was not required because increases in concentrations above baseline levels were not occurring.~~

~~In light of that experience, Cameco is proposing to employ media sampling (soil and sediment, addressed above) to identify increasing concentration trends that may require additional dose evaluation and sampling. Given the pathway dynamics, increasing detectable concentrations in the soil and sediment media will occur earlier and to a larger extent than the more attenuated levels present in the contact media (forage, food crops, livestock, and fish).~~

~~Vegetation (Forage)~~

~~At Marsland, the wind transport/deposition mechanism for contaminants ends up either in the surface soil, surface water, or as folial deposition on forage. Forage may then uptake contaminates in surface soil and shallow subsurface soil. As an alternate approach to operational vegetation (forage) sampling at Marsland, Cameco proposes to use soil samples taken annually from gardens in the AOR to identify uptake trends in foliage radionuclide concentrations. If increasing concentrations are noted, Cameco will further evaluate the dose implications and if appropriate propose additional forage sampling for NRC written verification.~~

~~Surface water flows at Marsland are not suitable for ongoing monitoring given the highly sporadic nature of flows in the otherwise dry drainages. Sediment is the best media to track wind transport and dispersion of contaminants in lieu of operational surface water sampling. Cameco proposes to use the annual sediment samples to identify potential uptake trends in foliage radionuclide concentrations. If increasing concentrations are noted, Cameco will further evaluate the dose implications and, if appropriate, will propose additional forage sampling for NRC written verification.~~

~~Folial deposition is periodic in nature and occurs only for a portion of each year; any deposited contaminants are either grazed or harvested each year or the forage dies over the winter and is eventually returned to the soil column. In contrast, surface soil samples collected annually accumulate deposited contamination and increase the likelihood that rising trends will be detected.~~

~~As an alternate approach at Marsland, Cameco proposes to use the annual surface soil samples collected at the air monitoring locations to identify trends in airborne deposition of radionuclides. If increasing concentrations are noted, Cameco will further evaluate the dose implications and, if appropriate, propose additional forage sampling to NRC for written verification.~~

~~5.7.6.6~~5.7.7.6 Food ~~Crops, Livestock, and Fish~~

~~Food~~ Crops ~~(garden vegetables)~~

Based on MILDOS-AREA results that show the total effective dose equivalent (TEDE) from all pathways is less than 5% of the applicable radiation protection standard (the modeled dose to potential maximally exposed member of the public is approximately 27 mrem/year), the ingestion pathway from crops would not likely exceed 5% of the applicable radiation protection standard. If the pre-operational crop results described in Section 2.9.5.2 supported by MILDOS-AREA modeling demonstrate no significant exposure pathway, CBR will propose to modify the monitoring plan to remove the sampling of crops from the operational monitoring program. This approach is consistent with the recommendations contained in RG 4.14. ~~As an alternate approach~~

~~to operational food crop sampling at Marsland, Cameco proposes to use soil samples taken annually from gardens in the AOR to identify trends in food crop radionuclide concentrations. If increasing concentrations are noted, Cameco will further evaluate the dose implications and, if appropriate, propose additional food crop sampling to the NRC for written verification.~~

Livestock

CBR commits to collecting livestock samples annually consistent with guidance contained in RG 4.14. Livestock samples will be collected and analyzed for uranium (natural), thorium-230, radium-226, lead-210 and polonium-210. If the analysis of livestock tissue supported by the annual MILDOS-AREA modeling indicates grazing animals demonstrate no significant exposure pathway, CBR will propose to modify the monitoring plan to remove livestock from the operational monitoring program. This approach is consistent with the recommendations contained in RG 4.14, Table 2, footnote "o". ~~Similar to the above proposals, as an alternate approach for operational livestock sampling, Cameco proposes to use the approach described above for forage and crops to trigger further evaluation of the dose implications. If appropriate, Cameco will propose additional livestock sampling to NRC for written verification.~~

Fish

Due to the arid nature of the area in which the MEA is located, the dry drainages that traverse to MEA license boundary do not support a fish population. The two major ephemeral drainages eventually connect to the Niobrara River, which is the nearest stream with permanent water. The river is located south of the license boundary, flowing west to east. The Box Butte Reservoir is located on the Niobrara River approximately 3.5 miles (5.6 km) from the southeastern corner of the MEA license boundary. The storm water controls (berms) employed at the Marsland operation will prevent the discharge of liquids into the ephemeral drainages. Any spills that could occur would be contained per the site spill control plans, and it is highly unlikely that any liquid spills would ever reach the Niobrara River. However, at certain times of the year, the Niobrara River may gain flow from Brule or Arikaree groundwater. If those sources of groundwater were contaminated, it could impact fish. Therefore operational fish samples will be collected from Box Butte Reservoir per **Table 5.7-1**.

Game Animals

Due to the migratory nature, small herd size and relatively large home range of game animals in relation to the size of the project area, game animals are not a significant pathway to man, which RG 4.14 lists as a criterion for sampling in the operational monitoring program. This will be confirmed through annual MILDOS-AREA modeling.

~~5.7.6.7~~5.7.7.7 Direct Radiation

Environmental gamma radiation levels will be monitored continuously at the air monitoring stations (MAR-1 through MAR-6) during operations. Gamma radiation will be monitored using environmental dosimeters obtained from an NVLAP certified vendor. Dosimeters will be exchanged quarterly.



~~5.7.6.8~~5.7.7.8 Sediment

Sediment samples will be collected annually at the sample locations described in Section 2.9 and shown in **Figure 2.7-4**. Samples will be collected as described in Section 2.9.7 and analyzed for natural uranium, radium-226, thorium-230, and lead-210. The quality of sample collection and analysis shall be maintained by adhering to QC procedures as discussed in Section ~~5.7.9~~5.7.10 and LLD concentration limits discussed in Section 2.9.7.1.

~~5.7.7~~5.7.8 Groundwater/Surface Water Monitoring Program

~~5.7.7.1~~5.7.8.1 Program Description

During operations at the satellite facility, a detailed water sampling program will be conducted to identify any potential impacts to water resources of the area. The CBR operational water monitoring program includes the regional evaluation of groundwater, groundwater within the permit or licensed area, and surface water on a regional and site-specific basis. The quality of sample collection and analysis shall be maintained by adhering to QC procedures discussed in Section 5.7.10~~9~~.

~~5.7.7.2~~5.7.8.2 Groundwater Monitoring

The groundwater excursion monitoring program is designed to detect excursions of lixiviant into the ore zone aquifer outside of the wellfield being leached and into the overlying water-bearing strata. Monitor wells will be placed in the basal sandstone of the Chadron Formation and in the overlying Brule and Arikaree aquifers. All monitor wells will be completed by one of the three methods discussed in Section 3.1.2.2, developed prior to recovery solution injection. The development process for monitor wells includes establishing baseline water quality before the initiation of mining operations.

The Pierre Shale below the ore zone is more than 1,200 feet thick and contains no water-bearing strata. Therefore, it is not necessary to monitor any water-bearing strata below the ore zone.

~~5.7.8~~5.7.9 Private Well Monitoring

During operations, on a quarterly basis, all active, operational and accessible private wells located within the MEA license boundary and within 0.62 mile (1 km) of the MEA license boundary will be monitored (**Figures 2.7-6 and 2.9-3**). Groundwater samples are taken in accordance with the instructions contained in SHEQMS Volume VI, Environmental Manual, and samples are analyzed for natural uranium and radium-226. Water well samples will be collected and analyzed as described in Section 2.9.3.1.

~~5.7.8.1~~5.7.9.1 Monitor Well Baseline Water Quality

After delineation of the production unit boundaries, monitor wells are installed no further than 300 feet from the wellfield boundary and no further than 400 feet apart or as required by the NDEQ. After completion, wells are washed out and developed (by air-lifting or pumping) until pH and specific conductivity appear stable and consistent with the anticipated quality of the area. After development, wells are sampled to obtain baseline water quality data. For baseline sampling, wells



- A preliminary investigation is completed to determine the probable cause.
- Production and/or injection rates in the vicinity of the monitor well are adjusted as necessary to increase the net over recovery, thus forming a hydraulic gradient toward the production zone.
- Individual wells are pumped to enhance recovery of mining solutions.

Injection into the wellfield area adjacent to the monitor well may be suspended. Recovery operations continue, thus increasing the overall bleed rate and the recovery of wellfield solutions.

In addition to the above corrective actions, sampling frequency of the monitor well on excursion status is increased to weekly. An excursion is considered concluded when the concentrations of excursion indicators do not exceed the criteria defining an excursion for three consecutive 1-week samples.

Surface Water Monitoring

Whenever sufficient flow is available for sampling in the ephermal drainages, surface water samples will be collected from the main drainage channel as described in Section 2.9. In addition, a seventh location MED-7 has been added where one of the two ephemeral drainages leaves and then quickly re-enters the license boundary. In the Niobrara River, samples will be collected quarterly and analyzed for dissolved and suspended natural uranium, radium-226, thorium-230, lead-210, and polonium-210. The seven sample locations are shown on **Figure 2.7-4.** The quality of sample collection and analysis shall be maintained by adhering to QC procedures discussed in Section 5.7.10~~9~~ and LLD concentration limits discussed in Section 2.9.4.5.

Surface water samples will be taken in accordance with the instructions contained in SHEQMS Volume VI, Environmental Manual. Upstream and downstream samples from all locations will be obtained quarterly. Surface water samples are analyzed for the parameters identified in Section 2.9. Surface monitoring results are submitted in the semi-annual environmental and effluent reports submitted to NRC.

~~5.7.9~~5.7.10 Quality Assurance Program

A quality assurance (QA) program is in place at Crow Butte Uranium Project for all relevant operational monitoring and analytical procedures. The objective of the program is to identify any deficiencies in the sampling techniques and measurement processes so that corrective action can be taken and to obtain a level of confidence in the results of the monitoring programs. The QA program provides assurance to both regulatory agencies and the public that the monitoring results are valid.

The QA program addresses the following:

- Formal delineation of organizational structure and management responsibilities. Responsibility for both review/approval of written procedures and monitoring data/reports is provided
- Minimum qualifications and training programs for individuals performing radiological monitoring and those individuals associated with the QA program

Redline Changes – Section 6

MEA TR

Reponses to Open Issues

6-29-2017



During restoration, sampling and analysis will be conducted in accordance with the operational groundwater monitoring program described in Section 5.7.8 and 5.7.~~9~~10. Consistent with the Class III UIC Permit, the specifics of the restoration monitoring are provided in a restoration plan for each MU or group of MUs for submission to the NDEQ.

6.1.3.1 Establishment of Baseline Water Quality

In addition to pre-operational baseline groundwater monitoring, before mining in each MU, the baseline groundwater quality is determined. The baseline data are established in each MU by assigning and evaluating groundwater quality in "baseline restoration wells". A minimum of one baseline restoration well for each 4 acres, but not fewer than six wells total for each MU, are sampled to establish the MU baseline water quality. A minimum of four samples are collected from each well. The samples are collected at least 14 days apart. The samples are analyzed for the parameters listed in **Table 6.1-1**.

Table 2.7-5 is the restoration tables for MU-1 in the current commercial license area. This is provided as an example of the 11 restoration tables for MU-1 through MU-11. These tables provide the baseline average and the range for all restoration parameters as well as the NDEQ restoration standard approved for that MU in the NOI. Similar tables will be provided for the MEA mine units at the appropriate time to address restoration activities.

6.1.3.2 Establishment of Restoration Goals

The baseline data are used to establish the restoration standards for each MU. As previously noted, the primary goal of restoration is to return the MU to PPMP water quality condition on an MU average. Because ISR operations alter the groundwater geochemistry, it is unlikely that restoration efforts will return the groundwater to the precise water quality that existed before operations.

Restoration goals are established by NDEQ to ensure that, if baseline water quality is not achievable after diligent application of best practicable technology (BPT), the groundwater is suitable for any use for which it was suitable before mining. NRC considers these NDEQ restoration goals as the secondary goals. The NDEQ restoration values are established for each MU and are approved with the NOI to Operate submittals according to the following analyses:

- For parameters that have numerical groundwater standards established in Title 118 (NDEQ 2006). The restoration goal is based on the Title 118 Maximum Contaminant Level (MCL).
- If the baseline concentration exceeds the applicable MCL as noted above, the standard is set as the MU baseline average plus two standard deviations.
- If there is no MCL for an element (e.g., vanadium), the restoration value is based on a wellfield average of the PPMP sampling data. Normal statistical procedures will be used to obtain the average.
- The restoration values for the major cations (calcium, magnesium, potassium, and sodium) allow the concentrations of these cations to vary by as much as one order of magnitude as long as the TDS restoration value is met. The total carbonate restoration criterion allows for the total carbonate to be less than 50 percent of the TDS. The TDS restoration value is set at the baseline MU average plus one standard deviation.



clean-up criteria for thorium-230 will be developed using the radium-226 Benchmark Approach and submitted to the NRC for approval prior to final site decommissioning.

6.4.2 Surface Soil Cleanup Verification and Sampling Plan

Cleanup of surface soils will be restricted to areas where there are known spills and, potentially, small spills near wellheads. ~~Final GPS-based gamma surveys will be conducted in potentially contaminated areas, including 10-m buffer zones.~~ CBR commits to meeting the soil cleanup criteria established in 10 CFR 40 Appendix A, Criterion 6(6). CBR will follow survey methodology as described in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM).

CBR will divide the area systematically into 100 m^2 grid blocks and sample all grid blocks containing gamma count rates exceeding~~the average background~~ gamma action level ~~exposure rate~~ (~~Tetra Tech Report – **Appendix BB**~~**Appendix N**). The samples will be five-point composites, and analyzed at an offsite analytical laboratory for radium-226 and natural uranium. CBR will sample the remaining grid blocks with average gamma count rates ranking in the top 10 percent.

If any grid blocks within the top 10 percent fail the cleanup criteria, CBR will sample the second 10 percent of grid blocks. This will continue until all grid blocks pass within a 10 percent grouping. To meet the cleanup criterion, each of the sampled grid blocks must satisfy the following inequality:

$$\sum \frac{C_i}{Cc} < 1$$

Where, C_i is the concentration of the constituent and C_c is the concentration of the constituent that is equivalent to the Benchmark Dose.

CBR will remediate the grid blocks failing this inequality or propose alternatives consistent with Appendix A of 10 CFR 40.

After all sampled grids have met the inequality rule; an NRC-approved statistical test will be conducted to demonstrate that the survey method provides for a 95-percent confidence level that cleanup guidelines have been met, as per acceptance criteria 6.4.3 of NUREG-1569 (NRC 2003). An appropriate statistical test for analysis of the survey data as described in NUREG-1575 ("Multi-Agency Radiation Survey and Site Investigation Manual") will be utilized (NRC 2000). If the mean of the sample concentrations is lower than the criterion but the data fail the statistical test, CBR will follow procedures similar to those recommended in NUREG-1575.

6.4.3 Subsurface Soil Cleanup Verification and Sampling Plan

For subsurfaces CBR will adopt different survey and sample protocols, depending on the type and size of excavation. CBR will rely on sampling and analysis of radium-226 and natural uranium over surveying, to verify cleanup of subsurface excavations. The protocols will be submitted to the NRC for approval prior to post-reclamation and decommissioning.

Redline Changes – Section 7

MEA TR

Reponses to Open Issues

6-29-2017



- Each resin hauling truck will be equipped with a radio that can communicate with either the CPF or the satellite facility. In the event of an accident and spill, the driver can radio to both sites to obtain help.
- A check-in and check-out procedure will be instituted where the driver will call the receiving facility prior to departure from his location. If the resin shipment fails to appear within a set time, a crew would respond and search for this vehicle. This system will ensure a reasonably quick response time in the case that the driver is incapacitated in the accident.
- Each resin transport vehicle will be equipped with an emergency spill kit that the driver can use to begin containment of any spilled material.
- Both the satellite and central process facilities will be equipped with emergency response packages to quickly respond to a transportation accident.
- Personnel at the satellite and central process facilities, as well as the designated truck drivers, will have specialized training to handle an emergency response to a transportation accident.

7.5.6 Natural Disaster Risk

NUREG/CR-6733 evaluates the potential risks to an ISR facility from natural disasters. Specifically, the risk from an earthquake and a tornado strike were analyzed. NRC determined that the primary hazard from these natural events was from dispersal of yellowcake from a tornado strike and failure of chemical storage facilities and the possible reaction of process chemicals during either event. NUREG/CR-6733 recommended that licensees follow industry best practices during design and construction of chemical facilities. CBR is committed to following these standards.

7.5.6.1 Tornado Risk

NUREG/CR 6733 evaluates tornado risks associated with ISL facilities for the release of radioactive materials or hazardous chemical due to the effects of a tornado. ~~It was determined that in the event of a tornado strike, chemical storage tanks could fail result in the release of chemicals.~~ NUREG/CR 6733 ~~This guidance document~~ ; concluded the risk of a tornado strike on an ISL facility was very low, that structures (e.g. buildings, wellhouses) at ISL facilities were not designed to withstand tornado winds, a conservative assessment of yellowcake dispersal by a tornado resulted in negligible radiological consequence and that no design or operational changes were necessary to mitigate the potential risks.

NUREG/CR 6733 determined that in the event of a tornado strike, chemical storage tanks could fail resulting in the release of chemicals and i~~However, i~~t was important to locate chemical storage tanks far enough from each other to prevent contact of reactive chemicals in the event of an accident. During the final design phase, CBR will assess the location(s) and construction of chemical storage tanks and containment features in order to reduce the risk of potential leaks caused by tornado damage which may result in harmful chemical reactions. CBR will have separate containment berms around storage tanks to reduce the risk of mixing of incompatible chemicals in the event of a spill.

~~I~~~~The Crow Butte operation is located in an area subject to tornadoes. The site is located i~~n Dawes County, ~~Nebraska in which five~~ eight tornadoes ~~touch downs~~touched down ~~were reported during the period from~~of 2000 ~~and~~ to 2017~~2~~ ~~-~~between the months of May and August (NOAA 2017~~2~~). None of these tornadoes occurred in the MEA. One magnitude EF1 (Enhanced Fujita scale) tornado occurred June 11, 2013, near the Box Butte Reservoir. Based on local reports several small structures sustained minor damage or were destroyed (The Chadron Record 2013). The other seven ~~The five~~ tornadoes ~~events~~ were ~~did not exceed~~ a magnitude F0 and/or EF0 (Fujita or Enhanced Fujita scale). ~~(F- or EF-scale, respectively) magnitude of F0 or EF0~~ ~~and~~ According to NOAA, no injuries, deaths, property or crop damage occurred (NOAA 2017). ~~According to the Fujita Tornado Damage Scale, a typical F0 tornado event will exhibit wind estimates less than 73 mph and produce light damage to the surrounding area.~~ Most tornado events were reported to have taken place in open country, rangeland, and wooded areas. ~~One of the tornados reported in Chadron had a magnitude of EF0 and produced damage to a tree and a windmill. The tornado events had damage paths ranging from 0 to 0.4 miles (3.6 km) in length and had path widths ranging from 20 to 30 yards. Although Dawes County can be considered relatively weak in tornado risk, surrounding counties such as Sheridan County have been known to have tornado events classified as F1.~~ From 2000 to 2017~~Within the same time period~~, nearby Sheridan County experienced an F1 and an EF2 tornado ~~that~~ causinged approximately $~~150~~175,000 in total property damage. EF0 wind scale ranges from 65-85 mph, EF1 wind scales range from 86-110 mph and EF2 wind scales range from 110-137 mph (NOAA 2017).

Tornadoes are rare in the Marsland Expansion Area. In the USNRC, "Draft Generic Environmental Impact Statement on Uranium Milling" (USNRC 1980), the authors calculated a mean annual frequency of 0.6 for tornadoes in intensity Category I at Rapid City. A tornado in intensity Category I has a rotational speed of 134 meters per second (m/s) and a translational speed of 26 m/s. The annual probability of occurrence at the MEA is calculated at 1.05×10^{-3} with a mean annual frequency of 1.3 (H. Thom 1963).

~~It has been concluded that tornado risk in Dawes County is relatively low compared to the surrounding region. Dawes County historical area-adjusted tornado activity is significantly below Nebraska state average, and is 1.6 times below the overall U.S. average (City-Data 2012). The tornado index, a measure of the probability of tornado events and calculated using historical tornado events data and USA.com algorithms, was 205.07 for the State of Nebraska as a whole and 64.92 for Dawes County (USA.com 2013). During the final design phase, CBR will assess the location(s) and construction of chemical storage tanks and containment features in order to reduce the risk of potential leaks caused by tornado damage which may result in harmful chemical reactions.~~

CBR emergency procedures currently contained in the SHEQMS Volume VIII, Emergency Manual, provide instructions for response and mitigation of natural disasters and spills or radioactive materials. Mitigation of damage due to tornado activity (structure damage, spills, radioactive materials, etc.) is described throughout the SHEQMS Volume VIII, Emergency Manual. CBR's Emergency Manual contains emergency provisions such as notification to personnel of severe weather; evacuation procedures, security plans and threats associated with source material, medical emergencies, damage inspection/assessment and reporting, and cleanup and mitigation of spills of chemicals. ~~CBR will have separate containment berms around storage tanks to reduce the risk of mixing of incompatible chemicals in the event of a spill.~~ In addition, the site's SOPs, training and personnel protective equipment will be available to personnel for response and mitigation of hazardous chemical releases.

Table 2.9-31	Summary of Radiological Baseline Data for Niobrara River Near Marsland Expansion Area Collected by Crow Butte
Table 2.9-32	Marsland Expansion Area Vegetation Seasonal Radiological Laboratory Analysis
Table 2.9-33	Radionuclide Analyses for Livestock Samples
Table 2.9-34	Daily Contents in Acre-Feet of Water for Box Butte Reservoir (USGS 06455000)– 2003 to 2013
Table 2.9-35	Range Values for Box Butte Reservoir Water Contents
Table 2.9-36	~~Wet-weight Vegetable Concentrations from Dry-weight Soil Concentrations~~MEA Garden Soil Radiological Laboratory Analysis
Table 2.9-37	Total Radionuclides and Metals in Tissue of Northern Pike Collected from Inlet of Box Butte Reservoir
Table 2.9-38	Radionuclide and Metal Analyses for Niobrara River Sediment Sample Locations N-1 and N-2
Table 2.9-39	Radionuclide and Metal Analyses for Marsland Ephemeral Drainage (MED) Sediment Sample Locations
Table 2.9-40	Marsland Expansion Area Gamma Exposure Results
Table 2.9-41	Marsland Expansion Area Preoperational/Preconstruction Monitoring Program
Table 2.9-42	Marsland Expansion Area Radiological Analytical Results (Q4 2013 - Q3 2014) – Arikaree Wells
Table 2.9-43	Marsland Expansion Area Non-Radiological Analytical Results (Q4 2013 - Q3 2014) – Arikaree Wells
Table 3.1-1	Background Information for Logging Probes Used at the Marsland Expansion Area
Table 3.1-2	Summary of Risk of Erosion for Proposed Marsland Expansion Area Mine Units
Table 3.1-3	The Peak Flow for Hydrologic Project South
Table 3.1-4	The Peak Flow for Hydrologic Project East
Table 3.1-5	Typical Lixiviant Concentrations
Table 3.1-6	Lixiviant Parameters Measured in the Injection Stream at Crow Butte MU-3, MU-4, MU-5, and MU-6
Table 3.1-7	Disposal Water Balance (Marsland Expansion Area)
Table 4.2-1	Deep Disposal Well No. 1 Injection Radiological Data for Crow Butte Central Processing Facility (2008-2012)
Table 4.2-2	Deep Disposal Well No. 2 Injection Radiological Data for Crow Butte Central Processing Facility 2012
Table 4.2-3	Deep Disposal Wells Injection Non-Radiological Data for Current Crow Butte Operations for 2012
Table 5.7-1	Marsland Expansion Area Operational Effluent and Environmental

Figure 2.6-3t	Expanded Marsland Cross-Section A – A' Panel 6
Figure 2.6-3u	Expanded Marsland Cross-Section E – E'
Figure 2.6-4	Marsland Expansion Area Coring Location
Figure 2.6-5	Marsland Expansion Area Type Log (M-1252)
Figure 2.6-6	Marsland Isopach Map – Arikaree Group
Figure 2.6-7	Marsland Isopach Map – Brule Formation
Figure 2.6-8	Marsland Isopach Map – Upper and Middle Chadron Formation
Figure 2.6-9	Marsland Isopach Map – Basal Sandstone of the Chadron Formation
Figure 2.6-10	Marsland Structure Map — Top of Brule Formation
Figure 2.6-11	Marsland Structure Map – Top of Chadron Formation
Figure 2.6-12	Marsland Structure Map – Top of Basal Sandstone of the Chadron Formation
Figure 2.6-13	Marsland Structure Map – Top of Pierre Shale
Figure 2.6-14	Regional Structure Contour Map – Top of Pierre Shale
Figure 2.6-15	Location of Chadron Arch and Cambridge Arch in Nebraska
Figure 2.6-16	Structural Features Map of the Crawford Basin
Figure 2.6-17	Earthquake Hazard Ranking in the U.S.
Figure 2.6-18	Seismic Hazard Map for Nebraska (2008)
Figure 2.6-19	Seismicity of Nebraska 1973 – 2013
Figure 2.6-20	Soils
Figure 2.6-21	Regional Geologic Cross-Section Location Map
Figure 2.6-22	Regional Geologic Cross-Section R0-R0'
Figure 2.6-23	Regional Geologic Cross-Section R1-R1'
Figure 2.6-24	Regional Geologic Cross-Section R2-R2'
Figure 2.7-1	Nebraska's Major River Basins
Figure 2.7-2	Niobrara River Basin (And Subbasins)
Figure 2.7-3	Niobrara River Subbasin N14
Figure 2.7-4	~~Surface Water/Sediment, Vegetable Garden and Livestock~~ Sampling Locations
Figure 2.7-5	Mirage Flats Project, Nebraska
Figure 2.7-6	Major Surface Features/Structures Within AOR as per Title 122, Chapter 11, Section 006.09
Figure 2.7.7	Marsland Expansion Area Pumping Test Well Locations
Figure 2.7-8	Marsland Arikaree and Brule Monitor Wells
Figure 2.7-9	Location of MEA Active, Inactive, and Abandoned Chadron Monitor Wells That Penetrate the Injection Zone
Figure 2.8-1	Wetland and Vegetation

Appendices (Volume II & Volume III)

Appendix A	Water User Survey Information for Water Supply Wells within 2.25-Mile Area of Review
Appendix B	Calibration Records for Marsland Expansion Area Meteorological Station
Appendix C	Geophysical Boring Logs
Appendix D	Well Plugging and Abandonment Records
D-1	Oil and Gas Plugging Records
D-2	Water Well Abandonment Records
Appendix E	Water Well Registration and Completion Records
E-1	Water Well Registration Records
E-2	Water Well Completion Reports
Appendix F	Pump Test # 8 Report
Appendix G	Mineralogical and Particles Size Distribution Analyses
Appendix G-1	Mineralogical and Particles Size Distribution Analyses (2011)
G-2	Mineralogical and Particles Size Distribution Analyses (2013)
Appendix H	Flora and Fauna Lists
H-1	Plant Species List
H-2	Mammal Species List
H-3	Bird Species List
H-4	Amphibian and Reptile Species List
H-5	Fish Species List
H-6	Macroinvertebrate Species and Relative Abundance
H-7	Range Maps for State and Federally Listed Threatened and Endangered Species for Dawes County, Nebraska
Appendix I	Standard Operating Procedures for Air Particulate Samplers
Appendix J	Groundwater Analytical Lab Results
Appendix K	Hydrologic, Erosion and Flood Study Reports for Marsland Expansion Area
K-1	Hydrologic and Erosion Study Report for Marsland Expansion Area
K-2	Hydrologic and Flood Study for Marsland Expansion Area
Appendix L	Crow Butte Solubility Characteristics of Crow Butte Yellowcake
Appendix M	MILDOS Analysis for Marsland Expansion Area
Appendix N	Wellfield Decommissioning Plan for Marsland Expansion Area~~Crow Butte Uranium Project~~
Appendix O	Swift Fox Survey Protocol

Appendix P	Cost Estimate for Decontamination, Decommissioning and Reclamation of Proposed Marsland Expansion Area (One Mine Unit)
Appendix Q	MEA Baseline Crop and Vegetation Sampling Analytical Data
Appendix R	Siting of Meteorological Instruments
Appendix S	Justification for Use of 15 Years of Scottsbluff Meteorological Data
Appendix T	Marsland Water Balance (Production, Restoration and Stabilization Sampling)
Appendix U	Air Particulate Composite Laboratory Records
Appendix V	Radiological Records
Appendix V-1	Air Sampling Pump Calibration Records
Appendix V-2	Radon (Track Etch Cups) Laboratory Records
Appendix V-3	Gamma (OLSs) Laboratory Records
Appendix W-1	Niobrara River Surface Water Laboratory Records
Appendix W-2	Niobrara River and Ephemeral Drainages Sediment Laboratory Records
Appendix X	Niobrara River Fish Tissue Laboratory Records
Appendix Y	Cameco Evaluation of Site Ventilation Systems
Appendix Z	Three Crow Expansion Area Cross-Sections
Appendix AA-1	MEA Agricultural Well Impact Analysis
Appendix AA-2	Validation of Agricultural Well Impact Analysis
Appendix AA-3	AquiferTek Hydraulic Containment (October 2015)
Appendix BB	MEA Baseline Radiological Investigation Report – Tetra Tech
Appendix CC	Garden Analysis and Polonium LLD Evaluation
Appendix DD	Livestock Analytical Data
Appendix EE	Kozeny-Carman Calculations
Appendix FF	Quarterly Water Level Data – MEA
Appendix GG	Drawdown Impact Assessment MEA
Appendix HH	Deep Brule Monitor Well Installation Program

Linder, Director, Department of Environmental Quality, Lincoln, Nebraska regarding a request for approval of the 2013 surety estimate. September 28.

Cameco Resources, Crow Butte Operation. (CBR). Crow Butte Materials License SUA-1534, Docket No. 40-8943. November 2014.

Caribbean Disaster Emergency Response Agency (CDERA). 2009. CDERA Virtual Disaster Library – *Earthquakes and Seismic Activity*. [Web Page]. Located at: http://www.cdera.org/doccentre/fs_earthquakes.php. Accessed on: December 30, 2009.

Carrier, W. David, III. 2003. Goodbye Hazen; Hello, Kozeny-Carman. Journal of Geotechnical and Geo-environmental Engineering, Vol. 129, No. 11, November 2003, pp. 1054-1056.

Center for Earthquake Research and Information (CERI). 2010. Recent Earthquakes in Central US. [Web Page] Located at: http://folkworm.ceri.memphis.edu/recenteqs/ Accessed on: February 20, 2010.

Center for Nuclear Waste Regulatory Analyses (CNWRA). 2001. NUREG/CR–6733, *A Baseline Risk-Informed, Performance-Based Approach for In Situ Leach Uranium Extraction Licenses*.

Century Geophysical Corporation. 2009. Dipmeter User Guide. [Web Page]. Located at: http://www.centurywirelineservices.com/9411UG.pdf. Accessed on: April 29, 2011.

Chadron State College (CSC). 2010a. *Student Enrollment Information*. [Web Page]. Located at: http://www.csc.edu/ir/enrollment.csc. [225, 2006 and 2007 data]. Accessed on: February 25, 2010.

Chadron State College. (CSC). 2010b. *Enrollment Quick Facts*. [Web Page]. Located at: http://www.csc.edu/ir/quickfacts.csc. [2008 data]. Accessed on: February 25, 2010.

Chapman, S.S., Omernik, J.M., Freeouf, J.A., Huggins, D.G., McCauley, J.R., Freeman, C.C., Steinauer, G., Angelo, R.T., and Schlepp, R.L. 2001. Ecoregions of Nebraska and Kansas. [Web page]. Located at: ftp:/ftp.epa/gov/wed/ecoregions/ks/ksne_front.pdf. Accessed on: February 24, 2011.

City-Data.com (City-Data). 2010. *Crawford, NE (Nebraska) Houses and Residents.* [Web Page]. Located at: http://www.city-data.com/housing/houses-Crawford-Nebraska.html. Accessed on: August 18, 2011.

City-Data.com. (City-Data). 2012. Dawes County, Nebraska (NE). [Web Page]. Located at: http://www.city-data.com/county/Dawes_County-NE.html. Accessed on: March 8, 2013.

Evans, J.E. and Terry, D.O., Jr. 1994. The significance of incision and fluvial sedimentation in the Basal White River Group (Eocene-Oligocene), badlands of South Dakota, U.S.A. Sedimentary Geology, v. 90, p. 137-152.

F. G. Driscoll, Ground Water and Wells, Second Edition, (St. Paul Minnesota, Johnson Filtration Systems Inc. 1986) Chapter 9, Well Hydraulics p. 205-267.

Federal Emergency Management Agency. (FEMA). 2011. Map Service Center. [Web Page]. Located at: http://www.msc.fema.gov/webapp/wcs/stores/servlet/FemaWelcomeView?storeId=10001&catalogId=10001&langId=-1. Accessed on: October 7, 2011.

Ferraro, J. 2011. Extension Associate Professor and Herpetologist, School of Natural Resources, University of Nebraska-Lincoln. Personal communication with Hayden-Wing Associates, June 10, 2011.

Ferret Exploration Company of Nebraska. 1987. *Application and Supporting Environmental Report For USNRC Commercial Source Material License.* September 1987.

Ferris, J.G., Knowles, D.B, Brown, R. H., and R.W. Stallman (1962). Theory of Aquifer Tests, U.S. Geological Survey Water Supply. Paper 1536-E, page 174.

Fetter, C.W. 1994. Applied Hydrology, Third Edition, (Englewood Cliffs NJ, Prentice-Hall). p.257-258

Fitzgerald J.P., C.A. Meaney, and D.M. Armstrong. 1994. Mammals of Colorado. Denver Museum of Natural History, Denver, Colorado.

Florida Oceanographic Online (FOO). 2002. Earthquake Magnitude and Intensity Information. [Web Page]. Located at: http://www.floridaoceanographic.org/reference/earthquake.htm. Accessed on: December 30, 2009.

Fogell, D.D. 2010. A field guide to the amphibians and reptiles of Nebraska. University of Nebraska-Lincoln. Conservation and Survey Division, School of Natural Resources. May 2010.

Fricke, Kent A., Cover, Michael A., Hygnstrom, Scott E., Genoways, Hugh H., Groepper, Scott R., 2008. *Historic and Recent Distributions of Elk in Nebraska,* Fall 2008.

Gjelsteen, T.W., and S.P. Collings, 1988, Relationship between ground water flow and uranium mineralization in the Chadron Formation, northwest Nebraska: Wyoming Geological Association Guidebook, Thirty-ninth Field Conference, p. 271-284.

Gosselin, D. C., Headrick, J., Chen, X-H., Summerside, S. E. 1996. Regional Analysis of Rural Domestic Well-water Quality -- Hat Creek-White River Drainage Basin;

from Domestic Water-well Quality in Rural Nebraska, Nebraska Department of Health.

Graves, Adam, Natalie Graves, Maureen Boyle, and Ashley Howder. 2011. Marsland Expansion Area Uranium Project Cultural Resource Inventory. ARCADIS U.S., Inc., Buffalo, Wyoming. Prepared for Cameco Resources, Crawford, Nebraska. 152 pages plus attachments. April.

Graves, Natalie and Graves, Adam. 2012. Marsland Expansion Area Uranium Project. Prepared for Cameco Resources, Crawford, Nebraska. Addition. 11 pages plus attachments. March.

Graves, Natalie. 2011. Submittal letter to Terry Steinacher, Nebraska State Historical Society for Marsland Expansion Area Uranium Project, Cultural Resource Inventory. April 28.

Gutentag, E.D., Heimes, F.J., Krothe, N.C., Luckey, R.R., Weeks, J.B., 1984. Geohydrology of the High Plains Aquifer in Parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas and Wyoming. USGS Professional Paper 1400-B, p.63.

Haag, Justin. 2012. CSC Information Services. Rapid City Journal. January 10.

Hams, Kit. 2017. Personal communication with Teahon, L. [March 30, 2017 e-mail from Big Game Program Manager, Nebraska Game and Parks Commission, RE: Elk and Pronghorn Harvest in Ash Creek Unit. 1 page.

Hansley, P.L. and Dickinson, K.A. 1990. Uranium Mineralization Favorability in the Oligocene Chadron Formation, Southeaster Wyoming and Northwestern Nebraska. Short Paper of the USGS Uranium Workshop. p. 27-31.

Hansley, P.L., S.P. Collings, I.K. Brownfield, and G.L. Skipp. 1989. Mineralogy of Uranium Ore from the Crow Butte Uranium Deposit, Oligocene Chadron Formation, Northwestern Nebraska. USGS Open File Report 89-225.

Harksen, J.C. and Macdonald, J.R. 1969. Type sections for the Chadron and Brule Formations of the White River Oligocene in the Big Badlands of South Dakota. South Dakota Geological Survey Report of Investigations #99, p. 23.

Harlan, Casey & Associates, Inc. and Resource Technologies Group, Inc., (HCA & RTG) 1993; Hydrogeologic Review and Engineering Design for Proposed Underground Injection Well, Crow Butte Project, Dawes County, Nebraska; May 10, 1993.

Hayden, T. 2011. Supervisor, Nebraska Department of Natural Resources, Bridgeport, NE Personal communication [telephone conversation with Jack Cearley, Project Director, ARCADIS-US, Inc., Highlands Ranch, Co. Regarding availability of water quality data on the Upper Niobrara River]. August 23.

Leftwich, Josh. 2013. Letter from Director of SHEQ, Cameco Resources, Inc. to Michael Linder, Director, Nebraska Department of Environmental Quality, Lincoln, Nebraska Regarding 2014 Surety Estimate. cc: Ronald Burrows, Fuel Cycle Licensing Branch, U.S. Nuclear Regulatory Commission. September 30.

Lilligraven, J.A. 1970. Stratigraphy, structure, and vertebrate fossils of the Oligocene Brule Formation, Slim Buttress, northwestern South Dakota. Geological Society of America Bulletin, v. 81, p. 831-850.

Lindeman, G.H. 2011. Personal communication [July 27 email to J. Cearley, ARCADIS U.S., Inc., Highland Ranch, Colorado Regarding Niobrara River Flow Measurements. Nebraska Department of Natural Resources, Lincoln, Nebraska. 1 p.

Lisenbee, A.L. 1988. Tectonic history of the Black Hills uplift. *In:* Wyoming Geological Association Guidebook, 39th Field Conference, pp. 45–52. Located at: http://www.epa.gov/air/criteria.html. Accessed on: May 6, 2013.

Lombard, Teresa. 2016. Personal communication to Larry Teahon. [November 17, 2016 e-mail to Nebraska Game and Parks Commission, Hunters Helping the Hungry Program Coordinator. RE: Wild Game Samples. SHEQ Manager, Crow Butte Resources, Inc., Crawford, Nebraska. 1 page.

Lugn, A. L., 1939. Classification of the Tertiary System in Nebraska. Geological Society of America Bulletin, v. 50, p. 673-696.

MacFadden, B.J. and Hunt, Jr., R. M., 1998. Magnetic Polarity Stratigraphy and Correlation of the Arikaree Group, Arikareean (Late Oligocene-Early Miocene) of Northwestern Nebraska. *In:* Terry, D. O., Jr., LaGarry, H. E. and Hunt, R. M., eds., Depositional Environments, Lithostratigraphy, and Biostratigraphy of the White River and Arikaree Groups (Late Eocene to Early Miocene, North America): Geological Society of America Special Paper #325.

Mayer, W. M., DeOreo, W.B., Opitz, E.M., Kiefer, J.C., Davis, W.Y., Dziegielewski, B., and Nelson, J.O. 1999. Sponsored by American Water Works Association Research Foundation. (AWWARF). Residential End Uses of Water. 310 p.

National Agricultural Statistics Service. (NASS). 2009a. Census of Agriculture Volume 1 Chapter 2: Nebraska County Level Data. Issued February, 2009. [Web Page]. Located at: http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Nebraska/index.asp. Accessed July 2011.

National Agricultural Statistics Service. (NASS). 2009b. Quick Stats Nebraska County Data - Livestock. [Web Page]. Located at: http://www.nass.usda.gov/QuickStats. Accessed on: July 2011.

National Agricultural Statistics Service. (NASS). 2009c. Quick Stats Nebraska County Data-Crops. [Web Page]. Located at:

http://www.nass.usda.gov/QuickStats/PullData_US_CNTY.jsp. Accessed on: July 2011.

National Agricultural Statistics Service. (NASS). 2011. QuickStats Ad-hoc Query Tool. [Web Page]. Located at: http://quickstats.nass.usda.gov. Accessed June 2011.

National Agricultural Statistics Service. (NASS). 2013. Census of Agriculture Volume 1 Chapter 2: Nebraska County Level Data. Issued February, 2009. [Web Page]. Located at: http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Nebraska/index.asp. Accessed on: June 17.

National Agricultural Statistics Service. (NASS). 2016. Quick Stats Nebraska County Data-Crops. [Web Page]. Located at: https://quickstata.nass.usda.gov/data/printable/7035A76A-A444-3105-BF25-E3377F9E2C82. Accessed on: November 17, 2016.

National Climatic Data Center (NCDC). 2011. *Surface Data, Monthly Extremes.* [Web Page]. Located at: http://gis.ncdc.noaa.gov/website/ims-cdo/extmo/viewer.htm?Box=-110.307738654357:41.4493000825986:-102.349767058746:45.2536595444503. Accessed on: July 5, 2011.

National Fire Protection Association (NFPA). 1996. NFPA-50, Standard for Bulk Oxygen Systems at Consumer Sites.

National Land Cover Data (NLCD). 2006. Citation: Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, PE&RS, Vol. 77(9):858-864.

National Oceanic and Atmospheric Administration. (NOAA). 2012. National Climatic Data Center Storm Events Database: Nebraska. 2012. [Web Page]. Located at: http://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=31%2CNEBRASKA. Accessed on: March 07, 2013.

National Park Service. (NPS). 2002. Agate Fossil Beds National Monument, Fish. [Web Page]. Located at: http://www.nps.gov/agfo/naturescience/fish.htm. Accessed on: July 21, 2011.

National Park Service. (NPS). 2010. Mammal Fossils. [Web Page] Located at: http://www.nps.gov/agfo/naturescience/mammalfossils.htm. Accessed on: May 5, 2011.

National Park Service. (NPS). 2013. National Park Service Visitor Summary Report, Total Recreation Visitors for August 2013. [Web Page]. Located at: https://irma.nps.gov/Stats/SSRSReports/System%20Wide%20Reports/YTD%20Report%20(By%20Park-State-Park%20Type-Region)?RptMonth=8/1/2013&RptField=TRV&FeeOption=All. Accessed on: September 3, 2013.

Nebraska Tourism Statistics. 2012. [Web Page]. Located at: http://industry.visitnebraska.org/index.php?option=com_content&view=article&id=3&Itemid=4. Accessed on: September 13, 2013.

Nebraska, State of. (Nebraska). 2010. Nebraska Energy Statistics – Energy Production in Btu. [Web Page] Located at: http://www.eia.doe.gov/emeu/states/sep_prod/P2/PDF/P2.pdf._Accessed on: May 17, 2011.

Nebraska's Coordinating Commission for Postsecondary Education. (NCCPE). 2005. *2005 Nebraska Higher Education Progress Report for the LR75 Legislative Evaluation Task Force:* Volume *One*. [Web Page] Located at: http://www.ccpe.state.ne.us/publicdoc/ccpe/reports/LR174/2005/default.asp. Accessed on: February 25, 2010.

Neuzil, C.E. 1993. Low Fluid Pressure Within the Pierre Shale: A Transient Response to Erosion, *Water Resour. Res.*, v. *29*(7), pp. 2007–2020.

Neuzil, C.E. and Bredehoeft, J.D. 1980. Measurement of In-Situ Hydraulic Conductivity in the Cretaceous Pierre Shale, 3rd Invitational Well-Testing Symposium, Well Testing in Low Permeability Environments, Proceedings March 26-28, 1908, Berkeley, California, p. 96-102.

Neuzil, C.E., Bredehoeft, J.D. and Wolff, R.G. 1982. Leakage and fracture permeability in the Cretaceous shales confining the Dakota aquifer in South Dakota. *In:* Jorgensen, D.G. and Signor, D.C., eds., Geohydrology of the Dakota aquifer-Proceedings of the First C.V. Theis Conference on Geohydrology, October 5-6, 1982: National Water Well Association, p. 113-120.

Nixon, D.A. 1995. The structure of the Pine Ridge of the tri-state region of Wyoming, Nebraska, and South Dakota and its relationship to the Black Hills Dome. Geological Society of America Abstracts with Programs, 29th annual meeting, p.77.

NOAA. 2017. Storm Events Database. [Web Page]. Located at: https://www.ncdc.noaa.gov/stormevents/listevents.jsp?eventType=%28C%29+Tornado&beginDate_mm=01&beginDate_dd=01&beginDate_yyyy=2000&endDate_mm=04&endDate_dd=27&endDate_yyyy=2017&county=DAWES%3A45&hailfilter=0.00&tornfilter=0&windfilter=000&sort=DT&submitbutton=Search&statefips=31%2CNEBRASKA. Accessed on April 27, 2017.

Nuclear Regulatory Commission. (NRC). 1979. Description of the United States Uranium Resource Areas and Supplement to the Generic Environmental Impact Statement on Uranium Milling, NUREG-0597, June 1979.

Nuclear Regulatory Commission. (NRC). 1980a. Regulatory Guide 4.14. Radiological Effluent and Environmental Monitoring at Uranium Mills. (1980).

Nuclear Regulatory Commission. (NRC). 2011b. Locations of Fuel Cycle Facilities. [Web Page]. Located at: http://www.nrc.gov/info-finder/materials/fuel-cycle. Accessed on: October 7, 2011.

Nuclear Regulatory Commission. (NRC). 2011c. Regulatory Guide 8.2 *Guide For Administrative Practices In Radiation Monitoring*. Revision 1, May 2011.

Nuclear Regulatory Commission. (NRC). 2012. Letter from Keith I. McConnell, Deputy Director, Decommissioning and Uranium Recovery Licensing Directorate, Division of Waste Management and Environmental Protection, Office of Federal and State Materials and Environmental Management Programs, US Nuclear Regulatory Commission to Thomas P. Young, Vice-President of Operations, Cameco Resources Regarding License Amendment No. 26 Regarding 2011 Surety Update, Crow Butte Resources Inc., Crawford, Nebraska, Source Materials License SUA-1534 (TAC No. J00634). March 6.

Nuclear Regulatory Commission. (NRC). 2012a. Safety Evaluation Report, License Renewal of the Crow Butte Resources ISR Facility, Dawes County, Nebraska, Materials License No. SUA-1534. Docket No. 40-8943. December.

Nuclear Regulatory Commission. (NRC). 2013. Letter from U.S. Nuclear Regulatory Commission to Tribal Historic Preservation Officer Regarding Update of Section 106 Consultation for the Proposed Crow Butte In-Situ Uranium recovery (ISR) License Renewal, North Trend, Marsland and Three Crow Projects. January 3.

Nuclear Regulatory Commission. (NRC). 2013. Major Uranium Recovery Licensing Applications, [Web Page]. Located at: http://www.nrc.gov/materials/uranium-recovery/license-apps/ur-projects-list-public.pdf. Accessed on: May 06, 2013.

On Road Mobile Emission Factors from California ARB EMFAC2002 Scenario Year 2004 (Model Years A11965 to 2004). 2013. [Web Page]. Located at: http://www.google.com/advanced_search?hl=en&authuser=0, exact word search: CE-Emission-Factor-Calcs. Accessed: August 7, 2013.

Organization for Economic Co-operation and Development, (OECD) 2016. Meat consumption (indicator). doi: 10.1787/fa290fd0-en. https://data.oecd.org/agroutput/meat-consumption.htm. Accessed on: 16 May 2017.

Petersan, Donis N. 2005. *Economic Importance of and Economic Impacts Associated with Livestock Production in Dawes County*. Economic Development Department, Nebraska Public Power District.

Petersen, M.D., Frankel, A.D., Harmsen, S.C., Mueller, C.S., Haller, K.M., Wheeler, R.L., Wesson, R.L., Zeng, Y., Boyd, O.S., Perkins, D.M., Luco, N., Field, E.H., Willis, C.J., and Rukstales, K.S. 2008. *Documentation for the 2008 Update of the United States National Seismic Hazard Maps*. United States Geological Survey, Reston, Virginia. Open-File Report 2008 – 1128.

Terry, D.O., Jr. and J.E. Evans. 1994. Pedogenesis and paleoclimatic implications of the Chamberlain Pass Formation, Basal White River Group, Badlands of South Dakota. Paleogeography, Paleoclimatology, Paleoecology. v. 110, p. 197-215.

Tetra Tech. 2015. Marsland Expansion Area Baseline Radiological Investigation Report, Revision 2.

The Chadron Record. 2013. [Web Page]. Tornado leaves trail of damage in rural area. [Web Page]. Located at: http://rapidcityjournal.com/news/local/communities/chadron/ tornado-leaves-trail-of-damage-in-rural-area/article_e74dc3c8-d836-11e2-b5ec-0019bb2963f4.html. Accessed on April 27, 2017.

Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., vol. 16, pp. 519-524.

Troester, B. 2011. Landowner. Personal communication with Hayden-Wing Associates, June 2011.

U.S. Army Corps of Engineers (USACE). 2008. Interim regional supplement to the Corps of Engineers wetland delineation manual: Great Plains region. J. S. Wakeley, R. W. Lichvar, and C. V. Noble, eds. ERDC/EL TR-08-12. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

U.S. Bureau of Reclamation. (USBR). 2008. Reclamation Managing Water in the West. Resource Management Plan, Box Butte Reservoir, Nebraska, Great Plains Region. November.

U.S. Bureau of Reclamation. (USBR). 2011a. Mirage Flats Project. [Web Page]. Located at: http://www.usbr.gov/projects/Project.jsp?proj_Name=Mirage%20Flats%20Project. Accessed on: August 8, 2011.

U.S. Bureau of Reclamation. (USBR). 2011b. Hydromet: ARC050 Database. Water Operations: Reservoirs, Dams & Hydropower. [Web Page]. Located at: http://www.usbr.gov/gp/lakes_reservoirs/. Accessed on: August 8, 2011.

U.S. Census Bureau (USCB). 1990a. 1990 Census of Population and Housing – Population and Housing Counts - Nebraska. CPH-2-29. [Web Page] Located at: http://www.census.gov/prod/cen1990/cph2/cph-2.html. Accessed on: February 25, 2010.

U.S. Census Bureau. (USCB). 1990b. 1990 Census of Housing – General Housing Characteristics - Nebraska. CH-1-29. [Web Page] Located at: http://www.census.gov/prod/cen1990/ch1/ch-1.html. Accessed on: February 25, 2010.

U.S. Census Bureau. (USCB). 2003a. 2000 Census of Population and Housing - Population and Housing Unit Counts - Nebraska. PHC-3-29. Issued September

Redline Changes – Tables and Figures

MEA TR

Reponses to Open Issues

6-29-2017

Table 2.6-2 Representative Stratigraphic Section – Marsland Expansion Area

Elevation (ft amsl)	Average Depth (ft bgs)	Group	Formation & Member (Schultz and Stout 1955)			Formation and Member (Revised)		References (Revised)	Formation & Member (USGS)		Formation & Member (MEA)		
Varying 4,3080 - 4,0380	15 - 135	Arikaree Group	Monroe Creek Formation			Upper Harrison Beds		Swinehart et al. (1985)	Arikaree Group	Harrison Sandstone	Arikaree Group		Upper Harrison Beds
						Harrison-Monroe Creek Formation				Monroe Creek Sandstone			Harrison – Monroe Creek Formation
			Gering Formation			Gering Formation				Gering Formation			Gering Formation
Varying 4,080 -3,620	135 - 460	White River Group	Brule Formation	Whitney Member		Brule Formation	Brown Siltstone Member	LaGarry (1998)	Brule Formation	Whitney Member	White River Group	Brule Formation	Brown Siltstone Member
							Whitney Member						Whitney Member
				Orella Member	Orella D		Orella Member			Orella Member			Orella Member
					Orella C								
					Orella B								
					Orella A								
3,620 – 3,480	460 – 600		Chadron Formation	Upper Chadron	Chadron C	Chadron Formation	Big Cottonwood Creek Member	Terry (1998) Terry and LaGarry (1998)	Chadron Formation			Chadron Formation	Upper Chadron
				Upper/Middle Chadron	Chadron B								
3,480 – 3,230	600 -850			Middle Chadron			Peanut Peak Member	Terry (1998) Terry and LaGarry (1998)					Middle Chadron
3,230 -3,180	850 – 1,200			Upper Interior Paleosol	Chadron A	Chamberlain Pass Formation	Upper Interior Paleosol	Terry (1998)					basal sandstone of the Chadron Formation
				basal sandstone of the Chadron Formation			Channel Sandstone	Terry (1998) Terry and LaGarry (1998)					
3,180 – 3,130	1,200 - ? (Bottom not seen in logs)	Montana Group	Pierre Shale	Interior Paleosol		Pierre Shale	Yellow Mounds Paleosol	Retallack (1983) Terry (1998)	Pierre Shale		Montana Group	Pierre Shale	
				Pierre Shale			Pierre Shale	Terry (1998) Terry and LaGarry (1998)					

Notes:

1) The Shultz and Stout conventions for Formation & Member are utilized throughout this document for consistency with historical permitting, with the exception of the Red Clay Horizon, which is referred to as the Upper Interior Paleosol.
2) Topsoil, colluvial and alluvial deposits are not shown, but are Quaternary in age and range in thickness from 0 to 30 ft-bgs.
3) The terms "Arikaree Group", "Arikaree Formation", and "Arikaree Sandstone" are accepted usages by USGS in Nebraska.
4) The terms "Gering Formation" and "Gering Sandstone" are both accepted usages by USGS in Nebraska.
5) Subdivisions of the Chadron Formation are not formally recognized by USGS in Nebraska.
6) ft amsl = feet above mean sea level; ft bgs = feet below ground surface.
7) Elevations are representative averages for MEA only, and based on Log M-1252.

Table 2.9-32 MEA Vegetation Seasonal Radiological Laboratory Analysis

Location ID:		Marsland West						Marsland Middle						Marsland East						NRC LLD [a]
Date Collected:		6/26/2013		7/19/2013		9/13/2013		6/26/2013		7/19/2013		9/13/2013		6/26/2013		7/19/2013		9/13/2013		µCi/kg (wet)
	UNITS	RESULTS	RL	RESULTS	RL	RESULTS	RL	RESULTS	RL	RESULTS	RL	RESULTS	RL	RESULTS	RL	RESULTS	RL	RESULTS	RL	
RADIONUCLIDES																				
Lead 210	µCi/kg	4.6E-05	4.6E-06	1.0E-04	8.2E-06	1.5E-04	3.3E-06	1.2E-04	5.0E-06	1.1E-05	4.5E-06	9.8E-05	2.8E-06	2.5E-05	2.6E-06	2.7E-05	2.4E-06	7.5E-05	2.5E-06	1E-06
Lead 210 precision (±)	µCi/kg	4.0E-06		8.0E-06		4.6E-06		6.2E-06		3.1E-06		3.5E-06		2.3E-06		2.2E-06		3.0E-06		
Lead 210 MDC	µCi/kg	4.6E-06		8.2E-06		3.3E-06		5.0E-06		4.5E-06		2.8E-06		2.6E-06		2.4E-06		2.5E-06		
Polonium 210	µCi/kg	4.6E-06	4.4E-06	2.9E-05	2.5E-06	5.9E-05	2.8E-06	2.4E-05	3.1E-06	2.1E-06	1.2E-06	3.5E-05	2.4E-06	2.7E-06	1.3E-06	3.4E-06	1.3E-06	1.4E-05	2.1E-06	1E-06
Polonium 210 precision (±)	µCi/kg	4.2E-06		7.0E-06		1.0E-05		8.6E-06		1.4E-06		6.7E-06		1.4E-06		1.7E-06		1.6E-06		
Polonium MDC	µCi/kg	4.4E-06		2.5E-06		2.8E-06		3.1E-06		1.2E-06		2.4E-06		1.3E-06		1.3E-06		2.9E-06		
Radium 226	µCi/kg	1.1E-06	1.0E-06	2.7E-06	1.7E-07	4.7E-06	3.1E-07	9.1E-06	9.6E-07	4.0E-07	8.0E-08	2.8E-06	2.5E-07	1.8E-06	4.7E-07	<2.4E-08 1.8E-06	2.4E-08	2.6E-06	1.8E-07	5E-08
Radium 226 precision (±)	µCi/kg	6.7E-07		3.0E-07		5.0E-07		1.0E-06		8.9E-08		3.6E-07		3.8E-07		1.2E-08		2.9E-07		
Radium MDC	µCi/kg	1.0E-06		1.7E-07		3.1E-07		9.6E-07		8.0E-08		2.5E-07		4.7E-07		2.4E-08		1.8E-07		
Thorium 230	µCi/kg	4.6E-06	2.2E-06	3.6E-06	1.8E-06	9.3E-06	1.6E-06	7.4E-06	4.9E-06	9.3E-07	7.2E-07	6.2E-06	1.8E-06	1.6E-06	1.5E-06	2.3E-06	1.5E-06	3.1E-06	1.1E-06	2E-07
Thorium 230 precision (±)	µCi/kg	2.1E-06		1.6E-06		2.4E-06		4.2E-06		5.7E-07		1.9E-06		1.1E-06		1.2E-06		1.2E-06		
Thorium MDC	µCi/kg	2.2E-06		1.8E-06		1.6E-06		4.9E-06		7.2E-07		1.8E-06		1.5E-06		1.5E-06		1.1E-06		
METALS																				
Uranium	mg/kg	0.63 D	0.0031	0.0093	0.00073	0.08	0.02	0.043 D	0.0015	0.0023	0.00040	0.20	0.02	0.0010 D	0.00072	0.0021	0.00030	0.16	0.02	
Uranium Activity	µCi/kg	4.2E-04 D	2.1E-06	6.3E-06	4.9E-07	5.0E-05	1.0E-05	2.9E-05 D	9.9E-07	1.6E-06	2.7E-07	1.3E-04	1.0E-05	6.8E-07 D	4.9E-07	1.4E-06	2.0E-07	1.1E-04	1.0E-05	2E-07

µCi/kg - microcuries per kilogram

mg/g - milligrams per gram

RL - Analyte Reporting Limit

D - RL increased due to sample matrix

LLD - Lower Limit of Detection

MDC - Minimum Detectable Concentration

[a] NRC Regulatory Guide 4.14, Revision 1, Radiological Effluent and Environmental Monitoring at Uranium Mills, April, 1980.

Table 2.9-33 MEA Radionuclide Analyses for Livestock Samples						
Radionuclide, Total	**Units**	**Reporting Limit (RL)**	**Beef Sample No. 1**	**Beef Sample No. 2**	**Beef Samples No. 3**	**Average Value** [a]
Lead 210	*u*Ci/kg	1.0E-6	8.8E-6	5.0E-6	6.1E-6	6.6E-6
Lead 210 Precision (+)	*u*Ci/kg		4.0E-6	2.5E-6	6.2E-6	
Polonium 210	*u*Ci/kg	1.0E-6	~~<1.0E-6~~4.0E-7	~~<1.0E-6~~4.0E-7	~~<1.0E-6~~9.0E-7	~~NA~~6.0E-7
Polonium 210 Precision (+)	uCi/kg		~~NA~~6.0E-7	4.0E-7~~NA~~	~~NA~~7.0E-7	
Radium 226	*u*Ci/kg	5.0E-8	1.2E-6	2.0E-7	~~<5.0E-8~~1.5E-7	~~4.8E-7~~5.2E-7
Radium 226 Precision (+)	*u*Ci/kg		4.0E-7	2.0E-7	~~NA~~3.0E-7	
Thorium 230	*u*Ci/kg	2.0E-7	~~<2.0E-7~~1.0E-7	~~<2.0E-7~~5.0E-8	1.0E-6	~~4.0E-7~~3.8E-7
Thorium 230 Precision (+)	*u*Ci/kg		~~NA~~1.0E-7	~~NA~~9.0E-8	6.0E-7	
Thorium 229 Tracer (30-120)	Percent		95.6	102	107	
Uranium	*u*Ci/kg	2.0E-7	9.0E-7	2.0E-7	<2.0E-7	4.0E-7

Source: Inter-Mountain Labs Sample Analysis Reports presented in Appendix DD.

~~NA - Not Applicable~~

~~[a] - Values less than detection limits reduced by one-half in order to provide a conservative estimate.~~

Table 2.9-36 Wet-weight Vegetable Concentrations from Dry-weight Soil Concentrations

Parameter	Parameter Description	Plant Type	Radionuclide	Value	Concentration Factor[4] (C_{svhj})	Average Vegetable Concentration - Seven Gardens[5]
ML_v	Mass Loading factor	Root Vegetables	Not Radionuclide Specific	0.1[1]		
		Leafy Vegetables				
		Fruits				
B_{jv}	Concentration Factor for Root Uptake	Root Vegetables	Natural Uranium	0.014[2]	22.8	13.35
			Thorium-230	0.00012[2]	20.24	6.01
			Radium-226	0.0032[2]	20.64	13.85
			Lead-210	0.0032[2]	20.64	26.24
			Polonium-210	0.009[2]	21.8	Not detected
		Leafy Vegetables	Natural Uranium	0.017[2]	29.5	17.13
			Thorium-230	0.0025[2]	25.63	7.69
			Radium-226	0.075[2]	43.75	22.06
			Lead-210	0.0058[2]	26.54	38.74
			Polonium-210	0.0025[2]	25.63	Not detected
		Fruits	Natural Uranium	0.004[2]	18.72	11.87
			Thorium-230	0.000085[2]	18.02	5.4
			Radium-226	0.0061[2]	19.1	12.82
			Lead-210	0.009[2]	19.62	24.95
			Polonium-210	0.0004[2]	18.07	Not detected
W_v	Dry-weight to Wet Weight Conversion Factor	Root Vegetables	Not Radionuclide Specific	0.2[3]		
		Leafy Vegetables		0.25[3]		
		Fruits		0.18[3]		

[1] pCi/kg dry-weight plant per pCi/g dry-weight soil

[2] pCi/kg dry-weight plant per pCi/g dry-weight soil

[3] Dry-weight to wet-weight conversion factor, unitless

[4] pCi/kg wet-weight plant per pCi/g dry-weight soil

[5] pCi/kg wet-weight plant

ML_v = plant soil mass-loading factor for re-suspension of soil to plant v (pCi/kg dry-weight plant per pCi/g dry-weight soil)

B_{jv} = concentration factor for uptake of radionuclide j from the soil in plant v (pCi/kg dry-weight plant per pCi/g dry-weight soil)

W_v = dry to wet-weight conversion factor (unitless)

Table 2.9-37 Total Radionuclides and Metals in Tissue of Northern Pike Collected from Inlet of Box Butte Reservoir

	May 25, 2014		September 26, 2014		
Radionuclide - Total	**Result [a]**	**Units**	**Result [a]**	**Units**	**RL**
Lead 210	2.8E-05	uCi/kg	~~<1.0E-06~~6.0E-7	uCi/kg	1.0E-06
Lead 210 Precision (+)	1.5E-05	uCi/kg	2.9E-06	uCi/kg	--
Lead 210 MDC	1.0E-06	uCi/kg	1.0E-06	uCi/kg	--
Polonium 210	8.1E-06	uCi/kg	~~<1.0E-06~~2.0E-7	uCi/kg	1.0E-06
Polonium 210 Precision (+)	7.0E-06	uCi/kg	8.0E-07	uCi/kg	--
Polonium 210 MDC	1.0E-06	uCi/kg	1.0E-06	uCi/kg	--
Radium 226	4.1E-06	uCi/kg	8.0E-07	uCi/kg	5.0E-08
Radium 226 Precision (+)	2.2E-06	uCi/kg	3.0E-07	uCi/kg	--
Radium 226 MDC	5.0E-08	uCi/kg	5.0E-08	uCi/kg	--
Thorium 230	8.0E-07	uCi/kg	4.0E-07	uCi/kg	2.0E-07
Thorium 230 Precision (+)	1.6E-06	uCi/kg	3.0E-07	uCi/kg	--
Thorium 230 MDC	2.0E-07	uCi/kg	2.0E-07	uCi/kg	--
Metals - Total					--
Uranium, Total	.0031	mg/kg	.0023	mg/kg	0.0003
Uranium Activity	2.1E-6	uCi/kg	1.5E-06	uCi/kg	2.0E-07

[a] Results reported on a wet weight basis (as received) for composite of two or more samples (digestion, radiochemistry).
uCi/kg = microcuries per kilogram.
RL = Analyte reporting limit.
MDC = Minimum detectable concentration.
mg/kg – milligram per kilogram

Table 2.9-38 Radionuclide and Metal Analyses for Niobrara River Sample Locations N-1 and N-2 Sediment Samples

Radionuclide	Units	10/25/2013 (Fall Collection Date)		5/02/2014 (Spring Collection Date)	
		Result	Reporting Limit (RL)	Result	Reporting Limit (RL)
N-1					
RADIONUCLIDES - TOTAL					
Lead-210	µCi/g - dry	1.0E-6	~~7E-7[a]~~2.0E-7	1.3E-6	2.0E-7
Lead 210 precision (+)	µCi/g - dry	4.0E-7		2.0E-7	
Radium 226	µCi/g - dry	6.0E-7	2.0E-7	7.0E-7	2.0E-7
Radium 226 precision (+)	µCi/g - dry	3.0E-7		3.0E-7	
Thorium 230	µCi/g - dry	3.0E-7	2.0E-7	2.0E-7	2.0E-7
Thorium 230 precision (+)	µCi/g - dry	1.0E-7		1.0E-7	
Thorium 229 Tracer (30-120)	%	51.2		107	
METALS - TOTAL					
Uranium Activity	µCi/g - dry	3.0E-7	2.0E-7	6.0E-7	2.0E-7
N-2					
RADIONUCLIDES - TOTAL					
Lead-210	µCi/g - dry	3.0E-7	2.0E-7	5.0E-7	2.0E-7
Lead 210 precision (+)	µCi/g - dry	1.0E-7		1.0E-7	
Radium 226	µCi/g - dry	4.0E-7	2.0E-7	5.0E-7	2.0E-7
Radium 226 precision (+)	µCi/g - dry	3.0E-7		2.0E-7	
Thorium 230	µCi/g - dry	~~<2E-7~~1.0E-7	2.0E-7	~~<2E-7~~1.0E-7	2.0E-7
Thorium 230 precision (+)	µCi/g - dry	~~NA~~1.0E-7		~~NA~~1.0E-7	
Thorium 229 Tracer (30-120)	%	70.7		93.0	
METALS - TOTAL					
Uranium Activity	µCi/g - dry	2.0E-7	2.0E-7	~~3E-7~~4.0E-7	2.0E-7

RL - Analyte reporting limit
MDC – Minimum detectable concentration
mg/kg-dry – milligram/kilogram-dry weight
pCi/g-dry – picocuries per gram -dry weight

~~[a] The RL used by the laboratory exceeded the NRC RG 4.1 LLD of 2E-7, but the actual sample results exceeded the RL reported by the laboratory; therefore, the reported results are valid.~~

Table 2.9-39 Radionuclide and Metal Analyses for Marsland Ephemeral Drainage (MED)

Radionuclide	Units	Result	Reporting Limit (RL)		Result	Reporting Limit (RL)
		10/25/2013 (Fall Collection Date)			5/02/2014 (Spring Collection Date)	
MED - 1						
Lead-210	µCi/g-dry	2.1E-6	~~1E-6~~ ª2.0E-7		3.0E-7	2.0E-7
Lead 210 precision (+)	µCi/g-dry	4.0E-7			1.0E-7	
Radium 226	µCi/g-dry	3.0E-7	2.0E-7		3.0E-7	2.0E-7
Radium 226 precision (+)	µCi/g-dry	3.0E-7			2.0E-7	
Thorium 230	µCi/g-dry	2.0E-7	2.0E-7		~~<2E-7~~1.9E-7	2.0E-7
Thorium 230 precision (+)	µCi/g-dry	1.0E-7			1.0E-7~~NA~~	
Thorium 229 Tracer (30-120)	%	92.8			95.2	
METALS						
Uranium Activity	µCi/g-dry	4.0E-7	2.0E-7		3.0E-7	2.0E-7
MED - 2						
Lead-210	µCi/g-dry	6.0E-7	2.0E-7		1.3E-6	2.0E-7
Lead 210 precision (+)	µCi/g-dry	2.0E-7			2.0E-7	
Radium 226	µCi/g-dry	4.0E-7	2.0E-7		5.0E-7	2.0E-7
Radium 226 precision (+)	µCi/g-dry	3.0E-7			4.0E-7	
Thorium 230	µCi/g-dry	~~<2E-7~~1.9E-7	2.0E-7		4.0E-7	2.0E-7
Thorium 230 precision (+)	µCi/g-dry	~~NA~~1.0E-7			1.0E-7	
Thorium 229 Tracer (30-120)	%	96.6			98.9	
METALS						
Uranium Activity	µCi/g-dry	2.0E-7	2.0E-7		6.0E-7	2.0E-7
MED - 3						
Lead-210	µCi/g-dry	4.0E-7	2.0E-7		1.4E-6	2.0E-7
Lead 210 precision (+)	µCi/g-dry	2.0E-7			2.0E-7	
Radium 226	µCi/g-dry	2.0E-7	2.0E-7		8.0E-7	2.0E-7
Radium 226 precision (+)	µCi/g-dry	3.0E-7			3.0E-7	
Thorium 230	µCi/g-dry	~~<2E-7~~1.0E-7	2.0E-7		3.0E-7	2.0E-7
Thorium 230 precision (+)	µCi/g-dry	1.0E-7~~NA~~			1.0E-7	
Thorium 229 Tracer (30-120)	%	95.6			94.1	
METALS						
Uranium Activity	µCi/g-dry	2.0E-7	2.0E-7		5.0E-7	2.0E-7

Table 2.9-39 Radionuclide and Metal Analyses for Marsland Ephemeral Drainage (MED)

Radionuclide	Units	Result	Reporting Limit (RL)		Result	Reporting Limit (RL)
		10/25/2013 (Fall Collection Date)			5/02/2014 (Spring Collection Date)	
MED - 4						
Lead-210	µCi/g-dry	1.7E-6	~~1E-6~~ [a] 2.0E-7		2.1E-6	2.0E-7
Lead 210 precision (+)	µCi/g-dry	4.0E-7			3.0E-7	
Radium 226	µCi/g-dry	7.0E-7	2.0E-7		8.0E-7	2.0E-7
Radium 226 precision (+)	µCi/g-dry	4.0E-7			4.0E-7	
Thorium 230	µCi/g-dry	5.0E-7	2.0E-7		5.0E-7	2.0E-7
Thorium 230 precision (+)	µCi/g-dry	1.0E-7			1.0E-7	
Thorium 229 Tracer (30-120)	%	87.2			90.3	
METALS						
Uranium Activity	µCi/g-dry	5.0E-7	2.0E-7		5.0E-7	2.0E-7
MED - 5						
Lead-210	µCi/g-dry	1.2E-6	2.0E-7 ~~1E-6~~ [a]		2.0E-6	2.0E-7
Lead 210 precision (+)	µCi/g-dry	3.0E-7			2.0E-7	
Radium 226	µCi/g-dry	6.0E-7	2.0E-7		1.2E-6	2.0E-7
Radium 226 precision (+)	µCi/g-dry	4.0E-7			5.0E-7	
Thorium 230	µCi/g-dry	~~<2E-7~~ 1.9E-7	2.0E-7		5.0E-7	2.0E-7
Thorium 230 precision (+)	µCi/g-dry	~~NA~~ 1.0E-7			2.0E-7	
Thorium 229 Tracer (30-120)	%	54			85.4	
METALS						
Uranium Activity	µCi/g-dry	4.0E-7	2.0E-7		6.0E-7	2.0E-7
MED - 6						
Lead-210	µCi/g-dry	9.0E-7	~~7E-7~~ [a] 2.0E-7		1.0E-6	2E-7
Lead 210 precision (+)	µCi/g-dry	4.0E-7			2.0E-7	
Radium 226	µCi/g-dry	7.0E-7	2.0E-7		7.0E-7	2E-7
Radium 226 precision (+)	µCi/g-dry	3.0E-7			3.0E-7	
Thorium 230	µCi/g-dry	4.0E-7	2.0E-7		2.0E-7	2E-7
Thorium 230 precision (+)	µCi/g-dry	1.0E-7			1.0E-7	
Thorium 229 Tracer (30-120)	%	93.5	93.5		88.3	
METALS						

Table 2.9-39 Radionuclide and Metal Analyses for Marsland Ephemeral Drainage (MED)

Radionuclide	Units	Result	Reporting Limit (RL)		Result	Reporting Limit (RL)
		10/25/2013 (Fall Collection Date)			5/02/2014 (Spring Collection Date)	
Uranium Activity	µCi/g-dry	4.0E-7	2.0E-7		45.0E-7	2.0E-7
		10/17/2014 (Fall Collection Date)			4/30/2015 (Spring Collection Date)	
MED-7 [b]						
Lead-210	µCi/g-dry	7.0E-7	2.0E-7		1.8E-6	2.0E-7
Lead 210 precision (+)	µCi/g-dry	1.0E-7			5.0E-7	
Radium 226	µCi/g-dry	6.0E-7	2.0E-7		1.0E-6	2.0E-7
Radium 226 precision (+)	µCi/g-dry	1.0E-7			3.0E-7	
Thorium 230	µCi/g-dry	1.5E-6	2.0E-7		4.0E-7	2.0E-7
Thorium 230 precision (+)	µCi/g-dry	1.7E-6			2.0E-7	
Thorium 229 Tracer (30-120)	%	80.5			38.4	
METALS						
Uranium Activity	µCi/g-dry	7.2E-6	2.0E-7		5.4E-6	2.0E-7

MED - Marsland Ephermeral Drainage
RL - Analyte reporting limit
µCi/g-dry - microcuries/gram-dry weight

~~[a] The RL used by the laboratory exceeded the NRC RG 4.1 LLD of 2E-7, but the actual sample results exceeded the RL reported by the laboratory; therefore, the reported results are valid.~~

[b] New sampling point added after sampling of MED-1 through MED-6 was completed.

Table 2.9-41 Marsland Expansion Area Preoperational/Preconstruction Monitoring Program

	Sample Collection				Sample Analysis	
Type of Sample	**Number**	**Location**	**Method**	**Frequency**	**Frequency**	**Type of Analysis**
Air Particulates	3	On MEA southern boundary	Continuous	Weekly filter change	Quarterly composites of weekly samples	Natural uranium, Ra-226, Th-230, and Pb-210
	1	Nearest Resident	Continuous	Weekly filter change	Quarterly composites of weekly samples	Natural uranium, Ra-226, Th-230, and Pb-210
	1	Control background location west of MEA License Boundary	Continuous	Weekly filter change	Quarterly composites of weekly samples	Natural uranium, Ra-226, Th-230, and Pb-210
Radon Gas	3	On MEA southern boundary	Continuous	Quarterly	Quarterly	Rn-222
	1	Nearest Resident	Continuous	Quarterly	Quarterly	Rn-222
	1	Control background location west of MEA License Boundary	Continuous	Quarterly	Quarterly	Rn-222
Groundwater	1	Wells within MEA license boundary and 2 km radius: • Private Wells • MEA Arikaree Wells • MEA Brule Wells • MEA Ore Zone Wells	Grab	Quarterly	Quarterly	Suspended & Dissolved Natural Uranium, Ra-226, Th-230, Pb-210 & Po-210
Surface Water	2 [a]	Niobrara River (N-1 and N-2) Ephemeral Drainages	Grab	Monthly	Monthly	Suspended & Dissolved Natural Uranium, Ra-226, Th-230
			Grab	Semiannually	Semiannually	Suspended & Dissolved Pb-210 & Po-210
Vegetation	3	Grazing areas near the site in different sectors that will have the highest predicted air particulate concentrations during milling operations	Grab	3 times during grazing season	3 Times	Natural Uranium, Ra-226, Th-230, Pb-210, & Po-210
Food	3	Crops (alternate of garden soil sampling used)	Grab	Time of Harvest or Slaughter	1	Natural Uranium, Ra-226, Th-230, Pb-210, & Po-210
	3	Livestock			1	

Table 2.9-41 Marsland Expansion Area Preoperational/Preconstruction Monitoring Program

	Sample Collection				Sample Analysis	
Type of Sample	**Number**	**Location**	**Method**	**Frequency**	**Frequency**	**Type of Analysis**
Fish	Each Body of Water	Box Butte Reservoir	Grab	Semiannually	2	Natural Uranium, Ra-226, Th-230, Pb-210, & Po-210
Surface Soil [b]	Up to 40	300 meter intervals to a distance of 1500 meters in each of 8 directions from center-point of satellite facility; additional transects through wellfields	Grab	Once prior to construction. Repeat for location disturbed by excavation, leveling or contouring	1	All samples for Ra-226, 10% of samples natural uranium, Th-230 & Pb-210
	5	Same location used for collection of air particulates	Grab	Once prior to construction	1	Natural Uranium, Ra-226, Th-230 & Pb-210
Subsurface Soil [c]	5	At center-point of satellite facility & at distances of 750 meters in each of 4 directions	Grab	Once prior to construction. Repeat for location disturbed by construction	1	Ra-226 (all samples) Natural Uranium, Th-230 & Pb-210 (one set of samples)
Sediment [d]	1 from each stream (2) & ephemeral drainage (7) sampling points	Up and down gradient samples from ephemeral drainages (total of 7 samples) & Niobrara River (N-1 & N-2)	Grab (Composite samples)	Once following spring runoff & late summer following period of extended low flow	2	Natural Uranium, Ra-226, Th-230 & Pb-210
Direct Radiation (Survey)	Up to 80	150 meter intervals to a distance of 1500 meters in each of 8 directions from center-point of satellite facility	Grab	Once prior to construction. Repeat for areas disturbed by site preparation or construction	1	Gamma exposure using sodium iodide scintillometer
Direct Radiation (Continuous)	5	Same location used for collection of air particulates	Grab	Once prior to construction	1	Gamma exposure using a continuous integrating device
Radon Flux [e]	-	-	-	-	-	-

[a] Two samples from the Niobrara River per sampling event and one (1) from each sampling point (total of 7) located on ephemeral streams (**Figure 2.7-4**) .

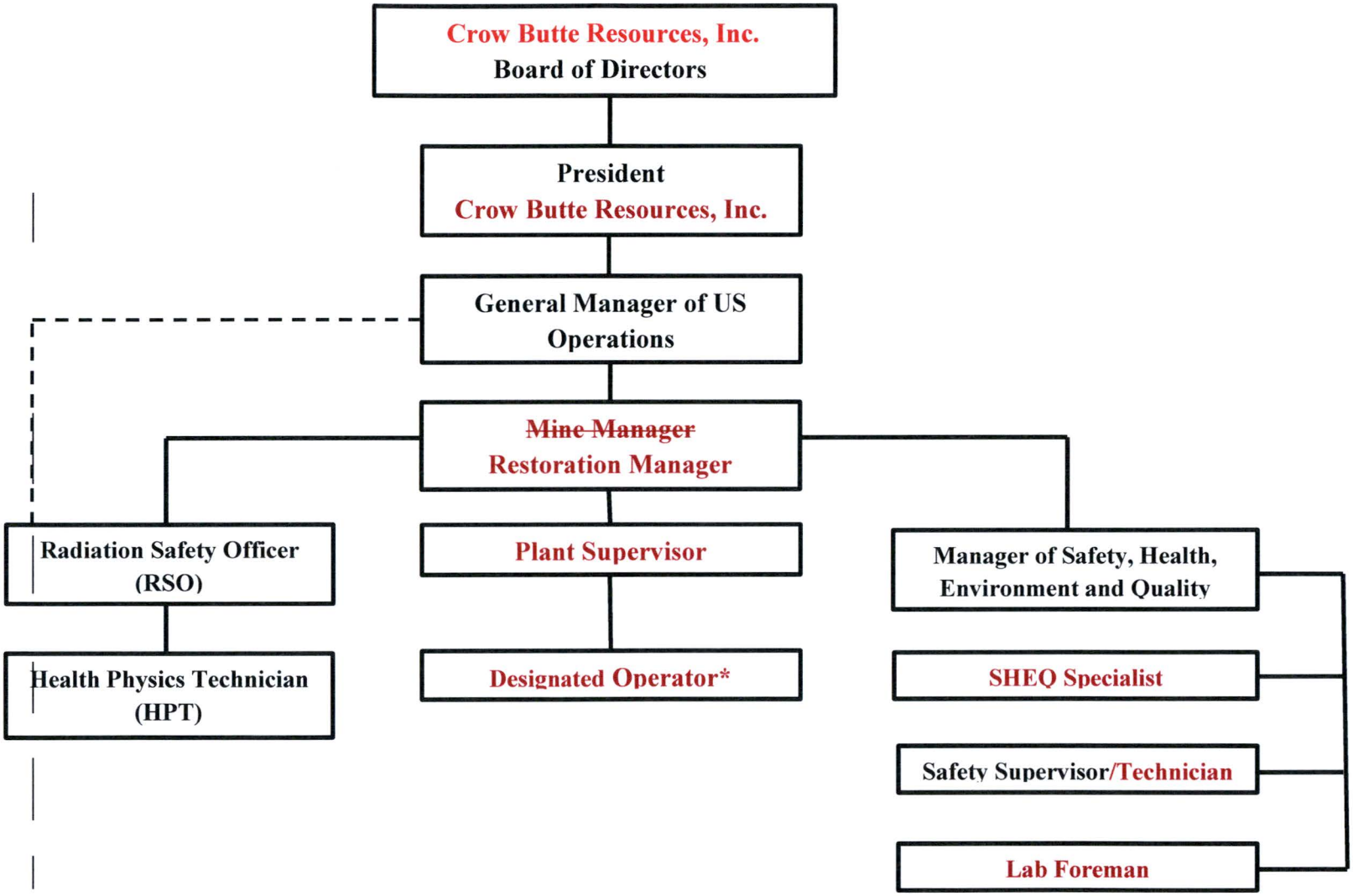
[b] Surface soil samples collected to a depth of 5 cm and 15 cm using a consistent technique.

[c] Subsurface soil samples collected to a depth of 1 meter; samples divided into 3 equal sections for analysis.

[d] Sediment sample locations shown in Figure 2.7-4

[e] Radon Flux measurements are not applicable to ISR facilities.

Figure 5.1-1: Crow Butte Resources Organizational Chart



*Qualifications for Designated Operator described in Marsland Expansion Area Technical Report, Section 5.5.4