CAMECO RESOURCES
CROW BUTTE OPERATION

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May 20, 2016

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

Mr. Thomas Lancaster, Project Manager
Uranium Recovery and Waste Programs
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
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Response to Open Issues – Marsland Expansion Area Technical Report
Teleconference on April 6, 2016
Source Materials License SUA-1534
CAC NO. J00683

Dear Mr. Lancaster:

Please find below Crow Butte Resources, Inc. d/b/a Cameco Resources (CR) Crow Butte Operation (CBO) responses to open issues identified during the April 6, 2016 teleconference. The purpose of the meeting was to discuss issues relating to CBO's MEA ISR license amendment. The meeting was publicly noticed on the NRC Web site on March 24, 2016.

Open Issue Request No. 1

In Section 3.1.3 of the license application (second full paragraph) it is stated the: "Pumping tests will ...be performed for each MU not covered by the regional pump test...." The wording in the license application is not clear with regard to the meaning of "...not covered by the regional pump test." Per NUREG-1569, Section 5.7.8.3, Acceptance Criterion No. 4: "Once a well field is installed, it should be tested to establish that the production and injection wells are hydraulically connected to the perimeter horizontal excursion monitor wells and are hydraulically isolated from the vertical excursion monitor wells... Test approaches typically consist of a pumping test that subjects the well field to a sustained

NM5501

maximum withdrawal rate while monitoring the perimeter and vertical excursion wells for drawdown."

The application should be modified to make it clear that the applicant intends to perform a pumping test involving a pumping well and monitoring wells for each mine unit.

CBO Response

Section 3.1.3, has been revised to indicate that a pumping test will be conducted for each mine unit to establish that the production and injection wells are hydraulically connected to the perimeter horizontal excursion monitor wells and are hydraulically isolated from the vertical excursion monitor wells.

The redline changes are included in Attachment A.

The entire text section of the Technical Report has been reprinted and is included in Attachment B.

Open Issue Request No. 2

There is an inconsistency in the application regarding the presence of irrigation wells within the Marsland Expansion Area (MEA). In Section 2.9.3.2 (pg. 2-119, 1st sentence, 3rd paragraph in the "Risk Conclusion" subsection), it is stated that: "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" (emphasis added). However, Table 2.2-11 of the application does not indicate the presence of any agricultural irrigation wells within the license boundary.

The inconsistency described should be addressed and corrected.

CBO Response

Table 2.2-11, Figure 2.7-6, Figure 2.9-3, Appendix AA-2, and the text in Sections 2.2.4 and 2.9.3.1 have been revised to show that the irrigation well (#732) is within the permit boundary.

The redline changes are included in Attachment A.

The entire text section of the Technical Report has been reprinted and is included in Attachment B.

The replacement tables and figures are included in Attachment G.

Open Issue Request No. 3

Staff's technical review of Basal Chadron Sandstone water level data provided in the 2015 revision of the Marsland Technical Report has identified the following information needs to complete staff's independent evaluation:

a. For the time period from 2011 to 2015, hydrographs and raw water level data (Excel file format) for a representative number of Basal Chadron Sandstone wells at the Crow Butte Resources (CBR) licensed facility. Raw data should include well identification, screened interval(s), water level elevations, data collection times, and spatial coordinates.

   CBO Response

   Hydrographs for the time period 2011 to 2015 of ten monitor wells representing the Basal Chadron Sandstone at the Crow Butte facility and a figure showing their location are included. (Attachment C and Attachment C Figure 1)

   The raw data is submitted electronically on the enclosed disk as *Master Data Regional Water Levels.xls.*

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b. For all time periods available, hydrographs and raw water level data (Excel file format) for Basal Chadron Sandstone wells located at potential expansion areas (Marsland, North Trend, Three Crow). Raw data should include well identification, screened interval(s), water level elevations, data collection times, and spatial coordinates.

   CBO Response

   Hydrographs for the time period 2013 to 2016 of thirteen monitor wells representing the Basal Chadron Sandstone at the Marsland Expansion Area are included in Attachment D1. The location of these monitor wells can be found on Figure 2.7-9 in the Marsland Expansion Area Technical Report.

   Hydrographs for the time period 2006 to 2008 of seven monitor wells representing the Basal Chadron Sandstone at the North Trend Expansion Area and a figure showing their location are included. (Attachment D2 and Attachment D2 Figure 1)

Hydrographs for the time period 2008 to 2016 of ten monitor wells representing the Basal Chadron Sandstone at the Three Crow Expansion Area and a figure showing their location are included. (Attachment D3 and Attachment D3 Figure 1)

The raw data is submitted electronically on the enclosed disk as *Master Data Regional Water Levels.xls.*

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c. Conceptualization of regional groundwater flow directions in the Basal Chadron Sandstone encompassing data from the main Crow Butte facility and the proposed Crow Butte satellite facilities (Marsland, North Trend, Three Crow) along with a discussion pertaining to the data supporting the conceptualization.

CBO Response

A conceptual groundwater flow diagram of the regional Basal Chadron Sandstone is included in Attachment E. It should be noted that the flow diagram map is based on water levels collected in April 2016. All of the monitor wells at the North Trend Expansion Area have been plugged and abandon, therefore the map does not include this area.

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d. Water balance information (i.e., extraction, injection, and consumptive use rates), preferably by mine unit, at the Crow Butte licensed facility for the time period from 2011 to 2015. The raw data (Excel file format) should also be provided.

CBO Response

Water balance information by mine unit for the period 2011 to 2015 is included in in Attachment F.

The raw data is submitted electronically on the enclosed disk as *CBO Water Balance 2011-2015.xls.*

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e. An analysis (preferably analytical) of estimated drawdowns within the Basal Chadron Sandstone within and in the vicinity of the proposed Marsland Expansion Area based on projected consumptive use rates presented in Appendix T of the

Technical Report. Results should include projected drawdown versus distance and potentiometric surface maps of the Basal Chadron Sandstone at intermittent times (including the period of highest consumptive use). Provide the executable code, data input and output files and any other information necessary for the Staff to independently verify the analysis.

Note: The licensee requested clarification of the open issue request (Item 3e) during the public meeting. After the public meeting, e-mail correspondence occurred with the licensee that allowed staff to provide clarity of the request. Staff's clarification of the open issue request is:

Conduct a cumulative drawdown impact assessment for the Basal Chadron Sandstone aquifer at the MEA including drawdown impacts from the MEA, Crow Butte Operation Facility and Three Crow Expansion Facility. The assessment will use the projected consumptive use at each facility, and actual consumptive use estimates for CBO facility prior to 2016. The assessment will be performed using a Theis analytical solution for confined aquifiers and the principal of superposition for cumulative drawdown impacts. The assessment will include drawdown impacts over the period 2011 to approximately 2052, corresponding to the historical groundwater monitoring period at the MEA, facility operations, and 10 years beyond last consumptive use at MEA and TCEA to include the aquifer recovery period. Hydrographs depicting projected drawdown over time will be produced at selected locations within and around the MEA including the MEA In situ recovery (ISR) wellfields, existing MEA Basal Chadron monitoring wells (Monitor 1 thru Monitor 11), and at a 2.25 mile radius form the MEA facility. Drawdown contour maps will be provided illustrating the cumulative drawdown impacts at the MEA for the period of maximum cumulative drawdown.

In addition to the cumulative drawdown impact assessment described above, drawdown impacts resulting solely form MEA operations will be evaluated as part of this work. Hydrographs and drawdown contour maps will be prepared illustrating projected drawdown in the Basal Chadron aquifer due to MEA operations.

<u>**CBO Response**</u>

The items requested are present in a report prepared by AquiferTek and is included in Attachment G. (The report becomes a new appendix to the Marsland Expansion Area Technical Report which is titled Appendix GG).

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f. An analysis (preferably analytical) of estimated cumulative regional drawdowns in the Basal Chadron Sandstone that considers potential impacts of multiple Crow Butte ISR facilities (Marsland, North Trend, Three Crow, the main facility) operating simultaneously based on their respective production schedules. Provide the executable code, data input and output files and any other information necessary for the Staff to independently verify the analysis.

CBO Response

The items requested are present in a report prepared by AquiferTek and is included in Attachment G. (The report becomes a new appendix to the Marsland Expansion Area Technical Report which is titled Appendix GG).

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g. Maps of available head above the top of the Basal Chadron Sandstone within and in the vicinity of the MEA for both the pre-development period and during the period of highest projected consumptive use.

CBO Response

The items requested are present in a report prepared by AquiferTek and is included in Attachment G. (The report becomes a new appendix to the Marsland Expansion Area Technical Report which is titled Appendix GG).

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h. Description of Crow Butte's monitoring and contingency plans to ensure that the Basal Chadron Sandstone aquifer remains saturated throughout the proposed operations and ground water restoration at the MEA.

CBO Response

Section 7.2.5.4, *Water Level Impacts,* was revised to include the information provided in the AquiferTek report with a paragraph added which describes a monitoring and contingency plan.

The redline changes are included in Attachment A.

The entire text section of the Technical Report has been reprinted and is included in Attachment B.

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i. Any other information that CBR has not already submitted that relates to potential sources of drawdown in the Basal Chadron Sandstone aquifer regionally or locally with respect to the MEA.

CBO Response

CBO is not aware of any other information that has not already been submitted, including this submittal that relates to potential sources of drawdown in the Basal Chadron Sandstone aquifer regionally or locally with respect to the MEA.

CBO has also included in Attachment A additional redline page changes that were previously discussed in PM to PM phone calls. To capture all the page changes; a complete resubmittal of the entire text for the Marsland Expansion Area Technical Report is included in Attachment B.

If there are any further questions or concerns feel free to contact me at (308) 665–2215 ext. 122.

Sincerely,

Bob Tiensvold
Mine Manager

cc: NRC – Document Control Desk
CBO- File
CR-Casper

Response to Open Issues
Marsland Expansion Area
Technical Report

Attachment A

Redline Text for the Marsland Expansion Area Technical Report

Volume I
Sections 1-10

Another source of groundwater consumption in the AOR is private water well use for livestock watering. The Nebraska Resources Conservation Service (NRCS) located in Nebraska uses 0.45 animal units (AU) per acre and estimates the water consumption to be 15 to 20 gallons per day per animal (Teahon 2013a). An AU is defined as an animal equivalent of 1,000 pounds live weight, with or without an un-weaned calf. There is an estimated 27,572.4 acres of rangeland located with the MEA AOR. Based on the NRCS values for calculating livestock water consumption in Dawes County, livestock consumption within the MEA AOR (assuming full use), would be 186,114 to 248,152 gallons per day. There are approximately ~~3,694.6~~ 4,622.3 acres located within the MEA license boundary, and based on the NRCS livestock consumption calculation values, livestock consumption (assuming full use of available rangeland acreage) would range from 24,938 to 33,251 gallons per day.

CBR conducted an updated water user survey in 2010 and 2011 to identify and locate all private water supply wells within the 2.25-mile (3.62-km) AOR of the proposed MEA. The water user survey targeted the location, depth, casing size, depth to water, and flow rate of all wells within the area that were (or potentially could be) used as domestic, agricultural, or livestock water supply. **Table 2.2-11** and **Appendix A** list the active, inactive, seasonal and abandoned water supply wells within the MEA and AOR. The locations of all active, inactive, seasonal and abandoned water supply wells are depicted on **Figure 2.7-6** and **2.9-3.** Available NDNR water well registrations within the AOR are presented in **Appendix E-1** and available well abandonment records in the AOR are shown in **Appendix D-2**. The NDNR's water well retrieval database (NDNR 2013b) was reviewed on September 6, 2013, (Teahon 2013b) and no additional private water supply wells were identified to be installed or modified within the license boundary or AOR since the TR was submitted to the NRC by letter dated May 16, 2012.

There were a total of 13~~5~~4 private water supply wells within the license boundary and associated AOR identified during the water user survey (excluding 7 abandoned wells). There are a total of 119 private water supply wells within the AOR and outside of the license boundary. ~~(~~Classification and use of private water supply wells are summarized in **Table 2.2-11**~~)~~. ~~Within this grouping 87 wells are active, 25 are inactive and seven are used seasonally. Of the 87 active private wells, there are 61 livestock wells, 12 domestic/livestock, five agricultural, four domestic, two domestic/garden, one domestic/agricultural, one domestic/livestock/agricultural and one livestock/garden well. It should be noted that 17 of these wells have multiple or mixed well use classifications. In terms of aquifer assignments, three wells are assigned to the Arikaree Group, 35 wells are assigned to the Arikaree/Brule, 24 wells are assigned to the Brule Formation, and 25 wells are unassigned.~~

Within the MEA, there are a total of 10 active private water supply wells, five inactive and one seasonal (irrigation) (**Table 2.2-11**). ~~Within this grouping of active private wells, eight are classified as livestock use, and two wells, installed and used by CBR as driller water supply wells, have an "other" well use classification.~~ In terms of aquifer assignments of the active wells, three wells are assigned to the Arikaree Group, four wells are assigned to the Arikaree/Brule, and three wells are assigned to the Brule Formation. ~~Five wells within the license boundary are designated as inactive.~~

The NDNR water well retrieval database uses the code "other" for well uses defined as lake supply, fountain, geothermal, wildlife, wetlands, recreation, plant and lagoon, sprinkler, test, and other

uses. (NDNR 2013b). For comparison, the following are water use designations used by the NDNR:

A Aquaculture
C Commercial/Industrial~~]~~
D Domestic
E Pit - Irrigation
G Ground Heat Exchanger Well - Closed Loop Heat Pump Well
H Heat Pump Well - Open Loop Heat Pump Well
I Irrigation
J Injection
L Observation (Groundwater Levels)

For well water uses that do not fall within these categories, the "other" well use code is used.

For all of the active private wells described above that remain unassigned to a formation, information provided by the well owner and from nearby wells was insufficient to accurately determine the well completion depth. However, based on discussions with land owners and known completion depths of private water supply wells in the area, these wells have suggested well completions within the Arikaree Group or Brule Formation (**Table 2.2-11**). Well construction and water quality information for these wells are not available in the NDNR water well data retrieval database (NDNR 2013a) or known by the well owner. Based on available information, all water supply wells within the MEA and AOR are completed in the relatively shallow Arikaree Group and Brule Formations, with no domestic or agricultural use of groundwater from the basal sandstone of the Chadron Formation (**Figure 2.7-6 and 2.9-3** and **Table 2.2-11**). Sampling results of these wells by CBR indicate water quality of Arikaree Group and/or Brule Formation aquifers. Based on water quality and the depth of the Arikaree Group and Brule Formation in the MEA Project area, it can be assumed that wells less than ~~285~~400 feet in depth are located in the Arikaree Group and/or Brule Formation.

Active private wells within the license boundary and 1.2-miles (2-km) radius of the license boundary have been sampled quarterly as part of the preoperational/preconstruction monitoring program (PPMP). ~~There are currently 10 active private wells within the license boundary and an additional 33 active private wells with the 1.2-mile (2-km) radius of the license boundary (**Figure 2.9-3** and **Table 2.2-11**).~~ The PPMP baseline groundwater sampling and analysis program for the private wells is discussed in Section 2.9.3. Wells were selected for sampling based on landowner approval for access to the wells and condition of the wells.

Based on population projections, future water use within the MEA and AOR will be a continuation of present use (see Section 2.3). ~~There is o~~One irrigation well is located within the license boundary, with a portion of ~~the~~its center pivot ~~that~~ located within- ~~extends into~~ the ~~license~~ boundary (SE ¼ section of Section 18, T29N R50W; **Figure 7.3-2**). The nearest mine units to the center pivot are MU-B and MU-C, which are located, at the nearest points, 0.37 and 0.28 mile (0.59 and 0.45 km, respectively from the center pivot, respectively. Th~~is~~e center pivot located within the license boundary may continue to be operated by the land owner, but the pivot will not be operated inside any MEA monitor well ring. There are no other lands within the license boundary that are irrigated, and no additional irrigation within the license boundary will occur during MEA operations. Irrigation within the MEA AOR is anticipated to be consistent with the past. Any further

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~~Literature has named~~ the ~~upper Harrison Beds the~~ Marsland, ~~Formation or split into the~~ Harrison, or ~~and~~ Monroe Creek Formations. This application ~~uses~~ follows the revised nomenclature presented in Swinehart et al. (1985), which uses the U~~u~~pper Harrison Beds, Harrison-Monroe Creek, and Gering Formations.

The Arikaree Group contains numerous interbedded channel and flood-plain deposits, along with the eolian volcaniclastic deposits. Grain size analyses of core samples (**Appendix G-2**) support observations of drill cuttings and cores~~, which demonstrate that~~ indicating a wide range of interbedded lithologies ~~are present~~ within the Arikaree Group, including illite/smectite-dominated ~~mudstones (e.g., M-533C Run 5 Sample 1),~~ siltstones (e.g., M-533C Run 1 Sample 2), and fine-grained sandstones (e.g., M-1912C Run 1 Sample 1)~~ 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~~. The SP curve~~ can also be off~~-the~~ 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 contact between the Arikaree Group and Brule Formation is characterized by a decrease in resistivity from the overlying coarser-grained Arikaree Group. A corresponding decrease in the SP curve is often observed from Arikaree Group to the Brule Formation, and t~~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~~s~~ 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 U~~u~~pper Harrison Beds contain three dominant units; ~~s of~~ 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 UUpper 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 uUpper and middle portions of the Harrison-Monroe Creek Fformation 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 (19501951), 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 19511950). 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,

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 2025 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 flood~~-~~plain or low velocity deposits normally associated with fluvial sedimentation.

Two c~~C~~ore samples (M-1454C~~,~~ Run~~s~~ 3~~ and 4~~, and M-1624C~~,~~ Run~~s 3 and~~ 4) were collected from the basal sandstone of the Chadron Formation by CBR at boreholes M-1454C~~c~~ and M-1624C~~c~~ ~~in sections 1 and 7, T29N, R51W~~ (**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~~c~~, Run 3 and M-1624C~~c~~, Run 4 give median grain sizes of 0.075 mm (very fine sand) and 0.711 mm (coarse sand), respectively. M-1454C~~c~~, Run 3 contained 29.85 percent silt and 19.92 percent clay. M-1624~~c~~C, 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~~c~~ sample indicates a varied composition. Run 3 is mainly composed of quartz, whereas Run 4 is mainly composed of mixed-layered ~~smectitie~~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 R~~r~~un 4 had minor amounts of dolomite and chlorite. The sample from M-1912C~~c~~ 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

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 ~~dips~~ 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~~e~~, M-1624C~~e~~, M-2169C~~e~~, M-533C~~e~~, M-1956C~~e~~, M-1912C~~e~~, and M-1635C~~e~~, 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~~0~~.40 (M-1454~~e~~C Run 4) to 75.95 (M-1635C~~e~~ 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-1624~~e~~C. 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

~~Six deep oil and gas exploration wells were drilled in the vicinity of the MEA: Chicoine 1, Chicoine 1A, Hollibaugh No. 1, Porter, Roscoe Royal #1, and #1-A Smith (**Appendix C**). Oil and gas exploration wells have typically been drilled to depths much greater than on-lease uranium exploration wells. The character of the entire Pierre Shale in the vicinity of the MEA can best be observed in geophysical logs from three of the six nearby abandoned oil and gas wells (Hollibaugh No. 1, Roscoe Royal #1, and #1-A Smith), and the CBR DDW (CBR UIC #1), which were completed through the entire thickness of the unit. Based on observations from logging, the thickness of the Pierre Shale in the vicinity of the MEA ranges from approximately 750 to more than 1,000 feet.~~

~~The top of the Pierre Shale was encountered in all wells at depths ranging from approximately 925 to 1,200 feet bgs. The Hollibaugh No. 1 well is located within the license boundary (T29N, R51W, section 12) and has a total depth of 3,283 feet bgs. The Pierre Shale was encountered at 1,025 to 1,915 feet bgs. The Roscoe Royal #1 is located about 0.5 mile (0.8 km) north of the license boundary (T30N, R51W, section 23) and has a total depth of 3,956 feet bgs. The Pierre Shale was encountered at 1,200 to 2,200 feet bgs. The #1-A Smith well is located about 0.25 mile (0.4 km) east of the license boundary (T29N, R50W, section 29) and has a total depth of 2,902 feet bgs. The Pierre Shale was encountered at 947 to 1,716 feet bgs. DDW CBR UIC #1 (T31N, R52W, section 19) is located approximately 10.7 miles (17.2 km) northwest of the MEA license boundary and has~~

~~a total depth of 3,910 feet bgs. At UIC #1, the Pierre Shale was encountered from 925 to 1,560 feet bgs, where the base of the Pierre Shale is indicated by an increase in resistivity at the contact with the underlying Niobrara Formation (**Appendix C**). Plugging records for these wells are shown in **Appendix D-1**.~~

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**).

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 ~~f~~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*

Falling Head Permeameter Testing (ASTM D5084) of core sample (M-1635C~~e~~, Run 3, Sample 1) from the upper Chadron Formation returned an average measured hydraulic conductivity value of 1.32 x 10^{-7} cm/s. The same core (M-1635C~~e~~, Run 3, Sample 1) using the Kozeny-Carma~~e~~n equation to calculate hydraulic conductivity based on particle grain size returned an estimate of 4.3 x 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-Carma~~e~~n 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 x 10^{-10} cm/sec (WFC 1983a), which is consistent with other studies in the region. Particle grain-size analyses of seven ~~two~~ 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**

~~As described in Section 2.7.2.1, estimated hydraulic conductivities for the upper confining unit were developed using particle grain size distribution data from the six core samples collected from~~

~~the upper Chadron and middle Chadron. Results of the particle size distribution analyses indicate sediments dominated by silts and clays. Estimated hydraulic conductivities of the four core samples collected within the upper Chadron and middle Chadron ranged from 1.7 x 10^{-5} to 5.9 x 10^{-5} cm/sec. Estimated hydraulic conductivities of the two core samples collected from within the middle Chadron ranged from 1.7 x 10^{-5} to 2.9 x 10^{-5} cm/sec. Hydraulic conductivities for the seven core samples collected within the Pierre Shale were not estimated by the Kozeny-Carman method due to significant levels (up to 76 weight percent) of clay. The vertical hydraulic conductivity across the upper and lower confining layers is likely to be even lower due to vertical anisotropy. Additionally, hydraulic resistance to vertical flow is expected to be low due to the significant thickness of the upper confining zone within the MEA, which ranges between 650 and 700 ft.~~

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**).

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 360650 to 450700 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 x 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

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 1354 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, and five5 inactive, and 1 seasonal (irrigation).
- Located within 0.62 miles (1 km) radius of the License Boundary: 12 active, 18 inactive, and 2three 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 9eight 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 20114 and- 20142105.

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 0.0282373 mg/L (average of 0.007145 mg/L]). Suspended uranium activity for the private wells ranged from <0.0003 to 0.001 2.0E-10 to 0.4 μCi/mL (average of 0.0002151 μCi/mL), and dissolved uranium ranged from 3.8E-10 to 3.9E-918.1 μCi/mL (average of 2.14E-91.3349 μCi/mL).

Suspended radium-226 values for the private wells ranged from <3.06E-11 to 2.0E-10 μCi/mL (average of 8.57E-11 μCi/mL) and dissolved radium-226 ranged from <1.3E-10 to 9.5E-9 μCi/mL (average of 2.35E-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 0.0282373 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 394408 mg/L and 26.2 versus 1723 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**.

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

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~~2015~~).

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~~48~~. 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~~048~~ (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

Lead-210 (dry)	2 x 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. ~~following spring runoff, and in late summer following period of extended low flow~~. 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 becomes available prior to mining, 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 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**.

Regional information, previous CBR license and permit submittals, and historical operational practices indicate that the minimum pressure that could initiate hydraulic fracture is 0.63 psi per foot of well depth. This value has historically and successfully been applied to CBR operations. Calculations for MEA result in a value of 0.53 psi. As such, the injection pressure is limited to less than 0.63 psi per foot of well depth. Injection pressures also will be limited to the pressure at which the well was integrity tested.

As discussed in Section 2.7, a regional pumping test has been conducted to assess the hydraulic characteristics of the basal sandstone of the Chadron Formation and overlying confining units. Pumping tests will also be performed for each MU ~~not covered by the regional pump test~~ to demonstrate hydraulic containment above the production zone, demonstrate communication between the production zone mining and exterior monitor wells, and to further evaluate the hydrologic properties of the basal sandstone of the Chadron Formation.

Prior to the startup of a MU the following wellfield package will be submitted to the NRC for review:

1) hydrologic test data;
2) completion reports on the monitoring wells;
3) water quality data used to determine excursion control parameters, and;
4) –baseline preoperational groundwater quality including; well density, sampling frequency, and determination of groundwater restoration goals;~~.~~
5) pumping test to establish that the production and injections wells are hydraulically connected to the perimeter horizontal excursion monitor wells and are hydraulically isolated from the vertical excursion monitor wells..

A full and detailed analysis of the potential impacts of the mining operations at Marsland on surrounding water users will be provided in an Industrial Groundwater Use Permit application. A similar permit application was submitted by Ferret Exploration of Nebraska (predecessor to Crow Butte Resources) in 1991, and that application provides a reasonable analogy between the current licensed area and satellite facility. The application states that water levels in the City of Crawford (approximately 3 miles [4.8 km] northwest of the mining area) could potentially be impacted by approximately 20 feet by consumptive withdrawal of water from the basal sandstone of the Chadron Formation during mining and restoration operations (based on a 20-year operational period).

A similar order of magnitude impact (drawdown) exists for the MEA operations. No impact to other users of groundwater is expected because there is no documented existing use of the basal sandstone of the Chadron Formation in the proposed MEA.

Because the basal sandstone of the Chadron Formation (production zone) is a deep confined aquifer, no surface water impacts are expected. Based on available information, all water supply wells within the MEA and AOR are completed in the relatively shallow Arikaree and/or Brule Formation, with no domestic or agricultural use of groundwater from the basal sandstone of the Chadron Formation.

Further, the geologic and hydrologic data presented in Sections 2.6 and 2.7, respectively, demonstrate that (1) uranium mineralization is limited to the basal sandstone of the Chadron Formation, and (2) this formation is isolated from underlying and overlying sands. Hence, the mining operations are expected to impact water quality only in the basal sandstone of the Chadron

maintain an inward hydraulic gradient. Water quality in the basal sandstone of the Chadron Formation is considered poor as compared to the shallower Brule formation. Therefore, there are limited wells completed in the basal sandstone of the Chadron Formation to allow for monitoring of offsite water levels. According to a 1991 Industrial Groundwater Use Permit, water levels in Crawford are expected to decrease up to 20 feet from static levels as a result of mining operations at the CPF site (CBR 2007).

Additionally, pumping tests have been conducted in the basal sandstone of the Chadron Formation at similar rates as anticipated production bleed rates. These tests have generally been less than three days in duration, and have resulted in estimated water level decreases greater than one foot at a distance up to 5,700 feet from the pumping well (Petrotek 2002). The cone of depression would continue to expand during long-duration pumping, as is the case during production and groundwater restoration activities. Therefore, the results of pumping tests as well as observed and projected water levels resulting from the CPF mining operations indicate that water levels in the basal sandstone of the Chadron Formation will decrease in a mining unit, with drawdown propagating up to several miles from the pumping center.

Observed water levels in the overlying Brule Formation resulting from CPF mining operations and during pumping tests indicate the basal sandstone of the Chadron Formation and Brule Formations are hydraulically disconnected. Therefore, sustained water level decreases in the basal sandstone of the Chadron Formation are expected to have an insignificant effect on Brule Formation water levels.

The disposal option for process bleed water and groundwater restoration that is likely to impact groundwater levels or water quality is injection into the Lower Dakota, Morrison, and/or Sundance Formations using deep disposal wells. Each expansion area is expected to operate up to two deep disposal wells. Characterization of the injection zone of Deep Disposal Well #2 at the CPF site indicates the formation thickness is approximately 67 feet. In order to calculate a radius of influence resulting from deep disposal well injection over the course of 10 years, mobile porosity was assumed to be 10 percent. The radius of influence resulting from injecting 45 gpm into a single well over 10 years is approximately 1,200 feet. The calculated radius of influence assumes uniform flow across the full injection interval (thickness) and area, and that no impediments to injection such as injection pressure or aquifer boundaries exist. While deep disposal well configurations and locations at each expansion area are not yet determined, this calculation provides some estimate of the area where deep disposal wells will displace formation groundwater, which may result in increased pressures or redistribution of groundwater to adjacent areas.

~~Cumulative impacts to aquifer water levels resulting from operation of expansion area mines should consider the duration of overlap and formation where impacts are likely to occur.~~

An analysis of the drawdown impacts resulting from MEA operations, and the cumulative drawdown impacts resulting from the simultaneous operation of the MEA, Crow Butte, and Three Crow Expansion Area facilities, was conducted and is located in **Appendix GG** (AquiferTek 2016b). The drawdown of the potentiometric surface of the basal sandstone of the Chadron Formation was computed using the Theis solutions for confined aquifers (Theis, 1935). Drawdown impacts were computed over the period 2011 through 2052, corresponding to the approximate historical groundwater monitoring period at MEA, future ISR facility operations and aquifer recovery period. Cumulative drawdown impacts from multiple ISR facilities were computed by summing the drawdown impacts of individual facilities using the principal of superposition.

Additional drawdown resulting from a lateral no-flow boundary was computed using image well theory (Ferris and others, 1962).

CBO will use performance confirmation to verify actual mining performance follows model drawdown projections (**Appendix GG, AquiferTek, 2016b**) to ensure that the basal sandstone of the Chadron Formation remains saturated. To monitor performance, CBO will install within each mine unit a minimum of one monitor well for collection of quarterly water level data. If needed recalibration of the models drawdown projections will be performed and if necessary, a corrective action plan will be developed and submitted to the NRC for review and approval.

~~In the basal sandstone of the Chadron Formation, drawdown associated with production at NTEA (start date in 2024), MEA (start date in 2015), and TCEA (start date in 2016) will all overlap with the final years of groundwater restoration at the CPF site. Based on the water level decreases expected to occur onsite and propagate out from each mine, overlapping drawdown in the basal sandstone of the Chadron Formation is expected. In the years 2024 through 2038, it is possible that each expansion area mine may be drawing water from the basal sandstone of the Chadron Formation. During this period, the overlapping water level decrease is expected to be greatest in the center point between two mines, and will likely be on the order of tens of feet. As restoration activities at the TCEA and MEA conclude (anticipated to be completed in 2038 and 2039, respectively), the only withdraw of basal sandstone of the Chadron Formation water will be at the NTEA. Few monitoring wells exist in the basal sandstone of the Chadron Formation outside mining lease boundaries, making extrapolation of observed onsite water level drawdowns resulting from CPF activities challenging. Therefore, quantification of overlapping water level drawdown resulting from simultaneous operation of multiple mines is difficult. However, the operation of multiple mines is expected to cause potentiometric surfaces in the basal sandstone of the Chadron Formation to decrease tens of feet in locations where overlap occurs.~~

Potential cumulative impacts to the Lower Dakota, Morrison, and Sundance Formations resulting from operation of deep disposal wells at expansion area mines are unclear. While ROI calculations indicate the area where formation water will be displaced by injected water, it is unclear where the displaced water migrates. The ability of these confined aquifers to accept injected water is limited by the presence of overlying and underlying confining units, aquifer storage, and hydraulic connection within the injected formation and with adjacent aquifers. Little characterization of the Lower Dakota, Morrison, or Sundance Formations is available in the area of interest that would enable a meaningful evaluation of overlapping influences among the four mines.

Surface water levels have been shown to be unaffected by current mining operations, as no discharge to surface water is permitted and the deep disposal aquifers appear to be hydraulically disconnected from surface water. No changes to the lack of surface water impacts are expected as a result of expanded mining operations.

Water Quality Impacts

Water quality in the basal sandstone of the Chadron Formation during mining is controlled by induced hydraulic gradients toward the mine unit that limit injectate excursions. Monitoring wells

outside the production wellfield are sampled biweekly to ensure that extraction wells are adequately removing the injectate. Changes to extraction well pumping rates are made to remedy observed injectate excursions that are indicated by perimeter monitoring well water quality results. Therefore, water quality in the basal sandstone of the Chadron Formation is not expected to be significantly affected during mining.

Mining unit-specific groundwater restoration water quality goals are determined as endpoints for restoration activities. During groundwater restoration, water is returned to at, or near background conditions using the best practice technology for treatment. If background concentrations for mining-related groundwater constituents cannot be achieved using best practice cleanup technologies, NDEQ groundwater standards become the restoration goal. The objective of groundwater restoration is to return water quality back to that which is consistent with pre-mining use. Future use of groundwater is not expected to be affected by mining activities.

The combined water quality controls in place during mining and aquifer restoration goals should result in water quality in mine units that are not significantly different than background, and do not influence future use. Therefore, cumulative influences on water quality of the basal sandstone of the Chadron Formation resulting from operation of multiple mines is not expected. Injected water quality in the Morrison, and Sundance Formations is monitored on a daily or weekly basis, depending on the parameter, and reported to the NDEQ on a monthly basis. Therefore, water quality in the deep injection formations will not be adversely impacted beyond what is permitted due to operation of deep disposal wells at multiple mines as long as injectate water quality does not deviate from permit limitations.

Conclusions

~~Water levels in the basal sandstone of the Chadron Formation have been shown to decrease near an active mine unit, with potentiometric surface depressions expanding several miles after years of active mining. This provides hydraulic control of injected water in order to minimize excursions that cause water quality issues. However, these water level decreases are expected to radiate from all mines that simultaneously draw water from the basal sandstone of the Chadron Formation during either production or groundwater restoration, and will induce overlapping potentiometric surface cones of depression. It is unclear as to the magnitude of decreases that may result from pumping at multiple mining areas, but it is expected to be on the order of tens of feet. The majority of the regional water wells are completed in the Brule Formation, and not the basal sandstone of the Chadron Formation, as water from the Brule Formation is preferred due to higher water quality and the preference for shallower wells.~~

A drawdown impact assessment was completed for the basal sandstone of the Chadron Formation at the MEA and for the simultaneous operation of the MEA, CBO, and TCEA (e.g. cumulative drawdown assessment) along with an assessment of the projected available head and basal Chadron potentiometric surface at the time of maximum cumulative drawdown **Appendix GG** (AquiferTek, May 2016b)

Results of the impact assessment indicates maximum cumulative drawdown at the MEA will be less than 111 feet over the period of combined ISR operations (2011-2042). Minimum available head at the MEA is projected to be greater than 320 feet within the MEA ISR wellfields, and greater than 270 feet within the MEA permit area for the duration of combined ISR operations.

Model drawdown projections can be considered conservative because they do not include the impact of groundwater recharge on the basal sandstone of the Chadron Formation over a large radius of influence and because consumptive use for the MEA and TCEA are based in part on a conservative 30% reverse osmosis (RO) efficiency during wellfield restoration (25% RO efficiency has been routinely achieved at the CBO facility).

The drawdown impact assessment does not include potential drawdown impacts resulting from groundwater withdrawals other than Cameco ISR operations, including large seasonal agricultural groundwater withdrawals from a tributary arm of the basal sandstone of the Chadron Formation approximately 35 to 50 miles southwest of the MEA in the North Platte drainage. Irrigation wells in the North Platte Irrigation District have been operating for over 40 years. Although there may not be a direct hydraulic connection between the tributary arm of the basal sandstone of the Chadron Formation in the North Platte drainage and the MEA (Sibray, 2010), there does appear to be less direct flow paths (on the order of 60 to 100 miles in length) that may hydraulically connect the MEA and the North Platte basin. Given the large reported seasonal groundwater withdrawals in excess of 1000 GPM from the basal sandstone of the Chadron Formation in the North Platte drainage, some measurable drawdown impact at the MEA would not be unexpected in a confined aquifer over a long period of time. Some of the historical drawdown observed at the MEA may therefore be attributable to irrigation withdrawals southwest of the MEA, and not entirely due to CBO operations.

Wastewater injected into the Lower Dakota, Morrison, and Sundance Formations using deep disposal wells will likely have injected radii of influences of greater than a 1,000 feet. These injections will displace formation groundwater, although it is unclear where that water will migrate. Little characterization of the Lower Dakota, Morrison, and Sundance Formations has been completed and only observations of injection pressures and flow rates can be used to infer the ability to dispose of water using this method. The Morrison Formation has demonstrated the capacity to accept large volumes of an injected waste stream over an extended period of time at the nearby CPF.

The subsurface geologic characteristics beneath the proposed expansion areas will prevent disposal fluids injected into the deep disposal well injection zone from impacting the overlying fresh water aquifers. Between the lowermost drinking water source aquifer and the deep disposal well injection are more than 2,500 feet of sediments primarily consisting of low permeability shale. This separating aquitard protects against vertical migration of injected fluids to the drinking water source aquifers. Shales above and below the deep disposal well injection zone will encase the disposal fluids within the receiving formations and no structural elements with the potential to disrupt the natural vertical containment have been identified.

Water quality in the basal sandstone of the Chadron Formation during production is maintained by providing hydraulic control of the injectate. Changes to extraction well operation are made to remedy observed injectate excursions. Formation water quality is restored to either background conditions, or conditions that are consistent with pre-mining water quality under the direction of the NDEQ. As a result, no significant degradation of water quality is expected to result from operation of expansion area mines. Water quality of the Lower Dakota, Morrison, and Sundance Formations is protected by permitted specifications on injectate water quality. Therefore, if permit limitations are not exceeded, there will be no adverse cumulative impact beyond permitted levels as a result of operation of multiple mines. The EPA and NDEQ will not authorize deep disposal via a Class I injection well unless the permitting process demonstrates that adequate operating

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Response to Open Issues
Marsland Expansion Area
Technical Report

Attachment B

Revised Text for the Marsland Expansion Area Technical Report

Volume I
Sections 1-10

(Replaces September 2015 text)

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Tables

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Appendices (Volume II & Volume III)

ACRONYMS AND ABBREVIATIONS

ACL	Alternative Concentration Limit
AERMOD	AMS/EPA Regulatory Model
ALARA	As Low as Reasonably Achievable
ALI	Annual Limit on Intake
AMS	American Meteorological Society
amsl	above mean sea level
ANSI	American National Standards Institute
AOR	area of review
API	American Petroleum Institute
ASOS	automated surface observing systems
ASTM	ASTM International
ATV	all-terrain vehicle
AWWARF	American Water Works Association Research Foundation
BBS	Breeding Bird Society
BEA	Bureau of Economic Analysis
bgs	below ground surface
BLM	Bureau of Land Management
BMP	Best Management Practice
BNSF	Burlington Northern Santa Fe
BPT	best practicable technology
$CaCO_3$	calcium carbonate
CAD	computer-aided design
CBR	Crow Butte Resources, Inc.
CDERA	Caribbean Disaster Emergency Response Agency
CEDE	Committed Effective Dose Equivalent
cfm	cubic feet per minute
CFR	Code of Federal Regulations
cfs	cubic feet per second
CGA	Compressed Gas Association
cm^2	square centimeter
cm/sec	centimeters per second
CO	carbon monoxide
CO_2	carbon dioxide
COOP	Cooperative Observer Program
CPF	Central Processing Facility

CPM	counts per minute
CPS	counts per second
CRSO	Corporate Radiation Safety Officer
CSC	Chadron State College
D/W/Y	day/week/year
DAC	derived air concentration
dBA	A-weighted decibels
DDE	deep dose equivalent
DDW	deep disposal well
DEM	digital elevation model
DFIRM	Digital Floodplain Insurance Rate Map
DLG	Digital Line Graph
DOE	Department of Energy
dpm	disintegrations per minute
DOT	Department of Transportation
DPS	Distinct Population Segment
DQO	Data Quality Objective
dpm	disintegrations per minute
DUSA	Dension Mines, USA
EA	Environmental Assessment
Eh	oxidation-reduction potential
EIS	Environmental Impact Statement
ELI	Energy Laboratories, Inc.
EPA	U.S. Environmental Protection Agency
ESA	Ecological Study Area
ESRI	Earth Sciences and Resources Institute
ET	evapotranspiration
FEMA	Federal Emergency Management Agency
FESA	Federal Endangered Species Act
ft amsl	feet above mean sea level
ft/day	feet per day
ft^2/day	square feet per day
ft^3	cubic feet
g	gravity
GAM(NAT)	natural gamma
GIS	Geographic Information System

GNIS	Geographical Names Information System
gpd	gallons per day
gpd/ft	gallons per day per foot
gpm	gallons per minute
GPS	Global Positioning System
GR	gamma ray
H_2O_2	hydrogen peroxide
H_2S	hydrogen sulfide
HDPE	high-density polyethylene
HMR	Hazardous Materials Regulation
HPRCC	High Plains Regional Climate Center
HPT	Health Physics Technician
HUC	hierarchal hydrologic unit (hydrologic unit code)
HWA	Hayden-Wing Associates
i	exposure period
ICRP	International Commission on Radiological Protection
I*r*	annual intake of radionuclide *r* by inhalation
ISO	International Organization for Standardization
ISR	in-situ recovery
IX	ion exchange
JFD	joint frequency distribution
km	kilometers
LAN	local area network
lbs	pounds
LDE	Lens Dose Equivalent
LLD	lower limit of detection
LSA	Low Specific Activity
LULC	land use and land cover
Ma	million years ago
m^2	square meters
m/s	meters per second
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MBTA	Migratory Bird Treaty Act
MCL	Maximum Contaminant Level
md	millidarcies
MDC	Minimum Detectable Concentration

MEA	Marsland Expansion Area
Meq/L	milliequivalents per liter
MeV	million electron volts
mg/cm^2	milligrams per square centimeter
mg/L	milligrams per liter
Mgpd	million gallons per day
mi^2	square miles
MILDOS-AREA	calculation of radiation dose from uranium recovery operations
MIT	mechanical integrity testing
MM	Mercalli Modified
mm	millimeters
mph	miles per hour
mR/hr	milliRoentgens per hour
mRem	millirem
mRem/yr	millirem per year
mSv	milliSievert
MU	mine unit
n	number of exposure periods in the year
NA	not applicable
Na_2S	Sodium sulfide
$NACO_3$	Sodium Carbonate
$NaHCO_3$	sodium bicarbonate
NAAQS	National Ambient Air Quality Standards
NAD 1927	North American Datum of 1927
NaI	sodium iodide
NAIP	National Agricultural Imagery Program
NaOH	Sodium Hydroxide
NASS	National Agricultural Statistics Service
NBELF	Nebraska Board of Educational Lands and Funds
NCCPE	Nebraska's Coordinating Commission for Postsecondary Education
NCDC	National Climate Data Center
NDA	Nebraska Department of Agriculture
NDE	Nebraska Department of Education
NDED	Nebraska Department of Economic Development
NDEQ	Nebraska Department of Environmental Quality
NDHHS	Nebraska Department of Health and Human Services

NDNR	Nebraska Department of Natural Resources
NDOL	Nebraska Department of Labor
NDOR	Nebraska Department of Roads
NED	national elevation dataset
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NGPC	Nebraska Game and Parks Commission
NGS	National Geodetic Society
NHD	national hydrography database
NHPA	National Historic Preservation Act
NLCD	national land cover data
NNHP	Nebraska Natural Heritage Program
NNLP	Nebraska Natural Legacy Project
NO_2	nitrogen dioxide
NOAA	National Ocean and Atmospheric Administration
NOGCC	Nebraska Oil and Gas Conservation Commission
NOI	Notice of Intent
NOU	Nebraska Ornithologists Union
NO_x	nitrogen oxides
NPDES	National Pollution Discharge Elimination System
NPS	National Park Service
NRC	Nuclear Regulatory Commission
NRCS	National Resources Conservation Service
NREL	National Renewable Energy Laboratory
NRPH	National Register of Historic Places
NRS	Nebraska Revised Statutes
NSHS	Nebraska State Historical Society
NTEA	North Trend Expansion Area
NTU	nephelometric turbidity unit
NVLAP	National Voluntary Laboratory Accrediation Program
NWI	National Wetlands Inventory
NWS	National Weather Service
O_2	gaseous oxygen
OSHA	Occupational Safety and Health Administration
OSLD	optically stimulated luminescence dosimeter
PBL	performance-based license

PBLC	Performance-Based License Condition
pCi/L	picoCuries per liter
person-Rem/yr	person-Rem per year
PFYC	potential fossil yield classification system
PM_{10}	particulate matter measuring 10 micrometers or less in diameter
$PM_{2.5}$	particulate matter measuring 2.5 micrometers or less in diameter
PPE	personal protective equipment
ppm	parts per million
PPMP	Preoperational/Preconstruction Monitoring Program
PSD	Prevention of Significant Deterioration
psi	pounds per square inch
PVC	polyvinyl chloride
QA	quality assurance
QA/QC	Quality Assurance/Quality Control
QAM	Quality Assurance Manual
QC	quality control
rad/d	rad per day
RCRA	Resource Conservation and Recovery Act
R&D	research and development
Rem	Roentgen equivalent man
RES	single point resistance
RFFA	reasonable forseeable future actions
RG	Regulatory Guide
RL	reporting limit
RMP	Risk Management Program
RO	reverse osmosis
ROI	radius of influence
RPPA	Respiratory Protection Program Administrator
RSO	Radiation Safety Officer
RUSLE	Revised Universal Soil Loss Equation
RWP	radiation work permit
SCDA	sequential control and data acquisition
SCS	Soil Conservation Service
SDE	shallow dose equivalent
SDR	Standard Deviation Ratio
SER	Safety Evaluation Report

SERP	Safety and Environmental Review Panel
SH	State Highway
SHEQMS	Safety, Health, Environment and Quality Management System
SHPO	State Historic Preservation Office
SO_2	sulfur dioxide
SOP	standard operating procedure
SP	spontaneous potential
SPCC	Spill Prevention, Control, and Countermeasure
SRWP	Standing Radiation Work Permit
SS	stainless steel
SSC	structure, system, or component
SSURGO	soil survey geographic database
su	standard unit
SWMA	State Wildlife Management Area
SWPPP	Storm Water Pollution Prevention Plan
TCEA	Three Crow Expansion Area
TCP	Traditional Cultural Properties
TCR	The Chadron Record
TDS	total dissolved solids
T&E	threatened and endangered
TEDE	Total Effective Dose Equivalent
TER	Technical Evaluation Report
THC	total hydrocarbon
TLD	thermoluminescent dosimeter
TMDL	total maximum daily load
TSP	total suspended particulates
TSS	total suspended solids
U_3O_8	uranium oxide
μCi/ml	microCurie per milliliter
UCL	Upper Control Limit
UDC	uranyl dicarbonate
U-nat	natural uranium
$\mu g/m^3$	micrograms per cubic meter
UIC	underground injection control
μmhos/cm	micromhos per centimeter
UMTRCA	Uranium Mill Tailings Radiation Control Act

UNRI	Urban Natural Resource Institute
μR/hr	microRoentgens per hour
US	United States
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USCB	United States Census Bureau
USDA	United States Department of Agriculture
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USLE	universal soil loss equation
UTC	uranyl tricarbonate
VMT	vehicle miles travelled
VOC	volatile organic compound
VRM	visual resource management
VTPD	vehicle trips per day
WFC	Wyoming Fuel Company
WL	Working Level; measured concentration of radon decay products
WLM	working level month
WRCC	Western Regional Climate Center
WSA	Wilderness Study Area
x	number of radionuclides of interest
XRD	x-ray diffraction
yd^3	cubic yards
ZOEI	zone of endangering influence

1 PROPOSED ACTIVITIES

1.1 Licensing Action Requested

Crow Butte Resources, Inc. (CBR) makes this application to the United States Nuclear Regulatory Commission (NRC) to amend Radioactive Source Materials License SUA-1534, for development of additional uranium *in-situ* recovery (ISR) operations in Dawes County, Nebraska. The area proposed for use as a satellite facility to the main CBR Central Processing Facility (CPF) is referred to as the Marsland Expansion Area (MEA).

By letter dated Nov. 27, 2007, CBR applied for a renewal of Source Materials License No. SUA-1534 for the CPF. This renewal will allow for the continued operation of the current CPF. The NRC issued a draft license by letter dated May 23, 2011. Following comments by CBR, the NRC issued a second draft of the CBR renewal license on August 11, 2011. As part of the licensing process, the NRC issued a Safety Evaluation Report (SER) for the license renewal dated December 2012 (NRC 2012a). The SER documents the safety portion of the NRC staff's review of the license renewal application, as amended, and includes an analysis to determine CBR's compliance with these and other applicable 10 Code of Federal Regulations (CFR) Part 40 requirements, and applicable requirements set forth in 10 CFR Part 40, Appendix A (NRC 2012a). The SER also evaluates CBR's compliance with applicable requirements in 10 CFR Part 20, "Standards for Protection against Radiation." An Environmental Assessment (EA) is also being prepared in parallel with the SER to address environmental impacts of the proposed action, which complies with NRC's implementation regulations for the National Environmental Policy Act (NEPA; NRC 2012a). While the license renewal is pending, the current license remains in effect.

The application is presented primarily in the NRC format found in NRC Regulatory Guide (RG) 3.46, *"Standard Format and Content of License Applications, Including Environmental Reports, For In Situ Uranium Solution Mining"* (June 1982). NRC document NUREG-1569, *Standard Review Plan for In Situ Leach Uranium Extraction License Applications* (June 2003) was followed to ensure that all information is provided to allow NRC Staff to complete their review of this amendment application.

1.2 Crow Butte Uranium Project Background

The original CPF was developed by Wyoming Fuel Company, which constructed an R&D Facility in 1986. The project was subsequently acquired and operated by Ferret Exploration Company of Nebraska until May 1994, when the name was changed to Crow Butte Resources, Inc. This change was only a name change and not an ownership change. CBR is the owner and operator of the Crow Butte Project.

The land (fee and leases) at the CPF is held by Crow Butte Land Company, which is a Nebraska corporation. All of the officers and directors of Crow Butte Land Company are U.S. Citizens. Crow Butte Land Company is owned by CBR, which is the licensed operator of the facility. CBR, which does business as Cameco Resources, is also a Nebraska corporation. All of its officers are U.S. citizens, as are two thirds of its directors. CBR is owned by Cameco US Holdings, Inc., which

is a U.S. corporation registered in Nevada. For Cameco US Holdings, three quarters of the officers are U.S. citizens, as are two thirds of the directors. Cameco US Holdings is held by Cameco Corporation, which is a Canadian corporation that is publicly traded on both the Toronto and New York Stock Exchanges.

The R&D Facility was located in N½ SE¼ of section 19, Township (T) 31 North (N), Range (R) 51 West (W). Operations at this facility were initiated in July 1986, and mining took place in two wellfields (WF-1 and WF-2). Mining in WF-2 was completed in 1987, and restoration of that wellfield has been completed. WF-1 was incorporated into Mine Unit 1 of current operations.

The current production wellfield is located within the current license area as shown in **Figure 1.7-2**. The main production facility is located in section 19, T31N, R51W, Dawes County, Nebraska. The current license area occupies approximately 2,861 acres, and the surface area affected over the estimated life of the project is approximately 2,000 acres.

CBR has successfully operated the current production area since commercial operations began in 1991. Production of uranium has been maintained at design quantities throughout that period with no adverse environmental impacts. Groundwater restoration for Mine Unit 1 has been completed and approved by the NRC and Nebraska Department of Environmental Quality (NDEQ), with NRC issuing the final approval on February 12, 2003. The operating history and timelines for the current production area are discussed in more detail in Section 1.7.

1.3 Site Location and Description

The proposed MEA is located within sections 26, 35, 36 of T30N, R51W; sections 1, 2, 11, 12, 13 of T29N R51W; and sections 7, 18, 19, 20, 29, 30 of T29N, R50W. The project area encompasses 4,622.3 acres. The MEA satellite facility is located approximately 11.1 miles (17.9 km) south-southeast of the CPF (centerpoint of MEA satellite building to centerpoint of CPF building) and approximately 4.6 miles (7.4 km) northeast of the community of Marsland (centerpoint of MEA satellite building to centerpoint of Town of Marsland). **Figure 1.3-1** shows the locations of the current license area and the proposed MEA.

All of the mineral resources leased within the MEA are privately owned, with the exception of the SW ¼ section of section 36 of T30N, R51W. This quarter section is designated as State Trust Land and is a small part of the nearly 1,300,000 acres of land now held in Trust for Nebraska's K-12 public schools. The Trustee of Nebraska's School Trust lands is the Board of Educational Lands and Funds (NBELF 2010). The surface and mineral rights are leased by Cameco from the State of Nebraska. There are no federal surface lands or minerals in the MEA license boundary. **Figure 1.3-2** shows surface land ownership in the proposed MEA.

1.4 Ore Body Description

Similar to the CPF, uranium will also be recovered from the basal sandstone of the Chadron Formation. The depth of the ore body in the MEA ranges from 850 to 1,200 feet below ground surface (bgs). The ore body width varies from approximately 1,000 feet to 4,000 feet. The ore

body ranges in grade from 0.11 percent to 0.33 percent uranium oxide (U_3O_8), with an average grade estimated at 0.22 percent U_3O_8. The ore-grade uranium deposits underlying the MEA are depicted in **Figure 1.4-1**.

1.5 Solution Mining Method and Recovery Process

The ISR process for uranium recovery consists of an oxidation step which occurs underground. Gaseous oxygen (O_2) or hydrogen peroxide (H_2O_2) is used to oxidize the uranium, and bicarbonate is used for dissolution. The uranium-bearing solution is recovered from the wellfield, and the uranium is extracted in the CPF process building. The CPF process uses the following steps:

- Loading of uranium complexes onto ion exchange (IX) resin
- Reconstitution of the solution by the addition of bicarbonate and O_2
- Elution of the uranium complexes from the resin
- Drying and packaging of the uranium

1.5.1 Advantages of ISR Uranium Mining

ISR uranium mining is a proven technology that has been demonstrated commercially in Wyoming, Texas, and at Crow Butte in Nebraska. ISR mining of uranium is environmentally superior to conventional open pit and underground uranium mining because:

- ISR mining results in significantly less surface disturbance because mine pits, waste dumps, haul roads, and tailings ponds are not needed.
- ISR mining carries a much lower water demand than conventional mining and milling, avoiding the water usage associated with pit dewatering, conventional milling, and tailings transport.
- The lack of heavy equipment, haul roads, waste dumps, and other features results in very little air quality degradation.
- Fewer employees are needed at ISR mines, thereby reducing transportation and socioeconomic concerns.
- Aquifers are not excavated, but remain intact during and after ISR mining.
- Tailings ponds are not used, thereby eliminating a major groundwater pollution concern.
- The majority of other contaminants (e.g., heavy metals) remain where they occur naturally instead of being relocated to waste dumps and tailings ponds with additional environmental concern.

1.5.2 Ore Amenability to the ISR Mining Method

Amenability of the uranium deposits in the current CBR license area to ISR mining was demonstrated initially through core studies. Results of the core studies were confirmed in the R&D project at the CPF site using bicarbonate/carbonate leaching solutions with O_2. Reports concerning the results of the R&D activities, including restoration of affected groundwater, were previously submitted to NRC and the NDEQ.

The information and experience gained during these pilot programs formed the basis for the commercial uranium ISR mining operations. The current operation, including the successful

restoration of groundwater in Mine Unit 1, demonstrates that such a program can be implemented at the MEA with minimal short-term environmental impacts and with no significant risk to the public health or safety. The remainder of this application describes the mining and reclamation plans for the current CBR license area and the MEA, and the concurrent environmental monitoring programs employed to ensure that any impact to the environment or public is minimal.

1.6 Operating Plans, Design Throughput, and Production

The CPF is licensed for a flow rate of 9,000 gallons per minute (gpm), excluding restoration flow, under License No. SUA-1534. Total annual production is limited to 2,000,000 pounds of yellowcake.

Uranium extracted from the Marsland wellfield will be processed at a satellite facility located within the MEA. The MEA will operate at an overall average production flow rate of 6,000 gpm (excluding 1,500 gpm for restoration). The anticipated bleed rate is assumed to be 0.5 to 2.0 percent of the total mining flow. The MEA will operate with an expected annual production rate of approximately 600,000 pounds (lbs) U_3O_8. Indicated ore reserves as U_3O_8 for the MEA are 6,161,679 lbs, with an additional inferred estimate of 3,389,518 lbs. Total reserves for the MEA are currently estimated at 9,551,197 lbs. The uranium extracted from the MEA will be loaded onto IX resin in the MEA satellite facility, which will then be transported by tanker truck to the main plant for elution, precipitation, drying, and packaging. Barren resin will be returned to the MEA satellite facility by tanker truck. The MEA operations are discussed in more detail in Section 3. The proposed MEA occupies approximately 4,622.3 acres. Over the life of the project, an estimated 1,753 acres may be impacted.

1.7 Proposed Operating Timelines

1.7.1 Current Production Area

Sufficient reserves in the current license area have been estimated to allow mining operations to continue until the end of 2015. Completion of groundwater restoration in the current license area is scheduled for 2033, with site restoration completed by 2038. Projected production and restoration timelines for the CPF are shown on **Figure 1.7-1**. The current status of the 11 mine units (MUs) are shown in **Table 1.7-1**. In 2010, the total annual production rate for the CPF was 592,541 pounds U_3O_8, and in 2009 it was 700,000 pounds U_3O_8. Additional mine unit plans are developed approximately 1 year prior to the planned commencement of new mining operations. For the current production area, production is ongoing in Mine Units 7, 8, 9, 10, and 11. Mine Unit 1 has been restored, and restoration is occurring in Mine Units 2, 3, 4, 5, and 6. The layout of the current and planned mine units in the current license area is shown on **Figure 1.7-2**.

1.7.2 Marsland Expansion Area

The proposed MEA project site map and project timeline are shown on **Figures 1.7-5** and **1.7-4,** respectively. There is a potential for 11 MUs, with construction for Mine Unit 1 (MU-1) to commence in 2014. Production for the project (all MUs) will start in 2015 and terminate in 2033.

Restoration in designated MUs will commence in the year 2020 and will be completed in 2039. Site reclamation will be completed in 2040.

The MEA will be subdivided into an appropriate number of MUs (**Figure 1.7-5**). Each MU will contain a number of wellhouses where injection and recovery solutions from the satellite plant building are distributed to the individual wells. The injection and production manifold piping from the MEA satellite facility to the wellhouses will be either polyvinyl chloride (PVC) or high-density polyethylene (HDPE) with butt-welded joints or an equivalent. Pressure switches will be installed to each injection manifold in the wellhouse to alert the plant and wellfield operators of increasing manifold pressures. Pressure gauges, pressure shutdown switches, and pressure transducers will be used to monitor and control trunkline pressures. Oxidizer will be added to the injection stream, and all injection lines off of the injection manifold will be equipped with totalizing flowmeters, which will be monitored in the satellite Control Room. The MEA wellfield will be designed in a manner consistent with the existing CPF wellfield. More detailed information about the site operations is discussed in Section 3.

1.7.3 Three Crow Expansion Area Timeline

On July 12, 2010, CBR submitted a Class III UIC Application and Aquifer Exemption Petition for the proposed Three Crow Expansion Area (TCEA), which will be used as a satellite facility supporting the CPF. On August 3, 2010, CBR submitted a request to the NRC for an amendment to Source Materials License SUA-1534 for the development of the TCEA. In 2011, CBR advised the NDEQ and NRC of a possible change from a full satellite facility (production of impregnated resin for transport to the main CPF) to use of pipelines to transport all process fluids from the TCEA to the CPF. If feasible, the revised license would allow for construction and operation of these process pipelines. CBR requested that the NRC and NDEQ suspend review of the respective TCEA applications so that CBR could supplement the applications with the alternate approach (Leftwich 2011; ML111160020). By letter dated October 11, 2012, CBR provided the NRC with a Notice of Intent to restart the TCEA application process, with the use of a satellite facility (Leftwich 2012; ML12299A211). The only major change in the proposed TCEA satellite facility is that surge/evaporation ponds are deemed to no longer be required to support deep disposal well (DDW) operations. The satellite facility will operate without surge/evaporation ponds or surge tanks.

TCEA construction is planned for completion in 2016, with production from 2016 to 2032, restoration from 2023 to 2038, and completion of final site reclamation in 2039.

1.7.4 North Trend Expansion Area Timeline

The proposed North Trend Expansion Area (NTEA) will consist of a support satellite facility for the CPF. CBR has received approval from the NDEQ for a Class III Underground Injection Control (UIC) permit (NDEQ 2011a) and an aquifer exemption (NDEQ 2011b) that will allow for construction and operation of the satellite facility for ISR mining of the proposed NTEA. A radioactive source material license amendment for the NTEA is pending before the NRC for the proposed NTEA. Current plans are for this project to be constructed in 2023, production from 2024

into 2032, with groundwater restoration activities ongoing from 2029 through 2039. Final site reclamation would be completed in 2041.

1.8 Waste Management and Disposal

1.8.1 Liquid Waste

Alternative wastewater disposal options that were considered were deep disposal well (DDW) injection, surge/evaporation ponds, point source discharge, and/or land application. In addition, surge/evaporation ponds and surge tanks were evaluated as waste management facilities to support the selected DDW alternative.

The proposed method of disposal will be DDW injection without supporting surge/evaporation ponds or surge tanks. The justification for this proposed action is discussed in Sections 3.1.7 and 4.2.1.7. There are currently no plans for any point source discharges or land application of wastewaters. However, the land application option could be applied in the future if such disposal is deemed feasible and more beneficial for a specific wastewater stream. Any such action would require an NRC license amendment and a discharge permit from the NDEQ. The alternatives considered for the waste disposal options are discussed in Section 8.

Operation of the MEA satellite facility will result in the following liquid waste streams:

- **Water generated during well development** - This water is recovered groundwater similar to well development water currently produced at the CPF. This water will be disposed of in an onsite DDW.
- **Liquid process waste** - The operation of the satellite facility results in one primary source of liquid waste - a production bleed. This bleed will be routed to an onsite DDW.
- **Aquifer restoration** - Restoration of **the affected aquifer** (which commences following mining operations) results in the production of wastewater similar to that produced during current restoration activities at the CPF (See **Figure 6.1-1**). This wastewater will be disposed of in an onsite DDW.

Domestic sewage will be disposed of in an onsite wastewater treatment (i.e., septic) system permitted by the NDEQ under the Class V UIC Regulations.

Based on the proposed project development schedule and the water balance of the MEA project, liquid waste disposal methods used will be phased for the MEA operations. For approximately the first 6 years of operation (2015 through 2020), the MEA operations will discharge wastewaters to storage tanks located in the satellite building, which will discharge to two onsite DDWs. There will be no evaporation ponds or large surge tanks, because the project can be safely operated in a sound environmental manner without them (see discussions in Sections 3.1.7 and 4.2.1.7). The proposed waste management system will be sufficient to handle the total quantities of wastewaters that will be generated and will require disposal.

Restoration flows will increase in 2021 to the extent that additional wastewater management and controls will be needed, because the increased flows are expected to exceed the capacity of two DDWs. CBR will use the first 5 to 6 years of operations to assess the maximum injection rates of the DDWs and the overall efficiency of the waste management system. Efforts will be made to

maximize the DDW injection rates, minimize the amounts of wastewaters generated during production and restoration that require disposal, better quantify actual site wastewater flows, and further assess viable waste management alternatives and environmental implications. This time period will allow CBR time to develop an updated waste management system that will provide for the most optimum long-term economic and technical viable approach to managing liquid wastes. Additional wastewater management systems to be evaluated will include additional DDWs, surge tanks, surge/evaporation ponds, land application, wastewater treatment with a permitted discharge, and process optimizations/modifications to minimize liquid waste generation.

CBR will submit an evaluation for proposed changes to the waste management system for NRC written verification and if necessary submit a license amendment request.

Sources and methods of handling liquid wastes are discussed in more detail in Section 4. Disposal alternatives for liquid 11e.(2) byproduct materials are discussed in Section 8.3.1.3.

1.8.2 Solid Waste

Solid wastes generated consist of wastes such as spent resin, resin fines, filters, miscellaneous pipe and fittings, and domestic trash. These wastes are classified as contaminated 11e.(2) byproduct material or non-contaminated waste according to radiological survey results. Contaminated byproduct waste that cannot be decontaminated is packaged and stored until it can be shipped to a licensed 11e.(2) byproduct material waste disposal site or licensed mill tailings facility. Non-contaminated solid waste is collected regularly on the site and disposed of in a sanitary landfill permitted by the NDEQ.

CBR currently has a contractual agreement with Dension Mines (USA) Corp. (DUSA) for the disposal of 11e.(2) byproduct materials at DUSA's White Mesa Mill site located near Blanding, Utah (CBR and DUSA 2010). The White Mesa Mill is licensed by the NRC to allow the disposal of byproduct material generated as a result of operations at licensed uranium ISR facilities by placement of the byproduct material in the White Mesa Mill's tailings impoundment. For this agreement, the maximum annual volume for disposal is 3,823 cubic meters (5,000 yds) of byproduct, which is a common maximum volume for agreements with the White Mesa Mill. Unless terminated by either party, the contract shall be automatically renewed each year for a maximum of four additional periods (i.e., up to June 30, 2015 at the latest). At the end of this period, Cameco can seek renewal for a designated period of time. Should Cameco contract with a new disposal facility, Cameco will notify the NRC in accordance with License Condition 9 of SUA-1534.

Additional discussions of solid wastes are presented in Section 4.2.

1.8.3 Contaminated Equipment

Materials and equipment that become contaminated as a result of normal operations are decontaminated if possible and disposed of by conventional methods. Equipment and materials

that cannot be decontaminated are treated in the same manner as other contaminated solid waste discussed in Section 1.8.2.

1.9 Groundwater Restoration

Restoration activities will be carried out at the MEA concurrent with mining activities. The restoration process will be similar to that used to restore the wellfield at the current CBR license area, and will consist of four basic activities:

- **Groundwater transfer**- groundwater is transferred between the MU commencing restoration and an MU commencing production or another water source.
- **Groundwater sweep**- water is pumped from the wellfield with no injection, which results in an influx of baseline quality water from the wellfield perimeter.
- **Groundwater treatment**- water from production wells is pumped to the satellite plant, where combinations of IX, reverse osmosis (RO), filtration, and other treatment methods take place.
- **Wellfield recirculation** - water is recirculated by pumping from the production wells and reinjecting the recovered solution. This will homogenize the quality of the aquifer.

Following these restoration phases, a groundwater stabilization monitoring program is initiated. Once the restoration values are reached and maintained, restoration is deemed complete. Results are documented in a Restoration Report and submitted to the NDEQ and the NRC for approval. Groundwater restoration is described in more detail in Section 6.

1.10 Decommissioning and Reclamation

At the completion of mine life and after groundwater restoration has been completed, all injection and recovery wells will be plugged and the site decommissioned. Decommissioning will include satellite facility disassembly and disposal and land reclamation of all disturbed areas. Applicable NRC Regulatory Guidelines will be followed. Decommissioning and reclamation are discussed in more detail in Section 6.

1.11 Surety Arrangements

CBR maintains an NRC-approved financial surety arrangement consistent with 10 CFR 40, Appendix A, Criterion 9 to cover the estimated costs of reclamation. Crow Butte maintains an Irrevocable Standby Letter of Credit issued by the Royal Bank of Canada in favor of the State of Nebraska in the present amount of $35,398,802. The surety amount is revised annually in accordance with the requirements of SUA-1534. The latest approved surety update is dated November 12, 2013 and is included as Amendment No. 27 to the NRC license. CBR's current surety is $43,223,280, and has been approved by the NRC.

By letter dated September 30, 2013, Cameco submitted an annual update to the Surety Estimate for the CBR uranium mine Surety Estimate for the year 2014 (Leftwich 2013). The proposed 2014 Surety Estimate is $44,719,032, an increase of $1,495,752 over the 2013 Surety Estimate of $43,223,280, approved on November 12, 2013.

The surety amount will be revised to reflect the estimated costs of reclamation activities for the MEA as development activities proceed. At Marsland, the 2013 estimated surety amount for the first wellfield put into operations is $2,286,647. Detailed discussions of the MEA surety can be found in the 2013 update of the MEA Environmental Report.

2 SITE CHARACTERISTICS

2.1 Site Location and Layout

The location of the current license area is sections 11, 12, 13, 24 of T31N, R52W and sections 18, 19, 20, 29, 30 of T31 N, R51W, Dawes County, Nebraska. The proposed MEA is located in sections 26, 35, 36 of T30N, R51W; sections 1, 2, 11, 12, and 13 of T29N, R51W; and sections 7, 18, 19, 20, 29, and 30 of T29N, R50W. The MEA is located approximately 4.6 miles (7.4 km) northeast of the unincorporated community of Marsland, Nebraska (centerpoint of MEA satellite building to centerpoint of Town of Marsland; **Figure 1.7-3**).

The maps used in this and other sections of this amendment application are Vector 7.5-minute quad maps. These are computer-aided design (CAD)/geographic information systems (GIS) drawings that depict each road, stream, and contour line as an individual entity. The layers in these maps were derived from the U.S. Census Bureau TIGER/Line data, U.S. Geological Survey (USGS) Digital Line Graph (DLG) Data, USGS Digital Elevation Model (DEM) data, Bureau of Land Management (BLM) Section Line data, National Geodetic Survey (NGS) Benchmark data, and USGS Geographical Names Information System (GNIS) data. This base map was then used for each of the figures prepared for this document with the addition of the pertinent information for that figure.

The longitudes and latitudes for the site boundary vertices and satellite facility are identified in **Table 2.1-1**. The datum for all topography maps in this application was North American Datum of 1983 (NAD 1983), and the geographic coordinate reference system (projection) was: *NAD_1983_StatePlane_Nebraska_North_FIPS_2600 (US_Foot).*

Figure 1.7-3 shows the general area surrounding the proposed project area, including the proposed MEA, Area of Review (AOR) and Zone of Endangering Influence (ZOEI).

Figure 1.7-2 shows the general project site layout and Restricted Areas for the current license area including the CPF building area, the RO facility, the current mine unit boundaries, and the R&D and commercial evaporation ponds.

Figure 1.7-5 shows the proposed location of the satellite facility, mine units, access roads, and DDW within the MEA. The latitude and longitude for the center of the satellite facility is provided in **Table 2.1-1**.

Figure 5.7-2 shows the proposed MEA satellite building and the designated restricted area.

Figure 1.3-1 shows the proposed MEA project location in relation to the CPF and proposed NTEA and TCEA. This figure shows topographical features; drainage and surface water features; nearby population centers; political boundaries; and principal highways, railroads, transmission lines, and waterways.

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2.2 Uses of Adjacent Lands and Waters

This section evaluates the effects of the proposed uranium mining on the physical, ecological, and social characteristics of the surrounding environments. Land and water use in the current Crow Butte license area are discussed in the license renewal application previously submitted for NRC License Number SUA-1534 (NRC 2007a). Land and water use for the proposed NTEA are discussed in a license amendment application submitted to the NRC on May 30, 2007 (NRC 2007b). In addition, land and water use are discussed in a license amendment application for the proposed TCEA (NRC 2010), which is pending.

This section describes the nature and extent of present and projected land and water use and trends in population or industrial patterns. The information for the CPF was initially developed over a 9-month period in 1982 as part of the R&D License Application, updated in 1987 for the Commercial License Application, and in 1997 and 2007 during license renewal. The information for the MEA was developed in 2011. Preliminary data were obtained from several sources including previous licensing documents supported by field studies and interviews with various state and local officials.

NUREG 1569 requires a discussion of land and water use in the proposed MEA and within a 2.0-mile (3.3 km) distance from the site boundary. The NDEQ requires an assessment of a 2.25-mile (3.62 km) radius of the proposed project site boundary (AOR) for the Class III UIC application. Therefore, the NRC's 2.0-mile (3.2-km) radius has been extended to 2.25 miles (3.62 km) for consistency. Land use within the MEA and the 2.25-mile (3.62-km) AOR is illustrated on **Figure 2.2-1**.

Land use and water use data were updated from previous license applications by additional data collection and review, personal communications, and site reconnaissance. Population distribution characteristics were updated using current 2010 Census data and other applicable sources (USCB 2011).

Little change in land use has been noted in recent decades, reflecting the stagnant nature of economic activity and a slight decline in the populations of the City of Crawford and Dawes County.

2.2.1 General Setting

The MEA is located in southwestern Dawes County, Nebraska, just south of the Pine Ridge. The MEA is located approximately 4.6 miles (7.4 km) northeast of the community of Marsland (centerpoint of MEA satellite building to centerpoint of Town of Marsland; **Figure 2.2-1**). The main access route to the MEA is via State Highway (SH) 2/71 west of Marsland, then east along the Niobrara River and River Road, and then north on either Squaw Mound Road or Hollibaugh Road.

2.2.2 Land Use

Land use of the MEA and surrounding AOR is dominated by agricultural uses (**Figure 2.2-1 and Figure 2.8-1**). **Table 2.2-1** describes major land use types, including those depicted on **Figure 2.2-1**. Land use acreages for the AOR (**Table 2.2-2**) and MEA (**Table 2.2-3**) are presented in

Figure 2.2-1 in 22-½ sectors centered on each of 16 compass points radiating out from the proposed satellite facility. Major land uses within the MEA and AOR are further discussed below.

Rangeland comprises the greatest land cover within the 2.25-mile (3.62-km) AOR (73 percent). Forest lands (13.4 percent), cropland (7.8 percent), and recreational land (3.3 percent) are the other significant land cover types. Less than 0.07 percent (30 acres) of the AOR is accounted for by wetlands. Scattered rural residences are mostly associated with agricultural operations.

Residential and commercial land uses in Dawes County are concentrated within the city limits of Crawford and Chadron and in the communities of Whitney and Marsland. Industrial land uses within the city limits of Crawford are generally associated with railroad facilities.

Within the MEA, rangeland is the dominant land use (80 percent), with cropland (10 percent) and forestland (7.8 percent) accounting for smaller areas.

2.2.2.1 Agriculture

Several of the soil types found in the vicinity of the MEA are classified as prime farmland. However, in Dawes County, soils are classified by the U.S. Natural Resource Conservation Service (NRCS) as prime farmland only if irrigated. According to 2009 Census of Agriculture for Nebraska, nearly 9 percent of Dawes County agricultural land is irrigated, and about 16 percent of harvested cropland acreage is irrigated (NASS 2009a). The remainder of the irrigated land is used for pasture, habitat, or rangeland (NASS 2009b). Irrigated land is found both in the MEA and in the AOR.

Table 2.2-4 and **Table 2.2-5** show agricultural productivity and livestock inventory, respectively, within Dawes County. Wheat and forage are the major crops grown on croplands in Dawes County. Most of these crops are used for livestock feed, while the remaining crops are commercially sold. In 2010, total wheat production in Dawes County was 1,195,000 bushels, a decrease of 24 percent from 2009 production (NASS 2011). In 2010, 96,600 tons of forage was grown; this was a decrease of approximately 11 percent from the 2009 harvest. Non-livestock agricultural lands in Dawes County had a value of $13.61 per acre, indicating that crop production on existing farmed lands in the AOR have a potential value (assuming full use of lands) of $39,801 and $6,041 in the MEA (NASS 2009a).

In 2007, 69,429 head of livestock was reported in Dawes County (NASS 2009a). The livestock inventory for Dawes County indicates that cattle account for more than 90 percent of all livestock. Livestock, poultry, and their products account for approximately 75 percent of the total market value of all agricultural products sold in 2007; this is a slight decrease from 2002, when livestock accounted for approximately 86 percent of market value. In 2007, cash receipts for livestock and products totaled $34.3 million in Dawes County (NASS 2009a). Livestock, poultry, and their products had a value of $40.40 per acre, indicating that livestock production on rangeland within the AOR has a potential value (assuming full use of lands) of approximately $1.1 million and $145,448 in the MEA (NASS 2009a).

The market value of crops of $13.61 per acre was calculated as follows:

Market value of crops, including nursery and greenhouse crops ÷ Land in Farms: $11,550,000 ÷848,753 acres = $13.61/acre.

The market value of livestock poultry and their products of $40.40 was calculated as follows:

Market value of livestock, poultry, and their products ÷ Land in farms
$34,286,000 ÷ 848,753 acres = $40.40/acre

These values were calculated using the data from Table 1, County Summary Highlights: 2007 for Dawes County (NASS 2009a). The methodology used for the calculations are from a publication by Doris N. Petersan (Petersan 2005).

2.2.2.2 Recreation

There are no developed recreation facilities within the MEA or the AOR. The key recreational facilities within 50 miles (80 km) of the MEA, along with natural areas with recreational opportunities, are shown on **Figure 2.2-2** and listed in **Table 2.2-6**. **Table 2.2-6** includes the approximate distances from the proposed MEA satellite facility to the recreational facilities. In the vicinity of MEA, key natural areas with recreational opportunities include the Box Butte Reservoir State Recreation Area (SRA); Fort Robinson and Chadron State Parks; the Soldier Creek Wilderness Area; the Bighorn, Fort Robinson, Peterson, Ponderosa, and Chadron Creek Ranch Wildlife Management Areas (WMAs); Whitney Lake; and the Nebraska National Forest (NGPC 2011a). The Pine Ridge National Recreation Area is located approximately 1 mile (1.6 km) south of Chadron State Park and includes the Roberts Trailhead and Campground.

Recreational opportunities provided by federal and state lands in Dawes County have become an important component of the local economy. According to the Final Environmental Impact Statement for the Northern Great Plains Management Plans Revision (May 2001), the various state parks in northwest Nebraska, the Pine Ridge Ranger District of the Nebraska National Forest, and the Oglala National Grassland are increasingly becoming regional tourist destinations.

Participation in outdoor recreational activities is expected to increase nationwide. An increase in visitor use of recreation facilities in Dawes County would have beneficial effects on the local economy. Employment related directly to tourism and recreation is difficult to gauge, as the services provided for visitors can also be used by residents. The retail and leisure/hospitality industry sectors (arts, entertainment, recreation, accommodation, and food services) combined account for approximately 27 percent of jobs in Dawes County (USCB 2013).

The Agate Fossil Bed National Monument is located approximately 24 miles (38.6 km) from the MEA. The Agate Fossil Beds National Monument had approximately 9,409 visitors in 2012 (NPS 2013).

In 2008, the Nebraska National Forest had 181,000 visitors (USFS 2012). The Nebraska National Forest provides a wide range of other undeveloped backcountry recreation opportunities such as hunting, hiking, backpacking, fishing, horseback riding, off-highway motorized vehicle use, and wildlife observation. Camping and motorized travel/sightseeing are the two most popular recreation categories within the Pine Ridge Ranger District and the Oglala National Grassland. The

Pine Ridge District is an important destination for deer hunting, provides the most popular turkey hunting area in Nebraska, and includes the greatest number of miles of mountain biking trails in the state. The Ponderosa WMA is adjacent to the National Forest.

In 2010, there were more than 11.1 million visitors to Nebraska State Parks and Recreation Areas. The Nebraska State Parks and Recreation Areas generated almost $18 million of income and revenue (USCB 2012).

Fort Robinson State Park, the largest state park in Nebraska, includes portions of the Red Cloud Agency Historical Site and the White River Trail, the Fort Robinson WMA and the Peterson WMA. The park features a variety of developed recreation facilities, including the Soldier Creek and Red Cloud Campgrounds and other lodging facilities, trails, and museums. Approximately 345,923 people visited Fort Robinson State Park in 2010, 257,194 in 2011 and 370,821 in 2012 (NDED 2011b; Nebraska Tourism Statistics 2012).

Chadron State Park was founded in 1921 and is Nebraska's oldest state park (Journey to Western Nebraska 2013). It encompasses nearly 1,000 acres of Pine Ridge wilderness and is located 9 miles (14.5 km) south of the City of Chadron on Highway 385. The park offers trout fishing, camping, hiking, mountain biking, bird watching, and horseback riding. Approximately 247,400, 280,200, and 298,350 people visited the park in 2010, 2011, and 2012, respectively (Journey to Western Nebraska 2013).

2.2.2.3 Residential

In 2010, there were a total of 567 houses in the City of Crawford, with 470 occupied (334 owner-occupied and 136 renter-occupied), and 418 houses in the Town of Hemingford, with 315 occupied (253 owner-occupied and 82 renter-occupied; USCB 2011).

Based on site reconnaissance in May 2011 and a combination of Google Earth and Nebraska Department of Natural Resources (NDNR) aerial imagery of the area, there are two housing units in the MEA, only one of which was occupied at the time of the reconnaissance. The occupied residence is located in SW¼ NW¼ section 7, and the unoccupied residence is located in T29N, R50W and SE¼ NE¼ section 2, T29N, R51W, as shown on **Figure 2.2-3**. The AOR contains an additional 25 structures, of which seven are occupied. There are a total of eight occupied housing units within the MEA and the 2.25-mile (3.62-km) AOR.

Table 2.2-7 shows the distance to the nearest residence within the 2.25-mile (3.62-km) AOR and to the nearest site boundary from the center of the MEA for each 22 ½ sector centered on each compass point. There are two residences within 1 mile (1.6 km) of the center point of the proposed MEA.

2.2.2.4 Habitat

Habitat lands are those dedicated wholly or partially to the production, protection, or management of species of fish or wildlife. Significant areas classified as habitat nearest to the MEA include the Ponderosa SWMA, located approximately 5.2 miles (8.4 km) north of the MEA boundary; the Fort Robinson WMA, located 13.7 miles (22.0 km) northwest of the MEA boundary; and the Petersen WMA, located 13.8 miles (22.2 km) north-northwest. There is no land within the MEA used

primarily for wildlife habitat. Wildlife habitat is a secondary use of rangeland, forestland, and recreational land within the MEA and the 2.25-mile (3.62-km) AOR. An evaluation of habitat in the MEA is included in Section 2.8, with habitat types in the MEA shown in **Figure 2.8-1**.

2.2.2.5 Industrial and Mining

Numerous exploratory wells targeting mineral resources and hydrocarbons have been drilled in the MEA and the AOR. CBR has an ongoing exploratory drilling program that, to date, has completed more than 1,800 drill holes in the MEA. Besides CBR, Conoco, Amoco Minerals, Santa Fe Mining, and Union Carbide have also drilled exploratory test holes for uranium resources in the general area. With the exception of these exploratory wells, there are no other industrial facilities within the 2.25-mile (3.62-km) AOR.

There is one abandoned oil and gas exploratory well located within the MEA or the 0.25-mile (0.4-km) ZOEI, but five abandoned wells are present within the 2.25-mile (3.62-km) AOR (**Figure 2.2-4**). Based upon review of public records, all referenced oil and gas wells have been properly plugged and abandoned in accordance with the Nebraska Oil and Gas Conservation Commission regulations (NOGCC 2011). A discussion of oil and gas test holes pertinent to the MEA is presented in Section 2.6.1.1 (see Pierre Shale subheading under Montana Group).

The nearest operating uranium recovery facility is the CBR operations located approximately 11.1 miles (17.9 km) to the north-northwest of the MEA (centerpoint of CPF building to centerpoint of MEA satellite building; NRC 2011a). The location of the MEA site in relation to other proposed CBR satellite facilities is shown on **Figure 1.3-1**.

Project descriptions and locations of operating and proposed uranium recovery facilities in neighboring Wyoming and South Dakota can be found at the NRC website (NRC 2011a). The other uranium in-situ facilities nearest to the MEA in eastern Wyoming and western South Dakota in different stages of development are identified in **Table 2.2-8**. There are no existing or proposed uranium recovery facilities located within 75 miles (120.7 km) of the proposed MEA project. The nearest operating uranium recovery facility is the Power Resources, Inc. Smith Ranch/Highland Central Processing Plant in Wyoming, and the nearest proposed uranium in-situ facilities are Powertech Uranium Corporation's Dewey-Burdock facility located in Fall River and Custer Counties of South Dakota, and the Uranium One's Moore Ranch project located in Converse County, Wyoming. The NRC maintains a status of major uranium recovery licensing applications in the U.S., which is periodically updated (NRC 2013).

Other than CBR uranium recovery activities, there are no other known planned uranium recovery operations in Nebraska (NRC 2011b). There are two nuclear power reactors located in extreme eastern Nebraska that are more than 300 miles (482.8 km) from the proposed MEA project site. The nearest licensed nuclear fuel cycle facility (a gas centrifuge uranium enrichment facility) is located in Idaho Falls, Idaho and operated by AREVA Enrichment Services.

2.2.2.6 Commercial and Services

There are no known retail or commercial establishments within the MEA or the 2.25-mile (3.62-km) AOR. The nearest retail and commercial establishments are found in Crawford and Hemingford. The distance between the City of Crawford and the MEA (centerpoints of city and

MEA satellite building) is 15.1 miles (24.3 km), and the distance between the Town of Hemingford and the MEA (centerpoints of town and MEA satellite building) is 15.4 miles (24.8 km; **Figure 7.3-3**).

2.2.2.7 Transportation and Utilities

SH 2/71 runs to the west of the MEA. It converges with U.S. Highway 20 in the City of Crawford north-northwest of the MEA. The northern portion of the MEA is accessed from SH 2/71 via East Belmont Road; the southern portion of the MEA is accessed from SH 2/71 via River Road and Hollibaugh Road. The 2010 average daily traffic counts for a segment of Highway 2/71 near Marsland at the southern end of the MEA was 675 total vehicles, including 90 heavy commercial vehicles. Traffic levels on SH 2/71 increase to 695 total vehicles, including 90 heavy commercial vehicles in the vicinity of East Belmont Road (NDOR 2010). Secondary and private roads connect with East Belmont Road, River Road, Hollibaugh Road, and Squaw Mound Road to provide access to residences and agricultural lands within the MEA. No railways cross the MEA; a Burlington Northern Santa Fe rail line runs to the west of the MEA and through a small portion of the 2.25-mile (3.62-km) AOR between the MEA and SH 2/71.

2.2.3 Water Use Information

2.2.3.1 Dawes County Water Use

Every 5 years since 1950, the USGS assesses U.S. water use (USGS 2005) and includes water use estimates for the State of Nebraska. The latest study examined usage in 2005. The USGS works in cooperation with local, state, and federal environmental agencies to collect and distribute water-use information. For Nebraska water use data, the USGS works in cooperation with the NDNR. The USGS's National Water-Use Information Program is responsible for compiling and disseminating the nation's water-use data (USGS 2013). Every 5 years, the USGS compiles these data at the county level to produce water-use information aggregated at the county, state, and national levels. The next report was scheduled to be issued in 2010, but due to delays, the next report completion and data availability is not expected until 2014 (USGS 2013). The State of Nebraska does not update the data in the above referenced USGS reports, so any more recent data listed in **Table 2.2-9** will not be available until the USGS issues its water use report in 2014. **Table 2.2-10** was updated to reflected information on non-abandoned registered water wells for Dawes County as of April 8, 2013.

Estimated water use in 2005 for Dawes County, Nebraska is presented in **Table 2.2-9** (USGS 2005). The total 2005 population for Dawes County was 8,636 people, with public supply groundwater and surface water use totaling 2,590,000 gallons per day (gpd). Irrigation using groundwater and surface water accounted for a total of 24,550,000 gpd to irrigate an estimated 13,000 acres. Essentially all of the rural residents of Dawes County use groundwater for their domestic supply.

A summary of the number and types of registered non-abandoned water wells located in Dawes County as of April 8, 2013 is presented in **Table 2.2-10.** Note that this table refers to registered wells. Under current Nebraska law, water supply wells used solely for domestic purposes and completed prior to September 9, 1993, do not have to be registered (NRS 2008). Therefore, there

are a number of domestic/agricultural and agricultural unregistered wells located in Dawes County. CBR identifies such wells through interviews with landowners and local drillers.

There are a total of 5,828 registered water wells in Dawes County used for a variety of purposes, as described in **Table 2.2-10**. According to the NDNR, there are a total of 251 domestic and 232 livestock wells located in Dawes County (NDNR 2013a). There are 36 public water supply wells located in Dawes County. Livestock water wells make up the majority of the wells identified in the MEA.

2.2.4 **Marsland Expansion Area Project Area**

The town nearest to the MEA project site is Marsland, NE, which is located approximately 4.6 miles (7.4 km) southwest of the nearest MEA site (centerpoint of Town of Marsland to centerpoint of MEA satellite building). There is no public water supply system for Marsland. The residential homes scattered throughout the MEA area are supplied with domestic water from private wells. Private well use is discussed in more detail below. In general, groundwater supplies in the vicinity of the MEA are limited due to topography and shallow geology (University of Nebraska-Lincoln 1986). Groundwater quality in the vicinity near the MEA is generally poor (Engberg and Spalding 1978). Locally, groundwater is obtained from the Arikaree and Brule Formations. The primary groundwater supply is the Brule Formation, typically encountered at depths from approximately 50 to 350 feet bgs. In general, the static water level for Brule Formation wells in the MEA ranges from 50 to 150 feet bgs, depending on local topography (**Figures 2.6-3a** through **2.6-3n**).

Groundwater from the underlying basal sandstone of the Chadron Formation is not used as a domestic supply within the MEA because of the greater depth (850 to 1200 feet bgs) and inferior water quality. Gosselin et al. (1996) state that: (1) "*the sands near the bottom of the Chadron Formation yield sodium-sulphate water with high total dissolved solids*," and (2) in proximity to "*uranium deposits in the Crawford area, groundwater from the Chadron Formation is not suitable for domestic or livestock purposes because of high radium concentrations*." In addition, it is economically impractical to install water supply wells into the deeper basal sandstone of the Chadron Formation in the vicinity of the MEA, in contrast to the vicinity of the NTEA, where most basal sandstone of the Chadron Formation wells either flow at the surface or have water levels very close to surface elevation because of artesian pressure.

Based on a research study funded by the American Water Works Association Research Foundation (AWWARF), the average household water use annually (including outdoor) is approximately 409 gpd (Mayer et al. 1999). The results of the study suggested a daily indoor per capita water use of 69.3 gallons. According to the U.S. EPA, the average family of four can use 400 gallons of water every day; on average, approximately 70 percent of that water is used indoors (EPA 2013). Because there is only one occupied residence located within the proposed MEA (NW¼ SW¼ section 7, T29N R50W), total water use would be expected at an average of approximately 400 gpd, using the U.S. EPA water use value. Eight occupied residences have been identified within the 2.25-mile (3.62-km) AOR. Therefore, water use would be expected to average at about 3,200 gpd for the entire area.

Another source of groundwater consumption in the AOR is private water well use for livestock watering. The Nebraska Resources Conservation Service (NRCS) located in Nebraska uses 0.45 animal units (AU) per acre and estimates the water consumption to be 15 to 20 gallons per day per

animal (Teahon 2013a). An AU is defined as an animal equivalent of 1,000 pounds live weight, with or without an un-weaned calf. There is an estimated 27,572.4 acres of rangeland located with the MEA AOR. Based on the NRCS values for calculating livestock water consumption in Dawes County, livestock consumption within the MEA AOR (assuming full use), would be 186,114 to 248,152 gallons per day. There are approximately 4,622.3 acres located within the MEA license boundary, and based on the NRCS livestock consumption calculation values, livestock consumption (assuming full use of available rangeland acreage) would range from 24,938 to 33,251 gallons per day.

CBR conducted an updated water user survey in 2010 and 2011 to identify and locate all private water supply wells within the 2.25-mile (3.62-km) AOR of the proposed MEA. The water user survey targeted the location, depth, casing size, depth to water, and flow rate of all wells within the area that were (or potentially could be) used as domestic, agricultural, or livestock water supply. **Table 2.2-11** and **Appendix A** list the active, inactive, seasonal and abandoned water supply wells within the MEA and AOR. The locations of all active, inactive, seasonal and abandoned water supply wells are depicted on **Figure 2.7-6** and **2.9-3.** Available NDNR water well registrations within the AOR are presented in **Appendix E-1** and available well abandonment records in the AOR are shown in **Appendix D-2**. The NDNR's water well retrieval database (NDNR 2013b) was reviewed on September 6, 2013, (Teahon 2013b) and no additional private water supply wells were identified to be installed or modified within the license boundary or AOR since the TR was submitted to the NRC by letter dated May 16, 2012.

There were a total of 135 private water supply wells within the license boundary and associated AOR identified during the water user survey (excluding 7 abandoned wells). There are a total of 119 private water supply wells within the AOR and outside of the license boundary. Classification and use of private water supply wells are summarized in **Table 2.2-11**. Within the MEA, there are a total of 10 active private water supply wells, five inactive and one seasonal (irrigation) (**Table 2.2-11**). In terms of aquifer assignments of the active wells, three wells are assigned to the Arikaree Group, four wells are assigned to the Arikaree/Brule, and three wells are assigned to the Brule Formation.

The NDNR water well retrieval database uses the code "other" for well uses defined as lake supply, fountain, geothermal, wildlife, wetlands, recreation, plant and lagoon, sprinkler, test, and other uses. (NDNR 2013b). For comparison, the following are water use designations used by the NDNR:

A Aquaculture
C Commercial/Industrial
D Domestic
E Pit - Irrigation
G Ground Heat Exchanger Well - Closed Loop Heat Pump Well
H Heat Pump Well - Open Loop Heat Pump Well
I Irrigation
J Injection
L Observation (Groundwater Levels)

For well water uses that do not fall within these categories, the "other" well use code is used.

For all of the active private wells described above that remain unassigned to a formation, information provided by the well owner and from nearby wells was insufficient to accurately determine the well completion depth. However, based on discussions with land owners and known completion depths of private water supply wells in the area, these wells have suggested well completions within the Arikaree Group or Brule Formation (**Table 2.2-11**). Well construction and water quality information for these wells are not available in the NDNR water well data retrieval database (NDNR 2013a) or known by the well owner. Based on available information, all water supply wells within the MEA and AOR are completed in the relatively shallow Arikaree Group and Brule Formations, with no domestic or agricultural use of groundwater from the basal sandstone of the Chadron Formation (**Figure 2.7-6 and 2.9-3** and **Table 2.2-11**). Sampling results of these wells by CBR indicate water quality of Arikaree Group and/or Brule Formation aquifers. Based on water quality and the depth of the Arikaree Group and Brule Formation in the MEA Project area, it can be assumed that wells less than 400 feet in depth are located in the Arikaree Group and/or Brule Formation.

Active private wells within the license boundary and 1.2-miles (2-km) radius of the license boundary have been sampled quarterly as part of the preoperational/preconstruction monitoring program (PPMP). The PPMP baseline groundwater sampling and analysis program for the private wells is discussed in Section 2.9.3. Wells were selected for sampling based on landowner approval for access to the wells and condition of the wells.

Based on population projections, future water use within the MEA and AOR will be a continuation of present use (see Section 2.3). One irrigation well is located within the license boundary, with a portion of its center pivot located within the boundary (SE ¼ section of Section 18, T29N R50W; **Figure 7.3-2**). The nearest mine units to the center pivot are MU-B and MU-C, which are located, at the nearest points, 0.37 and 0.28 mile (0.59 and 0.45 km, respectively from the center pivot, respectively. The center pivot located within the license boundary may continue to be operated by the land owner, but the pivot will not be operated inside any MEA monitor well ring. There are no other lands within the license boundary that are irrigated, and no additional irrigation within the license boundary will occur during MEA operations. Irrigation within the MEA AOR is anticipated to be consistent with the past. Any further development would be expected to be limited due to limited water supplies, topography and climate. It is anticipated that the residents of Marsland and the surrounding area will continue to use water supplied exclusively by private wells.

By operation of the leases, no new wells will be installed within the license area without CBR permission. The NDNR registered well database will be reviewed annually, and where appropriate, arrangements will be made to monitor any new wells.

In Nebraska, groundwater is subject to a combination of case law and statutory provisions administered by the Upper Niobrara White Natural Resource District and the courts when necessary (Kelly 2010). Case law has adopted the "rule of reasonable use" in combination with a correlative rights doctrine for allocation among groundwater users in times of shortage. In essence, the owner of land is entitled to groundwater under his land, but the owner may not extract groundwater in excess of reasonable and beneficial use upon the land, especially if such use impacts others who use the same groundwater. If the supply is insufficient for all owners, each is entitled to a reasonable proportion. Because there are no nearby users of basal sandstone of the Chadron Formation groundwater, conflict is unlikely.

2.2.4.1 Wellhead Protection Area

The nearest town to the MEA project site is Marsland, NE. It is located approximately 4.6 miles (7.4 km) southwest of the MEA project (centerpoint of Town of Marsland to centerpoint of MEA satellite building). Marsland is an unincorporated community, with the only business being a U.S. Post Office. There are scattered home sites in the area, with domestic water being supplied by private wells. Approximately eight households and ten people can be found in the immediate area of Marsland (Key to the City 2011). There is no public water supply system; therefore, there is no wellhead protection plan. The other nearest communities to the proposed MEA are the Town of Hemingford, NE and City of Crawford, NE, which are located approximately 15.4 miles (24.8 km; centerpoints of Hemingford and MEA satellite building) and 15.1 miles (24.3 km; centerpoints of Crawford and MEA satellite building). The City of Crawford and Town of Hemingford have wellhead protection plans in place (NE IDs NE3101303 and NE3104505, respectively). However, these communities are located at a distance from the MEA that precludes any potential impacts from the MEA operations. A horizontal distance of 1,000 feet is the minimum required separation of a city water supply well (used for domestic, irrigation, stock, or heat pump purposes) from potential sources of contamination (NDHHS 2010). The minimum horizontal distances required for additional potential sources of contamination range from 10 to 1,000 feet and are provided in **Table 2.2-12**.

2.3 Population Distribution

Information presented in this section concerns those demographic and social characteristics of the environments that may be affected by the proposed expansion of the Crow Butte Uranium Project to include operations in the MEA. Data were obtained through the 1980, 1990, and 2000 Decennial Census, with updates from the 2010 Census; various State of Nebraska government agencies; and other publicly available sources.

2.3.1 Demography

2.3.1.1 Regional Population

The area within a 50-mile (80-km) radius of the project site includes portions of six counties in northwestern Nebraska, two counties in southwestern South Dakota, and two counties in eastern Wyoming. Because the 50-mile (80-km) radius extends only slightly into two very rural portions of Garden County in Nebraska and Niobrara and Goshen Counties in Wyoming, these areas are not discussed in detail beyond data summarized in **Table 2.3-1** through **Table 2.3-3**. **Figure 2.3-1** depicts significant population centers within a 50-mile (80-km) radius of the proposed MEA.

Historical and current population trends in the project area counties and communities are contained in **Table 2.3-1**. Most counties have experienced a decline in population since either the 1970 or 1980 Decennial Census; the exceptions are Shannon County, South Dakota and Goshen County, Wyoming, which have both seen population increases. All of the Nebraska counties comprising the project area experienced slight growth or actual population decline between 1960 and 1980, and population decline between 1980 and 2010. The state experienced its fastest growth since the 1920s during the years between 1990 and 2000. The total state population in 2010 was 1,826,000, which was a 6.7-percent increase over the 2000 population of 1,711,000. The Nebraska counties in the project area experienced little of the 15.7-percent growth spurt seen state-wide in the 1990-2010 period; only Scotts Bluff and Dawes Counties registered positive population growth in this time period, and that growth was less than 3 percent. In general, population trends for the past two decades show that population in urban areas is increasing, while population in rural areas is declining. Areas within 50 miles (80 km) of the project site that are defined as urban (all territory, population, and housing units in urbanized areas and in places of more than 2,500 persons outside of urbanized areas) by the U.S. Census 2000 are the Cities of Chadron and Alliance, Nebraska (USCB 2003a).

Dawes County grew slightly between 1990 and 2000, gaining 1.8 percent in population; this is attributed to growth in the City of Chadron, which more than offset the population declines in other communities in the county. This population growth has not offset the large loss of population that occurred in the 1980 to 1990 time period; the population today remains below its 1980 level. The City of Chadron and the City of Crawford are the nearest large communities in Dawes County to the project site. The City of Chadron is located approximately 25 miles (40 km) northeast of the project site; its 2010 population was recorded at 5,851 - an increase of 3.9 percent from 2000 (USCB 2011). The City of Crawford, within 15.1 miles (24.3 km) of the site (centerpoint of City of Crawford to centerpoint of MEA satellite building), had a 2010 population of 1,997 - an almost 10 percent decrease from 2000 (USCB 2011). The population declines in the City of Crawford were greater than the losses in most other communities and the county as a whole.

Sioux County has been losing population since the 1970 Decennial Census; the pace of these losses has fluctuated over the last 40 years, but has averaged approximately 10 percent per decade. The population decline was slowest in the 1990 to 2000 period due to a population increase of nearly 16 percent in the City of Harrison.

Box Butte County experienced a significant gain in population in the 1970 to 1980 timeframe, but has been losing population ever since. The population decline has averaged approximately 6 percent per decade since the 1980 Census, with the county losing 7 percent of its population since the 2000 Census. The Town of Hemingford, the nearest significant community in Box Butte County to the project site, has seen fluctuating population levels since the 1970 Census, although the Village lost approximately 19 percent of its population in the past decade.

Similarly, Sheridan County saw a gain in population in the 1970 to 1980 timeframe, but has been steadily losing population at an average rate of approximately 10 percent per decade since. This decline in population has been seen in the county's larger communities of Hay Springs and Rushville, both of which have similar rates of decline in their populations since 1980.

Scotts Bluff and Morrill Counties have experienced less severe population losses over the 1980 to 2010 timeframe, with losses of 6 and 1.1 percent per decade, respectively. The communities of Scotts Bluff and Minatare in Scotts Bluff County have experienced population growth of 0.7 and 2.1 percent, respectively, since the 2000 Census.

Within South Dakota, portions of Fall River and Shannon Counties fall inside the 50-mile (80-km) study area. Fall River County experienced population growth in the 1970 to 1980 period, but has lost more than 16 percent of its population in the last 30 years despite a small positive growth rate in the 1990 to 2000 period. The county-wide trends in population growth and loss are mirrored in the community of Oelrichs, which has lost more than 21 percent of its population since 1980. Shannon County, on the other hand, has grown by an average of better than 15 percent per decade since 1970; this growth has been realized in significant swings, with 38 percent growth in the 1970 to 1980 period followed by a 12.5 percent decline in population over the 1980 to 1990 period, which was then followed by a decade of nearly 26 percent growth from 1990 to 2000 and then 9 percent growth from 2000 to 2010. Much of the growth occurred in the Pine Ridge and Oglala Census Designated Places, which are urban areas as defined by the U.S. Census, but are not incorporated municipalities.

The population declines in the counties within the 50-mile (80-km) radius reflect trends in the overall region, where population declines have been attributed to the declines in the rural farming-based economy and limited economic opportunities for youth. Persistent drought conditions have also contributed to the shrinking of the agriculture-based economy. Rural residents have been migrating to larger cities, depopulating the largely rural Great Plains states. Many of the people migrating out of the state are young adults and families, which results in fewer people of childbearing age, and therefore, fewer children. This trend also contributes to the increasing proportion of the elderly population in the state (UNRI 2008).

2.3.1.2 Population Characteristics

2010 population by age and sex for counties within 50 miles (80 km) of the MEA is shown in **Table 2.3-2**. Overall, 74.5 percent of the population in the region is more than 18 years old. Fewer than

20 percent of the populations of Garden, Fall River, and Niobrara Counties are under the age of 18; Shannon County has the youngest population, with nearly 40 percent of its population under the age of 18. Females slightly outnumbered males in all but four counties, with an overall population of 50.6 percent female to 49.4 percent male (USCB 2011).

In 2010, 81.5 percent of the population of the 11 counties was classified as white. American Indians comprised the largest non-white classification. The largest American Indian population is found in Shannon County, South Dakota, where American Indians comprise 96 percent of the 13,586 people in the county (USCB 2011).

2.3.1.3 Population Projections

The projected population for selected years by county within the 50-mile (80-km) radius of the Crow Butte Project Area is shown in **Table 2.3-3**. The population is expected to decrease or hold steady in all 11 counties surrounding the project area. These counties are primarily rural, with agriculture-based economies. It is anticipated that the declining population trends of the last two decades will continue into the foreseeable future for these counties as populations shift to more urban counties (e.g., Douglas, Lancaster, and Sarpy). The largest declines are projected for Dawes and Garden Counties, which are each expected to lose more than 20 percent of their current populations by the year 2030.

2.3.1.4 Seasonal Population and Visitors

According to the Final Environmental Impact Statement for the Northern Great Plains Management Plans Revision (May 2001), the various state parks in northwest Nebraska (the Pine Ridge Ranger District and the Oglala National Grassland) are increasingly becoming regional tourist destinations.

Approximately 345,923 people visited Fort Robinson State Park in 2010. This number represents a 25 percent decrease from 460,154 in 2007 and a 2 percent decrease from 356,352 in 1993 (NDED 2011a). Approximately 50 percent of the visitors in 2002 were from other states, which is an increase in the number of out-of-state visitors from 1981, as the majority of 1981 visitors were Nebraskan families. It is likely that the decline of visitors from Nebraska has resulted from the overall decline of population in rural counties within a few hours commuting distance of the park.

There were 55,000 visitors to the Pine Ridge District of the Nebraska National Forest in 2001. Camping and motorized travel/sightseeing are the two most popular recreation categories within the Pine Ridge Ranger District and the Oglala National Grassland.

The forest provides a wide range of other undeveloped backcountry recreation opportunities such as hunting, hiking, backpacking, fishing, and wildlife observation. The district provides the greatest number of miles of mountain biking trails in the state. District trails also attract horseback riders and off-highway motorized vehicle use. The Pine Ridge is an important destination for deer hunting, and provides the most popular turkey hunting area in Nebraska.

One source of seasonal population in this region is Chadron State College, located approximately 21.6 miles (35 km) from the site. During the fall seasons of 2005, 2006, 2007, 2008, 2009, 2010, and 2011, the enrollment was 2,601, 2,767, 2,726, 2,769, 2,744, 2,759, and 2,609, respectively (CSC 2010a, 2010b, 2012, and Universities.com 2010). The average enrollment from 1994 through

1999 was 2,944, with a range of 2,768 to 3,189 (NCCPE 2005). Enrollment from 2011 (2,609) versus this later average of 2,944 is a 0.11 percent reduction in student enrollment. A rising enrollment trend has been observed at the college since 2006, with an overall increase of near 30 percent during the period (Haag 2012). Actual enrollment values presented in this paragraph may vary depending on the time of the year of the enrollment count.

2.3.1.5 Schools

The City of Crawford is served by the City of Crawford Public School District. The Crawford High School and grade school are presently under capacity (Vogl pers. comm. 2010). Enrollment for the 2010-2011 school years was 138 in the grade school and 109 in the high school; this represents a decline of about 9.5 percent in total enrollment for both schools from the 2007-2008 school years (NDE 2011a).

The Town of Hemingford is served by the Hemingford Public Schools. Enrollment for the 2010-2011 school years was 219 in the grade school and 173 in the high school, an increase of more than 9 percent in total enrollment for both schools from the 2007-2008 school years (NDE 2011b). This enrollment level is lower than in past years, reflecting continuing pressures on population levels in the area.

Families moving into the Crawford or Hemingford School Districts as a result of the proposed MEA operations would not stress the current school system.

2.3.1.6 Sectorial Population

Existing population, as determined for the original analysis in the CBR commercial license application prepared in 1987 for the 50-mile (80-km) radius, was estimated for 16 compass sectors, by concentric circles of 0.6, 1.2, 1.9, 2.5, 3.1, 6.2, 12.4, 18.6, 24.9, 31, 37.3, 43.5, and 50 miles (1, 2, 3, 4, 5, 10, 20, 30, 40, 50, 60, 70, and 80 km, respectively) from the site (a total of 208 sectors). 2010 US Census data were used; subtotals by sector and compass points as well as the total populations are shown in **Table 2.3-4**.

Population within the 50-mile (80-km) radius was estimated using the following techniques:

- U.S. Census 2010 data were used to estimate the total population within a 50-mile (80-km) radius, measured from the center of the proposed MEA site. The data were created by Geographic Data Technology, Inc., a division of Earth Sciences and Research Institute (ESRI), from Census 2000 boundary and demographic information for block groups within the United States.
- ArcInfo GIS was used to extract data from U.S. Census 2000 population estimates for 40 Census Tract Block Groups located wholly or partially within the 50-mile (80-km) radius from the approximate center of the MEA site. Urban areas within each county were generally assigned their own block group.
- To assign a population to each sector, a percentage area of each sector within one or more block groups was calculated for all of the block groups.
- 2010 U.S. Census of population estimates for cities and counties in Nebraska, South Dakota, and Wyoming were used to determine total urban population.

2.3.2 Local Socioeconomic Characteristics

2.3.2.1 Major Economic Sectors

In 2009, average annual unemployment rates in Dawes and Box Butte Counties decreased from the 2008 rates. **Table 2.3-5** summarizes unemployment rates and employment in the Nebraska project area counties, as well as the overall change in employment in economic sectors between 1994 and 2009. Dawes and Box Butte Counties exhibited unemployment rates at 4.4 percent in Dawes County and 6.8 percent in Box Butte County in 2009. The Dawes County unemployment rate was slightly lower than the statewide rate of 4.7 percent, whereas the Box Butte County rate was significantly higher (NDOL 2010).

The major economic sectors in the project area have changed little in recent years, although individual sectors have shifted in their relative proportion in the overall economy. The area continues to depend on trades, government, and services. Economic sectors in the City of Crawford area include farming, ranching, cattle feed lots, tourism, and retail sales.

Agriculture accounted for a significant portion (19.2 percent) of the total employed labor force in Dawes County in 2009. During the same time period, farm employment was 2.0 percent of total employment in Box Butte County. Retail trade accounted for 14.7 percent of total employment in Dawes County, followed by local government employment (12.6 percent), leisure and hospitality (11.1 percent), education and health services (9.8 percent), and state government (6.5 percent). Mining and construction accounted for 5.0 percent. In Box Butte County, the largest four non-farm employment sectors are local transportation, communication and utility services (20.2 percent); local government (17.7 percent); production (8.6 percent); and leisure and hospitality (8.0 percent; NDOL 2010).

While agriculture employment is not dominant, agriculture provides the economic base for the counties, as other economic sectors support the agricultural industry. Events that affect agriculture are generally felt throughout rural economies. According to the Nebraska Department of Economic Development (NDED 2010), farm employment in Nebraska is expected to decline by nearly 14,000 jobs (20 percent) between 2000 and 2045, while overall non-farm employment will increase by nearly 26 percent. The decrease in jobs in the agricultural sector could continue to fuel migration from rural counties to urban areas, resulting in overall declines in other sectors of the local economy as dollars spent from personal income and agricultural business expenditures move out of the counties.

Per capita personal income is the income received by persons from all sources, including wages and other income, over the course of 1 year. In 2010, personal income in Dawes County was $28,981, which was 74 percent of the state average of $39,332. The county ranks 87th out of 93 counties in the state (BEA 2011). In 2010, personal income in Box Butte County was $35,225, which was 89 percent of the state average of $39,332. Box Butte County ranks 58th out of 93 counties in the state.

2.3.2.2 Housing

Between 1970 and 1980, total housing units increased by 17 percent in Dawes County from 3,388 to 3,965 units (USCB 1990a). After a decline in total units during the 1980s, growth increased by

2.4 percent from 3,909 units in 1990 to 4,004 units in 2000, and then increased again by 6.2 percent to 4,252 units in 2010. The City of Chadron, the largest community in Dawes County and within 25 miles (40 km) of the project site, experienced a negligible increase (0.3 percent) in housing stock between 1980 and 1990, a 5 percent increase between 1990 and 2000, and a 4.4 percent increase to 2,559 units between 2000 and 2010. Between 1980 and 1990, the City of Crawford housing stock decreased by nearly 7 percent to 576 (USCB 2003a). The number of housing units continued to decline through 2010, when 567 units were reported.

Box Butte County, which borders Dawes County to the south, exhibited a 1 percent loss in total housing units between 1990 and 2000, when 5,488 units were counted in the 2000 Census; a similarly small loss of 10 units was reported in the following decade, with a total of 5,478 units reported in 2010. In the Town of Hemingford, 418 housing units were reported in 2010; this represents a slight decrease from the 438 units reported in 2000.

In 2000, Dawes and Box Butte Counties had homeowner vacancy rates of 1.7 and 1.4 percent, respectively. In 2010, these rates were 2.3 and 2.4 percent, respectively. As of June 2011, there were six single-family housing units for sale in the City of Crawford. Five of the units were listed at prices below $100,000. One unit was listed at a price higher than $250,000. Three new single-family housing units were constructed between 2006 and 2008 in the City of Crawford, and average new home construction costs were $70,000 (NPPD 2012); one permit was issued in 2009 for a home with a construction cost of $60,000. In Hemingford, one permit was issued in 2006 for a residence with a construction cost of $25,100. The median gross rent for the City of Crawford in 2009 was $440 per month; in the Town of Hemingford, the median gross rent was $344 (Advameg 2010).

The demand for rental housing did not change significantly between 1990 and 2000, as rental vacancy rates were 11.8 percent in Dawes County and 15.4 percent in Box Butte County in 2000 (USCB 2003c) compared with 1990 rental vacancy rates of 12.6 percent and 14.9 percent, respectively (USCB 1990b). Similar rates continue to be seen: the rental vacancy rate in Dawes County is currently 10.2 percent and 17.7 percent in Box Butte County (USCB 2011).

High interest rates and tax rates were the major deterrents for potential homebuyers in the project area in the past. Current deterrents are economic uncertainty and unemployment, as home mortgage interest rates have recently been at historic lows.

The majority of housing demand expected over the next two decades in Dawes County is most likely to occur in the City of Chadron, reflecting a continued shift from rural to more urbanized environments.

The purchase of homes by Crow Butte employees provides the City of Crawford with ad valorem property taxes. The City of Crawford levies taxes at a dollar per hundred of valuation. In 2010, the total levy was 0.424539, which would result in taxes on a $50,000 property of approximately $212 per year. The Town of Hemingford levies taxes at a dollar per hundred of valuation. In 2010, the total levy was 0.98062, which would result in taxes on a $50,000 property of approximately $490 per year (NE Revenue 2010).

2.3.3 Environmental Justice

The 2010 Census provides population characteristics for Census Tracts, which contain Block Groups that are further divided into Blocks. The Blocks are the smallest Census areas that contain the race characteristics of the population in the MEA region. The MEA contains all or a portion of (or is adjacent to) 23 Blocks within Census Tract 9506 in Dawes County. Census Bureau-generated 2009 data on the poverty status of school district populations were used as a proxy.

The affected area selected for the Environmental Justice analysis includes the racial characteristics of the population within Census Tract Blocks within the MEA and the poverty status of students enrolled in local school districts.

The State of Nebraska was selected as the geographic area to compare the demographic data for the population in the affected Blocks. This determination was based on the need for a larger geographic area encompassing affected area Block Groups in which equivalent quantitative resource information is provided. The population characteristics of the MEA are compared with Nebraska population characteristics to determine whether there are concentrations of minority or low income populations in the MEA relative to the state.

According to the 2010 Census and summarized in **Table 2.3-6**, the combined population of the Census Block Groups within or adjacent to the MEA was 32. The entire population was white; with one individual identified as Hispanic. The next nearest minority populations reside within the City of Crawford, located approximately 15.1 miles (24.3 km) north-northwest of the MEA (centerpoint of City of Crawford to centerpoint of MEA satellite building), and the Town of Hemingford, located approximately 15.4 miles (24.8 km) south-southeast (centerpoint of Town of Hemingford to centerpoint of MEA satellite building). Races in the City of Crawford are white non-Hispanic (95.6%), American Indian (0.9%), Hispanic (1.0%), persons reporting two or more races (2.3%), and smaller percentages of other races. Races in the Town of Hemingford are white non-Hispanic (96.1%), American Indian (1.2%), Hispanic (4.6%), persons reporting two or more races (2.1%), and smaller percentages of other races. The total percentage is greater than 100 percent because Hispanics could be counted in other races.

No concentrations of minority populations were identified as residing in rural areas near the proposed MEA. There would be no disproportionate impact to any minority population from the construction and implementation of the MEA.

The schools located nearest the MEA are those in the City of Crawford (operated by Crawford Public Schools), the Town of Hemingford (operated by Hemingford Public Schools), and in the community of Marsland (the Pink Public School operated by the Sioux County Public Schools). 12.9 percent of all students aged 5 to 17 in the State of Nebraska are identified as living in families in poverty. This compares to 22.8 percent of students in the Crawford Public Schools, 13.8 percent in the Hemingford Public Schools, and 19.8 percent in the Sioux County Public Schools. These data indicate that more students in the vicinity of the MEA live in families in poverty than are found in the state as a whole. Lower income levels are characteristic of predominantly rural populations and small communities that serve as a local center of agricultural activity. No adverse environmental impacts would occur to the population within the MEA from proposed Project activities; therefore, there would be no disproportionate adverse impact to populations living below the poverty level in these Block Groups.

2.4 Regional Historic, Archeological, Architectural, Scenic, and Natural Landmarks

2.4.1 Historic, Archeological, and Cultural Resources

There have been few cultural resources investigations on private land in southern Dawes County. Cultural resources investigations have been more numerous around the White River and the Cities of Chadron and Crawford about 10 miles (16.1 km) to 15 miles (24.1 km) to the north, and the results of those surveys can provide a cultural context for comparison to the MEA. Known resources in that area include indigenous people, artifact scatters, faunal kill and processing sites, and camps; fur trade and other contact period sites; the Sidney-Deadwood Trail; historic railroads; historic farming sites; Fort Robinson; and the Cities of Chadron and Crawford. In the mid-1800s, this region was occupied predominantly by bands of Lakota Sioux and Cheyenne. In the 1870s, the Red Cloud Indian Agency was located at Fort Robinson west of Crawford. By 1878, the tribes had officially been relocated to reservations, but sporadic Lakota and Cheyenne resistance continued through the 1880s. The MEA is south of the Pine Ridge Escarpment near the Niobrara River, and the nearby Town of Marsland is small in comparison to the Cities of Chadron and Crawford. The Town of Marsland is located along the Sidney-Deadwood Trail, along one of the historic railroad corridors that also passed through Crawford, and along a major river that would have attracted fur trappers. The fur trade in northwest Nebraska was centered along the White and Niobrara Rivers.

The proposed MEA is located on private lands east of SH 2/71 and north of the Niobrara River. An archaeological files search through the Archaeology Division of the Nebraska State Historical Society (NSHS) indicated that there have been no previous archaeological investigations within 1 mile (1.6 km) of the MEA and that no archaeological sites have been previously reported. An architectural and structural properties search through the Nebraska State Historic Preservation Office (SHPO) indicated that four historic structures (DWOO-240, DWOO-241, DWOO-242, and DWOO-243) have been reported in the study area. Two of these structures are within the MEA and the other two are close to the MEA. A search of the BLM Public Land Patent Records indicates that nine patents were granted for lands in the MEA from 1891 to 1917. This is consistent with the completion of the Chicago, Burlington, and Quincy Railroad through Crawford in 1889, which made the land more accessible to homesteaders, and with a brief moist period in the region between 1910 and 1920. A search of the National Register of Historic Places (NRHP) online database for Dawes County yielded 11 sites in the northern portions of the county. None of these NRHP-listed sites is within 10 miles (16.1 km) of the MEA. Fort Robinson and the Red Cloud Indian Agency, about 15 miles (24.1 km) north-northwest of the MEA, are also listed as a National Historic Landmark.

ARCADIS completed an intensive pedestrian block cultural resources inventory of approximately 4,500 acres for the MEA during the period from November 2010 to February 2011 (Graves et al. 2011). The MEA was inventoried for the presence of euroamerican and indigenous peoples' properties (cultural resources that are listed or eligible for listing on the NRHP) and may be impacted by proposed mine development. Graves et al. (2011) recorded 15 newly discovered euroamerican historic sites and five euroamerican historic isolated finds and updated the documentation on two of the previously recorded historic farmstead sites (DWOO-242 and DWOO-243).

ARCADIS submitted the "Cameco Resources Marsland Expansion Area Uranium Project Cultural Resource Inventory" report and associated Nebraska Archeological Site Survey Forms to the Nebraska State Historic Preservation Society/State Historic Preservation Office on April 28, 2011 (Graves 2011), and SHPO concurrence was granted by the Deputy State Historic Preservation Officer on May 19, 2011. The SHPO approval was issued via a stamped concurrence on the April 28, 2011 submittal letter. CBR requested that ARCADIS complete a field survey of an additional 160 acres in section 36 T30N R51W completed during the original field investigation but not reported in the original report. The 160 acres was field investigated by ARCADIS on February 19, 2011, and no new cultural resources were discovered. One historic bridge (25DW362) was identified in section 36 T30N R51W and reported within the original cultural resource inventory report. An addendum to the original cultural resources report was prepared to address the additional 160 acres (Graves and Graves 2012). Historic site 25DW362 was recommended not eligible for listing on the NRHP with SHPO concurrence.

The Nebraska SHPO concurred with the findings of the addition to the cultural resources report that no archaeological, architectural, or historic context property resources will be affected by the proposed project (NSHS 2012). As stated in the SHPO concurrence letter, the SHPO's review does not constitute the opinions of any Native American Tribes that may have an interest in Traditional Cultural Properties potentially affected by this project.

No indigenous people sites or artifacts were found in the project area. Regardless, a process for tribal identification of Traditional Cultural Properties is being developed and will be implemented during review of the MEA Environmental Report to satisfy NEPA.

The newly recorded historic sites included six farmsteads (25DW359, 25DW360, 25DW361, 25DW365, 25DW366, and 25DW370), three artifact scatters (25DW357, 25DW363, and 25DW369), two cisterns (25DW358 and 25DW364), one corral and windmill (25DW367), one bridge (25DW362), one dugout depression and berm (25DW368), and one stone quarry (25DW371). All of these sites were recommended not eligible for the NRHP.

The previously recorded farmstead sites were recorded jointly by SHPO and NSHS as part of a historic building survey of Dawes County in 2005 as the B. Chapman House (DWOO-242; built about 1910) and an abandoned farmhouse (DWOO-243; built about 1890). Updated documentation was prepared for the two buildings in the survey area. This documentation included the completion of NSHS archaeological site survey forms that included documentation of associated artifacts and features in addition to the buildings. Updated documentation of the DWOO-242 included a concrete cistern, a storage shed, two modern propane tanks, and historic and modern artifacts. The house is well maintained and appears to be occupied. Site DWOO-243 is more extensive. This site includes two abandoned 1½-story farmhouses; a smaller 1-story house; two storage sheds; one stock shelter; one foundation with a chicken coop gate; two metal grain bins; abandoned vehicles, wagons, and farm implements; a network of fenced enclosures; and a large pile of historic debris.

All of the newly recorded historic sites were recommended not eligible for the NRHP and do not qualify as historic properties. Isolated finds are by definition not eligible for the NRHP. Historic farmstead DWOO-242 is recommended not eligible for the NRHP, but appears to be currently or recently occupied. Site DWOO-243 may have the potential to yield information important in history and may be potentially eligible for the NRHP. Avoidance of these two sites by project actions is recommended. If these recommendations are followed, the proposed project will have

no adverse effect on historic properties, and no further cultural resource investigations are recommended.

Specific information included in cultural resources investigations falls under the confidentiality requirement for archaeological resources under Section 304 of the National Historic Preservation Act (NHPA;16 U.S.C. 470w-3(a)). In addition, disclosure of such information is protected under Nebraska State Statute Section 84-712.05 (13 and 14). The cultural resources inventory report and Attachment A of that report have been marked "FOR OFFICIAL USE ONLY: DISCLOSURE OF SITE LOCATIONS IS PROHIBITED (43 CFR 7.18). In compliance with Nebraska SHPO, NRC NUREG-1569 Section 24, and NDEQ Title 122 Ch. 11 Sections 006.07, "These materials should be treated as confidential information for the purpose of public disclosure of this NRC license amendment." The cultural resources report will be submitted to the NRC and State of Nebraska SHPO under separate cover.

The NRC is responsible for the government-to-government NHPA Section 106 consultation for the Crow Butte project areas near Crawford, Nebraska. These project areas include the CBR current operation ISR facility license renewal and the proposed NTEA, TCEA, and MEA. As part of the NRC's ongoing efforts to identify historic properties of religious and cultural significance to Native American Tribes that could be affected by CBR's proposed projects, the NRC sent a letter, dated October 31, 2012, offering each consulting tribe an opportunity to participate in a field study to identify potential places of religious and cultural significance at these sites (NRC 2013). In support of the NRC's offering, CBR offered to open each of the four project areas for field inspection during the period of November 14 through December 7, 2012.

Two consulting Tribes accepted CBR's offer to open the CBR project areas during the November 14 through December 7, 2012 timeframe (NRC 2013). Tribal field crews completed coverage for the current operation, the TCEA, and the MEA for zones thought to potentially contain places of Tribal religious and cultural significance. The Santee Sioux Nation submitted a Traditional Cultural Properties Survey report on the behalf of the Crow Tribe of Montana and the Santee Sioux Nation for the Crow Butte operations (Santee Sioux Nation 2013). A report for this survey was submitted to the NRC; the survey did not result in the recognition of any historic property of potential significance for NRHP listing. A redacted copy of the report is included as an Appendix U to the ER.

2.4.2 Scenic Resources

2.4.2.1 Introduction

The MEA is on private land that is not managed to protect scenic quality by any public agency. The MEA is located on generally level ground south of the Pine Ridge area of northwestern Nebraska, and may be visible from some public roads in the areas. The existing landscape and the visual effect of the proposed facilities have been inventoried and assessed for the proposed project using the BLM Visual Resource Management (VRM) system.

2.4.2.2 Methods

The VRM system is the basic tool used by the BLM to inventory and manage visual resources on public lands. The VRM inventory process involves rating the visual appeal of a tract of land,

measuring public concern for scenic quality, and determining whether the tract of land is visible from travel routes or observation points.

The scenic quality inventory was based on methods provided in BLM Manual 8410 – Visual Resource Inventory (BLM 1986a). The key factors of landform, vegetation, water, color, influence of adjacent scenery, scarcity, and cultural modifications were evaluated according to the rating criteria, and provided with a score for each key factor (BLM 1986b). The criteria for each key factor ranged from high to moderate to low quality based on the variety of line, form, color, texture, and scale of the factor within the landscape. A score was associated with each rating criterion, with a higher score applied to greater complexity and variety for each factor in the landscape. The results of the inventory and the associated score for each key factor are summarized in **Table 2.4-1**. According to NUREG-1569; 2.4.3(7), if the visual resource evaluation rating is 19 or less, no further evaluation is required. The total score of the scenic quality inventory is 9; however, an analysis was prepared to reflect the growing concern some residents may have for the scenic resource, as Dawes County is expected to continue to develop tourism in the region.

<u>VRM Classes</u>

The elements used to determine the visual resource inventory class are the scenic quality, sensitivity levels, variety classes, and distance zones. Each of the elements used to identify the VRM Class is defined below:

Scenic Quality – Scenic quality is a measure of the visual appeal of a tract of land. In the visual resource inventory process, public lands are assigned an A, B, or C rating based on the apparent scenic quality, which is determined using seven key factors: landform, vegetation, water, color, adjacent scenery, scarcity, and cultural modifications. During the rating process, each of these factors is ranked comparatively against similar features within the physiographic province.

Sensitivity Level – A degree or measure of viewer interest in the scenic qualities of the landscape. Factors to consider include 1) type of users, 2) amount of use, 3) public interest, 4) adjacent land uses, and 5) special areas. Three levels of sensitivity have been defined:

- Sensitivity Level 1 – The highest sensitivity level, referring to areas seen from travel routes and use areas with moderate to high use.
- Sensitivity Level 2 – An average sensitivity level, referring to areas seen from travel routes and use areas with low to moderate use.
- Sensitivity Level 3 – The lowest sensitivity level, referring to areas seen from travel routes and use areas with low use.

Distance Zones – Areas of landscapes denoted by specified distances from the observer, particularly on roads, trails, concentrated-use areas, rivers, and other locations. The three categories are foreground-middleground, background, and seldom seen.

- Foreground-Middleground – The area visible from a travel route, use area, or other observer position to a distance of 3 miles (4.8 km) to 5 miles (8.0 km). The outer boundary of this zone is defined as the point where the texture and form of individual plants are no longer apparent in the landscape and vegetation is apparent only in pattern or outline.
- Background - The viewing area of a distance zone that lies beyond the foreground and middleground. This area usually measures from a minimum of 3 miles (4.8 km) to 5 miles

(8.0 km) to a maximum of about 15 miles (24.1 km) from a travel route, use area, or other observer position. Atmospheric conditions in some areas may limit the maximum to about 8 miles (12.9 km) or increase it beyond 15 miles (24.1 km).

- Seldom Seen – The area is screened from view by landforms, buildings, other landscape elements, or distance.

The visual resource inventory classes are used to develop VRM classes, which are generally assigned by the BLM through the resource management plan process. VRM objectives are developed to protect scenic public lands, especially those that receive the greatest amount of public viewing. The following VRM classes are objectives that outline the amount of disturbance an area can tolerate before it no longer meets the visual quality of that class.

- Class I Objective: To preserve the existing character of the landscape. The level of change to the characteristic landscape should be very low and must not attract attention.
- Class II Objective: To retain the existing character of the landscape. The level of change to the characteristic landscape should be low.
- Class III Objective: To partially retain the existing character of the landscape. The level of change to the characteristic landscape should be moderate.
- Class IV Objective: To provide for management activities which require major modification of the existing character of the landscape. The level of change to the characteristic landscape can be high.

The Scenic Quality, Sensitivity Level, and Distance Zone inventory levels are combined to assign a VRM Class to inventoried lands as shown in **Table 2.4-2**.

2.4.2.3 **Affected Environment**

The MEA lies mostly in the Sandy and Silty Tableland ecoregion, with the northern portion of the MEA lying in the Pine Ridge Escarpment; both are subregions of the Western High Plains ecoregion. The physiography of the Pine Ridge Escarpment is characterized by alternating ridges and valleys with entrenched channels and rock outcrops, with elevations increasing from the northeast to the southeast. Vegetation includes ponderosa pine woodlands with Rocky Mountain juniper, western snowberry, skunkbush sumac, choke cherry, and Arkansas rose. Mixed-grass prairie is also found, containing little bluestem, western wheatgrass, prairie sandreed, needle-and-thread, blue grama, and threadleaf sedge. The physiography of the Sandy and Silty Table is characterized by tablelands with areas of moderate relief, with some areas of isolated sand dunes, and canyons along stream valleys. Vegetation includes mixed-grass prairie containing blue grama, little bluestem, threadleaf sedge, and needle-and-thread, and some scattered Sand Hills prairie with sand reed and little bluestem (EPA 2011c).

The MEA landscape is rural and agricultural in character, and is composed primarily of scenery that is common for the ecoregion. Vegetation cover consists of grassy meadows and croplands interspersed with shrubby riparian growth along drainages. The landscape colors are dominated by tan, gold, and green vegetation. The colors and values (degrees of lightness and darkness) of soils and vegetation are similar, exhibiting little contrast during most of the year, although the dark greens of Ponderosa pine visible in the background from the MEA exhibit striking color contrasts

throughout the year. The scenic quality of the MEA is enhanced by the backdrop of the slopes covered with Ponderosa pine in the Nebraska National Forest to the south.

The characteristic landscape of the MEA consists of flat to rolling hills dissected by tributaries of the Niobrara River, which is located south of the MEA. The terrain becomes progressively higher in elevation to the north. The MEA is blocked from view along the entirety of SH 2/71 by low ridges located close to the highway. Portions of the MEA are visible from E. Belmont Road, Squaw Mound Road, Hollibaugh Road, and River Road.

The visual character of the landscape includes human modification from a variety of land uses, including open lands, cropland, roadways, rural residences, and utility corridors. Open land used for grazing activities is the dominant land use in the MEA. The northern portion of the MEA is accessible from E. Belmont Road, and the southern portion from River Road. Both are gravel-surfaced county roads, which in turn connects to SH 2/71, one of the primary north-south roadways through Dawes County. Human modifications to the natural landscape evident in the MEA include private roads, rural residences, agricultural implements, and electric distribution lines.

2.4.2.4 MEA Visual Inventory

Most of the MEA is characterized by the low, rolling plains and agricultural land uses characteristic of the area in northwestern Nebraska. The scenic quality of the MEA landscape is typical of the ecoregion, and is rated as Class B. There are no Class A landscapes visible from the MEA.

<u>Sensitive Viewing Areas</u>

Sensitive viewing areas in the MEA include E. Belmont Road, River Road, Squaw Mound Road, and Hollibaugh Road (the primary transportation routes through and adjacent to the MEA) and rural residences. In general, residents and other users of the region are accustomed to viewing human modification in the rural landscape, but could be sensitive to increased levels of development.

The characteristic landscape of the MEA as viewed from any of the roads and the residences consists of a broad expanse of mixed-grass prairie and cropland with scenic backdrops to the north. The MEA is located more than 3.5 miles (5.6 km) east of State Highway 2/71 at its nearest point, and is not visible from the highway. Public use of county and private roads within the MEA is relatively low, with motorists falling into the categories of local ranchers and residents.

The greatest number of viewers of the proposed facilities would be traveling on either E. Belmont Road, River Road, Squaw Mound Road, or Hollibaugh Road. The majority of motorists on the road would be residents within and outside of the MEA. There is one occupied residence within the MEA. The MEA landscape is also within view of five residences within the 2.25-mile (3.62-km) AOR.

The level of use on E. Belmont Road, River Road, Squaw Mound Road, or Hollibaugh Road and residences within or near to the MEA is low to moderate, or a Sensitivity Level 2, due to the fact that River Road is one of only three routes into Box Butte Reservoir State Recreation Area. Viewers at isolated rural residences with views of the project area are few.

A potential sensitive viewing area is the Nebraska National Forest located north of the north boundary of the MEA. However, there are no developed campgrounds or other facilities within the National Forest that could view the MEA due to the topography of the area. Individuals hiking through the National Forest could view the MEA in the background. While the level of concern for scenic landscapes would be high for many park visitors, the MEA would not be visible from most of the National Forest.

VRM Class

Based on the project area Class B scenic quality; the Sensitivity Level 2 (Medium) as viewed from E. Belmont Road, River Road, Squaw Mound Road, or Hollibaugh Road, and residences; and the location of the project area in the background distance zone as seen from the Nebraska National Forest, the MEA has been assigned Class III for both the visual resource inventory and the VRM objective.

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2.5 Climate, Meteorology, and Air Quality

2.5.1 Introduction

The proposed MEA 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).

Yearly precipitation totals typically range from 13 to 16 inches. Migratory storm systems that originate in the Pacific Ocean release a majority of their moisture over the Rocky or Cascade Mountains. Major precipitation events can occur when these systems regain moisture already present in the area or moisture advected from the Gulf of Mexico. The region is prone to severe thunderstorm events throughout the spring and early summer months, and much of the precipitation is attributed to these events. In a typical year, the area will experience four or five severe thunderstorm events (as defined by the National Weather Service [NWS] criteria) and 40 to 50 thunderstorm days. Autumn stratiform rain events also contribute to precipitation totals, but to a lesser degree. Snow frequents the region throughout winter months (30 to 50 inches per year), but generally provides less moisture than rain events.

Windy conditions are fairly common to the area. Roughly 3 percent of the time, hourly wind speed averages exceed 25 miles (40.2 km) per hour (mph). The predominant wind directions are north-northwesterly and northwesterly, with the wind blowing from those directions roughly 25 percent of the time. Surface wind speeds are relatively moderate at a year-round, hourly average of 10 to 11 mph. Higher average wind speeds are encountered during the winter months, while summer months experience lower average wind speeds.

For the regional analysis, meteorological data have been compiled for 21 sites surrounding the MEA. Data were acquired for these sites through the Western Regional Climate Center (WRCC 2011) for Cooperative Observer Program (COOP) and Automated Surface Observation Stations (ASOS) operated by the NWS. Among these regional sites, the Scottsbluff Airport was selected as most representative of the MEA meteorology. Scottsbluff is less than 50 miles (80 km) south of the project site, with an elevation roughly 300 ft. lower than the project area. It is also the closest NWS station to the project site that collects hourly wind and relative humidity data. Available hourly data from Scottsbluff represent the last 15 years.

Hourly data for the Scottsbluff weather station were only available from the National Climate Data Center (NCDC) in electronic form for years 1996 and later. In order to corroborate the conclusions drawn in this report regarding temporal representativeness, hourly data from the Chadron Airport have been compiled and analyzed. Only 12 years of NCDC hourly data were available for Chadron in electronic form, spanning the period from January 1, 2001 through December 31, 2012. The results of the Chadron data analysis are discussed in these responses as **Appendix S**. In addition, **Appendix S** presents the regression analyses for both Scottsbluff and Chadron, with associated p-values. For both sites, the conclusion reached is that the consistently low p-values render the high coefficients of determination (near 1.0) statistically significant. The strong correlation implied

between wind characteristics during the baseline monitoring year and wind characteristics over a longer period is real at both the Scottsbluff and the Chadron sites. One may infer that a similar relationship exists at the project site, some 30 miles (48.3 km) southwest of Chadron and 48 miles (77.2 km) north of Scottsbluff. This justifies the conclusion that the baseline year's wind data represent the long term.

For the site-specific analysis, meteorological data from the MEA meteorological station were used. These data were collected during the 1-year baseline monitoring period extending from August 24, 2010 through August 29, 2011. **Table 2.5-1** provides the station IDs, coordinates, and periods of operation for the regional and site-specific meteorological stations. The locations of the regional and MEA meteorological station are shown on **Figure 2.5-1**.

These sites have been analyzed collectively to evaluate regional climatic temperature and precipitation in the proposed project area. The NWS sites have also been incorporated into the snowfall discussion. The nearest available long-term monitoring site that continuously records all weather parameters is the Scottsbluff Airport. This site was analyzed for the regional wind summaries. At the project site, hourly average meteorological data include wind speed, wind direction, sigma theta, temperature, relative humidity, precipitation, and solar radiation. Evapotranspiration rates were calculated for both the Scottsbluff site and project site by applying Penman's equation to available solar radiation, wind speed, temperature, and relative humidity data. As solar radiation data were not available from the Scottsbluff data set, estimated monthly averages for solar radiation were obtained for the Scottsbluff area from the U.S. Department of Energy's National Renewable Energy Laboratory (NREL 1990).

In the information that follows, a regional overview is presented first. This section includes a discussion of the maximum and minimum temperatures and relative humidity, annual precipitation including snowfall estimates, a brief wind speed and direction summary, and a discussion of evapotranspiration rates. A combination of monitoring stations is analyzed for the regional overview of temperature, snowfall, and total precipitation.

A site-specific analysis follows the regional overview. Most of this analysis is based on the on-site monitoring. An in-depth wind analysis summarizes average wind speeds and directions, wind roses, wind speed frequency distributions, and a joint (wind speed and direction) frequency distribution to characterize the wind data for the MEA by atmospheric stability class. A discussion of monthly and seasonal data is included for the temperature, precipitation, evapotranspiration, and wind parameters. General upper atmosphere data from the NWS station at Rapid City, South Dakota are used to represent the project site.

The site-specific analysis includes a justification for using wind data from the baseline monitoring year to predict meteorological conditions over the long term. This is necessary to validate air sampling locations and MILDOS dispersion modeling inputs. The short- and-long term wind data from the Scottsbluff site are correlated for this purpose.

2.5.2 Regional

2.5.2.1 Temperature

The annual average temperature for the region is approximately 48° F (8.9° C). The Scottsbluff Airport meteorological station is considered to be representative of the region.

Figure 2.5-2 shows monthly average temperatures for the Scottsbluff Airport site, along with the monthly maximum and minimum temperatures over the last 15 years. July has the highest average monthly temperature (74.5° F), followed by August. December records the lowest average temperatures for the year (26.0° F), followed by January. **Table 2.5-2** shows average, minimum, and maximum monthly temperatures for the Scottsbluff Airport site. Low temperatures in the region can drop to nearly -30° F, while high temperatures can reach around 107° F.

Large diurnal temperature variations occur in the region due in large part to its high altitude and low humidity.

Figure 2.5-3 depicts the monthly diurnal temperature variation for the Scottsbluff Airport site from 1996 through August, 2011. Spring and summer daily variations of 30° F are common, with maximum temperature variations exceeding 40° F during extremely dry periods. Less daily variation is observed during the cooler portions of the year, as fall and winter have average variations of roughly 20° F. This can be attributed to the more stable atmospheric conditions in the region during the fall and winter months. Stable periods have much lower mixing heights and accompanying lapse rates, allowing for less temperature variation.

On a year-round basis, daily maximum temperatures in the project region average approximately 60° F, and daily minimum temperatures average approximately 33° F. July has the highest maximum temperatures, with averages near 90° F, while the lowest minimum temperatures are observed in January, with averages near 10° F (NCDC 2011). Annual average minimum and maximum temperatures are shown on **Figure 2.5-4** and **Figure 2.5-5**, respectively.

2.5.2.2 Relative Humidity

The Scottsbluff Airport site records relative humidity (dew point) data. The graph on **Figure 2.5-6** charts monthly average relative humidity values for this site. The Scottsbluff Airport data are from 1996 through August 2011. These data indicate that July has the driest air, with relative humidity averaging around 58 percent. The winter months of December, January, and February make up the most humid part of the year, with average relative humidity approaching 70 percent. The overall average relative humidity is 63 percent at Scottsbluff Airport.

Relative humidity is a temperature-based calculation which reflects the fraction of moisture present relative to the amount of moisture for saturated air at that temperature. Warmer air holds more moisture at saturation than colder air. Therefore, for a given amount of moisture in the air, relative humidity maximum values occur more frequently in the early mornings, while minimum values typically occur during the mid-afternoon hours. The summer months exhibit a much greater variation in relative humidity between morning and afternoon values due to greater temperature variations (**Figure 2.5-7**).

2.5.2.3 Precipitation

The region is characterized by moderately dry conditions. The Scottsbluff Airport received measurable (>0.01 in) precipitation on an average of 82 days per year between 1996 and 2011. Average annual precipitation during that period was 15.2 inches per year. In general, the project region has an annual average from 14 to 23 inches (**Figure 2.5-12**). Spring showers and thunderstorms produce nearly half of the precipitation at Scottsbluff Airport (**Figure 2.5-8**). May and June are typically the wettest months of the year; with most of the region receiving an average greater than 2 inches for each of those months (**Figure 2.5-9**). The region receives less precipitation in January than in any other month, averaging generally 0.5 inch or less. The winter months (December through February) typically account for less than 10 percent of the yearly precipitation totals. Only moderate precipitation occurs in late summer, when atmospheric conditions are more stable and the absence of convective activity limits storm development.

Severe weather does arise throughout the region, but is limited on average to five or six severe events per year. These severe events are generally split between hail and damaging wind events. Tornadoes can occur but are rare in western Nebraska.

Average annual snowfall varies throughout the region. Major snowstorms (more than 5 in/day) are relatively infrequent in the region. The region experiences fewer than three major snowstorms per year. Hay Springs, Nebraska has the highest annual snowfall of the sites closest to the project, with an average of 52 inches, while Sidney, Nebraska has the lowest averages at 30.7 inches per year. The interpolated values (**Figure 2.5-13**) show average snowfall of 30 to 60 inches per year in the project region.

Snowfall at the Scottsbluff Airport site averaged 38.2 inches per year over the last 15 years. Monthly average snow amounts are depicted on **Figure 2.5-10**, which shows the highest amount of snowfall in March. Monthly snowfall amounts in the overall region follow a similar pattern (**Figure 2.5-11**).

2.5.2.4 Wind Patterns

Year-round wind speeds in the area average between 8 and 11 mph. **Table 2.5-3** shows monthly average wind speeds for the Scottsbluff Airport site. The overall average wind speed at this site was 8.9 mph for the 1996 to 2011 period analyzed in this study. Mean monthly average wind speeds are lowest in the summer months and highest in April at nearly 11 mph.

Table 2.5-3 also shows monthly maximum hourly wind speeds for the Scottsbluff Airport. High wind events are fairly common in this region; wind data from this site show every month recording peak hourly wind speeds greater than 30 mph during the 15-year period analyzed.

Figure 2.5-14 graphs the Scottsbluff Airport 15-year monthly average and monthly maximum wind speeds listed in **Table 2.5-3.**

Figure 2.5-15 shows the 15-year wind rose for the Scottsbluff Airport site. Predominant winds are generally from the west-northwesterly or northwesterly directions. These winds, often associated with storm fronts, dominate the late fall, winter, and early spring seasons. A secondary mode occurs from the east-southeasterly or easterly directions. These winds are generally associated with the

summer season when regional high pressure dominates. The highest wind speeds tend to occur from the northwesterly direction. **Table 2.5-4** provides the same information as the wind rose, but in tabular form.

Winds at the Scottsbluff Airport site and throughout the region exhibit a diurnal pattern. **Figure 2.5-16** shows the pattern at Scottsbluff for each season of the year. Wind speeds peak during the early afternoon for the winter and fall seasons. During spring and summer, wind speeds peak in late afternoon. This is largely due to longer daylight hours and the predominant effect of solar heating on wind patterns. **Figure 2.5-16** also shows that the highest average wind speeds occur during the spring season, when the atmosphere tends to be least stable and storm systems are the strongest. The lowest wind speeds occur during summer, when the atmosphere is generally stable and storm systems are weak.

2.5.2.5 Heating, Cooling, and Growing Degree Days

Figure 2.5-17 summarizes the monthly cooling, heating, and growing degree days for Scottsbluff, Nebraska (NWS meteorological monitoring site 257665). The data are assumed to be indicative of the project area due to its proximity and comparable elevation.

The heating and cooling degree days are included to show deviation of the average daily temperature from a predefined base temperature. In this case, 50° F has been selected as the base temperature for computation of growing degree days. The base temperature for computing heating and cooling degree days is 65° F. The number of heating degree days is computed by taking the average of the high and low temperatures occurring that day and subtracting it from the base temperature. The calculation for growing and cooling degree days is the same, except that the base temperature is subtracted from the average of the high and low temperatures for the day. Negative values are disregarded for both calculations.

As expected, the graphs of heating degree days and cooling degree days are inversely related, and the growing and cooling degree days are directly related. The maximum number of heating degree days occurs in December and January, at roughly 1,200 degree days. This coincides with the months having the lowest minimum average temperatures. Conversely, July registers the most growing degree days with nearly 700, and the most cooling degree days at fewer than 300. This also corresponds to July having the highest average temperature.

2.5.2.6 Evapotranspiration

The project region is characterized by high evaporative demand during much of the year. This demand is related to dry air (low dew points), high daytime temperatures, and moderate wind speeds. **Figure 2.5-18** graphs monthly potential evapotranspiration (ET) rates, in inches of water per month, at the Scottsbluff Airport site. Potential ET is an estimate only, calculated using the Penman Equation (Jensen et al. 1990). Meteorological inputs to this equation include wind speed, barometric pressure, solar radiation, and temperature and humidity extremes.

For the Scottsbluff site, barometric pressure was estimated based on the elevation. Because solar radiation data were not available at this site, estimated monthly averages for solar radiation were obtained for the Scottsbluff area from the U.S. Department of Energy's National Renewable Energy Laboratory (NREL 1990). A flat-plate collector at zero degrees incline from horizontal represents

the global solar radiation available at a given location. Wind speed, temperature, and humidity data for the ET calculation were obtained from the Scottsbluff Airport hourly database.

Potential ET values are highest in July, at 10 inches, and lowest in December and January, at 2 inches. Annual ET for this area is projected at 68.6 inches per year.

2.5.3 Site-Specific Analysis

2.5.3.1 Introduction

The site-specific discussion of climate, meteorology, and air quality is limited to onsite meteorological data collected for the baseline monitoring period of August 2010 through August 2011. These onsite data are supplemented by meteorological data from the nearby Scottsbluff Airport site, collected during the 15-year period from 1996 through August 2011. The Scottsbluff site is included to incorporate wind monitoring results from a longer period of record and to demonstrate that, for this region, winds during the baseline monitoring period are representative of the longer term. The Scottsbluff site is located 48 miles (77.2 km) south of the MEA, with elevation and topographic features comparable to the project area. In both cases, the surrounding area is characterized by rolling hills and flat plains bordered by small ridges and breaks with ephemeral drainages. With the exception of cultivated land, the vegetation types are mainly confined to native grasses with some sage brush and wooded areas.

2.5.3.2 Temperature

The annual average project site temperature is similar to the regional average temperature at approximately 46° F. The maximum temperature for the baseline monitoring year was 99° F, and the minimum temperature was -28° F.

Figure 2.5-19 shows the monthly average, minimum, and maximum temperatures for the project site. **Table 2.5-5** provides the same data in tabular form. Daily average temperatures range from near 20° F in the winter months to above 70° in the summer months.

Table 2.5-6 provides a meteorological summary for the MEA site for the baseline monitoring year. The averages, maximums, and minimums are specified for each parameter recorded at the site along with the data recovery rate for each. The recovery rates are greater than 97 percent for all parameters.

2.5.3.3 Wind Patterns

Figure 2.5-20 presents a wind rose for the project site during the 12-month baseline monitoring period. **Table 2.5-7** presents the same information in tabular form. The predominant wind direction is north-northwesterly and northwesterly, with the highest wind speeds also coming from those directions. During periods of fair weather, particularly in late spring and summer, high pressure located over the northern plains produces moderate southeasterly winds in the project area. Synoptic weather systems generally interrupt this pattern, producing high north-northwesterly winds. **Figure 2.5-21** shows seasonal wind roses for the project area. Spring experiences the greatest variability in wind direction with secondary modes as a result of the synoptic scale transition period that occurs during this time. Low pressure regions develop on the lee side of the

Rockies, bringing southeasterly winds during storm development. As the low pressure systems form and move off with the general atmospheric flow, winds switch to a north-northwesterly direction.

Figure 2.5-22 presents a diurnal graph of wind speeds at the project site by season. For all seasons, wind speeds peak during the afternoon. Winds during the summer plateau at less than 12 mph, while the rest of the year experiences peak afternoon wind speeds averaging roughly 15 mph. Nighttime winds average 8 to 10 mph throughout the year.

Figure 2.5-23 shows the time distribution of wind speeds at the project site. Half of the time, wind speeds are less than 8 mph, while winds exceed 18 mph 10 percent of the time.

The average wind speed for the project site was 10.6 mph over the 12 months of monitoring, slightly higher than the 8.9 mph long-term average at Scottsbluff. The monthly average and maximum hourly wind speeds at the project site are summarized in **Figure 2.5-24**. The graph shows higher wind speeds in the winter and spring, peaking in April.

Table 2.5-8 provides a breakdown of wind speeds by wind direction. Wind speeds average near or above 12 mph when the wind blows from the northwest quadrant. A secondary maximum occurs for southerly winds, averaging more than 10 mph. For all other directions, wind speeds average less than 10 mph.

The Joint Frequency Distribution (JFD) provides more detail on wind speed distribution by wind direction and atmospheric stability class. The distribution shows the frequencies of hourly average wind speed for each direction based on stability class. **Table 2.5-9** lists the annual JFD for the MEA. **Tables 2.5-10** through **2.5-13** list the seasonal JFDs. A majority of the winds at the project site fall into stability class D, which represents near neutral to slightly unstable conditions. The light winds which accompany stable environments are reflected in the stability class F summary.

2.5.3.4 Precipitation

Figure 2.5-25 shows monthly precipitation at the project site during the baseline monitoring year. Total precipitation was 18 inches, although 10 inches fell during the abnormally wet month of May. Very little precipitation fell during the fall and winter months. Based on long-term records at other weather stations in the region, precipitation recorded during the baseline monitoring year at Marsland is probably not representative of the long term. An annual average precipitation of 15 inches is considered more likely.

2.5.3.5 Evapotranspiration

Daily ET rates were calculated for the project site by applying Penman's equation to recorded solar radiation, wind speed, temperature, and relative humidity data. These calculations were then summed for each month. **Figure 2.5-26** shows projected monthly ET at the project site during the baseline monitoring period. From these calculations, annual ET is computed at approximately 60 inches. This compares favorably to the long-term calculated average of 68 inches at the Scottsbluff Airport site.

2.5.3.6 Justification of Baseline Year as Representative of Long Term

The proposed project is situated in northwest Nebraska. The baseline meteorological monitoring period extended approximately 1 year, from August 24, 2010 through August 29, 2011. To demonstrate that this baseline year is representative of the longer-term wind conditions, the Scottsbluff Airport site was analyzed. Among the weather stations in this region, the Scottsbluff Airport was chosen to represent wind conditions in the vicinity of the project due to proximity, similar elevation, similar terrain, and the limited availability of hourly wind data in the region. Within a 50-mile (80 km) radius, only three of the numerous meteorological stations collect hourly wind data: Scottsbluff (48 miles [7.2 km] from the MEA site), Chadron (25 miles [40 km] from the MEA site), and Alliance (34 miles [54.7 km] from the MEA site). Although closest to the MEA site, Chadron is 800 ft. lower in elevation and on the opposite side of a prominent, east-west oriented ridge. Scottsbluff and Alliance are approximately 300 ft. lower in elevation than the MEA site. Both exhibit flat or mildly rolling terrain, reasonably similar to the MEA site. Neither site exhibits a long-term wind rose that strongly resembles the baseline-year wind rose from the MEA site (see **Figures 2-5-15, 2.5-20** and **2.5-32**). However, the Scottsbluff wind rose more closely resembles the MEA site. It shows prominent winds from the northwesterly, north-northwesterly, and northerly directions that resemble the MEA site. These wind directions are not as prominent in the Alliance wind rose. Moreover, the Alliance wind rose shows dominant winds from the west, a feature lacking in both the Scottsbluff and MEA wind roses.

Either the Alliance or the Scottsbluff site would likely fulfill the purpose behind selecting a regionally representative meteorological station. Localized differences in wind patterns are typical of western Nebraska and eastern Wyoming, where even mild terrain differences influence the wind rose. However, the primary purpose of this exercise is interpreted to be the demonstration of temporal representativeness, not spatial representativeness. As discussed in **Appendix S**, even the Chadron site suffices for the temporal demonstration. If the baseline year at the regional weather station is shown to represent the long term at that location, this demonstration has been made. A similar temporal representation at the project site is then inferred because both locations are subjected to the same, regional climate regime.

Hourly wind data from Scottsbluff were available electronically through the National Climatic Data Center (NCDC) for a 15-year period. In order to validate the use of 15 years instead of 30, **Appendix S** presented a temporal comparison for the Chadron site similar to that given for the Scottsbluff site. Only 12 years of data were available for Chadron. The result was a strong linear correlation between baseline-year and longer-term wind speed and wind direction distributions, reinforcing the results obtained for Scottsbluff. It is believed that 30 years of data would not significantly change these results.

Figure 2.5-27 shows wind roses for Scottsbluff (Scottsbluff 15-year vs baseline year wind roses). The wind rose on the left reflects 15 years of monitoring (1996 through August, 2011), while the one on the right reflects the MEA baseline monitoring period only. It can be seen that wind speeds and directions are very similar between the 15-year and 1-year monitoring periods.

Figure 2.5-28 compares the wind direction frequency distributions between the 15-year and baseline periods at Scottsbluff. The percent of the time the wind blows from each of the 16 cardinal directions shown is quite similar for the two monitoring periods.

Figure 2.5-29 compares the wind speed frequency distributions of the 15-year and baseline periods at Scottsbluff. The percent of the time the wind speed falls within each of the six wind speed classes shown is quite similar for the two monitoring periods.

In order to quantify this similarity, it is useful to isolate wind speed and wind direction variables in order to correlate short-term and long-term frequency distributions. IML Air Science has developed a statistical methodology for assessing the degree to which the distributions of wind speed class and wind direction frequencies from 1 year of monitoring at a particular location represent the long-term distributions at that same location.

For the joint frequency wind distribution used in the MILDOS-AREA model, wind speeds are divided into six classifications ranging from mild (0 to 3 mph) to strong (> 24 mph) as illustrated in **Table 2.5-9** and on **Figure 2.5-29**. Likewise, wind directions are divided into 16 categories corresponding to the compass directions illustrated in the wind roses presented above and on **Figure 2.5-28**.

The percent of the time that winds occur in each of the six wind speed categories can be calculated to produce a wind speed frequency distribution. The percent of the time that winds blow from each of the 16 directions can be calculated to produce a wind direction frequency distribution. For each parameter, the 1-year and 15-year distributions can then be compared. Linear regression analysis provides a useful tool to assess the degree of correlation between short- and long-term distributions.

Figure 2.5-30 presents this correlation for the wind speed distributions at Scottsbluff. Each point represents one of the six wind speed classes. The x coordinate corresponds to the percent of the 1-year period during which the wind speed fell in a given class, while the y coordinate corresponds to the percent of the 15-year period during which the wind speed fell in that same class.

The regression line (red) on **Figure 2.5-30** represents the least-squares fit to the six data points. The corresponding R^2 value of 94.5 percent implies very strong linear correlation. The linear slope of 0.98 further implies that short- and long-term wind speed frequencies not only correlate, but are substantially equivalent in magnitude.

A similar analysis can be performed for wind direction frequencies. **Figure 2.5-31** presents this correlation, again for the Scottsbluff Airport site. Each point represents one of the 16 wind direction categories. The x coordinate corresponds to the percent of the 1-year period during which the wind blew from a given direction, while the y coordinate corresponds to the percent of the 15-year period during which the wind blew from that same direction.

The regression line (red) on **Figure 2.5-31** represents the least-squares fit to the 16 data points. The corresponding R^2 value of 97.2 percent implies very strong linear correlation. The linear slope of 1.02 further implies that short- and long-term wind speed frequencies not only correlate, but are substantially equivalent in magnitude.

Figures 2.5-30 and **2.5-31** offer conclusive evidence that the 2010-2011 baseline monitoring year adequately represents the last 15 years at Scottsbluff Airport. Because the 1-year wind data serve as reliable predictors of the long-term wind conditions at Scottsbluff, and because the MEA site experiences similar regional weather patterns, it is proposed here that the 1-year baseline monitoring represents long-term meteorological conditions at the MEA site.

2.5.3.7 Onsite Meteorological Instrument Specifications

Table 2.5-14 lists the meteorological instruments employed at the MEA meteorological monitoring station. The table shows instrument models, accuracy specifications, and instrument heights above the ground. **Appendix B** to this document is an example of a calibration report for the meteorological instruments.

Meteorological data collection, management, and reporting methods at the project site conform to NRC atmospheric dispersion modeling requirements for uranium milling operations, and meet the acceptance criteria established in the NRC's NUREG-1569. The onsite monitoring program was developed according to RG 3.63, "Onsite Meteorological Measurement Program For Uranium Recovery Facilities – Data Acquisition and Reporting." Hourly average values for wind speed, wind direction, sigma theta, temperature, relative humidity, precipitation, and solar radiation are generated by field instruments and recorded by continuous data loggers. Data recovery exceeded 97 percent for the 12-month monitoring period. All hourly data have been downloaded to a relational database for quality assurance, statistical analysis, and reporting purposes.

The meteorological instruments are placed at a location in the MEA area that represents as closely as possible the long-term meteorological characteristics of the area measured. NRC RG 3.63 provides guidance acceptable to the NRC regarding the siting of meteorological instruments. The siting of the MEA meteorological instruments followed this NRC guidance in siting and is discussed in **Appendix R** of this document. This appendix addresses the NRC's siting conditions identified as being necessary to achieve meteorological data representative of the proposed project site.

2.5.3.8 Upper Atmosphere Characterization

Mixing height is the height of the atmosphere above the ground that is well mixed due either to mechanical turbulence or convective turbulence. The air layer above this height is stable. Higher mixing heights are associated with greater dispersion, all other parameters being the same. Stable periods have much lower mixing heights and accompanying lapse rates, allowing for less temperature variation. The MILDOS-AREA model uses mixing height, along with other wind parameters, to predict pollutant dispersion. Unstable air leads to more dispersion, which leads to lower predicted impacts on ambient air quality. The default mixing height used by MILDOS-AREA is 100 meters, a very conservative value given that typical mixing heights exceed 1,000 meters.

The nearest upper-air data available from the NWS are from Rapid City, South Dakota, approximately 108 miles (173.8 km) north of the project area. Average mixing heights were derived from the American Meteorological Society (AMS)/U.S. Environmental Protection Agency (EPA) Regulatory Model (AERMOD) calculations used for dispersion modeling, based on hourly data obtained from the NWS stations in Rapid City (upper air). The AERMOD calculation is based on a combination of mechanically and convectively driven boundary layer processes. The results of these calculations are provided for morning and afternoon in **Table 2.5-15**. The annual average mixing height is 1,110 meters.

The mixing or inversion heights are entered as inputs to the MILDOS-AREA model for pollutant dispersion modeling. For the MEA project, the MILDOS default value of 100 meters was used for

both morning and afternoon mixing heights. Argonne National Laboratory has employed a default value of 100 meters for the annual average morning and afternoon atmospheric mixing heights (ANL 1998). Page 12 of the Guide states *Mixing Heights: annual average Morning and Afternoon atmospheric mixing height in meters. The default value is 100 m for both.* Therefore, this default value was used for MILDOS modeling of the MEA site.

Because this mixing height of 100 m is lower than the calculated mixing heights in **Table 2.5-15**, and lower mixing heights lead to less pollutant dispersion, the dosage concentrations calculated by the MILDOS model are conservatively high.

2.5.3.9 Bodies of Water and Special Terrain Features

The only significant body of water near the proposed MEA is the Niobrara River, which flows easterly through a point approximately 4 miles (6.4 km) south of the project site. The average flow rate at this location, however, is only 29 cubic ft/sec (USGS 2009g). It is unlikely that the influence of such a small stream could be measured 4 miles (6.4 km) away with a standard humidity probe.

The nearest mountain ranges to the project site are:

- The Laramie Mountains, approximately 100 miles (160.9 km) to the west
- The Black Hills, approximately 65 miles (104.6 km) to the north

It is believed that, at these distances, the mountain ranges have minimal impact on meteorology in the project area. As discussed above, storms moving eastward from the Rocky Mountains generally relinquish moisture on the windward side of the mountains, creating a drier climate on the leeward side. This is mitigated, however, by occasional moist air masses moving into Nebraska and Wyoming from the Gulf of Mexico.

2.5.4 Conclusion

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. The region has large diurnal and annual variations in temperature.

Thirteen NWS meteorological stations were used to characterize regional weather patterns. The region experiences average daily maximum temperatures near 90° F in July and average daily minimum temperatures around 15° F in January. There are 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 site average temperature is expected to be 46° F with extremes of -30° to +105° F. The region generally receives little precipitation, with annual averages between 13 and 16 inches. Spring and early summer precipitation events are responsible for the majority of the yearly average.

The region is characterized by annual average wind speeds of 9 to 12 mph. Winds at the project site are expected to average 10 to 11 mph annually, with summer averages dipping below 8 mph and winter averages exceeding 12 mph. The predominant wind directions are from the north-northwest and northwest.

The MEA meteorological station and the Scottsbluff Airport meteorological station were both analyzed in the site-specific analysis. The Scottsbluff site is included to validate the temporal representativeness of onsite wind data by incorporating wind monitoring results from a longer period of record. The Scottsbluff site is located 48 miles (77.2 km) south of the MEA, with elevation and topographic features comparable to the project area. The distribution of wind speeds and directions at Scottsbluff during the baseline monitoring period have been shown to closely represent long-term wind speeds and directions.

2.5.5 Air Quality

2.5.5.1 National Ambient Air Quality Standards

The NDEQ air quality regulations are based on federal and/or state law, with the primary source of the authority for air quality regulations being the federal Clean Air Act (NDEQ 2003). The NDEQ adopts the majority of these federal regulations into Title 129 (Nebraska Air Quality of the Nebraska Administrative Code). The basic foundation of the NDEQ air program is the National Ambient Air Quality Standards (NAAQS), which are concentrations of pollutants the EPA has established (and adopted by the NDEQ) as being protective of human health and the environment. The standards are established for six "criteria" pollutants: particulate matter, sulfur dioxide, nitrogen oxides, carbon monoxide, ozone, and lead (**Table 2.5-16;** EPA 2013). The State of Nebraska is required to keep areas in compliance with the standards and restore compliance in any areas out of compliance. The NDEQ has several ambient air monitors located throughout the state to measure the concentrations of pollutants in the ambient air (NDEQ 2011c). An area may be classified as nonattainment if the concentration of one or more criteria pollutants in an area is found to exceed the regulated or "threshold" level for one or more of the NAAQS. Those areas with concentrations of criteria pollutants below the levels established by the NAAQS are considered in attainment or unclassifiable.

On February 14, 2012, the EPA proposed thresholds for classifying nonattainment areas for the 2008 ozone NAAQS promulgated by the EPA on March 12, 2008 (EPA 2012). This proposal also addresses the timing of attainment dates for each classification and revokes the 1997 zone NAAQS 1 year after the effective date of designations for the 2008 ozone NAAQS for transportation conformity purposes only. The February 14, 2012 proposal establishes a necessary step to implement the 2008 NAAQS for ground-level ozone. The EPA set those standards at 0.075 parts per million (ppm) on March 12, 2008. When the rule is finalized, the Omaha/Council Bluffs area may be significantly impacted if its levels of ozone pollution are above the new regulatory limits.

There are no ambient air quality monitoring data for criteria pollutants in the proposed MEA license boundary or AOR. However, there are a limited amount of state and federal monitoring sites in the region of the MEA that can be used as levels representative of the region for the monitored parameters. These monitoring sites are maintained for a variety of purposes, including for regional background purposes by the NDEQ, as per Appendix D of 40 CFR Part 58. However, the parameters measured are limited to particulate and ozone monitoring.

Regional monitoring sites and parameters measured are presented in **Table 2.5-17**. The locations of the monitor sites in western Nebraska are shown on **Figure 2.5-33**. The data available at the time of preparation of this section are summarized in **Tables 2.5-18** through **2.5-25**. The results of

this monitoring indicate that the regions being monitored, including the MEA area, are well within compliance of NAAQS standards.

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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 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 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. As observed in drill cuttings, 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. 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**).

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 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. **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 2-6a** through **Figure 2-6n**).

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, 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 Frmation, 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**).

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**).

<u>Niobrara River Fault</u>

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.

<u>Pine Ridge Fault</u>

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).

<u>Soil Limitations</u>

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.

<u>Bankard Series Soils</u>

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:

<u>1013 – Bankard loamy coarse sand, frequently flooded</u>

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.

<u>1014 – Bankard loamy fine sand, frequently flooded</u>

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.

<u>Glenberg Series Soils</u>

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.

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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 the presence of water within any portions of the upper Chadron or middle Chadron Formation. 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.

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.

<u>Basal Sandstone of the Chadron Formation</u>

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.

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 x 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 x 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 x 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 110 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 x 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.

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*), barley (*Hordeum* spp.), and rye (*Secale cereale*). 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).

<u>Black-footed Ferret</u>

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.

<u>Whooping Crane</u>

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.

<u>Gray Wolf</u>

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.

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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**.

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).

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

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).

<u>Box Butte Reservoir</u>

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.

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.

$$Csvhj = 1000\,(MLv + Bjv)\,Wv\ \{ACsj, tgv\}/Csj \quad \text{(Equation 1)}$$

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:

$$Csvhj = 1000\,(MLv + Bjv)\,Wv \qquad (Equation\ 2)$$

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.

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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 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

No preoperational samples of game animals were collected due to the following considerations:

- Hunting access is limited by private landowners.
- 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.

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 recommends 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.
- 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. 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.**

2.9.8 Water **was not present in the ephemeral** drainage system during Q4 2013 through Q2 2015, therefore no baseline **water** samples were collected. **If water becomes available** prior to mining, CBR will **collect baseline water samples in the ephemeral drainages at**

sampling the points MED-1 through MED-7. 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.

3 DESCRIPTION OF PROPOSED FACILITY

Production of uranium by ISR mining techniques involves a mining step and a uranium recovery step. Mining is accomplished by installing a series of injection wells through which the leach solution is pumped into the ore body. Corresponding production wells and pumps promote flow through the ore body and allow for the collection of uranium-rich leach solution. Uranium is removed from the leach solution by IX, and then from the IX resin by elution. The leach solution can then be reused for mining purposes. The elution liquid containing the uranium (the "pregnant" eluent) is then processed by precipitation, dewatering, and drying to produce a transportable form of uranium called yellowcake.

The MEA is being developed by CBR in conjunction with the CPF licensed under NRC Source Material License SUA-1534. The MEA will be developed by constructing independent mine units and mining support facilities while employing existing processing equipment for uranium recovery. Transfer of recovered leach solutions from the area is prohibitive because of the distance over which a relatively large stream would have to be pumped. Therefore, a satellite facility will be constructed in the MEA to provide chemical makeup of leach solutions, recovery of uranium by IX, and restoration capabilities. The IX processes at the satellite facility recover the uranium from the leach solution in a form (loaded IX resin) that is relatively safe and simple to transport by tanker truck to the CPF, which will serve as feed to the CPF for elution and further processing of recovered uranium. Regenerated resin is then transported back to the satellite facility for reuse in the IX circuit.

3.1 Solution Mining Process and Equipment

3.1.1 Orebody

In the CPF license area, uranium is recovered by ISR from the basal sandstone of the Chadron Formation at a depth that varies from 400 feet to 900 feet. The overall width of the mineralized area varies from 1,000 feet to 5,000 feet. The orebody ranges in grade from less than 0.05 to more than 0.5 percent U_3O, with an average grade estimated at 0.27 percent U_3O_8.

In the MEA license area, uranium will also be recovered via ISR from the basal sandstone of the Chadron Formation. 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 (**Figures 2.6-3a** through **2.6-3n**). The width of the ore body varies from approximately 1,000 to 4,000 feet. The ore grade as U_3O_8 ranges from 0.11 to .33 percent with an average ore grade of 0.22 percent.

Typical stratigraphic intervals to be mined by the ISR method are shown in the geologic cross-sections contained in Section 2.6. For ISR wellfields, the production zone is the geological sandstone unit where the leaching solutions are injected and recovered.

3.1.2 Well Construction and Integrity Testing

Three well construction methods and appropriate casing materials are used for the construction and installation of production and injection wells.

3.1.2.1 Well Materials of Construction

The well casing material will be PVC, which is 5-inch Standard Dimension Ratio-17 (SDR-17) or equivalent. However, should a larger pump size be required, 6-inch SDR-17 or greater casing will be used. The PVC casing joints are 20 feet long, and the bottom joint can be made either 10 or 20 feet long depending on the casing depth. With SDR-17 PVC casing, each joint has a watertight O-ring seal and is held together with a high-strength nylon spline.

CertainTeed Certa-Lok well casing or like material will be used for well construction at Marsland. Based on manufacturer's information, there is no one recommended maximum depth for a particular size and class of PVC well casing. As explained by the manufacturer, proper design criteria allow a wide range of applications for a particular size and class of PVC casing. For example, it is possible to use thinner-walled casing at significant depths as long as design criteria address hydraulic collapsing pressures and heat. Conversely, thicker-walled casing may fail at shallow depths if collapsing pressures and heat are not designed for accordingly. To ensure that hydraulic collapse pressures are not exceeded during well construction, wells will be constructed using pressure grouting and weighted displacement fluid.

Pressure grouting through the inside of the casing essentially eliminates hydraulic collapsing pressures by retaining pressure on the cement and displacement fluid with a closed well head valve. Weighted displacement fluid consisting of water, bentonite-based drilling mud, and/or a weighting agent (such as barite) may also be used to displace cement. Weighted displacement fluid helps maintain the hydraulic collapse pressure in case of a leaky well head and reduces the pumping pressures required to push the annular column of cement to the surface.

The net external hydraulic collapsing pressure at the bottom of the casing can be calculated to ensure the weight of the displacement fluid provides sufficient offsetting internal pressure. External collapsing pressure at the bottom of the casing is calculated using the following equation:

$Pd = Pe - Pi$

Where:

Pd = Pressure differential

Pe = Pressure external

Pi = Pressure internal

Pressure (psi) may be calculated using the following equation:

Pressure (psi) = H x W x 0.052

Where:

H = Height of fluid column (ft.)

W = Weight of fluid (lbs./gallon)

It is important to note that, once the cement has begun to cure and reaches a semi-rigid state, the collapse pressure forces are eliminated. The cured cement provides lateral support and holds the casing firmly in place. It seals the borehole against water infiltration from the surface and

undesirable aquifers. Note also that all wells must successfully pass a Mechanical Integrity Test (MIT) prior to being placed into service.

CBR has widely used both PVC and stainless steel well screens in the injection, production, and monitoring wells at the Crow Butte Operation since 1991. Both screen types have demonstrated good reliability with minimal maintenance required when operating within anticipated chemical and pressure environments required for mining. **Table 3.1.5** of the application shows the typical lixiviant concentrations anticipated for mining wells at Marsland. These concentrations are similar to those observed at Crow Butte. **Table 3.1-6** shows additional lixiviant concentrations of constituents measured at injection points for four mine units at the current CBR operations; these concentrations are expected to be similar for the MEA operations.

Stainless steel well screens used at Crow Butte are made out of type 304 and type 316L stainless steel. PVC screens are constructed from white PVC Type 1, Grade 1 material as described in ASTM F480 and ASTM D1784, Class 12454B. Both stainless steel and PVC screens provide excellent resistance to corrosion and corrosion-stress cracking and pitting.

The PVC well casing used at Crow Butte also shows excellent corrosion resistance and durability, meeting the ASTM F480 specifications for plastic pipe. Since 1991, more than 5,000 wells have been placed into production at Crow Butte. Down-hole video surveys do show some calcite and sodium bicarbonate scale buildup on the casing walls that can be removed with the well jetting procedure discussed below. After removal, no evidence remains to indicate that corrosion or destructive forces have degraded the casing.

Down-hole video surveys of wells with declining flow rates have shown well screen fouling and plugging due to sand, calcite, and bicarbonate scale. Wells identified with this type of fouling are rehabilitated using a drill rig to jet and flush the scale, generally restoring the well back to original flow rates. Post-rehabilitation down-hole video surveys have shown that the jet-and-flush process removes most foreign material, alleviating fouling and plugging.

SS screens are more durable than PVC screens, are rated for greater depths than PVC screens, are easier to install, and can achieve better flow. The SS screens are significantly more expensive than the PVC screens. Currently, CBR primarily uses SS screens, but would maintain the option to use PVC screens as necessary at the satellite facility based on site conditions and purpose of the borehole. For example, PVC well screens are currently used in both shallow observation monitor wells and commercial production monitor wells. This practice will continue to be an option for Marsland. PVC screens are used for these types of wells primarily because these types of monitor wells typically have much longer screen intervals than other types of wells. This results in employee safety issues due to the handling of the heavy SS screens. In addition, flow rate using PVC screens is less of a concern for these monitoring wells, as the amount of flow is limited by the formation, not the screen. The PVC well screen consists of a perforated 3-inch PVC pipe. PVC rods run longitudinally along the sides of the pipe. Keystone-shaped PVC wire is helically wrapped around the outsides of the pipe and ribs and solvent-welded to the pipe. Spacing between consecutive wraps of the wire varies depending upon the screen ordered. Slot sizes from 0.010 to 0.020 inch have been used successfully at Crow Butte. In most cases, a slot size of 0.020 inch is sufficient to prevent sand from entering the screens. All Class III wells will be screened and naturally developed. CBR does not intend to introduce a sized gravel pack for wells at Marsland at this time.

The SS well screen consists of longitudinal ribs of SS with a SS "V" shaped wire wrapped helically around the interior ribbing. The wire is welded to the circular rib array for support. As with PVC screens, slot sizes of 0.010 to 0.020 inch have been used historically at Crow Butte.

3.1.2.2 Well Construction Methods

Pilot holes for monitor, production, and injection wells will be drilled through the target completion interval with a small rotary drilling unit using native mud and a small amount of commercial drilling fluid additive for viscosity control. The hole will be logged, reamed, casing set, and cemented to isolate the completion interval from all other aquifers. Three well construction methods are described. Any of these methods is appropriate for monitor wells and have been approved by the NDEQ under the current Crow Butte Class III UIC Permit and recently issued Class III UIC Permit for the NTEA satellite facility. All wells will be constructed in accordance with the provisions of this section. Of the three methods, CBR primarily uses Method 1, shown on **Figure 3.1-1,** on a routine basis. Method 2, shown on **Figure 3.1-2,** may be used by the CBR geologic staff when there is a need to study the geology of an area and to determine the best placement of the screens without having to attach screens to the casing string. Method 3, shown on **Figure 3.1-3,** is not routinely used, but this method is maintained as an option so that the method (including minor modifications) can be used if warranted for specific geological formations. All of these methods are appropriate for constructing monitor wells and have been approved by the NDEQ under the UIC Permit.

<u>Method 1</u>

For this method, the well is drilled to depth in the Pierre Shale and then logged. Based upon the e-log, geologic staff will pick a casing depth, and will then begin to review the local area wells for the best location (depth) to select the screened interval. The well is cased through the mining zone and cemented in place. Cement flows down the inside of the casing, exits out the bottom, and flows back up the annulus to the surface. Cement may be pushed out of the bottom of the casing by using rubber cement plug that is pushed to the bottom and stays in the bottom of the well, or cement may be displaced using fresh water. If the cement is displaced with water, a rig will need to drill the excess cement out of the casing prior to under-reaming and setting screens. If the cement is displaced using a cement plug, then nothing further is required prior to under-reaming. The under-reaming process begins with a rig tripping (inserting in borehole) a specialized drill bit into the depths to be screened. Blades on the bit open outward to cut away and remove the casing and cement grout from the area to be screened. When the interval to be screened has been cut away, the drill rig removes the drill pipe, and the hole is logged to make certain that the cut is accurate. If the cut-check depths are determined to be satisfactory, the rig is used to place the screen assembly at the selected depth and then develop the well.

Method 1 is the primary method used for all injection and production wells. A slight variation of this method is used for monitor wells. Monitor wells are cased to the top of the mining zone and cemented using water displacement. Allowing for time for the cement to set up (harden), the excess cement is drilled out of the casing and the well is logged to determine where to place the well screens.

Method 1 is similar to Method 2, except that a plug and weep holes are not used.

Method 2

Method 2 uses a screen telescoped down inside the cemented casing. A hole is drilled and geophysically logged to locate the desired screen interval. The hole is then reamed if necessary only to the top of the desired screen interval. Next, a string of casing with a plug at the lower end and weep holes just above the plug is set into the hole. Cement is then pumped down the casing and out the weep holes. It returns to the surface through the annulus. After the cement has cured, the residual cement in the casing and plug are drilled out, with the drilling continuing through the desired zone. The screen with a K-packer and/or shale traps is then telescoped through the casing and set in the desired interval. The packer and/or shale traps serve to hold the screen in the desired position while acting as a fluid seal. Well development is again accomplished by airlifting or pumping. Minor variations from these procedures may be used as conditions require.

Method 2 is an improvement over Method 3 due to drilling only to the top of the mining zone. At that point, the well is cased and cemented. Because the drill hole does not penetrate through the mining zone, no cement basket must be used. A cement plug and weep holes are used to place the cement.

Method 3

This method involves setting an integral casing/screen string. The method consists of drilling a hole to the Pierre Shale; geophysically logging the hole to define the desired screen interval; and reaming the hole, if necessary, to the desired depth and diameter. Next, a string of casing with the desired length of screen attached to the lower end is placed into the hole. A cement basket is attached to the blank casing just above the screen to prevent plugging of the screen interval during cementing. The cement is pumped down the inside of the casing to a plug set just below the cement basket. The cement passes out through weepholes in the casing and is directed by the cement basket back to the surface through the annulus between the casing and the drill hole. After the cement has cured sufficiently, the residual cement and plug are drilled out, and the well is developed by airlifting or pumping.

For all three well completion methods, casing centralizers, located at a maximum spacing of 100 feet, are run on the casing to ensure that it is centered in the drill hole and that an effective cement seal is provided. The purpose of the cement is to stabilize and strengthen the casing and plug the annulus of the hole to prevent vertical migration of solutions. The volume of cement used in each well is determined by estimating the volume required to fill the annulus and ensure that cement returns to the surface. In almost all cement jobs, returns to the surface are observed. In rare cases, however, the drilling may result in a larger annulus volume than anticipated, and cement may not return all the way to the surface. In these cases, the upper portion of the annulus will be cemented from the surface to backfill as much of the well annulus as possible and stabilize the wellhead. This procedure is performed by placing a tremie hose from the surface as far down into the annulus as possible. Cement is pumped into the annulus until return to the surface is observed.

Current CBR Class III permits allow a 100-foot maximum spacing for casing centralizers. Historically, Crow Butte has placed centralizers every 60 feet except when a centralizer is scheduled to fall within the potential zone to be screened. In those instances, that centralizer is moved upward on the casing string and out of the screened zone so that it does not interfere with the under-reaming and screening process. Centralizers placed at this spacing still ensure that there

is sufficient annular space for the correct placement of the sealing grout and is supported by a successful MIT rate of 98 percent at the current CBR facility.

Screening

The exact size of the screen slot is determined by analyzing the formation samples brought to the surface during the drilling process, and is selected at the discretion of the Crow Butte geologic staff. The location and amount of drill screen to be set in a well are based upon the geologic and economic factors. Well screens are placed at a selected depth using the drilling rig. The screens are secured in place using a rubber K-packer and blank assembly that is attached to the top of the screens. The K-packer suspends the screens in the open portion of the well until well development creates a natural gravel pack surrounding the screen.

For injection and production wells, the screen interval is determined by the geologic staff based on the location of sands and ore grade material. The zones to be mined are correlated and selected by reviewing geophysical logs, which also confirms that the screened intervals between wells are hydrologically connected. Typically, an interval of approximately 18 feet is screened; however, individual intervals may range from 6 feet to 35 feet in length.

For monitor wells, a slightly different process is followed for placement of the screens. When the monitor well is drilled, the total thickness of the production zone is calculated. The number of screens to be placed in the well must cover the production zone, and the screen-to-blank ratio must exceed 50 percent. Care should be taken to ensure that those zones impacted by nearby wells are covered by screens, and not left blank. A well completion report is documented for each well and maintained at the site for review. All wells are constructed by a licensed/certified water well contractor, as defined by the Nebraska Health and Human Services System, Water Well Standards and Licensing Act, Article 46.

3.1.2.3 Cement/Grout Specifications

All cement will be ASTM International (ASTM) Type I, II or American Petroleum Institute (API) Class B or G and will meet the following criteria:

- The cement will have a density of no less than 11.5 lbs/gal.
- A bentonite grout shall be mixed as close as possible to a concentration of 1.5 lb. bentonite per gallon of water (1 quart polymer per 100 gallons of water may be premixed to prevent the clays from hydrating prematurely) and shall have a density of 9.2 lbs./gal or higher.

3.1.2.4 Logging Procedures and Other Tests

Appropriate geophysical logs and other tests are conducted during the drilling and construction of new Class III wells. These are determined based on the intended function, depth, construction, and other characteristics of the well; availability of similar data in the area of the drilling site; and the need for additional information that may arise from time to time as the construction of the well progresses.

Logging Equipment

CBR currently owns three operational logging units. All were built by Century Geophysical Corporation in Tulsa, Oklahoma. These units are capable of logging drill holes to a depth of approximately 2,000 feet.

These trucks are capable of using a wide variety of tools. All of these tools (or probes, as used by CBR) measure Single Point Resistance (RES), SP, Natural Gamma (GAM[NAT]), and Deviation. Some of the probes used by CBR are also capable of measuring temperature, 16-inch normal resistance, and 64-inch normal resistance (**Table 3.1-1**). Deviation with these units is measured using a slant angle and azimuth technique. Standardized procedures are used by trained personnel to carry out the logging tasks.

Borehole Geophysical Logs

As of November 1, 2011, there have been 1,653 exploration/development holes and 22 monitor and observation wells drilled within the MEA boundary. A sample portion of a borehole geophysical log (M-1252) is shown on **Figure 2.6-5.** Detailed analysis of a carefully chosen suite of borehole geophysics provides a method for interpreting lithology, stratigraphy, and depositional environment; and for deriving porosity values, permeability index, and water salinity. The log curves used for interpretation and parameter derivation measure RES, SP, GAM(NAT), and Deviation.

Log interpretation and parameter evaluation involves analysis of the measured log curve values and responses. The measured curve and resultant analysis are influenced by drilling processes, properties of the formation, and limitations of the logging tools themselves. Common hydrogeologic objectives of borehole geophysical logging include: (1) definition and correlation of aquifer or other lithologic units; (2) estimation of aquifer properties such as porosity and permeability; and (3) assessment of physical properties of formation water including conductivity, TDS, and total hardness. These objectives must be considered in the design, selection, and implementation of an effective logging program.

There are three basic parameters derived or interpreted from borehole geophysical logs: lithology, resistivity, and porosity. From these basic parameters, there are numerous variations that can provide information regarding lithologic identification, correlation, facies evaluation, delineation of permeable and porous zones, and identification of pore fluids. The type of measurements used to determine this information are:

- SP
- GAM(NAT)
- resistivity/induction

The following represent the general log suite at each borehole location:

Gamma ray (GR) tools measure naturally occurring GR radiation emitted spontaneously from the formation by uranium, thorium, and the potassium 40 isotope. Natural gamma logs are powerful tools in identification and correlation of lithology, identification of potential migration pathways, and evaluation of water quality with respect to radionuclides, such as uranium salts. GR logs usually show the clay content in sedimentary rocks because heavy radioactive elements (potassium, thorium, and uranium-radium) tend to concentrate in clays. While clays and clayey sands are

higher in radioactivity, clean sands (no clay content) and carbonates usually exhibit low levels of radioactivity. The GR curve can differentiate among sands, clays, and the gradation between the two. As radioactive elements tend to concentrate in shales and clays, high GR readings reflect high shale or clay content in sedimentary units. Very low levels of radioactive elements or isotopes are present in clean formations (sands, gypsum, and anhydrite) unless contaminants are present such as dissolved potassium or uranium salts, volcanic ash, or granite wash.

The tool records counts per second (CPS), which should be converted to API units. Natural gamma logs should always be calibrated in API units. The API unit is a unit of counting rate used for scaling GR logs and neutron logs (Schlumberger 2010). The API unit of radioactivity is used for natural GR logs and is based on an artificially radioactive concrete block located at the University of Houston, Texas. This unit was chosen because it was considered to carry twice the radioactivity of typical shale. The United States Department of Energy (DOE) maintains facilities for the calibration of geophysical probes used in creating gamma logs, with one being located in Casper, Wyoming. CBR employs the test pits monthly at the DOE Casper facility to calibrate the geophysical probes.

The Spontaneous Potential (SP) log is a measurement of the electrical potential (voltage) that occurs in a boring when fluids of different salinities are in contact. The electrical potential is produced by the interaction of formation water, conductive drilling fluids, and certain ion-selective sediments (clay). Because clays have a very low permeability and sands have a high permeability, the SP can be a valuable lithology indicator. In general, clay-free permeable beds of moderate to low resistivity are sharply defined by the SP curve. High resistivity beds distort the SP currents, flattening the slope of the SP curve at bed boundaries. This causes poor bed boundary definition. The SP curve is also distorted (depressed or elevated) by permeable zones that contain clay, hydrocarbons, gas, or contaminants.

Single point resistance (RES) tools measure the resistance to current flow between a tool electrode and a ground electrode (conventional single point resistance), or between an electrode in the tool and the shell of the tool (differential single point resistance). Response of the log curve is attributed to lithologic units of varying resistance. Resistance increases in freshwater-filled sands or gravels and decreases in shales, clays, silts, and brine-filled sands. Curve values are recorded in ohms. Point resistance tools have a relatively small radius of investigation and poor thin bed resolution compared to resistivity tools. These logs are mainly used for correlation of beds.

Borehole Deviation Logging

Deviation of boreholes is measured using a slant angle and azimuth technique. CBR uses a Century Geophysical Corporation Tool Borehole deviation log tool 9057 or equivalent to record the attitude (dip angle and dip direction) of rock layers in the borehole. Borehole deviation and pad 1 azimuth are recorded in real time, via a deviation package contained within the tool, which contains the X-Y inclinometers and the X-Y-Z magnetometers. From these sensors, the Compu-Log computes and records slant angle (angle of the tool) and slant angle bearing (tool direction) as the tool proceeds along the borehole path. This device is aligned to correct for spatial indications with pad 1 azimuth. The deviation calibration is performed by recording two CPS rotating logs, and then using the dipmeter calibration to produce a special deviation calibration file (Century Geophysical Corporation 2009).

3.1.2.5 Field Observations and Core Samples Analysis

At CBR, subsurface formation lithology mapping and interpretation for boreholes during the drilling and construction of Class III wells are primarily based on field observations and geophysical logging. Field observations documented during drilling include depth, drilling rate, size of cuttings, and changes in lithology. Drill cuttings or core samples may be analyzed for physical and chemical parameters as needed in support of geophysical measurements. For example, core samples were recently collected in the MEA for four lithostratigraphic units. Sample analyses included XRD and sieve analysis (i.e., grain size distribution). Of particular importance for this sampling program was a better understanding of the hydraulic characterization of the upper and lower confining units for the basal sandstone of the Chadron Formation. This information was required for the Aquifer Exemption Petition.

Core samples may be collected as needed, but coring is typically not needed during the drilling and construction of Class III wells. The types of tests conducted on core samples are based on the intended need (e.g., porosity, relative permeability, and lithology).

Groundwater Measurements

Groundwater sampling and water level measurements are two tests typically conducted for new wells. Results of the groundwater sampling and analysis are used to evaluate water quality baseline values for future restoration to groundwater standards, and water level measurements provide for a more detailed understanding of the hydraulic gradient within the MEA. Groundwater monitoring for new wells is discussed below.

3.1.2.6 Well Development

Following well construction (and before baseline water quality samples are taken for restoration and monitoring wells), the wells must be developed to restore the natural hydraulic conductivity and geochemical equilibrium of the aquifer. All wells are initially developed immediately after construction using airlifting or other accepted development techniques. This process is necessary to allow representative samples of groundwater to be collected. Well development removes water and drilling fluids from the casing, formation, and borehole walls along the screened interval. The primary goal for well development is to allow formation water to enter the well screen.

Initially, well development is generally performed by airlifting and cleanup with a drill rig. The well is developed until the water produced is clear. This can be determined visually or with a turbidimeter. During the final stages of initial development, water samples will be collected in a transparent or translucent container and visually examined for turbidity (i.e., cloudiness and visual suspended solids). Development is continued until clear, sediment-free formation water is produced.

When the water begins to clear, the development flow will be temporarily stopped and/or the flow rate will be varied. Sampling and examination for turbidity will continue. When varying the development rate no longer causes the sample to become turbid, the initial development will be deemed complete.

Before obtaining baseline samples from monitor or restoration wells, the well must be further developed to ensure that representative formation water is available for sampling. Final

development is performed by pumping the well or swabbing for an adequate period to ensure that stable formation water is present. pH and conductivity are monitored during this process to ensure that development activities have been effective. The field parameters must be stable at representative formation values before baseline sampling will begin.

Following well installation, all well development water will be captured in water trucks specifically labeled and dedicated for such purpose and equipped with signage indicating that these trucks may only discharge their contents for injection into the DDW. Alternatively, these fluids may be transported to the CPF evaporation ponds, but only if there are fluid separation equipment issues at the MEA satellite facility. Section 3.1.6 (Wellfield and Process Waste) discusses process wastewaters generated by the wellfield and satellite facility in further detail. Section 4.2.1.1 discusses handling and disposal of well drilling fluids and well development water.

3.1.2.7 Well Integrity Testing

All wells (i.e., injection, production, and monitor) are field tested using pressure-packer tests to demonstrate the mechanical integrity of the well casing. Every well will be tested after well construction is completed before it can be placed into service; after any work-over with a drill rig or servicing with equipment or procedures that could damage the well casing; at least once every 5 years; and whenever there is any question of casing integrity. To ensure the accuracy of the integrity tests, periodic comparisons are made between the field pressure gauges and a calibrated test gauge. The mechanical integrity test procedure has been approved by the NDEQ and is currently contained in the SHEQMS Volume III, Operating Manual. These same procedures will be used at the MEA.

The following general mechanical integrity test procedure is employed:

- The well is tested after well development and prior to the well being placed into service. The test consists of placement of two packers within the casing. The bottom packer is set just above the well screen, and the upper packer is set at the wellhead. The packers are inflated with nitrogen, and the casing is pressurized with water to 125 percent of the maximum operating pressure (i.e., 125 pounds per square inch [psi]).
- The well is then "closed in" and the pressure is monitored for a minimum of 20 minutes.
- If more than 10 percent of the pressure is lost during this time period, the well has failed the integrity test. When possible, a well that fails the integrity testing will be repaired and the testing repeated. If the casing leakage cannot be repaired or corrected, the well is plugged and reclaimed as described in Section 6.

CBR submits all mechanical integrity testing records to the NDEQ for review after the initial construction of a mine unit or wellfield. Test results are also maintained on site for regulatory review.

3.1.3 Wellfield Design and Operation

The proposed MEA mine timeline and MU map are shown on **Figure 1.7-4** and **Figure 1.7-5**, respectively. The preliminary map and mine timeline are based on current knowledge of the area. As the MEA is developed, the mine timeline and a mine unit map will be further developed. The MEA will be subdivided into an appropriate number of mine units. Each mine unit will contain a

number of wellhouses where injection and recovery solutions from the satellite facility building are distributed to the individual wells. The injection and production manifold piping from the satellite process facility to the wellhouses will be either PVC or HDPE with butt welded joints or an equivalent. In the wellhouse, injection pressure will be monitored on the injection trunk lines. Oxidizer will be added to the injection stream, and all injection lines off of the injection manifold will be equipped with totalizing flowmeters, which will be monitored in the satellite control room. The MEA mine units will be designed in a manner consistent with the existing CBR mine units.

The wellfield injection/production pattern employed is based on a hexagonal seven-spot pattern, which is modified as needed to fit the characteristics of the ore body. The standard production cell for the seven-spot pattern contains six injection wells surrounding a centrally located recovery well.

The cell dimensions vary depending on the formation and the characteristics of the ore body. The injection wells in a normal pattern are expected to be between 65 feet and 150 feet apart. A typical wellfield layout is shown on **Figure 3.1-4**. The wellfield is a repeated seven-spot design, with the spacing between production wells ranging from 65 to 150 feet. Other wellfield designs include alternating single line drives.

All wells are completed so they can be used as either injection or recovery wells, so that wellfield flow patterns can be changed as needed to improve uranium recovery and restore the groundwater in the most efficient manner. During operations, leaching solution enters the formations through the injection wells and flows to the recovery wells. Within the monitor well ring, prior to stability monitoring, more water is produced than injected to create an overall hydraulic cone of depression in the production zone. Under this pressure gradient, the natural groundwater movement from the surrounding area is toward the wellfield, providing additional control of the leaching solution movement. The difference between the amount of water produced and injected is the wellfield "bleed." The minimum overproduction or bleed rates will be a nominal 0.5 percent of the total wellfield production rate, and the maximum bleed rate typically approaches 2.0 percent. Bleed is adjusted as necessary to ensure that the perimeter ore zone monitor wells are influenced by the cone of depression until stability monitoring described in Section 6.1.5 begins.

Monitor wells will be placed in the basal sandstone of the Chadron Formation and in the overlying Brule Formation and Arikaree Group aquifers. All monitor wells will be completed by one of the three methods discussed above and developed prior to leach solution injection. The development process for monitor wells includes establishing baseline water quality before the initiation of mining operations.

Injection of solutions for mining will be at a rate of 6,000 gpm with a 0.5 to 2.0 percent production bleed stream. Production solutions returning from the wells to the production manifold will be monitored with a totalizing flowmeter. All pipelines and trunklines will be pressure checked for leaks and buried prior to production operations.

A water balance for the proposed satellite facility is presented in **Appendix T**. The primary liquid waste generated at the satellite facility will be the production bleed which, at a maximum scenario, is estimated at 1.2 percent of the production flow. At 6,000 gpm (4,500 gpm process flow and 1,500 gpm restoration flow), the maximum volume of liquid waste in year 2024 would be approximately 31 gpm. CBR proposes to handle the liquid waste using DDW injection. Detailed discussions of to the MEA water balance calculation and evaluation are presented in Section 3.1.7

Regional information, previous CBR license and permit submittals, and historical operational practices indicate that the minimum pressure that could initiate hydraulic fracture is 0.63 psi per foot of well depth. This value has historically and successfully been applied to CBR operations. Calculations for MEA result in a value of 0.53 psi. As such, the injection pressure is limited to less than 0.63 psi per foot of well depth. Injection pressures also will be limited to the pressure at which the well was integrity tested.

As discussed in Section 2.7, a regional pumping test has been conducted to assess the hydraulic characteristics of the basal sandstone of the Chadron Formation and overlying confining units. Pumping tests will also be performed for each MU to demonstrate hydraulic containment above the production zone, demonstrate communication between the production zone mining and exterior monitor wells, and to further evaluate the hydrologic properties of the basal sandstone of the Chadron Formation.

Prior to the startup of a MU the following wellfield package will be submitted to the NRC for review:

1) hydrologic test data;
2) completion reports on the monitoring wells;
3) water quality data used to determine excursion control parameters, and;
4) baseline preoperational groundwater quality including; well density, sampling frequency, and determination of groundwater restoration goals;
5) pumping test to establish that the production and injections wells are hydraulically connected to the perimeter horizontal excursion monitor wells and are hydraulically isolated from the vertical excursion monitor wells..

A full and detailed analysis of the potential impacts of the mining operations at Marsland on surrounding water users will be provided in an Industrial Groundwater Use Permit application. A similar permit application was submitted by Ferret Exploration of Nebraska (predecessor to Crow Butte Resources) in 1991, and that application provides a reasonable analogy between the current licensed area and satellite facility. The application states that water levels in the City of Crawford (approximately 3 miles [4.8 km] northwest of the mining area) could potentially be impacted by approximately 20 feet by consumptive withdrawal of water from the basal sandstone of the Chadron Formation during mining and restoration operations (based on a 20-year operational period).

A similar order of magnitude impact (drawdown) exists for the MEA operations. No impact to other users of groundwater is expected because there is no documented existing use of the basal sandstone of the Chadron Formation in the proposed MEA.

Because the basal sandstone of the Chadron Formation (production zone) is a deep confined aquifer, no surface water impacts are expected. Based on available information, all water supply wells within the MEA and AOR are completed in the relatively shallow Arikaree and/or Brule Formation, with no domestic or agricultural use of groundwater from the basal sandstone of the Chadron Formation.

Further, the geologic and hydrologic data presented in Sections 2.6 and 2.7, respectively, demonstrate that (1) uranium mineralization is limited to the basal sandstone of the Chadron Formation, and (2) this formation is isolated from underlying and overlying sands. Hence, the mining operations are expected to impact water quality only in the basal sandstone of the Chadron

Formation, and restoration operations will be conducted in the basal sandstone of the Chadron Formation following completion of mining.

Based on a bleed of 0.5 to 2.0 percent (0.5 to 1.5 percent have been successfully applied in the current licensed area), the potential impact from consumptive use of groundwater is expected to be minimal. In this regard, the vast majority (e.g., on the order of 98 percent) of groundwater used in the mining process will be treated and re-injected (**Figure 3.1-5**). Potential impacts on groundwater quality due to consumptive use outside the license area are expected to be negligible.

The data were evaluated using a Theis semi-steady state analytical solution, which includes the following assumptions:

- The aquifer is confined and has apparent infinite extent.
- The aquifer is homogeneous and isotropic, and of uniform effective thickness over the area influenced by pumping.
- The piezometric surface is horizontal prior to pumping.
- The well is pumped at a constant rate.
- No recharge to the aquifer occurs.
- The pumping well is fully penetrating.
- Well diameter is small, so well storage is negligible.

Based on a drawdown response observed during the MEA pumping test at the most distant observation well locations, the 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, with a maximum drawdown of 23.40 feet observed in the test pumping well during the test. During the test (pumping and recovery periods), no discernable drawdown or recovery responses attributed to the test were observed in overlying Brue Formation observation wells, which supports the conclusion that adequate confinement exists between the overlying Brule Formation and the basal sandstone of the Chadron Formation. Detailed discussions of the MEA pumping test are provided in Section 2.7.2.2 and in **Appendix F**.

As discussed in Section 5.7 of this application, an extensive water sampling program will be conducted prior to, during, and following mining operations at the satellite facility to identify any potential impacts to water resources in the area.

The groundwater monitoring program is designed to establish baseline water quality prior to mining, detect excursions of lixiviant either horizontally or vertically outside of the production zone, and determine when the production zone aquifer has been adequately restored following mining. The program will include sampling of monitoring wells and private wells within and surrounding the license area to establish pre-mining baseline water quality. Water quality sampling will continue throughout the operational phase of mining for detection of excursions. Water quality sampling will also be conducted during restoration, including stabilization monitoring at the end of restoration activities, to determine when baseline or otherwise acceptable water quality has been achieved.

During operation, the primary purpose of the wellfield monitoring program will be to detect and correct conditions that could lead to an excursion of lixiviant or detect such an excursion, should one occur. The techniques employed to achieve this objective include monitoring of production and injection rates and volumes, wellhead pressure, water levels, and water quality.

Monitoring of production (extraction) and injection rates and volumes will enable an accurate assessment of water balance for the wellfield. A bleed system will be employed that will result in less leach solution being injected than the total volume of fluids (leach solution and native groundwater) being extracted. A bleed of 0.5 to 2.0 percent will be maintained during production. Maintenance of the bleed will cause an inflow of groundwater into the production area and prevent loss of leach solution.

Injection pressures are monitored in the wellhouse at the manifold with an audible and visible alarm monitored 24 hours per day, 7 days per week in the control room. The alarms are set at 90 to 95 psi to prevent pressure in excess of 100 psi at the wellhouse manifold, below the 125 psi integrity test pressure demonstrated in each injection well. Due to line losses, pressures at the wellheads remain below that which is monitored at wellhouse manifold.

Each new production well (extraction and injection) will be pressure-tested to confirm the integrity of the casing prior to being used for mining operations. Wells that fail pressure testing will be repaired or abandoned and replaced as necessary.

Water levels will be routinely measured in the production zone and overlying aquifer. Sudden changes in water levels within the production zone may indicate that the wellfield flow system is out of balance. Flow rates would be adjusted to correct this situation. Increases in water levels in the overlying aquifer may indicate fluid migration from the production zone. Adjustments to well flow rates or complete shutdown of individual wells may be required to correct this situation. Increases in water levels in the overlying aquifer may also indicate casing failure in a production, injection, or monitor well. Isolation and shutdown of individual wells can identify the well causing the water level increases.

To ensure the leach solutions are contained within the designated area of the aquifer being mined, the production zone and overlying aquifer monitor wells will be sampled once every 2 weeks as discussed in Section 5.7.

Cameco also conducted an analysis, presented in **Appendix AA-1**, of the potential hydrologic impacts to local irrigation wells resulting from a hypothetical shallow casing leak in the overlying aquifer (Aqui-Ver 2013a). After pumping well 732 continuously for 5 months at 800 gpm, at the end of the irrigation season approximately 0.1 to 0.7 feet of drawdown (low and high transmissivity, respectively) is predicted in the nearest shallow monitor wells (AOW-9/BOW-9).

The 30-year capture zone of well 732 was computed using reverse particle-tracking techniques. 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 should not impact irrigation well 732 at any time in the future given similar operating conditions. Given the location of other irrigation and domestic wells outside the license boundary, and the area and configuration of the worse-case capture zone for well 732, it is also reasonable to conclude there are no other private irrigation or domestic

wells outside the license boundary that could be impacted by a release of MEA regulated material to the shallow aquifer.

Cameco controls all existing private wells inside the license boundary. Cameco will prohibit the use of a private well by the lessor(s) once well field construction begins in that vicinity. For existing private wells inside the license boundary and near active wellfields, biweekly monitoring will be performed on all wells being actively used by Cameco (e.g. well 720 at the drillers pond). This will ensure that any impact of the private wells inside the license boundary on hypothetical shallow casing leaks will be quickly identified.

3.1.4 Assessment of Flooding and Erosion Potential

The potential for flooding or erosion that could impact the proposed *in-situ* Marsland mining processing facilities and mine units has been assessed through two separate studies. The complete report of the hydrologic and erosion study, including tables and figures, is provided in **Appendix K-1** (ARCADIS 2012). The complete report of the hydrologic and flood study, including tables and figures, is provided in **Appendix K-2** (ARCADIS 2013). The studies addressed guidance in NUREG-1569 for an NRC licensee to assess the potential effects of erosion or surface water flooding on a proposed uranium *in-situ* facility. The ultimate objective of the studies was to determine whether the potential for erosion or flooding may require special design features or mitigation measures to be implemented.

The studies focused on catchment and watershed delineation, hydrologic characteristics, determination of areas most prone to flooding and erosion due to rainfall runoff, and determination of flood flow characteristics. The analysis presented in **Appendix K-1** identifies proposed wells and facilities in areas of moderate to high risk of erosion that may require mitigation measures. The analysis presented in **Appendix K-2** provides estimates of storm-related discharge rates and velocities within the MEA. Seven primary tasks comprise the comprehensive hydrologic and erosion analysis:

- Data collection and analysis: rainfall, digital elevation data, soil and land use data
- Watershed delineation: dividing the project area basin into watersheds for detailed hydrologic analysis Hydrologic and erosion analysis: determining the flood routing characteristics of watersheds and generating the erosion risk map using hydrologic, land use, and soil data
- Erosion risk assessment: identifying MEA wells and other site facilities in locations of high erosion potential that may require erosion mitigation;
- Flood assessment: determining estimated storm-specific discharge rates within MEA watersheds
- Flood assessment: determining estimated storm-specific flood velocities within MEA watersheds.

3.1.4.1 Data Collection

Similar data collection processes were followed for the studies presented in **Appendix K-1** and **Appendix K-2**. The data necessary to complete the studies included digital terrain data or a digital

elevation model (DEM), existing floodplain maps, land use and land cover data (LULC), National Hydrography Dataset (USGS NHD) published stream network data, soil data, and rainfall data.

The terrain data were downloaded from the USGS National Elevation Dataset (NED) at a resolution of 30 m. DEM data were used throughout the model domain to describe watershed topography and streams within the hydrologic model. The project area is in the watershed HUC12 101500020607 (Belmont Cemetery-Niobrara River Basin).

Floodplain maps in the form of Federal Emergency Management Agency (FEMA) Digital Flood Insurance Rate Maps (DFIRM) were downloaded from the FEMA Map Service Center (FEMA 2011). Land use data for the study area were the National Land Cover Data (NLCD) 2006, which were downloaded from the USGS seamless online Data Warehouse.

Supplementary data used to prepare and recondition the DEM include the USGS National Hydrography Dataset (NHD) published stream network, NHD Flowline (Simley and Carswell 2009) and the NRCS published 12-digit hydrologic unit code (HUC12) watershed delineation (NRCS 2009).

Soil data were downloaded from the NRCS geospatial data gateway, Soil Survey Geographic Database (SSURGO; NRCS 2009). Regional soil characteristics, most importantly the infiltration rate, were represented by the Soil Conservation Service (SCS) Curve Number Method. Meteorological data, including precipitation, evaporation, and runoff values, were collected from the National Ocean and Atmospheric Administration (NOAA 2012), NWS, and NCDC.

3.1.4.2 Analysis Procedures

A detailed description of procedures used for watershed delineation and basin characteristics, hydrologic and soil erosion analysis, and modeling is presented in **Appendix K-1.** Procedures for analysis of flood characteristics are presented in **Appendix K-2.**

A GIS-based erosion model (Revised Universal Soil Loss Equation [RUSLE]) was used to investigate potential erosion in the project area. The model provides a fine spatial resolution of the model results. The RUSLE model is relatively simple and is one of the most practical methods to estimate soil erosion potential and the effects of different management practices. It was selected due to its wide acceptance, including for construction site management at the federal level in NPDES Phase II permitting (Wachal and Banks 2007, EPA 2000).

The RUSLE is the modified version of U.S. Department of Agriculture's Universal Soil Loss Equation (USLE), which has been used to measure soil loss from agriculture lands with relatively uniform slopes. The RUSLE modified certain factors in USLE to more accurately account for more complex terrain. The output of the RUSLE model is an annual rate of erosion and sedimentation in tons per acre per year, as opposed to erosion resulting from specific storm events. A detailed description of RUSLE is presented in **Appendix K-1.**

For the flood analysis, software developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center was used to delineate watershed boundaries and, approximate rainfall-runoff volumes. Detailed descriptions of models and modeling procedures used are presented in **Appendix K-2**. HEC-GeoRAS software was used to construct a hydraulic model to calculate flow

velocity through the study area. Peak runoff calculated from the HEC-GeoHMS modeling was applied as the peak flow in the HEC-GeoRAS modeling.

3.1.4.3 Erosion Risk Analysis

Mine units and other MEA facility locations were compared to the RUSLE map to evaluate erosion risk potential for each location. Proposed mine units, the satellite building, and the areas adjacent to the satellite building for potential placement of the access road and DDW were all evaluated. **Table 3.1-2** lists the risk of erosion for each mine unit. Maps displaying the average annual erosion potential as estimated by the RUSLE model in relation to the MUs and satellite facility locations are provided in **Appendix K-1**.

MU-A and MU-1 have low or very low erosion risk throughout the unit, while MU-C, MU-D, MU-E, and MU-F have very low erosion risk throughout the unit. MU-5 has multiple locations of moderate erosion risk. MU-2, MU-3, MU-4, and MU-B have locations of moderate and high erosion risk. Although MU-2, MU-3, MU-4, and MU-B have areas of high erosion risk, only 2 to 7 percent of the area within the units is at a moderate to high risk. Placement of well locations around areas of moderate and high potential erosion should be feasible in these units, particularly in MU-3, were only 2 percent of the land is at an increased risk of erosion. In comparison, 11 percent of MU-5 has a moderate risk of erosion. Though the overall risk of MU-5 is lower than in other units, it may be more difficult to place wells without additional mitigation measures due to the widespread risk of erosion in the unit.

If wells cannot be placed outside of areas within the wellfields deemed to have moderate to high risks, mitigation measures (e.g., berms) can be implemented to minimize the potential for flooding and erosion. The mitigation measures can be defined during final engineering and prior to any construction. Model results indicate that the risk of erosion is low or very low at the satellite facility, satellite facility access road, and DDW. Therefore, the probable need for erosion mitigation in this area is low.

As part of the concentrated flow analysis, drainage lines (i.e., channels, gulleys, or areas of concentrated flow) and DFIRM floodplain extents were compared to MU locations. Although drainage lines are the primary contributor to increased erosion risk as part of the RUSLE analysis, the model was unable to accurately define erosion rates in these areas of concentrated flow during flood events. Thus, published FEMA DFIRM 100-year floodplain extents were compared to MUs in the area. MU locations within the 100-year floodplain should be considered at risk to flooding, as well as erosion caused by flood events. Further analysis, mitigation measures, or modification of well locations should be considered for those wells near concentrated flow routes or in the 100-year floodplain during the final engineering phase and prior to well installation and construction activities.

Figures 22 through 27 of **Appendix K-1** display the drainage lines and floodplain extents relative to the MU and satellite facility locations. Drainage line 21 (NRCS HUC number 149152245) runs generally north-to-south and crosses mining units MU-2, MU-3, MU-4, and MU-5. Well locations in these mining units will be positioned outside of the floodplain or will include flood protection measures in the final engineering plans. Drainage line 24 (NRCS HUC number 149157281) crosses the proposed access road to the satellite facility. However, the proposed access road and satellite facility are not within the 100-year floodplain. The access road will be constructed with

consideration given to the location of the drainage and potential for concentrated runoff and erosion to occur. Drainage line 21 is predicted to accumulate notably more surface runoff than other drainages and therefore has a higher potential for flooding and erosion. Further analysis, mitigation measures, or modification of well locations will be considered for those wells near concentrated flow routes during the final engineering phase and prior to well installation and construction activities.

3.1.4.4 Flood Risk Analysis

The hydrologic and flood study presented in **Appendix K-2** divides the MEA into two study areas based on drainage characteristics: Hydrologic Project South and Hydrologic Project East. Hydrologic Project South contains the majority of sub-basins and drainages where project facilities and activities would occur (e.g., wellfields, satellite facility). Drainage lines 21 and 24, described above in Section 1.3.2.16, are both located within Hydrologic Project South. Peak discharge rates and flood velocities were calculated for storms with return intervals of 10, 25, 50, and 100 years and are provided in **Appendix K-2**. Model results for the 100-year storm event are described below.

Peak discharge rates for the main drainages where they exit the MEA license boundary are summarized in **Tables 3.1-3 and 3.1-4**. The peak discharge for Hydrologic Project South during a 100-year storm is estimated to be 1,455 (cfs, whereas the peak discharge for Hydrologic Project East during the same storm is estimated to be 2,659 cfs. These discharge values are almost double the rates expected for storms with a 10-year recurrence interval.

In order to determine the potential risk of project facilities and infrastructure due to flooding, the velocity of flood waters within MEA drainages during a 100-year storm were calculated using the HEC-RAS model. For the western tributary within Hydrologic Project South (drainage line 24 of **Appendix K-2**), the maximum flow velocity is estimated to be 5.8 ft/s. For the main stem drainage within Hydrologic Project South (drainage line 21 of **Appendix K-2**), the maximum flow velocity is estimated to be 6.3 ft/s upstream of the confluence with the western tributary and 6.5 ft/s downstream of the confluence. The maximum flow velocity for the main stem drainage within Hydrologic Project East is estimated to be 8.9 ft/s.

Although not within FEMA-designated flood zones, portions of the MEA may be subject to concentrated water flow during storm runoff and may also be at risk of damage. FEMA-designated flood zones supersede any estimated flood widths presented in **Appendix K-2**. For locations within or adjacent to the drainages assessed in this study, but beyond the FEMA flood zones, model results can be used as described below to estimate areas potentially affected under these circumstances, in addition to peak discharge rates and flood velocity. For example, the location where the access road to the proposed satellite facility crosses drainage line 24 (**Appendix K-2**) is outside of a FEMA-designated flood zone. However, model results indicate that runoff velocity within that drainage during a 100-year storm is estimated to be between 2.8 and 3.3 ft/s. Model results also indicate that the total width of flowing water at the access road crossing during a 100-year storm would be between approximately 140 and 220 feet.

3.1.4.5 Flood Risk Planning

CBR will use the results of the two hydrologic and erosion studies to support current and future planning and additional project design and layout. Once more detailed engineering commences, the results of these studies will be used to assess the potential for erosion and flooding that may require implementation of special design features or mitigation measures (e.g., berms around areas of MUs, strategically located drainage channels, culverts on roadways). Additional hydrologic and erosion analysis may be required during specific phases of site grading and engineering design to supplement the current studies. For example, specific phases requiring additional analysis may include the final design of MU (locations of buildings, wells, and piping), DDWs, or the satellite facility building and associated structures.

3.1.4.6 Surface Water Management and Erosion Control

In general, CBR will carry out tasks including the following in regard to surface water management and erosion control.

CBR will use ditches, diversions, culverts and other best management practices (BMPs) to control surface water flow within the license boundary.

An erosion and sediment control plan will be developed and implemented during construction, operation and reclamation activities in order to reduce soil losses within the license area and to protect surface and subsurface assets.

Using the results of erosion and flood analyses, CBR will construct facilities outside of these flood-prone boundaries in order to avoid potential impacts to facilities from flooding and potential impacts to major ephemeral drainages, and the Niobrara River in the event of any potential spills or leaks. When possible CBR will locate surface structures/wells outside of the 100-year flood zone boundaries. Any facilities that will have to be built within the 100-year flood zone boundaries will be protected from flood damage by the use of control measures such as diversion/collection ditches, channels, storm drains, slope drains, and/or berms.

Pipelines will be buried below the frost line, and pipeline valve stations will be located outside of the 100-year flood zone in order to avoid damage due to potential surface flooding.

Efforts will be made to avoid placement of production, injection and monitor wells in potential flood prone areas (using results of erosion and flood risk analyses), but if it is necessary to place such wells in these areas, surface water control measures (e.g., diversion or erosion control structures) will be used. Wellheads in these areas can be built so that the casing extends above grade and is mounted on a concrete pad. In addition, an above ground protective housing can be used to protect the well casing in the event of flooding. CBR currently uses an anchored metal or plastic protective housing (similar to a 55-gallon drum with the ends cut out), which affords protection in the event of flooding. As applicable, well heads will be sealed in order to withstand brief periods of submergence.

CBR will carry out all construction tasks in compliance with applicable NPDES stormwater general permit requirements.

Sections 4.2.1.14 and 7.2.6 describe mitigation measures used to protect surface water from potential spills and leaks. Section 7.2.5.3 describes mitigation measures used to protect groundwater from potential spills and leaks.

3.1.4.7 Erosion Control during Construction and Decommissioning

The events that carry the greatest potential for erosion and sedimentation will be the construction and decommissioning phases of the MEA project. Land management and farming techniques will be used by CBR in order to minimize the erosion of disturbed, reclaimed, and native areas. Mitigation measures are discussed in Section 7.2.2. CBR will typically prepare and seed ground areas that are disturbed as soon as possible in order to minimize the potential for erosion. As discussed above, erosion controls (runoff control diversion structures, storm drains, slope drains, channels, mulch, cover crops, rip-rap, sediment fences, and other controls) will be used in order to reduce overland flow velocity,, reduce runoff volume, and minimize the transport of sediment into drainages. Construction of the mine units will be sequenced so that only part of the site is affected at one time. This sequencing provides a timeline that coordinates the timing of land-disturbing activities and the installation of erosion and sediment control measures (EPA 2013). This will assist with the erosion and sediment control because it helps to ensure that management practices are installed where necessary and when appropriate (EPA 2013).

The need to control sediment will be most critical during wellfield construction and immediately after redistributing topsoil. Sediment control features that may be required include silt fences, sediment basins, sediment traps, vegetation buffers, and other features. CBR will use existing roads when possible and limit the various access road widths, which will minimize the surface disturbance to soil and vegetation. Traffic will be limited to established roadways to the extent possible.

Erosion and sediment controls will be developed prior to commencement of construction, at a time when site disturbance activities are clearly defined.

3.1.5 Process Description

Uranium solution mining is a process that takes place underground, or *in-situ*, by injecting lixiviant (leach) solutions into the ore body and then recovering these solutions when they are rich in uranium. The chemistry of solution mining involves an oxidation step to convert the uranium in the solid state to a form that is easily dissolved by the leach solution. H_2O_2 or gaseous O_2 is typically used as the oxidant because both revert to naturally occurring substances. Carbonate species are also added to the lixiviant solution in the injection stream to promote the dissolution of uranium as a uranyl carbonate complex.

The reactions representing these steps at a neutral or slightly alkaline pH are:

Oxidation: $UO_{2\,(solid)} + H_2O_{2\,(in\ solution)} \longrightarrow UO_{3\,(at\ solid\ surface)} + H_2O$

$UO_{2\,(solid)} + \frac{1}{2}\,O_{2\,(in\ solution)} \longrightarrow UO_{3\,(at\ solid\ surface)}$

Dissolution: $UO_3 + 2\,HCO_3^{-1} \longrightarrow UO_2(CO_3)_2^{-2} + H_2O$

$$UO_3 + CO_3^{-2} + 2HCO_3^{-1} \longrightarrow UO_2(CO_3)_3^{-4} + H_2O$$

The principal uranyl carbonate ions formed as shown above are uranyl dicarbonate, $UO_2(CO_3)_2^{-2}$, (UDC), and uranyl tricarbonate $UO_2(CO_3)_3^{-4}$ (UTC). The relative abundance of each is a function of pH and total carbonate strength.

Solutions resulting from the leaching of uranium underground will be recovered through the production wells and piped to the satellite facility for extraction. The uranium recovery process employs the following steps:

1. Loading of uranium complexes onto an IX resin
2. Reconstitution of the leach solution by addition of CO_2 and/or $NaHCO_3$ and an oxidizer
3. Elution of uranium complexes from the resin
4. Precipitation of uranium.

The first two steps will be performed at the satellite facility. Steps 3 and 4 will be performed at the CPF. The process flow sheet for the above steps is shown on **Figure 3.1-6**. The left side of this figure depicts the uranium extraction process that is completed at the satellite facility. The right side of the figure shows the uranium recovery steps that will be performed at the CPF. Once the IX resin at the satellite facility is loaded to capacity with uranium complexes, the resin will be transferred to the CPF for the completion of uranium recovery.

3.1.5.1 Uranium Extraction

The recovery of uranium from the leach solution in the satellite facility will take place in the IX columns. The uranium-bearing leach solution enters the pressurized downflow IX column and passes through the resin bed. The uranium complexes in solution are loaded onto the IX resin in the column. This loading process is represented by the following chemical reaction:

$$2\ R\ HCO_3 + UO_2(CO_3)_2^{-2} \longrightarrow R_2UO_2(CO_3)_2 + 2HCO_3^{-1}$$

$$2\ RCl + UO_2(CO_3)_2^{-2} \longrightarrow R_2UO_2(CO_3)_2 + 2Cl^{-}$$

$$R_2SO_4 + UO_2(CO_3)_2^{-2} \longrightarrow R_2UO_2(CO_3)_2 + SO_4^{-2}$$

As shown in the reaction, loading of the uranium complex results in simultaneous displacement of chloride, bicarbonate, or sulfate ions.

The now barren leach solution passes from the IX columns to be reinjected into the formation. The solution is refortified with sodium and carbonate chemicals, as required, and pumped to the wellfield for reinjection into the formation. The expected lixiviant concentration and composition are shown in **Table 3.1-5. Table 3.1-6** lists non-radiological and radiological parameters for the lixiviant injection streams at the current operations MU-3, MU-4, MU-5, and MU-6. These are based on one sample per MU for sampling on MU-3 (July 23, 1999), MU-4 (October 31, 2003), MU-5 (August 14, 2007), and MU-6 (October 27, 2010). These measurements are considered representative of the lixiviant injections streams at the current operations, and are expected to be similar at the MEA project.

3.1.5.2 Resin Transport and Elution

Once the majority of the IX sites on the resin in an IX column are filled with uranium, the column will be taken out of service. The resin loaded with uranium will be transferred to a tanker truck for transport to the CPF for elution and final processing. Once the resin has been stripped of the uranium by elution, it will be returned to the satellite facility for reuse in the IX circuit.

At the CPF, the loaded resin will be stripped of uranium by an elution process based on the following chemical reaction:

$$R_2UO_2(CO_3)_2 + 2Cl^- + CO_3^{-2} \longrightarrow 2\ RCl + UO_2(CO_3)_2^{-2}$$

After the uranium has been stripped, the resin is rinsed with a solution containing $NaHCO_3$. This rinse removes the high-chloride eluent physically entrained in the resin and partially converts the resin to bicarbonate form. In this way, chloride ion buildup in the leach solution can be controlled.

3.1.5.3 Precipitation

When a sufficient volume of pregnant eluent is held in storage, it is acidified to destroy the uranyl carbonate complex ion. The solution is agitated to assist in removal of the resulting CO_2. The decarbonization can be represented as follows:

$$UO_2(CO_3)_3^{-4} + 6H^+ \longrightarrow UO_2^{++} + 3\ CO_2 + 3H_2O$$

Sodium hydroxide (NaOH) is then added to raise the pH to a level conducive for precipitating pure crystals.

H_2O_2 is then added to the solution to precipitate the uranium according to the following reaction:

$$UO_2^{++} + H_2O_2 + 2H_2O \longrightarrow UO_4 \bullet 2H_2O + 2H^+$$

The precipitated uranyl peroxide slurry is pH adjusted, allowed to settle, and the clear solution decanted. The decant solution is recirculated back to the barren makeup tank, sent to fresh salt brine makeup, or sent to waste. The thickened uranyl peroxide is further dewatered and washed. The solids discharge is either sent to the vacuum dryer for drying before shipping or is sent to storage for shipment as slurry to a licensed recovery or converting facility.

The production aquifer at the MEA (the basal sandstone of the Chadron Formation) is the same formation currently mined at the nearby CBR property. The baseline water quality of the MEA is comparable to the water quality of the current mining operation at the CBR property. The baseline water quality at both sites exhibit elevated sodium concentrations compared to the overlying aquifers. A concern during ISR mining is that clays in the formation will interact with the lixiviant and cause a reduction in permeability.

As discussed in Section 2.6.1, The XRD clay analysis from the core taken at the MEA showed that the five predominant clays in the samples were kaolinite, chlorite, illite, mixed-layered illite/smectite, and montmorillonite. kaolinite, chlorite, and illite are less likely to be ion-exchanging clays. The smectite and montomorillonite clays known to have ion-exchanging properties have potassium and sodium signatures in the XRD analysis. The lack of a calcium or

magnesium signature in the clays explains why a relatively small amount of calcium is liberated during the mining process.

The operating history at CBR has shown that the formation clays in the basal sandstone of the Chadron Formation are minimally reactive to the proposed lixiviant. A significant increase in the sodium concentrations during the mining process does not lead to a large increase in calcium concentrations in the mining solution. Careful monitoring of the pH during the mining process minimizes the chances of scale restricting the permeability at the injection well screens.

3.1.6 Wellfield and Process Wastes

All well development water will be captured in water trucks specifically labeled and dedicated for such purpose, and equipped with signage indicating that these trucks may only discharge their contents for injection into the DDW. Alternatively, these fluids may be transported to the CPF evaporation ponds, but only if there are fluid separation equipment issues at the MEA satellite facility. The operation of the satellite facility will result in a production bleed stream that is continuously withdrawn from the recovered lixiviant stream at an expected rate of 0.5 to 2.0 percent of the total volume of recovered lixiviant. The production bleed stream is taken following the recovery of uranium by IX and has the same chemical characteristics as the lixiviant. The production bleed waste stream will be managed by using a DDW, which will be constructed and operational at the satellite facility prior to commencement of production.

The other source of wastewater resulting from uranium mining activities in the MEA is the eluent bleed stream at the CPF. This existing source of wastewater at the CPF is currently produced at a rate of approximately 5 to 10 gpm. It is likely that the eluent bleed stream will increase by a maximum of 10 percent due to processing of IX resin from the satellite facility. The eluent bleed waste stream will be managed in the CPF and disposed into the evaporation ponds or the DDW's at the current Crow Butte site.

All byproduct material produced as a result of the operation of the satellite facility will be disposed of at a licensed facility approved for disposal of 11e.(2) byproduct material, similar to provisions made for the byproduct material currently produced. All solid waste will be disposed of in an approved landfill in accordance with current practice. There will be no onsite disposal of these materials.

3.1.7 MEA Water Balance

From 2015 to 2020, the majority of the wastewater produced at the MEA satellite facility will be the production bleed. Starting in 2021, the wastewater flows will rise sharply as the bleed from the RO process must be addressed. Other liquid wastewater generated will consist of process liquids (e.g., affected well development water, laundry water and plant wash down water). These waste streams will account for an intermittent discharge with a maximum average of 1 to 2 gpm. The disposal water balance discussed below is of such a magnitude that these small quantities of wastewaters will be small enough to be easily managed in the proposed disposal system. The well development water will be collected using a dedicated vacuum truck and delivered to the well work-over fluid tank located in the satellite building (**Figure 5.7-2**). The other liquid wastes (i.e., laundry and plant wash water originating in restricted areas) described above will flow to plant sumps and

be transferred to a wastewater tank located within the satellite building. All of the above waste streams will be disposed of through the DDWs.

Liquid waste will be generated from process bleed and groundwater restoration water (approximately 96 percent), plant cleanup water (miscellaneous non-hazardous water; approximately 2 percent), and water originating from fresh water well(s) (approximately 2 percent). The detailed MEA water balance for production and restoration for the life of the project is shown in **Appendix T**. The project required disposal water balance is presented **Table 3.1-7** and depicted graphically in **Figure 3.1-7**. These water balances illustrate the anticipated water management and disposal capacity needed for production bleed and restoration activities. These schedules are based on installation of two wells prior to commencing operation, with the assumption that each well will have an injection capacity of approximately 45 gpm. The 45 gpm injection capacity assumption is based upon the Crow Butte well with lower flow. Both of the DDWs at the existing plant are drilled into the same formations proposed for the MEA.

Two DDWs will accommodate all wastewater generated from startup in 2015 through the end of 2020. In 2021, groundwater restoration will result in increased wastewater volumes, which will require additional disposal capacity. Considering the capacity of the two DDWs, the need to install additional deep disposal well(s) and/or new surge/evaporation ponds will be evaluated to supply long-term wastewater disposal. Additional deep disposal well(s) or surge/evaporation ponds will be installed to satisfy the wastewater capacity requirements. CBR has submitted an area permit application for multiple Class I nonhazardous waste injection wells at the MEA site. CBR will install the first DDW prior to the startup of mining operations.

Operating procedures at the MEA site that will minimize the amount of water requiring disposal via DDW include: designing wellfields to maximize the ability to continuously minimize the amount of production bleed through continuous and effective wellfield balancing; minimizing the consumptive use of process water by injecting all of the ISR fluids except for the small production and restoration bleed streams necessary to maintain an inward hydraulic gradient in each wellfield configuration; and if necessary, using two stages of RO to treat restoration fluids and reduce the total required wastewater disposal capacity.

As shown in **Appendix T**, only five mine units will be in production mode at any one given time. Total production flow over the life of the project will be variable, ranging from 1,100 to 5,400 gpm. The production bleed (1.2 percent) and the RO bleed, over the life of operations, will vary from approximately 13 to 65 gpm and 75 to 225 gpm, respectively. Permeate flows will vary from 500 to 750 gpm, with 750 gpm being the estimated average flow from 2022 to 2037. The amount of brine sent to DDW will range from approximately 150 to 225 gpm beginning in year 2021 and continuing until 2037.

Figure 3.1-8 depicts the water balance at MEA during the third quarter of 2024 when maximum production and restoration flows will occur (5,400 gpm and 1,550 gpm, respectively). As illustrated in **Figure 3.1-8**, up to an additional 241 gpm (65 gpm production bleed plus 225 gpm RO bleed) of disposal capacity is needed to accommodate groundwater restoration. DDWs are expected to provide all of the disposal capacity needed at each expansion area. As has been demonstrated at the CPF, DDW injection rates may vary from the assumed 45 gpm per well at the MEA site

Until the capacity of the first two DDWs is known, the exact needs for additional water disposal wells beyond 2020 are not understood. Additional disposal options required for use during production and restoration activities will be dependent on the volume of wastewater generated, the efficiency of production and restoration activities including the RO process, and the actual injection capacity of DDWs, e.g., surge/evaporation ponds and/or land application.

For the years 2015 through 2020, two DDWs will be used. Each DDW can act as a backup for the other if maintenance is required. At the same time, plant operations can be curtailed as needed to ensure that an inward hydraulic gradient is maintained. A third option would be trucking water to the CPF evaporation ponds.

In the event of an extended total facility shutdown (e.g., lengthy power failures), the ability to maintain hydraulic containment of the wellfields has been assessed. This analysis demonstrated that hydraulic containment of the ISR wellfields could be provided using one or two wells (powered by portable generator) located near the downgradient edge of the mine unit wellfield, operating at a total pumping rate of 30 gpm. Groundwater extracted from the ISR wellfields would be either disposed of in an onsite DDW equipped with a portable generator, or trucked to the main CPF facility for disposal in the evaporation ponds.

In order to evaluate the ability to maintain hydraulic containment during an extended total facility shutdown, the following basic analyses were performed (Aqui-Ver 2013b):

- The maximum velocity of groundwater under non-pumping conditions was calculated for the MEA ISR wellfields.
- A hypothetical pumping well was placed within an ISR wellfield, and the zone of hydraulic containment (capture zone) was computed using an analytical groundwater flow model and particle tracking techniques. The well location and pumping rate were adjusted until an optimal capture zone was achieved.

Groundwater Velocity of the Basal Sandstone of the Chadron Formation

Under non-pumping conditions (e.g. facility shut down, pre-development), the velocity of groundwater within the basal sandstone of the Chadron Formation (production aquifer) can be computed from Darcy's Law and a knowledge of aquifer properties and hydrologic data collected as part of the regional aquifer pumping test conducted at the MEA in May 2011 (Aqui-Ver 2011), as follows:

$V = KI/ne$

where V is the groundwater velocity, K is the hydraulic conductivity of the production aquifer, I is the baseline or pre-development hydraulic gradient, and ne is the aquifer effective porosity.

As a conservative measure, the maximum groundwater velocity was computed by using the maximum observed values for hydraulic conductivity (61.7 ft/day) and hydraulic gradient (0.00048) identified from baseline sampling and aquifer testing at the MEA. Using these aquifer properties and an estimated effective aquifer porosity of 0.2, the resulting maximum groundwater velocity of the production aquifer is approximately 0.15 ft/day (55 ft/year). It was concluded from this calculation that mining solutions from ISR operations would only migrate a very small distance over any reasonable period of time representing temporary facility shutdown.

ISR Wellfield Hydraulic Containment Analysis

Additional analyses were performed to demonstrate that hydraulic containment can be maintained in the event of an extended facility shut-down. Because groundwater velocity is a maximum of 0.15 ft/day, hydraulic containment would essentially be provided without active remediation unless monitor wells were already on excursion status. Therefore, for purposes of this analysis, we have assumed a worst-case scenario in which downgradient monitor wells are on excursion status when the facility experiences a hypothetical temporary shut-down.

To accomplish this task, an analytical groundwater flow model (ESI 1999) was used to simulate groundwater flow in the production aquifer at the MEA. Particle-tracking techniques were used to illustrate the zone of hydraulic containment (capture zone) produced by a hypothetical pumping well(s) placed within an ISR wellfield. MU-5 at the MEA was used for illustrative purposes in this analysis.

The monitor well ring is assumed to be located 300 feet from the edge of the ISR wellfield pattern area (production zone), identical to the design used at the main Crow Butte ISR facility. Input parameters for the groundwater flow model were assigned in order to produce a conservatively small capture zone and provide a margin of safety, as follows:

- Aquifer Transmissivity (T) - 2469 ft^2/day (maximum observed from aquifer pumping test) (Aqui-Ver 2011)
- Regional Hydraulic Gradient (I) – 0.00048 (maximum observed from baseline monitoring) (Aqui-Ver 2011)
- Effective Porosity – 0.2
- Pumping Rate – 30 gpm

The zone of hydraulic containment was computed using reverse particle-tracking techniques after 30-days of pumping (zone will expand over time). **Figure 3.1-9** illustrates the zone of hydraulic containment produced by a single well placed near the downgradient edge of the MU-5 wellfield. The zone of hydraulic containment includes the entire ISR wellfield plus an adequate buffer zone. Although an adequate zone of containment is provided using a single well operating with a sufficiently large pump at 30 gpm, a similar zone of containment can be provided using two wells operating at 15 gpm each (30 gpm total) located in the same general location and separated by approximately 300 feet (east-west) along the downgradient edge of the mine unit.

The 30 gpm pumping rate is conservatively estimated based on maximum values of aquifer transmissivity and hydraulic gradient observed at the site. Under more realistic conditions (e.g. using average values for aquifer properties), the pumping rate needed to maintain hydraulic containment is significantly lower (10 gpm).

These results are generally applicable to all MEA mine units. If multiple mine units are in operation at the time of the hypothetical shut-down, additional wells would be needed (e.g. one or two wells at a total rate of 30 gpm per mine unit) to maintain complete containment of multiple mine units.

Historically, power outages at the CPF site last less than 24 hours. The longest time without power at the CPF was approximately 40 hours due to a winter storm. Potential adverse impacts associated with power outages are not anticipated.

CBR will ensure that adequate DDW disposal capacity is available at each mine unit under normal operating conditions during production, production and restoration, and restoration phases described in this document. Such capacity demonstration will be phased, initially to address years 2015 through 2020 (with two DDWs), with additional demonstrations as needed in order to address future increases in production and restoration flows. Capacity demonstrations will be addressed in written procedures for NRC written verification prior to preoperational inspection (for years 2015 through 2020) and prior to construction of future mine unit expansions beginning in 2021.

Cumulative impacts associated with the potential impacts on groundwater due to the concurrent operations of the CPF, MEA, NTEA, and TCEA projects are discussed in Sections 7.2.5 and 7.2.5.2.

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3.2 Central Processing Facility, Satellite Facility, Wellfield, and Chemical Storage Facilities – Equipment Used and Material Processed

The uranium recovery process described in the preceding section will be accomplished in two steps. The uranium recovery from the leach solution by IX will be performed at the satellite facility. The subsequent processing of the loaded IX resin to remove the uranium (elution), the precipitation of uranium, and the dewatering and packaging of solid uranium (yellowcake) will be performed at the existing CPF. Depending upon the mining timelines for the existing CPF wellfields and the MEA, it is possible that the belt filter and dryer capacity at the CPF may need to be increased.

3.2.1 Marsland Satellite Facility Equipment

Only the equipment proposed for the satellite facility is described in this section. The equipment and processes in the CPF are covered under the existing NRC Source Materials License Number SUA-1534. A general arrangement of equipment for the satellite facility is shown on **Figure 5.7-2**. The satellite facility equipment will be housed in a building approximately 130 feet long by 100 feet wide. The satellite facility equipment includes the following systems:

- Ion exchange
- Filtration
- Resin transfer
- Chemical addition.

The satellite facility will be located within section 12, T29N, R51W. The DDW will be located nearby (**Figure 1.7-5**). **Figure 5.7-2** shows the plan view of the satellite facility.

The satellite facility will house the IX columns, water treatment equipment, resin transfer facilities, pumps for injection of lixiviant, wastewater tanks, and an employee lunch room/break area. Bulk soda ash, CO_2 and O_2 in compressed form, and/or H_2O_2 will be stored adjacent to the satellite facility or in the wellfield. $NaHCO_3$ and/or gaseous CO_2 are added to the lixiviant as the fluid leaves the satellite facility for the wellfield. Gaseous O_2 is added to the injection line for each injection well at the wellhouses.

The IX system consists of eight fixed-bed IX columns. The IX columns will be operated as three sets of two columns in series with two columns available for restoration. The IX system is designed to process recovered leach solution at a maximum rate of 6,000 gpm. Once a set of columns is loaded with uranium, the resin is transferred to a truck for transport to the CPF. The downflow columns are pressurized, sealed systems, so there is no overflow of water; O_2 stays in solution; and radon emissions are contained. Radon releases from the pressurized downflow columns occur only when the individual columns are disconnected from the circuit and opened to remove the resin for elution. One disadvantage of the downflow column is that there must be good pressure control. Exposure pathways associated with downflow columns to be used at MEA are discussed in Section 7.3.1.

After the IX process, the barren leach solution recovered from the wellfield is replenished with an oxidant and leaching chemicals (i.e., $NaHCO_3$ and/or CO_2). The injection filtration system consists

of optional backwashable filters, with an option of installing polishing filters downstream. The lixiviant injection pumps are centrifugal type.

The areas in the proposed satellite facility where fumes or gases could be generated are discussed in Section 7.3. The potential sources are minimal in the satellite facility because the mining solutions contained in the process equipment are maintained under a positive pressure. Building ventilation in the process equipment area will be accomplished by the use of an exhaust system that draws in fresh air and sweeps the satellite facility air to the atmosphere.

3.2.2 Chemical Storage Facilities

Chemical storage facilities at the satellite facility will include both hazardous and non-hazardous material storage areas. Bulk hazardous materials, which have the potential to impact radiological safety, will be stored outside and segregated from areas where licensed materials are processed and stored. Other non-hazardous bulk process chemicals (e.g., $NaCO_3$) that do not have the potential to impact radiological safety may be stored within the satellite facilities.

3.2.2.1 Process-Related Chemicals

Process-related chemicals stored in bulk at the satellite facility will include carbon dioxide (CO_2), oxygen (O_2), and hydrogen peroxide (H_2O_2). Sodium sulfide (Na_2S) may also be stored for use as a reductant during groundwater restoration.

CO_2

CO_2 is stored adjacent to the satellite facility, where it will be added to the lixiviant prior to leaving the satellite facility.

O_2

O_2 is also typically stored at the satellite facility, or within wellfield areas, where it is centrally located for addition to the injection stream in each wellhouse. Because O_2 readily supports combustion, fire and explosion are the principal hazards that must be controlled. The O_2 storage facility will be located a safe distance from the satellite facility and other chemical storage areas for isolation. The storage facility will be designed to meet industry standards in NFPA-50 (NFPA 1996).

O_2 service pipelines and components must be clean of oil and grease because gaseous O_2 will cause these substances to burn with explosive violence if ignited. All components intended for use with the O_2 distribution system will be properly cleaned using recommended methods in CGA G-4.1 (CGA 2000). The design and installation of O_2 distribution systems is based on CGA-4.4 (CGA 1993).

Na_2S

Hazardous materials typically used during groundwater restoration activities include the addition of a chemical reductant (i.e., Na_2S or hydrogen sulfide [H_2S] gas). To minimize potential impacts to radiological safety, these materials are stored outside of process areas. Na_2S is currently used as the chemical reductant during groundwater restoration at the current license area. The material consists of a dry flaked product and is typically purchased on pallets of 55-pound bags or super

sacks of 1,000 pounds. The bulk inventory is stored outside of process areas in a cool, dry, clean environment to prevent contact with any acid, oxidizer, or other material that may react with the product. H_2S gas has never been used at the CPF. In the event that CBR determines that use of H_2S as a chemical reductant is necessary, proper safety precautions will be taken to minimize potential impacts to radiological and chemical safety.

As part of the SHEQMS, a risk assessment was completed to identify potential hazards and risks associated with chemical storage facilities (and other processes) and to mitigate those risks to acceptable levels. The risk assessment process identified hydrochloric acid as the most hazardous chemical with the greatest potential for impacts to chemical and radiological safety. The hydrochloric acid storage and distribution system is located only at the CPF and will not be used at the satellite facility.

None of the hazardous chemicals used at the CPF are covered under the EPA Risk Management Program (RMP) regulations. The RMP regulations require certain actions by covered facilities to prevent accidental releases of hazardous chemicals and minimize potential impacts to the public and environment. These actions include measures such as accidental release modeling, documentation of safety information, hazard reviews, operating procedures, safety training, and emergency response preparedness.

3.2.2.2 Non-Process Related Chemicals

Non-process related chemicals that will be stored at the satellite facility include petroleum (gasoline, diesel) and propane. Due to the flammable and/or combustible properties of these materials, all bulk quantities will be stored outside of process areas at the satellite facility. All gasoline and diesel storage tanks are located above ground and within secondary containment structures to meet regulatory requirements

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3.3 Satellite Facility Instrumentation and Control

The instrumentation and controls at the MEA will be configured similar to those at the existing Crow Butte plant. Other than newer equipment, the interaction among the operators, computers, instrumentation, alarm systems, and process equipment will not change. The configuration employed at the existing Crow Butte plant has effectively minimized upsets and provides balanced operation.

The wellhouse will be located remotely from the satellite facility building. A distribution system will be used to control the flow to and from each well in the wellfield. Wellfield instrumentation will measure total production and injection flow and indicate the pressure being applied to the injection trunklines. A wellhouse will be equipped with wet alarms to monitor the presence of liquids in the wellhouse sumps. The system is monitored 24 hours per day, 7 days per week by control room operators. The operators rely on visual and audible alarms from a variety of systems to control mine operations. Power failures, pressure exceedances and flow disruption are some of the conditions for which alarm systems will be monitored.

Instrumentation will monitor the total flow into the satellite facility, the total injection flow leaving the facility, and the total waste flow leaving the facility. Instrumentation on the facility injection manifold will record an alarm in the event of any pressure loss that might indicate a leak or rupture in the injection system. The instruments used for flow measurement will include, but are not limited to, turbine meters, ultrasonic meters, variable area meters, electromagnetic flow meters, differential pressure meters, positive displacement meters, and piezoelectric and vortex flow meters.

The injection pumps are equipped with pressure reducing valves so that they are incapable of producing pressures high enough to exceed design pressure of the injection lines, the 125 psi integrity test, the maximum pressure demonstrated in each injection well, or the 100 psi maximum injection pressure measured at the wellhouse manifold. Pressure gauges, pressure shutdown switches, and pressure transducers will be used to monitor and control the trunkline pressures. During power failures, over-pressuring of wells is not possible, as all pump systems are shut down.

The basic control system at the satellite facility and associated wellfield will be built around a Sequential Control and Data Acquisition (SCDA) network. At the heart of this network is a series of programmable logic controllers. This system allows for extensive monitoring and control of all waste flows, wellfield flows, and facility recovery operations.

The SCDA system will be interconnected throughout the facility via a Local Area Network (LAN) to computer display screens. The software used to display facility processes and collect data incorporates a series of menus which allows the facility operators to monitor and control a variety of systems and parameters. Critical processes, pressures, and wellfield flows will have alarmed set-points that alert operators when any are out of tolerance. The injection manifold in each wellhouse is alarmed at 90 to 95 psi, to ensure that the pressure remains below the 100 psi maximum injection pressure measured at the wellhouse manifold. As noted in the application, due to line losses, the actual pressure at the wellhead is lower than the pressure monitored in the wellhouse manifold.

In addition, each wellhouse will contain its own processor, which will allow it to operate independent of the main computer. Pressure switches will be fitted to each injection manifold in the wellhouse to alert the facility and wellfield operators of increasing manifold pressures. All critical equipment will be equipped with uninterruptible 30-minute power supply systems in the event of a power failure.

Through this system, not only will the facility operators be able to monitor and control every aspect of the operation in real-time, but management will be able to review historical data to develop trend analysis for production operations. This will not only ensure an efficient operation, but will allow Crow Butte personnel to anticipate problem areas and to remain in compliance with appropriate regulatory requirements.

In the process areas, tank levels are measured in chemical storage tanks as well as process tanks.

Detailed information on the instrumentation and controls will be developed as part of the final design activities prior to construction. This information will be made available to the NRC for review prior to any construction activities. The final design, including installation and use of devices to monitor injection pressure, flow rate, and volume, must be submitted for approved by the NDEQ and written verification by the NRC.

Handheld radiation detection instruments and portable samplers will be used to monitor radiological conditions at the satellite facility. Specifications for this equipment are included in the SHEQMS Volume IV, Health Physics Manual, and are discussed in further detail in Section 5. The locations of monitoring points, monitoring procedures, and monitoring frequencies for in-plant radiation safety are also discussed in Section 5.

The types of health physics instrumentation that would be used at the proposed MEA include the following:

<u>Air Sampling Equipment</u>

- Eberline RAS-1 or Aircon 2 samplers (0-100 lpm) or equivalent

  Calibrated semiannually or after repair on site with a primary standard instrument or a properly calibrated secondary standard instrument
- BDX II or SKC lapel samplers (0-5 lpm) or equivalent

  Calibrated daily before each use on site with a primary standard instrument or a properly calibrated secondary standard instrument.

<u>External Radiation Equipment</u>

- Ludlum Model 19 Gamma Meter (μR/hr) or equivalent
- Ludlum Model 3 Beta/Gamma Meter with Ludlum Model 44-38 G-M detector (mR/hr) or equivalent
- Ludlum Model 2221 Ratemeter/Scaler with a Ludlum Model 44-10 NaI detector (CPM) or equivalent

  Calibrated annually or after repair by the manufacturer or qualified accredited vendor.

Surface Contamination Equipment

- Ludlum Model 2241 scaler or a Ludlum Model 2224-1 Ratemeter with a Model 43-93 probe or Ludlum Model 3030E with 43-93 probe or equivalent (Total Alpha)
- Ludlum Model 177 Ratemeter with a Ludlum Model 43-5 alpha scintillation probe or equivalent (Personnel Contamination)
- Ludlum Model 2000 Scaler or Model 2200 Scaler with an Eberline SAC-R5 or Ludlum Model 43-10 alpha scintillation sample counter or equivalent (Removable Alpha, Radon Daughters, Airborne Radioactivity)

Instruments will be calibrated annually or at a frequency recommended by the manufacturer, whichever is more frequent. Repairs will be by the manufacturer by or by a qualified accredited vendor, and the instrument will be calibrated following such repair. The calibration vendor shall provide the as-found calibration condition of each instrument. If more than 10 percent of the instruments are out of calibration when received by the calibration vendor, more frequent calibration will be considered.

New radiation survey instruments will be acquired for use at the MEA. The number of instruments purchased will be sufficient so that backup instruments are available in the event of failure of one, or if one instrument has been sent to the vendor for calibration or repair.

The manufacturer or a qualified accredited vendor shall calibrate portable survey instruments, counter/scalers, mass flow meters and/or dry cell calibrators, and calibration sources. Calibration will be performed as recommended in ANSI N323 and ANSI N323A. The ANSI standard requires that radiation detection instruments are performance tested annually to verify that they continue to meet operational and design requirements. Instruments must be tested for range, sensitivity, linearity, detection limit, and response to overload. The specific calibration requirements for various types of instruments are discussed in the SHEQMS Volume IV Health Physics Manual.

RG 8.30 specifies requirements for routine maintenance and calibration of radiological survey instruments. RG 8.30 references the standards contained in ANSI N323-1978, Radiation Protection Instrumentation Test and Calibration. ANSI is in the process of a major revision of this Standard that will result in three separate Standards applicable to radiological instrumentation. The first revision, ANSI-N323A-1997, Radiation Protection Instrumentation Test and Calibration, Portable Survey Instruments, was incorporated in this Chapter. When conflicts arise between NRC RG 8.30 and the ANSI Standard, the RG recommendations will be followed.

Calibration vendors will provide a certificate of calibration for all instruments. These calibration certificates will be maintained by the Radiation Safety Officer (RSO) on file for that instrument. Records of repair completed by the calibration vendor will also be maintained in the instrument file.

Documentation of calibration of air samplers performed on site will be maintained by the RSO in the sampler file.

Records of instrument checks, including the daily checks and initial checks, will be maintained in a format determined by the RSO. These records will be readily available and in a format that will allow the RSO to review the records for potential problems (e.g., background drift in a continuous

direction, battery check that does not respond, ratemeter that does not zero and alpha background rates greater than 0.5 CPM).

All records of instrument calibration and checks will be retained until NRC License termination. The RSO will be responsible for record retention.

Details about calibration, functional tests, procedures, and recordkeeping/retention are discussed in the SHEQMS Volume IV Health Physics Manual.

4 EFFLUENT CONTROL SYSTEMS

The proposed MEA will generate both radioactive and non-radioactive airborne effluents during construction and/or operations. The primary effluents of concern at the proposed MEA are the release of radon gas (radon-222) and the potential for accumulation of radon progeny. As with the existing CPF, effective ventilation will be the primary effluent control at the MEA.

Yellowcake will be processed and dried nearby at the CPF and not at the MEA. Loaded IX resin from the satellite facility will be transported to the CPF for elution, precipitation, drying, and packaging. As such, emissions from these sources will not occur at the MEA.

4.1 Gaseous and Airborne Particulates

4.1.1 Non-radioactive Airborne Emissions

The operation of internal combustion engines will be the primary source of non-radioactive gaseous airborne emissions. The majority of the combustion emissions are expected to be diesel emissions, which will be limited. Other minor releases may include: drilling rigs and support equipment (e.g., pipe trucks, water trucks, cement units, haul trucks, and pipe and other well completion equipment); maintenance vehicles; wellfield utility vehicles (e.g., work-over units, mechanical integrity testing units, and swabbing units); and light vehicles used during operations, construction, and travel to and from the site. Non-radioactive emissions that can be expected from such activities include CO_2, carbon monoxide, nitrogen dioxide, sulfur dioxide, PM_{10}, and total hydrocarbon (THC).

One of the primary non-radioactive emissions will be fugitive dust generated during all project phases (construction, operation, and decommissioning). Minor non-radioactive airborne effluents may include: dust from small releases of particulates during delivery and unloading of dry bicarbonate powder to a storage silo; CO_2, O_2, and water vapor vented from process operations; and dust generated during cementing operations, building construction activities (e.g., welding fumes and grinding), and various maintenance activities.

There are no significant combustion-related emissions from the process facility, as commercial electrical power is available at the site. The primary types of non-radiological pollutants that could occur during operations at the MEA site are discussed in Section 7.2. The satellite facility operational building would not house combustion devices, except for the propane heaters.

Mitigation measures to address airborne emissions are discussed in Sections 7.1, 7.2 and 7.4.

4.1.2 Radioactive Airborne Emissions

The principal radioactive airborne gaseous radiological effluent at the MEA will be radon-222 gas. Processing at the satellite facility will produce water-based solutions and loaded resins (no yellowcake processing or drying); therefore, airborne uranium concentrations are expected to be at or near background levels.

4.1.2.1 Airborne Uranium Emissions

One process area at the proposed MEA where small quantities of airborne uranium particulates have the potential for occurring is the resin transfer station, where minor spills may occur. The loaded IX resin is transferred to a truck for transport to the CPF for completion of uranium recovery. Spills can occur during resin transfer, and this is where exposure to uranium particulates is possible. All spills will be cleaned up as soon as possible to prevent the wet materials from drying and creating the potential for airborne particulates. Spills associated with resin transfer would involve the impregnated resin itself. The uranium is still bound to the resin at this stage, reducing the potential of employee exposure.

Maintenance activities on piping containing pregnant lixiviant could also result in the release of radon and uranium. Any spills or releases during maintenance of these potential sources would be cleaned up promptly to prevent drying of the material and creation of particulates subject to dispersion. All non-routine operations or maintenance activities where the potential exists for significant exposure to radioactive materials, and for which there is no SOP, require a Radiation Work Permit (RWP). The RWP ensures that the applicable radiological safety measures are used by the workers, and identifies the type of personnel monitoring that would be required for determining radiation exposure (i.e., internal and external radiation).

One stationary sample point would be established near the resin transfer station and sampled monthly for potential airborne uranium particulates. Monitoring activities for routine operations, maintenance activities, and spill cleanups are discussed in Section 5.7.

4.1.2.2 Wellfield Radon Emissions

Injection wells are generally closed and pressurized, but are periodically vented, releasing radon to the atmosphere. Production wells will be continually vented to the surface, but water levels will typically be low and radon venting will be minimal. All of the well releases will be outside of buildings and directly vented to the atmosphere.

Wellhouses are vented, with exhaust fans located in the wall directly opposite the entryway. This allows personnel to immediately verify that the vent is operational. In addition, all wellhouse vents are inspected daily. Direct release to the atmosphere from the wellhouses results in rapid dispersion of the radon emissions. For the majority of the year (except during extreme cold weather), the doors will remain opened when the buildings are accessed, allowing for additional ventilation of the building during entry by personnel.

Wellfield and wellhouse offgassing is not considered a significant source of radon or a safety issue. This statement is supported by monitoring at the current CPF. Radon individual exposure levels from 1994 through 2006 for Crow Butte employees ranged from 5 to 16 percent of the occupational exposure limit of 4 working level months. Exposure to radon is reported as working level months, a unit commonly used in occupational environments and refers to exposure to a set concentration of radon and its associated progeny. Radiological exposure pathways are discussed in Section 7.3.

4.1.2.3 Satellite Plant Radon Emissions

At the CPF, a combination of passive and active ventilation systems keeps radon and radon progeny levels ALARA. An evaluation of these systems is presented in **Appendix Y**. The evaluation noted that the large overhead doors may be open or closed at any time in the course of a day. Most important, even when all the overhead doors are closed, there is sufficient air intake capacity to maintain the desired negative pressure.

As at the CPF, in addition to exhaust fans installed in the walls, hard-piped ventilation systems will be installed for all indoor non-sealed process tanks and vessels where radon-222 or process fumes would be expected. The system consisting of air ducts or piping system connected to the top of each of the process tanks that could produce radon will include:

- IX tanks
- resin transfer tanks
- bicarbonate mix tanks

Separate hard-piped ventilation systems will be installed for areas known to emanate especially large amounts radon, such as the bicarbonate mix tanks, to ensure that exposures are maintained ALARA.

Exhaust fans will direct collected gases to discharge piping that will exhaust fumes to the outside atmosphere. The fans will be designed such that the system will be capable of limiting employee exposures with the failure of any single fan. Discharge stacks will be located away from building ventilation intakes to prevent introducing exhausted radon into the facility as recommended in RG 8.31 (NRC 2002a). Airflow through any openings in the vessels will be from the process area into the vessel and into the ventilation system, controlling any releases that occur inside the vessel. These exhaust fans would be located at different levels to ensure sufficient ventilation of areas where radon could accumulate. The exhaust fans will create negative pressure, ensuring that air will not enter the process areas from vessels and systems within the satellite building. Separate ventilation systems may be used as needed for the functional areas within the satellite facility.

A tank ventilation system of this type is used in the existing CPF. An evaluation of that system is provided in **Appendix Y**. Operational radiological in-plant monitoring for radon concentrations and recent upgrades have demonstrated this system to be an effective method for minimizing employee exposure. The ventilation system at the proposed Marsland facilities would be similar to that used at the CPF. Separate and independent local ventilation systems may be used temporarily as needed for non-routine activities such as maintenance. Similar to the CPF, the Marsland Satellite Plant will be designed to achieve 4 to 5 air exchanges per hour. A preoperational test will be conducted to verify the air exchange rate.

As discussed above for the CPF, radon daughter monitoring at the proposed satellite facility would be used to verify that radon daughters are maintained below the 25 percent Derived Air Concentration (DAC) action level. Ongoing operations would ensure that the ventilation system operates satisfactorily and as designed through the use of SOPs.

4.1.3 Response to Emergency Events Associated with Effluent Control Systems

Elevated radon levels are the primary health and safety impact of ventilation system failure. Through the utilization of portable temporary ventilation, additional PPE and engineering controls the dose impacts from ventilation system failures will be maintained ALARA. Currently Crow Butte adheres to requirements in the SHEQMS Emergency Manual, Volume VIII and SHEQMS Operating Manual, Volume III, SOP P.16, Plant Ventilation System Operation, when responding to ventilation system failures. The Marsland project will follow the same requirements.

SHEQMS Operating Manual, Volume III, SOP P.16, Plant Ventilation System Operation, for the CPF addresses; repair, maintenance and inspection of the ventilation system as summarized below:

- Restart after power bump or power outage
- Alarm response
- Evacuation requirements
- RSO notification
- Use of Prism radon progeny monitors
- System Maintenance/Inspections
  - Daily Walk-through Inspection
  - Daily Manometer Readings
  - Weekly RSO Walk-through
  - Annual Roof Vent Inspections
  - Filter Maintenance/Replacement

Health and safety impact resulting from ventilation system failures are deemed to be minimal, as the engineered and process controls will be similar to those in place at the CPF. Ventilation fans will run continuously and will be inspected daily to minimize unplanned shut downs. In addition, a respiratory protection program will be implemented as regulated by the NRC's Regulatory Guide 8.15, Acceptable Programs for Respiratory Protection.

In response to the shutdown of either an individual fan or a ventilation system failure, CBR will immediately begin the process of restoring appropriate ventilation. This will be accomplished either through the repair of existing ventilation or through the utilization of portable temporary ventilation. Radon progeny monitoring will be initiated and respiratory protection will be utilized as deemed appropriate by the RSO per 10 CFR §20.1702(a)(3) until the system ventilation has been restored.

If an emergency situation, such as an extended power failure, where exposure levels are considered unacceptable, the facility will be evacuated in accordance with SHEQMS Emergency Manual, Volume VIII. The individuals responsible for responding and managing emergencies must use their best judgment when making decisions related to the emergency. In the event of a failure of an effluent control device or other mishap that could result in exposure of an individual to elevated quantities of radiation present in gases, liquids, or solids, emergency procedures outlined in the emergency manual and other applicable procedural manuals will be implemented. Guidelines, on which employees receive training, will be implemented to minimize individual exposures. The Emergency Manual addresses emergency situations such as medical emergencies, fires, explosions, radiological emergencies, chemical emergencies, transportation emergencies, natural disasters, and security threats. The Crow Butte Chemical Emergency Response Guide, Chapter 11, of the

SHEQMS Emergency Manual, provides detailed instructions for responding to emergencies involving bulk, petrochemical, and compressed gases used at the site. If needed, CBR maintains emergency evacuation procedures that all employees, contractors, and visitors are trained to follow.

4.1.4 ALARA Evaluations of Effluent Control Systems

As with the CPF, CBR will operate the effluent controls so that all airborne effluent releases are maintained ALARA. The recent addition of a hard-piped ventilation system dedicated to the bicarbonate mix tank at the CPF will also be incorporated into the Marsland design to ensure that employee exposures remain ALARA.

CBR maintains a strict ALARA policy to keep exposures to all radioactive material and other hazardous material as low as possible and to as few personnel as possible, as defined in the SHEQMS Volume IV, Health and Physics Manual (CBR 2010c). The project radiation control program and ALARA program are comprehensively reviewed annually. Such a review would include exposures associated with the effluent control systems.

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4.2 Liquids and Solids

4.2.1 Liquid Waste

ISR mining will produce several sources of liquid waste. The potential wastewater sources that exist at the satellite facility include the following:

4.2.1.1 Water and Drill Cuttings Generated during Well Drilling and Development

Well drilling and development will generate the following wastewaters:

- "well drilling fluids" (fluids used while drilling in order to lubricate and cool the drill bit, remove drill cuttings from the borehole, and to seal the borehole walls to minimize fluid loss into the surrounding formation)
- "well development water" (generated during the under-reaming, air-lifting, and well rehabilitation phases of well installation)

Well Drilling Fluid

Well drilling fluid is drilling fluid and recovered groundwater that has not been exposed to any mining process or chemicals. However, the fluid may contain elevated concentrations of naturally occurring radioactive material from the mineralized zone. Well drilling fluid is discharged to the drilling pit where it is allowed to evaporate.

Drill cuttings will be captured within earthen drill pits during drilling. Upon completion of the hole, and the drilling fluid has evaporated, the pits will be filled in and the dirt mounded to allow for subsidence. Later, topsoil will be applied, and the site and any surface disturbance will be leveled to conform with the surrounding area. Disposal of drilling cuttings in an approved disposal pit is allowed by Nebraska Administrative Code (NAC) Title 135, Chapter 5, paragraph 002.02E.

Well Development Water

Once a well has been cased, any water generated during under-reaming, air-lifting, or other subsequent rig work that results in removing water from the cased well will be captured in water trucks specifically labeled for such purpose and equipped with signage indicating that these trucks may only discharge their contents to the MEA wastewater disposal system. The development waters collected in water trucks will be discharged into a cone bottom tank (well work-over fluid tank) at the satellite plant. That tank will feed a belt filter or other separation equipment to separate solids from water. Filtered water will be discharged to the DDW water supply tank for disposal in the onsite DDWs. Solids will be bagged for 11e.(2) disposal. This will allow treatment and disposal of the fluids without the accumulation of waste solids.

As a backup to this system, the well fluids would be transported to the existing evaporation ponds at the CPF. This option would only be used if there were equipment issues with the separation system.

4.2.1.2 Liquid Process Waste

The operation of the satellite facility results in one primary source of liquid waste, a production bleed, as previously discussed in Section 3. This bleed will be routed to wastewater tanks housed in the satellite building and then pumped from the tanks to the DDW.

4.2.1.3 Waste Petroleum Products and Chemicals

Small quantities of waste petroleum products and chemicals typical of ISR facilities will be generated and will include items such as waste oil and out-of-date or partially used reagents/chemicals. All such wastes that are non-hazardous will be temporarily stored in appropriate sealed containers above ground prior to disposal by a contracted waste disposal entity at an approved waste disposal or recycling facility. Such wastes are not considered to be affiliated with the processing or generation of 11e.(2) byproduct material and will not be classified as Atomic Energy Act-regulated waste. It is estimated that less than 50 gallons of waste petroleum products and chemicals will be disposed of annually. Any used oil that may be generated will be recycled by employing an approved commercial recycler, and such materials are not classified as a hazardous waste. Hazardous waste generation is discussed in Section 4.2.2.4.

4.2.1.4 Aquifer Restoration Waste

Following mining operations, restoration of the affected aquifer results in the production of wastewater. The current groundwater restoration plan consists of four activities:

1. Groundwater transfer
2. Groundwater sweep
3. Groundwater treatment
4. Wellfield circulation

Only the groundwater sweep and groundwater treatment activities will generate wastewater. Based on historical restoration activities at the current Crow Butte operation, it is unlikely that groundwater transfer and/or groundwater sweep will be used. Therefore these activities were not reflected in the restoration schedule **(Figure 1.7-4 and Appendix T)**.

During groundwater sweep, water would be extracted from the mining zone without injection, causing an influx of baseline quality water to sweep the affected mining area. The extracted water must be sent to the wastewater disposal system during this activity. As has been the case with past operations at Crow Butte, it is anticipated that, during restoration, groundwater at the MEA will be treated using IX and RO. Using this method, there would be no water consumption, and only the bleed has to be disposed, with the rest of the treated water being reinjected.

Groundwater treatment activities involve the use of process equipment to lower the ion concentration of the groundwater in the affected mining area. An RO unit will be used to reduce the TDS in the groundwater. The RO unit produces clean water (permeate) and brine. The

permeate is either injected into the formation or disposed of in the wastewater disposal system. The brine is sent to the wastewater disposal system.

4.2.1.5 Stormwater Runoff

Stormwater may be contaminated by contact with industrial materials. Stormwater management is controlled under permits issued by the NDEQ. CBR is subject to stormwater NPDES permitting requirements for industrial facilities and construction activities. The NDEQ NPDES regulatory program contained in Title 119 (NDEQ 2010a) requires that procedural and engineering controls be implemented so that runoff will not pose a potential source of pollution. The design and engineering controls for the proposed MEA facilities will be such that any potentially contaminated stormwater runoff or snowmelt (e.g., any tankage diking or curbing outside of the satellite building) will be collected and disposed of in the DDW. Engineering and procedural controls contained in a Stormwater Pollution Prevention Plan (SWPPP), in combination with the design of the project facilities, will ensure that stormwater runoff is not a potential source of pollution.

4.2.1.6 Domestic Liquid Waste

Domestic liquid wastes from the restroom, toilets and lavatories and the sink in the lunchroom/break area will be disposed of in an approved septic system that meets the requirements of the State of Nebraska. The septic system will be designed with a capacity sufficient to handle the projected number of employees, contractors, and visitors. CBR currently maintains a Class V UIC Permit issued by the NDEQ for operation of the septic system at the current license area. A similar permit will be required for the satellite facility.

CBR will employ an estimated 10 to 12 employees at the proposed MEA satellite facility. Assuming 13 gallons per day (gpd) for each employee (based on estimate for industrial employees by EPA), a total of approximately 130 to 160 gpd of sanitary waste would be generated (EPA 2002). An assumed additional 50 gpd of miscellaneous sanitary wastewater (e.g., lavatories and sink in lunchroom/break area) would result in approximately 180 to 210 gpd of sanitary wastewater being discharged to the septic system.

The number of temporary construction employees for the proposed satellite facility is estimated at 10 to 15 personnel. An assumed an average of five to 10 full-time employees during construction would result in a total of 15 to 25 employees on site for some periods. This would result in approximately 200 to 325 gpd of sanitary waste generation. During initial construction, portable sanitary units will be used, which will be provided and serviced by a third-party contractor. The septic system will be designed, constructed, operated, and permitted as per applicable NDEQ Title 124 regulations.

4.2.1.7 Liquid Waste Disposal

As discussed in Section 3.1.7, from 2015 through 2021, the majority of the wastewater produced at the MEA satellite facility requiring disposal will be the production bleed (25 to 65 gpm over the life of project). Starting in 2022, the wastewater flows will rise sharply as the bleed from the RO process used during restoration must be addressed.

Other liquid production wastewater will consist of process liquids (e.g., affected well development water, laundry water, and plant wash down water). These waste streams will account for an intermittent discharge with a maximum average of 1 to 2 gpm. The disposal water balance discussed below is of such a magnitude that these small quantities of wastewaters will be easily managed in the proposed disposal system. The well development water will be collected using a dedicated vacuum truck and delivered to the well work-over fluid tank located in the satellite building (**Figure 5.7-2**). The other liquid wastes (i.e., laundry and plant wash water originated in restricted areas) will flow to plant sumps and be transferred to a wastewater tank located within the satellite building. All of the above waste streams and tankage will be disposed of through the DDWs. The satellite building will not have a laboratory and a septic system will be used for discharges from toilets, lavatories and a sink in the lunchroom/break area. The MEA water balance is discussed in Section 3.1.7, with discussions on the management of the production and restoration waste streams.

Upon well completion, all water generated during baseline or operational monitoring, is discharged to the surface with the exception of well rehabilitation work and excursions. When a monitor well is on excursion, the purge water is collected and disposed in the wastewater disposal system or taken to the evaporation ponds at the CPF. All water and solids resulting from well rehabilitation will be captured in water trucks and discharged into the wastewater disposal system or taken to the evaporation ponds at the CPF.

Restoration for MU-1will begin approximately in the sixth year of operation. Two major waste streams generated during restoration that will require disposal will be RO bleed and brine. The RO bleed will be disposed of over the life of the project (2021 through 2037) at an average rate of 80 to 250 gpm. The amount of brine to be disposed of will range from 167 to 250 gpm beginning in the year 2022 and continuing until 2037.

4.2.1.8 Deep Disposal Well

Like the CPF, CBR will initially use two DDWs as the primary liquid waste disposal system at the MEA site. The basic components of the system include:

- Alarmed and ventilated equalization/storage tanks in the satellite plant
- Underground piping to the deep disposal well
- A deep disposal wellhouse containing a set of filters, flowmeters, check valve, and annulus fluid tank

The DDWs will be operated without the need for surge tanks or surge/evaporation ponds.

CBR currently operates two non-hazardous Class I injection wells in the CPF license area for disposal of wastewater (DDW-1 and DDW-2). The wells are permitted under NDEQ regulations in Title 122 (NDEQ 2010b) and operated under a Class I UIC Permit. CBR has operated the initial DDW-1 at the current license area for more than 10 years with excellent results and no serious compliance issues. The second disposal well (DDW-2) started up on November 30, 2011. CBR expects that the liquid waste stream at the satellite facility will be chemically and radiologically similar to the waste disposed of in the current DDWs. Radiological data for the years 2008 and 2012 for DDW-1 injection stream are shown in **Table 4.2-1,** and radiological data for DDW-2 for

the year 2012 in **Table 4.2-2.** The non-radiological data for DDW-1 and DDW-2 injection stream for 2012 are presented in **Table 4.2-3.**

The DDW at Marsland will be designed, constructed and operated like those at the CPF. The primary potential environmental impacts are surface spills from pipe failure and casing failures that release injection fluid into drinking water aquifers or the mining zone. To minimize these potential impacts the DDWs are:

- Monitored and alarmed 24-hours per day, 365 days per year to quickly detect and respond to above ground pipeline failures
- Double cased into the Pierre Shale formation with continuous flow and pressure monitoring of the injection fluid and pressure monitoring in the casing annulus
- Located inside the monitor well rings in the overlying aquifers and the mining zone
- Subject to Mechanical Integrity Testing every 2 years.

This combination of controls has and will effectively control the potential impacts to the environment.

CBR has submitted an application to the NDEQ for an Area Permit to install and operate Class I Nonhazardous Waste Injection Wells on private lands within the MEA license boundary. When approved, the Class I area permit:

- Allows initial construction and operation of two deep disposal wells
- Provides requirements for construction, monitoring, reporting, operation, abandonment, and aquifer restoration
- Allows Cameco to construct and operate additional, similarly constructed injection wells in the same injection zone, provided:
    - The NDEQ is notified of Cameco's intent to construct additional well as specified in the area permit
    - Plans and specifications for the additional wells accompany the NDEQ notification to the NDEQ
    - The additional proposed well(s) meet the requirements specified in the area permit and are approved by the NDEQ

The purpose of establishing an Area Permit is to allow for multiple injection wells to be installed at the MEA site over the expected multi-year life of the project. This permit application is for the initial two Class I Nonhazardous Waste Injection Wells to be installed under the Area Permit. Cameco is aware that a permit modification would be required for any wells added to the Area Permit at a later date. The permit application was prepared in accordance with regulatory requirements presented in the NDEQ Assessment Section, Title 122 Rules and Regulations for Underground Injection and Mineral Production Wells (Effective April 02, 2002). The formation receiving the injected waste fluids (Injection Zone) shall be restricted to the Lower Dakota, Morrison, and Sundance Formations, which have been demonstrated to be located below the lowermost underground source of drinking water. In addition, the Lower Dakota, Morrison, and Sundance Formations exhibit water quality that is not considered under state and federal regulations to be underground sources of drinking water due to measured concentrations of their total dissolved solids.

CBR plans to install the DDWs at the satellite facility as the primary liquid waste disposal method. CBR has found that permanent deep disposal is preferable to evaporation in ponds. The basic reasons for this position are as follows:

- The potential for human contact while using a DDW is lower because the waste is handled in enclosed systems.
- The potential for emissions from the pond surface is higher than the enclosed DDW system.
- Evaporation ponds carry the potential for leaks and impacts to the environment.
- Use of evaporation ponds creates a larger amount of 11e.(2) byproduct waste.

Similar to the CPF, two DDWs at Marsland will be located in the vicinity of the satellite building (**Figure 1.7-5**). All tankage, filtration, and process equipment will be located in the satellite facility. Wastewater feed from the satellite facility will pass through a set of bag filters and will be pumped via a PVC/HDPE pipeline to the wellhouse. At the DDW wellhouse, there will be a set of filters, flowmeters, check valves, and an annulus fluid tank. In accordance with NDEQ permitting requirements, CBR will use a computer-based system to continually monitor and record the wellhead injection pressure, injection flowrate, and annulus pressure. Wellhead injection pressure and annulus pressure have audible alarms.

Two dedicated storage tanks located in the satellite building will supply feed to the DDWs. One tank will serve as the primary DDW supply tank, with all makeup water to the DDW flowing to this tank (e.g., RO brine, wellfield bleed, plant sump, and filtered well work-over fluid). At the CPF, a similar DDW water supply tank is operated at a 66 percent level and the primary DDW supply tank at the MEA site is expected to be operated in a similar fashion. All flow to the DDWs will pass through a set of bag filters at the satellite building and the DDW wellhouse. Current plans are to use the second tank for managing special wastewaters that are periodically generated, such as collecting filtered water from the well work-over fluid tank, which is then sent to the primary DDW tank for disposal. This second tank would also be used for surge capacity for the DDW well system when needed. Based upon existing operations, this occurs very infrequently.

The surge capacity will be designed to only handle short-term flows and not for long-term periods when additional capacity is needed and/or the DDWs may not be available. It is important to note that the "surge" does not happen quickly, and the flow balance is rarely disrupted. In addition, the DDW tanks are continuously monitored, and a two-level alarm system is used. Like the CPF, the discharge pump from the DDW tank will be computer-controlled. The pump speeds up and slows down automatically to maintain a 66 percent level. At all times, tank levels can be visually assessed on a computer display with graphical readout. When and if the levels become high enough, the lower level and then the higher level audible alarms will sound. If further adjustments do not extinguish the lower and/or higher level alarms, the operators can curtail flows until the upset is resolved. Section 3.1.7 (MEA water balance) discusses actions that will be taken to address longer-term shutdown of the DDWs.

As noted above, the MEA DDW system will be designed and operated similar to that currently used at the CPF. Radiation exposures associated with the tanks in the MEA satellite plant will remain ALARA, as the ventilation system will be designed to incorporate the recent CPF ventilation upgrades described in Section 4.1.2.3. Radiation exposures associated with access to the DDW wellhouses are maintained at ALARA levels, as described in Section 4.1.2.2.

4.2.1.9 Disposal of Other Radioactive Liquids as per NRC License SUA-1534

In addition to the use of DDWs as a disposal method, the NDEQ has issued CBR an NPDES permit for the CPF license area that allows land application of treated wastewater. CBR has not used this waste disposal method at the current operation. At this time, CBR does not intend to apply for an NPDES permit to allow land application at the satellite facility. It is expected that liquid waste generated in the MEA can be satisfactorily managed with deep disposal. If needed in an emergency situation, contaminated wastewater can be collected and trucked to an approved commercial disposal facility for disposal.

4.2.1.10 Potential Pollution Events Involving Liquid Waste

Although there are a number of potential sources of pollution present at the CPF, existing regulatory requirements from the NRC and NDEQ and provisions of the SHEQMS have established a framework that significantly reduces the possibility of a pollution incident. Extensive training of all personnel is standard policy at the existing Crow Butte facility and will be implemented at the satellite facility. Waste management facilities and systems will be inspected frequently. Detailed procedures are included in the SHEQMS, which will be adapted for use at the satellite facility.

Potential sources of pollution include the following:

4.2.1.11 Wellfield Buildings and Piping

Wellfield buildings are not considered to be a potential source of pollutants during normal operations, as there will be no process chemicals or effluents stored within. The only instance in which a wellfield building could contribute to pollution would be in the event of a release of injection or recovery solutions due to pipe failure. The possibility of such an occurrence is considered to be minimal, as the piping will be leak-checked before initial placement into service. Piping from the wellfield will generally be buried, minimizing the possibility of an accident. In addition, the flows through the wellfield, piping and manifold pressure gauges in the wellhouses are monitored 24 hours per day, 7 days per week by control room operators using visual and audible alarms. Flow monitoring systems will alarm in the event of a significant piping failure, which will allow flow to be stopped, preventing any significant migration of process fluids. Wellfield buildings will also be equipped with wet alarms for early detection of leaks.

4.2.1.12 Satellite Facility

The satellite facility will serve as a central hub for the mining operations in the MEA. Therefore, the satellite facility carries the greatest potential for spills or accidents resulting in the release of potential pollutants. Spills could result from a release of solutions due to a piping failure or a process storage tank failure.

The satellite facility building will be designed so that any release of liquid waste would be contained within the structure. A concrete curb will be built around the entire process building. This pad will be designed with a capacity equal to that of the largest tank within the building in the event of a rupture. In the event of a piping failure, the pump system will immediately shut down, limiting

any release. Liquid inside the building, either from a spill or from wash down water, will be drained through a sump and sent to the liquid waste disposal system.

4.3 Deep Well Pumphouse and Wellhead

The deep well pumphouse and wellhead will be designed so that any release of liquids will be contained within the building or in a bermed containment area surrounding the facilities. Liquid inside the building will be contained and managed as appropriate.

4.3.1.1 Transportation Vehicles

The release of pollutants to the environment could occur due to accidents involving transportation vehicles. This could involve either vehicles transporting IX resin to and from the satellite facility, to the CPF, or transporting radioactive contaminated waste from the satellite facility to an approved disposal site.

All chemicals and products delivered to or transported from the satellite facility will be carried in DOT-approved packaging. In the event of an accident, procedures are currently in place in the SHEQMS Volume VIII, Emergency Manual, to ensure a rapid response.

The uranium-loaded resin will be transported from the satellite facility to the CPF processing building in a specially designed, low profile, 4,000-gallon capacity tanker trailer. The primary access route is approximately 30 miles (48.3 km) long, of which approximately 11.6 miles (18.7 km) are on county or private roads (**Figure 4.2-1**). The Alternate A access route is approximately 14 miles (22.5 km) long, with all of the roads being unpaved county and private roads. In the event of an accident, each resin transport vehicle will be equipped with an emergency contingency package whereby the driver could initiate containment of any spilled material. Because the uranium adheres to the resin and the resin is wet when transferred, the radiological and environmental impacts of a spill due to an accident would be minimal. Finally, each resin transfer vehicle will be equipped with a radio for communications with the CPF. This allows quick response and implementation of the emergency response plan for transportation accidents.

4.3.1.2 Spills

Spills can take two forms within an *in-situ* facility. These are surface spills (e.g., pond leaks, piping ruptures) and subsurface releases (e.g., well casing failure, pond liner leak) resulting in a release of waste solutions. Spill contingency plans are discussed in Section 5.7.1.3.

Engineering and administrative controls are in place at the CPF and will be implemented at the satellite facility to prevent both surface and subsurface releases to the environment, and to mitigate the effects should an accident occur. The most common form of surface release from *in-situ* mining operations occurs from breaks, leaks, or separations within the piping that transfers mining fluids from the satellite processing building to the wellfield and back. With the current CBR monitoring system, these release are generally, small, quickly discovered, and promptly mitigated.

In general, piping from the satellite facility to and within the wellfield will be constructed of HDPE with butt-welded joints or equivalent. All pipelines will be pressure-tested before final operation. A break in a buried section of line would be unlikely because no additional stress is placed on the pipes. In addition, underground pipelines will be protected from vehicles driving over the lines, which is the major cause of failure. Typically, the only exposed pipes will be at the satellite facility,

at the wellheads, and in the wellhouses in the wellfield. Trunkline flows and manifold pressures will be monitored for spill detection and process control.

4.3.2 Solid Waste

Any facility or process with the potential to generate industrial waste should practice good housekeeping. This activity generally consists of keeping facilities, equipment, and process areas clean and free of industrial waste or other debris. Good housekeeping includes promptly cleaning any spillage or process residues on floors or other areas that could be spread and collecting solid wastes in designated containers or areas until proper disposal.

Solid waste generated at the satellite facility is expected to include spent resin, resin fines, empty reagent containers, miscellaneous pipe and fittings, waste oil, out-of-date reagents and domestic trash. Solid wastes will be classified as contaminated or non-contaminated waste according to survey results. The solid waste will be segregated based on whether it is clean or has the potential for contamination with 11(e).2 byproduct materials. These non-hazardous wastes will be stored in appropriate containers prior to disposal by a contracted waste disposal operator, at an approved off-site waste disposal facility.

The largest volume of solid wastes requiring disposal at the MEA site will be produced during facility decommissioning. Soils would be included in decommissioning surveys, and any soils exceeding NRC release limits at 10 CFR Part 40, Appendix A, Criterion 6 would be removed and disposed of as 11e.(2) byproduct waste. Proposed decommissioning and reclamation activities are discussed in Section 6.

4.3.2.1 Non-contaminated Solid Waste

Non-contaminated solid waste is waste which is not contaminated with 11(e).2 byproduct material or which can be decontaminated and re-classified as non-contaminated waste. This type of waste may include trash, piping, valves, instrumentation, equipment, and any other items that are not contaminated or that may be successfully decontaminated. Release of contaminated equipment and materials is discussed in further detail in Section 5.

CBR has recently estimated that the CPF produces approximately 1,055 cubic yards (yd^3) of non-contaminated solid waste per year. This estimate is based on the number of collection containers on site and the experience of the contract waste hauler. CBR estimates that the proposed satellite facility would produce approximately 700 yd^3 of non-contaminated solid waste per year. Non-contaminated solid waste will be collected on the site in designated areas and disposed of in the nearest permitted sanitary landfill.

4.3.2.2 11(e).2 Byproduct Material

Solid 11e.(2) byproduct wastes consists of solid waste contaminated with 11e.(2) byproduct material that cannot be decontaminated.

11(e).2 byproduct material generated at ISR facilities consists of filters, personal protective equipment (PPE), spent resin, piping, and other materials. CBR has recently estimated that the CPF produces approximately 60 to 90 yd^3 of 11(e).2 byproduct material waste per year. This

estimate is based on the historical number of shipments to the licensed disposal facilities. CBR estimates that the proposed satellite facility would produce approximately 60 yd^3 of 11(e).2 byproduct materials per year. These materials will be stored on site until a full shipment can be shipped to a licensed waste disposal site or licensed mill tailings facility. CBR currently maintains an agreement for waste disposal at a properly licensed facility as a License Condition for SUA-1534. CBR is required to notify NRC in writing within 7 days if the disposal agreement expires or is terminated, and to submit a new agreement for NRC approval within 90 days of the expiration or termination.

If decontamination is possible, surveys for residual surface contamination will be made prior to releasing the material. Decontaminated materials carry activity levels lower than those specified in NRC guidance (NRC 1987). An area will be maintained inside the restricted area boundary for storage of contaminated materials prior to their disposal.

4.3.2.3 Septic System Solid Waste

Domestic liquid wastes from the toilets, lavatories and a sink in the lunchroom/break areas will be disposed of in an approved septic system that meets the requirements of the State of Nebraska. The satellite building will not have a laboratory. Solid materials collected in septic systems must be disposed of by companies or individuals licensed by the State of Nebraska. NDEQ regulations for control of these systems are contained in Title 124 (NDEQ 2010c).

4.3.2.4 Hazardous Waste

The potential exists for any industrial facility to generate hazardous waste as defined by the Resource Conservation and Recovery Act (RCRA). In the State of Nebraska, hazardous waste is governed by the regulations contained in Title 128 (NDEQ 2010d). Based on waste determinations conducted by CBR as required in Title 128, CBR is a Conditionally Exempt Small Quantity Generator. To date, CBR only generates universal hazardous wastes such as fluorescent light tubes, used waste oil, and batteries. CBR recently estimated that the current operation generates approximately 1,325 liters of waste oil per year. CBR estimates that the proposed satellite facility would produce approximately 800 liters of waste oil per year. Waste oil is disposed of by a licensed waste oil recycler. CBR has management procedures in place in the SHEQMS Volume VI, Environmental Manual, to control and manage these types of wastes.

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5 OPERATIONS

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 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 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 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 Mine Manager.

5.1.7 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).

5.1.8 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 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.

5.1.9.1 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

5.1.9.2 **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

5.1.9.3 **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

5.1.10 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.

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5.2 Management Control Program

5.2.1 Safety Health Environment and Quality Management System (SHEQMS)

The SHEQMS formalizes the approach to environmental, health, and safety management to ensure consistency across its operations. The SHEQMS is a key element in ensuring that all employees demonstrate "due diligence" in addressing environmental, health, and safety issues and describes how the operations of the facility will comply with the Cameco SHEQ Policy and regulatory requirements. The SHEQ Manager, with assistance from the RSO and Safety Supervisor, is responsible for drafting, approving, and updating (as needed) the SHEQMS site-specific procedures annually. More frequent updates may be made if site activities and/or conditions warrant such actions.

The SHEQMS:

- Ensures that sound management practices and processes are in place to sustain strong SHEQ performance
- Clearly sets out and formalizes the expectations of management
- Provides a systematic approach to the identification of issues and ensures that a system of risk identification and management is in place
- Provides a framework for personal, site, and corporate responsibility and leadership
- Provides a systematic approach for the attainment of CBR objectives
- Ensures continued improvement of programs and performance

The SHEQMS has the following characteristics:

- The system is certified to meet the ISO 14001 Environmental Management System Standard.
- The system is straightforward in design, is intended as an effective management tool for all types of activities and operations, and is capable of implementation at all levels of the organization.
- The system is supported by standards that clearly spell out CBR expectations, while leaving the means by which these are attained as a responsibility of line management.
- The system is readily auditable.
- The system is designed to provide a practical tool to assist the operations in identifying and achieving their SHEQ objectives while satisfying CBR government requirements.

The SHEQMS uses a series of standards that align with specific management processes and sets out the minimum expectations for performance. The standards consist of management processes that require assessment, planning, implementation (including training, corrective actions, safe work programs, and emergency response), checking (including auditing, incident investigation, compliance management, and reporting), and management review. These standards meet the recommendations contained in RG 8.2 (NRC 2011c).

5.2.1.1 Operating Procedures

CBR has developed procedures consistent with the corporate policies, standards, and regulatory requirements to implement these management controls. The SHEQMS consists of the following standards and operating procedures contained in eight volumes:

Volume 1 – *Standards*
Volume 2 – *Management Procedures*
Volume 3 – *Operating Manual* (SOPs)
Volume 4 – *Health Physics Manual*
Volume 5 – *Industrial Safety Manual*
Volume 6 – *Environmental Manual*
Volume 7 – *Training Manual*
Volume 8 – *Emergency Manual*

Written operating procedures have been developed for all process activities including those involving radioactive materials. Where radioactive material handling is involved, pertinent radiation safety practices are incorporated into the operating procedure. Additionally, written operating procedures have been developed for non-process activities including environmental monitoring, health physics procedures, emergency procedures, and general safety.

The procedures enumerate pertinent radiation safety procedures to be followed. A copy of the written procedure will be kept in the area where it is used. All procedures involving radiation safety will be reviewed and approved in writing by the RSO or another individual with similar qualifications prior to being implemented. The RSO will also perform a documented annual review of the operating procedures.

5.2.1.2 Radiation Work Permits

When employees are required to conduct activities of a non-routine nature where there is the potential for significant exposure to radioactive materials and for which no operating procedure exists, an RWP will be required. The RWP will describe the scope of the work, precautions necessary to maintain radiation exposures to ALARA, and any supplemental radiological monitoring and sampling to be conducted during the work. The RWP shall be reviewed and approved in writing by the RSO or qualified HPT in the absence of the RSO prior to initiation of the work. The HPT is instructed to assess the complexity of the activity and to contact the RSO by phone if any questions arise.

To become qualified, the HPT must meet the technical qualifications as described in RG 8.31 and demonstrate competency by preparing a minimum of six RWP's under the supervision of the RSO. Continued proficiency will be demonstrated by preparing a minimum of two RWP's annually under the supervision of the RSO. The RSO will document the competency and proficiency of the HPT.

The RSO may also issue Standing Radiation Work Permits (SRWPs) for periodic tasks that require similar radiological protection measures (e.g., maintenance work on a specified facility system). The SRWP will describe the scope of the work, precautions necessary to maintain radiation exposures to ALARA, and any supplemental radiological monitoring and sampling to be conducted

during the work. The SRWP shall be reviewed and approved in writing by the RSO prior to initiation of the work.

5.2.1.3 Record Keeping and Retention

The SHEQMS Volume II, Management Procedures, provides specific instructions for the proper maintenance, control, and retention of records associated with implementation of the program. The program is consistent with the requirements of 10 CFR 20 Subpart L and 10 CFR §40.61 (d) and (e). Records of surveys, calibrations, personnel monitoring, bioassays, transfers or disposal of source or byproduct material, and transportation accidents will be maintained on site until license termination. Records containing information pertinent to decommissioning and reclamation, such as descriptions of spills, excursions, contamination events, as well as information related to site and aquifer characterization and background radiation levels, will be maintained on site until license termination. Duplicates of all significant records will be maintained in the corporate office or other offsite locations.

5.2.2 Performance Based License Condition

This license application is the basis of the Performance-Based License (PBL) originally issued in 1998. Under that license, CBR may, without prior NRC approval or the need to obtain a License Amendment:

1. Make changes to the facility or process, as presented in the license application (as updated)
2. Make changes in the procedures presented in the license application (as updated)
3. Conduct tests or experiments not presented in the license application (as updated).

A License Amendment and/or NRC approval will be necessary prior to implementing a proposed change, test, or experiment if the change, test, or experiment would:

1. Result in any appreciable increase in the frequency of occurrence of an accident previously evaluated in the license application (as updated)
2. Result in any appreciable increase in the likelihood of occurrence of a malfunction of a structure, system, or component (SSC) important to safety previously evaluated in the license application (as updated)
3. Result in any appreciable increase in the consequences of an accident previously evaluated in the license application (as updated)
4. Result in any appreciable increase in the consequences of a malfunction of an SSC previously evaluated in the license application (as updated)
5. Create a possibility for an accident of a different type than any previously evaluated in the license application (as updated)
6. Create a possibility for a malfunction of an SSC with a different result than previously evaluated in the license application (as updated)
7. Result in a departure from the method of evaluation described in the license application (as updated) used in establishing the final SER or the EA or technical evaluation reports (TERs) or other analysis and evaluations for license amendments

8. For purposes of this paragraph as applied to this license, SSC means any SSC that has been referenced in a staff SER, TER, EA, or environmental impact statement (EIS) and supplements and amendments thereof.

Additionally, CBR must obtain a license amendment unless the change, test, or experiment is consistent with the NRC conclusions, or the basis of, or analysis leading to, the conclusions of actions, designs, or design configurations analyzed and selected in the site or facility SER, TERs, EIS, or EA. This would include all supplements and amendments, and TERs, EAs, and EISs issued with amendments to this license.

5.2.3 Safety and Environmental Review Panel

A SERP will determination compliance concerning the conditions discussed in Section 5.2.2. The SERP will consist of a minimum of three individuals. One member of the SERP will have expertise in management and will be responsible for managerial and financial approval for changes, one member will have expertise in operations and/or construction and in implementation of any changes, and one member will be the RSO or equivalent. Other members of the SERP may be employed as appropriate to address technical aspects of the change, experiment, or test in several areas, such as health physics, groundwater hydrology, surface water hydrology, specific earth sciences, and others. Temporary members, or permanent members other than the three identified above, may be consultants.

The SERP is responsible for monitoring any proposed change in the facility or process, changing procedures, and conducting tests or experiments not contained in the current NRC license. As such, they are responsible for ensuring that any such change results in no degradation in the essential safety or environmental commitments of CBR.

5.2.3.1 Safety and Environmental Review Panel Review Procedures

The SERP will implement the following review procedures for the evaluation of all appropriate changes to the facility operations as outlined in the SHEQMS Volume II, Management Procedures. The SERP may delegate any portion of these responsibilities to a committee of two or more members of the SERP. Any committees so constituted will report their findings to the full SERP for a determination of compliance with Section 5.2.2 of this chapter. In their documented review of whether a potential change, test, or experiment (hereinafter called the change) is allowed under the PBL (or Performance Based License Condition [PBLC]) without a license amendment, the SERP shall consider the following.

<u>Current NRC License Requirements</u>

The SERP will review the most current NRC license conditions to assess which, if any, conditions will have an impact on or will be impacted by the potential SERP action. If the SERP action will conflict with a specific license requirement, then a license amendment is necessary before initiating the change. This review includes information included in the approved license application.

Ability to Meet NRC Regulations

The SERP will determine if the change, test, or experiment conflicts with applicable NRC regulations (example: 10 CFR Parts 20 and 40 requirements). If the SERP action conflicts with NRC regulations, a license amendment is necessary.

Licensing Basis

The SERP will review whether the change, test, or experiment is consistent with NRC conclusions regarding actions analyzed and selected in the licensing basis. Documents that the SERP must review in conducting this evaluation include the SER and EA prepared in support of the license renewal application (February 1998) and any SERs, TERs, EAs, or EISs prepared to support amendments to the license. The RSO will maintain a current copy of all pertinent documents for review by the SERP during these evaluations.

Financial Surety

The SERP will review the proposed action to determine if any adjustment to financial surety arrangement or approved amount is required. If the proposed action will require an increase to the existing surety amount, the financial surety instrument must be increased accordingly before the change can be approved. The surety estimate must be updated either through a license amendment or through the course of the annual surety update to the NRC. The NRC incorporates the annual surety update by license amendment.

Essential Safety and Environmental Commitments

The SERP will ensure that there is no degradation in the essential safety or environmental commitment in the license application, or as provided by the approved reclamation plan.

5.2.3.2 Documentation of SERP Review Process

After the SERP reviews a proposed action, it will document its findings, recommendations, and conclusions in a written report format. All members of the SERP shall sign concurrence on the final report. If the report concludes that the action meets the appropriate PBL or PBLC requirements and does not require a license amendment, the proposed action may then be implemented. If the report concludes that a license amendment is necessary before implementing the action, the report will document the reasons why, and what course CBR plans to pursue. The SERP report shall include the following:

- A description of the proposed change, test, or experiment (proposed action)
- A listing of all SERP members conducting the review and their qualifications (if a consultant or other member not previously qualified)
- The technical evaluation of the proposed action, including all aspects of the SERP review procedures listed above
- Conclusions and recommendations
- Signatory approvals of the SERP members
- Any attachments such as all applicable technical, environmental, or safety evaluations, reports, or other relevant information including consultant reports.

All SERP reports and associated records of any changes made pursuant to the PBL or PBLC shall be maintained through termination of the NRC license.

CBR will submit an annual report to the NRC that describes all changes, tests, or experiments made pursuant to the PBL or PBLC. The report will include a summary of the SERP evaluation of each change. In addition, CBR will annually submit any pages of the license renewal application to reflect changes to the license renewal application or supplementary information. Each replacement page shall include both a change indicator for the area of change (e.g., bold marking vertically in the margin adjacent to the portion actually changed) and page change identification (date of change, change number, or both).

5.3 Management Audit and Inspection Program

The following internal inspections, audits, and reports are performed for the Crow Butte Project operations. Similar activities will be performed for the MEA.

5.3.1 Radiation Safety Inspections

5.3.1.1 Daily Inspections

The RSO, HPT, or trained designated operator conducts a daily facility inspection. The purpose of the walk-through inspection is to ensure proper implementation of radiation safety requirements and standard operating procedures.

The RSO will determine the specific areas at the facility that will be included in the daily inspection based on the potential for radiological hazards and specific license requirements. The inspection is primarily a visual inspection to ensure that process designs and procedural methods for maintaining exposures ALARA are being implemented and used correctly. During the walk through inspection, the RSO, HPT, or trained designated operator will document on a standard inspection form or in a log book the results of the inspection. The documentation contains the radiological/safety hazards examined.

In all areas where corrective actions are needed the appropriate employee or supervisor will be notified. A Radiation Work Permit will be issued if the RSO or designee determines a significant radiological hazard or potential hazard exists and for which there is no SOP.

Although the inspection helps ensure a satisfactory working environment, it cannot replace the employees' or supervisors' role in maintaining exposures ALARA. The walk through inspection is intended to assist both supervisory personnel and employees in maintaining an awareness of the potential radiological hazards and to institute preventative or corrective measures. The qualifications requirements for a designated operator are provided in section 5.5.4

5.3.1.2 Monthly Reviews

At least monthly, the RSO should review the results of daily and weekly inspections, including a review of all monitoring and exposure data for the month. The RSO should provide to the resident manager and all department heads for their review a written summary of the month's significant worker protection activities that contains (1) a summary of the most recent personnel exposure data, including bioassays and time-weighted calculations, and (2) a summary of all pertinent radiation survey records.

In addition, the monthly summary report should specifically address any trends or deviations from the radiation protection and ALARA program, including an evaluation of the adequacy of license conditions regarding radiation protection and ALARA. The summary should describe unresolved problems and the proposed corrective measures. Monthly summary reports should be maintained on file and readily accessible for at least 5 years.

5.3.2 Annual ALARA Audits

CBR will conduct annual audits of the radiation safety and ALARA programs. The Manager of SHEQ may conduct these audits. Alternatively, CBR may employ qualified personnel from other uranium recovery facilities or an outside radiation protection auditing service to conduct these audits. The purpose of the audits is to confirm that all radiation health protection procedures and license condition requirements are being conducted properly at the Crow Butte Uranium Project facility. Any outside personnel employed for this purpose will be qualified in radiation safety procedures as well as environmental aspects of solution mining operations. Whether conducted internally or through the use of an audit service, the auditor will meet the same minimum qualifications for education and experience as for the RSO as described in Section 5.4.

The audit of the radiation protection and ALARA program is conducted in accordance with the recommendations contained in RG 8.31. A written report of the results is submitted to corporate management. The RSO may accompany the auditor but may not participate in the documentation of conclusions.

The audit report should summarize the following data:

- Employee exposure records (external and time-weighted calculations)
- Bioassay results
- Inspection log entries and summary reports of daily, weekly, and monthly inspections
- Documented training program activities
- Radiation safety meeting reports
- Radiological survey and sampling data
- Reports on overexposure of workers submitted to the NRC
- Operating procedures that were reviewed during this time period

The report on the annual radiation protection and ALARA audit will specifically discuss the following:

- Trends in personal exposures for identifiable categories of workers and types of operational activities
- Whether equipment for exposure control is being properly used, maintained, and inspected
- Recommendations on ways to further reduce personnel exposures from uranium and its daughters

The ALARA audit report specifically discusses the following:

- Trends in personnel exposures
- Proper use, maintenance, and inspection of equipment used for exposure control
- Recommendations on ways to further reduce personnel exposures from uranium and its daughters

The ALARA audit report is submitted to and reviewed by the President and General Manager. Implementations of the recommendations to further reduce employee exposures, or improvements to the ALARA program, are discussed with the ALARA auditor.

Annual audits will be performed to verify implementation of the quality assurance program, as required by Chapter 2, Section 2.9.4 of CBR's SHEQMS Volume IV Annual ALARA Audits (CBR 2011). The audits are reviewed by facility and corporate management. The Quality Assurance/Quality Control (QA/QC) program is audited annually as per part of CBR's Annual ALARA Audits required by Section 5 of Chapter SHEQ-20 of CBR's Volume II of the SHEQMS manual (CBR 2009)

An individual qualified in analytical and monitoring techniques who does not have direct responsibilities in the areas being audited performs the audit. Results of the QA/QC audit are documented with the ALARA Audit. The RSO has the primary responsibility for the implementation of the radiological QA/QC programs at the Crow Butte Uranium Project facilities. CBR's radiation quality assurance program is discussed in Section 2.9 of Volume IV (Health Physics Manual) of the SHEQMS. The results of the audit, including deficient areas, shall be addressed and appropriate practices implemented to ensure correctness and validity of sampling.

The RSO has the ultimate responsibility for ensuring that the NRC radiological standards are being met at the MEA. The Lead Operator at the satellite facility or wellfield operations would have the responsibility for responding to any spill requiring cleanup. Facility operators and wellfield operators who have received spill response training would conduct the cleanup operations.

The proposed management audit and inspection programs for the satellite facility would be sufficient for the type of operations and number and type of employees. CBR has projected that the staffing level for the satellite facility would be 12 full-time CBR staff members to staff three employees per 12-hour shift (one Lead Operator and two facility operators). These new employees will be needed for the satellite facility, wellfield operations, and maintenance positions. Other staff members working out of the CPF that would occasionally visit the satellite facility and associated wellfield would include the RSO, HPT, Safety Supervisor, SHEQ Manager, as well as various technical and managerial staff members.

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5.4 Health Physics Staff Qualifications

CBR project staff is highly experienced in the management of uranium development, mining and operations. The following minimum personnel specifications and qualifications are strictly adhered to.

5.4.1 Radiation Safety Officer Qualifications

The minimum qualifications for the RSO are as follows:

- Education: A bachelor's degree in the physical sciences, industrial hygiene, or engineering from an accredited college or university or an equivalent combination of training and relevant experience in uranium recovery facility radiation protection. Two years of relevant experience are generally considered equivalent to one year of academic study.
- Health Physics Experience: At least 1 year of work experience relevant to uranium recovery operations in applied health physics, radiation protection, industrial hygiene, or similar work. This experience should involve actual work with radiation detection and measurement equipment, not strictly administrative or "desk" work.
- Specialized Training: At least four weeks of specialized classroom training in health physics specifically applicable to uranium recovery. In addition, the RSO should attend refresher training on uranium recovery facility health physics every 2 years.
- Specialized Knowledge: A thorough knowledge of the proper application and use of all health physics equipment used in the uranium recovery facility, the chemical and analytical procedures used for radiological sampling and monitoring, methodologies used to calculate personnel exposure to uranium and its daughters, and a thorough understanding of the uranium recovery process and equipment used in the facility and how hazards are generated and controlled during the uranium recovery process.

5.4.2 Health Physics Technician Qualifications

In addition to the RSO, there should be a minimum of one full-time health physics technician at any full-scale operating uranium recovery facility. The health physics technician should have **one** of the following combinations of education, training, and experience:

- Education: An associate's degree or 2 or more years of study in the physical sciences, engineering, or a health-related field
- Training: A total of at least 4 weeks of generalized training (up to 2 weeks may be on-the-job training) in radiation health protection applicable to uranium recovery facilities
- Experience: One year of work experience using sampling and analytical laboratory procedures that involve health physics, industrial hygiene, or industrial safety measures to be applied in a uranium recovery facility

  OR

- Education: A high school diploma;
- Training: A total of at least 3 months of specialized training (up to 1 month may be on-the-job training) in radiation health protection relevant to uranium recovery facilities; and
- Experience: Two years of relevant work experience in applied radiation protection.

The health physics technician should demonstrate a working knowledge of the proper operation of health physics instruments used in the uranium recovery facility, surveying and sampling techniques, and personnel dosimetry requirements. The HPT's qualifications are reviewed and documented by a Safety and Environmental Review Panel in accordance with Seciton 5.2.3.

5.5 Radiation Safety Training

All site employees and contractor personnel at the CPF are administered a training program based upon the SHEQMS covering radiation safety, radioactive material handling, and radiological emergency procedures. The CBR Training Program in the SHEQMS Volume VII, Training Manual, provides requirements for radiation safety training. The training program is administered in keeping with standard radiological protection guidelines and the guidance provided in RG 8.29, RG 8.31, and RG 8.13 (NRC 1996, 2002a, and 1999a). The technical content of the training program is under the direction of the RSO. The RSO or an HPT conducts all radiation safety training. CBR will implement this training program for activities at the MEA.

5.5.1 Training Program Content

5.5.1.1 Visitors

Visitors to the site who have not received training are escorted by onsite personnel properly trained and knowledgeable about the hazards of the facility. At a minimum, visitors are instructed specifically on what they should do to avoid possible hazards in the area of the facilities that they are visiting.

5.5.1.2 Contractors

Any contractors having work assignments at the facilities are given appropriate radiological safety training. Contract workers who will be performing work on heavily contaminated equipment receive the same training normally required of Crow Butte employees as discussed in Section 5.5.1.3.

5.5.1.3 Crow Butte Resources Employees

All CBR employees (and some contractors as noted in Section 5.5.1.2) receive training as radiation workers. The program incorporates the following topics recommended in RG 8.31:

1. Fundamentals of Health Protection
   - The radiologic and toxic hazards of exposure to uranium and its daughters,
   - How uranium and its daughters enter the body (inhalation, ingestion, and skin penetration)
   - Why exposures to uranium and its daughters should be kept ALARA.

2. Personal Hygiene at Uranium Recovery Facilities
   - Wearing protective clothing,
   - Using respiratory protective equipment correctly,
   - Eating, drinking, and smoking only in designated area,
   - Using proper methods for decontamination (i.e., showers).

3. Facility-Provided Protection
   - Ventilation systems and effluent controls,

- Cleanliness of the work place,
- Features designed for radiation safety for process equipment,
- Standard operating procedures,
- Security and access control to designated areas,
- Electronic data gathering and storage,
- Automated processes.

4. Health Protection Measurements
   - Measurement of airborne radioactive materials,
   - Bioassays to detect uranium (urinalysis and in vivo counting),
   - Surveys to detect contamination of personnel and equipment,
   - Personnel dosimetry.

5. Radiation Protection Regulations
   - Regulatory authority of NRC, the Occupational Safety and Health Administration (OSHA), and the state,
   - Employee rights in 10 CFR Part 19,
   - Radiation protection requirements in 10 CFR Part 20.

6. Emergency Procedures.

All new workers, including supervisors, are given specialized instruction on the health and safety aspects of the specific jobs they will perform. Instruction is provided in the form of individualized on-the-job training. Retraining is performed annually and documented. Every 2 months, all workers attend a general safety meeting.

Consistent with Regulatory Guide 8.13, Appendix A, it is CBR policy to accommodate pregnant workers when possible. To that end, CBR uses the following approach to address potential and actual prenatal exposure risks:

- Instructions
  - Give to all female new hires
  - Give to supervisors in charge of female workers
  - Provide prenatal instruction
  - Provide RG 8.13 and its appendix, review with worker
  - Provide opportunity to ask questions
  - Discuss possible effect on job status, which may involve adjustment of work duties as necessary
- Written declaration
  - View prenatal instructions again and review RG 8.13
  - Review worker-specific exposure monitoring (e.g., dosimetry, bioassay where appropriate) following declaration
  - Adjust work duties as necessary

5.5.2 Testing Requirements

A written test with questions directly relevant to the principals of radiation safety and health protection in the facility covered in the training course is given to each worker. The instructor reviews the test results with each worker and discusses incorrect answers to the questions with the worker until the worker understands the correct answer. Workers who fail the exam are retested, and test results remain on file.

5.5.3 On-The-Job Training

5.5.3.1 Health Physics Technician

On-the-job training is provided to HPTs in radiation exposure monitoring and exposure determination programs, instrument calibration, facility inspections, posting requirements, respirator programs and Health Physics Procedures contained in the SHEQMS Volume IV, Health Physics Manual.

5.5.3.2 Refresher Training

Following initial radiation safety training, all permanent employees and long-term contractors receive ongoing radiation safety training as part of the annual refresher training and, if determined necessary by the RSO, during monthly safety meetings. This ongoing training is used to discuss problems and questions that have arisen, any relevant information or regulations that have changed, exposure trends, and other pertinent topics.

5.5.3.3 Training Records

Records of training are kept until license termination for all employees trained as radiation workers (i.e., occupationally exposed employees).

5.5.4 Qualifications and Requirements for Daily Inspections

Cameco conducts daily walk-through inspections of all work and storage areas of the facility to ensure proper implementation of good radiation safety procedures, including good housekeeping and cleanup practices that minimize unnecessary contamination. Normally, these inspections are conducted by the RSO or an HPT. However, on certain occasions, such as weekends or holidays, a qualified operator may be designated to conduct the daily inspection.

Crow Butte Resources will use an alternative approach to qualify designated operators to conduct daily walkthrough inspections of all work and storage areas at the Crow Butte Plant and satellite facilities. One or more qualified designated operators will be identified to perform daily inspections in the occasional absence of the RSO and HPT.

A qualified designated operator will only perform daily inspections on weekends, holidays and times when both the RSO and HPT's must both be absent (e.g. illness or offsite training). With the exceptions of those instances when a Federal holiday falls on a Friday or Monday, the Thanksgiving holiday, or a site closure due to weather or other safety or security related event, qualified designated operators will not conduct the inspections for more than two days per week. When a

Federal holiday falls on Friday or Monday, qualified designated operators may perform the daily inspections for a total of three consecutive days. For the Thanksgiving holiday only, the qualified designated operator may perform the daily inspections for four consecutive days. When weather or other safety or security related event causes a site closure, a qualified designated operator, if available, will continue performing the daily inspections until the RSO or HPT can access the site after such an event. The licensee will also have the RSO or HPT available by telephone while a qualified designated operator is performing the daily inspections.

Reports generated by a qualified designated operator will be reviewed by the RSO or an HPT as soon as practicable, but not later than the close of business the next work day following an absence (including site closure due to weather or other safety or security related event), weekend or holiday. The RSO or HPT review shall be annotated with date and time on the report or other document that can be inspected upon request.

Any problems noted by the designated operator during the daily inspection will be recorded on an inspection form, signed and dated, and retained on file. The RSO will review the inspection forms and take appropriate action to correct any noted problems.

A qualified designated operator has no authority for the development and administration of the radiation protection program, other than conducting daily inspections. He may not approve plans for new equipment, process changes, or changes in operating procedures that may affect the radiation protection program. He will not conduct radiation safety audits or make determinations about personnel dosimetry. A qualified designated operator may not authorize non-routine maintenance jobs involving potential for personnel radiation exposure or radioactive contamination for which there are no standard operating procedures nor an existing radiation work permit. The designated operator will not have the authority to release materials for unrestricted use. In the event of an emergency, the on-call RSO or HPT will be responsible for radiation protection decisions.

At the Crow Butte Plant and satellite facilities, the only activity required to be performed by the RSO or HPT on a daily basis is the daily inspection. Instrument calibrations are performed on a weekly basis during the regular workweek by the RSO or HPT. For that reason, it is not necessary for the designated operator to perform any other HPT function on weekends or holidays.

The designated operator will observe, through visual inspection, radiation safety practices, housekeeping and implementation of the radiation safety program throughout the plant/satellite. Such duties include, but not be limited to, inspecting for compliance with radiation safety postings, contamination control, proper control point ingress and egress, control of airborne radioactivity, worker protection practices in the yellowcake drying and packaging area, and proper storage of byproduct material.

5.5.4.1 Minimum Qualifications for Designated Operators

Before a designated operator may conduct such inspections, he must be qualified by reason of training and experience to observe proper implementation of good radiation safety practices. In addition to the annual radiation worker training required by Regulatory Guide 8.31, Section 2.5, the operator seeking designation must not only complete one-time training specific to daily inspections, but also demonstrate proficiency. The additional training will emphasize how the inspections affect employee safety.

At a minimum, the operator seeking designation must have the following combination of education, training and experience:

Education: a high school diploma or equivalent.

Training: New employee radiation safety training, including guidance pertinent to prenatal radiation exposure (Regulatory Guide 8.13) and instruction concerning risks from occupational radiation exposure (Regulatory Guide 8.29) and additional training specific to conducting daily inspections at Crow Butte ISR facilities. In addition, the designated operator will be required to demonstrate proficiency during daily inspections to the RSO.

Experience: A minimum of three months' work experience in operations or maintenance at a uranium recovery facility, including procedures that involve health physics, industrial safety or industrial hygiene at a uranium recovery facility to demonstrate qualification is required.

5.5.4.2 Additional Training for Designated Operators

The additional radiation safety training afforded to operators seeking designation involves four hours training and a test covering the topics discussed below with an 80 percent passing grade, but does not include the more advanced topics required for the facility RSO or HPT.

The additional training for Designated Operator includes the following topics:

1. Employee PPE usage
2. Personal contamination control (ingress and egress)
3. Radiation area boundaries
4. Signage
5. Labeling
6. Leaks
7. Yellowcake spillage
8. Ventilation
9. General housekeeping
10. Reporting procedures specific to type of finding (e.g., how and when to contact the on-call RSO or HPT)
11. Completion and control of the daily inspection form

5.5.4.3 Demonstration of Proficiency

Upon completion of training and prior to designation, an operator will be required to demonstrate to the RSO an understanding of and proficiency in conducting the daily inspections. Prior to performing inspections, the operator seeking designation will perform a minimum of four (4) daily inspections under the supervision of the RSO or HPT. The supervised inspections will cover the training topics listed above and will be documented with signatures of the RSO and HPT and the

operator seeking designation on the daily inspection form. An operator who fails to qualify will be re-evaluated after performing additional supervised inspections until proficiency is demonstrated to the satisfaction of the RSO.

5.5.4.4 Documentation

The designation process will be documented in a file which includes education, training results with a passing test score, and signed supervised daily inspection forms. The designation itself will be co-signed by the Designated Operator and the RSO when the RSO is satisfied that the training and supervised inspections demonstrate proficiency.

5.5.4.5 Maintaining Designated Operator Status

To remain qualified, the Designated Operators must complete an annual refresher training which addresses the same topics covered in the additional training described above. A test will be given with a required passing grade of 80 percent. In addition, the Designated Operator must complete at least two (2) supervised inspections performed semiannually under the direct supervision of the RSO or HPT.

5.6 Security

CBR security measures for the current operation are specified in the Security Plan and Security Threat chapter in the SHEQMS Volume VIII, Emergency Manual. CBR is committed to:

- Providing employees with a safe, healthful, and secure working environment;
- Maintaining control and security of NRC licensed material;
- Ensuring the safe and secure handling and transporting of hazardous materials; and
- Managing records and documents that may contain sensitive and confidential information.

The NRC requires licensees to maintain control over licensed material (i.e., natural uranium ["source material"] and byproduct material defined in 10 CFR §40.4). 10 CFR 20, Subpart I, Storage and Control of Licensed Material, requires the following:

§20.1801 Security of Stored Material

The licensee shall secure from unauthorized removal or access licensed materials that are stored in controlled or unrestricted areas.

§20.1802 Control of Material Not in Storage

The licensee shall control and maintain constant surveillance of licensed material that is in a controlled or unrestricted area and that is not in storage.

Stored licensed material at the CPF would include uranium packaged for shipment from the facility or byproduct materials awaiting disposal. Examples of material not in storage would include yellowcake slurry or loaded IX resin removed from the restricted area for transfer to other areas.

At the satellite facility, licensed stored material would typically include loaded IX resin and byproduct waste awaiting disposal. Lixiviant would be found in production piping in the wellfield and wellhouses, production trunkline to the satellite facility, and within piping located in the satellite building. Loaded IX resin would be placed in a transport truck and temporarily stored in the vehicle until the truck is filled and ready for delivery to the CPF.

5.6.1 License Area and Facility Security

5.6.1.1 MEA Security

Security at the MEA site will be consistent with policies and procedures used at the CBR current operating site. The security systems used at the current site and proposed for the MEA site are sufficient to prevent unauthorized entry into a) controlled areas and b) restricted areas. As defined in 10 CFR 20.1003, a "controlled area" refers to an area outside a restricted area but within the site boundary, to which the licensee can limit access for any reason. A "restricted area" refers to any area to which access is controlled for the protection of individuals from exposure to radiation and radioactive materials.

CBR's security program has acceptable passive controls (such as perimeter fencing for wellfields) and active controls (such as daily inspections and locks on facility buildings). These security

measures have been demonstrated to prevent unauthorized entry in controlled areas in accordance with 10 CFR Part 20, Subpart I.

Entrance to the MEA will be via Squaw Mound Road west of the facility. The entrance to the site will be posted indicating that permission is required prior to entry. A gate on the access route will be locked when not in use. The satellite facility site within the license area will be properly posted in accordance with 10 CFR § 20.1902 (e). The primary and alternate access routes to the satellite facility are shown on **Figure 4.2-1** and discussed in Sections 4.2.1.13 and 7.2.1.

Similar to the existing Crow Butte Operation, other than access through the main gate, there are two means by which members of the public could gain access to the site. First, for those members of the general public traveling public roads adjacent to the license area, access is controlled by perimeter fences on one or both sides of the roads. These fences are posted with signs.

For the abutting ranchers who have leased property to Cameco (lessors), a second approach is used to control access. Prior to putting an MU into production, the area is closed to grazing or haying until the MU has been decommissioned and reclaimed. To accomplish this, Cameco uses a combination of existing and/or new perimeter fencing specific to each MU. Any new perimeter fencing will include appropriate signage advising of access restrictions prior to production.

The Restricted area at the satellite facility refers to *"...an area where access to is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials"* (10 CFR 20.1003). Proposed restricted areas for the satellite facility are shown on **Figures 5.7-2.** Each radiation area will be posted with a conspicuous sign or signs bearing the radiation symbol and the words "CAUTION, RADIATION AREA" (10 CFR 20.1902). Radiological warnings are posted based upon actual or likely conditions. Actual conditions are determined through area monitoring. Likely conditions are identified based on professional judgment or experience regarding the probability of a radiological condition. When evaluating the likelihood of specific conditions, normal situations and unique situations that can reasonably be expected to occur will be considered.

All visitors, contractors, or inspectors entering the satellite facility site will be required to register at the facility office and will not be permitted inside the facility or wellfield areas without proper authorization. All visitors needing safety equipment, such as hardhats and safety glasses, will be issued the items by company personnel. Inexperienced visitors will be escorted within the controlled area of the facility unless they are frequent visitors who have been instructed regarding the potential hazards in various site areas. All appropriate and necessary safety or radiological training will be provided and documented by the RSO or designee. Training requirements associated with visitors and contractors are discussed in Section 5.5.

The satellite facility will routinely operate 24 hours per day and 7 days per week, so that CBR employees will normally be on site except for occasional shutdowns. The satellite facility structure will be equipped with locks to prevent unauthorized access. All facility personnel are instructed to immediately report any unauthorized persons to their supervisors. The supervisor will contact the reported unauthorized person and make sure that they have been authorized for entry. If the person is unauthorized they will be escorted to the main entrance for departure.

Access by unauthorized personnel to the stored and non-stored licensed materials (pregnant lixiviant solution, loaded IX resin, and byproduct material awaiting disposal) would be controlled by perimeter access gates with locks and site personnel. This would include piping, process vessels, tankage, and any truck vehicle containing loaded IX resin and parked within or near the satellite facility building.

Wellhouses where pregnant lixiviant solutions would be present in the production piping would be kept locked. Only authorized personnel would have keys to the wellhouses. The production trunk line conveying pregnant lixiviant from the wellhouses to the satellite building would be located within perimeter fencing that only authorized personnel would be allowed to enter. Gates associated with perimeter fencing enclosing any operating wellfield would be kept locked when operators and workers are not present (e.g., remote from the satellite facility). Security may be increased by installing continuous video surveillance of outside areas.

CBR maintains and enforces requirements of the SHEQMS, Volume IV Health Physics Manual, which specify access controls and security issues applicable to visitors, contractors and employees, radiological posting, and radiological survey and monitoring requirements associated with activities at the site.

Even without consideration of reduced exposures due to the security measures discussed above, the highest estimated total effective dose equivalent (TEDE), as determined using methods described in Section 7.3.3, for a downwind receptor at the south boundary of the MEA license boundary is 21 (**Appendix M,** Figure 5). The highest dose rate at occupied residences was 27 mRem/yr for Occupied Resident #2, and for unoccupied residences, 18 mRem/yr for Unoccupied Residence #1: **Appendix M,** Figure 5). This is based on an occupancy factor of 100 percent or 8,760 hours per year. The average dose rate from the nearby ISR facilities was 2 mRem/yr. It is unlikely that even frequent visitors to the MEA could receive annual doses near the 100 mRem/yr public dose limit. For comparison, exposure to naturally occurring background radiation from cosmic and terrestrial sources is approximately 365 mRem/yr.

5.6.1.2 Transportation Security

CBR routinely receives, stores, uses, and ships hazardous materials as defined by the U.S. DOT. In addition to the packaging and shipping requirements contained in the DOT Hazardous Materials Regulations (HMR), 49 CFR 172, Subpart I, Security Plans, requires that persons that offer for transportation or transport certain hazardous materials develop a Security Plan. Shipments may qualify for this DOT requirement under the following categories:

§172.800(b) (4) A shipment of a quantity of hazardous materials in a bulk package having a capacity equal to or greater than 13,248 L (3,500 gallons) for liquids or gases or more than 13.24 cubic meters (468 cubic feet) for solids;

§172.800(b) (5) A shipment in other than a bulk packaging of 2,268 kg (5,000 pounds) gross weight or more of one class of hazardous material for which placarding of a vehicle, rail car, or freight container is required for that class under the provisions of subpart F of this part;

§172.800(b) (7) A quantity of hazardous material that requires placarding under the provisions of subpart F of this part.

DOT requires that Security Plans assess the possible transportation security risks and evaluate appropriate measures to address those risks. All hazardous materials shippers and transporters subject to these standards must provide personnel security by screening applicable job applicants, prevent unauthorized access to the hazardous materials or vehicles being prepared for shipment, and provide for enroute security. Companies must also train appropriate personnel in the elements of the Security Plan.

Transport of licensed/hazardous material by CBR employees will generally be restricted to moving IX resin from a satellite facility to the CPF or transferring contaminated equipment between company facilities. This transport generally occurs over short distances through remote areas. Therefore, the potential for a security threat during transport in a CBR vehicle is minimal. The goal of the driver, cargo, and equipment security measures is to ensure the safety of the driver and the security and integrity of the cargo from the point of origin to the final destination by:

- Clearly communicating general point-to-point security procedures and guidelines to all drivers and non-driving personnel
- Providing the means and methods of protecting the drivers, vehicles, and customer cargo while on the road
- Establishing consistent security guidelines and procedures that shall be observed by all personnel.

For the security of all tractors and trailers, the following will be adhered to:

- If material is stored in the vehicle, access must be secured at all openings with locks and/or tamper indicators.
- Offsite tractors will always be secured when left unattended, with windows closed, doors locked, the engine shut off, and no keys or spare keys in or on the vehicle.
- The vehicle is to be kept visible by an employee at all times when left unattended outside a restricted area.

The security guidelines and procedures apply to all transport assignments. All drivers and non-driving personnel are expected to know and adhere to these guidelines and procedures when performing any load-related activity.

5.7 Radiation Safety Controls and Monitoring

CBR has a strong corporate commitment to and support for the implementation of the radiological control program at the Crow Butte Uranium Project facilities. This corporate commitment to maintaining personnel exposures ALARA will be incorporated into the radiation safety controls and monitoring program at the MEA.

The purpose of the ALARA (As Low As Reasonably Achievable) Policy is to keep exposures to all radioactive material and other hazardous material as low as possible and to as few personnel as possible, taking into account the state of technology and the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to the utilization of atomic energy in the public interest.

The RSO shall be responsible for the development and administration of the ALARA program. A comprehensive review of the radiation protection program and ALARA program will be performed annually. The annual program evaluation will review the following:

- Employee exposures and incurred doses;
- Bioassay results;
- Inspection results;
- Documented training program activities;
- Radiation safety meetings;
- Radiological survey and sample results;
- Reports on overexposures;
- Operating procedures;
- Emergency preparedness;
- Environmental monitoring program; and
- Quality assurance program.

The audit will include trends in personnel exposures, airborne concentrations, whether equipment for exposure control is being properly used, maintained, and inspected, and recommendations to maintain exposures ALARA. The annual ALARA audit will be conducted by individuals that are knowledgeable concerning radiation protection programs at uranium recovery facilities. The RSO will assist the audit team but will not be a member.

The ALARA Policy will be required reading during initial employee training. The ALARA Policy is found in the SHEQMS Health Physics Manual, Volume IV, Chapter 2, Health Physics Organization and Management, Section 2.5 ALARA Program:

> "In order for any ALARA program to be functional, all individuals from management to the workers must participate and each is responsible in the program's success. In so doing, each will have a valued stake in the outcome and final success of the ALARA program. As such, it is the corporate policy that ALARA conditions be achieved by endeavoring to maintain and promote open communications between all employees, through training and by providing management support to philosophies which can minimize or otherwise reduce occupational exposure to radiation."

In an effort to maintain exposures ALARA, the emission control equipment will be utilized in the mode that best removes and maintains airborne radioactive material at a minimum. The ventilation rate or the air exchange rate for normal work areas will be designed to maintain airborne concentrations of natural uranium and radon gas or their daughters to 25% or less of the Derived Air Concentration (DAC) as given in Table 1 of Appendix B, Title 10, Code of Federal Regulations, Part 20. If the average radon daughter concentrations are greater than 25% of the DAC, the monitoring frequency will be increased to weekly. Weekly sampling will continue until four consecutive weekly samples are less than .08 WL. If the radon daughter concentrations from a single monitoring location within a room or area are greater than .08 WL, follow-up monitoring at that location will be performed as directed by the RSO. In the event that the elevated concentration persists the following shall be assessed:

- The potential source(s) of elevated uranium particulates or radon daughters.
- The need for respiratory protection and/or limited access to the area
- The need for additional engineering controls
- The need for additional monitoring.

To that end, Crow Butte is procuring instrumentation and other required equipment and has undertaken a sampling program to evaluate a variety of radiation protection issues raised in the context of the Crow Butte license renewal. The sampling plan identifies the sample type, location, equipment frequency/duration, and LLDs. In addition, the sampling plan presents objectives and purposes, components of the dose assessment, and a decision rule/path forward.

In summary, the sampling plan will provide site-specific data to evaluate:

- Dose to public
- Dose to office workers, lab workers, wellfield workers, and wellfield construction personnel
- Implications to worker dose from in growth of short-lived beta-emitting isotopes
- Implication of short-lived beta-emitting isotopes to contamination control, for both personal contamination and for free release of objects
- Implications of isotope mixtures in establishing the site-specific DAC
- Potential to use radium-226 concentrations in pregnant lixiviant as a component of 10 CFR 40.64 effluent reporting.

As elements of the sampling plan are completed, Cameco will provide data and propose program revisions where necessary for NRC consideration. Following deliberation, appropriate license amendments will be prepared. Where needed, these amendments to the base license will be implemented at the MEA. Because the existing program will continue until the various sampling activities are complete and NRC concurs with appropriate program modifications, the following text reflects current practice.

5.7.1 Effluent Control Techniques

5.7.1.1 Gaseous and Airborne Particulate Effluents

Under routine operations, the only radioactive effluent at the satellite facility will be the release of radon-222 gas from the production solutions. Uranium product will be eluted and processed at the

CPF, where a vacuum dryer is used for drying the yellowcake product. Therefore, there will be no airborne particulate effluent from the satellite facility.

The radon-222 is found in the pregnant lixiviant that comes from the wellfield into the satellite facility. The production flow will be directed to the satellite facility process building for separation of the uranium. The uranium will be separated by passing the recovery solution through pressurized downflow IX units. The vents from the individual vessels will be connected to a manifold that will be exhausted outside the satellite facility building through the facility stack.

Venting to the atmosphere outside of the facility building minimizes personnel exposure. Small amounts of radon-222 may be released in the satellite facility building during solution spills, filter changes, IX resin transfer operations, and maintenance activities. The satellite facility building will be equipped with exhaust fans to remove any radon that may be released in the building. No significant personnel exposure to radon gas is expected based on operating experience from similar facilities. Ventilation and effluent control equipment will be inspected for proper operation as recommended in RG 3.56 (NRC 1986). Ventilation and effluent control equipment will be inspected during radiation safety inspections as discussed in Section 5.3.1.

One process area at the proposed MEA where small quantities of airborne uranium particulates have the potential for occurring is the resin transfer station, where minor spills may occur. The loaded IX resin is transferred to a truck for transport to the CPF for completion of uranium recovery. Spills can occur during resin transfer, and this is where exposure to uranium particulates is possible. All spills will be cleaned up as soon as possible to prevent the wet materials from drying and creating the potential for airborne particulates. Spills associated with resin transfer would involve the impregnated resin itself. The uranium is still bound to the resin at this stage, reducing the potential of employee exposure.

5.7.1.2 Liquid Effluents

The liquid effluents from the satellite facility can be classified as follows:

- Water generated during well development - This water is recovered groundwater and has not been exposed to any mining process or chemicals. The water will be discharged directly to the well work-over fluid tank and silt, fines, and other natural suspended matter collected during well development will settle out.
- Liquid process waste - The operation of the satellite facility results in one primary source of liquid waste: a production bleed stream. The production bleed will be disposed of in the DDW permitted under the NDEQ Class I UIC Program.
- Aquifer restoration - Restoration of the affected aquifer following mining operations results in the production of wastewater. The current groundwater restoration plan consists of four activities: 1) Groundwater transfer; 2) Groundwater sweep; 3) Groundwater treatment; and, 4) Wellfield recirculation. Only the groundwater sweep and groundwater treatment activities will generate wastewater.

During groundwater sweep, water would be extracted from the mining zone without injection, causing an influx of baseline quality water to sweep the affected mining area. The extracted water must be sent to the wastewater disposal system during this activity (i.e., deep well disposal injection). Historically Crow Butte has not used groundwater sweep, but this option could be used

in the future if warranted. As has been the case with past operations at Crow Butte, it is anticipated that during restoration groundwater at the MEA will be treated using IX and RO. Using this method, there would be no water consumption, and only the bleed has to be disposed, with the rest of the treated water being reinjected.

Groundwater treatment activities involve the use of process equipment to lower the ion concentration of the groundwater in the affected mining area. An RO unit is typically used to reduce the TDS of the groundwater. The RO unit produces clean water (permeate) and brine. Permeate is normally injected into the formation but, under certain circumstances, may be disposed of in the wastewater disposal system. The brine is sent to the wastewater disposal system. There are no plans for land application as an alternate groundwater disposal option.

The existing NRC Source Materials License allows CBR to dispose of wastewater from the CPF by three methods:

- Evaporation from the evaporation ponds
- Deep well injection
- Land application.

At the MEA, CBR proposes to handle liquid effluents from the satellite facility using only deep well injection.

5.7.1.3 Spill Contingency Plans

The RSO is charged with the responsibility to develop and implement appropriate procedures to handle potential spills of radioactive materials. Personnel representing the engineering and operations functions of the Crow Butte Uranium Project facility will assist the RSO in this effort. Basic responsibilities include:

- Assignment of resources and manpower
- Responsibility for materials inventory
- Responsibility for identifying potential spill sources
- Establishment of spill reporting procedures and visual inspection programs
- Review of past incidents of spills
- Coordination of all departments in carrying out goals of containing potential spills
- Establishment of employee emergency response training programs
- Responsibility for program implementation and subsequent review and updating
- Review of new construction and process changes relative to spill prevention and control.

Spills can take two forms within an *in-situ* uranium mining facility: 1) surface spills such as tank failures, piping ruptures, transportation accidents, and other incidents; and 2) subsurface releases such as a well excursion, in which process chemicals migrate beyond the wellfield, or a pond liner leak resulting in a subsurface release of waste solutions.

Engineering and administrative controls are currently in place to prevent both surface and subsurface releases to the environment and to mitigate the effects should a release occur. Where appropriate, similar controls will be instituted for the satellite facility.

Supervisory personnel, satellite facility operators, and wellfield operators receive spill response training for release of radiological and non-radiological materials. In the event of a spill, a designated supervisor (dependent upon location of spill) would take the lead, providing guidance and direction to the facility operators responding to the spill. Supervisory personnel take guidance and direction from the RSO, Safety Supervisor, and SHEQ Manager, as applicable.

Surface Releases

Failure of process tanks - Any failures of process tanks will be contained within the satellite building. The entire building will drain to a sump that will allow transfer of the spilled solutions to appropriate tankage or DDW.

Surface Releases - The most common form of surface releases from ISR mining operations occurs from breaks, leaks, or separations within the piping system that transfers mining fluids between the CPF and the wellfield. These are generally small, short-duration releases because engineering controls detect pressure changes in the piping systems and alert the facility operators through system alarms.

In general, piping from the satellite facility to and within the wellfield will be constructed of PVC or HDPE pipe with butt-welded joints or an equivalent. All pipelines will be pressure-tested at operating pressures prior to operation. It is unlikely that a break would occur in a buried section of line because no additional stress is placed on the pipes. In addition, underground pipelines will be protected from vehicles driving over the lines, which could cause breaks. The only exposed pipes will be at the satellite process facility, the wellheads, and in the wellhouses. Trunkline flows and wellhead pressures will be monitored for process control. Spill response is specifically addressed in the Radiological Emergencies and Emergency Reporting chapters of SHEQMS Volume VIII, Emergency Manual.

CBR spill control programs have been very effective at limiting surface releases from mining operations. CBR has never had a spill that was reportable under 10 CFR 20 requirements. All spills are analyzed for root causes and contributing factors. Periodically, the CBR SERP meets to analyze recent spill events and to determine whether engineering or administrative improvements are indicated to reduce the frequency and magnitude of spills.

Releases Associated With Transportation

The Transportation Emergencies chapter of the SHEQMS Volume VIII, Emergency Manual, provides the CBR emergency action plan for responding to a transportation accident involving a radioactive materials shipment. The chapter provides instructions for proper packaging, documentation, driver emergency and accident response procedures, and cleanup and recovery actions. This chapter currently includes instructions that specifically address the CBR emergency action plan for responding to a transportation accident involving a shipment of eluent or IX resin en route to or from the CPF. Tanker trailers used for transportation of IX resin between the satellite facility and the CPF will meet or exceed DOT and NRC requirements.

The worst-case transportation accident would involve a failure of the tanker, spilling the entire contents of uranium-loaded resin en route to the CPF. The wet resin with the chemically bonded uranium would be confined to the immediate vicinity of the accident and would not become an airborne hazard. The close proximity of any accident to the CPF would ensure the rapid response of cleanup crews to contain and retrieve any spilled material.

Sub-Surface Releases

Well Excursions - Mining fluids are normally maintained in the production aquifer within the immediate vicinity of the wellfield. The function of the encircling monitor well ring is to detect any mining solutions that may migrate away from the production area due to fluid pressure imbalance. This system has been proven to function satisfactorily over many years of operating experience with ISR mining.

At the satellite facility, an undetected excursion will be highly unlikely. A ring of perimeter monitor wells located no farther than 300 feet from the wellfield and screened in the ore-bearing Chadron Aquifer will surround all wellfields. Additionally, shallow monitor wells will be placed in the first overlying aquifer above each wellfield segment. These wells will be sampled biweekly. Past experience at the CPF and other ISR mining facilities has shown that this monitoring system effectively detects lixiviant migration. The total effect of the close proximity of the monitor wells, the low flow rate from the well patterns, and over-production of leach fluids (production bleed) makes the likelihood of an undetected excursion extremely remote.

Migration of fluids to overlying aquifers has also been considered. Several controls are in place to prevent this. CBR will plug all exploration holes to prevent commingling of the Brule and Chadron Aquifers and to isolate the mineralized zone. In addition, mechanical integrity will be tested prior to placing a well into service. This requirement of the NDEQ UIC Program ensures that all wells are constructed properly and are capable of maintaining pressure without leakage. Finally, monitor wells completed in the overlying aquifer will be sampled regularly for the presence of leach solution.

In addition to the spills described above, the accumulation of sediment or erosion of existing soils can lead to potential releases of pollutants. The likelihood of significant sediment or erosion problems is highest during construction activities. If rain (producing runoff) occurs during construction a small amount of the fill may be carried away from the construction area. Significant precipitation during pond and satellite facility construction may produce the same effect. Vegetation cover for erosion control will be established as soon as possible on exposed areas. Little additional suspendable material should be produced during mining operations and restoration activities. Site reclamation in the future with backfilling of ponds, grading the facility site, and replacing the topsoil will also expose unsecured soil for suspension in runoff waters. The sediment load as a result of precipitation during future construction or reclamation activities should not significantly affect the quality of any watercourses because the projected satellite facility location is not crossed by any streams.

Runoff from precipitation events should be controlled to minimize any exposure to pollutants on the site. At the satellite facility, runoff should not be a major issue, given the engineering design of the facilities, as well as engineering and administrative controls. Rainwater entering a pond leading to a pond overflow would be the item of greatest concern. The design and operation of the ponds will preclude a runoff-induced overflow as a realistic possibility. Should there be high runoff

concurrent with a pipeline failure, some contamination could be spread depending upon the relative saturation of the soils beneath the leaking area. In any event, only minimal releases of solutions would occur in the event of a pipeline failure, and migration of pollutants due to runoff would be minimal.

5.7.2 External Radiation Exposure Monitoring Program

5.7.2.1 Gamma Surveys

External gamma radiation surveys have been performed routinely at the Crow Butte Uranium Project and will be performed at the satellite facility. The required frequency is quarterly in designated Radiation Areas and semiannually in all other areas of the facility. Surveys will be performed at worker-occupied stations and areas of potential gamma sources such as tanks and filters. CBR establishes a Radiation Area if the gamma survey exceeds the action level of 5.0 mRem in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates. The probable source is investigated, and survey frequency for areas exceeding 5.0 mRem per hour is increased to quarterly. Records of each investigation are maintained, and the corrective action taken. If the results of a gamma survey identify areas where gamma radiation exceeds levels that delineate a "Radiation Area", access to the area is restricted and the area is posted as required in 10 CFR §20.1902 (a). Designated Radiation Areas will be as defined in 10 CFR 20.1003: Radiation Area means an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 Rem (0.05 milliSeivert [mSv]) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

External gamma surveys are performed with survey equipment that meets the following minimum specifications:

- Range - Lowest range not to exceed 100 μR/hr full-scale with the highest range to read at least 5 mR/hr full-scale
- Battery-operated and portable.

The Ludlum Model 3 survey meter with a Ludlum 44-38 probe or equivalent meets these requirements. Gamma survey instruments are calibrated at the manufacturer's suggested interval or at least annually and are operated according to the manufacturer's recommendations. Instruments are checked before each day of use.

Gamma exposure rates will be surveyed in accordance with the instructions currently contained in the SHEQMS Volume IV, Health Physics Manual. Proposed survey locations for the satellite facility are shown on **Figure 5.7-2**. Gamma survey instruments will be checked before each day of use in accordance with the manufacturer's instructions. Surveys are performed in accordance with RG 8.30 (NRC 2002b).

To date, beta surveys of specific operations at the CPF that involve direct handling of aged yellowcake as recommended in RG 8.30, Section 1.4 have been performed in accordance with the instructions in SHEQMS Volume IV, Health Physics Manual. Beta evaluations may be substituted for surveys using radiation survey instruments. As noted earlier, Cameco is evaluating the

implications of short-lived beta-emitting isotopes at the CPF and will incorporate the results of that evaluation, as appropriate, into the Radiation Protection Program for both the CPF and the MEA.

5.7.2.2 Personnel Dosimetry

10 CFR §20.1502 (a)(1) requires exposure monitoring for "Adults likely to receive, in 1 year from sources external to the body, a dose in excess of 10 percent of the limits in §20.1201 (a)". Ten percent of the dose limit would correspond to a Deep Dose Equivalent (DDE) of 0.500 Rem. Maximum individual annual exposures at the Crow Butte Uranium Project facilities since 1987 have been well below the limit, with a maximum individual external exposure of 495 mRem in 1995.

CBR determines monitoring requirements in accordance with the guidance contained in RG 8.34 (NRC 1992a). Although monitoring of external exposure may not be required in accordance with §20.1201(a), CBR currently issues dosimeters to all process employees and exchanges them quarterly. The MEA process facility and wellfield operators would be included in this program.

Dosimeters are provided by a vendor that is accredited by National Voluntary Laboratory Accreditation Program (NVLAP) of the National Institute of Standards and Technology as required in 10 CFR § 20.1501. The dosimeters have a range of 1 mR to 1,000 R. Dosimeters are exchanged and read quarterly.

Results from personnel dosimetry will be used to determine individual DDE for use in determining TEDE in accordance with the instructions currently contained in the SHEQMS Volume IV, Health Physics Manual. External radiation exposure monitoring will be documented on NRC Form 5 or its equivalent.

CBR has data for other external dose parameters such as Shallow Dose Equivalent (SDE) and Lens Dose Equivalent (LDE) for the existing site. As with the DDE, it can be shown that the external doses are all less than 10 percent of the applicable limits. Extremity monitoring is required when the dose to the extremity is higher than the dose to rest of the body. This would be applicable to beta doses associated with aged yellowcake sources as discussed in Section 5.7.2.1.

5.7.2.3 Cumulative Exposures

Based on the proposed type of operations (i.e., wet process) and historical exposures at the current operations, no significant increase in risks associated with exposure levels are expected for employees that work at the MEA site and the current main operating CPF. The satellite facility will have a full-time staff dedicated to working at that site. However, there may be some employees who would work at both locations for specified periods of time. Regardless of work locations, all CBR employees would be monitored for occupational external exposure if the exposure is likely to exceed 10 percent of the occupational dose limit appropriate for the individual (e.g., adult or declared pregnant woman), as specified in 10 CFR 20 1201 (a). As stated above, all wellfield and facility personnel at the satellite facility will be included in the dosimetry program. The RSO would be responsible for determining the radiological monitoring requirements for all employees based on the facility radiation levels, worker job locations and tasks, and specific licensing requirements. The RSO would be responsible for reviewing the dosimetry results and comparing them with past data and regulatory exposure limits.

5.7.2.4 Exposure Reporting

The results of all radiation monitoring will be documented by the RSO and recorded as directed by Regulatory Guide 8.7. Routine and non-routine external and internal exposures will be recorded in the employee exposure database.

All monitoring data will be reviewed on an annual basis to assess trends and ensure that potential exposures to individuals for which monitoring is not required remains below 10% of the applicable standard.

In accordance with 10 CFR §19.13(b), monitored employees will be advised in writing on an annual basis of their calculated TEDE. Additionally, any employee may request a written report of their exposure history at any time. These reports will be provided within 30 days of the request and will provide the information outlined in 10 CFR §19.13.

Documentation of employee exposure reporting will include:

- Name
- SSN (where available)
- Gender
- Date of birth
- Monitoring period
- Licensee name and license number
- Quarterly deep dose
- Internal Exposures (Airborne Uranium, Radon Daughters)
- Deep, Committed Effective Dose Equivalent
- History

5.7.3 Satellite Facility Airborne Radiation Monitoring Program

The proposed airborne sampling location for the satellite facility is shown on **Figure 5.7-2**. The locations of the sampling points for radon, airborne uranium, and gamma surveys are based on experience with similar equipment and operations at the current CBR operations. Factors that would be considered are the stage of the process (some areas more prone to exposure than others), potential known release points associated with the equipment and operations, and airflow patterns (based on current CBR operations). The sites selected are expected to carry the highest potential for exposure (**Figure 5.7-2**). Proposed satellite facility survey and sampling locations address potential releases of radiological contaminants (specific release points in the process and resin storage areas) and in areas where sampling would identify any elevated exposure levels due to inadvertent contamination (i.e., office, change room, and restroom). Sampling points in the process area are similar to those in other proposed satellite facilities. During the first year of operation, CBR will assess the sampling locations and determine whether these locations provide data representative of the concentrations to which workers would be exposed.

The satellite facility would be subject to requirements of the SHEQMS Volume III, Operating Manual, which has a section on the operation of the ventilation system.

Locations of sample points are based, in part, on a determination of airflow patterns in areas where monitoring is needed. Once the ventilation system is installed and operational, and prior to process

operations, a portable anemometer would be used to assess the ventilation patterns (i.e., direction and velocity) in the work areas. Specific attention would be given to areas perceived as having a higher risk for releases. Assessments would be made of any different configurations that may be used for the ventilation system. The RSO would work with those designing the ventilation system to minimize worker exposure and to locate monitors at the optimum locations, drawing upon experience from the current CBR operating facilities.

Once the final design has been completed, the RSO and operations staff would assess the most optimum locations for radiological sampling points. Once the facility is constructed and operational, another assessment would be made of the sampling points and results, the need for any changes to the monitoring points and frequency would be determined.

Monitoring locations and planned surveys would be consistent with RG 8.30. The airborne radiation monitoring program would allow for the determination of concentrations of airborne radioactive materials (including radon) during routine and non-routine operations, maintenance, and cleanup. The controls and monitoring program will be sufficient to limit airborne radiation exposures and airborne radioactive releases ALARA and will conform to regulatory requirements identified in 10 CFR Part 20.

5.7.3.1 Airborne Uranium Particulate Monitoring

Airborne particulate levels at ISR facilities that ship loaded IX resin are normally very low because the product is wet. No precipitation, drying, or packaging of source material will be performed at the MEA. Yellowcake will be dried and packaged at the CPF. Therefore, the airborne uranium concentrations should be at or near local background levels. One location near the resin transfer station will be sampled monthly for airborne uranium particulates.

Airborne air particulate area samples will be taken in accordance with the instructions currently contained in SHEQMS Volume IV, Health Physics Manual. The Air Monitoring Chapter implements the guidance contained in RG 8.25 (NRC 1992b). Samples will be taken with a glass fiber filter and a regulated air sampler such as an Eberline RAS-1 or equivalent. Sample volume will be adequate to achieve the LLD for uranium in air. The LLD value for uranium in air would be $5e^{-11}$ µCi/ml, which is 10 percent of the Crow Butte Site-Specific DAC. Samplers will be calibrated at the manufacturer's suggested interval or semiannually with a digital mass flowmeter or other primary calibration standard. Samplers will be calibrated in accordance with the instructions currently contained in SHEQMS Volume IV, Health Physics Manual.

Breathing zones are sampled to determine individual exposure to airborne uranium during certain operations involving potential airborne exposure. Individual breathing zone monitoring may be required infrequently, at times when engineering controls are impracticable or inoperable (non-routine operations). This would include maintenance activities (e.g., tank entry, disconnection of piping, repair of equipment such as pumps) required to maintain or regain control of normal production activities. An RWP is required for activities that carry the potential for significant exposure to radioactive materials and for which there are no SOPs. The RWPs dictate the proper type of breathing zone monitoring and identifies procedures for protection against radiological hazards during the course of the work activity. Certain SOPs require individual monitoring, such as workers transferring resin beads, changing the bicarbonate mix system filter media, and changing deep disposal filter media.

Sampling is performed with a lapel sampler or equivalent. The air filters are counted and compared to the DAC using the same method described for area sampling. Air samplers are calibrated at the manufacturer's recommended frequency or daily before each use using a primary calibration standard.

Airborne uranium will be measured by gross alpha counting of the air filters using an alpha scaler such as a Ludlum Model 2000 or equivalent.

5.7.3.2 CBR Site-Specific DAC

Cameco analyzed the solubility characteristics of Crow Butte yellowcake, and the material was then classified according to the days, weeks, and years (D/W/Y) classification scheme of 10 CFR Part 20. The complete report, provided in **Appendix L,** includes a dosimetry interpretation.

This study showed that the yellowcake produced at Crow Butte was primarily of solubility type D with a relatively low type W component. The resulting Annual Limit on Intake (ALI) and DAC values are therefore 1 μCi and $5.0E^{-10}$ μCi/ml, respectively.

The expected mix of long-lived radionuclides would be predominantly natural uranium with a lesser amount of radium-226. The DAC for radium-226 is $3x10^{-10}$ μCi/ml. The DAC for the mixture would be between the natural uranium DAC and the radium-226 DAC. As noted earlier, Cameco is evaluating this issue at the CPF and will incorporate the results of that evaluation, as appropriate, into the Radiation Protection Program for both the CPF and the MEA.

An action level of 25 percent of the DAC for soluble natural uranium will be established at the satellite facility. If an airborne uranium sample exceeds the action level of 25 percent of the DAC, the cause will be investigated. If a monthly airborne uranium sample exceeds 25 percent of the action level, the sampling frequency would be increased from monthly to weekly until the airborne uranium levels do not exceed the action level for 4 consecutive weeks. The RSO may initiate corrective actions that may reduce future exposures.

No dose is calculated when comparing the measured airborne uranium concentrations to the natural uranium DAC. The purpose for this comparison is to see if the airborne uranium concentration is higher than the administrative action level of 25 percent DAC, which triggers an investigation. If internal doses are required to be estimated pursuant to 10 CFR 20.1202, methods described in Section 5.7.4 of the application will be used.

Per 10 CFR 20.1201 (e), in addition to the annual dose limits, the intake of soluble uranium by an individual is limited to 10 mg in a week in consideration of chemical toxicity. If exposure to soluble uranium exceeds 25 percent of the weekly allowable intake of 10 mg, which would be 2.5 mg/week, then the RSO would investigate the cause of the occurrence and initiate corrective actions that may reduce future exposures. As with any hazardous material handled on the site, the ALARA program would be applied to such potential chemical exposures, as described in Section 2.5 of the SHEQMS Volume III Health Physics Manual.

Any worker likely to receive, in 1 year, an occupational dose in excess of 10 percent of the limits in 10 CFR 20 1201(a) will be monitored. The RSO will use historical and current monitoring and survey data to confirm worker external radiation exposures. The external and internal doses that

an individual may be allowed to receive in the current year may be reduced by the amount of occupational dose received or amount of intake while employed by any other person. The record of prior occupational dose that the individual received while performing work involving radiation exposure would be obtained per 10 CFR 20.2104.

All new employees would be asked to provide their past radiological exposure history and to sign an Exposure Release Form so previous radiological exposure history may be obtained. If a complete record of the individual's current and previously accumulated occupation dose is not available, the allowable dose limit for the individual would be reduced by 1.25 Rems (12.5 mSv) for each quarter for which records were unavailable and the individual worker engaged in activities that could have resulted in occupational radiation exposure. It would also be assumed that the individual would not be available for planned special exposures. Per 10 CFR 20.2104, CBR would not be required to partition historical data between external dose equivalent(s) and internal committed dose equivalent(s).

5.7.3.3 Radon Daughter Concentration Monitoring

Surveys for radon daughter concentrations will be conducted monthly in the operating areas of the satellite facility. Sampling locations will be determined in accordance with the guidance contained in RG 8.25. Section 3.1 of RG 8.25 states "lapel samplers or samplers located within about 1 foot of the workers head may be accepted as representative without further demonstration that the results are representative." Working Level (WL) measurements will be made using the Modified Kusnetz method (ANSI-N13.8-1973), which involves taking a grab sample, typically every 5 minutes, and analyzing the filter for alpha activity. This grab sample will be taken at locations depicted on **Figure 5.7-2** at a height typical of a worker's breathing zone and within the breathing zone of the worker collecting the sample.

Routine radon daughter monitoring will be performed in accordance with the instructions currently contained in the SHEQMS Volume IV, Health Physics Manual. Samplers will be calibrated at the manufacturer's suggested interval or daily before use with a digital mass flowmeter or other primary calibration standard. Air samplers will be calibrated in accordance with the instructions currently contained in the SHEQMS Volume IV, Health Physics Manual.

Results of radon daughter sampling are expressed in WLs where one WL is defined as any combination of short-lived radon-222 daughters in one liter of air without regard to equilibrium that emit 1.3×10^5 MeV of alpha energy. The DAC limit from Appendix B to 10 CFR §§ 20.1001 - 20.2402 for radon-222 with daughters present is 0.33 WL. CBR has established an action level of 25 percent of the DAC or 0.08 WL. The LLD for radon measures would be 0.033 WL, which is 10 percent of the DAC limit. Radon daughter results in areas with an average concentration in excess of the action level will result in an investigation of the cause and an increase in the sampling frequency to weekly until the radon daughter concentration levels do not exceed the action level for 4 consecutive weeks.

5.7.3.4 Respiratory Protection Program

Respiratory protective equipment has been supplied by CBR for activities where engineering controls may not be adequate to maintain acceptable levels of airborne radioactive materials or

toxic materials. Use of respiratory equipment at Crow Butte Uranium Project is in accordance with the procedures currently set forth in the SHEQMS Volume IV, Health Physics Manual.

The respirator program is designed to implement the guidance contained in RG 8.15 (NRC 1999b) and RG 8.31 (NRC 2002a). The respirator program is administered by the RSO as the Respiratory Protection Program Administrator (RPPA).

Because airborne uranium concentrations at the satellite facility during typical operations are not expected to exceed action levels, it is not expected that respirator use will be required for normal operation of the satellite facility. However, any time the potential exists for elevated exposures to employees, respirators could be required. For example, certain maintenance activities (e.g., tank entry, disassembly of potentially contaminated piping and equipment, and welding/grinding on contaminated piping/equipment) and failure of the process building ventilation system could require the use of respirators. The use of respirators at MEA would be determined by SOPs and RWPs for specific tasks. The CBR respirator policy and requirements of respirator use are discussed in detail in the SHEQMS.

5.7.4 Exposure Calculations

Employee internal exposure to airborne radioactive materials at the satellite facility will be determined based upon the requirements of 10 CFR § 20.1204 and the guidance contained in RGs 8.30 and 8.7 (NRC 2002b and 1992c). Following is a discussion of the exposure calculation methods and results.

5.7.4.1 Natural Uranium Exposure

Exposure calculations for airborne natural uranium are carried out using the intake method from RG 8.30, Section 3. The intake is calculated using the following equation:

$$I_u = b \sum_{i=1}^{n} \frac{X_i \times t_i}{PF}$$

where:

I_u	=	uranium intake, μg or μCi
t_i	=	time that the worker is exposed to concentrations X_i (hr)
X_i	=	average concentration of uranium in breathing zone, μg/m^3, μCi/m^3
b	=	breathing rate, 1.2 m^3/hr
PF	=	the respirator protection factor, if applicable
n	=	the number of exposure periods during the week or quarter

The intake for uranium is calculated and recorded. The intakes are totaled and entered onto each employee's Occupational Exposure Record.

The data required to calculate internal exposure to airborne natural uranium are determined as follows.

Time of Exposure Determination

One hundred percent occupancy time is used to determine routine worker exposures. Exposures during non-routine work are always based upon actual time.

When calculating radiological exposures for the satellite facility, the occupancy time for "routine" operations would be an exposure period based on actual hours worked (12-hour shift period for facility personnel). This would be considered a 100 percent occupancy time. For such routine exposures (i.e., 12-hour shift period), it is assumed that the worker was exposed to the measured "work area" average concentration of uranium for the entire work period (exposure 100 percent of the time). During part of that exposure period, the worker would be expected to spend some time in non-work areas such as the lunch room, office, restroom, hallways, and other areas. The 100 percent occupancy time approach generally results in a conservative (i.e., higher than actual) estimate of internal exposure to airborne natural uranium because it does not account for time the employee may have spent outside the work area, as described above.

The measured average airborne uranium concentration is multiplied by the time of worker exposure (12 hours) to obtain the estimated average worker exposure for that time period. Routine operations refer to the facilities operating in a normal fashion with no upsets, maintenance activities, or other activities that may result in non-routine and elevated exposures. If a worker works more than the normal 12-hour shifts, the measured average airborne uranium concentration and the total hours actually worked are used to establish exposure levels.

Measured exposures during non-routine work tasks (e.g., maintenance or cleanup) are based on actual time. The results of breathing zone samples collected during maintenance activities or RWPs are from a specific time period and are added to the calculations of routine employee exposures for a given work period. For example, a worker working under a RWP for 2 hours would have exposures based on measurements taken for that time period (actual time), with the exposures for the remaining 10 hours of routine work based on the measured average concentration of airborne uranium.

Airborne Uranium Activity Determination

Airborne uranium activity is determined from surveys performed as described in Section 5.7.3.1.

CBR proposes to institute the same internal airborne uranium exposure calculation methods at the satellite facility that have been used to date at the CPF and which are currently described in the SHEQMS Volume IV, Health Physics Manual. Exposures to airborne uranium will be compared to the site-specific Crow Butte Operations DAC developed in response to NRC comments. The information was provided pursuant to a request for confidentiality by email dated March 14, 2011 with further clarifications submitted by email on April 5, 2011 (ML11102020132). The results show that the average ALI for the Crow Butte Operations yellowcake is 0.98μCi and the average DAC is 4.8E-10μCi/ml. For consistency with the convention used to round values in the regulation, an ALI and DAC of 1μCi and 5E-10μCi/ml will be used. Footnote 3 in Table 1 of Appendix B to 10 CFR 20 states "the specific activity for natural uranium is 6.77 E-7 curies per gram U". This is

equivalent to 6.77 E^{-7} µCi/µg of natural uranium. This is the specific activity CBR will use to calculate the mass of uranium from an activity measurement and vice versa.

When required by 10 CFR 20.1202, CBR will use methods in RG 8.30 to estimate internal doses. As an example, the Committed Effective Dose Equivalent (CEDE) can be calculated using Equation 2 in RG 8.30 where:

H_{iE}	=	CEDE from radionuclide (Rem)
I_i	=	is the intake in µCi of Class D natural uranium as determined by the equation in Section 5.7.4.1 of the application
ALI_{iE}	=	Value of the stochastic inhalation ALI for natural uranium from Column 2 of Table 1 in Appendix B to 10 CFR Part 20 (2 µCi)
5	=	CEDE from intake of 1 ALI (Rem)

If an intake (I_i) of 0.5 µCi was determined using the stated equation, the estimate CEDE from this intake would be:

H_{iE} = 5*0.5/2 = 1.25 Rem

If an intake (I_i) of 0.5 µg of natural uranium was determined using the stated equation, the estimated CEDE from this intake would be:

H_{iE} = 5*0.5*6.77 E-7/2 = 8.5 E-7 Rem

It should be noted that the weekly limit for soluble uranium in 10 CFR 20.1202 (e) due to chemical toxicity is 10 milligrams (10,000 µg), which would be equivalent to a CEDE of 17 mRem per week or 844 mRem per year. The occupational weekly toxicity limit for Class D natural uranium is more restrictive than the radiological limit.

5.7.4.2 Radon Daughter Exposure

Exposure calculations for airborne radon daughters are carried out using the intake method from RG 8.30, Section 3. The radon daughter intake is calculated using the following equation:

$$I_r = \frac{1}{170} \sum_{i=1}^{n} \frac{W_i \times t_i}{PF}$$

where:

I_r	=	radon daughter intake, WLmonths
t_i	=	time that the worker is exposed to concentrations W_i (hr)
W_i	=	average number of WLs in the air near the worker's breathing zone during the time (t_i)
170	=	number of hours in a working month
PF	=	the respirator protection factor, if applicable
n	=	the number of exposure periods during the year

The data required to calculate exposure to radon daughters are determined as follows.

Time of Exposure Determination

One hundred percent occupancy time is used to determine routine worker exposure times. Exposures during non-routine work are always based upon actual time. A clarification of the 100 percent occupancy time is presented in Section 5.7.4.1 for natural uranium exposure. This explanation would also apply to radon daughter exposure.

Radon Daughter Concentration Determination

Radon-222 daughter concentrations are determined from surveys performed as described in Section 5.7.3.3. The WL months (WLMs) for radon daughter exposure are calculated and recorded. The WLMs are totaled and entered onto each employee's Occupational Exposure Record.

CBR proposes to institute the same internal radon daughter exposure calculation methods at the satellite facility that have been used to date and which are currently contained in the SHEQMS Volume IV, Health Physics Manual. Exposures to radon daughters will be compared to the DAC for radon daughters from Appendix B of 10 CFR §§20.1001 - 20.2401 (0.33 WL).

The equation above calculates WLMs. If required by 10 CFR 20.1202, CBR can calculate a CEDE from the WLM estimate using Equation 2 in RG 8.30 where:

H_{iE}	=	CEDE from radionuclide (Rem)
I_i	=	the intake in WLM of radon-222 and its associated progeny as determined by the equation in this section.
ALI_{iE}	=	Value of the stochastic inhalation ALI for radon-222 with progeny present from Column 2 of Table 1 in Appendix B to Part 20 (4 WLM)
5	=	CEDE from intake of 1 ALI (Rrem)

If an intake (I_i) of 1 WLM was determined using the stated equation, the estimate CEDE from this intake would be:

$$H_{iE} = 5*1/4 = 1.25 \text{ Rem}$$

5.7.4.3 Prenatal and Fetal Exposure

Dose Equivalent to an Embryo/Fetus

10 CFR §20.1208 requires that licensees ensure that the dose equivalent to an embryo/fetus during the entire pregnancy, due to the occupational exposure of a declared pregnant woman, does not exceed 0.5 Rem (5 mSv). Licensees are also required to make efforts to avoid substantial variation above a uniform monthly exposure rate to a declared pregnant woman that would satisfy the 0.5 Rem limit. The dose equivalent to the embryo/fetus is calculated as the sum of (1) the DDE to the declared pregnant woman; and, (2) the dose equivalent to the embryo/fetus resulting from radionuclides in the embryo/fetus and radionuclides in the declared pregnant woman. If the dose equivalent to the embryo is determined to have exceeded 0.5 Rem (5 mSv), or is within 0.05 Rem (0.5 mSv) of this dose, by the time the woman declares the pregnancy to the licensee, the licenses

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

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 5.7.9 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

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 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.

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.

5.7.7.4 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 and adhering to the LLD concentration limits discussed in Section 2.9.6.

5.7.7.5 Vegetation

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.

5.7.7.6 Food Crops, Livestock, and Fish

Food Crops (garden vegetables)

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

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**.

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 5.7.9 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 5.7.9.

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 5.7.9 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.

5.7.10 **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

6 GROUNDWATER QUALITY RESTORATION, SURFACE RECLAMATION, AND FACILITY DECOMMISSIONING

6.1 Plans and Timelines for Groundwater Restoration

The objective of the Restoration and Reclamation Plan is to return the affected ground water and land surface to the uses for which they were suitable before mining. The methods to achieve this objective for both the affected groundwater and the surface are described in the following sections. Before discussing restoration methodologies, the ore body genesis and chemical and physical interactions between the ore body and the lixiviant are discussed.

6.1.1 Ore Body Genesis

The uranium deposit in the MEA is similar to that found in the CPF license area. It is a roll-front deposit in fluvial sandstone and is similar to those in the Wyoming such as the Gas Hills, Shirley Basin, and the Powder River Basin. The origin of the uranium in the deposit could lie within the host rock itself from either the feldspar or volcanic ash content of the Chadron Sandstone. The source of the uranium could also be volcanic ash of the Chadron Formation, which overlays the Chadron Sandstone. Regardless of the source of the uranium, it has precipitated in several long, sinuous roll fronts. The individual roll fronts are developed within subunits of the Chadron Sandstone. The Chadron Sandstone is divided into local subunits by thin clay beds that confined the uranium-bearing waters to several distinct hydrological subunits of the sandstone. These clay beds are laterally continuous for hundreds of feet but control the deposition of the uranium over greater distances as other clay beds exert vertical control when the locally controlling beds pinch out. Precipitation of the uranium resulted when the oxidizing water containing the uranium entered reducing conditions. These reducing agents are likely H_2S and, to a lesser degree, organic matter and pyrite. More detailed discussions of the geochemical description of the mineralized zone are presented in Section 2.6.1.2.

Solution mining of the deposit is accomplished by reversing the natural processes that deposited the uranium. Oxidizing solution is injected into the mineralized portion of the Chadron Sandstone to oxidize the reduced uranium and to complex it with bicarbonates. Pumping from recovery wells draws the uranium-bearing solution through the mineralized portion of the sandstone. The presence of reducing agents will increase oxidant requirements over that necessary to only oxidize the uranium.

Because the deposition of the uranium was controlled between clay beds within the Chadron Sandstone, the mining solutions will be confined to this portion of the sandstone by selectively screening these intervals. This will limit the contamination and thus the required restoration of unmineralized portions of the sandstone.

6.1.2 Chemical and Physical Interactions of Lixiviant with the Ore Body

The following discussion is based on a range of lixiviant conditions from 0.5 to 3.0 grams per liter total carbonate and a pH from 6.5 to 9.0 su. This represents the normal range of operating conditions for the MEA *in-situ* mining operations.

6.1.2.1 Ion Exchange

The principal IX reaction is the exchange of sodium from the lixiviant onto exchangeable sites on ore minerals with the release into solution of calcium, magnesium, and potassium. This reaction can be shown as follows:

$$Ca_{clay} + 2\ Na^{+}_{solution} = 2\ Na_{clay} + Ca^{++}_{solution}$$

Similar reactions can be written for magnesium and potassium. Due to higher solubility of their sulfate and carbonate compounds and their low concentrations in Chadron Sandstone and the ore, magnesium and potassium in solution have no impact. The limited solubility of calcium carbonate ($CaCO_3$), and to a lesser degree, calcium sulfate, may lead to the potential for calcium precipitation.

Laboratory tests have indicated that the maximum calcium IX capacity of the ore in a sodium lixiviant with 3.0 g/L total carbonate strength is 1.21 meq of calcium per 100 grams of ore. This equates roughly to 0.5 pound of calcium or about 1.2 pounds of calcium carbonate per ton of ore that could potentially precipitate. Not all of this calcium, however, will be realized because laboratory testing is run to indicate the maximum amount of calcium that can be exchanged. Somewhat less than this amount will be released and only a portion of that precipitated. There is no way to directly control the buildup of calcium in the lixiviant circuit. In practice, the lixiviant carbonate concentration and the lixiviant pH are controlled. The formation characteristics dictate an equilibrium calcium concentration in the lixiviant system, and IX and/or precipitation will occur until the equilibrium is satisfied. The production bleed represents a departure from this equilibrium and as such has some effect on the amount of calcium exchanged. If the bleed is kept generally small, on the order of 0.5 percent, the effect of the bleed on the IX is small.

6.1.2.2 Precipitation

In the presence of carbonate ions and bicarbonate ions in the lixiviant system, calcium ions will precipitate provided the limit of saturation has been reached. Calcium precipitation is a function of total carbonate, pH, and temperature. For example, at 15° C, a pH of 7.5 su, and 1 g/L carbonate in lixiviant, the equilibrium solubility of calcium is approximately 40 to 100 ppm. Some uncertainty is seen in these numbers due to the effect of ionic strength and supersaturation considerations. However, these figures illustrate the effect of carbonate concentration and pH on the equilibrium solubility of calcium.

The amount of calcium produced depends on the IX that is taking place, while the precipitation of calcium is a function of the lixiviant chemistry and the degree of supersaturation observed in the system. As a first approximation, the proportion of calcium precipitation occurring aboveground and underground will occur in the ratio of the residence times. In other words, if the residence time is much longer underground than it is aboveground, as is the case for most ISR operations including those projected for the MEA, then more of the calcium will precipitate underground than aboveground. The calcium precipitation is a function of turbulence in the solution, changes in dissolved CO_2 partial pressure or pH, and the presence of surface area. The most likely places for calcium to precipitate are underground where the ore provides abundant surface area for precipitation; at or near the injection or production wellbore where changes in pressure, turbulence, and CO_2 partial pressure are all observed; and on the surface in the filters, in pipes, and in tanks. If

all the calcium were to precipitate (based on 1.2 pounds of $CaCO_3$ per ton of ore) the precipitate would occupy about 0.15 percent of the void space in that ton of ore.

Calcium may be removed from the system in two ways:

- Filters will be routinely backwashed to the MEA wastewater system (i.e., wastewater tanks in the satellite building) and periodically acid cleaned, if necessary, to remove precipitated $CaCO_3$ from the filter housing or filter media.
- The solution bleed (approximately 0.5 to 1.0 percent) taken to create overproduction and a hydrologic sink in the mining area eliminates some calcium from the system.

Should precipitation of calcium carbonate at or near the wellbore of the wellfield wells become a problem, these wells may be air lifted, surged, water jetted, or acidified to remove the precipitated calcium. Any water recovered from these wells containing dissolved $CaCO_3$ or particulate $CaCO_3$ is collected and placed into the waste disposal system. Upon decommissioning, $CaCO_3$ from the facility equipment tank residues will be disposed of in either a licensed tailings pond or a commercial disposal site.

The other possible precipitating species that has been identified is iron, which could precipitate as either the hydroxide or the carbonate, causing some fouling. Such fouling is usually evidenced by a reduction in the IX capacity of the resin in the extraction circuit. Should this fouling become a serious problem, the resin can be washed and the wash solution disposed of in the waste disposal system. Due to the small amount of iron present in the Chadron Sandstone, iron precipitation has not been a problem in mining operations to date.

6.1.2.3 Hydrolysis

Hydrolysis reactions, which involve minerals and hydrogen or hydroxide ions, do not play an important role in the ore/lixiviant interaction. In the pH range of 6.5 to 9.0 su, the concentration of hydrogen and hydroxide ions is so small that these types of reactions do not occur to any great degree. The only potential impact would be a small increase in the dissolved silica content of the lixiviant system and a possible small increase in the cations associated with the siliceous minerals. The hydrolysis reaction does not have a significant effect on operations.

6.1.2.4 Oxidation

The oxidant consumers in the basal sandstone of the Chadron Formation are H_2S in the groundwater, uranium, vanadium, iron pyrite, and other trace and heavy metals. The impact of these oxidant consumers on the operation of the facility is a general increase in the oxidant consumption over that which would be required for uranium alone. The second effect is a release of iron and sulfate into solution from the oxidation of pyrite. A third effect is an increase in the levels of some trace metals such as arsenic, vanadium, and selenium into solution. As mentioned previously, the iron solubilized will most likely be precipitated as the hydroxide or carbonate, depending on its oxidation state. Any vanadium oxidized along with the uranium will be solubilized by the lixiviant, recovered with the uranium, and could potentially contaminate the precipitated yellowcake product. H_2O_2 precipitation of uranium is used to reduce the amount of vanadium precipitated in the product. Oxidation will also solubilize arsenic and selenium. The restoration program will return these substances to acceptable levels. A final potential oxidation

reaction is the partial oxidation of sulfur species, increasing the concentrations of compounds such as polythionates, which can foul IX resins. In *in-situ* operations with chemistries similar to the MEA, these sulfur species are completely oxidized to sulfate, which poses no problems.

6.1.2.5 Organics

Organic materials are generally not present in the MEA ore body at levels greater than 0.1 to 0.2 percent. Where present, organic materials effectively increase the oxidant consumption and reduce uranium leaching. On longer flow paths, organic material could potentially re-precipitate uranium should all of the oxidant be consumed and conditions become reducing. Another potential impact of mobilized organics could be the coloring and fouling of leach solutions. As the aquifer is maintained in the pH range of 6.5 to 9.0 su, mobilization of the organics and coloring of the leach solution is avoided.

6.1.3 Basis of Restoration Goals

The primary goal of the groundwater restoration program is to return groundwater affected by mining operations to pre-injection baseline values on an MU average as determined by the baseline water quality sampling program. This sampling program is performed for each MU before mining operations commence. Should restoration efforts be unable to achieve baseline conditions after diligent application of the best practicable technology available, CBR commits, in accordance with the Nebraska Environmental Quality Act and NDEQ regulations, to return the groundwater to the restoration values set by the NDEQ in the Class III UIC Permit. These secondary restoration values ensure that the groundwater is returned to a quality consistent with the use, or uses, for which the water was suitable prior to ISR mining. These secondary restoration values are approved by the NDEQ in the individual Notices of Intent (NOIs) for each MU based on the permit requirements and the results of the baseline monitoring program.

EPA groundwater protection standards issued under the authority of the Uranium Mill Tailings Radiation Control Act (UMTRCA) are required to be followed by ISR licenses of the NRC and its Agreement States. The EPA regulations issued under UMTRCA authority provide the principal standards for uranium ISR operations and groundwater protection, while the UIC regulations are considered additional requirements for ISR operations. CBR is required to restore groundwater quality to the standards listed in Criterion 5B (5) of 10 CFR Part 40, Appendix A as required by the UMTRCA, as amended. Under EPA requirements, groundwater restoration at ISR facilities must meet the UMTRCA standards and not those associated with the Safe Drinking Water Act or analogous state regulations.

Under Criterion 5B (5) of 10 CFR Part 40, Appendix A, at the point of compliance (mine unit after restoration), the concentration of hazardous constituent must not exceed:

a. The NRC approved background concentration of that constituent in the groundwater
b. The respective value given in **Table 6.1-1** for the UMTRCA values if the constituent is listed in the table and of the background level of the constituent is below the value listed or
c. Alternate concentration limit established by the NRC.

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. 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

quarterly monitoring will continue until the data from the most recent four consecutive quarters indicate no statistically significant increasing trend for all constituents of concern. At that point, stabilization will be deemed complete subject to approval.

Throughout restoration and stabilization, excursion monitoring consistent with Section 5.7.8.2 will continue until NRC determines that groundwater stabilization has been demonstrated. Stability monitoring may continue beyond the 6-month period as necessary. Stability monitoring will conclude, instead, when stabilization samples show that restoration goals on an MU average for monitored constituents are met and there is no significant increasing trend for a minimum of four quarters. At the end of the stabilization period, when restoration parameters have been achieved and there are no significant increasing trends for any of the restoration parameters, a request would be made to the appropriate regulatory agencies. A cone of depression (inward hydraulic gradient) is not maintained during stabilization.

During mining until the start of stabilization, an overall hydrologic bleed will be maintained within the perimeter monitor well ring to prevent lateral migration of mining lixiviant. If a proper hydrologic bleed is not maintained, it is possible for water with chemistry similar to that in **Table 2.7-6** column "Typical Water Quality During Mining at CPF" to begin migrating toward the monitor well ring. The mobile ions, such as chloride and carbonate, would be detected at the monitor well ring, and adjustments would be made to reverse the trend. The maintenance of a hydrologic bleed and the close proximity of the monitor well ring, less than 300 feet from the mining patterns, will ensure control of mining fluid. Vertical migration of fluid is less of a concern than lateral migration due to the underlying and overlying aquitards. The vastly different piezometric heads between the Lower and Middle Chadron, as well as the results of the pumping test, support the conclusion that the Lower Chadron is vertically isolated.

Crow Butte initiated a bioremediation pilot study in MU 4 at the existing CPF on December 17, 2008. If CBR decides to employ this type of bioremediation in the future, a request for a license amendment will be submitted to the NRC.

6.1.4.2 Restoration Process

Restoration activities include four steps designed to optimize restoration equipment used in treating groundwater and to minimize the number of pore volumes circulated during the restoration stage. The number of pore volumes that would be displaced during groundwater restoration would be as follows: three pore volumes through IX treatment; six pore volumes through the RO; and two pore volumes of recirculation (total of 11 pore volumes for restoration). CBR will monitor the quality of selected wells during restoration to determine the efficiency of the operations and to determine if additional or alternate techniques are necessary.

Because the final layout of the MUs has not been defined, an assumed pore volume for the MUs will be calculated as per the following:

Pore Volume (PV) = area x thickness x porosity x flare factor x 7.48 gal/ft^3

The calculated pore volume will be based on the square footage of the potential wellfield area, average under-ream interval of approximately 25 feet and an assumed 29 percent open pore space value, and an assumed flare factor of 20 percent. As additional drilling is performed, these values

may be refined for use in calculating surety. All of these values are based upon experience at the CPF.

The CPF has geology and hydrology that is very similar to Marsland. Because there are fewer stacked roll fronts at Marsland, Cameco expects an under-ream interval closer to 20 feet. The 29 percent assumed open pore space value remains valid at Marsland.

NUREG-1569 indicates that, for surety purposes, the licensee should include the flare factor in its calculation of the number of pore volumes necessary for groundwater restoration (NRC 2003). The flare factor is defined by the NRC *as a proportionality factor designed to estimate the amount of aquifer water outside of the pore volume that has been impacted by lixiviant flow during the extraction process*. The flare factor is usually expressed as a horizontal and vertical component to account for differences between the horizontal and vertical hydraulic conductivity of an aquifer material (NRC 2003). At the MEA little vertical flare is expected by virtue of the consistent overlying clay breaks and the underlying Pierre Shale.

The horizontal and vertical flares are typically expressed as a multiple of the calculated pore volume. However, R/CR-6870 states that there are zones with low permeabilities that have proven more of a concern than in a wellfield where the balance is maintained. As in the case of the current CBR operations, a wellfield at MEA will be balanced on an individual pattern basis. Within the uranium ISR industry, this is the most effective way to mine an *in-situ* wellfield and restore groundwater (Powertech 2009). During operations, CBR will balance the MEA individual wells daily, a method that will reduce the pore volumes for restoration and minimize excursions beyond the flare zone.

Acceptance Criteria 2 in Section 6.1.3 of RG-1569 (NRC 2003) states, "Specific flare factors approved in the past vary from 20 to 80 percent and are typically based on experience from research and development pilot demonstrations." CBR's technical basis for the proposed 20% flare factor is the limited vertical flare and operational experience and hydrological modeling at the CPF. Given the similar operating approach and similar geology and hydrology, the NRC 2011 determination of 20% as an acceptable flare at the CPF is also appropriate for calculating pore volume at the MEA (NRC 2012b; ML110320362)

As an example for use in the license application surety calculation, the calculated pore volume for a 75 acre MEA wellfield will be approximately 177,193,095 gallons. A 75 acre wellfield is the maximum area allowed by the State of Nebraska. In fact, the wellfields at the CPF average 50 to 60 acres and similar, smaller wellfields expected at the MEA. This is based on a calculated square footage (75 acres = 3,267,000 ft^2) of the example wellfield, an average under-ream interval of 25 feet, an estimated 29 percent open pore space value and a 20 percent flare factor. As noted earlier, this example calculation over estimates both the area and the under-ream interval, so that surety calculations for wellfields will be based upon the actual area and under-ream interval.

<u>Groundwater Transfer</u>

During groundwater transfer, water may be transferred between the MU commencing restoration and an MU commencing mining operations. The higher TDS water from the MU in restoration is recovered and injected into the MU commencing mining. The direct transfer of water will act to lower the TDS in the MU being restored by displacing water affected by the mining with baseline quality water.

The goal of the groundwater transfer step is to blend the water in the two MUs until they become similar in conductivity. The recovered water may be passed through IX columns and filtration during this step if suspended solids are sufficient in concentration to present a problem with blocking the injection well screens.

For the groundwater transfer step to occur, a newly constructed MU must be ready to commence mining. If an MU is not available to accept transferred water, groundwater sweep, or other activity will be employed as the first step of restoration. The advantage of using the groundwater transfer technique is that it reduces the amount of water that must ultimately be sent to the wastewater disposal system during restoration activities.

Groundwater Sweep

During groundwater sweep, water is pumped without injection from the wellfield, causing an influx of baseline quality water from the perimeter of the MU, which sweeps the affected portion of the aquifer. The cleaner baseline quality water has lower ion concentrations that act to strip off the cations that have attached to the clays during mining. The affected water near the edge patterns of the wellfield is also drawn into the boundaries of the MU. The number of pore volumes transferred during groundwater sweep, if any, is dependent upon the presence of other active MU along the MU boundary, the capacity of the wastewater disposal system, and the success of the groundwater transfer step in lowering TDS.

Groundwater Treatment

Following the groundwater sweep step, water will be pumped from production wells to treatment equipment and then re-injected into the wellfield. IX, RO, and/or Electro Dialysis Reversal treatment equipment is generally used during this stage as shown on the generalized restoration flow sheet on **Figure 6.1-1**.

Water recovered from restoration that contains uranium is passed through the IX system. The IX columns exchange the majority of the contained soluble uranium for chloride or sulfate. Once the solubilized uranium is removed, a small amount of reductant may be metered into the restoration wellfield injection to reduce any pre-oxidized minerals. The concentration of reductant injected into the formation is determined by the concentration and type of trace elements encountered. The goal of reductant addition is to reduce those minerals solubilized by carbonate complexes to prevent the buildup of dissolved solids, which would increase the time for restoration to be completed.

A portion of the restoration recovery water can be sent to the RO unit. The use of an RO unit: 1) reduces the TDS in the contaminated groundwater; 2) reduces the quantity of water that must be removed from the aquifer to meet restoration limits; 3) concentrates the dissolved contaminants in a smaller volume of brine to facilitate waste disposal; and 4) enhances the exchange of ions from the formation due to the large difference in ion concentration.

The RO unit contains membranes that pass about 60 to 75 percent of the water through, leaving 60 to 90 percent of the dissolved salts in the water that will not pass the membranes. **Table 6.1-2** shows typical RO manufacturers specification data for removal of ion constituents (Pure Water Products, LLC 2013). The clean water, called "permeate", will be re-injected, sent to storage for use in the mining process, or to the wastewater disposal system. The 25 to 40 percent of water that is rejected, called "brine", contains the majority of dissolved salts that contaminate the groundwater

and is sent for disposal in the waste system. Makeup water may be added to the wellfield injection stream to control the amount of "bleed" in the restoration areas.

The reductant (either biological or chemical) added to the injection stream during the groundwater treatment stage will scavenge any O_2 and reduce the oxidation-reduction potential (Eh) of the aquifer. During mining operations, certain trace elements are oxidized. By adding a reductant, the Eh of the aquifer is lowered, thereby decreasing the solubility of these elements. H_2S, Na_2S, or a similar compound will be added as a reductant. CBR typically uses Na_2S due to the chemical safety issues associated with proper handling of H_2S. A comprehensive reductant use safety plan is implemented.

The number of pore volumes treated and re-injected during the groundwater treatment stage will depend on the efficiency of the RO in removing TDS and the reductant in lowering the uranium and trace element concentrations.

<u>Wellfield Recirculation</u>

At the completion of the groundwater treatment stage, wellfield recirculation may be initiated. To homogenize the aquifer, pumping from the production wells and re-injecting the recovered solution into injection wells may be performed to recirculate solutions.

The sequence of the activities will be determined by CBR based on operating experience and wastewater system capacity. Not all phases of the restoration stage will be used if deemed unnecessary by CBR.

Once the restoration activities are completed, CBR will sample the restoration wells and determine if the MU has achieved the restoration values, on an MU average basis. If so, CBR will notify the regulatory agencies that it is initiating the Stabilization Stage and will submit supporting documentation that the restoration parameters are at or below the restoration standards. If, at the end of restoration activities, the parameters are not at or below the approved values, CBR will either re-initiate certain steps of the restoration plan or submit documentation to the agencies that the best practical technology has been used in restoration. The documentation will include a justification for alternate parameter value(s) including available water quality data and a narrative of the restoration techniques used.

6.1.5 Stabilization Phase

Upon completion of restoration, all groundwater extraction and injection ceases and no inward hydraulic gradient is maintained. Only stability monitoring (sampling) occurs.

A groundwater stabilization monitoring program will begin in which the restoration wells and any monitor wells on excursion status during mining operations will be sampled and analyzed for the restoration parameters listed in **Table 6.1-1**. A cone of depression (inward hydraulic gradient) is not maintained during stabilization.

Although CBR's CSA Class III UIC Permit requires one sample a month for a minimum of 6 months for stability monitoring of an MU to demonstrate the success of restoration (stabilization), for CPF's NRC license, the specified ore zone monitoring wells will be sampled at a frequency of once each quarter. The quarterly monitoring will continue until the data from the most recent four

consecutive quarters indicate no statistically significant increasing trend for all constituents of concern. At that point, stabilization will be deemed complete subject to NRC approval.

The sampling frequency will be one sample every other month for four quarters, and if the six samples show that the restoration values for all wells are maintained during the stabilization period with no significant increasing trends, restoration shall be deemed complete.

Throughout restoration and stabilization, excursion monitoring (consistent with Section 5.7.8.2) will continue until NRC determines that groundwater stabilization has been demonstrated.

6.1.6 Reporting

During the restoration process, CBR will perform daily, weekly, and monthly analyses as needed to track restoration progress. These analyses will be summarized and discussed in the Semiannual Radiological Effluent and Environmental Monitoring Report submitted to NRC. This information will also be included in the final report on restoration. In the unlikely event that a well goes on excursion during restoration, the process described in Section 5.7.8.3 of NUREG-1569 will be followed. Excursion monitoring operational procedures will include corrective action and notification plans in the event of an excursion. The NRC will be notified within 24 hours by telephone and within 7 days in writing from the time an excursion is verified. A written report describing the excursion event, corrective actions taken, and the corrective action results will be submitted to the NRC within 60 days of the excursion confirmation. If any of the wells are still on excursion status when the report is submitted, the report will also contain a timeline for submittal of future reports describing the excursion event, corrective actions taken, and results obtained. In the event of a vertical excursion, the report will contain a projected completion date for the extent of the vertical excursion would be completed.

Upon completion of restoration activities and before stabilization, all designated restoration wells in the MU will be sampled for the constituents listed in **Table 6.1-1**. If restoration activities have returned the wellfield average of restoration parameters to concentrations at or below those approved by the NRC and the NDEQ, CBR will proceed with the stabilization phase of restoration. Groundwater restoration standards for the current CBR operations are established by the NDEQ, with concurrence of the NRC and EPA. This process will be adhered to for the MEA project.

CBR will compile all water quality data obtained during restoration and stabilization and submit a final report to the regulatory agencies. If the analytical results continue to meet the appropriate standards for the MU and do not exhibit significant increasing trends, CBR would request that the MU be declared restored. Following agency approval, wells will be reclaimed, plugged, and abandoned as described in Section 6.2.3. CBR will not remove production or monitoring wells until the stability monitoring is concluded and agency approval is granted. In this way, these wells could be used to correct any excursion.

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6.2 Plans for Reclaiming Disturbed Lands

The following section addresses the methods for final decommissioning of disturbed lands including the wellfield, satellite facility areas, surface ponds (if any), and diversion ditches that will be used on the Crow Butte Project sites. The section discusses general procedures to be used during final decommissioning as well as the decommissioning of a particular phase or production unit area.

Decommissioning of a wellfield and process facilities will be scheduled after agency approval of groundwater restoration and stability. Decommissioning will be accomplished in accordance with an approved decommissioning plan and the most current applicable NDEQ and NRC rules and regulations, permit and license stipulations, and amendments in effect at the time of decommissioning.

The following is a list of general decommissioning activities:

- Plug and abandon all wells as detailed in Section 6.2.3.
- Determine appropriate cleanup criteria for structures (Section 6.3).
  and soils (Section 6.4).
- Conduct radiological surveys and sampling of all facilities, process-related equipment, and materials on site to determine their degree of contamination and identify the potential for personnel exposure prior to and during decommissioning. A pre-reclamation radiological survey program that will be part of the final decommissioning plan will consist of an integrated area gamma survey and sampling of soils for confirmation of whether cleanup action is required and to what extent. 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), structures in process and storage areas, areas around the deep disposal wells, and on-site transportation routes for contaminated material and equipment.
- Remove from the site all contaminated equipment and materials to an approved licensed facility for disposal or reuse, or relocate to an operational portion of the mining operation as discussed in **Section 6.3**.
- Decontaminate items to be released for unrestricted use to levels consistent with NRC requirements.
- Survey excavated areas for contamination and remove contaminated materials to a licensed disposal facility.
- Perform final site soil radiation surveys.
- Backfill and recontour all disturbed areas.
- Establish permanent revegetation on all disturbed areas.

The following sections generally describe the planned decommissioning activities and procedures for the Crow Butte facilities. These activities and procedures will apply to the MEA facilities as well as the current facilities. CBR will, prior to onset of final decommissioning of an area, submit to the NRC and NDEQ a detailed decommissioning plan for their review and approval at least 12 months before the onset of final decommissioning. As required by 10 CFR 40.36 (f), records

important to MEA decommissioning will be maintained in the office of the onsite RSO. Such information shall meet the criteria of 10 CFR 40.42 (g) (4) and (5).

6.2.1 General Surface Reclamation Procedures

The primary surface disturbances will be the satellite facilities (uranium recovery building, fuel and chemical storage, shop, office, rest rooms and wellfield production areas. Surface disturbances also occur during well drilling, pipeline installation, and road construction. These more superficial disturbances, however, involve relatively small areas or have short-term impacts.

The objective of the surface reclamation plan is to return disturbed lands to production compatible with the post-mining land use of equal or better quality than the premining condition. For the Crow Butte area, the reclaimed lands should be capable of supporting livestock grazing and providing habitat for wildlife species. Soils, vegetation, wildlife, and radiological baseline data will be used as guidelines for the design, completion, and evaluation of surface reclamation. Final surface reclamation will blend affected areas with adjacent undisturbed lands to re-establish original slope and topography and present a natural appearance. Surface reclamation efforts will strive to limit soil erosion by wind and water and sedimentation, and to re-establish natural trough drainage patterns.

The following sections provide reclamation procedures for the facility sites, wellfield production units, and access and haul roads. Reclamation timelines for wellfield production units will be discussed separately because they are dependent upon the progress of mining and the successful completion of groundwater restoration. Cost estimates for bonding calculations are discussed in Section 6.6 and include all activities anticipated to complete groundwater restoration, decontamination, decommissioning, and surface reclamation of wellfield and satellite facilities installed. These cost estimates are updated annually to cover work projected for the next year of mining activity.

6.2.1.1 Topsoil Handling and Replacement

In accordance with NDEQ requirements, topsoil is salvaged from building sites (including the satellite buildings) and pond areas. Conventional rubber-tired, scraper-type earth moving equipment is typically used to accomplish such topsoil salvage operations. The exact location of topsoil salvage operations is determined by wellfield pattern emplacement and designated wellfield access roads within the wellfield, which are determined during final wellfield construction activities.

As described in Section 2.6, topsoil thickness varies within the MEA. Topsoil is usually thickest in and along drainages where material has been deposited and deep soils have developed. Therefore, topsoil stripping depths may vary, depending on location and the type of structure being constructed. In cases where it is necessary to strip topsoil in relatively large areas, such as a major road or building site, field mapping and Soil Conservation Service Soil Surveys will be employed to determine approximate topsoil depths.

Salvaged topsoil is stored in designated topsoil stockpiles. These stockpiles are generally located on the leeward side of hills to minimize wind erosion. Stockpiles are not located in drainage

channels. The perimeters of large topsoil stockpiles may be bermed to control sediment runoff. Topsoil stockpiles are seeded as soon as possible after construction with the permanent seed mix.

During mud pit excavation associated with well construction, exploration drilling, and delineation drilling activities, topsoil is separated from subsoil with a backhoe. When the mud pit is no longer needed, all subsoil is replaced and topsoil is applied. Mud pits generally remain open for a short time. The success of revegetation efforts at the current site shows that these procedures adequately protect topsoil and result in vigorous vegetation growth.

6.2.1.2 Contouring of Affected Areas

Due to the relatively minor nature of disturbances created by *in-situ* mining, there are only a few areas where subsoil and geologic materials are removed, causing significant topographic changes that need backfilling and recontouring. Generally speaking, solar evaporation pond construction results in redistribution of sufficient amounts of subsurface materials, which requires replacement and contour blending during reclamation. However, no evaporation ponds are planned for the MEA. The existing contours will only be interrupted in small, localized areas. Because approximate original contours will be achieved during final surface reclamation, no post-mining contour maps have been included in this application.

Changes in the surface configuration caused by construction and installation of operating facilities will be temporary during the operating period. These changes will be mitigated by topsoil removal and storage along with the relocation of subsoil materials used for construction purposes. Restoration of the original land surface, which is consistent with the pre- and post-mining land use, the blending of affected areas with adjacent topography to approximate original contours, and the reestablishment of drainage patterns will be accomplished by returning the earthen materials moved during construction to their approximate original locations.

Drainage channels that have been modified by the mine plan for operational purposes such as road crossings will be reestablished by removing fill materials and culverts and reshaping to as close to pre-operational conditions as practical. Surface drainage of disturbed areas that have been located on terrain with varying degrees of slope will be accomplished by final grading and contouring appropriate to each location to allow for controlled surface runoff and eliminate depressions where water could accumulate.

6.2.1.3 Revegetation Practices

Revegetation practices are conducted in accordance with NDEQ requirements. During mining operations the topsoil stockpiles, and as much as practical of the disturbed wellfield and pond areas, will be seeded with vegetation to minimize wind and water erosion. After placement of topsoil and contouring for final reclamation, an area will normally be seeded with a seed mixture developed in consultation with the Natural Resource Conservation Service as required by the NDEQ.

6.2.2 Process Facility Site Reclamation

Following removal of structures as discussed in Section 6.3, subsoil and stockpiled topsoil will be replaced on the disturbances from which they were removed during construction, as practicable. Areas to be backfilled will be scarified or ripped prior to backfilling to create an uneven surface for

application of backfill. This will provide a more cohesive surface to eliminate slipping and slumping. The less suitable subsoil and unsuitable topsoil, if any, will be backfilled first to place them in the deepest part of the excavation to be covered with more suitable reclamation materials. Subsoils will be replaced using paddle wheel scrapers, bulldozers, or other appropriate equipment to transfer the earth from stockpile locations or areas of use and to spread it evenly on the ripped disturbances. Motor graders may be used to even the spread of backfill materials. Topsoil replacement will commence as soon as practical after a given disturbed surface has been prepared. Topsoil will be picked up from storage locations by paddle wheel scrapers or other appropriate equipment and distributed evenly over the disturbed areas. The final grading of topsoil materials will be done to establish adequate drainage and the final prepared surface will be left in a roughened condition.

6.2.3 Wellfield Decommissioning

Surface reclamation in the wellfield production units will vary in accordance with the development sequence and the mining/reclamation timetable. Final surface reclamation of each wellfield production unit will be completed after approval of groundwater restoration stability and the completion of well abandonment activities discussed below. Surfaces will be prepared as needed to blend any disturbed areas into the contour of the surrounding landscape.

Wellfield decommissioning will consist of the following steps:

- The first step of the wellfield decommissioning process will involve the removal of surface equipment. Surface equipment primarily consists of the injection and production feed lines, wellhouses, electrical and control distribution systems, well boxes, and wellhead equipment. Wellhead equipment such as valves, meters, or control fixtures will be salvaged.
- Buried wellfield piping will be removed.
- Wells will be plugged and abandoned according to the procedures described below.
- The wellfield area may be re-contoured, if necessary, and a final background gamma survey conducted over the entire wellfield area to identify any contaminated earthen materials requiring removal to disposal.
- Final revegetation of the wellfield areas will be conducted according to the revegetation plan.
- All piping, equipment, buildings, and wellhead equipment will be surveyed for contamination prior to release in accordance with the NRC guidelines for decommissioning.

It is estimated that a significant portion of the equipment will meet release limits, which will allow disposal at an unrestricted area landfill. Other contaminated materials will be acid washed or decontaminated with other methods until they are releasable. If the equipment cannot be decontaminated to meet release limits, it will be disposed of at an NRC licensed disposal facility.

Wellfield decommissioning will be an independent ongoing operation throughout the mining sequence at the CPF and at the MEA. Once a production unit has been mined out and groundwater restoration and stability have been accepted by the regulatory agencies, the wellfield will be scheduled for decommissioning and surface reclamation.

6.2.3.1 Well Plugging and Abandonment

Cased Mining and Restoration Wells

All wells no longer useful to continue mining or restoration operations will be abandoned. These include all injection and production wells, monitor wells, and any other wells within the production unit used for the collection of hydrologic or water quality data or incidental monitoring purposes. The only known exception at this time may be a shallow well that could be transferred to the landowner for domestic or livestock use.

The objective of the Crow Butte well abandonment program is to seal and abandon all wells to protect the groundwater supply and to eliminate any potential physical hazard.

Prior to abandoning a well, data will be gathered (static water level, under-ream interval, casing depth) for use in a well abandonment spreadsheet that accounts for formation pressures, mining injection pressures, static water level, casing depth, materials used, and weight of material used. That information can be used to adjust the amount of bentonite chips used to plug the well screens and to calculate the minimum weight (lbs/gallon) of abandonment mud used to fill the hole to the surface and keep formation and mining pressures from allowing water to rise in the borehole. A pre-packaged bentonite-filled tube is currently used for plugging the well screens. These tubes are placed into the screens by filling the well to the surface with water from a water truck, and then dropping the bentonite tubes down the well. The water is allowed to run while the tubes descend into the screens. The drill rig then trips the drill pipe into the well and tags the bentonite to make sure it has reached the targeted depths. The drill stem is raised approximately 10 feet and an appropriate abandonment mud is mixed. If the weight of the abandonment mud needs to be increased, barite may be added to increase the weight. Likewise, an appropriate drilling additive may be added to improve the ability of the abandonment mud to carry the barite. In situations where it appears that the operating pressure and formation pressure are great enough to make it difficult to mix heavy mud, cement slurry may be substituted to fill the casing to the surface. All abandoned wells will remain above the surface until the wellfield is reclaimed. This will allow for the continuation of monitoring and observation of the integrity of the abandonment fluid. If needed, abandonment fluids will be added.

The plugging method is approved by the NDEQ and is summarized below:

- A mechanical plug may be placed above the screened interval.
- Thirty to 50 feet of coarse bentonite chips will be added to provide a grout seal.
- A Plug-gel™ or cement grout will be placed by tremie pipe from the chips to the top of the casing. The weight of the gel or grout plus the weight of the bentonite chips will be enough to exceed the local Chadron formation pressure plus the maximum injection pressure allowed (100 psi).
- The tremie pipe will be removed (when possible) and the casing will be filled to the surface.
- An approved hole plug will be installed.
- The well casing will be cut off below ground level, capped with cement, and the surface disturbance will be smoothed and contoured.
- The hole will be backfilled and the area revegetated.

Records of abandoned wells will be tabulated and reported to the appropriate agencies after decommissioning. CBR must submit a notarized affidavit to the NDEQ detailing the significant data and the procedure used in connection with each well plugged. The DNR also requires filing a well abandonment notice for all registered wells.

Exploratory Holes

Plugging and abandonment of exploratory holes (including core holes) is conducted in compliance with the State of Nebraska Title 135 Mineral Exploration Permit that requires NDEQ approval. Abandonment procedures described above apply to cased wells but not to uncased exploratory holes.

The Mineral Exploration Permit allows for exploratory holes within the boundaries of the permit, and includes a surety bond to cover abandonment and reclamation costs in the event the permit holder does not complete the abandonment and reclamation. Attachment 2 of the current permit details the procedures for abandonment of all exploratory holes per Title 135.

Hole Plugging Plan – Mineral Exploration Holes

Following collection of geological and geophysical data exploration holes will be plugged immediately using the following procedures:

1. When final drill depth is reached, the TD viscosity is measured and recorded using the Marsh Funnel.
2. Circulation of the drill fluid continues through the drill pipe while abandonment mud is mixed through the jet mixer. The abandonment mud "Plug Gel" (see product data sheet attached) is a finely ground sodium bentonite.
3. Mixing continues until the fluid system has a measured Marsh Funnel viscosity greater than 60 seconds or 20 seconds over the TD viscosity, whichever is greater.
4. Circulation continues for 15 to 30 additional minutes to ensure a homogeneous mix.
5. The drill pipe is then removed and the hole filled from the surface to replace the volume displaced by the drill pipe.
6. A cement plug of approximately 5 feet in length is placed near the ground surface.
7. If artesian flow to the surface is encountered the holes will be plugged using one of the following methods:

   A. A weighting agent "Barite" is added to the final plug gel mix in quantities sufficient to overcome artesian pressure.

   B. A type I-II cement slurry is mixed in a separate pit and circulated through the drill pipe back to the surface.

   In both instances, the hole is re-filled from the surface after the pipe is removed.

8. The drill pits will be filled back with the soil excavated during construction, taking care to replace the topsoil.

9. An amount of time to allow for settling of the soil in the drill pit is allowed prior to final reclamation smoothing and reseeding of the drill site.

6.2.3.2 Buried Trunklines, Pipes, and Equipment

Buried process-related piping, such as injection and production lines, will be removed from the MU undergoing decommissioning. Salvageable lines will be held for use in ongoing mining operations. Lines that are not reusable may either be assumed to be contaminated and disposed of at a licensed disposal site or may be surveyed and, if suitable for release to an unrestricted area, may be sent to a sanitary landfill.

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6.3 Removal and Disposal of Structures, Waste Materials, and Equipment

CBR would submit a final and detailed decommissioning plan for structures and equipment to the NRC for review and approval at least 12 months before the decommissioning of such structures and equipment. This final decommissioning plan would include a description of structures and equipment to be decommissioned, planned decommissioning activities, methods to be used to ensure protection of workers and the environment against radiation hazards, the planned final radiation survey, and an updated detailed cost estimate.

The procedures to be used for removing and disposing of structures, waste materials, and equipment would meet the following criteria:

- A written program is in place to control residual contamination on structures and equipment.
- Measurements of radioactivity on the interior surface of pipes, drain lines, and duct work would be taken at all traps and other appropriate access points, provided that such contamination is likely to be representative of contamination on the interior of the pipes, drain lines, and ductwork.
- Any surfaces of premises, equipment, or scrap that would likely be contaminated, but are of such size, construction, or location as to make the surface inaccessible for measurement, would be presumed to be contaminated in excess of the limits.
- Reasonable effort will be made to minimize contamination before the use of any paint, plating, or other covering material.
- Any surfaces of premises, equipment or scrap within a restricted area that has been covered by paint, plating or other covering material will be presumed to be contaminated in excess of the limits.
- Prior to the release of structures for unrestricted use, a comprehensive radiation survey would be made to establish that contamination is within the limits specified in NRC Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material (NRC 1993), and NRC approval would be obtained.
- A contract between CBR and a waste disposal operator would be in place to dispose of 11e.(2) byproduct material.

Equipment or scrap with surface contamination in excess of NUREG-1569, Table 5.7.6.3-1, will not be released for unrestricted use.

6.3.1 Preliminary Radiological Surveys and Contamination Control

Prior to decommissioning the satellite building, a preliminary radiological survey will be conducted to characterize the levels of contamination on structures and equipment and to identify any potential hazards. The survey will support the development of procedures for dealing with such hazards prior to decommissioning activities. In general, the contamination control program used during mining operations (as discussed in Section 5.7) will be appropriate for use during decommissioning of structures.

Based on the results of the preliminary radiological surveys, gross decontamination techniques will be employed to remove loose contamination before decommissioning activities proceed. This gross decontamination will generally consist of high-pressure washing of all accessible surfaces with water. In areas where contamination is not readily removed, a decontamination solution (e.g., dilute acid) may be used.

6.3.2 Removal of Process Buildings and Equipment

The majority of the process equipment in the process building will be reusable, as well as the building itself. Alternatives for the disposition of the building and equipment are discussed in this section.

All process or potentially contaminated equipment and materials at the process facility including tanks, filters, pumps, piping, and other components, will be inventoried, listed, and designated for one of the following removal alternatives:

- Removal to a new location within the Crow Butte site for further use or storage;
- Removal to another licensed facility for either use or permanent disposal; or
- Decontamination to meet unrestricted use criteria for release, sale, or other non-restricted use by others.

It is most likely that process buildings will be decontaminated, dismantled, and released for use at another location. If decontamination efforts were unsuccessful, the material would be sent to a permanent licensed disposal facility. Cement foundation pads and footings will be broken up and trucked to a licensed disposal site or properly licensed facility if contaminated.

6.3.2.1 Building Materials, Equipment, and Piping to be Released for Unrestricted Use

Salvageable building materials, equipment, pipe, and other materials to be released for unrestricted use will be surveyed for alpha contamination in accordance with license conditions contained in SUA-1534 and NRC guidance.

The CBR release limits for alpha radiation are as follows:

- Removable of 1,000 dpm/100cm^2
- Average total of 5,000 dpm/100 cm^2 over an area no greater than 1 square meter
- Maximum total of 15,000 dpm/100 cm^2 over an area no greater than 100 cm^2

Monitoring for beta contamination is a current license requirement. This requirement has been eliminated in subsequent ANSI standards, including ANSI/HPS N13.12 (ANSI 1999). In addition, CBR has routinely made these measurements but has never found them limiting.

Decontamination of surfaces will comply with the CBR ALARA policy to reduce surface contamination as far below the limits as practical.

Non-salvageable contaminated equipment, materials, and dismantled structural sections will be sent to an NRC-licensed facility for disposal. In most cases, the byproduct material will be shipped as Low Specific Activity (LSA-I) material, UN2912, pursuant to 49 CFR 173.427.

6.3.2.2 Disposal at a Licensed Facility

If facilities or equipment are to be moved to a facility licensed for disposal of 11e.(2) byproduct material, the following procedures may be used.

- Flush inside of tanks, pumps, pipes, and other components with water or acid to reduce interior contamination as necessary for safe handling.
- Survey the exterior surfaces of process equipment for contamination. If the surfaces are found to be contaminated, the equipment will be washed down and decontaminated to permit safe handling.
- Disassemble the equipment only to the degree necessary for transportation. All openings, pipe fittings, vents, and other components, will be plugged or covered prior to moving equipment from the satellite building.
- Equipment in the building, such as large tanks, may be transported on flatbed trailers. Smaller items, such as links of pipe and ducting material, may be placed in lined roll-off containers or covered dump trucks or drummed in barrels for delivery to the receiving facility.
- Contaminated buried process trunk lines and sump drain lines will be excavated and removed for transportation to a licensed disposal facility.
- All other miscellaneous contaminated material will be transported to a licensed disposal facility.

6.3.2.3 Release for Unrestricted Use

If a piece of equipment or structure is to be released for unrestricted use, it will be appropriately surveyed before leaving the licensed area. Both interior and exterior surfaces will be surveyed to detect potential contamination. Radioactivity levels would be determined on the interior surfaces of pipes, drain lines, or duct work by making measurements in all traps and other appropriate access points, provided that contamination at these locations would be expected to be representative of contamination on the interior of the pipes, drain lines, or duct work. If the shape, size, or presence of inaccessible surfaces prevents an accurate and representative survey, the material will be assumed contaminated and properly disposed of.

Appropriate decontamination procedures will be used to clean any contaminated areas, the equipment will be resurveyed, and documentation of the final survey will be retained to show that unrestricted use criteria were met prior to releasing the equipment or materials from the site. The current release criteria are based on NRC guidelines. The criteria to be used for release to unrestricted use will be the appropriate NRC guidelines at that time. Release surveys will be based on the release methods discussed in Section 5.7.

If a process building is left on site for unrestricted use by a landowner, the following basic decontamination procedures will be used. Actual corrective procedures will be determined by field requirements as defined by radiological surveys.

After the building has been emptied, the interior floors, ceiling, and walls of the building and exterior surfaces at vent and stack locations will be checked for contamination. Any remaining removable contamination will be removed by washing. Areas where contamination was noted will be resurveyed to ensure removal of all contamination to appropriate levels.

Process floor sumps and drains will be washed out and decontaminated using water and, if necessary, acid solutions. If the appropriate decontamination levels cannot be achieved, it may be necessary to remove portions of the sump and floor to disposal.

Excavations necessary to remove trunklines or drains will be surveyed for contaminated earthen material. Earthen material found to be contaminated will be removed to a licensed disposal facility prior to backfilling the excavated areas.

The parking and storage areas around the building will be surveyed for surface contamination after all equipment has been removed.

These areas will be decontaminated as necessary to meet the standards for unrestricted use.

6.3.3 Waste Transportation and Disposal

Materials, equipment, and structures that cannot be decontaminated to meet the appropriate release criteria will be disposed of at a disposal site licensed by the NRC or an Agreement State to receive 11e.(2) byproduct material. CBR currently maintains agreements with two such facilities located in the States of Utah and Wyoming for disposal of 11e.(2) byproduct materials generated by mining operations. A contract for disposal at a minimum of one facility will be maintained current as required in NRC License SUA-1534.

Transportation of all contaminated waste materials and equipment from the site to the approved licensed disposal facility or other licensed sites will be handled in accordance with the DOT Hazardous Materials Regulations (49 CFR Part 173) and the NRC transportation regulations (10 CFR 71).

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. Final GPS-based gamma surveys will be conducted in potentially contaminated areas, including 10 m buffer zones.

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 exposure rate (Tetra Tech Report – **Appendix BB**). 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.

6.4.4 Temporary Ditches and Impoundments Cleanup Verification and Sampling Plan

In addition the pre-reclamation survey procedures discussed in Section 6.2, CBR will adopt survey and sample protocols for temporary ditches and surface impoundments on a case-by-case basis. Ditches and impoundments can extend from the surface to the subsurface. For the purpose of decommissioning, the surfaces will be considered as part of adjacent soil surfaces. The subsurfaces will be surveyed and sampled systematically, based on their size and geometry. As with other subsurfaces, CBR will rely on sampling and analysis of radium-226 and uranium over surveying to verify cleanup of ditches and impoundments. Surveying is applicable in larger impoundments; however, the effects of geometry are not as pronounced, particularly in areas not influenced by adjacent walls.

6.4.5 Quality Assurance

Verification soil samples will be sent to a commercial laboratory for analysis of radium-226 and natural uranium. The criteria that CBR will use to select the commercial laboratory will follow the guidance published in the Multi-Agency Radiological Laboratory Analytical Protocols Manual (NRC 2004). The commercial laboratory will adhere to a well-defined quality assurance program that addresses the laboratory organization and management, personal qualifications, physical facilities, equipment and instrumentation, reference materials, measurement traceability and calibration, analytical method validation, SOPs, sample receipt, handing, storage, records, and appropriate licenses.

The analytical work performed by the commercial laboratory will adhere to CBR-defined Data Quality Objectives (DQOs). Part of the DQO process is specific analytical sensitivities required by CBR. The minimum sensitivity required for each sample will be 0.5 pCi/g dry weight for each analyte, with an estimated overall error of $\pm$ 0.5 pCi/g.

CBR will expect the reporting equivalent of an EPA Contract Laboratory Program Level 3 data package from the commercial laboratory.

CBR will maintain a laboratory QA file that will include, at a minimum, the laboratory Quality Assurance Manual (QAM) and audit reports.

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6.5 Decommissioning Health Physics and Radiation Safety

The health physics and radiation safety program for decommissioning will ensure that occupational radiation exposure levels are kept ALARA during decommissioning. This program will ensure that contamination and any use of the premises, equipment, or scrap will not result in an unacceptable risk to the health and safety of the public or the environment. The RSO, HPT, or designee will be on site during any decommissioning activities where a potential radiation exposure hazard exists. In general, the radiation safety program discussed in Section 5 will be used as the basis for development of the decommissioning health physics program. Health physics surveys conducted during decommissioning will be guided by applicable sections of RG 8.30 (NRC 2002b) or other standards applicable at the time.

6.5.1 Records and Reporting Procedures

At the conclusion of site decommissioning and surface reclamation, a report containing all applicable documentation will be submitted to the NRC and NDEQ. Records of all contaminated materials transported to a licensed disposal site will be maintained for a period of 5 years or as otherwise required by applicable regulations at the time of decommissioning.

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6.6 Financial Assurance

6.6.1 Bond Calculations

Cost estimates for the purpose of bond calculations are made annually for the CPF site. The cost assessment includes groundwater restoration, decontamination and decommissioning, and surface reclamation costs for all areas to be affected by the installation and operation of the proposed mine plan. The detailed calculations used in determining the bonding requirements for the CPF are submitted annually.

6.6.2 Financial Surety Arrangements

CBR maintains an NRC-approved financial surety arrangement consistent with 10 CFR 40, Appendix A, Criterion 9 to cover the estimated costs of reclamation activities. CBR is currently operating under the NRC surety amount of $43,223,280, which was approved by License Amendment No, 27 on November 12, 2013. CBR maintains an Irrevocable Standby Letter of Credit issued by the Royal Bank of Canada (New York Branch) in favor of the State of Nebraska.

By letter dated September 30, 2013, Cameco submitted an annual update to the Surety Estimate for the CBR uranium mine Surety Estimate for the year 2014 (Leftwich 2013). The proposed 2014 Surety Estimate is $44,719,032, an increase of $1,495,752 over the 2013 Surety Estimate of $43,223,280, approved on November 12, 2013.

The surety amount is revised annually in accordance with the requirements of SUA-1534. The surety amount will be revised to reflect the estimated costs of reclamation activities for the MEA as development activities proceed.

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