

**CROW BUTTE RESOURCES, INC.**

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June 25, 1997

Joseph J. Holonich, Chief  
Uranium Recovery Branch  
Division of Waste Management,  
NMSS (T-7-J9)  
Office of Nuclear Material Safety  
and Safeguards  
U.S. NUCLEAR REGULATORY COMMISSION  
11545 Rockville Pike  
Rockville, MD 20850

Re: Docket No. 40-8943  
License No. SUA-1534  
Response to Request for Additional Information - License Renewal

Dear Mr. Holonich:

On June 2, 1997 Crow Butte Resources received a request for additional information regarding the renewal of Source Material License No. SUA-1534 for the Crow Butte in situ leach mine. Enclosed are two copies of CBR's responses to the questions and comments. Corrected pages are included as appropriate. I have sent one copy directly to Mr. Pat Mackin at the Southwest Research Institute to facilitate his review.

If you have any questions or require further information, please do not hesitate to contact me.

Sincerely,

*Steve Collings*

Steve Collings  
President

Enclosures

c: Pat Mackin  
Ross Scarano

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**Request 1.** *Technical support should be provided for proposed changes to the in-plant monitoring programs.*

**Response:** CBR has not proposed any change to the in-plant monitoring programs or monitoring locations noted in the text accompanying this Request for additional information. In order to provide clarification, CBR is providing the following information for each of the three monitoring programs noted in Request 1.

Airborne Uranium: On page 5-23 of the License Renewal Application (LRA) under the section entitled "Proposed In-Plant Airborne Uranium Monitoring Program", CBR states that they "propose to institute the same airborne uranium monitoring program at Crow Butte Uranium Project that has been performed to date with the following changes." The monitoring locations shown in Figure 5.7-1 are the same that are currently in use at the plant. These locations were submitted to and approved by NRC prior to commercial plant start-up. CBR proposes no change in airborne uranium sampling locations from the current program.

Radon Daughter: On page 5-25 of the LRA under the section entitled "Proposed In-Plant Radon Daughter Monitoring Program", CBR states that they "propose to institute the same radon daughter monitoring program at Crow Butte Uranium Project that has been performed to date with the following changes." The monitoring locations shown in Figure 5.7-1 are the same that are currently in use at the plant and submitted to and approved by NRC prior to commercial plant start-up with two exceptions.

1.) The radon daughter sampling location shown in Figure 5.7-1 in the Dryer area has been deleted under Amendment Number 33 of SUA-1534. The request to eliminate this location was submitted on October 5, 1995.

2.) A radon daughter monitoring location near the Raw Water tank was inadvertently left out of Figure 5.7-1 during preparation of the LRA. A revised Figure 5.7-1 with the noted changes is attached for inclusion with the LRA. CBR proposes no change in radon daughter sampling locations from the current program.

**Gamma:** On page 5-18 of the LRA under the section entitled "Proposed Gamma Survey Program", CBR states that they "propose to institute the same gamma exposure monitoring program at the Crow Butte Uranium Project that has been performed to date with the following changes." The text indicates that the locations are indicated in Figure 5.7-1. In actuality, the figure does not depict gamma survey locations since there are no specified gamma survey locations at CBR other than the requirement that they be performed in "work areas". Gamma surveys are performed throughout the plant to monitor gamma radiation levels under changing operational conditions. No specific locations are required in SUA-1534.

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**Request 2.** *Technical support should be provided for the proposed discontinuation of vegetation sampling.*

**Response:** USNRC Regulatory Guide 4.14, "Radiological Effluent and Environmental Monitoring at Uranium Mills" requires vegetation sampling "if dose calculations indicate that the ingestion pathway from grazing animals is a potentially significant exposure pathway". "Potentially significant" is defined as exceedance of 5 percent of the applicable radiation protection standard (footnote (o) to Table 2).

MILDOS modeling performed for the Crow Butte Uranium project estimates individual doses from the ingestion pathway from grazing animals to be well below the 5 percent criteria. For Case 1 and Case 2, MILDOS has estimated the following meat ingestion and milk ingestion effective doses to the most affected resident.

Case 1:

Meat Ingestion Effective Annual Dose:	9.18 E <sup>-5</sup> mRem/yr
Milk Ingestion Effective Annual Dose:	2.58 E <sup>-5</sup> mRem/yr

Case 2:

Meat Ingestion Effective Annual Dose:	1.67 E <sup>-4</sup> mRem/yr
Milk Ingestion Effective Annual Dose:	4.67 E <sup>-5</sup> mRem/yr

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These estimated doses are well below the criteria from Regulatory Guide 4.14.

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**Request 3.** *Techniques used in defining hydrologic connection/isolation on a wellfield basis should be discussed.*

**Response:** The regional geology of northwestern Nebraska has been studied extensively, and is well documented and understood. Based on that information, the Brule/Chadron Formation (the confining zone overlying the Basal Chadron Sandstone) and the Pierre Shale (the underlying confining zone) are expected to occur in the vicinity of the Crow Butte Project. Drilling and electric logging information related to the mining operations have verified the presence, continuity, and thickness of the overlying and underlying confining zones. Field and laboratory tests have demonstrated the integrity of the confining zones with regard to vertical and horizontal permeability, hydraulic resistance, and travel times.

It is important to note that the mining zone (the Basal Chadron Formation) is a confined aquifer, which, as expected, has a low storage coefficient. As such, pressure transients created during mining activities or pumping tests, are transmitted over great distances in a short period of time. This is useful for two reasons: (1) pumping tests have been conducted using widely spaced monitoring wells to evaluate formation characteristics (and continuity) over large distances; and (2) pressure transients related to mining activities have proven to be readily detected, in a short period of time, in perimeter monitoring wells.

Analysis of pumping tests performed at the site have repeatedly demonstrated the integrity of the confining zones. Of significance, Pumping Test #2, conducted and analyzed according to the Neuman-Witherspoon method, demonstrated that there was no hydraulic response in monitoring wells completed within the upper or lower confining zones as a result of pumping in the mining zone. In addition, no hydraulic response has been observed in Brule Formation (i.e., the aquifer overlying the Brule/Chadron confining zone) monitoring wells during either (1) performance of conventional pumping tests, or (2) during mining operations.

In summary:

- The horizontal connection between perimeter monitoring wells in the mining zone and the mining/production unit has been, and will continue to be, demonstrated by a direct and rapid hydraulic response observed in the monitoring wells as a result of mining operations. For example, upon startup of a new mining unit, a hydraulic response is typically observed in the perimeter monitoring wells within six hours or less.
- The isolation of the upper monitoring wells (i.e., in the Brule Formation) has been, and will continue to be, demonstrated by (1) correlation of geologic information from drillholes, (2) comparison of water levels in the Brule wells to those in the mining zone.

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**Request 4.** *The effectiveness of site excursion monitoring and control should be documented.*

**Response:** In response to this request, the following summary is provided of exceedances of excursion parameters in wells at CBR.

Problems with well construction of shallow monitor wells in Mine Unit 4 resulted in exceedances of excursion parameters in three wells. Two-inch monitor wells were installed in order to lower sampling volumes required in this very low yield aquifer. Baseline was difficult to establish because of ineffective well clean-up. SM 4-5 went on excursion status on January 25, 1995. It was determined that poor water production and cement contamination caused high sulfate in the well. A replacement well was drilled with a four-inch diameter and sampling indicated baseline conditions. USNRC approved the replacement well on May 5, 1995 as Amendment 29 to SUA-1534.

Two additional wells in Mine Unit 4 had similar problems. SM4-2 and SM4-7 went on excursion status April 13 and December 29, 1995 respectively. It was determined that the exceedances of the UCL's for these wells was not related to excursions of mining fluids. The water quality sampled by these wells was approaching the average baseline values for the mine unit as a whole. In other words, the UCL's for these two wells were set too low. New UCL's were calculated for these wells based on

the mine unit basis. This method was approved by USNRC in Amendment 36 to SUA-1534 on February 20, 1997 and the wells were removed from excursion status.

In addition to the shallow monitor wells in Mine Unit 4, two wells have been placed on excursion status since the license renewal application was submitted on December 7, 1995.

A casing leak was discovered in well I196-5 of Mine Unit 2 during the routine 5-year Mechanical Integrity Test (MIT) of that well on March 29, 1996. Testing isolated the leak at the casing coupling 40 feet below ground level. Fifteen shallow test wells were drilled to delineate the contaminated area. Nine of these wells were uncontaminated and effectively delineated the excursion as covering an area of about 25,000 square feet. The contaminated area averaged about 2600  $\mu\text{mhos/cm}$  conductivity or about four to five times baseline. Continuous pumping from one to three of the contaminated wells at a rate of 1 to 6 gpm has reduced the conductivity of the contaminated area to an average of 660  $\mu\text{mhos/cm}$  as of April 1997 which is below drinking water standards and is approaching baseline. Plans are to continue pumping from these wells in accordance with the remediation plan as long as progress is being made.

A small leak was discovered on November 8, 1996 in a plugged and abandoned well, I752-14 in Mine Unit 5. Apparently the plugging material was washed into the ore zone during mining in the nearby replacement well I752a-14. It was determined that mining solutions leaked into a shallow aquifer at 100 feet below ground surface. Two wells were installed to delineate the leak. These wells showed no contamination. Remediation began December 30, 1996 by pumping from I752-14 at a rate of about 1 gpm. As of April, 1997 the water had been returned to baseline conditions.

No excursions have occurred in the Chadron Sandstone which is the mining unit.

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**Request 5.** *Experience to date in mine unit groundwater restoration should be documented.*

**Response:** Mine Unit 1 was placed in restoration on March 14, 1994. Initially a bleed or ground water sweep was maintained to control mining solutions. Baseline quality water was transferred from Mine Unit 4 into Mine Unit 1 during the period May 30, 1994 to May 26, 1995. Approximately 0.78 pore volumes (13.5 mm gals) were transferred. Ground water treatment with ion exchange (IX) to lower uranium levels began on September 12, 1994 and has continued to the present. Ground water treatment with reverse osmosis (RO) began September 28, 1995 and continues to the present. Approximately 2.28 pore volumes (39.1 mm gals) have been treated to date. Reductant addition to lower uranium and trace metals began April 17, 1996 with the addition of Na<sub>2</sub>S to the RO permeate injection. As of May 31, 1997, 20 of the 39 original well patterns in Mine Unit 1 had been returned to baseline conductivity. The conductivity in the remaining patterns has also been reduced significantly. It is expected that the conductivity of the remaining patterns will be returned to baseline by April 30, 1998. It is expected that most other parameters will meet baseline or secondary restoration target values once the conductivity has reached baseline levels. An evaluation of additional treatment that may be required will take place at that time.

Mine Unit 2 was placed in restoration on January 2, 1996. Restoration to date has consisted of IX treatment to lower uranium levels. RO treatment of Mine Unit 2 will follow completion of restoration of Mine Unit 1 and is expected to begin in 1998 and take approximately two years.

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**Request 6.** *Discussion of groundwater restoration target values should reflect NRC source material license requirements.*

**Response:** CBR recognizes that USNRC Source Material License SUA-1534 states that the "...goal of restoration shall be returning ground-water quality, on a mine unit average, to baseline conditions". As stated in Section 6.1.3, returning ground-water quality to baseline on a mine unit average is CBR's primary restoration goal. However, should it not be possible to achieve baseline for all parameters on a mine unit average, the secondary goal is to

achieve the secondary restoration goals based upon the State of Nebraska Department of Environmental Quality drinking water standards.

CBR has revised Section 6.1.3 and Table 6.1-1 to clarify restoration target values. The affected pages from this revision are attached.

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**Request 7.** *Fundamental conversion factors for radon release calculations should be clarified.*

**Response:** The calculations found in Tables 7-3(A) and 7-3(A)-5 follow the format found on pages 31 through 34 of NUREG/CR-4088, Methods for Estimating Radioactive and Toxic Airborne Source Terms for Uranium Milling Operations, June 1985. These pages from NUREG/CR-4088 are attached.

There are some constants in this format that are not fully explained and these are:

(a) Equation (8) has a constant of 1.44. This constant is based on the number of minutes in a day (1440) divided by the number of liters in a cubic meter (1000). The units for Equation 8 then cancel out and the yearly Radon release will be expressed in curies/year.

(b) Equation 9, on page 32, discusses Radon Release from Soaking. Crow Butte does not soak the mining units and there will be no release due to removal of a soak solution.

(c) The calculation of the residence time is based on the time required to remove one pore volume from a cell or wellfield. A pore volume (PV) for a cell is calculated as follows:

$$\begin{aligned} PV &= \text{Area} \cdot \text{Screened Interval} \cdot 7.48 \text{ gallons/ft}^3 \cdot \text{porosity} \\ PV &= 10,000 \text{ ft}^2 \cdot 15.1 \text{ ft} \cdot 7.48 \text{ gallons/ft}^3 \cdot 0.29 \\ PV &= 327,549 \text{ gallons} \end{aligned}$$

The time required to remove one pore volume will be:

$$327,549 \text{ gallons} \cdot \frac{1}{32 \text{ gal/min}} \cdot \frac{1 \text{ day}}{1440 \text{ min}} = 7.1 \text{ days}$$

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Where 32 gal/min is the average cell flow rate. See Table 7.3(A)-1 for cell area, screened interval and average cell flow rate.

The above calculation is the basis for the estimated 7 days of residence time during mining.

(d) The residence time during restoration will be significantly longer due to the lower flow. The restoration flow is 1000 gpm as compared to the production flow of 5000 gpm. This means that the average cell flow rate will be approximately one fifth of the production flow. One-fifth of 32 gpm will be 6.4 gpm. With a pore volume of 327,549 gallons, the time required to remove a pore volume will be

$$327,549 \text{ gallons} \cdot \frac{1}{6.4 \text{ gal/min}} \cdot \frac{1 \text{ day}}{1440 \text{ min}} = 35.5 \text{ days}$$

Based on the above, an estimate of 35 days was used for the residence time for restoration.

(e) The request for additional information asks for an explanation of the selection of times for evaluating the remaining Radon fraction.

We would like to note that equations (8) and (10) contain an equilibrium factor defined as  $1 - e^{-\lambda\tau}$  where  $\lambda$  is the Radon decay constant and  $\tau$  is the residence time. The equilibrium factor is not evaluating Radon decay but rather the amount of Radon going into the lixiviant solution. Please note that as  $\tau$  increases the term  $1 - e^{-\lambda\tau}$  approaches one and that the longer residence time means that the estimated Radon concentration in the production or restoration solution will be higher.

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**Request 8.** *The process for estimating the agricultural parameters used in radiological dose calculations should be discussed.*

**Response:** The estimates found in Table 7-3(A)-6: Miscellaneous Data were based on discussions with the land owners and with the Sioux

County Agricultural Extension Educator located in Harrison, Nebraska (Ms. Jenny Nixon). The estimates were reviewed with Ms. Nixon on June 12, 1997 and she recommended that the fraction of the year during which cattle graze locally should be increased from 33 percent to 67 percent and that the fraction of locally-produced meat which is consumed locally should be reduced from 50 percent to ten percent. Table 7-3(A)-6: Miscellaneous Data has been revised to reflect these changes. A revision of the table is attached. CBR repeated MILDOS run for Cases 1 and 2 with the changes recommended by Ms Nixon and found no significant changes in the radiological dose.

During review of Appendix 7-3(A), CBR noted a typographical error in Table 7-3(A)-2 of the LRA. A revised Table 7-3(A)-2 is attached.

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#### Editorial/Clarification Comments

1. *In Table 2.7-1 (p. 2.7-4), the specified units under the column headings for "Mean Discharge" are "inches" and "(cm)". The NRC staff believes these units should be revised to read "cfs" and "(cms)", respectively, to be consistent with the text of Section 2.7.*

Response: The units should be "cfs" and "(cms)". Revised page 2.7-4 is attached.

2. *On page 2.9-14, arsenic concentrations in the soil are stated as ranging from "0.59 mg/g to 3.30 µg/g." However, in Table 2.9-10, the lowest arsenic concentration reported is 0.59 µg/g. The extremely high reported arsenic concentration reported on page 2.9-14 is presumed to be an error. The text should be revised appropriately.*

Response: The units should be µg/g. Revised page 2.9-14 is attached.

3. *Table 2.10-14 (page 2.10-32) states that, for sample S-3, the uncertainty range for Th-230 is ± 40. This appears to be a typographical error. CBR should either revise the text appropriately or confirm that this is the correct uncertainty value.*

Response: The reported uncertainty value is a typographical error. Revised page 2.10-32 is attached.

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4. *On pages 4-5 and 7-6, CBR appears to equate PVC (polyvinyl chloride) with "high density polyethylene" (HDPE). These are two distinctly different materials. CBR should clarify the discussion on these pages.*

Response: The text on pages 4-5 and 7-6 does not equate PVC and HDPE. Rather, it offers either type of pipe as possible types of pipe to be used, or equivalent of either type as the third option.

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5. *Under "Radon Daughter Concentration Determination" (page 5-32), the reader is referred to "Section 0". This reference should be revised appropriately.*

Response: The appropriate reference has been made. Revised page 5-32 is attached.

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6. *In Section 5.7.5, reference is made to NRC Regulatory Guide 8.22, "Bioassay in Uranium Mills". This regulatory guide was updated in August 1988, and should be referenced as Revision 1 throughout the text.*

Response: Revised pages 5-34 and 5-35 are attached.

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7. *No units are provided in Tables 6.1-1 and 6.1-2 (pages 6-7 through 6-9). Appropriate units should be provided.*

Response: Revised Tables 6.1-1 and 6.1-2 are attached as part of the affected pages for the response to Request 6 above.

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8. *On page 2.7-29 and 2.7-31, reference is made to an "average porosity value" for the upper confining layer and the Pierre Shale, respectively, in the discussion addressing travel times through these units. It is not clear whether the porosity referred to is effective porosity or bulk porosity. For computing travel times, the effective, or kinematic porosity should be used; travel time computations using the bulk*

*porosity may be unreasonably long. This text should be revised appropriately.*

Response: CBR agrees that this comment is warranted. Porosity of subsurface materials is a function of the size and shape of the matrix particles. Massive clay and shale deposits typically consist of fine-grained materials, and initially contain a high percentage of void space (i.e., porosity). Upon burial and compaction, the porosity decreases, but may still be significant (e.g., greater than 20 percent).

In most groundwater applications, it is assumed that all of the void space is connected (i.e., the total void space [bulk porosity] is equal to interconnected void space [effective porosity]). This assumption, however, is incorrect when applied to shales and clays, especially those at depth. For this reason, effective porosity, rather than bulk porosity is used in the oil and gas industry to describe the interconnected pore space available to transmit fluids.

In terms of the rate of fluid movement (i.e., travel time), effective porosity can be viewed as the cross-sectional area available for flow. For a unit volume of fluid flowing through a unit of rock, the flow velocity (i.e., travel time) is higher for a low porosity case than for a high porosity case.

With regard to the Crow Butte Uranium Project, the overlying confining zone includes the Red Clay and Brule/Chadron Formations. The underlying confining zone is the Pierre Shale (the underlying zone). The engineering and hydrologic characteristics of these zones have been evaluated during previous activities related to CBR operations. As part of those evaluations, the bulk porosity for the Red Clay and the Pierre Shale, respectively, was determined to be 31.8 and 32.5 percent. However, based upon published values and experience with the Pierre Shale in Colorado, the effective porosity of these units is probably on the order of one to three percent. Therefore, CBR has recalculated the referenced travel times based upon the average effective porosity of two percent. The original values for hydraulic conductivity were used. The hydraulic resistance (C), which is independent of porosity, was checked, but did not change.

The revised travel time calculations are shown on the attached revised pages 2.7-13 and 2.7-29 through 2.7-34. Note that, while the revised travel times are shorter, they still range from 16,000 to 638,000 years. As such, the impact with regard to technical and/or regulatory issues related to the Crow Butte Uranium Project is negligible.

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9. *Section 2.3 provides 1990 population statistics for the region surrounding the Crow Butte site. However, it is stated in section 7.3.4, "Population Dose" (page 7-12), that 1980 population figures were used in the population dose calculations, rather than the more recent population statistics. It is not clear whether this is a typographical error. CBR should either revise the text appropriately or provide justification that the 1980 data yields valid population dose statistics.*

Response: The population figures given in Tables 2.3-1, 2.3-2, and 2.3-3 of the LRA as well as the accompanying discussion are updated 1990 figures. These figures are population numbers for entire counties that have any area that falls within the 80 km radius. Thus, these figures are much higher than the total number of residents that fall within the 80 km radius boundary. The population figures used for the MILDOS run are the 1980 figures and were not updated for the LRA. As can be seen from the data in Table 2.3-1, the population in Dawes County decreased by 0.22% from 1980 to 1990 and the population in Sioux County decreased by 1.60% during the same time period. Since Dawes and Sioux Counties are the most affected counties, it appeared reasonable to use the 1980 data for the population dose calculations.

It should be noted that no county within 80 kilometers of the project site had a population change of greater than 1.60% from 1980 to 1990.

**Request 1 Affected Pages**

**Revised Figure 5.7-1 (page 5-19)**



**Request 6 and Editorial/Clarification Comment 7 Affected Pages**

**Revised Section 6.1.3 (pages 6-5 through 6-6)**

**Table 6.1-1 (pages 6-8 and new Page 6-9)**

**Table 6.1-2 (pages 6-10 through 6-11)**

**(Revised pages 6-7 and 6-12 through 6-29 attached for pagination change)**

oxidant consumption and make uranium leaching a bit more difficult. On longer flow paths, organic material could potentially reprecipitate uranium, should all of the oxidant be consumed and conditions become reducing. Another potential impact of organics could be the coloring and fouling of leach solutions should the organics be mobilized. As the plant is operated in the pH range of 6.5 to 9.0, mobilization of the organics and coloring of the leach solution is avoided.

### **6.1.3 RESTORATION GOALS**

The primary goal of the groundwater restoration program is to return groundwater affected by mining operations to baseline values on a mine unit average. A secondary goal is to return the groundwater to a quality consistent with premining use or uses. The restoration values set by the Nebraska Department of Environmental Quality (NDEQ) are consistent with this secondary goal. Restoration values, secondary goal, for each mine unit have been specified by the NDEQ for groundwater restoration efforts. Prior to mining in each mine unit, baseline groundwater quality data is submitted. This data is established in each mine unit at the following minimal density:

- One production or injection well per four acres;
- One upper aquifer monitor well per five acres; and
- All perimeter monitor wells.

The baseline data support establishment of the upper control limits and restoration standards for each mine unit. The restoration values, secondary goal, are established as the average plus two standard deviations for any parameter that exceeds the applicable drinking water standard. If a drinking water standard exists for a parameter, and baseline is below that standard, the drinking water standard is used to establish the restoration value. If there is no drinking water standard for an element, for example vanadium, the restoration value will be based on best practicable technology. The restoration value for the major cations (Ca, Mg, K) should allow for 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 criteria should allow for the total carbonate to be less than 50% of the TDS. The TDS restoration value is set at the average plus one standard deviation.

Restoration values, secondary goal, for Mine Units 1 through 5 are given in Table 6.1-1. NDEQ Permit Number NE0122611 requires that Mine Unit be returned to a wellfield average of these restoration values. These

concentrations were approved by the NDEQ with the Notice of Intent to Operate submittals. Post mining water quality for Mine Unit 1 can be found in Table 6.1-2.

Crow Butte Resources operated a R&D Pilot Facility starting in July 1986 and initiated restoration activities of its Wellfield No. 2 in February 1987. Wellfield No. 1 was incorporated into Mine Unit 1, thus no restoration took place in that area. The techniques used during that program are the basis for the commercial restoration program outlined in this section. Crow Butte Resources will utilize ion exchange columns, a reverse osmosis unit and reductant addition equipment similar to those used in the R&D restoration during commercial restoration operations.

The commercial groundwater restoration program consists of two stages, the restoration stage and the stabilization stage. The restoration stage consist of four activities:

- Groundwater transfer;
- Groundwater sweep;
- Groundwater treatment; and
- Wellfield recirculation

A reductant may be added at anytime 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.

The stabilization stage consists of monitoring the restoration wells for six months following successful completion of the restoration stage. Stabilization will begin once restoration activities have returned the average concentration of restoration parameters to acceptable levels. Following the stabilization phase, Crow Butte Resources will make a request to the appropriate regulatory agencies that the wellfield is restored.

#### **6.1.4 RESTORATION STAGE**

Restoration activities include four steps which are designed to optimize restoration equipment used in treating groundwater and to minimize the number of pore volumes circulated during the restoration stage. Crow Butte Resources will monitor the quality of selected wells during restoration to

determine the efficiency of the operations and to determine if additional techniques are necessary.

**Table 6.1-1: Baseline and Restoration Values By Mine Unit**

Parameter	Groundwater Standard	MU-1 Baseline	MU-1 Restoration Value	MU-2 Baseline	MU-2 Restoration Value	MU-3 Baseline	MU-3 Restoration Value	MU-4 Baseline	MU-4 Restoration Value	MU-5 Baseline	MU-5 Restoration Value
Ammonium (mg/l)	10.0	≤ 0.372	10.0	≤ 0.37	10.0	≤ 0.329	10.0	0.288	10.0	0.28	10.0
Arsenic (mg/l)	0.05	≤ 0.00214	0.05	≤ 0.001	0.05	≤ 0.001	0.05	≤ 0.00209	0.05	≤ 0.001	0.05
Barium (mg/l)	1.0	≤ 0.996	1.0	≤ 0.01	1.0	≤ 0.1	1.0	< 0.1	1.0	≤ 0.10	1.0
Cadmium (mg/l)	0.01	≤ 0.00644	0.01	≤ 0.01	0.01	≤ 0.01	0.01	< 0.01	0.01	≤ 0.01	0.01
Chloride (mg/l)	250.0	203.9	250.0	208.6	250.0	197.6	250.0	217.5	250.0	191.9	250.0
Copper (mg/l)	1.0	≤ 0.0249	1.0	≤ 0.013	1.0	≤ 0.0108	1.0	≤ 0.0114	1.0	≤ 0.01	1.0
Fluoride (mg/l)	4.0	0.686	4.0	0.67	4.0	0.719	4.0	0.745	4.0	0.64	4.0
Iron (mg/l)	0.3	≤ 0.0441	0.3	≤ 0.05	0.3	< 0.05	0.3	≤ 0.0504	0.3	≤ 0.05	0.3
Mercury (mg/l)	0.002	≤ 0.00067	0.002	≤ 0.001	0.002	< 0.001	0.002	< 0.001	0.002	< 0.001	0.002
Manganese (mg/l)	0.05	≤ 0.00122	0.05	≤ 0.01	0.05	≤ 0.01	0.05	≤ 0.01	0.05	≤ 0.01	0.05
Molybdenum (mg/l)	1.0	≤ 0.0689	1.0	≤ 0.073	1.0	< 0.1	1.0	< 0.1	1.0	≤ 0.10	1.0
Nickel (mg/l)	0.15	≤ 0.0340	0.15	≤ 0.05	0.15	< 0.05	0.15	< 0.05	0.15	≤ 0.05	0.15
Nitrate (mg/l)	10.0	≤ 0.050	10.0	≤ 0.039	10.0	≤ 0.0728	10.0	≤ 0.114	10.0	≤ 0.10	10.0
Lead (mg/l)	0.05	≤ 0.0315	0.05	≤ 0.05	0.05	< 0.05	0.05	< 0.05	0.05	< 0.05	0.05
Radium (pCi/L)	5.0	229.7	584.0	234.5	1058.0	165.0	611.0	154.0	496.0	166.0	535.00
Selenium (mg/l)	0.01	≤ 0.00323	0.01	≤ 0.001	0.01	≤ 0.00115	0.01	≤ 0.00244	0.01	≤ 0.002	0.01
Sodium (mg/l)	N/A	412		411		428		416.6	416.6	397.6	397.6
Sulfate (mg/l)	250.0	356.2	375.0	348.2	369.0	377.0	404.0	337.0	375.0	364.5	385.0
Uranium (mg/l)	5.0	0.0922	5.0	0.046	5.0	0.115	5.0	0.118	5.0	0.072	5.0

**Table 6.1-1: Baseline and Restoration Values By Mine Unit**

Parameter	Groundwater Standard	MU-1 Baseline	MU-1 Restoration Value	MU-2 Baseline	MU-2 Restoration Value	MU-3 Baseline	MU-3 Restoration Value	MU-4 Baseline	MU-4 Restoration Value	MU-5 Baseline	MU-5 Restoration Value
Vanadium (mg/l)	0.2	≤ 0.0663	0.2	≤ 0.1	0.2	< 0.1	0.2	≤ 0.0984	0.2	≤ 0.10	0.2
Zinc (mg/l)	5.0	≤ 0.0384	5.0	≤ 0.025	5.0	≤ 0.0131	5.0	≤ 0.0143	5.00	≤ 0.02	5.0
pH (Std. Units)	6.5-8.5	8.46	6.5-8.5	8.32	6.5-8.5	8.37	6.5-8.5	8.68	9.28	8.5	6.5-8.5
Calcium (mg/l)	N/A	12.5	125.0	13.4	134.0	13.3	133.0	11.2	112.0	12.6	126.0
Total Carbonate (mg/l)	N/A	351.2	585.0	362.0	585.0	377.0	592.0	374.0	610.0	373.0	590.0
Potassium (mg/l)	N/A	12.5	125.0	12.6	126.0	13.9	139.0	16.7	167.0	11.5	115.0
Magnesium (mg/l)	N/A	3.2	32.0	3.5	35.0	3.5	35.0	2.8	28.0	3.4	34.0
TDS (mg/l)	N/A	1170.2	1170.0	1170.4	1170.4	1183.0	1183.0	1221.0	1221.0	1179.0	1202.0

**Table 6.1-2: Post Mining Water Quality for Mine Unit 1  
Restoration Well Sampling**

	PM-1	PM-4	PM-5	PT-5	IJ-6	IJ-13	IJ-25	IJ-28	IJ-45	PR-8	PR-15	PR-19
Ca (mg/l)	87.9	87.1	80.8	87.9	87.6	93.9	89.4	89.6	89.9	85.4	86.7	98.3
Mg (mg/l)	22.6	20.6	22.7	23.8	21.4	23.9	22.5	23.1	24.8	23.2	23.1	23.8
Na (mg/l)	1154	942	1054	1144	1054	1174	1177	1182	1126	1144	1172	1083
K (mg/l)	32.7	26.3	30	30	27.2	31.3	30	31.3	32.7	30	30	28.6
CO <sub>3</sub> (mg/l)	0	0	0	0	0	0	0	0	0	0	0	0
HCO <sub>3</sub> (mg/l)	1099	900	972	981	1057	1086	1111	1207	1104	1170	1170	959
SO <sub>4</sub> (mg/l)	1109	959	1115	1240	1031	1209	1119	1112	1134	1115	1115	1283
Cl (mg/l)	598	455	586	594	544	598	594	619	607	603	603	590
NH <sub>4</sub> (mg/l)	0.33	0.67	0.14	0.33	0.44	0.07	< 0.05	< 0.05	0.33	0.27	0.15	0.49
NO <sub>2</sub> (mg/l)	< 0.01	0.02	0.09	< 0.01	0.11	< 0.01	< 0.01	< 0.01	0.04	0.05	< 0.01	0.05
NO <sub>3</sub> (mg/l)	1.06	< 0.1	0.97	0.99	1.29	0.74	0.86	1.3	1.25	1.46	1.6	0.46
F (mg/l)	0.37	0.26	0.54	0.45	0.45	0.37	0.38	0.45	0.43	0.43	0.4	0.35
SiO <sub>2</sub> (mg/l)	25.7	18.2	35.3	24.7	33.3	34.3	26.4	31.6	28.3	33.2	30	22.2
TDS (mg/l)	3694	3121	3756	3851	3515	3899	3751	3886	3873	3820	3807	3765
Cond (µmho/cm)	5843	4841	5590	5964	5445	6012	5807	6025	5916	5819	5940	5819
CaCO <sub>3</sub> (mg/l)	901	738	797	804	866	890	911	989	905	959	959	786
pH (Std. units)	7.65	6.87	6.85	7.28	7.16	7.35	7.65	7.81	7.37	7.46	7.78	6.92
Trace Metals												
Al (mg/l)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.29
As (mg/l)	0.018	0.007	0.018	0.017	0.031	0.028	0.02	0.028	0.023	0.028	0.024	0.011
Ba (mg/l)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1

**Table 6.1-2: Post Mining Water Quality for Mine Unit 1  
 Restoration Well Sampling**

	PM-1	PM-4	PM-5	PT-5	IJ-6	IJ-13	IJ-25	IJ-28	IJ-45	PR-8	PR-15	PR-19
B (mg/l)	1.17	1.44	1.09	1.36	1.06	1.26	1.13	1.19	1.15	1.23	1.25	1.17
Cd (mg/l)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Cr (mg/l)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Cu (mg/l)	< 0.01	< 0.01	0.05	< 0.01	0.02	< 0.01	< 0.01	< 1	< 0.01	< 0.01	< 0.01	< 0.01
Fe (mg/l)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.38
Pb (mg/l)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Mn (mg/l)	0.02	0.11	0.05	0.04	0.14	0.15	0.08	0.06	0.06	0.02	< 0.01	0.16
Hg (mg/l)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Mo (mg/l)	0.6	0.2	0.42	0.53	0.47	0.5	0.56	0.54	0.53	0.59	0.53	0.37
Ni (mg/l)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.12	0.12	0.12	< 0.05	< 0.05	< 0.05	< 0.05
Se (mg/l)	0.139	0.012	0.129	0.24	0.112	0.122	0.1	0.138	0.149	0.154	0.148	0.041
V (mg/l)	1	0.1	0.38	1.15	1.12	1.18	1.03	1.24	1.29	1.23	1.56	0.28
Zn (mg/l)	< 0.01	0.14	0.11	0.01	0.11	0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Radionuclides												
U (mg/l)	8.63	6.29	54.52	9.3	13.9	9.31	9.9	2.52	14.83	5.24	5.18	6.78
Ra-226 (pCi/l)	370	126	329	1139	1113	1558	1258	1147	681	417	109	1182

#### **6.1.4.1 GROUNDWATER TRANSFER**

Prior to commencing restoration activities, the regulatory agencies will be notified that mining has ceased in a given mine unit and Crow Butte Resources will proceed to establish post mining water quality data for all of the required parameters listed in Table 6.1-1. The designated wells will be sampled and may be split with the NDEQ if requested.

During the groundwater transfer step, water may be transferred between the mine unit commencing restoration and a mine unit commencing operations. Baseline quality water from the mine unit starting production may be pumped and injected into the mine unit in restoration. The higher TDS water from the mine unit in restoration may be recovered and injected into the mine unit commencing production. The direct transfer of water will act to lower the TDS in the mine unit being restored by displacing water affected by mining with baseline quality water.

The goal of groundwater transfer is to blend the water in the two mine units until they become similar in conductivity. The recovered water may be passed through ion exchange 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 to occur, a newly constructed mine unit must be ready to commence mining.

The advantage of using the groundwater transfer technique is that it reduces the amount of water that must be ultimately be sent to the waste disposal system during restoration activities.

#### **6.1.4.2 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 mining unit which sweeps the affected portion of the aquifer. The cleaner baseline water has lower ion concentrations that act to strip off the cations that have attached to the clays during mining. The plume of affected water near the edge patterns of the wellfield is also drawn into the boundaries of the mine unit.

The number of pore volumes transferred during groundwater sweep is dependent upon the capacity of the waste water disposal system and the success of the groundwater transfer step in lowering TDS.

### 6.1.4.3 GROUNDWATER TREATMENT

Following the groundwater sweep step water is pumped from production wells to treatment equipment and then reinjected into the wellfield. Ion exchange and reverse osmosis treatment equipment is utilized during this stage as shown in Figure 6.1-1. Depending upon the final configuration of the main plant following the capacity increase to 5,000 gpm, the ion exchange step may utilize the existing fixed bed downflow columns located at the main plant, or may be relocated.

Water recovered from restoration containing a significant amount of uranium is passed through the ion exchange system. The ion exchange 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 that are solubilized by carbonate complexes to prevent build-up of dissolved solids which would increase the time required to complete restoration.

A portion of the restoration recovery water can be sent to the reverse osmosis unit. The use of a reverse osmosis unit has several effects:

- Reduces the total dissolved solids in the contaminated groundwater;
- Reduces the quantity of water that must be removed from the aquifer to meet restoration limits;
- Concentrates the dissolved contaminants in a smaller volume of brine to facilitate waste disposal; and
- Enhances the exchange of ions from the formation due to the large difference in ion concentration.

Before the water can be processed by the reverse osmosis unit, the soluble uranium must be removed by the ion exchange system. The water is then filtered, the pH lowered for decarbonation to prevent calcium carbonate plugging of the membranes, and then pressurized by a pump. The reverse osmosis unit contains membranes which 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 membrane. Table 6.1-3 shows typical manufacturers specification data for removal of ion constituents. The clean water, called permeate, will be re-injected, sent to storage for use in the mining process, or



sent to the waste disposal system. The twenty-five to forty percent of water that is rejected, referred to as the brine, contains the majority of dissolved salts that contaminate the groundwater and is sent for disposal in the wastewater system.

The sulfide reductant that may be added to the injection stream during this stage will 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. A comprehensive safety plan regarding reductant use will be implemented should it be utilized.

The number of pore volumes treated and re-injected during the groundwater treatment stage will depend on the efficiency of the reverse osmosis unit in removing total dissolved solids and the reductant in lowering the uranium and trace element concentrations.

#### **6.1.5 STABILIZATION PHASE**

Upon completion of restoration, a groundwater stabilization monitoring program will begin in which the restoration wells and any monitor wells on excursion status during the mining operations will be sampled and assayed. Sampling frequency will be one sample per month for a period of six months, and if all six samples show that restoration values for all wells are maintained during the stabilization period, restoration shall be deemed complete.

#### **6.1.6 REPORTING**

The initial step in the restoration process is to determine post-mining water quality in the mine unit by sampling all designated restoration wells for the required constituents listed in Table 6.1-1. These samples may be split with the NDEQ if required. Assay results will be submitted to both the NDEQ and the USNRC as required.

During the restoration process, Crow Butte Resources will perform daily, weekly, and monthly analysis as needed to track restoration progress. These analysis will be provided to NDEQ in Monthly Restoration Reports and the USNRC in the Semiannual Radiological Effluent and Environmental Monitoring Report. This information will also be included in the final restoration report.

Upon completion of restoration activities and prior to stabilization, all designated restoration wells in the mine unit will be sampled for the required constituents listed in Table 6.1-1. These samples may be split with NDEQ if

**Table 6.1-3: Typical Membrane Rejection**  
**Source: Osmonics, Inc.**

NAME	SYMBOL	PERCENT REJECTION
<b>Cations</b>		
Aluminum	Al <sup>+3</sup>	99+
Ammonium	NH <sub>4</sub> <sup>+1</sup>	88-95
Cadmium	Cd <sup>+2</sup>	96-98
Calcium	Ca <sup>+2</sup>	96-98
Copper	Cu <sup>+2</sup>	98-99
Hardness	Ca and Mg	96-98
Iron	Fe <sup>+2</sup>	98-99
Magnesium	Mg <sup>+2</sup>	96-98
Manganese	Mn <sup>+2</sup>	98-99
Mercury	Hg <sup>+2</sup>	96-98
Nickel	Ni <sup>+2</sup>	98-99
Potassium	K <sup>+1</sup>	94-96
Silver	Ag <sup>+1</sup>	94-96
Sodium	Na <sup>+</sup>	94-96
Strontium	Sr <sup>+2</sup>	96-99
Zinc	Zn <sup>+2</sup>	98-99
<b>Anions</b>		
Bicarbonate	HCO <sub>3</sub> <sup>-1</sup>	95-96
Borate	B <sub>4</sub> O <sub>7</sub> <sup>-2</sup>	35-70
Bromide	Br <sup>-1</sup>	94-96
Chloride	Cl <sup>-1</sup>	94-95
Chromate	CrO <sub>4</sub> <sup>-2</sup>	90-98
Cyanide	CN <sup>-1</sup>	90-95
Ferrocyanide	Fe(CN) <sub>6</sub> <sup>-3</sup>	99+
Fluoride	F <sup>-1</sup>	94-96
Nitrate	NO <sub>3</sub> <sup>-1</sup>	95
Phosphate	PO <sub>4</sub> <sup>-3</sup>	99+
Silicate	SiO <sub>2</sub> <sup>-1</sup>	80-95
Sulfate	SO <sub>4</sub> <sup>-2</sup>	99+
Sulfite	SO <sub>3</sub> <sup>-2</sup>	98-99
Thiosulfate	S <sub>2</sub> O <sub>3</sub> <sup>-2</sup>	99+

required. Assay results will be submitted to NDEQ and USNRC as required. If restoration activities have returned the wellfield average of restoration parameters to concentrations at or below those approved by the regulatory agencies, Crow Butte Resources will notify the regulatory agencies it is commencing the stabilization phase of restoration.

During stabilization all designated restoration wells will be sampled monthly for the required constituents listed in Table 6.1-1. At the end of a six month stabilization period Crow Butte Resources will compile all water quality data obtained during restoration and stabilization and submit a final report to the regulatory agencies. At that time, Crow Butte Resources would request that the mine unit be declared restored.

### **6.1.7 CURRENT RESTORATION STATUS**

The approval of the Notice of Intent to Operate for Mine Unit 4 was received from the NDEQ on March 11, 1994. With the approval, active mining operations ceased in Mine Unit 1 and restoration was initiated. On March 23, 1994 the baseline restoration wells were sampled to establish the post mining water quality. The results of this sampling are given in Table 6.1-2.

Groundwater transfer was performed for the Mine Unit 1 restoration by transferring water between Mine Unit 1 and Mine Unit 4. Uranium recovery was accomplished through the two fixed bed downflow columns located in the main process plant. Some groundwater treatment utilizing the reverse osmosis unit located in the R&D building has also been initiated.

### **6.2 DECONTAMINATION AND DECOMMISSIONING**

The following sections address the final decommissioning of process facilities, evaporation ponds, wellfields and equipment which will be used on the Crow Butte site. It discusses general procedures to be used, both during final decommissioning, as well as the decommissioning of a particular phase or production unit area.

Decommissioning of wellfields and process facilities, once their usefulness has been completed in an area, will be scheduled after agency approval of groundwater restoration and stability. It will be accomplished in accordance with an approved decommissioning plan and the most current applicable NDEQ and USNRC rules and regulations, permit and license stipulations and amendments in effect at the time of the decommissioning activity.

The following is a list of general decommissioning activities:

- Plug and abandon all wells as detailed per Section 6.2.3.
- Radiological surveys and sampling of all facilities, process related equipment and materials presently on site to determine their degree of contamination and identify the potential for personnel exposure during decommissioning.
- Removal from the site of all contaminated equipment and materials to an approved licensed facility for disposal or reuse, or relocation to an operational portion of the mining operation.
- Decontamination of items to be released for unrestricted use to levels consistent with the requirements of U.S. Nuclear Regulatory Commission.
- Survey excavated areas for earthen contamination and remove same to a licensed disposal facility.
- Backfill and recontour all disturbed areas.
- Perform final site soil radiation background surveys.
- Establish permanent revegetation on all disturbed areas.

The following sections describe in general terms the planned decommissioning activities and procedures for the Crow Butte facilities. Crow Butte Resources will, prior to final decommissioning of an area, submit to the USNRC and NDEQ a detailed plan for their review and approval.

### **6.2.1 PROCESS BUILDINGS AND EQUIPMENT**

Prior to process plant decommissioning, a preliminary radiological survey will be conducted to identify any potential hazards. The survey will also support the development of procedures for dealing with such hazards prior to commencement of decommissioning activities. 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 below.

#### **6.2.1.1 REMOVAL AND DISPOSAL ALTERNATIVES**

All process or potentially contaminated equipment and materials at the process facility including tanks, filters, pumps, piping, etc., 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.
- Decontamination to meet unrestricted use criteria for release, sale or other non-restricted use by the landowners and others.

It is most likely that process buildings will be dismantled and moved to another location or to a permanent licensed disposal facility. Cement foundation pads and footing will be broken up and trucked to disposal site or a licensed facility if contaminated. The landowners, however, could request that a building or other structures be left on site for his use. In this case, the building will be decontaminated to meet unrestricted use criteria.

#### **6.2.1.1.1 DISPOSAL AT A LICENSED FACILITY**

If a piece of process equipment is to be moved to another licensed area the following procedures may be used.

- Flush inside of tanks, pumps, pipes, etc., with water or acid to reduce interior contamination as necessary for safe handling.
- The exterior surfaces of process equipment will be surveyed for contamination. If the surfaces are found to be contaminated the equipment will be washed down and decontaminated to permit safe handling.
- The equipment will be disassembled only to the degree necessary for transportation. All openings, pipe fittings, vents, etc., will be plugged or covered prior to moving equipment from the plant 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 plastic lined 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.

#### **6.2.1.1.2 DISPOSAL TO UNRESTRICTED USE**

If a piece of equipment 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. Appropriate decontamination procedures will be used to clean any contaminated areas and the equipment resurveyed and documentation of the final survey retained to show that unrestricted use criteria were met prior to releasing the equipment or materials from the site. Criteria to be used for release to unrestricted use will be USNRC's *"Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct or Source Materials, Uranium Recovery Field Office Region IV, Denver, Colorado, September 1984"*, or the most current standards for decontamination at that time.

If a process building is left on site for landowner unrestricted use, 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 sump 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 that is 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.

Decontamination of these areas will be conducted as necessary to meet the standards for unrestricted use.

## **6.2.2 EVAPORATION POND DECOMMISSIONING**

### **6.2.2.1 DISPOSAL OF POND WATER**

The volume of water remaining in the lined evaporation ponds after restoration as well as its chemical and radiological characteristics will be considered to determine the most practical disposal program. Disposal options for the pond liquid include evaporation, treatment and disposal or transportation to another licensed facility or disposal site. The pond water from the later stages of groundwater restoration may be treatable to within discharge limits; if this can be accomplished, the water will be treated and discharged under an appropriate NPDES permit. Evaporation of the remaining water may be enhanced by use of sprinkler systems, etc.

### **6.2.2.2 POND SLUDGE AND SEDIMENTS**

Pond sludges and sediments will contain mining process chemicals and radionuclides. Wind blown sand grains and dust blown into the ponds during their active life also add to the bulk of sludges. This material will be contained within the pond bottom and kept in a dampened condition at all times, especially during handling and removal operation to prevent the spread of airborne contamination and potential worker exposure through inhalation. Dust abatement techniques will be used as necessary. The sludge will be removed from the ponds and loaded into dump trucks or drums and transported to a USNRC licensed disposal facility. All equipment and personnel working on sludge and liner removal will be checked prior to leaving the work area to prevent the tracking of sludge into uncontaminated locations.

### **6.2.2.3 DISPOSAL OF POND LINERS AND LEAK DETECTION SYSTEMS**

Pond liners will be kept washed down and intact as much as practical during sludge removal so as to confine sludges and sediments to the pond bottom. Pond liners will be cut into strips and transported to a USNRC licensed disposal facility or will be decontaminated for release to an unrestricted area. After removal of the pond liners, the pond leak detection system piping will be removed. Materials involved in the leak detection system will be surveyed and released for unrestricted use if not contaminated or transported to a USNRC licensed facility for disposal. The earthen material in the pond bottom and leak detection system trenches will be surveyed for soil

contamination; any contaminated soil in excess of limits defined in 10 CFR 40, Appendix A, will be removed.

Following the removal of all pond materials and the disposal of any contaminated soils, surface preparation will take place prior to reclamation. Pond surface reclamation will be performed in accordance with the surface reclamation plan, Section 6.3. An additional radiation background survey will be conducted on the recontoured area prior to topsoiling.

#### **6.2.2.4 ON SITE BURIAL**

At the present time, on site burial of contaminants is not anticipated. However, depending upon the availability of a USNRC licensed disposal site at the time of decommissioning, on site burial may become a potential alternative. Should this occur, pond locations would be considered initially as the on site disposal locations for contaminated materials. Appropriate licensing with the regulatory agencies would be obtained prior to any on site burial of contaminated wastes.

#### **6.2.3 WELLFIELD DECOMMISSIONING**

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, electrical conduit, well boxes, and wellhead equipment. All of the lines are above ground surface lines which will not require excavation for removal. Wellhead equipment such as valves, meters or control fixtures will be salvaged.
- Removal of buried well field piping.
- Wells will be plugged and abandoned according to the procedures described below.
- The well field area may be recontoured, if necessary, and a final background gamma survey conducted over the entire well field area to identify any contaminated earthen materials requiring removal to disposal.
- Final surface reclamation of the well field areas will be conducted according to the surface reclamation plan described in Section 6.3.

- All piping, boxes and wellhead equipment will be surveyed for contamination prior to release in accordance with the USNRC guidelines for decommissioning.

It is estimated that a significant portion of the equipment will meet releasable limits which will allow disposal at an unrestricted area landfill. Other materials which are contaminated will be acid washed or cleansed with other methods until they are releasable. If the equipment still does not meet releasable limits, it will be disposed of at a facility licensed to accept by-product material.

After the Crow Butte aquifer restoration and post-restoration stabilization has been completed and accepted in writing as successful by both the NDEQ and USNRC, the decommissioning of the mine unit wellfields will commence.

Wellfield decommissioning will be an independent ongoing operation throughout the mining sequence at the Crow Butte site. 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**

All wells no longer useful to continued mining or restoration operations will be abandoned. These include all injection and recovery 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 well which could be transferred to the landowner for domestic or livestock use.

The objective of the Crow Butte Resources well abandonment program is to seal and abandon all wells in such a manner as to assure the groundwater supply is protected and to eliminate any potential physical hazard.

The plugging method will be as follows:

- An approved abandonment mud (a mud-polymer mix) will be mixed in a cement unit and pumped down a hose, which is lowered to the bottom of the well casing using a reel.
- When the hose is removed, the casing is topped off and a cement plug placed on top.
- A hole is then dug around the well, and, at a minimum, the top three feet of casing removed.

- The hole is backfilled and the area revegetated.

Records of abandoned wells will be tabulated and reported to the appropriate agencies after decommissioning.

#### **6.2.3.2 BURIED TRUNKLINES, PIPES AND EQUIPMENT**

Buried process related piping such as injection and recovery lines will be removed from the production unit 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. If on site burial is an option in the future, lines may be disposed of on site according to conditions of the appropriate licenses/permits.

#### **6.2.4 DECONTAMINATION**

After all surface equipment is removed and all wells are properly plugged and abandoned, a gamma survey of the wellfield surfaces will be conducted. Any areas with elevated gamma readings which indicate radium-226 levels in excess of limits in 10 CFR 40, Appendix A, will be resurveyed. Soil samples will be collected from confirmed contaminated locations for the analysis of radium-226 and uranium. Based upon the soil sampling and additional gamma radiation readings, contaminated soil will be removed and transferred to a site licensed to accept by-product materials. Gamma survey results and soil sampling results will be submitted to the USNRC for their review, approval and opportunity to split soil samples. After approval of the soil contamination removal program, revegetation will commence.

The objective of site soil surveys during decommissioning will be to identify and remove to a licensed disposal facility any earthen materials which exceed EPA 40 CFR Part 192.32 standards or other applicable standards at the time of decommissioning. These standards presently require that radium concentrations in surface soils, averaged over areas of 100 square meters, do not exceed background levels by more than 5 pCi/g averaged over the first 15 cm below the surface and 15 pCi/g averaged over any 15 cm thick layer more than 15 cm below the surface.

Three general types of site soil surveys will be conducted on the site during decommissioning:

- Areas of potential surface contamination will be identified using a gross gamma survey on an adequately spaced grid.
- Spot checks of areas around the site of potentially contaminated areas.
- The final soil background survey on areas which have been prepared for surface reclamation using a grid spacing adequate for confirming clean up to applicable standards.

Contaminated soils which are removed from site surfaces will be transported to a licensed disposal site. The primary areas for potential soil contamination include well field surfaces, evaporation pond bottoms and berms, process building areas, storage yards and transportation routes over which product or contaminants have been moved.

#### **6.2.5 DECOMMISSIONING HEALTH PHYSICS AND RADIATION SAFETY**

The health physics and radiation safety program for decommissioning will document decommissioning processes and ensure that occupational radiation exposure levels are kept as low as reasonably achievable during decommissioning. The Radiation Safety Officer, Radiation Safety Technician or designee by way of specialized training, will be on site during any decommissioning activities where a potential radiation exposure hazard exists.

Health physics survey conducted during decommissioning will be guided by applicable sections of 10 CFR 20 and USNRC Regulatory Guide No. 8.30 entitled "*Health Physics Surveys in Uranium Mills*" or other applicable standards at the time.

#### **6.2.6 EQUIPMENT AND MATERIAL SURVEYS**

Any site equipment to be released for unrestricted use will be surveyed for alpha contamination and beta gamma as necessary to document levels for release, according to USNRC "*Guidelines for Decontamination of Facilities for Byproduct or Source Materials*", *Uranium Recovery Field Office Region IV, Denver, Colorado, September 1984*, or the most current standards for decontamination at that time.

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 Department of Transportation and U.S. Nuclear Regulatory Commission Regulations (49 CFR 173.389)(10 CFR 71).

## **6.2.7 RECORDS AND REPORTING PROCEDURES**

At the conclusion of site decommissioning and surface reclamation, a report containing all applicable documentation will be submitted to the USNRC and NDEQ. Records of all contaminated materials transported to a licensed disposal site will be maintained for a period of five years or as otherwise required by applicable regulations at the time of decommissioning.

## **6.3 SURFACE RECLAMATION**

The following reclamation plan provides procedural techniques for surface reclamation of all disturbances contained in the Crow Butte Resources mine plan. Provided are reclamation procedures for the process plant facilities, evaporation ponds, wellfield production units, access and haul roads. Reclamation techniques and procedures for subsequent satellite facilities, additional ponds and wellfields will follow the same concepts as presented below. Reclamation schedules 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 include all activities which are anticipated to complete groundwater restoration, decontamination, decommissioning and surface reclamation of wellfield and satellite plant facilities installed to operate for one year of mining activity.

The principal 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 its premining condition. The reclaimed lands should therefore be capable of supporting livestock grazing and provided stable habitat for native 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 so as 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, sedimentation and re-establish natural through drainage patterns.

### **6.3.1 WELLFIELD RECLAMATION**

Surface reclamation in the wellfield production units will vary in accordance with the development sequence, mining/reclamation time table. Final surface reclamation of each wellfield production units will be after approval of groundwater restoration stability and the completion of well abandonment and decommissioning activities specified in Section 6.2. Surface preparation will be accomplished as needed so as to blend any disturbed areas into the

contour of the surrounding landscape. The seed bed will be prepared and reseeded with assistance from the U.S. Soil Conservation Service.

### **6.3.2 PROCESS FACILITIES RECLAMATION**

Subsoils and stockpiled topsoil will be replaced on the disturbances from which they were removed during construction, within practical limits. 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 so as 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, push-cats or other appropriate equipment to transfer the earth from stockpile locations or areas of use and to spread it evenly on the ripped disturbances. Grader blades may be used to even the spread of backfill materials. Backfill compacting will be accomplished by movement of the equipment over the fill area. 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 so as to establish adequate drainage and the final prepared surface will be left in a roughened condition. There will be no topsoil used for construction of any kind; topsoil will have been salvaged and stockpiled.

### **6.3.3 CONTOURING OF AFFECTED AREAS**

Due to the relatively minor nature of disturbances created by in-situ mining, there are only a few areas disturbed to the extent to which subsoil and geologic materials are removed causing significant topographic changes which 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. 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 only temporary, during the operating period. These changes will be caused 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 re-establishment of drainage patterns will be accomplished by returning the earthen materials moved during construction to their approximate original locations.

Drainage channels which have been modified by the mine plan for operational purposes such as road crossings will be re-established by removing fill materials, culverts and reshaping to as close to pre-operational conditions as practical. Surface drainage of disturbed areas which have been located on terrain with varying degrees of slope will be accomplished by final grading and contouring appropriate to each location so as to allow for controlled surface run off and eliminate depressions where water could accumulate.

## **6.4 BONDING ASSESSMENT**

### **6.4.1 BOND CALCULATIONS**

Cost estimates for the purpose of bond calculations were made for the Crow Butte Project 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 calculation utilized in determining the bonding requirements for the Crow Butte Project are enclosed on Attachment 6.1.

### **6.4.2 FINAL SURETY ARRANGEMENTS**

Crow Butte Resources maintains a NRC-approved financial surety arrangement consistent with 10 CFR 40, Appendix A, Criterion 9 to cover the estimated costs of reclamation activities. Crow Butte maintains an Irrevocable Letter of Credit No. 74504 issued by First Bank N.A. during 1995 in favor of the State of Nebraska in the present amount of \$5,543,958.

**ATTACHMENT 6.1**

**Request 7 Clarification**

**Pages 31 through 34 of NUREG/CR-4088**

tailings surface flux ( $J_t$ ) of  $32 \text{ pCi/m}^2 \cdot \text{s}^1$  for the sand and  $112 \text{ pCi/m}^2 \cdot \text{s}^1$  for the slimes fractions, which is nearly the same as for the previous example (within the error of the graph).

### Radon Release During In-Situ Operations

The major source of radon release during in-situ mining operations is the lixiviant, which when exposed to the atmosphere will release radon. The release will occur when the lixiviant arrives at the process recovery surge tanks, ion exchange tanks, or columns or evaporation ponds.

Aquifer restoration that includes ground-water sweeping and clean water circulation is also a source of radon that must be considered.

The key parameters used to determine the average annual radon release are listed in Table 7.

In order to determine a reasonably conservative annual radon release, it is assumed that one mining unit will be mined, one unit soaked, and one unit restored during the year. The radon release from these operations is discussed in the following paragraphs.

### Radon Release from Mining

If the radium-226 content of the ore has not been measured, then it is assumed that the uranium-238 is in equilibrium with all its daughters. The radium-226 and radon-222 concentration present in the ore would therefore be

TABLE 7. Parameters Used to Determine Radon Release from In-Situ Mining

Ore grade, %  $\text{U}_3\text{O}_8$   
Radium-226 concentration in the ore body,  $\text{pCi/g}$   
Mined area per year,  $\text{m}^2$   
Average lixiviant flow rate,  $\text{L/min}$   
Average restoration flow rate,  $\text{L/min}$   
Number of operating days  
Formation thickness,  $T$   
Formation porosity, %  
Rock density,  $\text{g/cm}^3$   
Residence time for lixiviant, days  
Residence time for restoration solution, days  
Emanating power of ore

2820 pCi/g per % U<sub>3</sub>O<sub>8</sub>. The radon emanating power is assumed to average 0.2 unless otherwise determined. The radon release at equilibrium, G, in 1 m<sup>3</sup> of rock may be calculated as:

$$G = R\rho E (1 - p)/p \times 10^{-6} \quad (7)$$

where G = radon release, Ci/m<sup>3</sup> of rock

R = radium content, pCi/g

$\rho$  = rock density, g/cm<sup>3</sup>

E = emanating power

p = formation porosity.

The yearly radon release, Y, in Ci/yr may be calculated as follows:

$$Y = GM\varepsilon D \times 1.44 \quad (8)$$

where M = lixiviant production rate, L/min

$\varepsilon$  = equilibrium factor for radon

D = production days per year.

The equilibrium factor,  $\varepsilon$ , equals  $1 - e^{-\lambda t}$  where  $\lambda$  is the radon decay constant and t is the residence time. This is a conservative estimate since it assumes that the radon immediately goes into the lixiviant solution.

#### Radon Release from Soaking

In addition to the release of radon from the lixiviant dissolution, it is estimated that one pore volume of nonproduction solution will be removed as each mining unit is put into service. The startup radon release, S, may be calculated as:

$$S = GATp \quad (9)$$

where A = area of mining unit, m<sup>2</sup>

T = thickness of ore, m.

For a mining unit that will be soaked for 1 year, it is also assumed that one pore volume of mining solution will be removed when the lixiviant is added. Therefore, the release of radon would be the same as during the startup.

#### Radon Release During Restoration

The annual radon released during restoration, r, in Ci/yr is calculated using:

$$r = GNED \times 1.44$$

(10)

where G = radon release at equilibrium, Ci/m<sup>3</sup> of rock  
 N = restoration solution rate, L/min.  
 E = equilibrium factor  
 D = restoration days per year.

It is also assumed that one pore volume of solution will be removed before restoration begins, similar to startup.

Example Calculation: Radon Release from an In-Situ Mine

The following is a sample calculation of the total release of radon from a hypothetical in-situ uranium mining operation.

Assumptions:

Ore grade	0.1% U <sub>3</sub> O <sub>8</sub>
Average area to be mined	10 acres
Average lixiviant flow	4000 L/min
Average restoration flow	400 L/min
Operating days per year	365
Formation thickness	3 m
Formation porosity	0.3
Rock density	1.8 g/cm <sup>3</sup>
Residence time for lixiviant	5 days
Residence time for restoration solution	10 days
Emanating power	0.2

From mining and soaking, the radon release per m<sup>3</sup> of the rock is estimated using Equation (7).

The radium content, R is first calculated assuming secular equilibrium between the U<sup>238</sup> and Ra<sup>226</sup>.

$$R = 3.33 \times 10^5 \text{ pCi U}^{238}/\text{g U} \times 0.001 \text{ g U}_3\text{O}_8/\text{g ore} \times 0.85 \text{ g U/g U}_3\text{O}_8 \\ = 283 \text{ pCi/g ore.}$$

Next the radon release, G, is calculated.

$$G = R\rho E(1 - p)/p \times 10^{-6} \\ = 283 \text{ pCi/g} \times 1.8 \text{ g/cm}^3 \times 0.2 \\ \times (1 - 0.3)/0.3 \times 10^{-6} \\ = 2.4 \times 10^{-4} \text{ Ci/m}^3.$$

Next the radon release, G, is calculated using Equation (8).

$$\begin{aligned}
 Y &= G\epsilon D \times 1.44 \\
 \epsilon &= 1 - e^{-(0.181/d)(5 \text{ d})} = 0.6 \\
 Y &= 2.4 \times 10^{-4} \text{ Ci/m}^3 \times 4000 \text{ L/min} \times 0.6 \\
 &\quad \times 365 \text{ days/yr} \times 1.44 \\
 &= 303 \text{ Ci/yr.}
 \end{aligned}$$

The radon released from the startup solution and soaking is calculated using Equation (9).

$$\begin{aligned}
 S &= GATp \\
 &= 2.4 \times 10^{-4} \text{ Ci/m}^3 \times 10 \text{ acres} \times 4074 \text{ m}^2/\text{acre} \times 3 \text{ m} \times 0.3 \\
 &= 8.8 \text{ Ci/yr.}
 \end{aligned}$$

The total release of radon from the startup solution, production lixiviant, and soaking solution is:

Startup solution	8.8 Ci/yr
Production	303 Ci/yr
Soaking solution	8.8 Ci/yr
	<hr/>
	320.6 Ci/yr

The radon release from the restoration operation is calculated using Equation (10):

$$\begin{aligned}
 r &= G\epsilon D \times 1.44 \\
 \epsilon &= 1 - e^{-(0.181/d)(10 \text{ d})} = 0.84 \\
 r &= 2.4 \times 10^{-4} \text{ Ci/m}^3 \times 400 \text{ L/min} \times 0.84 \times 365 \text{ d/yr} \times 1.44 \\
 &= 42.4 \text{ Ci/yr}
 \end{aligned}$$

The total radon release from restoration includes a small increment of release similar to that from the startup solution. Therefore, the total release would be:

$$42.4 \text{ Ci/yr} + 8.8 \text{ Ci/yr} = 51.2 \text{ Ci/yr.}$$

The total release from this 10-acre hypothetical in-situ mining operation is then  $320.6 + 51.2 = 371.8 \text{ Ci/yr.}$

**Request 8 Affected Pages**

**Table 7-3(A)-6 (page 7-3(A)-10)**

**Table 7-3(A)-2 (page 7-3(A)-2)**

**Table 7-3(A)- 6: Miscellaneous Data**

Fraction of year during which cattle graze locally	Est. 67%
Fraction of cattle feed obtained by grazing	Est. 90%
Fraction of stored cattle feed grown locally	Est. 90% of the 10% remaining feed
Acreage required to graze 1 animal unit (450 kg) for one month (AUM)	3.5 ha
Length of growing season	4 mo/yr
Fraction of locally produced vegetables consumed locally	Est. 100%
Fraction of locally produced meat consumed locally	Est. 10%
Fraction of locally produced milk consumed locally	Est. 100%

Estimates based on personal communication with the Sioux County, Nebraska  
Agricultural Extension Educator located in Harrison, Nebraska (Ms. Jenny  
Nixon).

**Table 7-3(A)- 2: Source and Receptor Coordinates  
Crow Butte Project**

Source	East (km)	North (km)	Case 1	Case 2
			Rn-222 (Curies)	Rn-222 (Curies)
1. Plant Vent	0	0	3270	2400
2. MU-1	-0.13	0.30	119	119
3. MU-2	0.06	0.27	119	119
4. MU-3	-0.30	0.16	119	119
5. MU-4a	-0.17	0.00	0	159
6. MU-4b	0.33	0.12	445	159
7. MU-5	-0.13	0.74	445	318
8. McDowell WF	1.55	2.80	0	445
9. Raben WF	2.93	3.53	0	445
10. Brott WF	-1.19	1.65	383	0

**Editorial/Clarification Comment Number 1**

**Revised Table 2.7-1 (page 2.7-4)**

**Table 2.7-1: Comparison of Mean Monthly Precipitation With Normal Mean Monthly Discharge of the White River at Crawford, Nebraska**

Month	Mean Precipitation <sup>1</sup>		Mean Discharge <sup>2</sup>	
	inches	cm	ft <sup>3</sup> /s	m <sup>3</sup> /s
January	0.41	1.04	21.0	0.59
February	0.37	0.94	23.4	0.66
March	0.70	1.78	27.2	0.77
April	1.67	4.24	25.3	0.72
May	2.98	7.57	25.3	0.72
June	3.32	8.43	22.2	0.63
July	2.16	5.49	15.4	0.44
August	0.97	2.46	12.6	0.36
September	1.33	3.38	13.3	0.38
October	0.83	2.11	16.6	0.47
November	0.43	1.09	19.4	0.55
December	0.39	0.99	20.2	0.57

<sup>1</sup> U.S. Department of Commerce, 1982, Period of Record 1941-1970.

<sup>2</sup> U.S. Department of the Interior, 1981, Period of Record 1931-1980.

**Editorial/Clarification Comment Number 2**

**Revised Page 2.9-14**

process facility will be located and where maximum surface disturbance will occur. (Figure 2.9-6). Seven sites were also sampled in the proposed restricted area (Figure 2.9-7). At the plant and pond locations, another set of samples will be obtained before commercial construction and also after topsoil removal and excavation is complete.

Material collected for nonradiological analysis was in the form of surface samples. These were collected as follows: A two meter transect was laid out in either a north-south or east-west direction at the desired location. Points along this line were situated at 0, 0.67, 1.33 and 2 meters. At each point soil was removed from a 5 to 7.6 cm (2 to 3 in.) diameter circular area to a depth of 5 cm (2 in.).

Three trace elements were chosen for consideration in this sampling. Arsenic, selenium and vanadium are commonly associated with uranium ore deposits. This is especially true in roll-front type deposits where halos of metal sulfides and other reduced compounds occur at the "nose" or in front of the uranium mineralization. When leaching takes place during mining, varying concentrations of these companion compounds will also be solubilized. Thus, a surface spill of leach solution might contain small amounts of these three elements. The leach solution will also contain uranium and radium-226. The baseline uranium and radium-226 levels in the soil are found in Section 2.10.

Samples from the Permit Area and the specific samples from Section 19 (Figure 2.9-5) were analyzed for arsenic and selenium and the samples from the proposed restricted area (Figure 2.9-7) were analyzed for vanadium.

Results of the soil sampling are found in Tables 2.9-10 and 2.9-11. As can be seen from the data in Table 2.9-10 the arsenic concentration ranges from 0.59  $\mu\text{g/g}$  to 3.30  $\mu\text{g/g}$  and the selenium concentration ranges from <0.01  $\mu\text{g/g}$  to 0.06  $\mu\text{g/g}$ . There does not appear to be any relationship between the soils type and the levels of these elements. The vanadium analysis shown in Table 2.9-11 indicate that the vanadium levels in the restricted area are very consistent with a range of 22 to 29  $\mu\text{g/g}$ .

Soils develop over long periods of time and contain elements that are in equilibrium with the established chemical environment. Several factors govern solubility and stability of elements in soils. These include pH, drainage status, organic content, sulfate content, etc. In addition, many studies have pointed out there is no absolute correlation between the total concentration of an element in the soil and its uptake by plants. However, uptake of arsenic, selenium, and vanadium by plants depends highly on the chemical form and availability of the elements and upon the plant species.

**Editorial/Clarification Comment Number 3**

**Revised Table 2.10-14 (page 2.10-32)**

**Table 2.10-14: Average Radiometric Analysis of Sediment Samples From Squaw Creek  
Crow Butte Project**

Sample Location	Sample Period	U-Nat $\times 10^{-9}$ $\mu\text{Ci/ml}$	Th-230 $\times 10^{-9}$ $\mu\text{Ci/ml}$	Ra-226 $\times 10^{-9}$ $\mu\text{Ci/ml}$	Pb-210 $\times 10^{-9}$ $\mu\text{Ci/ml}$	Po-210 $\times 10^{-9}$ $\mu\text{Ci/ml}$
S-2	5/82 - 10/86	$4.9 \pm 9.43$	$2.4 \pm 4.6$	$0.9 \pm 1.1$	$0.4 \pm 0.3$	$1.0 \pm 0.5$
S-3	5/82 - 10/86	$2.5 \pm 4.2$	$2.2 \pm 4.0$	$0.8 \pm 0.5$	$0.3 \pm 0.4$	$0.5 \pm 0.2$

**Editorial/Clarification Comment Number 5**

**Revised Page 5-32**

### Radon Daughter Concentration Determination

Radon-222 daughter concentrations are determined from surveys performed as described in Section 5.7.3.2.

The working-level months for radon daughter exposure is calculated on Time Weighted Exposure (TWE) forms. The working-level months are totaled and entered onto each employee's Occupational Exposure Record.

### Historical Program Results

Table 5.7-5 summarizes the results of radon daughter exposure calculations at Crow Butte Uranium Project since 1990. The data shows that internal exposure due to radon daughters at Crow Butte Uranium Project has been maintained ALARA. The maximum individual internal exposure to radon daughters during the period from 1990 through 1994 was 0.502 working-level months or approximately 12.5% of the allowable regulatory limit of 4 working-level months. The maximum annual average internal exposure to radon daughters was 0.258 working-level months which is approximately 6.5% of the regulatory limit.

### Proposed Radon Daughter Exposure Monitoring Program

CBR proposes to institute the same internal radon daughter exposure calculation methods at Crow Butte Uranium Project that have been used to date and which are currently contained in Standard Operating Procedure C-16, "Internal Exposure Control and Calculations". 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).

**Editorial/Clarification Comment Number 6**

**Revised Pages 5-34 through 5-35**

## 5.7.5 BIOASSAY PROGRAM

### Program Description

CBR has implemented a urinalysis bioassay program at the Crow Butte Uranium Project facilities that meets the guidelines contained in USNRC Regulatory Guide 8.22, "Bioassay at Uranium Mills, Revision 1." The primary purpose of the program is to detect uranium intake in employees who are regularly exposed to uranium. The bioassay program consisted 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.
2. During operations, urine samples are collected from workers whose routine work assignment requires them to enter areas where the potential for inhalation of yellowcake exists. Samples from these workers are collected on a quarterly frequency. Workers who have the potential for exposure to dried yellowcake are sampled on a monthly basis. Samples are analyzed by an outside analytical laboratory for uranium content. 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  $\mu\text{g/l}$ .
3. Action levels for urinalysis are established based upon Table 1 in USNRC Regulatory Guide 8.22, "Bioassay at Uranium Mills, Revision 1."

### Historical Program Results

Following is a summary of the results of the bioassay program since 1990.

#### 1990

All bioassay samples were reported at less than the 5  $\mu\text{g/l}$  detection limit.

#### 1991

All bioassay samples were reported at less than the 5  $\mu\text{g/l}$  detection limit.

### 1992

All bioassay samples were reported at less than the 5 µg/l detection limit.

### 1993

All bioassay samples were reported at less than the 5 µg/l detection limit.

### 1994

All bioassay samples were reported at or less than the 5 µg/l detection limit with the exception of one sample which was 13.9 µg/l. Resamples of the individual that submitted this sample were less than 5 µg/l.

### Bioassay Quality Assurance Program Description and Historical Results

Elements of the Quality Assurance requirements for the Bioassay Program are based upon the guidelines contained in USNRC Regulatory Guide 8.22, "Bioassay in Uranium Mills", Revision 1. These elements included the following:

1. Each batch of samples submitted to the 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  $\pm 30\%$  of the spiked value. CBR has tracked the results of the blind spike analysis since 1990. All analytical results have fallen within the acceptable range.
2. The analytical laboratory spikes 10 to 30% of all samples received with known concentrations of uranium and the recovery fraction determined. Results are reported to CBR. All results have been within  $\pm 30\%$ .

### Proposed Bioassay Program

CBR proposes to continue to implement the Bioassay Program described in this section in accordance with the guidance contained in USNRC Regulatory Guide 8.22, "Bioassay in Uranium Mills, Revision 1" and with the instructions currently contained in Standard Operating Procedure C-10, "Bioassay Sampling."

**Editorial/Clarification Comment Number 8**

**Revised Pages 2.7-13 and 2.7-29 through 2.7-34**

The integrity of confinement of the ore-zone aquifer (Basal Chadron Sandstone) may be characterized most graphically by the hydraulic resistance factor,  $c$ . The hydraulic resistance of the overlying aquiclude is about 53,000 years and that of the underlying aquiclude is about 34,000,000 years. The times needed for a water molecule to travel through the entire thicknesses of the aquicludes, assuming an effective porosity of 2.0 percent, under unit gradient (one foot of head loss per foot of movement in the direction of flow) are about 1,050 years for the overlying aquiclude and about 685,000 years for the underlying aquiclude.

### Movement of Groundwater

The piezometric surface of the Basal Chadron Sandstone dips toward the north at a gradient of about 0.04 percent (0.0004) which is equal to one foot per 2500 feet. Using a directional hydraulic conductivity of 10 ft/day, a gradient of  $4 \times 10^{-4}$  and a porosity of 29 percent, the average pore velocity across the R&D site was computed to be 5.0 ft/year. The groundwater flux across the site was computed to be 0.16ft<sup>3</sup>/day per unit width of the aquifer.

### Second Aquifer Test

A second multiple-well aquifer test was performed in the mineralized area near the northern boundary of Section 19. This test was part of a hydrogeologic investigation of the commercial permit area north of the R&D site. This investigation consisted of: (1) a review of existing geologic and hydrogeologic data; (2) design of an appropriate aquifer test; (3) design and construction of an appropriate well array for the aquifer test; (4) laboratory testing of core samples from confining layers; (5) conducting the aquifer test, (6) analyzing the aquifer test data, and (7) interpreting the results. This hydrogeologic investigation was structured to address environmental and operational questions pertinent to ISL uranium mining at the site. Specifically, the requirements outlined by the Nuclear Regulatory Commission (NRC) in Regulatory Guide 3.46, Section 2.7.1 and Draft Staff Technical Position Paper WM-8203, Section 3.1.2. Therefore, this hydrogeologic investigation was oriented toward the characterization of the hydraulic properties of the ore-bearing aquifer, and the hydraulic relationship of the aquifer to the overlying and underlying confining strata and the overlying aquifer. The aquifer test site is located near the north boundary of Section 19, T 31 N, R51 W, Dawes County, Nebraska. This site is approximately 2800 feet north of the R & D site (Figure 0-7).

(8.7 ft/day) to about 66 gpd/ft<sup>2</sup> (8.89 ft/day) Table summarizes the results of the analysis of the aquifer test data.

The Hantush Method For Anisotropic aquifers was used to determine the direction and magnitude of the major and minor axes of transmissivity of the Basal Chadron Sandstone. The major axis of transmissivity in the Basal Chadron Sandstone lies along an azimuth of about 51° and has a magnitude of 2760 gpd/ft (369 ft<sup>2</sup>/day) (Figure 0-8). The minor axis of transmissivity has an azimuth of about 141° and a magnitude of 2692 gpd/ft 360 ft<sup>2</sup>/day.

#### Overlying and Underlying Confining Layers

The overlying confining layer piezometer (UCP-1) showed no response to the pumping from the Basal Chadron Sandstone during the aquifer test. However, this piezometer did respond to the rapid changes in barometric pressure that accompanied the passage of a low pressure system and a cold front which confirmed that it was indeed functioning properly. Because UCP-1 did not respond to pumping, it was not possible to use the water level data from UCP-1 to calculate the hydraulic properties of the upper confining layer using the Neuman-Witherspoon Method. Therefore, laboratory data from the consolidation tests of core samples from UCP-1 were used to calculate the hydraulic properties of the overlying confining layer.

Results of the laboratory consolidation test data from three core samples of UCP-1 are shown earlier in Table 0-4 The calculated average coefficient of compressibility,  $a_v$ , of the red clay portion of the overlying confining layer, is  $3.99 \times 10^{-7}$  cm<sup>2</sup>/g and the calculated average vertical hydraulic conductivity is  $3.49 \times 10^{-11}$  cm/sec. Using these consolidation test data, the calculated specific storage of the red clay portion of the overlying confining layer is  $3.08 \times 10^{-7}$  cm<sup>-1</sup> and the calculated hydraulic diffusivity is  $1.13 \times 10^{-4}$  cm<sup>2</sup>/sec. Analysis of drill cuttings and geophysical logs of UCP-1 and exploration holes in the vicinity of the test site show that the lithology of the strata between the red clay and the overlying Brule aquifer (Upper Chadron and Lower Brule Formations) is similar to the red clay. Therefore, it is reasonable to assume that the hydraulic characteristics of these strata are similar to those of the red clay. Given that the red clay is approximately 30 feet thick and the total overlying confining layer is approximately 325 feet thick, the hydraulic resistance,  $c$ , (Kruseman and de Ridder, 1979) is about 830,200 years for the red clay and 9,000,000 years for the entire confining layer. Assuming an average effective porosity of the overlying confining layer of 2.0%, the travel time through the red clay portion of the upper confining layer would be about 16,600,000 years and that of the entire upper confining layer would be about 180,000 years under unit gradient.

**Table 2.7-6: Summary of Aquifer Test Data Analysis**

**Jacob Method (Drawdown)**

Well	T (gpd/ft)	T (ft <sup>2</sup> /day)	S	K (gpd/ft <sup>2</sup> )	K (ft/day)
COW-1	2682	359	8.65x10 <sup>-5</sup>	67	8.98
COW-2	2687	359	1.14x10 <sup>-4</sup>	67	8.98
COW-3	2795	374	9.73x10 <sup>-5</sup>	70	9.35
Average	2721	364	9.93x10 <sup>-5</sup>	68	9.10

**Theis Method (Drawdown)**

Well	T (gpd/ft)	T (ft <sup>2</sup> /day)	S	K (gpd/ft <sup>2</sup> )	K (ft/day)
COW-1	2730	365	8.44x10 <sup>-5</sup>	68	9.13
COW-2	2733	365	1.11x10 <sup>-4</sup>	68	9.13
COW-3	2724	364	1.31x10 <sup>-4</sup>	68	9.10
Average	2729	365	1.09x10 <sup>-4</sup>	68	9.12

**Theis Recovery Method**

Well	T (gpd/ft)	T (ft <sup>2</sup> /day)	S	K (gpd/ft <sup>2</sup> )	K (ft/day)
COW-1	2659	355		66	8.88
COW-2	2626	351		66	8.78
COW-3	2604	348		65	8.70
Average	2630	351		66	8.79

**Average of Jacob and Theis Methods (Drawdown) <sup>1</sup>**

Well	T (gpd/ft)	T (ft <sup>2</sup> /day)	S	K (gpd/ft <sup>2</sup> )	K (ft/day)
COW-1	2706	362	8.55x10 <sup>-5</sup>	68	9.05
COW-2	2710	362	1.13x10 <sup>-4</sup>	68	9.05
COW-3	2760	364	1.14x10 <sup>-4</sup>	69	9.23
Average	2725	364	1.04x10 <sup>-4</sup>	68	9.11

Notes: <sup>1</sup> Used in anisotropy calculations.

Table 2.7-7 summarizes the confining layer properties determined by laboratory and field methods as part of this investigation.

The underlying confining layer piezometer (LCP-1) responded to the same rapid changes in barometric pressure which were measured in overlying confining layer piezometer. However, LCP-1 also showed a trend toward a very small amount of drawdown (.06 feet) during the aquifer test.

Because the vertical hydraulic conductivity of the underlying confining layer (Pierre Shale), as determined from the laboratory consolidation tests, is of the same order of magnitude as the vertical hydraulic conductivity of the upper confining layers (10-11 cm/sec), no drawdown was anticipated in LCP-1 during the test. For this reason, it is suspected that the small amount of drawdown observed in LCP-1 is the result of annular leakage between the borehole and the packer which was set to hydraulically isolate the piezometer tip from the overlying Basal Chadron Sandstone. If the packer did not completely seal the borehole above the piezometer tip, the piezometer would be affected by the pressure drop in the pumped aquifer which would be transmitted by the annulus leaks. Thus, the response of the piezometer would be the result of borehole-packer annulus leaks. If this were the case, the Neuman-Witherspoon analysis of the piezometer water levels would only serve to quantify the vertical leakage or hydraulic conductivity of the packer and borehole seal, not the vertical hydraulic conductivity of the underlying confining layer. Recognizing that this problem may exist, a Neuman-Witherspoon analysis was made of the water level data from LCP-1.

Results of the laboratory consolidation test data from two core samples from LCP-1 are shown earlier in Table 2.7-4. The calculated average coefficient of compressibility,  $a_v$ , of the Pierre Shale is  $5.13 \times 10^{-7}$  cm<sup>2</sup>/g and the calculated average vertical permeability is  $3.63 \times 10^{-11}$  cm/sec. Using these consolidation test data, the calculated specific storage of the top 5 feet of the underlying confining layer (Pierre Shale) is  $2.78 \times 10^{-7}$  cm<sup>-1</sup> and the calculated hydraulic diffusivity is  $5.22 \times 10^{-3}$  cm<sup>2</sup>/sec. Applying the Neuman-Witherspoon Method to the data from the aquifer test and the consolidation test, produces a field vertical hydraulic conductivity of  $1.45 \times 10^{-9}$  cm/sec. Oil test holes have shown that the Pierre Shale is approximately 1200 feet thick in the vicinity of the aquifer test site. Therefore, the calculated hydraulic resistance,  $c$ , using field measured vertical hydraulic conductivity, is about 799,900 years. The calculated hydraulic resistance using the vertical hydraulic conductivity calculated from the laboratory consolidation tests is about 31,919,000 years. The average effective porosity of the Pierre Shale is estimated to be 2.0%. Therefore, the travel time through the Pierre Shale would be about 16,000 years using field determined vertical hydraulic conductivity

**Table 2.7-7: Summary of Confining Layer Properties**

Parameters	Red Clay (UCP-1)	Pierre Shale (LCP-1)
Coefficient of compressibility, $a_v$ (cm <sup>2</sup> /g)	$3.99 \times 10^{-7}$	$5.13 \times 10^{-7}$
Specific storage, $S_s'$ , (cm <sup>-1</sup> )	$3.08 \times 10^{-7}$	$2.78 \times 10^{-7}$
Diffusivity, (cm <sup>2</sup> /sec)	$1.13 \times 10^{-4}$	$5.22 \times 10^{-3}$
Formation Thickness, (feet)	30	1200
Vertical hydraulic conductivity, $K_v'$ , (cm/sec)		
Lab Data	$3.49 \times 10^{-11}$	$3.63 \times 10^{-11}$
Field Data	----	$1.45 \times 10^{-9}$
Hydraulic resistance, c, (years)		
Lab Data	830,200 <sup>1</sup>	31,929,000
Field Data	----	799,300
Bulk Porosity (percent)	31.8	32.5
Assumed Effective Porosity	2.0	2.0
Travel time (years)		
Lab Data	16,600 <sup>2</sup>	638,000
Field Data	----	16,000

Notes: 1 Red clay member only - total overlying confining layer = 9,000,000.

2 Red clay member only - total overlying confining layer = 180,000.

and about 638,000 years using laboratory determined vertical hydraulic conductivity under unit gradient.

### Overlying Aquifer

The overlying aquifer monitor well, BMW-1, showed no response to the pumping from the Basal Chadron Sandstone during the aquifer test. However, this well did respond to barometric changes that occurred during the aquifer test which confirmed that it was functioning properly. Because BMW-1 did not respond to pumping, it is evident that the overlying aquifer is not in hydraulic communication with the Basal Chadron Sandstone. Therefore, no further analysis was made of the test data from BMW-1.

## **INTERPRETATION OF DATA**

### Aquifer Response to Pumping

The results of this investigation show that the Basal Chadron Sandstone, which is the ore-bearing aquifer at the Crow Butte site, is a non-leaky, confined, slightly-anisotropic aquifer. The effective transmissivity of the Basal Chadron Sandstone is 2726 gpd/ft. The average thickness of the aquifer at the test site is about 40 feet. Therefore, the average hydraulic conductivity is about 68 gpd/ft<sup>2</sup> (9.10ft/day). The average storativity is  $1.04 \times 10^{-4}$ . The azimuth and magnitude of the major axis of transmissivity are about 51° and 2760 gpd/ft (369 ft<sup>2</sup>/day). The azimuth and magnitude of the minor axis of transmissivity are about 141° and 2692 gpd/ft (360 ft<sup>2</sup>/day).

The piezometric surface of the Basal Chadron Sandstone is approximately 495 feet above the top of the aquifer. The piezometric surface of the overlying aquifer is about 204 feet above the top of the Brule Sand. The difference between the piezometric surfaces of the two aquifers is about 59 feet. This fact plus the fact that BMW-1 did not respond to pumping from the Basal Chadron Sandstone, are evidence that the Basal Chadron Sandstone is confined and that it is not hydraulically connected to the overlying aquifer.

### Integrity of Confinement

Confined aquifers may receive small amounts of water through vertical recharge from the confining layers. Even confining layers formed of very low permeability may yield small amounts of water if the hydraulic gradient in the aquifer-aquitard system is favorable. The aquitards which overlie and underlie the Basal Chadron Sandstone probably yielded some small amount of water as recharge (leakage) to the aquifer during the pumping of the aquifer test. However, the amount of this recharge or leakage was extremely

small as evidenced by the piezometer responses and the drawdown analysis of the Basal Chadron Sandstone. The overlying confining layer piezometer did not show any response attributable to the pumping. The underlying confining layer piezometer did show a maximum drawdown of 0.06 feet about 4300 minutes after pumping began. However, it is suspected that this small amount of drawdown is attributable to leakage at the annulus of the packer and borehole rather than to leakage from the confining layer.

The lack of substantial drawdown in the confining layer piezometers is attributable to the extremely low vertical hydraulic conductivity of the confining layers. The vertical hydraulic conductivity of the overlying confining layer is about  $3.49 \times 10^{-11}$  cm/sec., and that of the underlying confining layer is about  $1.45 \times 10^{-9}$  to  $3.63 \times 10^{-11}$  cm/sec. Confining layers with vertical hydraulic conductivities this low are, by definition, called aquicludes, rather than aquitards.

The integrity of confinement of the ore-zone aquifer (Basal Chadron Sandstone) may be characterized most graphically by the hydraulic resistance,  $c$ . The calculated hydraulic resistance of the entire thickness of the overlying aquiclude is about 9,000,000 years and that of the underlying aquiclude is between 799,900 years and 31,919,000 years. The times needed for a given water molecule to travel through the entire thicknesses of the aquicludes under unit gradient (one foot of head loss per foot of movement in the direction of flow) are about 180,000 years for the upper aquiclude and about 16,000 years to 638,000 years for the lower. Because the gradients would be much smaller during mining, actual travel times would be much longer than those stated above.

#### Movement of Groundwater

The piezometric surface of the Basal Chadron Sandstone dips approximately to the north at a gradient of  $7.84 \times 10^{-4}$  which is equal to 1 foot per 1275 feet. Using a directional hydraulic conductivity of 9.11 ft/day, a gradient  $7.84 \times 10^{-4}$  and a porosity of 29 percent, the average pore velocity across this part of the commercial study area is about 9.00 ft/year. The groundwater flux across the test site was computed to be about .29 ft<sup>3</sup>/day per unit width of the aquifer. (Darcy, 1856).

#### Extent of Investigated Area

Using the Cooper-Jacob Distance-Drawdown Method (Cooper and Jacob, 1946), the radius of influence of the aquifer test in the Basal Chadron Sandstone was calculated to be about 5000 feet. Therefore, the area investigated and characterized by this test is approximately 1803 acres.