Geochemical Consulting Services, LLC

Solubility, Speciation, and Reaction Path Modeling
Groundwater and Soil Geochemistry
Environmental Assessment
Risk Assessment

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Mr. Frankel:

I have reviewed documents associated with the Renewal of the Source Material License (No. SUA-1534) for Crow Butte, Nebraska and have found the applicant has not provided sufficient data to demonstrate proper development of (1) baseline water quality in the aquifer exemption zone and (2) excursion limits at monitoring wells.

<u>Baseline Water Quality in the Aquifer Exemption Zone</u>

Figure 2.9-2 illustrates the proposed aquifer exemption zone around the ore bodies, and there is no statistical justification for the location of the baseline wells to validate that the results in Table 2.9-4 represent the water quality in the exempt zone. Note that the baseline wells in Figure 2.9-2 are clustered and not spread out over the entire exempt zone, and this violates statistical protocol. Within the aquifer exemption zone (i.e., the zone within the monitoring well ring), a systematic grid must be laid out to determine the location of the baseline water-quality wells. The density of nodes within the grid will be determined by the size of the area and the data quality objectives. Data quality objectives (EPA 2000a & 2000b) state the statistical confidence one wishes to have in the estimate of the mean (normal or log normal distribution) or median (no defined distribution) for the water-quality parameters. If a high level of confidence is required for an estimate of the mean or median, more baseline wells will be required.

For example, if we wish to establish a 95 percent confidence interval on the mean for a normal or log normal set of data, with an estimated standard deviation of 20 and using a half width of 10 for the confidence interval, an exempt aquifer area measuring 1200 by 1200 feet would require a minimum of 9 baseline wells (PNNL, 2007). The location of the wells on the grid nodes is illustrated on Figure 1. The half width of the confidence level is a key consideration in determining the number of wells; as the half width decreases, the number of wells increases. The selected level of confidence and estimated standard deviation also affect the number of wells. A lower level of confidence and lower estimate of the standard deviation would result in fewer baseline wells.

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Alternatively, we may elect to locate wells on the grid using a random number generator. In general, less wells are required if they are located randomly, and this is shown on Figure 1 as two random locations per quadrant. Free modeling software, developed by the Pacific Northwest National Laboratory for the Department of Energy (PNNL 2007), allows a large number of scenarios to be evaluated to determine the optimum data quality objectives and sampling approach for the stakeholders.

The well logs provided indicate the Chadron is approximately 50 to 80 feet thick through most of the mining area (Figures 2.6-4 through 2,6-11). The sampling interval for the baseline wells is 20 feet (Table 2.9-3), which does not represent the entire thickness of the aquifer. Figure 2 shows that a water sample obtained from Well 1, screened only in the ore zone, returns a biased sample that does not represent the water quality of the column of water at the given location. Well 2 (Figure 2) indicates the correct method for sampling the water, which requires that the entire thickness of the aquifer be screened to obtain a representative sample.

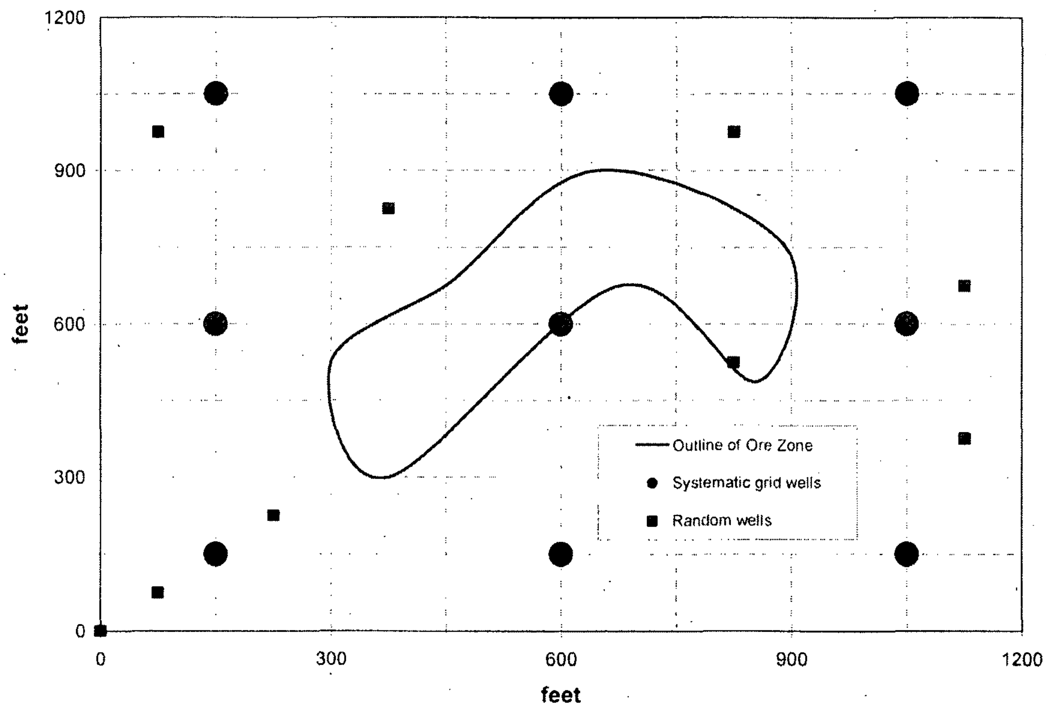

Figure 1. Chart of aquifer exempt zone (i.e., zone surrounded by monitoring wells) and locations for baseline wells established with valid statistical methods.

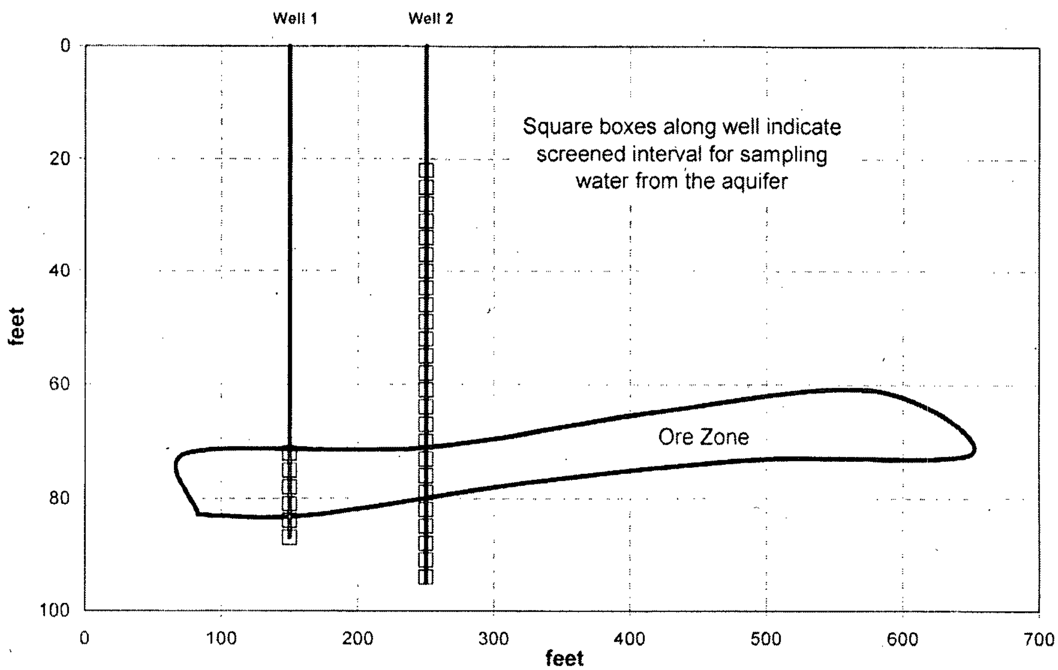

Figure 2. Cross section of an aquifer (20 to 90 feet) showing improper (Well 1) and proper (Well 2) sampling intervals to obtain a representative sample.

The number of sampling events used to establish the aquifer water quality in Table 2.9-4 and the analytical results for each sampling event are not provided to evaluate the results in the table. A minimum of 4 sampling rounds should be collected, and EPA recommends 8 rounds with sampling occurring no more frequently than once monthly.

After collecting a round of data, a proper statistical analysis must be performed to obtain a valid estimate of the mean or median for the water-quality parameter. The first statistical test that must be performed is to evaluate whether the data follow a normal or log normal distribution, and this can be done with the Shapiro-Wilk test or a probability plot (EPA 1992). If the data fail to follow a normal or log normal distribution, non-parametric methods must be used to estimate the median and confidence intervals. The importance of establishing the data distribution is summarized in Table 1.

Assume nine samples were taken from the nine locations on Figure 1 and analyzed for radium-226. A valid statistical sampling of the exempt aquifer zone collects more

samples from outside the ore zone than within the ore zone, as the greater area within the monitoring well ring is outside the ore zone. Reported results, mean and median values, and probability scores from the Shapiro-Wilk test are given in Table 1. Note the significant difference between the mean (exceeds EPA drinking water standard) and median (below EPA drinking water standard) values, and this is a fairly good indication that the data do not follow a normal or log normal distribution.

A probability plot of the data (Figure 3) and the results of the Shapiro-Wilk test confirm this. The normal-quantile values must fall on a straight line or the Shapiro-Wilk probability values must exceed 0.05 (at the 95 percent confidence level) for a normal or log normal distribution to be declared, which is clearly not the case. Therefore, the median, and not the mean, must be used to represent the central tendency of the data. Note that inappropriate use of the mean results in a high bias on the estimate of the baseline value for radium-226, which improperly elevates restoration clean-up levels and lowers the costs associated with the number of pore volumes needed to exchange to meet the clean-up levels.

Table 1. Radium-226 values and statistical results.

Radium-226 (pCi/L)	Mean (pCi/L)	Median (pCi/L)	Shapiro-Wilk test
0.8			Probability result
0.9	12	2.3	
1.1			Normal
1.7			$P < 0.01$
2.3			
2.8			Log normal
3.1			$P = 0.02$
5.2			
87			

The arguments presented above for Section 2.9-3 of the License Renewal Application also hold for the baseline and restoration values presented for the mining units (Tables 2,7-6 through 2.7-15 and Tables 6.1-2 through 6.1-11). That is, all data and methods used to construct baseline and restoration values must be included in the application to allow an independent evaluation of the summary tables and valid statistical protocols must be used to locate the wells and evaluate the analytical results. Baseline and restoration values presented in the application are improperly biased to high results, and this allows restoration to be achieved with less cost and time at the expense of greater contamination in the aquifer.

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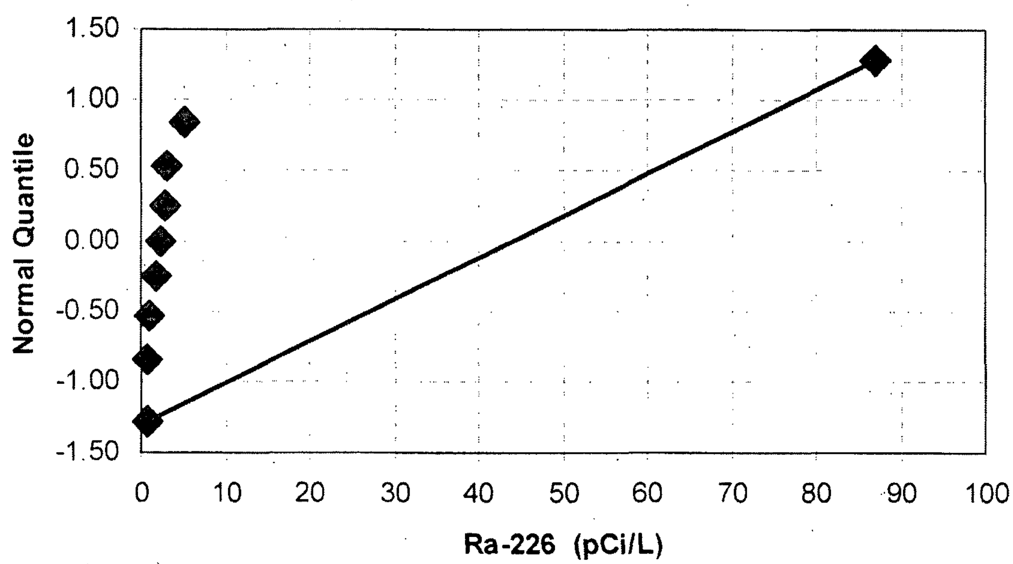

Figure 3. Probability plot indicating that all data do not lie near or on a straight line, which rules out a normal or log normal distribution.

Excursion Limits at Monitoring Wells

Section 5.8.8.2 briefly touches on baseline water quality for the monitoring wells, and upper control limits for indicating an excursion. Baseline water quality is determined on three samples collected 14 days apart, and this is inconsistent with the best practice and guidance discussed above. Chloride, conductivity and alkalinity are noted as the parameters used to monitor lixiviant migration. As uranium is mobilized and transported by the high oxygen and alkalinity in the lixiviant, there is no valid scientific reason to exclude it from the list of excursion monitoring parameters. Upper control limits are set at 20 percent above the maximum baseline value for parameters that exceed 50 mg/L, and for parameters below 50 mg/L 5 standard deviations or 15 mg/L is added to the average value for the indicator. There is no discussion of a valid statistical approach to justify the method for calculating upper control limits.

Ground-water quality data from the monitoring wells must be evaluated to determine if a normal or log normal distribution is present (see discussion above). If the data fail to

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follow a normal or log normal distribution, the mean and standard deviation cannot be used and non-parametric methods must be employed to develop the upper control limit for the excursion parameters.

Uranium is a key indicator of lixiviant excursion because its concentration in baseline wells is generally two or three orders of magnitude lower than the lixiviant and it is highly mobile as a carbonate complex in the lixiviant. Comparing Table 2.7-15 with Table 3.1-3 shows that the lixiviant/baseline concentration ratio is 27 for chloride, 11 for conductivity, 13 for alkalinity and 1300 for uranium (the higher the lixiviant/baseline ratio, the greater the probability that an excursion will be detected at a monitoring well). As the uranium ratio is approximately 100 times greater than the other parameters, it will perform about 100 times better in the detection of an excursion. Therefore, there is no rationale basis to exclude the best excursion indicator from the list of excursion parameters.

EPA (1992) discusses the proper statistical calculation of tolerance limits (a.k.a. upper control limits) using parametric (normal or log normal) and non-parametric techniques. In general, 3 or 4 samples are not sufficient to establish a normal or log normal distribution, and EPA recommends that a non-parametric tolerance limit be set at the maximum observed value (not the maximum value plus 20 percent). As more data are collected at the monitoring well, the distribution of the data is rechecked and if a normal or lognormal distribution is indicated, a tolerance limit can be calculated using the equations provided by EPA (1992). There is no basis or justification for calculating an upper control limit by adding 15 mg/L to the average value. Additionally, using 5 standard deviations added to the average applies only if the data follow a normal or log normal distribution and a Shewhart control chart is constructed.

EPA (1992) addresses the use of 4.5 standard deviations added to the mean via the construction of a Shewhart-cumulative sum control chart. The use of this approach is recommended provided that the data follow a normal or log normal distribution. Assuming a sufficient number of samples have been collected at a monitoring well to demonstrate that the measured values follow a normal distribution, two statistical parameters are calculated to evaluate contaminate migration at the well. First, the standardized mean is calculated from the mean and standard deviation (EPA 1992) and compared to the Shewhart control limit (SCL; set at 4.5 standard deviations above the mean) to evaluate a rapid increase in concentration at the monitor well. Second, the cumulative sum (CUSUM; set at 5 standard deviations above the mean) of the standardized means is calculated for each sampling period (EPA 1992) to determine if it has crossed the 'decision internal value' (h). If h is exceeded, it can indicate a rapid or

slow rise in concentration at the monitoring well. A gradual increase is indicated when the CUSUM exceeds h and the standardized mean does not exceed the SCL.

Figure 4 illustrates the importance of using the SCL and CUSUM for monitoring lixiviant excursion. The SCL (Z) and CUSUM (C) are plotted for an excursion parameter, a gradual increase in contamination exceeds the CUSUM limit in February of 2002, while the SCL limit is not exceeded until January of 2003. The SCL limit is similar to the CBR's use of 5 standard deviations above the mean for any one sampling event, although EPA recommends 4.5 standard deviations for any one sampling event. Using only the SCL limit allows contamination to migrate beyond the monitoring well for nearly a year before an excursion is declared. Therefore, if the CUSUM is not used with the SCL limit a gradual increase in contamination will not be detected and migration of diluted lixiviant will pass the montoring well without corrective action.

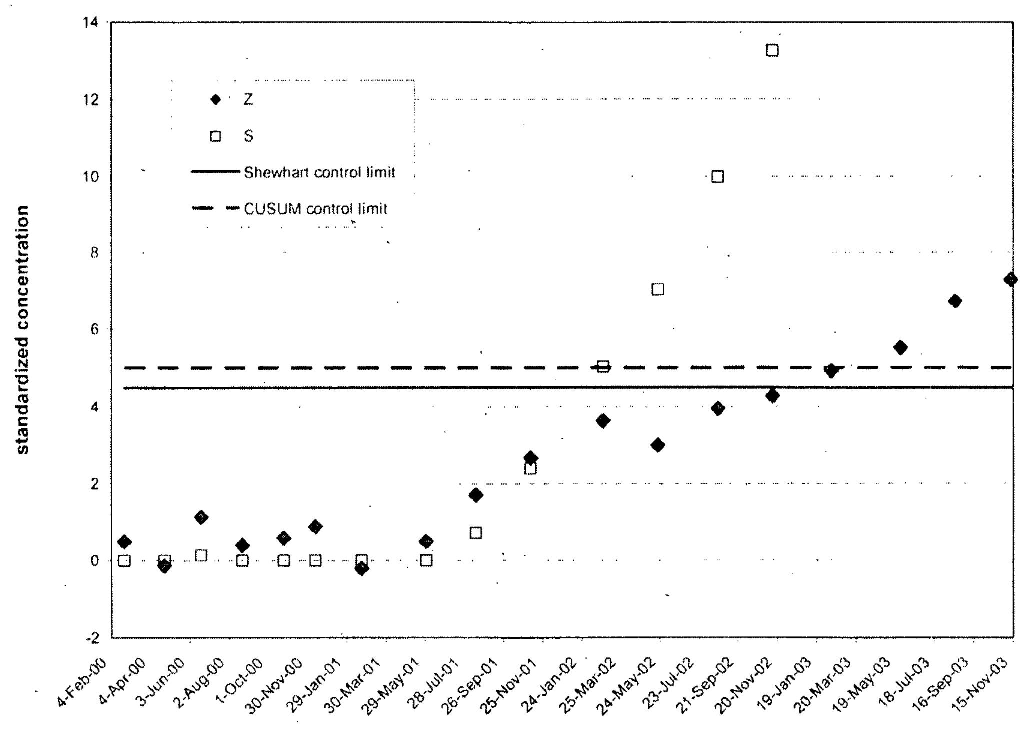

Figure 4. Proper use of a control chart to determine lixiviant excursions.

Although there was insufficient time to develop a detailed analysis of all the concerns and omissions in the application, I note 46 additional issues that warrant a more detailed evaluation.

1) Section 1.8.1 notes that the only radioactive airborne effluent is radon-222 gas. This is not correct in the strict sense, as the radioactive daughters of radon-222 (Po-218, Pb-214, Bi-214, Po-214, Pb-210, Bi-210, Po-210) form in the radon-22 gas cloud emitted from the facility. The radioactive daughters fallout as the plume drifts downwind, and particulate monitoring downwind should be performed to determine the fallout dose.

2) Section 1.11 notes that a yearly review is done to ensure that proper funds have been set aside for restoration. A key factor in calculating the amount of financial surety is the number of pore volumes of groundwater that must be processed to restore the aquifer to per-mining levels. As pre-mining levels are often biased improperly to high values, the number of pore volumes needed to restore the aquifer is underestimated and insufficient surety is posted.

3) There are no data to support the water quality results in Table 2.2-9. All data must be provided to allow an independent reviewer to derive values presented in the table. Use of the mean implies that the proper statistical test was performed to demonstrate that the data follow a normal or log normal distribution. There is no discussion of the use of statistical distribution tests.

4) Table 2.5-13 summarizes particulate data for the Black Hills and Rapid City, and is used to conclude that there is no problem with particulate matter less than 10 micorns (PM_{10}). This is unacceptable. Site specific data must be collected to demonstrate that the CBR site does not emit PM_{10} that exceeds 150 ug/m^3 (24-hour average) or 50 150 ùg/m^3 (annual average).

5) Section 2.6.1.5 notes that the Chadron Sandstone formed as part of a vigorous braided stream system in the early Oligocene. Braided stream systems form a complex assemblage of sediments that consist of channel sands and gravels isolated by sand, silt and clay bank deposits. The primary flow for groundwater is through the channel sands and gravels, and the width of these channels are generally much narrower than the 400-foot spacing of wells in the monitoring ring. Therefore, it is possible that a paleochannel could exist between two monitoring wells and allow pregnant lixiviant to flow past the montoring wells without being detected. There is no discussion on this type of aquifer heterogeneity in Section 2.7.2.3.

6) Figures 2.6-4 through 2.6-11 show the thickness of the Chadron to be 40 to 80-feet thick through most of the mine area. Therefore, it is inappropriate to use a screened interval of 20 feet to sample the groundwater from the ore zone (Table 2.9-3). The entire thickness of the aquifer must be sampled to obtain a representative sample.

7) Tables 2.7-6 through 2.7-16 are not supported by the analytical results used to derive the reported values. See comment 4.

8) Section 2.9 notes that a preoperational monitoring was conducted for nonradiological parameters. This is unacceptable. Uranium and radium must also be considered because exploration holes placed in the ore zone disturb the ore and create a path for oxygen. The disturbance of the ore will expose new uranium mineral surfaces to the groundwater, which will release additional uranium, radium and their progeny. Addition of oxygen to the disturbed region will increase the dissolution of uranium ore minerals.

9) No justification is provided for the location of water-quality wells within the monitoring ring on Figure 2.9-2. Valid statistical methods must be used to locate the systematic or random samples on a grid than covers the entire area enclosed by the monitoring wells.

10) There are no data to support the water quality results in Table 2.9-4. See comment 4. Additionally, if preoperational monitoring was only for nonradiological parameters (see comment 9), when where the samples collected for uranium and radium results that appear in the table?

11) Section 2.9.4 is on surface water quality, but there are no data in the report stream water quality. Surface and buried pipelines that fail catastrophically or slowly leak pregnant lixiviant could contaminate surface water. Pipelines transferring pregnant lixiviant from the well fields to the processing facility are monitored for sudden drop in pressure, which indicates a massive failure and spill. However, small leaks in the buried pipelines, along joints and valves, would not be indicated on the monitor. Therefore, large volumes of pregnant lixiviant could be released to the environment from small leaks over the period of years. Surface waters should be monitored and sampled on a quarterly basis.

12) The end of Section 2.9.4 notes that suspended sediment samples have not been collected since 1982 and there is no plan to collect further samples. This is unacceptable, for reasons noted in comment 11.

13) Soil results in Tables 2.9-10 and 2.9-11 have no results for molybdenum. Molybdenum is known to be concentrated by certain plants and cause problems when livestock ingest the plants containing Mo.

14) On page 3-21 the assumption is made that the aquifer is homogenous and isotropic. This is a poor assumption for fluvial deposits, as there is considerable lateral variability in the grain size (gravel, sand, silt, clay) and preferred flow paths will follow paleochannels.

15) Page 3-32 notes that a risk assessment was performed for the chemical storage facility. There are no assumptions or exposure scenarios discussed to determine if the conclusions are valid.

16) Section 3.3 discusses instrumentation used to monitor the flow out of and into the well fields. There is no detail provided on the pressure drop needed to denote a leak in the piping system transporting pregnant lixiviant. Is a leak of one liter a minute detectable? If so, what pressure drop is associated with such a leak and what is the sensitivity of the system to detect such a drop? If this cannot be detected, there is a potential for a significant amount of contamination to be released over the lifetime of the well field. A one liter per minute leak would result in 1440 liters per day released to the environment.

17) The pond inspection program discussed on page 4-5 does not address air monitoring around the ponds. Radon, mist, and particulate may be mobilized by the wind from the pond and dried margins. Why is air monitoring omitted? What data support such a decision?

18) Page 4-6 notes that if a pond liner leaks, the pond contents will be transferred to another pond. This creates a potential exposure scenario where the contaminated sediments dry out and become airborne by the wind. Air monitoring for particulate and radon is needed around the ponds.

19) Page 4-7 notes that flow-monitoring alarms are activated for a significant piping failure. This implies that a slow leak will not be detected. As noted in comment 16, a slow leak can result in significant contamination of the environment.

20) Page 4-8 (Piping) notes that large leaks would be detected quickly. Again, a small leak could go undetected for years because the piping is buried. This is unacceptable.

21) Page 4-9 notes that the most common surface release is from piping. How is the spill cleaned up? What is done with the contaminated soil?

22) Section 4.2.2.4 (Hazardous Waste) does not mention the arsenic and selenium released from the ore zone. What is the quantity generated and where does it end up in the waste streams?

23) Page 5-15 mentions pond sprays from the enhanced evaporation system. This system has the potential to release mist to the surroundings. See comment 17.

24) Section 5.8 discusses radiation safety controls and monitoring. There is no discussion of air monitoring for radon and daughters downwind of the exhaust vents. What data support such an omission, given hundreds of curies of radon are emitted from this facility.

25) Page 5-28 notes subsurface releases are from ponds and excursions. There can also be subsurface releases from slow leaking pipelines when the leak is too slow to set off the alarm.

26) Section 5.8.7.2 discusses radon monitoring, and notes that 7 locations are monitored. There is no map to show the location of these monitors relative to facilities and downwind direction.

27) Page 5-78 discusses results for air particulate, and notes uranium results are shown on Figs 5.8-18 through 5.8-24. Why are there no displayed results for Ra-226 and Pb-210?

28) Page 5-87 notes that uranium was elevated in the sediment from English Creek. Sediments downstream from the mine areas should be monitored in the future to determine if concentrations increase in the future.

29) The discussion on monitoring well baseline water quality (p. 5-107) indicates the wells are only used to establish excursion limits, which reveals the inadequate approach to establishing baseline in the exempt zone of the aquifer. Monitor wells will reflect the baseline water quality in most of the exempt zone, and should be used to establish baseline in the exempt zone.

30) The discussion on upper control limits and excursion monitoring (p. 5-107) does not cite statistically valid methods for establishing the upper control limits. The use of the noted improper method can result in a large volume of contaminated

groundwater to pass by the monitor wells, as the proposed method only accounts for a rapid increase in contamination, and not a slow increase that is more representative of a migrating plume.

31) The absence of uranium as an indicator of excursion is not justified (p. 5-107). Uranium is highly mobile in the lixiviant and is an excellent indicator of excursions.

32) Section 6.1.3.1 notes that one baseline well per 4 acres is used to establish water quality prior to mining. Are the wells randomly located within each 4 acre zone. If not, why not?

33) Section 6.1.3.2 states that if the baseline concentration exceeds the NDEQ MCL, then the baseline average plus two standard deviations is used to set the restoration goal. What is the justification for this approach? Using the mean and standard deviation is inappropriate unless it can be demonstrated that the data follow a normal or log normal distribution.

34) Analytical data to support the results in Tables 6.1-2 through 6.1-11 are not available to verify that proper statistical methods were used to derive the restoration results.

35) Section 6.1.4 states that Mine Unit 1 was successfully restored to primary or secondary standards. Bicarbonate, sulfate, manganese, selenium, vanadium, uranium and radium were not restored to their primary standard, and there is no summary of secondary standards in Table 6.1-2. What secondary standards apply and why?

36) Section 6.2.3.4 notes that on site burial is possible. If the disposal ponds are to be used as burial sites, will the liners in the system be redesigned to account for permanent disposal? What limits will be placed on the materials that can go into the disposal cell? Will a risk analysis be performed to justify the construction of a disposal cell?

37) Section 6.4.1 gives clean-up criteria for radium and uranium in soil. Why are there no clean-up levels listed for radon decay products (e.g., lead-210), arsenic, molybdenum and selenium?

38) Section 7.6 and 7.12.1.1 discuss air quality impacts. There is no discussion of potential air impacts from contaminated particulate during decommission

activities. The disturbance of contaminated soil during site remediation could suspend contaminants and transport them considerable distances. What type of air monitoring will be performed to ensure that contamination is not spread by air borne dust?

39) Section 7.12.5 discusses air exposure and notes radon and its decay products are the only concern. This is incorrect. Particulate from contaminated soil and mist from the evaporation ponds are also air exposure concerns. Why is there no discussion of these sources?

40) The MILDOS-Area code was used to model the radon dose to receptors. Why are there no input and output files provided to evaluate the model? Tables 7.12-3 through 7.12-7 provide some of the model information. Absent is the wind rose for the area, average wind speeds at 10 and 60 meters, rainfall events and duration, and topographic effects that influence the model results. Also, there is no summary table to compare model results with actual measurements from radon monitors.

41) There is insufficient data provided for the accident scenarios discussed in Section 7.14.5 to properly evaluate the meaning of the stated results.

42) The discussion of economic impacts under Section 8.1.2 notes that failure to renew the license will be detrimental to the economy in the area. However, there is no discussion of the long-term effects of mining. In reality, mining will end and the economy will suffer at some point, and there is little chance for recreation or other industry in an area contaminated by ISL operations. Therefore, the discussion in this section is merely innuendo to intimidate the reader.

43) Section 8.3.1.2 discusses the effectiveness of groundwater restoration as a reason to continue mining. Based on comment 35, one can hardly say the restoration was an overall success. Only by using undefined secondary standards can CBR claim to have restored the groundwater.

44) Section 9.3 notes the groundwater impact is temporary, as restoration returns the groundwater to pre-mining levels. This is simply not true. Restoration to pre-mining levels was not achieved in Mine Unit 1 (comment 35). Secondary standards are not pre-mining levels.

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45) Section 9.3 also notes radiological impacts will be small because all radioactive wastes will be transported off site. This is a false statement, as comment 36 notes that on site disposal is a possible option.
46) Section 9.4 states there is considerable value offered by CBR to the U.S. energy needs. This implies all the mined uranium is bought and used by the U.S. What assurance is given by CBR that all their mined uranium that is sold on the spot market ends up in the U.S.? Can any ISL operation tell the buyer of their product that the product has to stay in the U.S.?

References

Crow Butte Resources, Inc., 2007. Application for 2007 License Renewal, USNRC Source Materials License SUA-1534, Crow Butte License Area, Crawford, Nebraska.

U.S. Environmental Protection Agency (EPA), 1992. Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance, Washington, DC.

U.S. Environmental Protection Agency (EPA), 2000a. Guidance for the Data Quality Objective Process – QA/G-4, EPA/600/R-96/055, Washington, DC.

U.S. Environmental Protection Agency (EPA), 2000b. Guidance for the Data Quality Assessment – Practical Methods for Data Analysis - QA/G-9, EPA/600/R-96/084, Washington, DC.

Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance, Washington, DC.

Pacific Northwest National Laboratory (PNNL), 2007. Visual Sample Plan, Version 5.0 User's Guide, PNNL-16939, Richland, WA.

Sincerely,

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