



Baseline water quality at ISL uranium mines  
Richard.Abitz  
to:  
Jack Kooyoomjian  
07/19/2011 09:42 AM  
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From: Richard.Abitz@srnl.doe.gov

To: Jack Kooyoomjian/DC/USEPA/US@EPA

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### 3 Attachments



UEC-PA1.doc



GSA2010rev1.ppt



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Dr. Kooyoomjian:

Over the past 20 years, I have provided many technical reviews of ISL uranium mining permits in New Mexico, Texas, Wyoming and Nebraska for small communities and Native American tribes. Therefore, I was pleased to see the EPA move forward with consideration of revisions to 40 CFR 192 to account for the protection of groundwater resources affected by ISL mining. The *Draft Technical Report CONSIDERATIONS RELATED TO POST-CLOSURE MONITORING OF URANIUM IN-SITU LEACH/IN-SITU RECOVERY (ISL/ISR) SITES* addresses many of the areas of concern that we have raised in past comments on the improper collection of representative samples for baseline water quality, lack of proper statistical methods to establish background contaminant levels in the proposed exemption zone, and disregard of the heterogeneity of fluvial deposits in placing monitoring wells to detect excursions outside the mining zone. My attached comments to you today, with examples from Goliad, Texas, concern the following two phases identified in the draft report (p.11):

- Phase 1 – Measure baseline groundwater concentrations and establish regulatory approved restoration goals based on statistical procedures that embrace pre-mining temporal and spatial variability.

- Phase 2 – Conduct in-situ mining. Detect lixiviant excursions outside the mining area if they occur. Determine the groundwater chemistry at the end of ISL/ISR operation

Additionally, another important area that affects baseline water quality is exploration and well development to establish a commercially viable operation, which is touched upon briefly on page 11.

There is a lack of regulatory oversight on the closure and sealing of exploration boreholes, which generally involves dumping grout into the top of the hole rather than using a tremie line to grout from the bottom up. Bridging frequently occurs, which leaves multiple migration pathways for lixiviant between the stacked sand horizons that frequently host uranium ore deposits. Wells placed in the ore zone to establish baseline conditions have sometimes been developed using air purging, which has induced temporary oxidation of the uranium ore deposit and biased water quality results to high values for uranium and radium. The GSA2010 powerpoint slides and abstract show the results of this improper practice for the Goliad Sand B.

I appreciate the efforts put forth by you and your committee to protect the groundwater around ISL mining sites. Please contact me if I can clarify any of the points made in my comments.

Regards,

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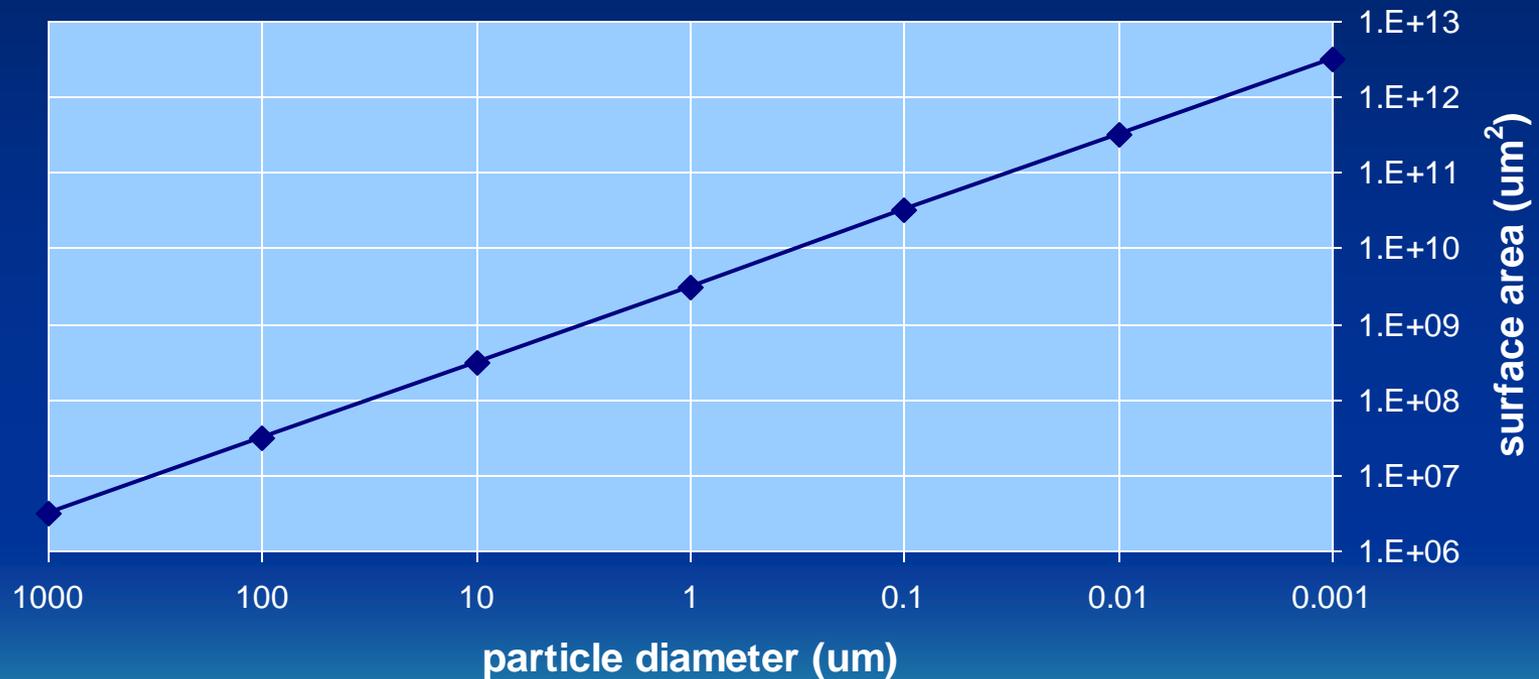
Richard J. Abitz, PhD  
Geochemist  
Technology Program Manager  
Savannah River National Laboratory  
Bldg 773-42A, Rm 239  
Aiken, SC 29808  
803 725-3320 (office)

# *Anthropogenic Induced Redox Disequilibrium in Uranium Ore Zones*

**Richard Abitz**, *Savannah River National Laboratory*  
**Bruce Darling**, *Southwest Groundwater Consulting, LLC*

# Drilling Issues Related to Redox Disequilibrium

Physical change to the ore minerals

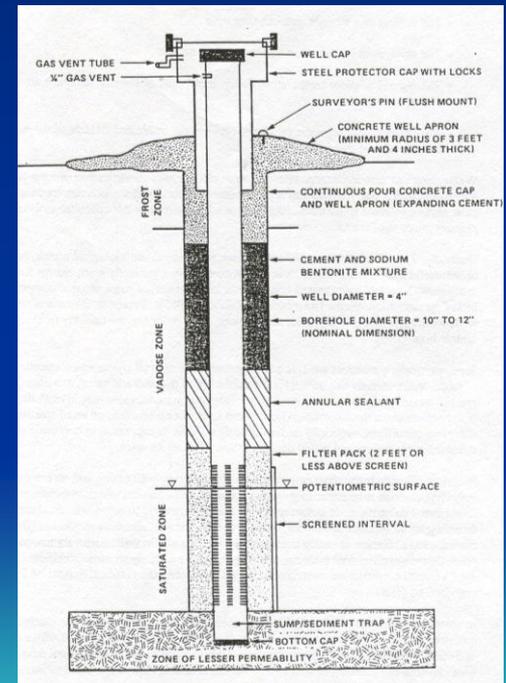


# Drilling Issues Related to Redox Disequilibrium

Chemical reactions in the ore zone



Airlift purge and pump adds  $\text{O}_2$



# Mineral Dissolution Rates

General form of rate law (Lasaga, 1995)<sup>1</sup>:

$$\text{Rate} = k_0 * A_{\text{min}} * e^{-E_a/RT} * a_{\text{H}^+}^n * g(I) * \prod_i a_i^{n_i} * f(\Delta G_r)$$

Increase in both surface area ( $A_{\text{min}}$ ) and  $\text{O}_2$  activity ( $a_{\text{O}_2}$ ) will increase dissolution rate.

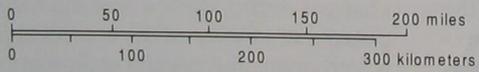
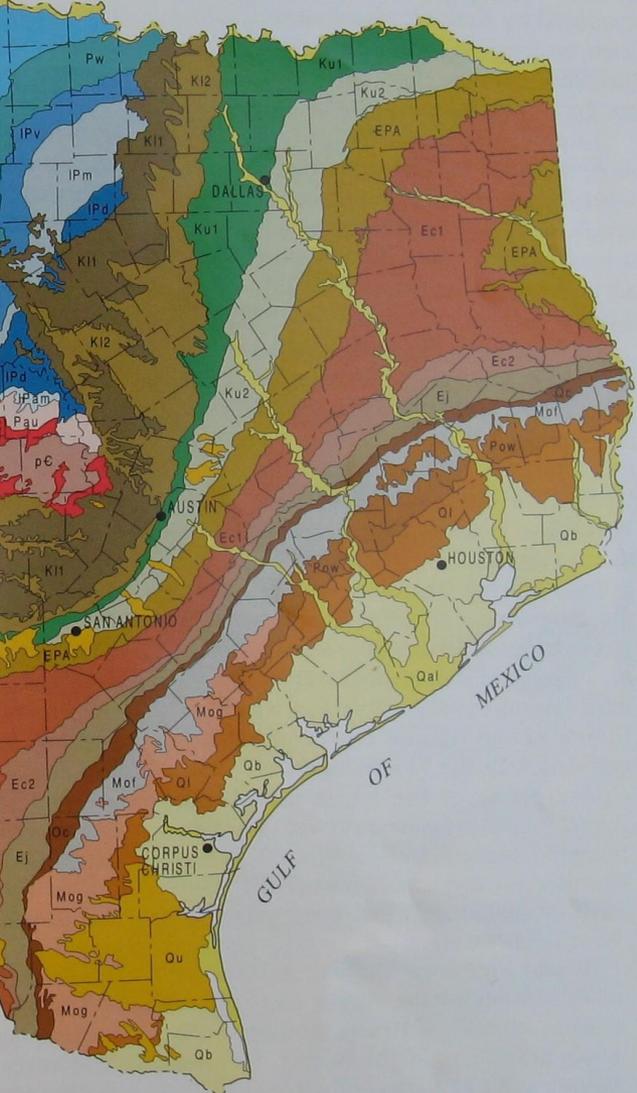
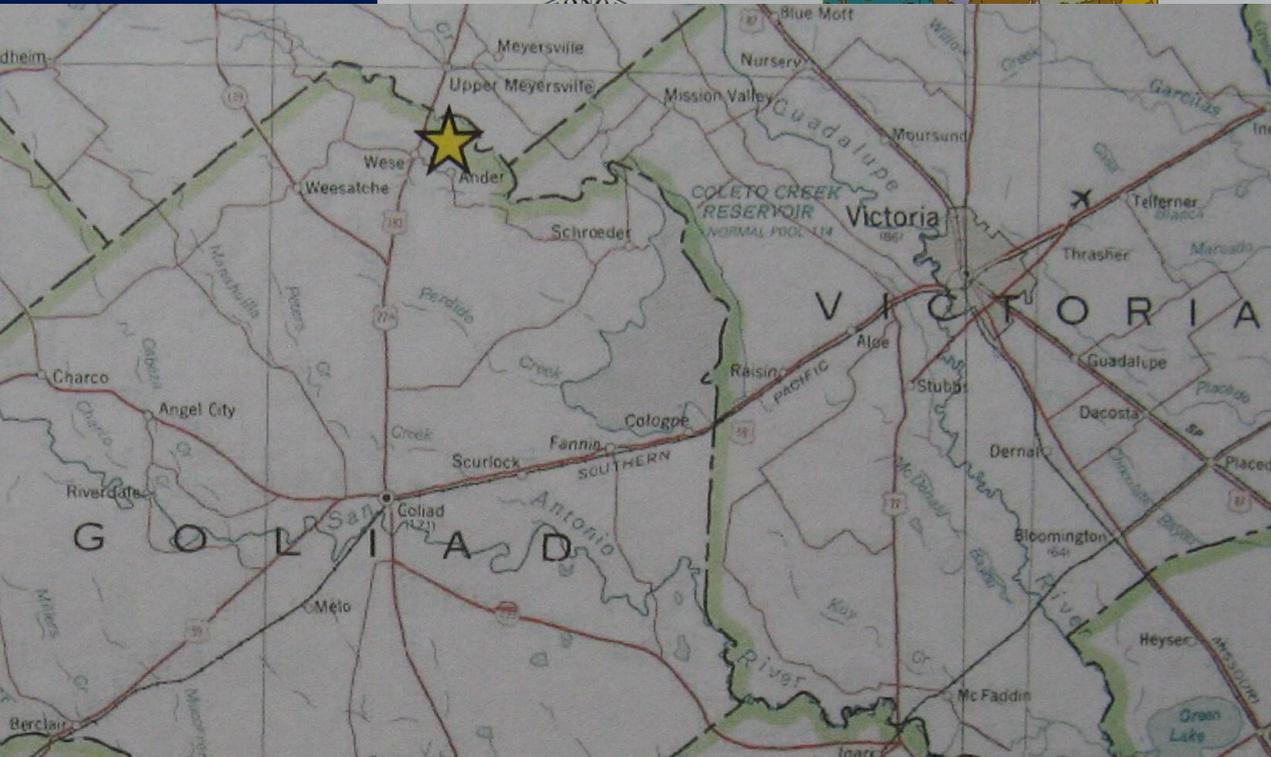
1 Lasaga, A.C., 1995, Fundamental Approaches in Describing Mineral Dissolution and Precipitation Reactions, *in* Reviews in Mineralogy, Volume 31, Chemical Weathering Rates of Silicate Minerals, Mineralogical Society of America.

# GEOLOGY OF TEXAS

1992

BUREAU OF ECONOMIC GEOLOGY  
THE UNIVERSITY OF TEXAS AT AUSTIN

University Station, Box X  
Austin, Texas 78713-8924  
(512) 471-1534

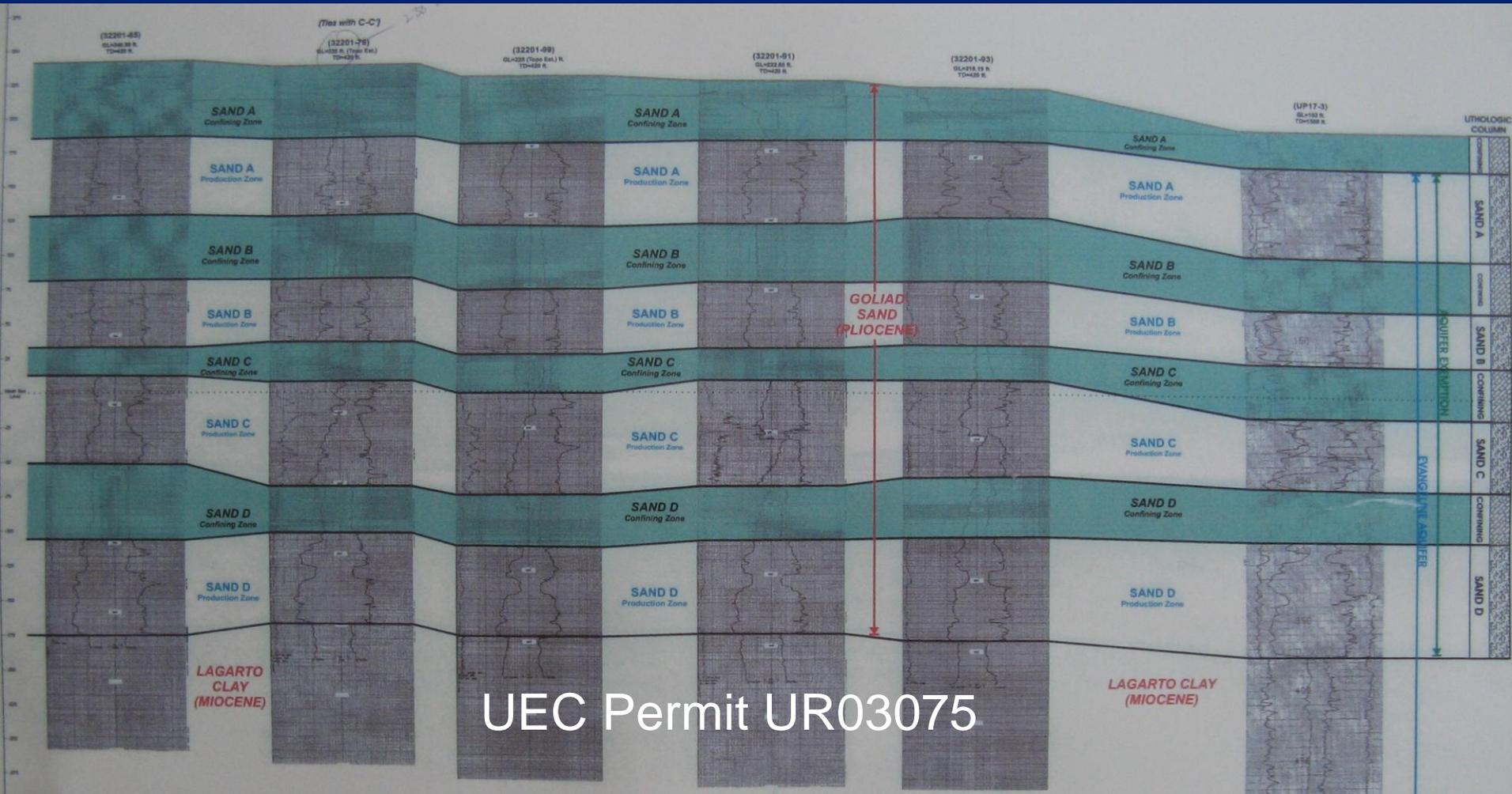


### EXPLANATION

Quaternary	2 m. y.	Alluvium (Qal)
	Pliocene	Quaternary undivided (Qu)
		Beaumont Formation (Qb)
		Lissie Formation (Ql)
		Blackwater Draw Formation (Qbd)
		Willie Formation (Qw)

# Garrison & Crouch (TAMU-CC, research web site)

“The Goliad Formation is a Pliocene coastal plain complex consisting of incised valley, meandering fluvial, barrier island and beach, tidal delta, lagoon, and flood plain deposits..”



UEC Permit UR03075

UEC  
Permit  
UR03075

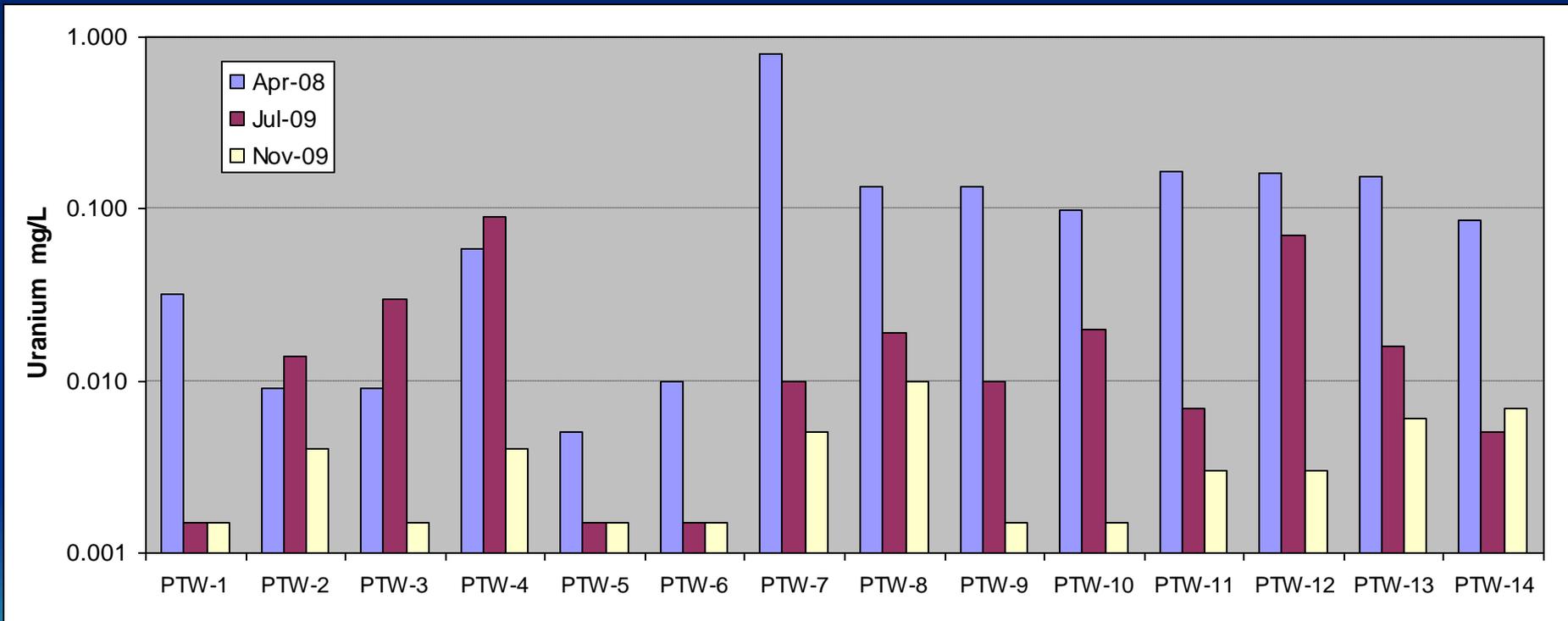
Initial ISL target  
is B Sand,  
yellow pattern



# Production Test Wells (PTW), Sand B

URANIUM:

Apr 2008: 0.005 to 0.804 mg/L  
July 2009: <0.003 to 0.090 mg/L  
Nov 2009: <0.003 to 0.010 mg/L



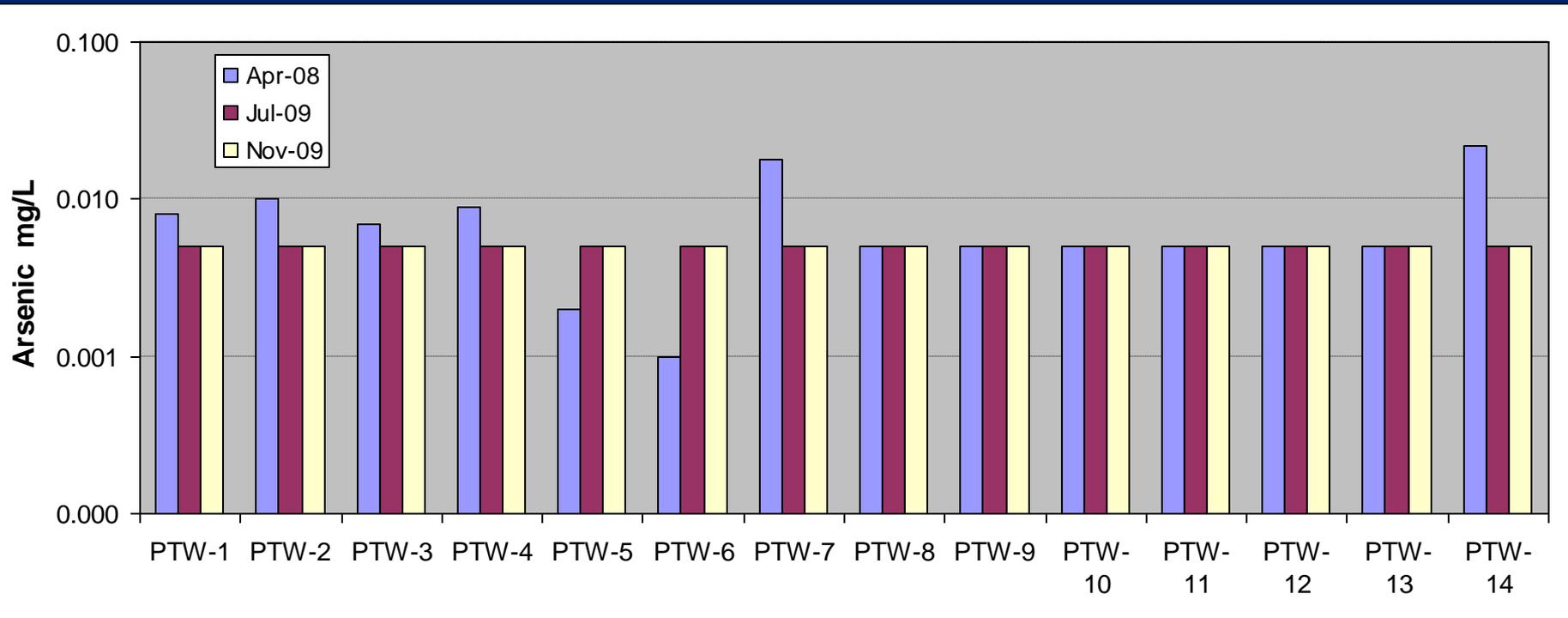
# Production Test Wells (PTW), Sand B

ARSENIC:

Apr 2008: 0.001 to 0.022 mg/L

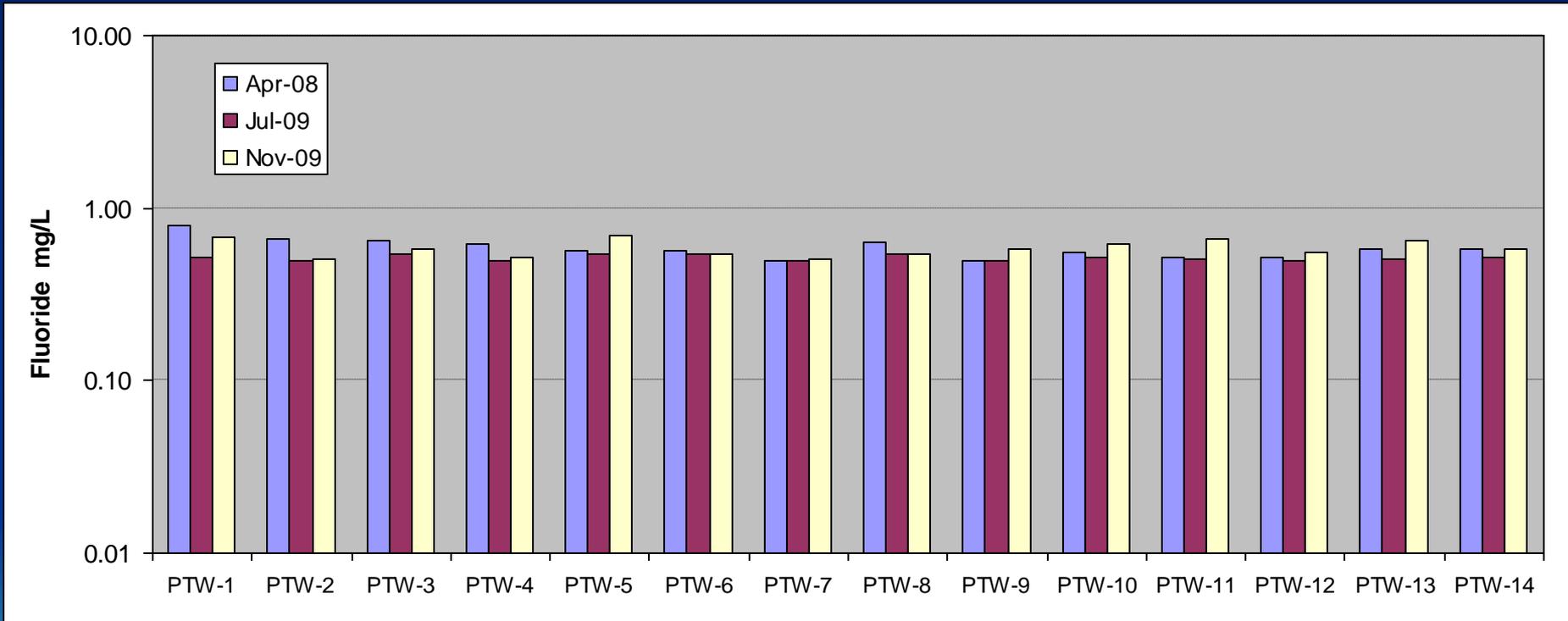
July 2009: <0.010 mg/L

Nov 2009: <0.010 mg/L



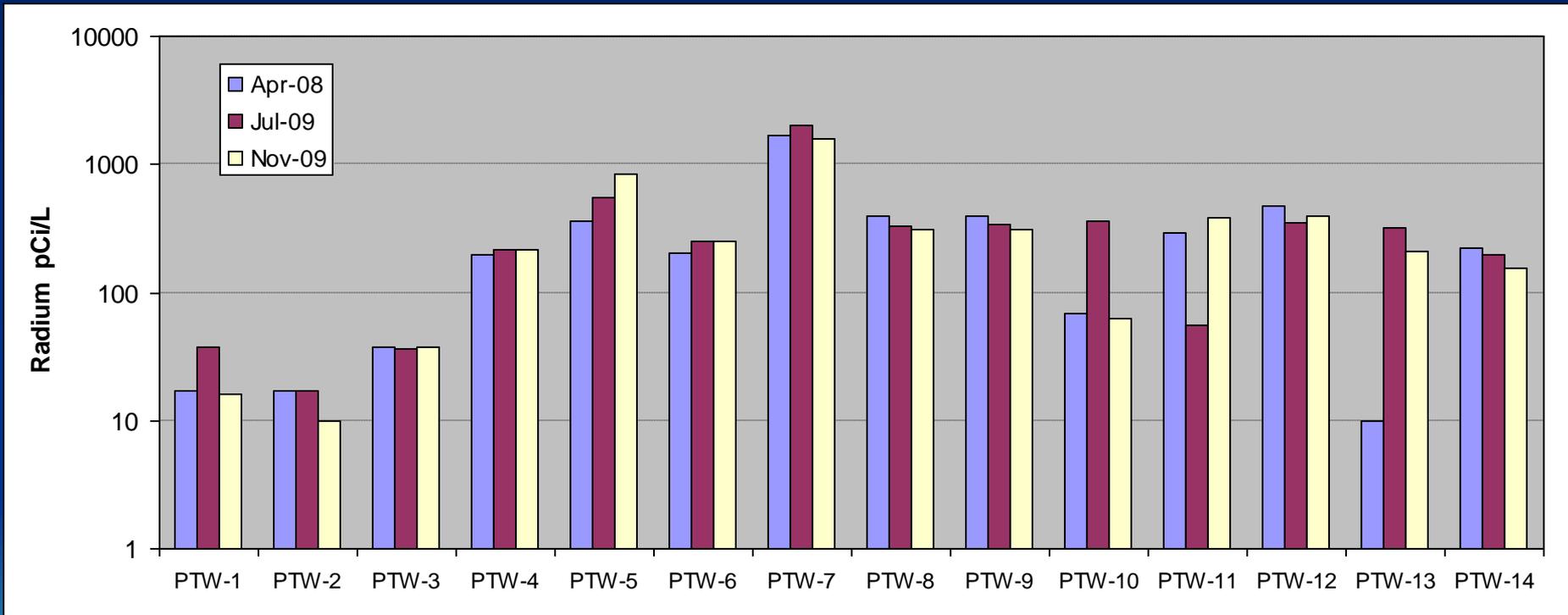
# Production Test Wells (PTW), Sand B

FUORIDE:                      Apr 2008:    0.50 to 0.79 mg/L  
   July 2009:    0.50 to 0.54 mg/L  
   Nov 2009:    0.50 to 0.69 mg/L



# Production Test Wells (PTW), Sand B

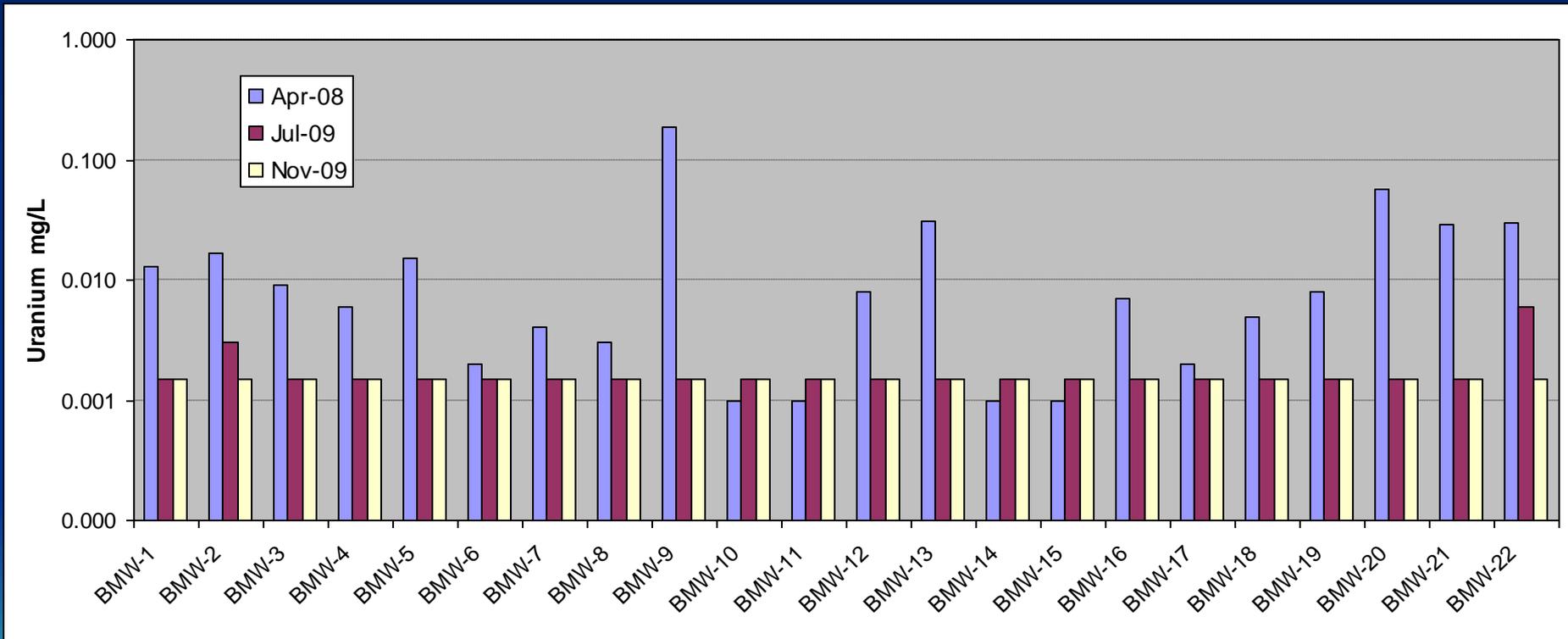
RADIUM:                      Apr 2008:    10 to 1,680 pCi/L  
                                      July 2009:    17 to 2,000 pCi/L  
                                      Nov 2009:    10 to 1,590 pCi/L



# B Monitor Wells (BMW), Sand B

URANIUM:

Apr 2008: <0.001 to 0.188 mg/L  
July 2009: <0.003 to 0.006 mg/L  
Nov 2009: <0.003 mg/L



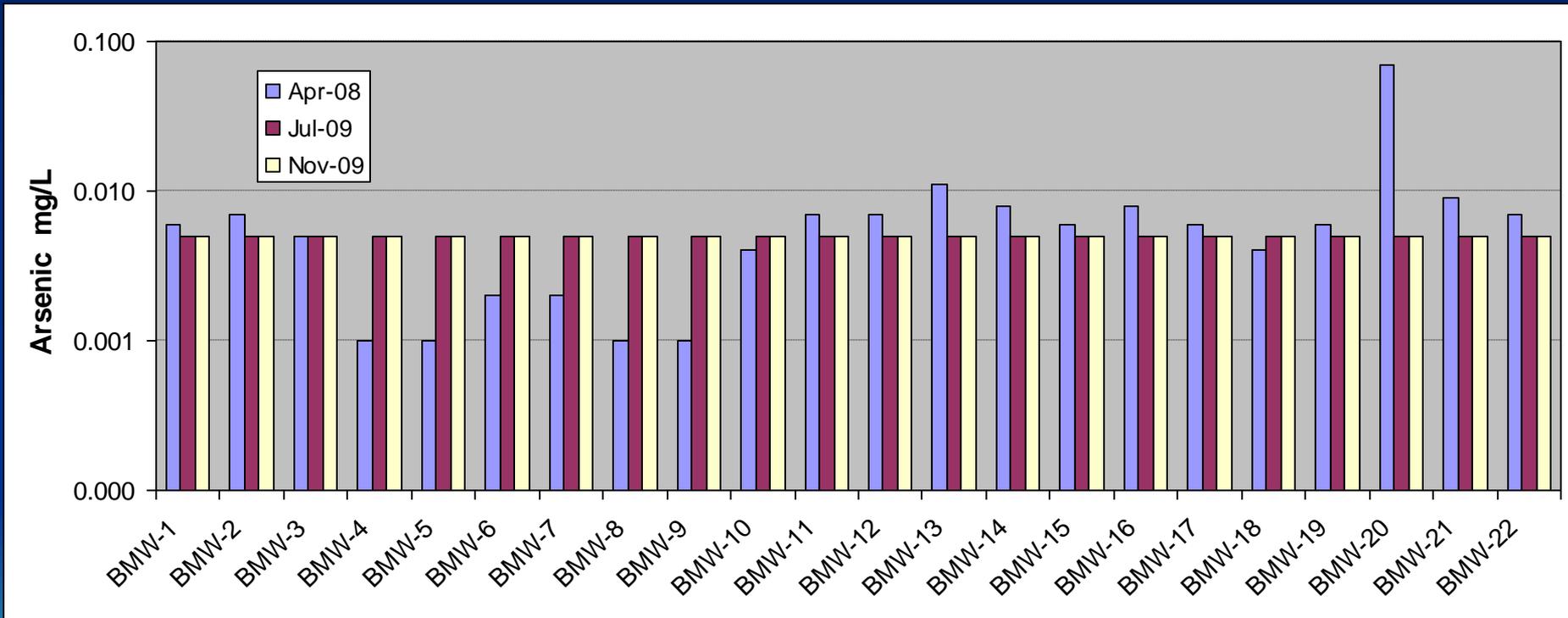
# B Monitor Wells (BMW), Sand B

ARSENIC:

Apr 2008: 0.001 to 0.069 mg/L

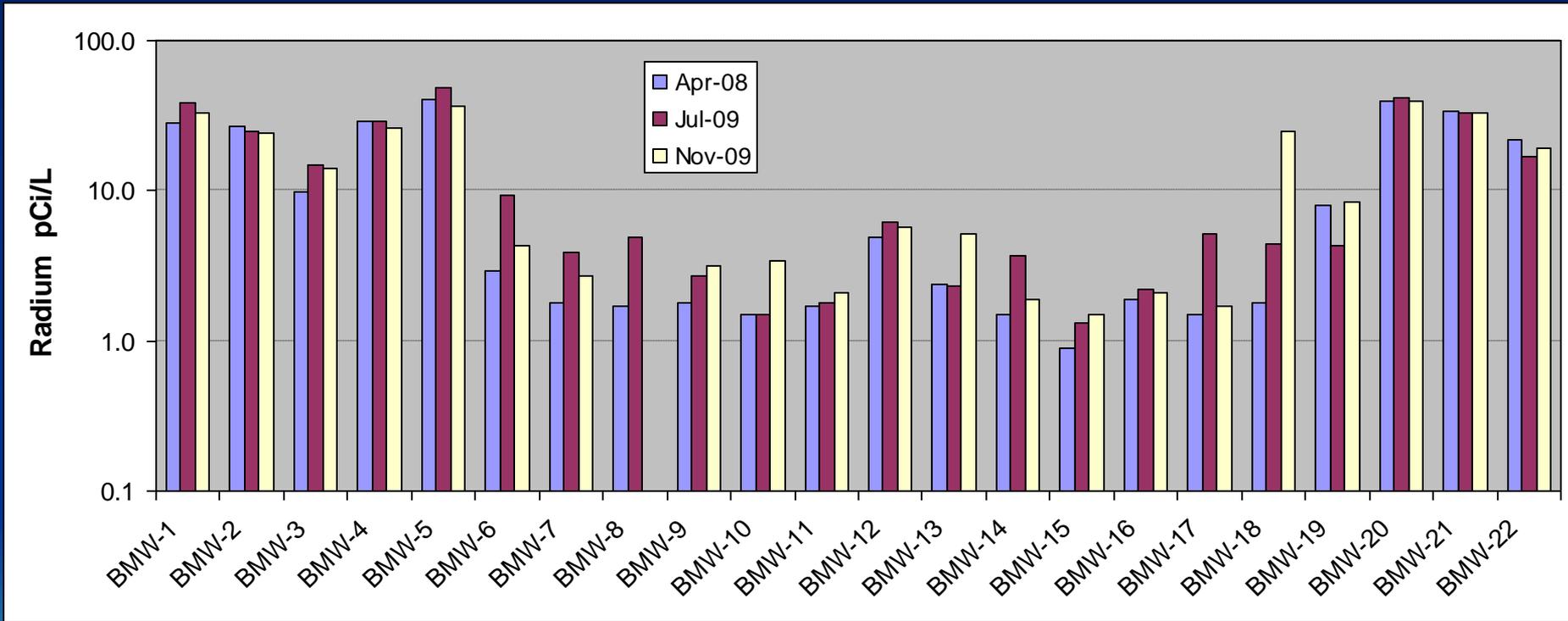
July 2009: <0.010 mg/L

Nov 2009: <0.010 mg/L



# B Monitor Wells (BMW), Sand B

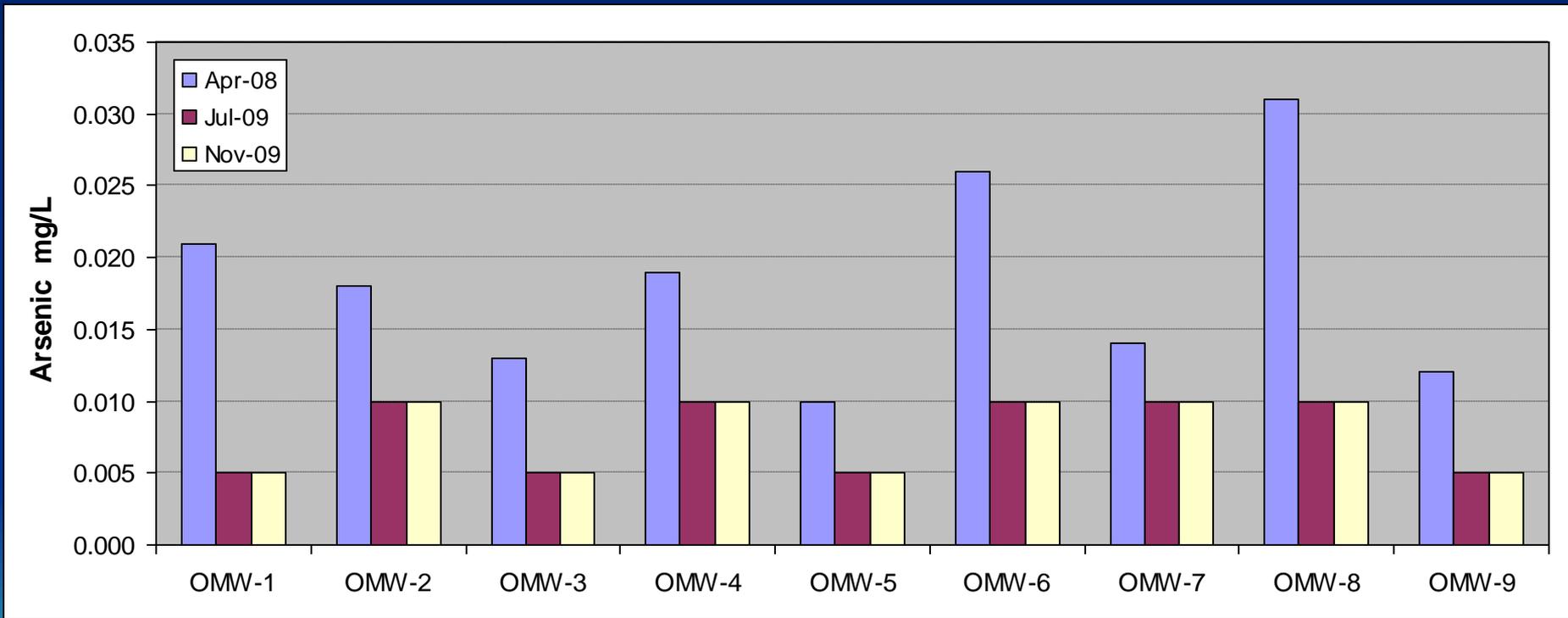
RADIUM:                      Apr 2008:    0.90 to 41 pCi/L  
                                      July 2009:    1.3 to 48 pCi/L  
                                      Nov 2009:    0.10 to 40 pCi/L





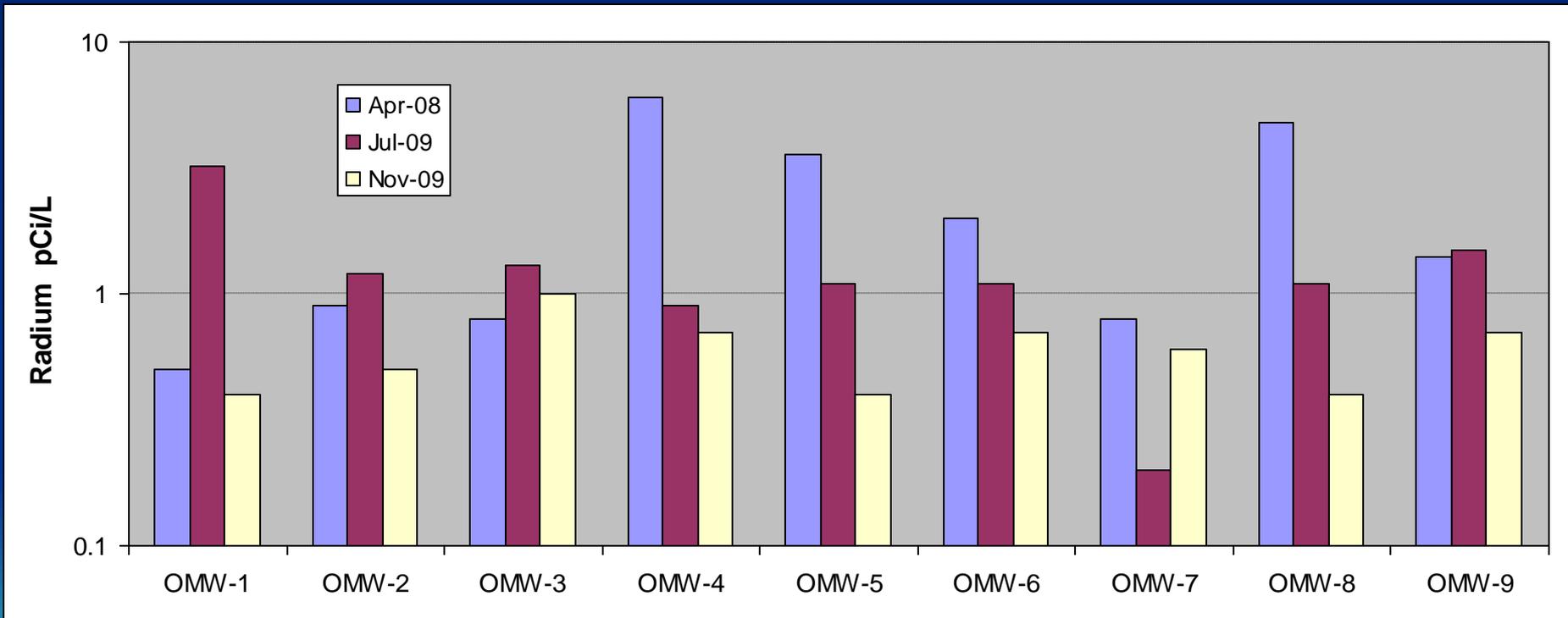
# Overlying Monitor Wells (OMW), Sand A

ARSENIC:                      Apr 2008:      0.010 to 0.031 mg/L  
   July 2009:     0.005 to 0.010 mg/L  
   Nov 2009:     0.005 to 0.010 mg/L

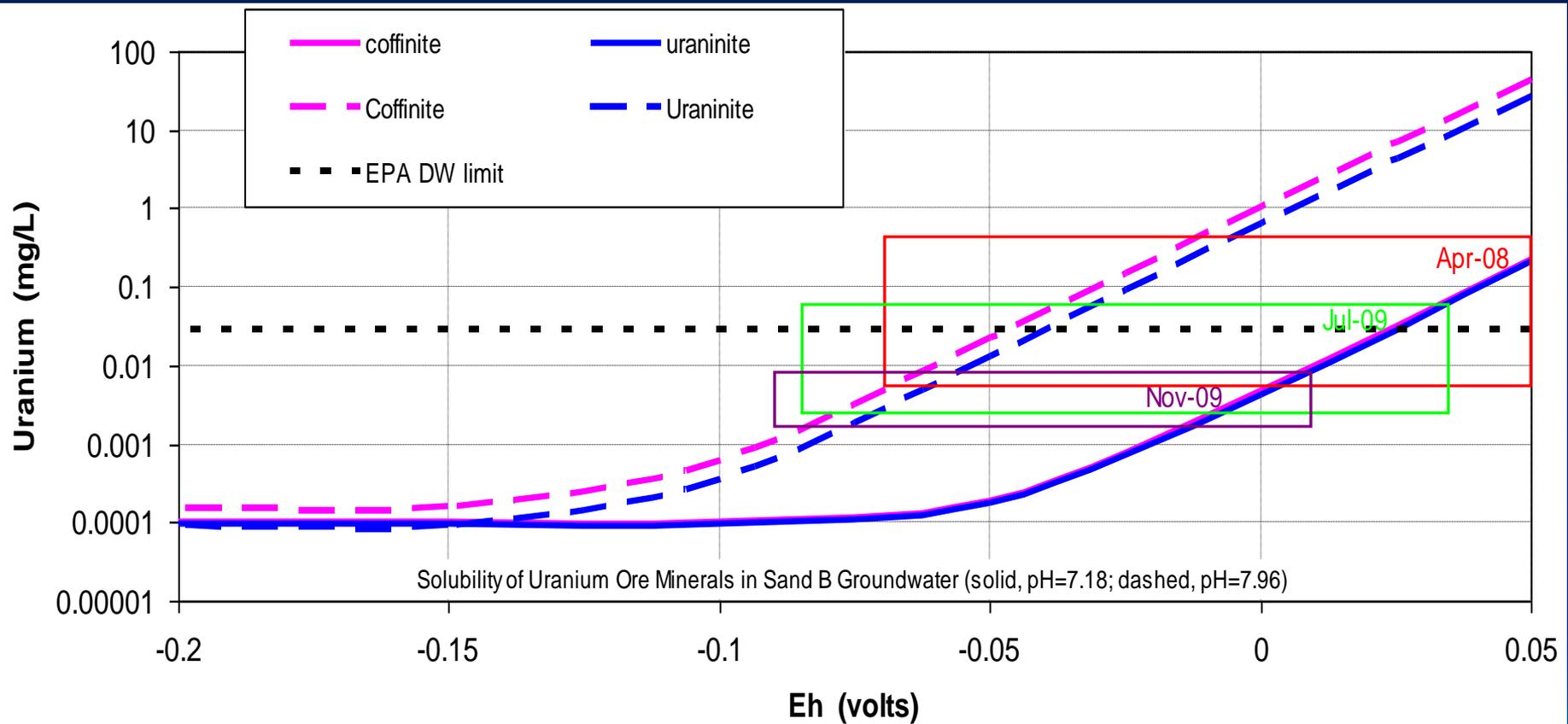


# Overlying Monitor Wells (OMW), Sand A

RADIUM:                      Apr 2008:    0.5 to 6.0 pCi/L  
                                      July 2009:    0.2 to 3.2 pCi/L  
                                      Nov 2009:    0.4 to 1.0 pCi/L



# Uranium solubility as a function of Eh



## **Attachment 2**

### **UEC Goliad Project Application for Production Area 1 (August 27, 2008)**

Comments by R. Abitz

#### **Section 4.0 Hydrologic Testing**

This section lacks data on the hydrological characteristics of the site, which are the basis for the location of the pumping and monitoring wells used in the test. Deficiencies are noted in the following areas:

- 1) Characterization of subsurface material (no data on grain-size analyses, permeability range, effective porosity, cation exchange capacity, organic carbon content, x-ray diffraction, Atterberg limits, etc).
- 2) A narrative and graphical presentation of the conceptual model.
- 3) Scientific basis for the location of the overlying monitoring wells in Sand A and justification for the length of the pump test (would a different location for the monitor well in Sand A and a longer test show connectivity between Sand A and Sand B?).
- 4) Transmissivity range is not discussed with respect to variation in fluid flow parallel and perpendicular to the fabric of the sediments.
- 5) Location of the no flow boundary (Section 4.3.1) and its impact on mining operations and monitoring wells.

#### **Section 5.0 Groundwater Quality**

Data presented in Section 5.0 are insufficient to draw valid scientific conclusions on groundwater quality in the proposed aquifer-exemption volume within the mine area. The following data deficiencies will be discussed:

- 1) Omission of valid statistical methods (i.e., systematic grids or random locations) to site the wells used to establish baseline water quality in the aquifer exemption zone.
- 2) Missing 'Completion and Recompletion Reports' (Appendix C) for the OMW and BMW wells, which establish screen lengths for the wells.
- 3) Failure to discuss or cite references for the development of baseline wells prior to sampling, the volume of purged water between well completion and sample collection, and field parameters measured (i.e., pH, Eh, conductivity ) to indicate chemical stability of the sample.
- 4) Improper selection of sampling horizons creates an invalid bias in the water-quality parameters by collecting samples from the ore horizons within Sand B, relative to samples collected from the entire thickness of Sand B.

- 5) A single sample from each well is insufficient to determine whether the water-quality parameters are stable and representative of the groundwater at the sample location.
- 6) Simple statistics (e.g., average and standard deviation) cannot be used to derive the baseline values unless a valid statistical test is performed to demonstrate that the data follow a normal distribution.

#### Comment 1 - Valid Statistical Methods to Locate Baseline Wells

Figure 1-4 in the UEC application shows the monitor-well ring that surrounds the mine area, and this is the portion of the aquifer that will be considered for exemption. As the monitor-well ring is the point of compliance for migrating mining fluids (i.e., excursions must be controlled at this boundary), the entire volume of groundwater within the mine area will be contaminated by the mining process. Therefore, it is statistically invalid to develop baseline water-quality parameters using only the wells placed in the production area. The invalid method produces a high bias in the contaminant concentration that does not represent the water quality in the mine area. This high bias allows a mining company to restore the groundwater to invalid high concentrations, which destroys the good water-quality resource that now exists throughout most of the mine area.

A statistically valid approach for establishing baseline water quality in the mine area is to locate baseline wells with a systematic grid or by random selection (Gilbert, 1987; Matzke et al., 2007). For a systematic grid, a 400-by-400 foot grid should be placed over the mine area to ensure that a minimum of one well is placed in every 4 acres (NRC, 2003; p. 5-39). Figure 1 illustrates the proper location of baseline wells using a 400-by-400 foot grid. Alternatively, a smaller grid could be used and the 24 baseline wells (1 per 4 acres) could be located randomly on the nodes of the smaller grid.

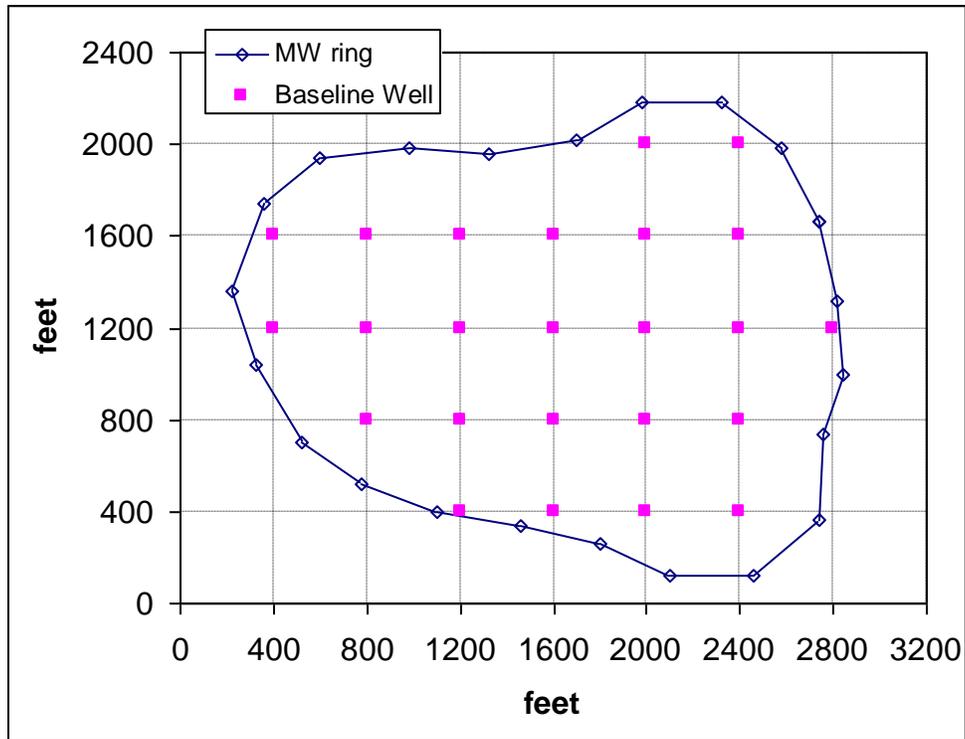


FIGURE 1. A Valid Statistical Method for Locating Baseline Wells

Comment 2 - Missing Completion and Recompletion Reports

Appendix C contains Completion and Recompletion Reports for the PTW wells, but has excluded this information for the OMW and BMW wells. A key piece of information contained in these records is the screened interval for the well. The available reports show that the screen interval is 20 feet for all the PTW wells, which is less than one-half of the thickness of Sand B (45 to 50 feet thick). It is important to know the screen intervals for the OMW and BMW wells to determine if samples collected from these wells were obtained from the entire thickness of Sands A and B. The Nuclear Regulatory Commission (NRC, 2003; p. 5-43) has discussed the importance of screening the entire thickness of the sand unit at the well to ensure representative groundwater samples are collected. Sample bias created by screening less than 100 percent of the sand thickness is discussed under Comment 4.

Comment 3 – Failure to Discuss or Cite Well Development and Sampling Methods

UEC’s application fails to discuss or provide a reference for the well development methods used to remove contamination and prepare the well for sampling. Additionally, there are no records to indicate the volume of water removed during development and the sampling methods used to collect the samples.

The drilling event associated with the installation of a groundwater well is considered to be the major source of contamination introduced into an undisturbed aquifer (Laaksoharju et al., 2008). For the case of drilling a well into an ore zone, the introduction of oxygen during the drilling and development will start the process of

slowly dissolving the ore, and this may elevate redox sensitive elements (i.e., uranium, arsenic, selenium, molybdenum, sulfur) in the collected water samples (Staub et. Al., 1986; p. 38). Therefore, proper well development is needed to remove the sediment and contamination prior to collecting the first round of water-quality samples (EPA, 1992b; p. 6-46), and the nephelometric turbidity unit (NTU) should be below 5 NTU prior to sample collection (EPA, 1992b; p. 6-48). One NTU is defined as 1 milligram of finely divided silica in a liter of water (1 mg/L), and NTU values above 5 have a considerable amount of suspended particulate in the sample. Appendix A reveals that the NTU value exceeds 5 mg/L in 3 of 9 OMW wells, 11 of 22 BMW wells, and 5 of 6 PTW wells. The NTU results are not reported for the RBLB wells. It is noted that many of the elevated radium concentrations are associated with wells that have high NTU readings, which may indicate radium is on the suspended particles that are contaminating the samples. This is logical from a geochemical perspective because radium ions are known to adsorb onto fine clay particles.

When sample collection dates in Appendix A are compared to well completion dates in Appendix C, the period between well completion and sampling is seen to be 2 to 4 weeks for the PTW wells, 5 to 9 weeks for the BMW wells, and 4 to 5 weeks for the OMW wells. What is the basis for the difference in the periods between the well groups? A shorter development period for the PTW wells could indicate that the aquifer was still in a disturbed state when the samples were collected, which is suggested by the elevated NTU measurements noted above. This is significant because the PTW wells sample groundwater from the ore zones and disturbance of this zone suspends micron-sized particulate from the ore in the groundwater, which could end up in the samples and lead to the measurement of anomalously high uranium and radium concentrations. To evaluate this scenario, a minimum of 4 samples should be collected from each well, with a minimum of two weeks between samples, to ensure that the initial sampling event is representative of baseline conditions. This is discussed further under Comment 5.

The NRC (2003; p. 5-39) and the U.S. Environmental Protection Agency (EPA, 1992b; p. 7-1) state that acceptable sampling procedures must be used to collect the samples. What procedures were followed to measure field parameters, collect the samples, and ensure container integrity between collection and analysis?

#### Comment 4 – Improper Screen Intervals for Collecting Representative Samples

Appendix C provides well logs and completion reports for the PTW wells that indicate the wells are screened only in the lower half of Sand B, generally in the most ore-rich interval of the sand. Appendix B of the UEC Application to Conduct In Situ Uranium Recovery (UEC, 2007) shows the same bias for the RBLB wells in the production zone. Failure to obtain a groundwater sample from the entire interval of Sand B produces a high bias on the contaminant concentration used to establish baseline because the sample is obtained only from the ore-rich interval of Sand B (Figure 2). The NRC recognizes this bias and states that fully screened intervals are more accurate in their representation of the water quality that a user is likely to encounter (NRC, 2003; p. 5-43).

Fully screened intervals, or multiple shorter screened intervals through the entire sand thickness, are the only valid statistical method for collecting a representative sample from the sand horizon. Therefore, analytical results for samples collected from the PTW and RBLB wells (Appendix A and Table 5-2) are invalid results for the purpose of calculating baseline water quality because they do not represent a statistically valid sampling event for groundwater in Sand B (Figure 2). A similar conclusion applies to the analytical results for the BMW and OMW wells if the sampling interval does not cover the entire sand thickness. As noted in Comment 2, Appendix C does not contain information on the sampling interval for the BMW and OMW wells.

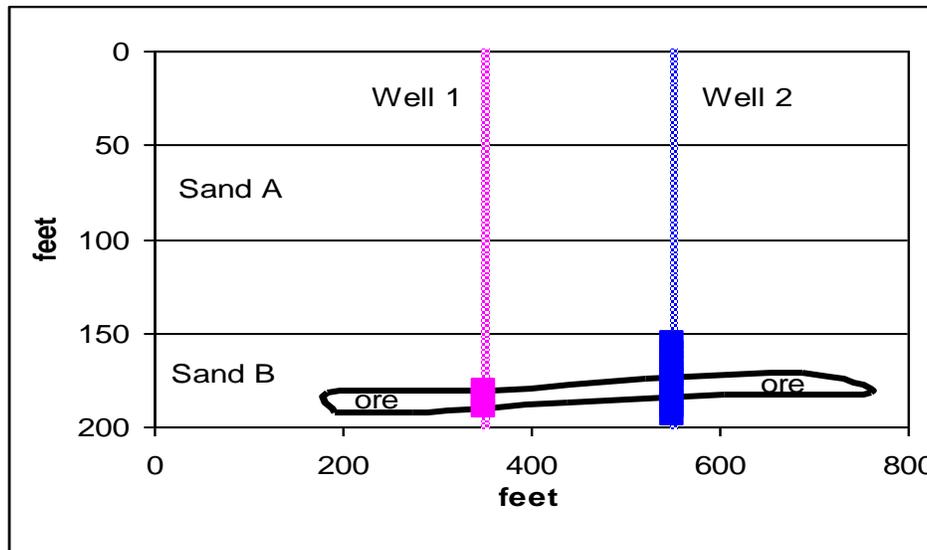


FIGURE 2. Well 1 samples only the ore zone, and it is an invalid statistical approach for obtaining a representative sample. Well 2 samples the entire sand interval, which is a proper statistical approach for obtaining a representative sample.

Comment 5 – One Sample per Well is Insufficient to Determine Groundwater Baseline  
Because the drilling event disturbs the aquifer (Comment 3) and seasonal variation in water levels and water quality may occur, multiple samples must be collected from a well to determine the baseline values for the groundwater. A minimum of 4 samples must be collected from each well, with adequate time between samples, to identify anthropogenic or natural temporal variations (NRC, 2003; P. 5-39). The EPA recommends a minimum of 8 samples over a year's time (EPA, 1992a; p. 78).

As noted in Comment 3, high NTU values for many of the wells indicates suspended particulate in the sample and suggests that well development was incomplete prior to collecting the first round of samples. Additional sample events are required to determine if the NTU and radium values are stable or decreasing with time. A single sample provides no credible basis for establishing the baseline water quality for radium or any other constituent. Therefore, the water-quality conclusions reached in Section 5.0 have no scientific merit and are invalid.

### Comment 6 – Valid Statistical Tests Must Determine Baseline Water Quality

Guidance on statistical analysis of groundwater data is readily available (EPA, 1989; ASTM, 1998), and these documents make it clear that the use of the mean (or average) and standard deviation to establish baseline water quality are only applicable if it can be demonstrated that the data set follows a normal or lognormal distribution. UEC has not performed a valid statistical test to demonstrate that the data follow a normal or lognormal distribution.

The first test that must be performed on a data set is a test to determine if the data follow a normal or lognormal distribution. Statistical tests for normality are widely available through spreadsheet programs (e.g., Microsoft Excel with Analyse It), and the Shapiro-Wilk Test is generally the most robust test for demonstrating that data follow a normal distribution (Shapiro and Wilk, 1965; Shapiro, Wilk and Chen, 1968; Madansky, 1988). The probability statistic,  $p$ , returned by the Shapiro-Wilk Test determines whether the data follow a normal distribution for the stated confidence interval. For a stated confidence level of 95 percent,  $p$  must be greater than 0.05 to accept the null hypothesis that the data follow a normal distribution. If the data do not follow a normal distribution, the data may be log transformed (using the natural logarithm) and re-run to determine if the log-transformed data follow a lognormal distribution. If neither the original data nor log-transformed data pass the Shapiro-Wilk Test (i.e.,  $p$  less than 0.05), then it must be concluded that the data do not follow a normal or lognormal distribution. When the data do not follow a normal or lognormal distribution, the mean and standard deviation are meaningless because these parameters are defined ONLY for a normal or lognormal distribution.

Data sets that do not follow a normal or lognormal distribution generally include those sets that have a large number of results at or near the detection limit or some results at very high values (i.e., an asymmetrical distribution). This type of data set is a non-normal data set, and its sample distribution must be analyzed with nonparametric techniques (Gilbert, 1987; Madansky, 1988) to define the median, quantiles, and inter-quantile range (IQR), provided the results at the detection limit do not exceed approximately 75 percent of the data points. The non-normal data sets are ordered, from lowest to highest values, and the median is the central value in the ordered data set, while the 0.25, 0.5 and 0.75 quantiles are the values such that 25%, 50% and 75% of all values fall below that value. The IQR is the difference between the 0.75 and 0.25 quantiles. Median and IQR are better indicators of the distribution in a non-normal, asymmetric distribution, because these statistical quantities are influenced less, relative to the mean and standard deviation, by very large or very small values.

For reasons discussed in Comments 1 through 5, there is not a valid data set for the well groups presented in Section 5.0 (OMW, BMW and PTW+RBLB), and the demonstration of proper statistical calculations will have to be performed using the same invalid data set to compare results using proper statistical tests to the invalid results reported in Section 5.0. However, it is noted here that this is simply a demonstration of the proper statistical methods and it should be understood that results from this analysis have no scientific validity because of the data-set deficiencies noted in Comments 1 through 5.

The BMW data set presented in Table 5-3 of the application will be used for the comparison, as it has wells spaced approximately 400 feet apart along the compliance perimeter. This spacing geometry can be thought of as a one-dimensional application (linear spacing) of the two-dimensional grid presented under Comment 1. In this sense, the BMW data set is more constrained than the OMW and PTW+RBLB data sets because there is a valid basis for the location of the wells.

Table 1 summarizes the statistical results for the 22 BMW wells. Results are presented for normal, lognormal and undefined distributions, along with the  $p$  value from the Shapiro-Wilk test (normal and lognormal only, as the undefined distribution is the default distribution when the  $p$  value for normal and lognormal is less than 0.05). When the  $p$  value is greater than 0.05 for the normal and lognormal distribution, the highest  $p$  value is selected (indicated by the bold font in the table). If the  $p$  value is less than 0.05 for the normal and lognormal distribution, the median value must be used for the data set. One-half of the reported detection limit value is used in the calculations, and the median value is used if the number of detection-limit values exceeds 50 percent (EPA, 1992a; p. 26). The mean for the lognormal distribution is calculated using the log-transformed mean and log-transformed standard deviation, and it will be different than the normal mean if the standard deviation is large.

Table 2 is a comparison between the average (equal to the mean for a normal distribution) value reported by UEC in Table 5.3 and the statistically valid results presented in Table 1. UEC results that are identical to results in Table 1 indicate that the UEC assumption for a normal distribution is appropriate for that parameter. However, there are significant differences for iron (Fe), molybdenum (Mo) and radium (226Ra). The Table 1 values for Fe, Mo and 226Ra are 3, 7 and 4 times less, respectively, than the UEC values. If the present BMW data set were a valid statistical data set, using the UEC results would lead to invalid baseline concentrations for Fe, Mo and 226Ra. As the invalid UEC results for Fe and Mo are still low and are not primary drinking water standards, the improper use of the UEC values for Fe and Mo poses no significant decision consequence. For 226Ra, the use of the invalid UEC result of 12.1 is significant because it exceeds the EPA primary drinking water standard of 5 pCi/L. Based on the valid statistical result of 2.7 pCi/L for 226Ra (Table 1), the water quality at the monitor-well ring meets all primary EPA drinking water standards and its class of use must be defined as suitable for human consumption. The TDS value of 652 exceeds the secondary drinking water standard of 500 mg/L, but this is a non-enforceable standard that has no bearing on the classification of the water as fit for human consumption.

TABLE 1. A Valid Statistical Analysis for the BWM Analytical Results  
 Bold numbers are valid results.

	<b>Ca</b> mg/L	<b>Mg</b> mg/L	<b>Na</b> mg/L	<b>K</b> mg/L	<b>HCO3</b> mg/L	<b>SO4</b> mg/L	<b>Cl</b> mg/L	<b>NO3-N</b> mg/L
<b>Normal</b>								
<i>P</i> value	0.494	0.474	0.309	<0.01	0.534	0.064	0.605	NP
Mean	<b>96.8</b>	<b>17.5</b>	105	NC	319	<b>58</b>	<b>165</b>	NP
<b>LogNor</b>								
<i>P</i> value	0.372	0.325	0.421	0.015	0.679	<0.01	0.565	NP
Mean	96.8	17.5	<b>105</b>	NC	<b>319</b>	NC	165	NP
<b>Undef</b>								
median	NA	NA	NA	<b>3.39</b>	NA	NA	NA	<b>0.01</b>
	<b>F</b> mg/L	<b>SiO2</b> mg/L	<b>TDS</b> mg/L	<b>pH</b> SU	<b>As</b> mg/L	<b>Cd</b> mg/L	<b>Fe</b> mg/L	<b>Pb</b> mg/L
<b>Normal</b>								
<i>P</i> value	0.045	0.036	0.448	<0.01	<0.01	NP	NP	NP
Mean	NC	NC	<b>652</b>	NC	NC	NP	NP	NP
<b>LogNor</b>								
<i>P</i> value	0.034	0.030	0.343	<0.01	<0.01	NP	NP	NP
Mean	NC	NC	652	NC	NC	NP	NP	NP
<b>Undef</b>								
median	<b>0.60</b>	<b>16.0</b>	NA	<b>7.46</b>	<b>0.006</b>	<b>0.001</b>	<b>0.015</b>	<b>0.001</b>
	<b>Mn</b> mg/L	<b>Hg</b> mg/L	<b>Mo</b> mg/L	<b>Se</b> mg/L	<b>U</b> mg/L	<b>226Ra</b> pCi/L		
<b>Normal</b>								
<i>P</i> value	<0.01	NP	NP	NP	<0.01	<0.01		
Mean	NC	NP	NP	NP	NC	NC		
<b>LogNor</b>								
<i>P</i> value	0.169	NP	NP	NP	0.918	<0.01		
Mean	<b>0.017</b>	NP	NP	NP	<b>0.021</b>	NC		
<b>Undef</b>								
median	NA	<b>0.0002</b>	<b>0.005</b>	<b>0.002</b>	NA	<b>2.7</b>		

*P* value is from the Shapiro-Wilk test and it must exceed 0.05 for a normal or lognormal distribution  
 NA = not applicable because the Shapiro-Wilk test indicates it is a normal or lognormal distribution.  
 NC = not calculated because the *p* value is less than 0.05.  
 NP = not performed because the detection-limit values exceeded 50% of the population.

TABLE 2. Comparison of UEC (Table 5.3) and Table 1 Water-Quality Results  
 Bold numbers are much lower than UEC results

	<b>Ca</b>	<b>Mg</b>	<b>Na</b>	<b>K</b>	<b>HCO3</b>	<b>SO4</b>	<b>Cl</b>	<b>NO3-N</b>
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
<b>UEC</b>	97	17.5	105	3.79	319	58	165	0.01
<b>Table 1</b>	96.8	17.5	105	3.39	319	58	165	0.01
	<b>F</b>	<b>SiO2</b>	<b>TDS</b>	<b>pH</b>	<b>As</b>	<b>Cd</b>	<b>Fe</b>	<b>Pb</b>
	mg/L	mg/L	mg/L	SU	mg/L	mg/L	mg/L	mg/L
<b>UEC</b>	0.58	15.7	652	7.58	0.008	0.001	0.043	0.002
<b>Table 1</b>	0.60	16.0	652	7.46	0.006	0.001	<b>0.015</b>	0.001
	<b>Mn</b>	<b>Hg</b>	<b>Mo</b>	<b>Se</b>	<b>U</b>	<b>226Ra</b>		
	mg/L	mg/L	mg/L	mg/L	mg/L	pCi/L	.	.
<b>UEC</b>	0.017	<0.0004	0.035	0.003	0.020	12.1		
<b>Table 1</b>	0.017	0.0002	<b>0.005</b>	0.002	0.021	<b>2.7</b>		

## **Section 6.0 Proposed Restoration Table, Monitor Well Designations and Upper Control Parameters**

Table 6.1 presents a summary of baseline water quality and, as discussed in the comments for Section 5.0, the summary has no scientific merit because invalid statistical methods were used to derive the values.

Table 6.2 is the proposed restoration table, which also has no scientific merit because it is based on the invalid results presented in Table 6.1

Table 6.3 identifies the monitor wells in Sand B and the overlying Sand A, but UEC has no discussion on the scientific basis for the location of the Sand A wells or the spacing distance between wells in the Sand B monitor-well ring.

The NRC (2003; p. 5-42) notes that the location of vertical excursion wells (the OMW wells in Sand A) should be such that the probability of detecting the excursion is maximized. How did UEC determine the location of the OMW wells? Are the OMW wells placed in the sedimentary horizons that have the highest hydraulic conductivity and the best potential for communication with Sand B? Why were no wells placed immediately above the pumping wells used for hydrologic testing? Placing a vertical excursion well immediately above a pumping well will test the integrity of the well construction (that is, sealing the well boring through the confining layer) as well as the confining layers between the sands.

With respect to the spacing of wells in the Sand B monitor-well ring, a uniform spacing of approximately 350 feet is used (Figure 1-4). The NRC (2003; p. 5-42) states that “In determining the appropriate spacing between monitoring wells, the applicant must consider such factors as the distance of the monitoring wells from the edge of the well field, the minimum likely size of an excursion source zone, ground-water flow directions and velocities outside of the well field, and the potential for mixing and dispersion.” There is no discussion of these technical factors in Section 6.0 or Section 4.0 (hydrologic Testing).

UEC indicates that chloride and conductivity are the best indicators for an excursion of mining fluid, and uranium is not useful because there is no scientific basis to support its use as a proper indicator. As support for their statement, UEC notes that thousands of water samples collected from monitoring wells show elevated uranium is rarely found in the excursions detected for Texas ISL mines. What is lacking here are the data to support their statements. If thousands of analyses show uranium is not present in the excursion fluid, why are the data not presented in a summary table?

The NRC also notes that uranium *may* not be a good excursion indicator because it *may* be removed by reducing conditions in the aquifer prior to the excursion reaching the monitoring wells (NRC, 2003; p. 5-41). However, excursion data summarized for Wyoming ISL mines shows that uranium does reach the monitor wells (Staub et al, 1986; pp. A-58 and A-112). That is, uranium is not always removed by the reducing conditions

in the aquifer because the oxygen-rich lixiviant destroys the reducing conditions of the aquifer over time.

The lixiviant is designed to destroy the reducing condition of the aquifer, and there is considerable evidence in the restoration data that uranium concentrations continue to increase after restoration is approved by a regulatory agency (Staub, 1986; p. A-175). Therefore, to establish scientific validity in the statement that reducing conditions in the aquifer prevent uranium from reaching most of the monitor wells, samples should be collected at the monitor wells surrounding restored ISL sites to demonstrate that uranium concentrations are not increasing over time.

UEC sets the upper control limits for chloride and conductivity by adding 25 percent of the highest value to the highest value recorded for the production area wells (Table 6.5). Although the NRC recommends that appropriate statistical methods be used to establish the upper control limit (UCL), they also note that the use of a simple percentage increase above baseline values is acceptable in some cases (NRC, 2003; p. 5-41). However, establishing the upper control limit as a not to exceed maximum value only protects the groundwater outside the monitor-well ring from a rapid increase in contaminant concentrations. This is an infrequent occurrence, as the monitor well is approximately 400 feet away from the production area and the lixiviant becomes diluted by mixing and dispersion as it moves to the monitor well.

Unfortunately, low levels of contamination are allowed to pass the monitor well, and the contaminant concentrations can continue to rise and pass the monitor well until the upper control limit is reached. If the upper control limit is not reached, contamination is allowed to bleed into the surrounding groundwater, as the mining company is not required to take action until the UCL is exceeded. To prevent the bleeding of low levels of contamination into the surrounding groundwater, the EPA recommends using control parameters that monitor for both a sudden and gradual increase in contamination at the compliance point (EPA, 1992; p. 79). This guidance is generally an EPA requirement for monitoring wells at superfund and hazardous-waste sites.

The EPA recommends the use of a Shewhart-cumulative sum control chart to detect rapid or gradual contamination at a monitor well (EPA, 1992; p. 79). Construction of this control chart requires that the data follow a normal distribution, and the chloride data for the Sand B monitor wells do follow a normal distribution (see Table 1 under Section 5 comments). Details on constructing the control chart are provided in the noted reference, and a summary of the control parameters and an example will be provided here. The control parameters are the Shewhart control limit (SCL) and the cumulative sum limit (CUSUM), which commonly are set at, respectively, 4.5 and 5 standard deviations above the baseline mean. The SCL parameter monitors for a rapid increase in the contaminate concentration, and the CUSUM parameter monitors for a slow increase in contamination by keeping track of how the concentration changes with time relative to the baseline mean value.

To demonstrate the application of the control chart, assume UEC's UCL for chloride (209 mg/L) applies to the SCL and CUSUM parameters. That is, if a single well exceeds a chloride value of 209 mg/L, it has exceeded its SCL, and if the CUSUM exceeds a value of 209, the wells with increasing chloride levels are indicative of an excursion, although individual wells have not exceeded 209 mg/L.

Figure 3 illustrates the concept of using both the SCL and CUSUM to indicate contamination at monitor wells. Assume chloride levels are slowly increasing at down gradient monitor wells BMW-18 through BMW-22. Although none of the wells have exceeded their SCL value of 209 mg/L (UEC's UCL for chloride), the CUSUM value exceeds 209 for Sampling Round 6. This is a statistical indication that contamination is moving past the monitor-well ring. Note that UEC is not required to take any action on an excursion unless an individual well exceeded 209 mg/L, yet contamination will be passing the monitor-well ring and impacting groundwater outside the aquifer exemption zone.

This has very important implications for obtaining an extension of the aquifer exemption zone and raising future restoration goals. If low levels of contamination are allowed to extend beyond the monitor-well ring, the future baseline sampling performed outside the monitor-well ring will reflect higher contaminant concentrations, which equates to higher restoration goals and a manipulated basis for an aquifer exemption.

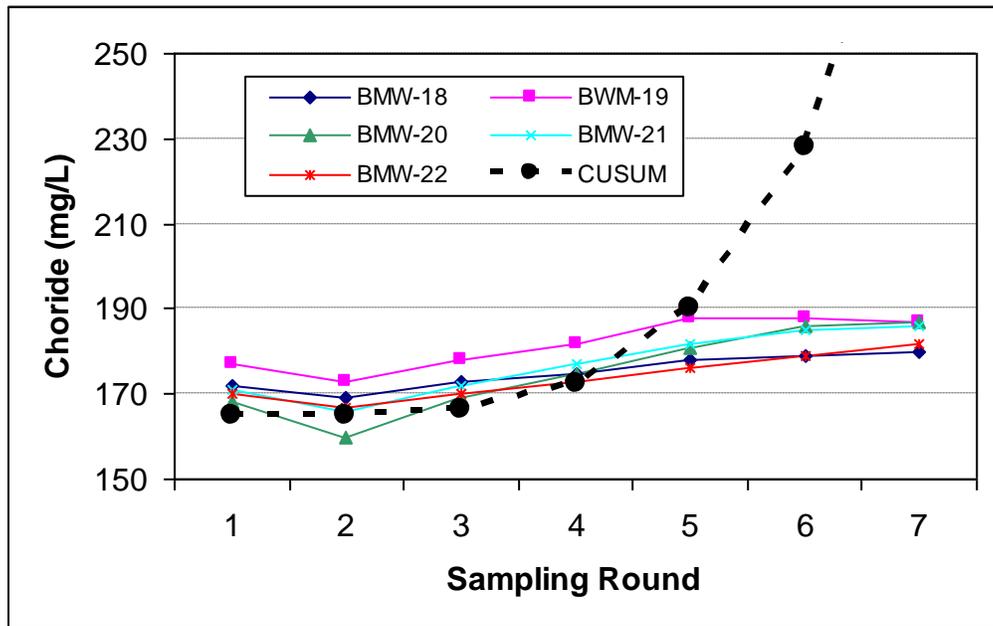


FIGURE 3. The use of a control chart to detect rapid and gradual contamination at monitor wells. An individual well above 209 mg/L or a CUSUM above 209 indicates mining fluid is moving past the monitor-well ring.

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## Attachment 3

### Anthropogenic Induced Redox Disequilibrium in Uranium Ore Zones

Drilling is a destructive process that disturbs the physical and chemical state of solid and liquid phases in uranium ore zones. Physical degradation occurs as the drill bit grinds through the ore and changes the surface area of the uranium phases. Chemical changes are induced by the introduction of mud, fluid and air during drilling and well development. The increase in surface area of the uranium phases exposed in the drill hole and introduction of oxygen from fluid and air may create a transient signature of redox disequilibrium in the first several rounds of groundwater samples. These changes must be understood and documented before establishing an accurate baseline that can be used for a valid assessment of the environmental impact of uranium *in situ* recovery (ISR) operations.

A transient redox condition is observed in groundwater samples collected from the proposed uranium ISR project in Goliad, TX. Groundwater samples collected over a period of approximately 18 months from monitoring wells placed outside and inside the ore zone show decreasing uranium and/or arsenic concentrations between the first, second, and third rounds of samples. In the ore zone, first round samples show uranium variation from 0.804 to 0.005 mg/L, while third round samples are tightly clustered between 0.010 and 0.005 mg/L. Decreasing uranium values follow solubility curves for uraninite and soddyite as Eh decreases. Samples collected from monitoring wells in the overlying sand outside the ore zone show arsenic variation of 0.032 to 0.010 mg/L in Round 1 decreases to 0.010 to 0.005 in Round 3. The anthropogenic disturbance of the ore zone also releases additional radium-226 into the groundwater, and radium-226 remains elevated in subsequent sampling rounds because it is insensitive to redox variation. This example serves to illustrate that conventional drilling and development methods may not produce accurate baseline values for uranium and arsenic until initial redox conditions return. However, once the ore deposit is disturbed, it is unlikely that a true baseline value can be developed for radium-226. Alternate sampling methods (e.g., geoprobe push rods) should be used to collect the most representative sample possible to ensure valid baseline values will be established for important water-quality parameters.