UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	Docket No. 40-8943-MLA-2
CROW BUTTE RESOURCES, INC.	ASLBP No. 13-926-01-MLA-BD01
(Marsland Expansion Area)	

Hearing Exhibit

Exhibit Number: OST005

Exhibit Title: Dr. Kreamer Supplemental Testimony September 16, 2015

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
CROW BUTTE RESOURCES, INC. ,	)	Docket No. 40-8943
	)	ASLBP No. 08-867-02-OLA-BD01
(License Renewal for the	)	
In Situ Leach Facility, Crawford, Nebraska)	)	September 16, 2015

SUPPLEMENTAL TESTIMONY OF DR. DAVID K. KREAMER

The following is my supplemental testimony in this matter embodying an analysis of vertical groundwater movement at the Crow Butte Resources site near Crawford, Nebraska. This testimony specifically deals with:

1. Analysis of Aquifer Tests 1, 2, and 3, labeled as Exhibits BD 2a, b and c respectively,

2. Large changes in the water levels in the Brule formation from (CBR-011), between 1982 pre-mining conditions (BRD-008A-00-BD01 annotated Figure 2.7-3a) and 2008 active mining conditions (008B-00-BD01 annotated figure 2.7-3b),

3. And modeling work conducted by the NRC staff, which are 12 exhibits labeled as BRD-007A through BRD-007J plus NRC-093 and 2015.9.8 Staff Letter.

1.0 AQUIFER TESTS 1, 2, AND 3

Introduction

Aquifer tests were performed at Crow Butte Resources (CBR) site near Crawford, Nebraska to determine hydraulic properties of the target ore body formation the Chamberlain Pass (Basal Chadron) and to assess vertical leakage in the overlying and underlying formations. Aquifer Tests 1, 2, and 3 were the first of 10 reported aquifer tests (pumping tests) performed at Crow Butte. Of the 10 tests, 6 were discussed in hearings conducted in Crawford August 21-24,

2015. The tenth test (2006) was not discussed nor complete information provided. Five tests that were invalidated by CBR because of possible vertical leakage (Tests 5 through 9 in 2004 and 2005) were discussed but complete information on those tests was not provided, and the presented information on Test 4 (CBR-12) was discussed in the hearings. Test 4 included evidence of a recharge boundary in the data (indicating potential vertical leakage) in a Cooper-Jacob Plot of data, and atmospheric response in wells both in the Brule Formation and the Chamberlain Pass Formation indicating vertical communication. Reports on the remaining three tests (1,2 and 3) were distributed at the August 2015 hearings, not discussed in the hearings, and are presented here.

1.1 Aquifer Test 1 - Exhibit BD 2a (1982)

1.1.1 Atmospheric Response Of Deep Well Water Levels As An Indicator Of Vertical Groundwater Communication

Atmospheric response in Chamberlain Pass (Basal Chadron in December of 1982 is portrayed in Figure 2.7A-3 on page 2.7A(11). All six deep wells in the Chamberlain Pass Formation (Basal Chadron) exhibit a strong correlation with atmospheric variations over the course of 8 days, with the same periodicity. The report for Test 1 (BD2a) notes this correlation for all wells and calculates the Barometric Efficiency of the Chamberlain (Basal Chadron) to be significant at 0.4 (page 2.7A (10)). This clear corollary response is indicative of vertical communication of groundwater pressure between the land surface, the Brule aquifer and the Chamberlain (Basal Chadron) Formation, and therefore the ability of groundwater to have a vertical pressure response.

The graphical evidence provided in report BD 2a indicates that the water levels in shallow wells in the Brule aquifer (Figure 2.7A-2 on page 2.7A (8)) show discernible negative correlation with barometric pressure variation during the pumping test with the exception of the early data of well PM7, attributed in the report to a faulty probe. The negative correlation is expected, as high atmospheric pressure can depress shallow water levels, lowering the hydraulic head in the Brule Formation. Conversely low barometric pressure would allow Brule piezometric surfaces to rise, increasing the hydraulic head in that shallow formation. Significantly, the head response of the deep wells (0.4 Barometric Efficiency as noted earlier) is a positive correlation with barometric pressure and apparently negative correlation to head changes in the Brule aquifer, from the data provided in the report.

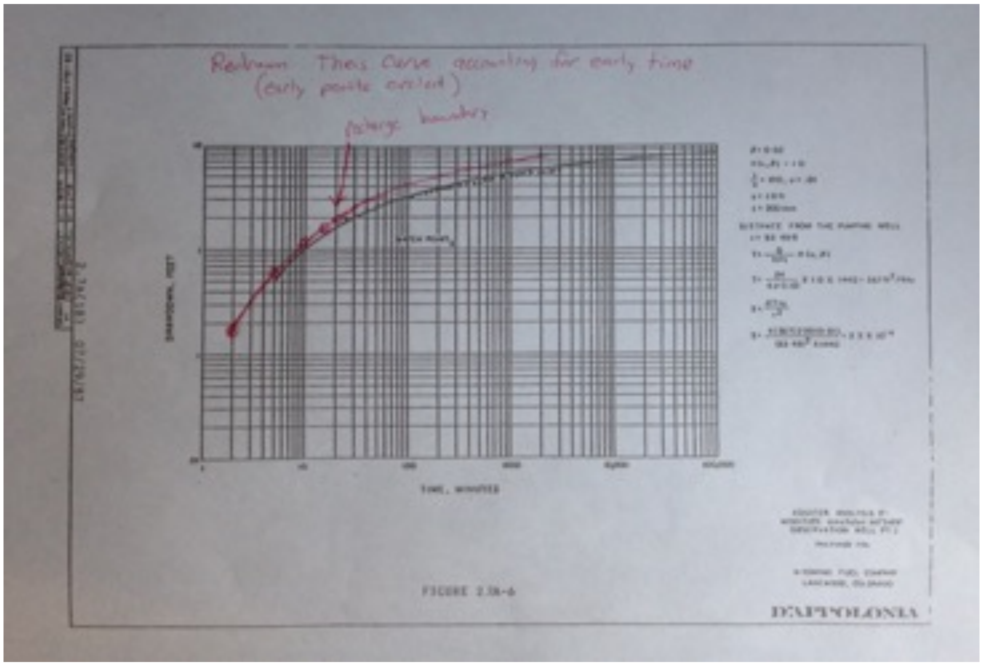
Figure 2.7A-3 on page 2.7A (11), shows discernible positive correlation of deep piezometric water levels in the Chamberlain Pass (Basal Chadron) Formation with barometric pressure variation. The positive correlation to barometric pressure to head changes in the

Chamberlain Pass is the opposite of what one would expect if there was atmospheric short-circuiting through a poorly constructed well bore; if there was atmospheric communication in the borehole a negative correlation (water level depressed at high atmospheric pressure) would be expected. The conclusion therefore that piezometric head changes in the Chamberlain Pass (Basal Chadron) respond to surface barometric pressure changes and head changes in the shallow Brule aquifer is reasonable and consistent with evidence discussed in the hearing concerning head changes in the Brule and Chamberlain Pass before Aquifer Test 4.

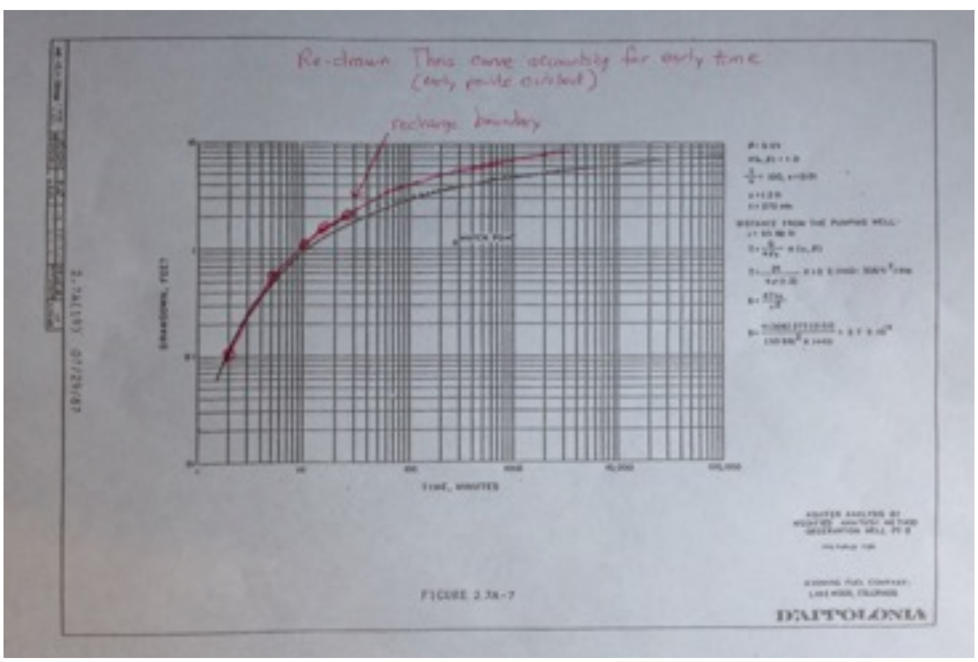
1.1.2 Aquifer (Pumping) Test One - Evidence for Vertical Communication of Groundwater

Aquifer Test 1, BD 2a, clearly documents existence of a recharge boundary, which invalidates assumptions made by CBR contractors basic to the data analysis in the report, and which can be interpreted as evidence of vertical recharge (leakage) to the Chamberlain Pass Formation from overlying strata. On page 2.7A (15) the report explicitly states, *"Figures 2.7A-4 through 2.7A-7 give the apparent indication of leakage especially noticeable at late times."* Although no raw data were provided in report BD 2a for this test to allow independent analysis, evidence in the report shows that drawdown of piezometric surfaces with time are much less than would be expected from early data, i.e. leakage. (On the issue of data not being provided in the report, only selected graphs including Theis plots and not raw data were provided. This does not allow rigorous independent analysis. If Cooper Jacob semilog, and Modified Hantush analysis were carried out, as mentioned in the report, only summary information was provided and no data or graphical analysis appeared).

Figures 2.7 A-4 through Figure 2.7 A-7 show Theis drawdown curves where, incorrectly, only the late time drawdown data is matched with a type-curve. If correctly matched with the early time data, as shown in red in Kreamer September 2015 Testimony Exhibits 1 and 2 below, the data clearly show a break in the data, moving below the type-curve for the late data, indicating reduction in the rate of expected drawdown. Kreamer Exhibits 1 and 2 below are Figures 2.7A-5 and 2.7A-6 with an overlay of Theis match with early time data. Importantly, this signifies an unexpected water source, or recharge boundary. On page 2.7A (8) on the report the authors states that, *"Based on significant deviation of the pump test data from the Theis type curve in the original analysis the USNRC questioned the use of a non-leaky analysis method in the data."* On page 2.7A (22) they state, *"Examination of the drawdown/time curves plotted for observation well indicated that some leakage from confining bed occurred during the pumping test."*



Kreamer Testimony September 2015 Exhibit 1. Re-drawn Figure 2.7A-6, with Theis type-curve matching early time in red. Early data points are circled – late time data below type curve indicates recharge.



Kreamer Testimony September 2015 Exhibit 2. Re-drawn Figure 2.7A-7, with Theis type-curve matching early time in red. Early data points are circled – late time data below type curve indicates recharge.

Further on page 2.7A (13) recovery tests are noted to have hysteresis compared to pumping tests. This can also be a sign of vertical leakage.

The authors of the Aquifer Test 1 report (BD 2a) assume layer-cake geology (that the Formations at CBR are horizontal, of unvarying thickness, continuous, and are homogeneous and isotropic) in their use of the Theis, Cooper Jacob, and Modified Hantush equations. Yet surprisingly they provide conjecture that the added "leakage" noted in Test 1 might be due to the varying thickness of the Chamberlain Pass formation (Basal Chadron) which they state changes from 32 to 49 feet (page 2.7A (13)). Restated, the authors argue that late "leakage" is attributable to an increase in aquifer thickness and commensurate increase in aquifer transmissivity, the added water comes from the Chamberlain Pass (Basal Chadron) and not vertical leakage, and therefore a non-standard two-stage Theis analysis is justified. Unfortunately for the authors' argument to hold water, let us say, the aquifer thickness would have to <u>increase in all directions radially from the pumping well</u>. This is not the case as the thickness actually decreases in some directions, the transmissivity would be expected to lessen in those directions, and less water would be available as the radius of influence of the pumping well increases, not more as indicated by the data.

The Theis and Cooper Jacob methods used in the BD 2a report assume *a priori* that no vertical leakage occurs. In response to USNRC concerns that the data showed leakage, the report authors conducted a Modified Hantush analysis to attempt to characterize vertical leakage page 2.7A (15)). However the Hantush analysis used by the consultants also made critical *a priori* assumptions. The leakage analysis assumed that there were no faults and fractures in the underlying Pierre Shale and/or the overlying Red Clay "aquitard" and assumed that these units were homogeneous, isotropic, continuous, of uniform thickness, and without any possibility of secondary porosity. The Hantush method requires the user to input hydraulic conductivity data for all the strata. In the report (BD 2a), authors use only a single, low hydraulic conductivity for leaking strata over the Chamberlain Pass Formation and assign a high hydraulic resistance to that leaking strata. Only a single value for each strata is reported, rather than a range of values. Importantly, no apparent attempt was made to see, if by varying hydraulic conductivity values particularly in strata overlying the Chamberlain /Basal Chadron Formation, field observations of leakage could be replicated.

Further, ensemble field data were not used to characterize the hydraulic conductivity of these underlying and overlying formations, but characterization was simply done in the laboratory geotechnical analysis on selected samples from a single borehole. These samples were disturbed during sampling and were from a single location on the site property. There is a lack of information in the report on methodologies, how the hydraulic conductivity tests were run, the number of replications, etc. No information on sampling technique, number of samples,

or statistical analysis on the representativeness of these samples was presented in the report. No visual documentation of these samples from a single borehole, which were sent to the laboratory, for analysis were provided in the report. No information on fracture analysis from borehole logs, that is fracture frequency, orientation, aperture size, was reported. No geophysical analysis, surface or downhole, was reported. The BD 2a report authors' *a priori* exclusion of any possibility of fractures, fractures, discontinuities, or secondary porosity in their leakage calculations, coupled with the lack or listing of raw data, makes independent peer review and further analysis of their findings difficult.

The calculations used by the report authors used inappropriate assumptions. The leakage analysis assumed that there were no faults and fractures in the underlying Pierre Shale and/or the overlying Red Clay "aquitard" and assumed that these units were homogeneous, isotropic, continuous, of uniform thickness, and without any possibility of secondary porosity.

All the analytical methods employed by the report authors (Theis, Cooper Jacob, Hantush) assume *a priori* that the formations are of uniform thickness. They are not, as documented on page 2.7A (13). All the analytical methods employed by the report authors assume the strata are homogeneous and isotropic. They are not. Pages 2.7A (20 and 22) document and quantify "directional transmissivity" in the Chamberlain Pass/ Basal Chadron aquifer, which is another term for anisotropy. No groundwater dating information is given to support the stated confinement of the production aquifer. As mentioned, no surface or downhole geophysical testing is reported to support the report's conclusions.

Even with the violated assumptions, exclusion of consideration of secondary porosity, and *a priori* assumptions of no vertical movement, significant vertical leakage is evident from the data, and documented in the report. Vertical movement can be attributed to many conditions including faults and fractures, heterogeneities in the geologic strata, and/or improperly plugged and abandoned wells.

1.2 Aquifer Test 2 - Exhibit BD 2b (1987)

1.2.1 Response Of Deep Well Water Levels (Chmberlain Pass/ Basal Chadron to Barometric (Atmospheric) and Shallow Brule Head Changes As An Indicator Of Vertical Groundwater Communication

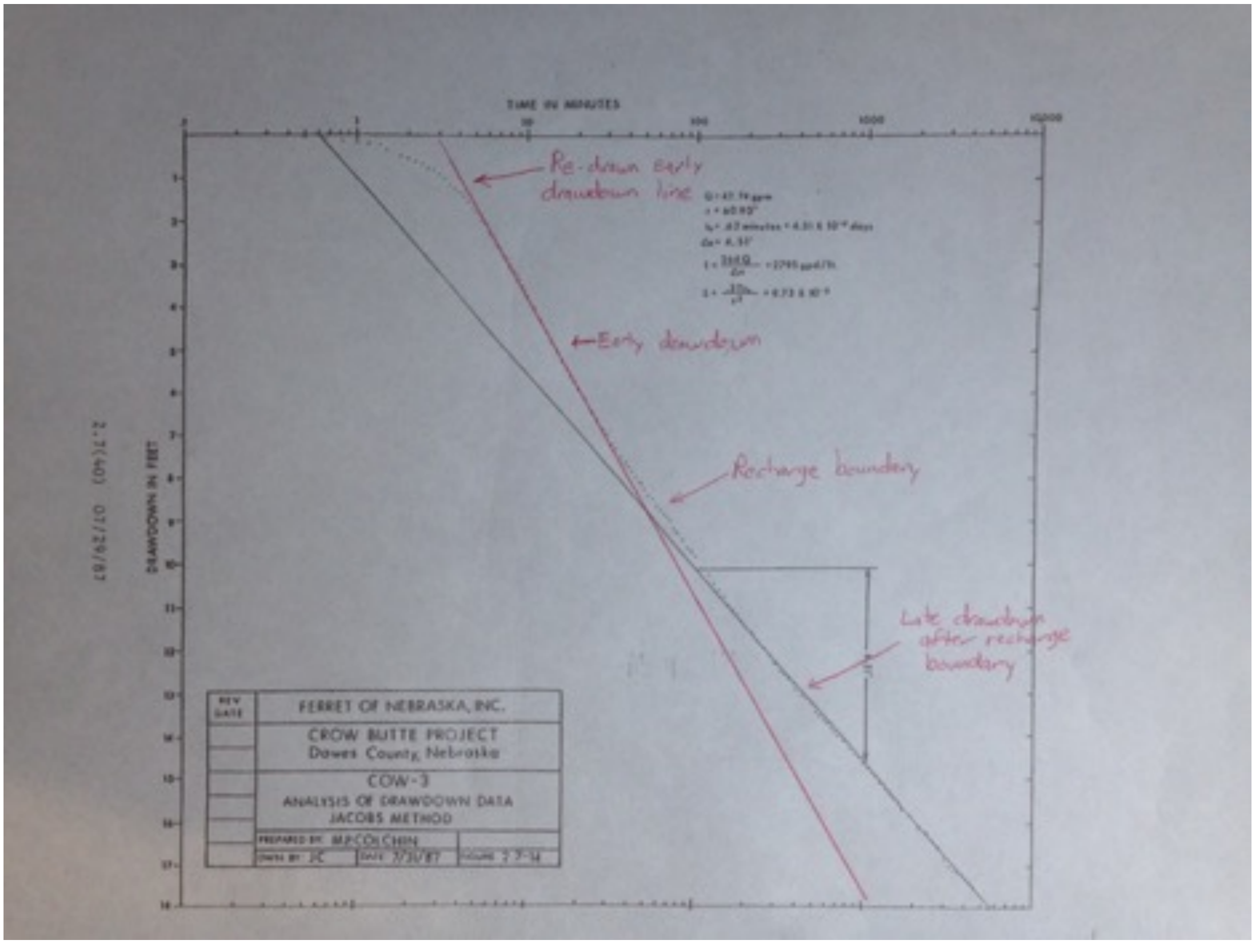
The Figure 2.7-21 on page 2.7 (49) of Report BD 2b on the second aquifer test documents responses in the both the upper Brule formation and Chamberlain Pass/ Basal

Chadron Formation to barometric changes on land surface. As in 1.1.1 above, this supports the existence of vertical pressure connection between the Brule aquifer and the Chamberlain Pass aquifer.

1.2.2 Aquifer (Pumping) Test Two - Evidence for Vertical Communication of Groundwater

Aquifer Test 2, BD 2b, clearly documents existence of a recharge boundary, which invalidates assumptions made by CBR contractors basic to the data analysis in the report, and which can be interpreted as evidence of vertical recharge (leakage) to the Chamberlain Pass Formation from overlying strata.

Probably the clearest demonstration of a recharge boundary for Aquifer Test 2 is shown in Figure 2.7-14 on page 2.7 (40) which in a semi-logarithmic Cooper Jacob plot of the time drawdown of the piezometric surface of COW-3 during the second pumping test. The figure has been miss-drawn to consider only the late time data. Kreamer Testimony September 2015 Exhibit 3 below is Figure 2.7-14 with additional early time interpretation, showing a distinct break point at about 30 minutes, signifying a clear recharge boundary, which can be interpreted as additional vertical flow. Residual time-drawdown data for COW-3 also exhibits this recharge boundary (Figure 2.7-20 on page 2.7 (46)).



Kreamer Testimony September 2015 Exhibit 3. Cooper Jacob semi-logarithmic plot (Figure 2.7 -14) modified (in red) to show early drawdown. A recharge boundary appears at approximately 30 minutes, and forms a line of late time data to the right of the red early data trend.

As in Aquifer Test 1, the analytical approaches used by CBR contractors to interpret the second aquifer test require assumptions about the nature of the geological and hydrological environment. However, the assumptions made by CBR contractors in the second aquifer test report are not supported by the data. In interpreting the aquifer test data, the CBR report wrongly assumes uniform, continuous, horizontal geologic (layer-cake) strata, of uniform thickness and relatively infinite horizontal extent. Page 2.7 (15) of BD 2b, the report on the second aquifer (pumping) test, lists the regional thickness of the Chamberlain Pass/ Basal Chadron ranging from 0 to 350 feet, and only provides an approximate average thickness of 40 feet at the site.

The analytical approaches used for interpretation assume homogeneity and isotropy which is debunked by the quantification of anisotropy in BD 2b, (page 2.7 (53)). Note that the major axes of anisotropy reported in Aquifer Test 1 have azimuth difference of 49 degrees from those reported here in Test 2, and there are large differences in magnitude of hydraulic

conductivity, indicating the complete lack of homogeneity in the Chamberlain Pass Formation, and the likelihood of preferential flow throughout the geologic sequence. This observable but unreported heterogeneity is consistent with the reported unequal distribution of spot contamination during site stabilization at the site and the need to utilize more complex numerical modeling to understand preferential flow in the remedial process.

As in the previous aquifer (pumping) test, the assignation of low hydraulic conductivity values and high hydraulic resistances in the geologic strata overlying the Chamberlain Pass/Basal Chadron Formation are based on solely on laboratory tests on material from a single borehole, UCP-1, which was identified as having no response to pumping below during the aquifer test. Restated, the single location chosen to sample for geotechnical test was known to represent a zone of low hydraulic conductivity. In this case there were three samples that were tested from the same borehole taken within a few vertical feet of each other (pages 2.7 (27) and 2.7 (47). The samples showed variation of approximately double the coefficient of consolidation and hydraulic conductivity in just these few vertical feet, demonstrating the lack of homogeneity, (although homogeneity was assumed in the analytical mathematical interpretive approaches by the report's authors). No attempt was reported to quantify vertical or horizontal variation of geologic and hydrologic properties. No visual documentation of these samples from the single borehole, which were sent to the laboratory, were provided in the report. No information on fracture analysis or on fracture frequency, orientation, or aperture size was reported. Lastly, the laboratory test values from the UCP-1 samples was extrapolated to be the value not only for the "Red Clay" layer overlying the Chamberlain Pass, but also for the for other formations including the overlying Upper Chadron and lower Brule, when calculating the hydraulic resistance. There is no basis for this arbitrary assignation low hydraulic conductivity vales to strata that were not measured.

Single, averaged values were selected by the report authors for reporting vertical hydraulic conductivity in "confining layers", rather than a range of values to simulate field drawdown scenarios from the pumping test data. This selection of only one value, when nearby samples exhibit variation, is unusual and restrictive. Some key analytical results are not presented in report BD 2b for the second aquifer test, for example the complete results of the Hantush analysis (leakage information), are not reported with the principal axes of anisotropy are only reported.

1.3 Aquifer Test 3 - Exhibit BD 2c (1996)

The shortcomings in Aquifer (Pumping) Tests 1 and 2 are also reflected in the third Aquifer Test in 1996. Specifically, the mathematical analytical approaches (Theis, Jacob, and Cooper Jacob) are based on assumptions which are not true to field conditions (e.g. uniform,

continuous, horizontal geologic (layer-cake) strata, of uniform thickness and relatively infinite horizontal extent).

The possibility of secondary porosity and fractures in the strata overlying the Chamberlain Pass Formation was not even considered. Importantly, no vertical leakage analysis was performed, and the report authors document that Test 3 was *"not performed to quantitatively assess the nature of the confining layer above the Chadron Sandstone".* In fact, the authors of the report on Aquifer Test 3 simply make a broad, statement that the hydraulic characteristics of the overlying layers would be the same as in Aquifer tests 1 and 2 (BD-02c page 8). No geotechnical testing on geologic material, geophysical testing, or fracture analysis was documented for this third site to support this summary assumption.

What is inferred from their above statement was that the first two Aquifer Tests, in their estimation, showed no vertical leakage and complete confinement, and this can be extrapolated to the third site without mathematical leakage analysis, geotechnical testing of confining materials, standard fracture analysis, or a complete monitoring array in the overlying, heterogeneous Brule Formation. As shown above, however, Aquifer Test 1 and 2 clearly show and are documented to have recharge boundaries and leakage.

Importantly, in Aquifer tests 1, 2, and 3, the report authors give great weight to what they estimate to be a lack of immediate response in overlying Brule Formation water levels to pumping below in the Chamberlain Pass Formation (Basal Chadron). No long term response is considered or measured by CBR consultants. Importantly, the interpretations made by CBR and their consultants, based on this minimal immediate response, presupposes that the one or two monitoring wells CBR used for analysis in the overlying strata were optimally placed and truly representative . This is very unlikely. The Brule Formation is documented to be heterogeneous, and piezometers and observation wells in it and in other strata overlying the Chamberlain Pass Formation were not documented to be optimally placed to observe any possible leakage. Standard practice is to measure response in an array of wells and not just a selected one or two. The absolute paucity of observation piezometers and wells in overlying strata used for these pumping tests is very surprising. Given the lack of homogeneity in geological and hydrological characteristics in the overlying strata, the report authors' use and interpretation of the water level response, based only one or two monitoring points, is flawed.

1.4 Summary of Aquifer (Pumping) Tests 1, 2, and 3.

Aquifers Tests 1 and 2 show multiple lines of evidence indicating leakage consistent with vertical communication of groundwater through strata at the LRA site. Aquifer Test 3 was expressly designed <u>not</u> to test for vertical leakage, and presumed no leakage *a priori*. Inadequate

monitoring was carried out in the Upper Brule Formation during these tests. Estimates of low hydraulic conductivity in "confining layers" are based, not on ensemble characteristics, like fracture analysis and pumping test results, but on laboratory testing of a very few selected samples from a single borehole for each test.

2.0 Evidence of Vertical Connection by Long Term Drawdown of Brule Formation Water Levels During CBR's Pumping of the Chamberlain Pass/ Basal Chadron Formation

Testimony in the August 2015 NRC Hearings in Crawford, Nebraska showed significant water table decline in the Brule aquifer between pre mining conditions (1982) and active mining operations in 2008 in the underlying Chamberlain Pass/ Basal Chadron Formation. This decline is visible, not only at a single point in the active mining area discussed in the Hearing, but at many monitoring points in that area. Conversely, in areas that were not mined by 2008, the Brule aquifer is not drawn down and even slightly increases in some spots. This is an indication of vertical communication of groundwater.

Verbal testimony was given in the Crawford August 2015 hearing by CBR that they believe the single one point chosen on Brule 1982 water levels for heuristic comparison by the Intervenors was a typographic error in the map they themselves (CBR) had presented in the License Renewal Application. However in the active mining, area numerous well points show drawdown in the Brule Aquifer from 1982 to 2008, not just a single location, and many points in areas that were not mined before 2008 show no draw down.

In response to concerns about draw down in the Brule due pumping/ mining activities in the underlying Chamberlain Pass/ Basal Chadron Formation, CBR presented evidence in the August 2015 Crawford Hearing from monitoring well SM7-22 and SM7-17 (Exhibits CBR-063 and CBR-064), which were Brule Aquifer monitoring wells near to and overlying the active mining area. To support their claim of little variation in the water levels in the Brule, CBR cited lack of large variation in these wells from 1999 to near present day. Mining activities began, however, in 1991 not in 1999, and no data were presented from the critical period from these eight years after mining began. No data are presented comparing pumping rates in the Chamberlain Pass/ Basal Chadron to the water levels in the Brule. This lack or presented data does not allow correlation analysis to be carried out by the intervening parties, by NRC staff, or by other external reviewers. Interestingly though, there is a water level rise in the reported Brule wells after some mining units completed operations and ceased pumping. This can indicate vertical flow and vertical head response. It is unclear whether data exist for Brule water levels during the critical, initial eight year period from 1991 to 1999.

It is a basic principle of hydrogeology and the mathematics of aquifer mechanics that the drawdown of water tables and or piezometric surfaces, in response to a pumping well, exhibit relatively rapid decline in water levels at first in a non-steady state systems. These more rapid declines are followed by continued but slowing rates of drawdown. After a certain period of time in these transient state pumping systems, with constant pumping, the initial large and rapid drawdown slows to near steady state. The large hydraulic head changes at first can induce large vertical leakage if fractures or zones of preferential flow exist. With time, induced leakage causes hydraulic head declines in overlying and/or underlying strata. Initial rapid leakage will slow with time as the hydraulic head is reduced in these overlying and/or underlying strata, and the once-larger head gradients during early pumping are diminished. Therefore the initial period of pumping of these mining operations, where head gradients are expected to change most rapidly and induced leakage is expected to be greatest, is crucial, but unreported by CBR.

Lastly, in addition to CBR's lack of presented data to support claims of no vertical flow, the lack of up-to-date techniques for geological analysis reduce the quality of the conclusions that CBR reaches on the issue. A complete reporting of even rudimentary, much less, up-to-date methodologies could better inform their generalized conceptual site model, and allow for open, external review. For example, CBR reports very general and vague statements of no or few fractures in their coreholes from the site, without presented evidence. However, typically sedimentary rocks can exhibit numerous fractures. Photo evidence of complete cores, or core sections, is not presented. Downhole T.V. logging of boreholes showing absence of fractures is not presented. Groundwater dating evaluation techniques have not been reported. Some of the current techniques like the FLUTe downhole technique for discrete determination of linear transmissivity, or the even better method of FLUTe coupled with external fiber optic temperature dissipation measurement capability is not reported as being used in site assessment. Basic fracture analysis including orientation, aperture size, fracture network analysis, and number and density of fractures is not reported by CBR, nor is appropriate software for fracture analysis reported as being employed (e.g. FracMan, or Fractran). No typical corehole geophysical methods are presented by CBR, nor are surface geophysical analysis. CBR's generalized conceptual model does not seem to be informed by typical, hydraulically isolated, downhole, high-resolution packer tests. While shallow aquifer monitoring of the Brule is reported and shallow excursions into the Brule are said by CBR to be correlated with external events, no mathematical quantitative analysis is presented. The low number of monitoring wells or single well used to evaluate the response of the heterogenous Upper Brule Formation during aquifer (pumping) tests provides extremely incomplete and biased information. Complete documentation for all boreholes is not given for well abandonment techniques described in CBR's direct testimony, claimed by CBR to be used on all wells, despite conflicting reports presented by CBR that suggest suspected vertical flow and failure of improperly abandoned

wells (ARCADIS report on pumping tests 5 through 9, 2004 and 2005). The number and location of improperly abandoned boreholes, available for vertical flow and transmission of groundwater, is not reported. Certainly more complete documentation by CBR would allow NRC staff, the State of Nebraska, and other external reviewers a better basis for appraisal of CBR's conceptual site model.

Summary of Long-term Water level Changes in the Upper Brule

Long-term water level changes in the Upper Brule Formation are another line of evidence of vertical communication of groundwater. Data from CBR presented on water levels of two wells in the Brule do not include the crucial period of 1991 to 1999 where maximum drawdowns and head gradients would be expected to occur.

3.0 NRC Modeling Results

NRC staff present a numerical model with the expressed major purpose of determining the probabilities of whether a single identified geological feature (White River fault) is a fold or a fault. Several observations on the model are offered below.

- Folds can have great vertical permeabilities, as great a potential for vertical flow as faults, or even greater, so the model results while interesting, are somewhat irrelevant.
- The model is set up to consider only a distant, single, large structural feature (the White River fold/fault) while largely ignoring possible smaller faults and fractures, and the causes and manifestations of the leakage that the USNRC noted in early aquifer (pumping) tests, much closer to current mining activities.
- The location of the model also ignores direct evidence of vertical leakage much closer to the mining site than this modeled, distant structural feature, evidence such as barometric and pressure responses and long-term water table responses in the Brule aquifer to mining activities, as described in Section 1.0 above.
- The model is somewhat rudimentary, and depends on chosen input values for hydrogeologic parameters, selected only as best estimates.
- Rigorous sensitivity analysis was not performed on the input variables, therefore there is a possibility that slight miss-estimations of input parameters and chosen initial conditions could result in large differences in model output and interpretation.
- No rigorous analysis is presented justifying the mathematical uniqueness of the solutions and probabilities generated.

- No justification was given for choice of grid layering, grid spacing, boundary conditions, grid domain which were chosen for the model. Variation in any one of these selected conditions would produce different modeling results and interpretations.
- Choice of the model and specific model algorithms have weaknesses when applied in this geologic setting.
- Numerical stability of the model is not adequately addressed
- Several modeling particulars concerning the architecture and running of the model, are choices that are not well justified.
- Rigorous calibration and model validation were not carried out, making the relation of model interpretation to actual physical reality more hypothetical.

Pursuant to 10 CFR 2.304(d) and 28 USC 1746, I declare under penalty of perjury, that the foregoing is true and correct to the best of my knowledge and belief.

Dated this 16th day of September, 2015.

Respectfully submitted,

David K. Kreamer

David K. Kreamer, Ph.D.