UNITED STATES OF AMERICA LBP-19-2
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD PANEL

Before the Licensing Board:

G. Paul Bollwerk, III, Chairman
Dr. Richard E. Wardwell
Dr. Thomas J. Hirons

In the Matter of	Docket No. 40-8943-MLA-2
CROW BUTTE RESOURCES, INC.	ASLBP No. 13-926-01-MLA-BD01
(Marsland Expansion Area)	February 28, 2019

INITIAL DECISION
(Ruling on Intervenor Oglala Sioux Tribe's Contention 2)

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ACRONYMS AND ABBREVIATIONS

ACL	Alternate Concentration Limit
AEA	Atomic Energy Act
ALARA	As Low as Reasonably Achievable
amsl	Above Mean Sea Level
AOR	Area of Review
ASTM	American Society for Testing and Materials
BC/CPF	Basal Chadron/Chamberlain Pass Formation
bgs	Below Ground Surface
BMPs	Best Management Practices
BPT	Best Practicable Technology
BS	Bachelor of Science
CBR	Crow Butte Resources, Inc.
C.F.R.	Code of Federal Regulations
cfs	cubic feet per second
cm./sec.	centimeters per second
DDW	Deep Disposal Well
EA	Environmental Assessment
EHD	Electronic Hearing Docket
EPA	Environmental Protection Agency
ER	Environmental Report
FONSI	Finding of No Significant Impact
FSDWA	Federal Safe Drinking Water Act
ft.	feet
ft./d	feet per day
ft./ft.	feet per foot
$ft.^2/d$	square feet per day
$ft.^3/d$	cubic feet per day
gpm	gallons per minute
gal./sq. ft.	gallons per square foot
ha	hectare
HCM	Hydrologic Conceptual Model
ISR	In Situ Uranium Recovery
LCU	Lower Confining Unit
MBA	Master of Business Administration
MCL	Maximum Concentration Limit
MEA	Marsland Expansion Area
mg/L	milligram per liter
MIT	Mechanical Integrity Test

MS	Master of Science
MU	Mine Unit
NDEQ	Nebraska Department of Environmental Quality
NPDES	National Pollutant Discharge Elimination System
NDNR	Nebraska Department of Natural Resources
NEPA	National Environmental Policy Act
NMSS	Office of Nuclear Material Safety and Safeguards
NRC	Nuclear Regulatory Commission
NTEA	North Trend Expansion Area
OST	Oglala Sioux Tribe
PDF	Portable Document Format
PG	Professional Geologist
Ph.D.	Doctoral Degree (Doctor of Philosophy)
ROI	Radius of Influence
SER	Safety Evaluation Report
SHEQMS	Safety, Health, and Environment Quality Management System
SPCC	Spill Prevention, Control, and Countermeasures
SWPPP	Storm Water Pollution Prevention Plan
TCEA	Three Crow Expansion Area
TDS	Total Dissolved Solids
Th	Thorium
Tr.	Transcript
TR/Tech. Rep.	Technical Report
U	Uranium
U_30_8	Triuranium Octoxide
UCU	Upper Confining Unit
UIC	Underground Injection Control
UMTRCA	Uranium Mill Tailings Radiation Control Act
USDW	Underground Source of Drinking Water
USGS	United States Geological Survey
USBR	United States Bureau of Reclamation
XRD	X-Ray Diffraction

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I. INTRODUCTION

On May 16, 2012, Crow Butte Resources, Inc., (CBR/Applicant/Crow Butte) filed an application with the Nuclear Regulatory Commission (NRC) to amend its current in situ uranium recovery (ISR) license for the existing Crow Butte ISR facility to permit CBR to construct and operate a satellite ISR facility in the Marsland Expansion Area (MEA), which is located in Dawes County, Nebraska.[1] This initial decision presents the Licensing Board's findings and conclusions relative to the sole remaining admitted contention in this proceeding, which was the subject of a fall 2018 evidentiary hearing.

[1] See LBP-13-6, 77 NRC 253, 265–66 (2013), aff'd, CLI-14-2, 79 NRC 11 (2014). Throughout this initial decision, when referring to the currently licensed ISR area and the Central Processing Facility, both located just southeast of Crawford, Nebraska, we will use the term "existing CBR ISR facility."

For the reasons set forth below, upon consideration of intervenor Oglala Sioux Tribe's (OST/Intervenor/Tribe) Contention 2 challenge to the NRC Staff's environmental assessment (EA) and CBR's application, including its Technical Report (TR/Tech. Rep.), the Board finds that the Staff and CBR have carried their respective burdens of proof to demonstrate that the EA and the MEA application satisfy the National Environmental Policy Act (NEPA), the Atomic Energy Act (AEA), and the agency's implementing regulations. The Board thus concludes that Intervenor's contention, along with the four associated "concerns" that provided a more detailed statement of OST's claims, cannot be sustained and we therefore enter a ruling on the merits regarding OST Contention 2 in favor of the Staff and CBR.

But before beginning our discussion of the merits of OST Contention 2, we provide a brief explanation regarding the organization of this somewhat lengthy initial decision, which is arranged into ten sections starting with this introduction. Sections II and III explain the procedural background and applicable legal standards for both the environmental and safety reviews associated with the MEA application. Section IV summarizes undisputed background information relating to Crow Butte's proposed ISR operations for the MEA, the local geologic setting, and the regional hydrogeologic conditions surrounding the MEA, followed by section V, which presents an analysis of the three overarching geologic and hydrogeologic disputes framed by OST. That, in turn, is followed by sections VI to IX, which address the four individual concerns associated with Contention 2, which are described in more detail in section I.A. Finally, the decision concludes with a statement of the Board's legal conclusions in section X.

The discussion regarding each of the overarching issues and the particular OST concerns is organized to reflect the Intervenor's position, specifically addressing the allegations raised in its written initial and rebuttal testimony, along with the written initial and rebuttal testimony providing the CBR and Staff positions and responses and the additional pertinent information obtained by the Board in questioning the parties' witnesses during the evidentiary hearing. And notwithstanding the somewhat overlapping nature of OST's concerns and the

Tribe's associated evidentiary presentations, the Board has chosen to treat separately the overarching geologic and hydrogeologic issues and each of the individual concerns in an effort to ensure that each of the Intervenor's claims and underlying evidentiary bases have been fully aired. As a consequence, there is a corresponding overlap in the discussion in the different sections, particularly with respect to the last two OST concerns in sections VIII and IX.[2]

A. Contention 2 Description

In its final form, Contention 2, a hybrid safety and environmental contention proffered by OST that raises issues regarding the adequacy of the application's "hydrogeologic characterization of the MEA site and its environs,"[3] provides as follows:

> OST Contention 2: Failure to Include Adequate Hydrogeological Information to Demonstrate Ability to Contain Fluid Migration
>
> The application and final environmental assessment fail to provide sufficient information regarding the geological setting of the area to meet the requirements of 10 C.F.R. part 40, Appendix A, Criteria 4(e) and 5G(2); the National Environmental Policy Act; and NUREG-1569 section 2.6. The application and final environmental assessment similarly fail to provide sufficient information to establish potential effects of the project on the adjacent surface and ground-water resources, as required by NUREG-1569 section 2.7, and the National Environmental Policy Act.[4]

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[2] This reiteration has twin advantages. Besides providing a comprehensive, standalone ruling on each of these Intevenor claims, the reader, casual or otherwise, can approach each section with the assurance that it will afford a comprehensive discussion regarding the matter in controversy without needing to delve extensively into the discussion in another section to understand the basis for the parties' positions or the Board's ruling on the particulars of the OST hydrogeological challenge at issue.

[3] LBP-13-6, 77 NRC at 294–95.

[4] Notice of Hearing (Notice of Evidentiary Hearing and Opportunity to Provide Oral, Written, and Audio-Recorded Limited Appearance Statements); In the Matter of Crow Butte Res., Inc. (Marsland Expansion Area), 83 Fed. Reg. 37,828, 37,828 (Aug. 2, 2018).

More specifically, within the scope of Contention 2 are four OST-identified "concerns" regarding

> (1) the adequacy of the descriptions of the affected environment for establishing the potential effects of the proposed MEA operation on the adjacent surface water and groundwater resources; (2) exclusively as a safety concern, the absence in the applicant's technical report, in accord with NUREG-1569 section 2.7, of a description of the effective porosity, hydraulic conductivity, and hydraulic gradient of site hydrogeology, along with other information relative to the control and prevention of excursions such as transmissivity and storativity; (3) the failure to develop, in accord with NUREG-1569 section 2.7, an acceptable conceptual model of site hydrology that is adequately supported by site characterization data so as to demonstrate with scientific confidence that the area hydrogeology, including horizontal and vertical hydraulic conductivity, will result in the confinement of extraction fluids and expected operational and restoration performance; and (4) whether the final EA contains unsubstantiated assumptions as to the isolation of the aquifers in the ore-bearing zones.[5]

For each of these four concerns, which for the purpose of this decision we will reference as Concerns 1 through 4, we have considered all the written initial and rebuttal testimony and the associated documentary evidence,[6] the evidence presented at the hearing by the parties'

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[5] LBP-18-3, 88 NRC 13, 53 (2018).

[6] As entered into the record and incorporated into the electronic hearing docket (EHD) associated with the agency's ADAMS document management system, the official exhibit number for each evidentiary item in this proceeding reflects a three-letter party or Licensing Board identifier (i.e., CBR, NRC, OST, BRD) followed in some instances by another alpha character (i.e., -R) to indicate that the exhibit was revised after its original submission as a prefiled exhibit (e.g., admitted exhibit CBR001-R would be a revised version of prefiled exhibit CBR001); followed by a two-character numeric identifier (i.e., 00) that identifies the exhibit as being used in a contested case (as opposed to a mandatory/uncontested proceeding (i.e., MA)); followed by the designation BD01, which indicates that this Licensing Board (i.e., BD01) was involved in its identification and/or admission. Accordingly, the official designation for prefiled exhibit CBR001-R, as ultimately admitted, is CBR001-R-00-BD01. For ease of reading, however, we will refer initially to all exhibits identified for the record in this proceeding without the final six characters that make up their official designation.

Additionally, we note that while each of the identified exhibits in this proceeding includes a cover sheet that provides the prefiled exhibit number for the document, for purposes of citing an exhibit we will disregard the cover sheet and use the pagination marked on the exhibit or, in instances when there is no marked pagination for the exhibit, the pagination for the portable witnesses in response to Board questions, and the parties' proposed initial and rebuttal findings of facts and conclusions of law. Insofar as the parties' evidence directly relates to and impacts our decision, it is summarized for each concern. If, however, we deemed the evidence to be of little or no relevance to our decision, we did not summarize or otherwise discuss it. And if there was an evidentiary dispute, we made any necessary factual findings based on the preponderance of the evidence standard that governs this proceeding.[7]

B. Parties' Witnesses

A total of eleven witnesses testified about the four concerns raised in connection with OST Contention 2. There was only one challenge to the qualifications of a witness. In a motion in limine, the Staff challenged, among other things, Dr. Hannan LaGarry's qualifications to proffer rebuttal testimony regarding the requirements of NEPA, arguing he had not demonstrated any expertise in that area.[8] Although the Board did not strike Dr. LaGarry's rebuttal testimony,[9] the Board nonetheless questioned Dr. LaGarry about his qualifications to give such testimony at the hearing,[10] and concluded that he possesses sufficient familiarity with NEPA to proffer the general opinions about NEPA-associated factual matters that he expressed in his written testimony and during the hearing.[11]

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document format (PDF) file version of the exhibit that is found in the EHD, designated as such (e.g., Ex. XXXYYY at PDF 1).

[7] See infra section III.C.

[8] See NRC Staff Motion in Limine to Exclude Portions of [OST's] Testimony and Exhibits (Sept. 12, 2018) [hereinafter Staff Motion in Limine].

[9] See Licensing Board Memorandum and Order (Granting in Part and Denying in Part Staff Motion in Limine) (Sept. 24, 2018) at 18 (unpublished) [hereinafter Board In Limine Ruling].

[10] See Tr. at 577–84.

[11] Of course, expert testimony regarding legal conclusions, as opposed to factual matters, generally would not be appropriate. See, e.g., United States v. McIver, 470 F.3d 550, 561–62 (4th Cir. 2006) ("[O]pinion testimony that states a legal standard or draws a legal

Three witnesses testified for Intervenor OST: Dr. Hannan LaGarry, Michael Wireman, and Dr. David Kreamer. Dr. LaGarry received his doctoral degree (Ph.D.) in Geology from the University of Nebraska-Lincoln and is a conservation biology instructor/researcher and co-chair in the Department of Math, Science, and Technology at Oglala Lakota College in South Dakota.[12] Mr. Wireman, who received a Master of Science (MS) degree from Western Michigan University, is a hydrogeologist with over 30 years of experience, including serving as a National Ground-Water Expert in the United States Environmental Protection Agency's (EPA) Region VIII.[13] Dr. Kreamer received his Ph.D. in hydrology from the University of Arizona and is a professor of hydrology and geoscience at the University of Nevada, Las Vegas.[14]

Four witnesses testified for the NRC Staff: David Back, Dr. Elise Striz, Thomas Lancaster, and Jean Trefethen. Mr. Back received his MS degree in geology with a hydrogeology concentration from Oklahoma State University and is a hydrogeologist at an environmental consulting firm.[15] Dr. Striz received her Ph.D. in petroleum engineering from the University of Oklahoma and is a hydrogeologist in the NRC's Uranium Recovery Licensing Branch.[16] Mr. Lancaster, who pursued graduate studies in geophysical and hydrogeological science at Old Dominion University and has a Master of Business Administration (MBA) degree from George Mason University, is a hydrogeologist and regulatory project manager in the NRC's

conclusion by applying law to the facts is generally inadmissible."); cf. Nieves-Villanueva v. Soto-Rivera, 133 F.3d 92, 99–100 (1st Cir. 1997) (noting that the "well-recognized exception" to excluding expert testimony on purely legal issues is for questions of foreign law).

[12] See Ex. OST013, at 1 (Hannan E. LaGarry, Curriculum Vitae).

[13] See Ex. OST002, at 1 (Michael Wireman, Curriculum Vitae).

[14] See Ex. OST001, at 1 (David Kenneth Kreamer, Curriculum Vitae).

[15] See Ex. NRC002, at 1 (David Back, Hydrogeologist, Statement of Professional Qualifications).

[16] See Ex. NRC004, at 1 (Elise A. Striz, Ph.D., Statement of Professional Qualifications).

Uranium Recovery Licensing Branch.[17] Ms. Trefethen received her Bachelor of Arts degree in Biology from Carroll College and is an environmental project manager in the NRC's Environmental Review Branch.[18]

Four witnesses testified for Crow Butte: Robert Lewis, James Shriver, Douglas Pavlick, and Walter Nelson. Mr. Lewis, who received his MS degree in geology (hydrogeology) from the Colorado School of Mines, is a certified PG and the owner and principal hydrogeologist of an environmental consulting firm.[19] Mr. Shriver received his BS in geology from the University of Wyoming and is a senior geologist for Cameco Resources.[20] Mr. Pavlick has a BS degree in geophysical engineering from the Montana College of Mineral Science and Technology and is the general manager of United States operations for Cameco Resources.[21] Mr. Nelson received his BS in environmental biology from Chadron State College and is the CBR safety, health, environmental, and quality coordinator.[22]

II. PROCEDURAL BACKGROUND

A. Contention Admissibility, Summary Disposition, Migration, and New and Amended Contention Admissibility

On January 29, 2013, OST submitted an intervention petition seeking to challenge CBR's application, including portions of CBR's TR and its environmental report (ER).[23] CBR

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[17] See Ex. NRC003, at 1 (Thomas R. Lancaster, MBA, [Bachelor of Science (BS)], [Professional Geologist (PG)], Statement of Professional Qualifications).

[18] See Ex. NRC005, at 1 (Jean A. Trefethen, Statement of Professional Qualifications).

[19] See Ex. CBR002, at PDF 3 (Aff. of Robert Lewis (Aug. 16, 2018)).

[20] See Ex. CBR037, at PDF 3 (Aff. of James Shriver (Sept. 7, 2018)).

[21] See Ex. CBR004, at PDF 3, 4 (Aff. of Doug Pavlick (Aug. 16, 2018)).

[22] See Ex. CBR003, at PDF 3, 4 (Aff. of Walter Nelson (Aug. 16, 2018)).

[23] See Petition to Intervene and Request for Hearing of [OST] (Jan. 29, 2013). In addition to OST, two organizations and three individuals filed a consolidated intervention petition

and the Staff opposed the hearing request on the grounds that OST had failed to establish its standing and had not submitted an admissible contention.[24] On May 10, 2013, the Licensing Board concluded that OST had standing and had submitted two admissible contentions: Contention 1, which challenged the ER's review of historical and cultural resources on the MEA site,[25] and Contention 2, which asserted that CBR's ER and TR had failed to include adequate hydrogeological information.[26] After the Staff and CBR appealed the Board's decision, the Commission affirmed the ruling as to standing and the admissibility of these two contentions.[27]

Subsequently, the Staff issued the cultural resources section of its draft EA in June 2014,[28] but OST did not submit new or amended contentions regarding that section of the draft EA. The Staff then filed a motion for summary disposition of Contention 1.[29] In an October 22, 2014 ruling, the Board agreed with the Staff that Contention 1 had been resolved based on the draft EA section, and dismissed Contention 1.[30]

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that the Board denied based on their lack of standing, a determination that was not appealed. See CLI-14-2, 79 NRC at 13 n.4.

[24] See NRC Staff Response to [OST's] Request for Hearing and Petition to Intervene (Feb. 25, 2013) at 1; Applicant's Response to Petition to Intervene Filed by [OST] (Feb. 25, 2013) at 1.

[25] See LBP-13-6, 77 NRC at 286.

[26] See id. at 289.

[27] See CLI-14-2, 79 NRC at 12.

[28] See Letter From Marcia J. Simon, NRC Staff Counsel, to Licensing Board (June 30, 2014).

[29] See NRC Staff's Motion for Summary Disposition of Contention 1 (Aug. 6, 2014) at 1, 3–4.

[30] See Licensing Board Memorandum and Order (Ruling on Motion for Summary Disposition Regarding [OST] Contention 1) (Oct. 22, 2014) at 2 (unpublished).

The Staff issued the remainder of the draft EA on December 11, 2017, and OST again did not submit any new or amended contentions or the Board-requested migration declaration regarding Contention 2. Thereafter, the Staff challenged the migration of the environmental portions of Contention 2, arguing that the environmental concerns raised had been addressed in the draft EA.[31] The Board denied the motion in part and allowed the majority of Contention 2 to migrate from a challenge to CBR's ER to a dispute with the Staff's draft EA; however, the Board granted the motion as to the environmental aspects of Concern 2.[32]

The Staff's safety evaluation report (SER) was published on January 31, 2018,[33] and the final EA was issued on April 30, 2018.[34] With publication of the final EA,[35] OST again had an

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[31] See NRC Staff's Motion to Deny Migration of Environmental Portion of Contention 2 (Jan. 26, 2018) at 1–3.

[32] See LBP-18-2, 87 NRC 21, 27–28, 35–36 (2018).

[33] See Ex. NRC008 (Division of Decommissioning, Uranium Recovery & Waste Programs, NRC Office of Nuclear Material Safety and Safeguards (NMSS), [SER], License Amendment for the [CBR] [MEA] In-Situ Recovery Project, Dawes County, Nebraska (Jan. 2018)) [hereinafter SER].

[34] See Ex. NRC006 (Division of Fuel Cycle Safety, Safeguards & Environmental Review, NRC NMSS, [EA] for the [MEA] License Amendment Application (Apr. 2018)) [hereinafter EA]. In contrast to instances when a new ISR facility license application has been the subject of agency review, triggering the preparation of an environmental impact statement, see Strata Energy, Inc. (Ross In Situ Uranium Recovery Project), CLI-16-13, 83 NRC 566, 570–71 (2016), petition for review denied sub nom. Nat. Res. Def. Council v. NRC, 879 F.3d 1202 (2018), for this amendment to CBR's license for its existing ISR facility that would authorize ISR operations in the MEA, the Staff developed an EA, accompanied by a finding of no significant impact (FONSI), see EA at xiv–xv; see also [CBR, MEA], 83 Fed. Reg. 19,576 (May 3, 2018) (providing notice of issuance of EA and FONSI).

[35] On May 24, 2018, the Staff notified the Board and the other parties that, in accord with 10 C.F.R. § 2.1202(a), the CBR license amendment authorizing MEA construction and operation had been issued, effective immediately. See Letter from Emily Monteith, NRC Staff Counsel, to Licensing Board at 1–2 & n.1 (May 24, 2014). Although section 2.1213(a) afforded OST the opportunity to seek a stay of this Staff action, no such request was filed pursuant to that provision.

opportunity to file new or amended contentions,[36] and on May 30, 2018, OST submitted fourteen new or "renewed" contentions and a migration declaration for Contention 2.[37] The Board found that migration of Contention 2 as a challenge to the final EA was appropriate,[38] but denied admission of the new and "renewed" contentions.[39]

B. Evidentiary Hearing

In preparation for the 10 C.F.R. Part 2, Subpart L evidentiary hearing on Contention 2, CBR, the Staff, and OST filed initial position statements and supporting exhibits (including their witnesses' written initial testimony) on or about August 17, 2018.[40] The Staff filed its rebuttal position statement and supporting exhibits (including its witnesses' written rebuttal testimony) on September 5, 2018, while CBR and OST filed their respective rebuttal position statements and supporting exhibits (including their witnesses' written rebuttal testimony) on September 7, 2018.[41] Relative to this prefiled evidentiary material, as was noted previously,[42] the Staff filed a motion in limine seeking to exclude portions of OST's witnesses' testimony and exhibits.[43] The

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[36] See Licensing Board Memorandum and Order (Revised General Schedule) (Apr. 20, 2017) app. A, at 2 (unpublished) [hereinafter General Schedule].

[37] See [OST] Migrated, Renewed, and New Marsland Expansion Final [EA] Contentions (May 30, 2018).

[38] See LBP-18-3, 88 NRC at 25.

[39] See id. at 53.

[40] See [CBR's] Initial Statement of Position (Aug. 17, 2018); NRC Staff's Initial Statement of Position (Aug. 17, 2018); [OST's] Initial Position Statement (Aug. 18, 2018) (dated August 17, 2018, but filed at 13:17 EDT on August 18, 2018) [hereinafter OST Initial Position Statement].

[41] See NRC Staff's Rebuttal Statement of Position (Sept. 5, 2018); [CBR's] Rebuttal Statement of Position (Sept. 7, 2018); [OST's] Rebuttal Statement (Sept. 7, 2018).

[42] See supra section I.B.

[43] See Staff Motion in Limine at 1.

Board determined that portions of the witness testimony in four prefiled exhibits should be excluded, and struck in toto three of OST's prefiled exhibits.[44] The Board also ordered OST to submit new versions of the testimony, revised in conformance with its issuance, and asked that OST submit, as exhibits, the documents referred to in rebuttal testimony submitted by OST witness Dr. LaGarry if OST wanted to avoid having the testimony stricken.[45]

Pursuant to the proceeding's general schedule, on October 30–November 1, 2018, the Board held an evidentiary hearing regarding Contention 2 in Crawford, Nebraska.[46] After providing the parties with an opportunity to submit proposed joint transcript corrections, on November 26, 2018, the Board issued an order that adopted transcript corrections, provided a list of the identified exhibits in the evidentiary record denoting their evidentiary status, and closed the evidentiary record.[47]

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[44] See Board in Limine Ruling, at 1 n.1, 6–7, 11, 15 n.11, 18–19 (unpublished). Striken in full were the following OST prefiled exhibits: Prefiled ex. OST009 (OST Hearing Petition); Prefiled ex. OST011 (Susan Hall, Groundwater Restoration at Uranium In-situ Recovery Mines, South Texas Coastal Plain, U.S. Geological Survey On-File Report 2009-1143 (2009)); Prefiled ex. OST012 (J.K. Otten & S. Hall, In-situ Recovery Uranium Mining in the United States: Overview of Production and Remediation Issues, IAEA-CN-175/87).

[45] See Board In Limine Ruling at 19–20. Refiled as revised prefiled exhibits were the following: Prefiled ex. OST004-R (Expert Opinion Testimony of [Michael] Wireman (rev. Oct. 3, 2018)); Prefiled ex. OST014-R (Rebuttal Testimony of David K. Kreamer (rev. Oct, 3, 2018)); Prefiled ex. OST015-R (Rebuttal Testimony of [Michael] Wireman (rev. Oct. 3, 2018)); Prefiled ex. OST016-R (Rebuttal Opinion of Hannon LaGarry (rev. Oct. 3, 2018)).

[46] See Tr. at 300–1039. In addition, the Board conducted a 10 C.F.R. § 2.315(a) limited appearance session in Chadron, Nebraska, on October 28, 2018, see Tr. at 1–83 (Oct. 28, 2018), and participated in a site visit to the existing CBR ISR facility on October 29, 2018.

[47] See Licensing Board Memorandum and Order (Adopting Transcript Corrections, Providing Final Exhibit List, and Closing Evidentiary Record) (Nov. 26, 2018) (unpublished) at 2–3. In citing to the evidentiary hearing transcript in this decision, we are referencing the transcript as modified by the corrections adopted by the Board. See id. app. A.

In accord with 10 C.F.R. § 2.1209 and this proceeding's general schedule,[48] on December 3, 2018, the parties filed their proposed findings of fact and conclusions of law, with the parties' reply findings of fact and conclusions following on January 4, 2019.[49]

III. APPLICABLE LEGAL STANDARDS

Contention 2 is a hybrid safety and environmental contention, raising concerns under both NEPA and the AEA, as well as the NRC's regulations implementing an applicant's and the agency's responsibilities pursuant to both statutes. For their part, the AEA and the agency's implementing regulations govern the applicant's duty to comply with safety-related strictures. NEPA and the NRC's implementing regulations likewise govern an applicant's information-gathering and other responsibilities associated with consideration of the environmental effects of a proposed agency licensing action, but define the Staff's central role in identifying and analyzing such impacts as well. Moreover, as we outline in section III.C infra, as a consequence of the Staff's role under NEPA, the burden of proof relative to AEA and NEPA issues is somewhat different.

A. Safety Requirements – AEA and Implementing Regulations

The AEA authorizes the NRC to issue licenses for the possession and use of source and byproduct material,[50] such as is involved in the ISR process and which the NRC regulates under 10 C.F.R. Part 40. The AEA further requires the NRC to ensure that facilities associated with

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[48] See General Schedule app. A, at 3; see also Licensing Board Memorandum and Order (Schedule for Post-Evidentiary Hearing Submissions) (Nov. 6, 2018) at 2 (unpublished).

[49] [CBR] Proposed Findings of Fact and Conclusions of Law (Dec. 3, 2018); NRC Staff's Proposed Findings of Fact and Conclusions of Law (Dec. 3, 2018); [OST] Proposed Findings of Fact and Conclusions of Law (Dec. 3, 2018) [hereinafter OST Proposed Findings]; [CBR] Reply Findings of Fact and Conclusions of Law (Jan. 4, 2019); NRC Staff's Reply Findings of Fact and Conclusions of Law (Jan. 4, 2019); [OST] Reply to CBR and NRC Proposed Findings of Fact and Conclusions of Law (Jan. 4, 2019).

[50] See AEA §§ 62, 81, 42 U.S.C. §§ 2092, 2111.

the licensed possession and use of such materials meet regulatory requirements developed to protect public health and safety from radiological hazards as set forth in 10 C.F.R. Part 20.

ISR license amendment applications such as that submitted by CBR thus require a safety review to determine if a license applicant has met all relevant criteria in 10 C.F.R. Part 40. These safety requirements include certain criteria in Appendix A to Part 40 that provide specific standards for uranium mill operation and waste material disposal, although, in this instance, not all criteria in Appendix A are applicable because the MEA is not a conventional uranium mill.[51] In this regard, Intervenor asserts in Contention 2 that the application has failed to provide sufficient information about the ability of the underlying geologic strata to control contaminant and solution transport as required by Appendix A, Criterion 5G(2).[52] The Intervenor also maintains in Contention 2 that the application has failed to fulfill the provisions of NUREG-1569, sections 2.6 and 2.7, regarding the geologic and hydrologic circumstances

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[51] Because 10 C.F.R. Part 40 lacks ISR-specific regulatory provisions, in 2006 the agency initiated a rulemaking to provide clarity and consistency to the licensing and regulation of ISR facilities. That effort was suspended in 2010 in deference to an Environmental Protection Agency proposed rule that would have promulgated generally applicable ISR standards. With the withdrawal of that proposed rule in 2018, the NRC is now considering whether to proceed with its earlier ISR-specific rulemaking. See Ground Water Protection at Uranium [ISR] Facilities, 84 Fed. Reg. 574, 576 (Jan. 31, 2019).

[52] As supporting its contention, OST also cited 10 C.F.R. Part 40, App. A, Criteria 4(e) and 5G(2). In its initial testimony, however, the Staff asserted that neither criterion is applicable to the MEA because the former provision concerns the location of permanent tailings or waste disposal impoundments relative to a capable earthquake fault and CBR does not propose any surface impoundments for the MEA nor is there any evidence of capable faults in the vicinity of the MEA, while the latter relates to tailings disposal system proposals at conventional uranium mines and so has no application to an ISR facility. See NRC001, at 8 (NRC Staff's Initial Testimony (Aug. 17, 2018)) (Lancaster, Striz) [hereinafter Staff Initial Test.]. Given that OST makes reference to these two Appendix A provisions only in the context of quoting or referencing the language of its Contention 2, see OST Initial Position Statement at 1, 39; OST Proposed Findings at 19, 23, we find no basis for further discussion of either criterion in this decision.

associated with the proposed ISR facility.[53] NUREG-1569 is the standard review plan guidance document for the Staff's safety review of an application for an ISR uranium recovery facility.[54]

B. Environmental Review Requirements

1. NEPA Requirements

NEPA requires federal agencies to take a "hard look" at the environmental impacts of a proposed action.[55] This "hard look" is intended to "foster both informed decision-making and informed public participation" so as to ensure that the agency does not act upon "incomplete information, only to regret its decision after it is too late to correct."[56] This "hard look" is, however, subject to a "rule of reason" in that consideration of environmental impacts need not address "all theoretical possibilities," but rather only those that have some "reasonable possibility" of occurring.[57]

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[53] See supra note 5 and accompanying text.

[54] See Ex. NRC010, at 1 (Office of Nuclear Material Safety and Safeguards (NMSS), NRC, Standard Review Plan for In Situ Leach Uranium Extraction License Applications, NUREG-1569 (June 2003)) [hereinafter NUREG-1569]. As the Staff points out in its initial testimony, see Staff Initial Test. at 9 (Back, Lancaster, Striz), the provisions of this and other standard review plans are "guidance" to an applicant about approaches to demonstrating compliance with the agency's regulatory requirements that the Staff generally deems acceptable, with the caveat that an applicant may take a different approach to compliance so long at the application information provided allows the Staff to make the requisite finding of environmental acceptability and regulatory compliance. While recognizing the "guidance" nature of such review plans, the Commission has also indicated that, having been developed to assist an applicant in complying with applicable regulations, such plans are entitled to "special weight." Private Fuel Storage, L.L.C (Independent Spent Fuel Storage Installation), CLI-01-22, 54 NRC 255, 264 (2001). By the same token, and in the absence of an applicant showing that it is attempting to reach regulatory compliance by some other means, as was the case in this proceeding, the degree to which an application reflects adherence to such guidance is a legitimate subject of inquiry, both at the contention admissibility and merits stages of a licensing adjudication.

[55] See La. Energy Servs., L.P. (Claiborne Enrichment Center), CLI-98-3, 47 NRC 77, 87–88 (1998).

[56] Id. at 88 (quoting Marsh v. Or. Nat. Res. Council, 490 U.S. 360, 371 (1989)).

[57] Long Island Lighting Co. (Shoreham Nuclear Power Station, Unit 1), ALAB-156, 6 AEC 831, 836 (1973).

With regard to such reasonably foreseeable impacts, NEPA “does not call for certainty or precision, but an estimate of anticipated (not unduly speculative) impacts.”[58] As a consequence, agencies are given broad discretion “to keep their inquiries within appropriate and manageable boundaries,”[59] because an EA “is not intended to be ‘a research document.’”[60]

Finally, “in the context of an NRC adjudicatory proceeding, even if an [EA] prepared by the Staff is found to be inadequate in certain respects, the Board’s findings, as well as the adjudicatory record, ‘become, in effect, part of the [final EA].’ Thus, the Board’s ultimate NEPA judgments can be made on the basis of the entire adjudicatory record in addition to the Staff’s [final EA].”[61]

2. 10 C.F.R. Part 51 Requirements Associated with Surface Water and Groundwater Information

The NRC’s NEPA-implementing environmental protection regulations are found in 10 C.F.R. Part 51. Acting pursuant to 10 C.F.R. § 51.21, the Staff prepared a draft and final EA in response to CBR’s request to amend its license to possess and use source material at its existing ISR facility and thereby authorize the construction and operation of the MEA. And in formulating its draft and final EA conclusions regarding the environmental impacts of that proposed licensing action, the Staff uses as guidance a standard scheme to categorize or

[58] La. Energy Servs, L.P. (National Enrichment Facility), CLI-05-20, 62 NRC 523, 536 (2005).

[59] Claiborne, CLI-98-3, 47 NRC at 103.

[60] Entergy Nuclear Generation Co. (Pilgrim Nuclear Power Station), CLI-10-22, 72 NRC 202, 208 (2010) (quoting Town of Winthrop v. FAA, 535 F.3d 1, 13 (1st Cir. 2008)).

[61] S. Nuclear Operating Co. (Early Site Permit for Vogtle ESP Site), LBP-09-7, 69 NRC 613, 632 (2009) (quoting Hydro Res., Inc. (P.O. Box 15190, Rio Rancho, NM 87174), CLI-01-4, 53 NRC 31, 53 (2001), and citing La. Energy Servs., L.P. (National Enrichment Facility), LBP-05-13, 61 NRC 385, 404 (2005), aff’d, CLI-06-22, 64 NRC 37 (2006), petition for review denied sub nom. Nuclear Infor. & Res. Serv. v. NRC, 509 F.3d 562 (D.C. Cir. 2007)), petition for review denied, CLI-10-5, 71 NRC 90 (2010); see Nat. Res. Def. Council, 879 F.3d at 1209–13.

quantify the impacts. This standard regime was created using the approach outlined in Council on Environmental Quality regulations indicating that agencies should consider both the context and intensity of impacts.[62] This benchmark employs three levels of impacts — SMALL, MODERATE, and LARGE — that are defined as follows:

- SMALL—environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.
- MODERATE—environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.
- LARGE—environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.[63]

C. Burden of Proof

As the proponent of the agency action at issue, an applicant generally has the burden of proof in a licensing proceeding.[64] This is clearly the case relative to AEA-related safety issues in that, while the Staff conducts its own independent safety review, parties may not litigate the adequacy of the Staff's safety review.[65] Thus, the primary responsibility to address and comply with the agency's safety-related requirements lies with the applicant that, in turn, has the burden of proof for a safety-related contention challenging the sufficiency of the application.[66]

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[62] See Ex. NRC011 (NMSS, NRC, Environmental Review Guidance for Licensing Actions Associated with NMSS Programs, NUREG-1748, at 4-13 to -14 (Aug. 2003)) (citing 40 C.F.R. § 1508.27)) [hereinafter NUREG-1748].

[63] EA at xiv; see NUREG-1748, at 4-14.

[64] See 10 C.F.R. § 2.325.

[65] See AmerGen Energy Co. (Oyster Creek Nuclear Generating Station), CLI-08-23, 68 NRC 461, 476–77 (2008).

[66] See id. at 477.

In contrast, the statutory obligation for complying with NEPA rests with the NRC Staff.[67] Consequently, when a NEPA-based contention is involved, the burden of proof is on the Staff.[68] At the same time, "because the Staff, as a practical matter, relies heavily upon the Applicant's ER in preparing the [EA], should the Applicant become a proponent of a particular challenged position set forth in the [EA], the Applicant, as such a proponent, also has the burden on that matter."[69]

And relative to factual matters arising in connection with either a safety or environmental issue, to carry that burden, the Staff and/or the applicant must establish that its position is supported by a preponderance of the evidence.[70]

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[67] See, e.g., Duke Power Co. (Catawba Nuclear Station, Units 1 & 2), CLI-83-19, 17 NRC 1041, 1049 (1983).

[68] See Progress Energy Fla., Inc. (Levy Cnty. Nuclear Power Plant, Units 1 & 2), CLI-10-2, 71 NRC 27, 34 (2010); see also S. Nuclear Operating Co. (Early Site Permit for Vogtle ESP Site), CLI-07-17, 65 NRC 392, 395 (2007) ("[W]hereas NRC hearings on safety issues concern the adequacy of the license application, not the NRC Staff's work, NRC hearings on NEPA issues focus entirely on the adequacy of the NRC Staff's work.").

[69] La. Energy Servs., L.P. (Claiborne Enrichment Center), LBP-96-25, 44 NRC 331, 339 (1996) (citing Pub. Serv. Co. of N.H. (Seabrook Station, Units 1 & 2), ALAB-471, 7 NRC 477, 489 n.8 (1978)), rev'd on other grounds, CLI-97-15, 46 NRC 294 (1997).

[70] See Pac. Gas & Elec. Co. (Diablo Canyon Nuclear Power Plant, Units 1 & 2), ALAB-763, 19 NRC 571, 577 & n.22 (citing cases), petition for review declined, CLI-84-14, 20 NRC 285 (1984).

IV. UNDISPUTED FACTUAL BACKGROUND[71]

A. In Situ Uranium Recovery Operations at the Marsland Expansion Area

The existing CBR ISR facility is authorized to operate in Crawford, Nebraska, under NRC source materials license SUA-1534.[72] The proposed MEA site is located in southwestern Dawes County, Nebraska, approximately 11 miles south-southeast of the existing CBR ISR facility.[73] The proposed MEA license area is approximately 4622 acres,[74] which has the potential to encompass 11 mine units (MUs) based on CBR's current knowledge of available reserves.[75] The total potential disturbed area over the life of the project is estimated to be up to 1754 acres.[76]

Consistent with the configuration at the existing CBR ISR facility, wells within each MU will be arranged in 7-spot patterns with a central production well surrounded by six injection

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[71] The factual information contained within this section generally was stipulated to by the parties and therefore is considered undisputed. See Ex. BRD001 (Joint Stipulation) [hereinafter Joint Stipulation]; see also Joint Response Accepting Revisions to Stipulated Factual Background (Oct. 16, 2018).

[72] The renewal of CBR's license in 2014 is the subject of a hearing before a different licensing board. While a petition seeking Commission review of that board's decision in favor of the Staff and CBR regarding hydrogeology and other matters was denied by the Commission, see Crow Butte Res., Inc. (In Situ Leach Facility, Crawford, Neb.), LBP-16-13, 84 NRC 271 (2016), petition for review denied, CLI-18-8, 88 NRC __ (Nov. 29, 2018) [hereinafter Renewal Site], a petition for Commission review regarding a board initial decision on cultural resources issues remains pending before the Commission, see Renewal Site, LBP-16-7, 83 NRC 340 (2016), petition for Comm'n review pending.

[73] See Ex. CBR006 (CBR, [TR], [MEA] at 1-3 (June 2017) (consolidated)) [hereinafter Tech. Rep.]; SER at 19.

[74] See Ex. CBR005-R (CBR, Application for Amendment of USNRC Source Materials License SUA-1534, [MEA], Crawford, Nebraska, [ER] at 1-3, tbl. 3.5-2 (rev. Apr. 25, 2014) (consolidated)) [hereinafter ER]; EA at 1-1, 2-5, 3-42.

[75] See ER at 1-3; EA at 2-5.

[76] See EA at 2-5.

wells spaced at between 65 feet (ft.) and 150 ft. from each other in a hexagonal pattern.[77] Under an existing license condition that also applies to the MEA, CBR is authorized to inject lixiviant that contains sodium carbonate or sodium bicarbonate, carbon dioxide, oxygen and/or hydrogen peroxide at the existing CBR ISR facility, and CBR has not requested a different lixiviant composition for the MEA.[78] From the MUs subsurface, CBR intends to extract uranium-bearing fluid via a production well and then pipe the uranium-bearing fluid to the satellite facility located within the MEA for processing by loading the uranium onto ion exchange (IX) resins.[79] The loaded resins would then be transported by tanker truck to the central processing facility at the existing CBR ISR facility for elution, drying, and packaging as yellowcake.[80] Barren resin would be returned to the MEA satellite building by tanker truck for reuse.[81] CBR would begin aquifer restoration activities in an active MEA MU when uranium recovery permanently ceases in that wellfield.[82]

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[77] See Tech. Rep. at 3-11; SER at 66.

[78] See SER at 72.

[79] See Tech. Rep. at 3-29; SER at 16; EA at 1-2. "Satellite facility" as used in the EA refers to the 1.8-acre (0.73 hectare (ha)) area shown in EA Figure 1-1. See EA at 1-3 (fig. 1-1), 4-26.

[80] See Tech. Rep. at 1-5.

[81] See id. at 1-5, 3-22; SER at 16.

[82] See SER at 150; Ex. NRC009, at 11 (NRC Materials License SUA-1534, amend. 3 (with License Condition Reference Sheet) (May 23, 2018) (License Condition 10.1.5)) [hereinafter CBR License Amend. 3].

B. Undisputed Local Geologic Setting

1. General Stratigraphic Units

Starting from the youngest to oldest and including the thickness of the units underlying the MEA, the geologic strata beneath the MEA are (1) the alluvium (less than 30 ft. thick); (2) the Arikaree Group (40 ft. to 160+ ft. thick); (3) the Brule Formation (350 ft. to 550 ft. thick); (4) the Upper and Middle Chadron Formations (360 ft. to 450 ft. thick); (5) the Basal Chadron /Chamberlain Pass Formation (BC/CPF) (20 ft. to 90 ft. thick), which contains the uranium mineralization for the production zone of the proposed MEA ISR operation;[83] and (6) the Pierre Shale (750 ft. to greater than 1000 ft. thick).[84] The White River Group, which is referenced in the parties' testimony, includes, from youngest to oldest, the Brule Formation overlying the Upper and Middle units of the Chadron Formation, and the BC/CPF.[85]

These geologic strata are consistent with the generally recognized regional units of northwestern Nebraska.[86] Further details of the hydrostratigraphic functions and properties for each formation are provided below starting with the youngest and ending with the oldest deposits.

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[83] Consistent with the Renewal Site proceeding, rather than using the historic terminology of the "Basal Chadron" for this formation or the more recent name of "Chamberlain Pass Formation," this formation will be referred to as the "Basal Chadron/Chamberlain Pass Formation." See Renewal Site, LBP-16-13, 84 NRC at 288–89 n.43 (2016); Renewal Site, CLI-18-8, 88 NRC at __ n.8 (slip op. at 4 n.8); see also Renewal Site, LBP-16-13, 84 NRC at 399–403 (indicating parties' experts agreed to use of this nomenclature, recognizing that its use did not affect the operation of the existing CBR ISR facility and demonstrating there was agreement that adopting the BC/CPF label would not change the hydrogeologic characterization of the formation).

[84] See Tech. Rep. at 2-43 to -55; SER at 29–33.

[85] See OST004-R, at 3 (Expert Opinion Testimony of Mike Wireman (rev. Oct. 3, 2018)) [hereinafter Wireman Initial Test.]; Tech. Rep. at 2-45; SER at 28.

[86] See SER at 29; see also id. at 28.

2. Hydrogeologic Properties

The hydraulic conductivity of a formation is a measure of the ease or difficulty for groundwater to flow through the porous geologic media.[87] As such, the stratigraphic units are categorized into "hydrostratigraphic" units based on factors such as hydraulic conductivity, aquifer thickness, and transmissivity (which, in turn, is calculated as hydraulic conductivity multiplied by thickness of the unit).[88] Hydrostratigraphic units that can transmit sufficient quantities of groundwater of sufficient quality to provide beneficial use are described as aquifers.[89] Hydrostratigraphic units of such low transmissivity that they cannot transmit beneficial volumes of groundwater are termed "aquitards," which units, as described in greater detail below, may act as confining units.[90] Definitions of the aquifer parameters are as follows:

K: hydraulic conductivity – measure of the ability of a porous material to transmit water, expressed as groundwater discharge (volume) per unit area under a unit hydraulic gradient (e.g., ft./day (ft./d), centimeter/second (cm./sec.)). Hydraulic conductivity is sometimes referred to as permeability.

T: transmissivity – the product of the hydraulic conductivity and aquifer thickness with units of distance squared per time (e.g., feet squared per day (ft.^{2}/d)).

Q: groundwater discharge – hydraulic conductivity multiplied by the hydraulic gradient and cross-sectional area (e.g., feet cubed per day (ft.^{3}/d)).

S: storativity – describes the volume of water released from storage per unit change in hydraulic head per unit area in a confined aquifer (dimensionless number).[91]

Sy: specific yield – volume of water that an unconfined aquifer releases from storage for a unit drop in the water table level (dimensionless number), i.e., drainable porosity of an unconfined aquifer.

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[87] See EA at 3-6.

[88] See id.

[89] See id.

[90] See id.

[91] A confined aquifer is one in which its potentiometric level (i.e., pressure level) rises above its top elevation, thus pressurizing the aquifer. See EA at 3-23.

i: hydraulic gradient – slope of the water table or potentiometric surface calculated as the difference in water level elevation over a unit distance (dimensionless number).

ϕ: porosity – ratio of volume of void space to the total volume of the aquifer (dimensionless number).

ϕ_h: hydraulic porosity – applies to turbulent flow in porous media, which is not significant in the operational setting of this application.

ϕ_e: effective porosity – percentage of void space within a rock matrix that is interconnected and allows fluid to flow through it, noting that the remaining porosity consists of isolated or unconnected pores (dimensionless number).[92]

3. Hydrostratigraphic Units

a. Alluvium and Upper Aquifers

Surficial alluvium, discontinuous within the MEA, consists of fragments of locally outcropping sedimentary rocks, sand, gravel, and sandy soil horizons and may include weathered portions of the Arikaree Group.[93] Where present, these alluvial deposits for the MEA range from less than 3 ft. to approximately 30 ft. in thickness.[94]

The Arikaree Group (Arikaree), the surficial unit at the MEA where the alluvium is absent, overlies the Brule Formation (Brule).[95] The Arikaree contains numerous interbedded channel and floodplain deposits along with aeolian volcanoclastics (i.e., wind-blown volcanic particles).[96] Based on grain size analysis of core samples, the interbedded layers within the unit include coarse to fine-grained sandstones with mudstones and siltstones.[97] Over the MEA, the

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[92] See EA at 4-16 to -17; Staff Initial Test. at 19–20.

[93] See Tech. Rep. at 2-42; SER at 33.

[94] See Tech. Rep. at 2-42; SER at 33 (citing Ex. CBR008-R, at 49–62 (figs. 2.6-3a to -3n) (Technical Report Figures) [hereinafter Tech. Rep. Figs.]).

[95] See Tech. Rep. at 2-43; SER at 33.

[96] See Tech. Rep at 2-43; Tech Rep. Figs. at 49–62 (figs. 2.6-3a to -3n); SER at 33.

[97] See Tech. Rep. at 2-43; SER at 33.

Arikaree Group generally ranges between 40 ft. to somewhat over 160 ft. in thickness, with an average thickness of 105 ft. and increasing thickness from south to north.[98] The coarse- to fine-grained sandstones represent locally water-bearing units that are interbedded with low-permeability mudstone units and vary widely in extent, ranging between 10 ft. to several hundred feet wide and up to 50 ft. thick.[99] The Arikaree is a surficial aquifer at the MEA.

The Brule Formation in the region overlies the Chadron Formation and, in turn, is overlain by sandstones of the Arikaree Group.[100] The Brule consists of an uppermost Brown Siltstone member underlain by siltstones with isolated beds of sandstone and volcanic ash (the Whitney member).[101] Beneath these upper siltstone layers of the Brule are other clayey siltstones, claystones, sandstones and volcanic ashes (the Orella member).[102] At the MEA, the Brule Formation is predominated by the uppermost Brown Siltstone and Whitney members.[103] At the base of the Brown Siltstone member are thick, fine- to medium-grained sandstones, which are present across the entire MEA.[104] These sandstones constitute the first overlying aquifer above the production zone.[105]

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[98] See Tech. Rep. at 2-43; Tech. Rep. Figs. at 72 (fig. 2.6-6); SER at 33.

[99] See Tech. Rep. at 2-80; SER at 33.

[100] See Tech. Rep. at 2-45; Tech. Rep. Figs. at 47 (fig. 2.6-1); SER at 49.

[101] See Tech. Rep. at 2-45 to -46; SER at 32.

[102] See Tech. Rep. at 2-46; SER at 32.

[103] See Tech. Rep. at 2-45; SER at 32.

[104] See Tech. Rep. at 2-45; SER at 32.

[105] See Tech. Rep. at 2-46; SER at 32.

The overall thickness of the Brule Formation in the MEA ranges from approximately 350 ft. to 550 ft., generally thinning from north to south across the MEA.[106]

b. Upper Confining Units (UCU)

The Brule Formation is separated from the underlying BC/CPF by the Upper and Middle Chadron confining units.[107] The Upper Chadron is a bentonitic clay grading downward to green and red clay, with some interbedded sandstone intervals,[108] while the Middle Chadron is clay-rich with interbedded bentonitic clay and sand.[109] The contact between the Upper and Middle Chadron is difficult to ascertain due to similarities in grain size and geophysical log responses.[110]

The thickness of the Upper and Middle Chadron units ranges from approximately 360 ft. to 450 ft. and generally thins toward the south across the MEA.[111] Geophysical logging indicates that the Upper/Middle Chadron units are laterally continuous throughout the MEA.[112]

Based on grain size analysis from the MEA, the Upper/Middle Chadron samples are classified as siltstone, with more than 50 percent of the sample grain sizes reported to fall in the silt-clay fraction range, indicating the low-permeability nature of these units.[113] X-ray diffraction (XRD) analyses show that the chemical compositions of core samples from the Middle Chadron

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[106] See Tech Rep. Figs. at 49–62 (figs. 2.6-3a to -3n (cross-section)), 73 (fig. 2.6-7 (isopach map)).

[107] See Tech. Rep. at 2-41; SER at 48.

[108] See Tech. Rep. at 2-48; SER at 31

[109] See Tech. Rep. at 2-48; SER at 31.

[110] See Tech. Rep. at 2-49; SER at 31.

[111] See Tech. Rep. at 2-49; see also Tech. Rep. Figs. at 74 (fig. 2.6-8); SER at 31.

[112] See SER at 31; Tech Rep. Figs. at 49–62 (figs. 2.6-3a to -3n).

[113] See Tech. Rep. at 2-47 to -49; SER at 31–32.

are highly similar to the Pierre Shale (e.g., predominantly mixed-layered illite/smectite or montmorillonite with quartz), which would be expected if the Pierre Shale was a contributing source of materials for the overlying Middle Chadron.[114]

c. Basal Chadron/Chamberlain Pass Formation (BC/CPF)

This formation, which overlies the thick Pierre Shale and hosts the uranium ore body in localized channels, is a coarse-grained sandstone interbedded with thin silt and clay beds of varying thickness.[115] The BC/CPF is laterally continuous throughout the MEA, occurs at depths ranging from approximately 850 ft. to 1200 ft. below ground surface (or bgs), and varies from approximately 20 ft. to 90 ft. in thickness.[116] The MEA production zone is a roll-front deposit with uranium mineral species present at concentrations ranging from 0.11 percent to 0.33 percent triuranium octoxide (U_30_8), with an average ore grade of 0.17 percent.[117] Based on the similarity of regional deposition for the existing CBR ISR facility and the MEA (whereby the ore bodies in the two areas are within the same geologic unit and have the same mineralization source), the MEA ore body is expected to be similar mineralogically and geochemically to that of the ore body at the existing CBR ISR facility.[118]

d. Pierre Shale Lower Confining Unit (LCU)

The Pierre Shale is a thick, homogeneous black marine shale with low permeability that represents one of the most laterally extensive formations of northwest Nebraska. It can be up to

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[114] See Tech. Rep. at 2-84.

[115] See Tech. Rep. at 2-49; SER at 30.

[116] See Tech. Rep. at 2-50; Tech Rep. Figs. at 49–62 (figs. 2.6-3a to -3n), 75 (fig. 2.6-9); SER at 67.

[117] See Tech. Rep. at 2-55; SER at 31.

[118] See Tech. Rep. at 2-55; SER at 31.

1500 ft. thick in the Dawes County area.[119] The regional estimates of the Pierre Shale's hydraulic conductivity range from 10^{-7} to 10^{-12} cm./sec.[120] and there has been no observed transmissivity between vertical fractures in the Pierre Shale (which appear to be short and not interconnected).[121] During the Renewal Site proceeding, there was no dispute among the parties that the very low permeability of the Pierre Shale in the LCU prevents ISR production fluids from flowing downward from the base of the BC/CPF aquifer. As an undisputed regional hydrogeologic condition, the low-permeability Pierre Shale is the base of the BC/CPF aquifer and acts as an LCU for the BC/CPF.[122]

C. Undisputed Regional Hydrogeologic Conditions

1. Surface Water Resources

The Niobrara River flows easterly through a point approximately 0.4 miles south of the southernmost MEA mine unit (i.e., MU-F).[123] The Niobrara River originates in eastern Wyoming near Manville, in Niobrara County, and flows in an east-southeast direction into western Nebraska.[124] The river flows across Sioux County in Nebraska, east through Agate Fossil Beds National Monument, passing the town of Marsland and the southern boundary of the MEA, and through the 1600-acre Box Butte Reservoir, the western end of which is located approximately three miles to the east of the southeast corner of the MEA license boundary.[125] There are no

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[119] See Tech. Rep. at 2-52.

[120] See id. at 2-53.

[121] See id.; ER at 3-43.

[122] See Renewal Site, LBP-16-13, 84 NRC at 296–97.

[123] See Tech. Rep. at 2-77; EA at 3-18.

[124] See Tech. Rep. at 2-77; EA at 3-19.

[125] See Tech. Rep. at 2-77 to -78; EA at 3-19.

apparent direct drainages from the MEA to the reservoir.[126] The primary purpose of the reservoir is to facilitate irrigation.[127] The Box Butte Reservoir has altered the hydrology of the Niobrara River by diverting water for irrigation.[128]

From the reservoir, the river flows east across northern Nebraska, and joins the Snake River approximately 13 miles southwest of Valentine, Nebraska.[129] The Niobrara River is a small stream of limited areal extent with an average flow rate of 29 cubic feet per second (or cfs).[130] While stream data indicates that the Niobrara River is gaining water from west to east, the mean average stream flows have decreased with time.[131] Groundwater is the primary source of flow into the Niobrara River in the vicinity of the MEA and, in this area of the river, the discharge of the river is steady and persistent, with overbank flooding uncommon except during winter ice jams.[132]

2. Groundwater Resources

Descriptions of the regional hydrostratigraphic units underlying the MEA and the region are provided for both the aquifers and confining units underlying the MEA.[133] The relevant

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[126] See Tech. Rep. at 2-78.

[127] See EA at 3-19.

[128] See id.

[129] See SER at 45; see also Tech. Rep. Figs. at 92–93 (figs. 2.7-2 to -3).

[130] See SER at 21.

[131] See id.

[132] See id.

[133] See Tech. Rep. at 2-79 to -81. Aquifers are geological formations “with sufficient permeability and porosity to significantly transmit and store groundwater,” and confining units are “strata with insufficient permeability (e.g., shale units) that hydraulically separate aquifers.” SER at 48.

regional aquifers are in the Arikaree Group and the Upper Brule Formation (both of which are unconfined, surficial aquifers),[134] and in the deeper, confined BC/CPF.[135] In the vicinity of the MEA, water has been observed in the Arikaree Group, Brule Formation, and the sandstone of the BC/CPF.[136] Alluvial deposits are discontinuous at the MEA and have not been shown to contain usable amounts of water.[137]

Separating the confined BC/CPF sandstone aquifer from the overlying aquifers in the Brule Formation and the Arikaree Group are the remaining members of the Chadron and Brule Formations, which collectively are identified as the UCU for the BC/CPF sandstone aquifer.[138] The LCU beneath the BC/CPF sandstone aquifer is the Pierre Shale.[139]

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[134] The parties have indicated their general agreement that the unconfined Arikaree and Brule aquifers in the MEA comprise a single aquifer system based on concurrent water table elevations and, therefore, act as one aquifer. See Wireman Initial Test. at 4; Tr. at 746–48 (Lewis, Back). Accordingly, any contaminated groundwater migrating into the Brule would also be pumped from Arikaree water wells. As a consequence, when referring to either one of these hydrogeologic formations or in discussing water withdrawal from the High Plains aquifer, the Board generally will use the term Arikaree/Brule aquifer.

[135] See SER at 48. To a large extent, Contention 2 deals with OST's allegations questioning CBR's conclusion that the Marsland facility production fluids will be contained within the BC/CPF and that those fluids also can be controlled within the aquifer during operations and restoration by fine-tuning the pumping rates for the production and observation wells. See OST Proposed Findings at 20, 40–41, 49–50. The word "confinement" is often used interchangeably in describing this "containment." To avoid confusion with discussions of the BC/CPF as a confined aquifer, the word "containment" will be used exclusively for the hosting and control of production fluids in the BC/CPF and the word "confinement" will be reserved for the description of the potentiometric levels in the BC/CPF aquifer. See Tr. at 450–51 (Kreamer).

[136] See Tech. Rep. at 2-79.

[137] See id.

[138] See id. at 2-79, 2-84 to -85.

[139] See id. at 2-52, 2-79, 2-84 to -86.

V. OVERARCHING HYDROGEOLOGIC CONDITIONS

OST challenges the analyses in CBR's TR, the Staff's EA, and the Staff's SER regarding hydrogeologic issues that apply to several of the stated concerns of Contention 2. In providing support for OST's position, Intervenor's witnesses relied on the premise that CBR's application was deficient insofar as it misinterpreted several hydrogeologic conditions underlying the MEA and, as such, did not correctly assess either the lack of containment of the BC/CPF or CBR's resulting inability to control production fluids during operations and restoration. OST thus criticized the TR, EA, and SER for (1) misinterpreting Crow Butte's aquifer test pumping data; (2) failing to recognize the heterogeneity and anisotropy of the BC/CPF and the UCU;[140] and (3) ignoring the variations in the BC/CPF aquifer thickness and lateral extent that allegedly results in reduced containment of the BC/CPF aquifer. According to the Intervenor, these deficiencies demonstrated the lack of hydraulic integrity of the BC/CPF and the UCU that was not quantified by the Applicant or assessed by the Staff in reaching their conclusions about the environmental impact of ISR activities in the Marsland MEA.

Each of these disputed topics is discussed in separate sections below. Given that these critiques all contribute to the Intervenor's overarching premise that the TR, EA, and SER did not adequately address potential pathways by which production zone contaminants will migrate from the proposed MEA, and that this premise underscores the bulk of the Contention 2 issues,

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[140] As is the case with the parties' testimony and exhibits, throughout this decision we will use the terms homogeneous/homogeneity and istrophy/istrophic and their counterparts heterogeneous/hetrogenity and anisotropy/anisotropic. Pursuant to the terms of 10 C.F.R. § 2.337(f), the official notice provision of the agency's procedural rules, we consider "homogeneity" to be synonymous with uniformity in space, i.e., a homogeneous medium being one whose hydrologic properties are identical everywhere, while isotropy is the condition in which all significant properties are independent of direction, i.e., an istropic medium being one whose hydrologic properties are the same in all directions. See Am. Soc'y of Civil Eng'rs, Hydrology Handbook 326, 327 (2d ed. 1996) (glossary definitions of "Homogeneity," "Isotropic," and "Isotropy"). In contrast, heterogeneity means having properties that are not uniform in space, while anisotropic involves having varying properties in different directions.

we will address these common, disputed facts prior to assessing each of the Intervenor's four Concerns.[141]

A. Misinterpretation of Aquifer Pumping Test Data

OST contested the accuracy and reliability of CBR's sole aquifer pumping test, which was performed between May 16 and May 20, 2011, during the initial permitting and development activities within the MEA. CBR witnesses Lewis, Nelson, and Pavlick testified regarding the test, as documented by the aquifer pumping test report entitled "Marsland Hydrologic Testing Report -Test # 8," which is presented in Appendix F of CBR's TR.[142] According to these witnesses, this so-called groundwater pumping Test # 8 was designed to (1) evaluate the degree of hydraulic communication between the production zone, pumping well, and the surrounding production zone observation wells; (2) determine the presence or absence of the production zone aquifer within the test area; (3) assess the hydrologic characteristics of the production zone aquifer within the test area, including the presence or absence of hydraulic boundaries; and (4) demonstrate sufficient containment (hydraulic isolation) between the production zone and the overlying aquifer for the purpose of ISR leaching.[143] While these goals of the pumping test are not in dispute, OST did question CBR's analysis of the aquifer pumping test data as we outline below.

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[141] While, as we note previously, see supra note 65 and accompanying text, the adequacy of the Staff's safety review process generally is not subject to challenge in an adjudication before a board, to the degree all the parties cite and rely upon the Staff's SER in discussing or supporting some aspect of their various positions, we do not consider such references as violative of that precept.

[142] See Ex. CBR001-R, at 26 (Initial Written Testimony of Crow Butte Resources Witnesses Robert Lewis, Walter Nelson, and Douglas Pavlick on Contention 2 (Aug. 17, 2018)) [hereinafter CBR Initial Test.]; Ex. CBR016 (Aqui-Ver, Inc., Marsland Hydrologic Testing Report - Test # 8, Final Report (rev. Oct. 28, 2015)) [hereinafter Test #8 Rep.]; see also Tech. Rep. at 27 (listing Test # 8 report as Appendix F).

[143] See CBR Initial Test. at 28.

1. Parties' Positions on Misinterpretation of Aquifer Pumping Test Data

OST challenged CBR's analysis of the aquifer pumping test data, for, among other things, using only one form of data analysis technique, i.e., the Theis methodology,[144] and for selecting only a portion of the data points when determining the aquifer parameters of transmissivity and storage coefficient that result from the use of this technique.

a. CBR's Use of Only One Method of Data Analysis

OST's principal critic in this regard was its witness Dr. Kreamer, who challenged CBR for using only the Theis method for analyzing the aquifer pumping test data and, in addition, claimed that CBR made reference to using the Cooper-Jacob data analysis technique, but then failed to present the results of this supplemental analysis.[145] According to Dr. Kreamer, this is significant because the Cooper-Jacob analysis can identify a recharge boundary that indicates a lack of containment of the aquifer.[146]

In response, NRC witnesses Back, Lancaster, and Dr. Striz confirmed that CBR's pumping test report clearly states that the Applicant used both the Theis drawdown and recovery methods and the Cooper-Jacob distance-drawdown method to analyze the aquifer pumping test data,[147] and presented the graphical results of the Cooper-Jacob analysis for the

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[144] The Theis solution is a mathematical model of transient flow of groundwater to a pumping well that is useful for determining the transmissivity and storativity of nonleaky confined aquifers that involves matching standardized Theis type-curves to drawdown data collected from a pumping test. See generally CBR024, at 4–6 (Charles V. Theis, The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Ground Water Storage, Geological Survey, U.S. Dep't of the Interior, Ground Water Notes No. 7 (Aug. 1952)) [hereinafter Theis Article].

[145] See Ex. OST003, at 6 (Expert Opinion Testimony of David K. Kreamer (Aug. 16, 2018)) [hereinafter Kreamer Initial Test.].

[146] See id. at 2.

[147] See Test #8 Rep. at 11.

entire duration of the aquifer pumping test in the MEA aquifer pumping test report.[148] Citing the Test # 8 report, CBR witnesses Lewis, Nelson, and Pavlick stated that the Cooper-Jacob method determined an estimated average transmissivity of 737 ft.^{2}/d, a storativity of 4.9x10^{-05}, and an average hydraulic conductivity of 18.4 ft./d (based on a 40 ft. average aquifer thickness), and noted that these values are consistent with the Theis drawdown analysis.[149]

During the hearing, Dr. Kreamer acknowledged that a Cooper-Jacob distance-drawdown analysis was performed, but indicated that he was referring to the failure to use a Cooper-Jacob analysis using time-drawdown parameters, as is more typically used in the Theis procedure.[150] CBR witness Lewis maintained, however, that the Cooper-Jacob analysis done by CBR was not inferior as a methodology, but just a different way of showing the information.[151] Additionally, Staff witnesses Back, Lancaster, and Dr. Striz indicated that the distance-drawdown Cooper-Jacob relationship, which was developed because its straight-line fit for the data is easier than the fit for a Theis type-curve, is not necessary to identify a recharge boundary and would not provide any additional information not already available from a Theis type-curve analysis, given the Cooper-Jacob analysis is an approximation to the Theis analysis.[152]

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[148] See Ex. NRC014, at 21 (NRC Staff's Rebuttal Test. (Sept. 5, 2018)) (citing Test #8 Rep. figs. app. at PDF 50 (fig. 18)) [hereinafter Staff Rebuttal Test.].

[149] See Ex. CBR033, at 10 (Written Rebuttal Test. of [CBR] Witnesses Robert Lewis, Walter Nelson, Douglas Pavlick & James [Shriver] on Contention 2 (Sept. 7, 2018)) (citing Test #8 Rep. at 12–13) [hereinafter CBR Rebuttal Test.].

[150] See Tr. at 424–27.

[151] See Tr. at 427.

[152] See Staff Rebuttal Test. at 20–21 (citing Ex. CBR025, at 90–91 (H.H. Cooper, Jr. & C.E. Jacob, A Generalized Graphical Method of Evaluating Formation Constants and Summarizing Well-Field History, Geological Survey, U.S. Dep't of the Interior, Ground Water Notes, No. 7 (Jan. 1953)) [hereinafter Cooper-Jacob Article].

Dr. Kreamer also testified that CBR erred in not addressing the omission of, and the Staff failed in not requiring, other forms of pumping test analysis (e.g., De Glee, Hantush-Jacob, and Walton methods).[153] In support of this criticism, Dr. Kreamer noted that both the Theis and Cooper-Jacob mathematical forms of analysis are considered the simplest forms of aquifer pumping test analyses and require the same fundamental uncontested assumptions (e.g., aquifer homogeneity, isotropy, uniform thickness, lateral extent) to be fulfilled for accurate results.[154]

Further in this regard, while recognizing CBR's referenced use of the Cooper-Jacob analysis, Dr. Kreamer emphasized that the Theis and Cooper-Jacob analyses are inappropriate in part because these have restrictive assumptions inherent in their solutions. He maintained instead that a leaky aquifer evaluation of the pumping test data should have been performed using the other identified standard analytical methods or a numerical analyses such as MODFLOW.[155] He added that analysis with these more complex methods is required so as to be consistent with the lack of containment indicated by the departure from the Theis type-curve observed during the solitary pumping test.[156]

Concerning the analysis of the pumping test data to derive the hydraulic parameters for the production zone, CBR witnesses Lewis, Nelson, and Pavlick confirmed that both the drawdown and recovery data were graphically analyzed to determine aquifer transmissivity and storativity using the Theis drawdown and recovery methods and the Cooper-Jacob straight-line

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[153] See Ex. OST014-R, at 2–3 (Rebuttal Testimony of David K. Kreamer (rev. Oct. 3, 2018)) [hereinafter Kreamer Rebuttal Test.].

[154] See Kreamer Initial Test. at 6.

[155] See id.; Kreamer Rebuttal Test. at 2–3; Tr. at 509.

[156] See Kreamer Rebuttal Test. at 2–3.

distance-drawdown method.[157] And these witnesses further opined that "Crow Butte used appropriate analytical techniques for such aquifers, but nevertheless was prepared to use more complex analytical techniques had it been necessary. It was not."[158]

Staff witnesses Back and Lancaster confirmed that CBR used the aquifer pumping test data to obtain information about the connectivity within the BC/CPF sandstone aquifer, the hydraulic properties of that aquifer, and the containment of that aquifer from overlying aquifers.[159] Also, CBR witnesses Lewis, Nelson, and Pavlick testified that the results of Cooper-Jacob distance-drawdown analysis were consistent with the Theis drawdown analyses in the Test # 8 report.[160]

As described by CBR witnesses Lewis, Nelson, and Pavlick, the results of the 2011 pumping test within the BC/CPF sandstone indicated a mean hydraulic conductivity of 25 ft./d (ranging from 7 ft./d to 62 ft./d) or 8.82 x 10^{-3} cm./sec. based on an average net sand thickness[161] of 40 ft. and a mean transmissivity of 1012 ft.^{2}/d.[162] According to these CBR witnesses, aquifer storativity values from the Theis method ranged from 1.7x10^{-3} to 8.3x10^{-5}, with a geometric mean value of 2.56x10^{-4} for the entire test area.[163] Further, they indicated that

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[157] See CBR Initial Test. at 29 (citing Theis Article; Cooper-Jacob Article).

[158] CBR Rebuttal Test. at 10.

[159] See Staff Initial Test. at 17 (citing ER at 3-45 to -47; Tech. Rep. at 2-81 to -84; Ex. CBR009, at 72–74 (Technical Report Tables) (tbls. 2.7-2 to -4) [hereinafter Tech. Rep. Tbls.]).

[160] See CBR Rebuttal Test. at 10.

[161] CBR witness Lewis defined "net sand thickness" as total thickness of the BC/CPF minus an allocation for the thickness of inter-bedded claystone stringers that are part of this unit. See Tr. at 458–59.

[162] See CBR Initial Test. at 29.

[163] See id. at 30.

based on both the drawdown and recovery analyses, hydraulic conductivities of the aquifer materials in the vicinity of the pumping wells (i.e., CPW-1A, CPW-1, and Monitor-3) were approximately 3 to 9 times greater than hydraulic conductivities estimated for other observation wells in the pumping test area.[164] In the opinion of these CBR witnesses, an apparent higher conductivity boundary condition effect in these wells was indicated by a flattening of drawdown and recovery curves,[165] an item that is discussed in greater detail later in this decision.[166]

CBR witnesses Lewis, Nelson, and Pavlick further opined that, given the great thickness, low permeability, and depth of the BC/CPF sandstone confining unit, there is no conceptual basis (i.e., hydrogeological justification) that would support the need for the additional aquifer test analyses called for by OST, and that the local variations in aquifer thickness and hydraulic conductivity are conceptually consistent with observed drawdown responses in a highly confined aquifer. As such, they maintained that the purported need to perform hypothetical aquifer leakage analyses has no conceptual support.[167]

And with respect to the analysis assumptions, these three CBR witnesses indicated that, while at some scale all geologic strata exhibit heterogeneity and anisotropy, at the relevant scale for licensing, CBR assumed homogeneous, isotropic responses and then reviewed the actual test results to determine whether there were significant deviations from the assumed homogeneity and isotropy that, in turn, would establish the need for the use of more complex analysis methods. They indicated, however, that CBR concluded there was no need for such

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[164] See id. at 29–30.

[165] See id. at 30.

[166] See infra section V.A.1.b.

[167] See CBR Rebuttal Test. at 10-11 (citing Test #8 Rep. at 12-13, figs. app. at PDF 50 (fig. 18)).

additional complexity for this site. Also, according to these witnesses, Dr. Kreamer has failed to support his call for CBR to implement an allegedly superior alternative method by not providing an independent estimate for the rate of leakage based on an interpretation of the Marsland pumping test data derived by employing such an alternative method.[168]

Staff witnesses Back and Lancaster likewise disputed Dr. Kreamer's assertion that CBR's analysis was inadequate because CBR used only one pumping test data evaluation method. They noted that the pumping test was conducted according to a plan approved by the Nebraska Department of Environmental Quality (NDEQ) and used accepted industry testing and analysis procedures.[169] Staff witnesses Back and Lancaster explained that the Theis type-curve matching and the Cooper-Jacob methods employed by CBR are widely used and accepted techniques that have been adopted into American Society for Testing and Materials (ASTM) standards.[170] Noting as well that at some scale all geologic strata are heterogeneous and anisotropic, they observed that in practice these equations are routinely applied to strata with an understanding of the assumptions inherent to their use. As a consequence, they indicated that if these methods are only applicable if the assumptions are strictly adhered to, as Dr. Kreamer suggested, these methods would never be used because these assumptions, if so rigorously applied, could not be met for any hydrogeologic strata.[171]

These Staff witnesses also claimed that (1) the Theis and Cooper-Jacob methods are consistent with the objectives of the pumping test; (2) it is not necessary that the assumptions in

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[168] See id. at 11.

[169] See Staff Initial Test. at 26 (citing ER at 3-45; Tech. Rep. at 2-82).

[170] See Staff Rebuttal Test. at 25 (citing Ex. NRC017 (ASTM Standards for Theis Analysis Methods) [hereinafter ASTM Theis Analysis Standards]).

[171] See id.

these analytical methods be strictly met; and (3) there is no evidence in the aquifer pumping test data to suggest that the assumptions were inappropriate for the BC/CPF sandstone aquifer at the MEA. Specifically, the MEA aquifer pumping test was a large, long-term, multiple-day test with a large ROI (8800 ft. or over 1.5 miles) that averages the hydraulic behavior over a wide area in the middle of the MEA, thereby minimizing the impact of small-scale anisotropy and heterogeneity encountered in most aquifers.[172]

Finally, while Dr. Kreamer maintained there is a lack of containment in the production zone as demonstrated by departure from the expected Theis type-curve from the pumping test,[173] he did acknowledge that the more complex analysis methods he suggested (i.e., De Glee, Hantush-Jacob, and Walton methods) have the same assumptions of aquifer homogeneity, isotropy, uniform thickness, and lateral extent as the Theis and Cooper-Jacob methods.[174]

b. CBR's Selective Use of Data

In his initial written testimony, Dr. Kreamer also claimed that CBR only analyzed selective portions of the data from the pumping test and that the complete data set, if analyzed, would demonstrate the lack of containment of the BC/CPF aquifer.[175] Dr. Kreamer stated further that the measured water levels in the MEA aquifer test monitoring wells break significantly from the expected Theis type-curve, and that there is no justifiable basis for arbitrarily analyzing only a selected portion of the pumping data and not the entire test

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[172] See id. at 26.

[173] See Kreamer Rebuttal Test. at 2.

[174] See Tr. at 507–09.

[175] See Kreamer Initial Test. at 2.

information.[176] In response, declaring that it was not clear what excluded data Dr. Kreamer was referencing, Staff witnesses Back, Lancaster, and Dr. Striz maintained that Dr. Kreamer appeared to be asserting that the Theis type-curves in CBR's pumping test report for the MEA observation wells show deviations for drawdown data that are consistent with a recharge boundary, which Dr. Kreamer characterized as leakage to the BC/CPF from the UCU.[177] They also responded to his "excluded data" allegation by stating that all data points for all of the observation wells used in the aquifer pumping test are presented in the graphs of drawdown and recovery included in Appendix C of the aquifer pumping test report.[178] Subsequently at the hearing, noting some confusion as to what he was referring to as "excluded data," Dr. Kreamer confirmed that he was talking about the deviations that show up on the pumping test data graphs.[179]

And in that regard, Dr. Kreamer opined there was no justifiable basis for arbitrarily analyzing only a selected portion of the pumping data and not the entirety of the test information given that using only selecting portions of the measured data can bias the results and such an approach is not consistent with getting a complete picture of the pumped region (which itself is just a small portion of the MEA).[180] Specifically, Dr. Kreamer asserted that in some well-response analyses, late-time data was chosen for analysis, while for other wells late-time data was disregarded and the middle-time period data was analyzed.[181] Indeed, hearing

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[176] See id. at 6, 7.

[177] See Staff Rebuttal Test. at 18–19.

[178] See id. at 17.

[179] See Tr. at 378, 380.

[180] See Kreamer Initial Test. at 7.

[181] See id.

testimony indicated that graphs of the pumping test data seemed to indicate data deviations in some of the wells, with wells Monitor-7 and Monitor-8 showing early-time effects, and wells CPW-1/1A and Monitor-3 showing late-time effects.[182] By analyzing selective portions, and ignoring other portions, of the early-time and late-time data, Dr. Kreamer maintained, the CBR pumping test report did not analyze the full data set that would demonstrate the lack of containment of the production zone.[183]

i. Early-time Data

Responding to Dr. Kreamer's concern about the bypassed early-time data, CBR witnesses Lewis, Nelson, and Pavlick pointed out that "[c]ertain data collected from the test are considered more reliable than others for purposes of data analyses," indicating that "early-time data does not characterize the aquifer response as accurately as do mid- and late-time data."[184] And Staff witnesses Back, Lancaster, and Dr. Striz supported this approach, declaring that CBR appropriately chose not to use early-time data and noting that the problems inherent with using this data from this testing time period are discussed in numerous textbooks and journal articles.[185]

Witnesses Lewis, Nelson, and Pavlick explained on behalf of CBR that early-time drawdown data are negatively influenced by a number of factors not related to the aquifer response to pumping. Valid drawdown data is achieved when the well discharge is constant,

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[182] See Tr. at 384–85 (Kreamer), 396–98 (Lewis), 433–34 (Lewis); Test #8 Rep. at 13; see also id. app. C at PDF 79–96 (graphs C1 to C17). Also mentioned by CBR witness Lewis as having some early-time deviations was well Monitor-2, see Tr. at 434, an observation that does not seem to be relevant in this context given that well's remote location relative to the pumping field, see id.; see also Test #8 Rep. app. C at PDF 80 (graph C2).

[183] See Kreamer Initial Test. at 7.

[184] CBR Rebuttal Test. at 4–5.

[185] See Staff Rebuttal Test. at 17–18 (referencing Ex. CBR029, at 16 (G.P. Kruseman & N.A. de Ridder, Analysis and Evaluation of Pumping Data (2d ed. 1994))).

and when release of aquifer water is directly proportional to the rate of decline in the measured potentiometric levels — conditions that do not occur during the early stages of pumping. This discrepancy creates a disagreement between the theoretical flow and the actual flow during the early-time period, effects that are minimized as the time of pumping extends, during which closer agreement may be attained.[186]

As a second factor, both CBR and Staff witnesses testified that wellbore storage or near-wellbore effects can also impact the early-time data (especially, according to CBR witnesses, for large diameter, deep production wells with large water column height).[187] Because the amount of water stored within the wellbore can be substantial, it must be removed before the aquifer can respond properly to the induced drawdown, which further reduces the value of early-time data.[188] And, as the Staff witnesses noted, while these storage effects will pass with time so that the aquifer responds properly to the induced drawdown, they often result in deviations from a Theis type-curve that can mimic a recharge boundary.[189] For instance, if the Theis type-curve is fit to early-time drawdown data impacted by wellbore storage and near-wellbore effects, the late-time data will then fall below the Theis curve and appear to be a recharge boundary.[190] The Staff witnesses concluded that the "use of early-time data in a Theis

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[186] See CBR Rebuttal Test. at 5.

[187] See id. (Lewis, Nelson, Pavlick).

[188] See id. (Lewis, Nelson, Pavlick); Staff Rebuttal Test. at 20 (Back, Lancaster, Striz).

[189] See Staff Rebuttal Test. at 20 (Back, Lancaster, Striz).

[190] See id. (citing Ex. NRC016, at 233 (Fletcher G. Driscoll, Groundwater and Wells (2d ed. 1986)) [hereinafter Driscoll Text]).

or Cooper-Jacob time-drawdown analysis is inappropriate,"[191] with Dr. Kreamer agreeing at the hearing that the early-time data is not as reliable.[192]

ii. Late-time Data

Dr. Kreamer admonished CBR for ignoring the flattening of the curve during the late-time periods of the well tests, which he claimed is associated with the drawdown encountered in a recharge zone and so evidences a preferential flow path through the heterogeneous UCU into the BC/CPF aquifer.[193] As described in the Test # 8 report, and confirmed by Staff review, two of the eight observation wells (CPW-1 and Monitor-3) and the pumping well (CPW-1A) show late-time deviations in the Theis type-curves that could be interpreted as recharge.[194]

Seeking to counter Dr. Kreamer's assertion of arbitrary data evaluation, Staff witnesses Back, Lancaster, and Dr. Striz declared that the authors of CBR's aquifer pumping test report clearly explained their rationale for matching the data to the Theis type-curve.[195] According to the Test #8 report, the type-curve matching used for this analysis generally focuses on late-time drawdown data since this data is normally considered the most reliable indicator of overall aquifer response. But according to the report, because the drawdown data for wells CPW-1/1A and Monitor-3 showed a late-time flattening of the curve, as contrasted with the drawdown data for well Monitor-5 (and all other distant observation wells) that exhibited a more typical confined aquifer drawdown response, the type-curve matching for wells CPW-1/1A and Monitor-3 focused on middle-time data for the drawdown phase of the test.[196] The pumping test report

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[191] Id. at 21 (Back, Lancaster, Striz).

[192] See Tr. at 385.

[193] See Kreamer Initial Test. at 6.

[194] See Test #8 Rep. at 13; Staff Rebuttal Test. at 19 (Back, Lancaster, Striz).

[195] See Staff Rebuttal Test. at 17 (citing Test #8 Rep. at 13).

[196] See Test #8 Rep. at 13.

further explained that the flattening of the drawdown curve in wells located in the immediate vicinity of the pumping well (i.e., CPW-1 and Monitor-3) was believed to be related to a transmissivity contrast between lower permeability aquifer materials near the pumped well location and higher permeability aquifer materials elsewhere within the test's ROI.[197]

While agreeing that the pumping test report acknowledged the flattening of the data, Dr. Kreamer criticized the report for presenting only one possible explanation for this deviation from the type-curve and for not discussing or analyzing the possibility of lack of containment.[198] But CBR witnesses Lewis, Nelson, and Pavlick noted, however, that Dr. Kreamer did not, either in his initial or rebuttal testimony, attempt to provide alternative results using one or more of his suggested curve fitting techniques (i.e., De Glee, Hantush-Jacob, and Walton methods) or otherwise demonstrate a sufficient effect that would alter the conclusions reached by CBR and the Staff in evaluating the pumping test data.[199]

In addressing this issue, the Staff disputed Dr. Kreamer's "lack of containment" explanation by offering several other reasons that might account for the flattening in the Theis curve at late-time data points during the pumping test. Staff witnesses Back, Lancaster, and Dr. Striz supported CBR's explanation that the deviation is related to an increase in transmissivity, stating that CBR's reasoning is plausible because an increase in flow capacity away from the pumping well could manifest as late-time data that differs from the Theis type-curve so as to resemble a recharge boundary.[200]

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[197] See id.

[198] See Kreamer Initial Test. at 6.

[199] See CBR Rebuttal Test. at 11.

[200] See Staff Rebuttal Test. at 19.

Another possible explanation, according to these Staff witnesses, is that water is being released from storage in the first several feet of the aquitard immediately overlying the BC/CPF aquifer. In this scenario, stresses induced during aquifer test pumping propagate into the thick, low permeability UCU, compressing the aquitard matrix and yielding a small amount of water from storage. Although this effect can show up on a Theis type-curve in a way that mimics a recharge boundary, it does not represent recharge from overlying aquifers. Moreover, these Staff witnesses asserted, this effect would be consistent with the MEA pumping test responses for wells CPW-1 and Monitor-3, which show apparent “recharge” behavior at late-time. These wells, the Staff witnesses maintained, were subjected to significant drawdown as a consequence of their proximity to the pumping well and the resulting differential pressure across the aquitard could have slightly compressed the overlying aquitard sediments to produce enough water to show this apparent “recharge” effect.[201]

Additionally, Staff witnesses Back, Lancaster, and Dr. Striz noted that misinterpretation of wellbore storage effects or near-wellbore effects could explain Theis type-curve deviations that can mimic a recharge boundary. If the Theis type-curve is fit to early-time drawdown data that are impacted by these early-time effects, the late-time data will fall below the Theis type-curve and appear to be aquifer recharge.[202] Furthermore, Dr. Striz testified that if there was a recharge boundary as alleged by Dr. Kreamer, the drawdown would not have reached out to 8800 ft. during the short period of time that the well was pumped.[203]

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[201] See id. at 19–20 (Back, Lancaster, Striz).

[202] See id. at 20. In this regard, the Staff witnesses provided a quotation from the Driscoll text, described as an industry standard, to the effect that “early data reflect the removal of water stored in the casing,” and “[b]efore the effect of casing storage on pumping test data was recognized, an interpreter might have mistaken the flattened or second part of the drawdown curve as an indication of aquifer recharge.” Id. (quoting Driscoll Text at 232, 233).

[203] See Tr. at 502.

On the last day of the hearing, Dr. Kreamer elaborated on his claims by attempting to show that well Monitor-3 detected a preferential pathway for groundwater flow indicating leakage in the containment of the production zone. In part, Dr. Kreamer postulated that a re-evaluation of the Cooper-Jacob analysis for well Monitor-3[204] would show a clear classic recharge boundary that supplies 30 percent more water in this area of the BC/CPF channel sand than would be predicted from the drawdown analysis, and that the storage coefficient for this monitoring well is almost two orders of magnitude different than the rest.[205] Dr. Kreamer also stated that this is a very localized flow from unknown sources in an area where there is a dip in the Pierre shale and corresponding depression in the top of the BC/CPF with resultant leakage through fractures in the UCU.[206]

CBR witness Shriver countered Dr. Kreamer's claim with testimony indicating that the top of the elevation of the Pierre Shale is an erosional surface where the ancestral stream channel flowed over a width of several miles, scouring as it meandered, and depositing a stack of channel sand on the eroded Pierre Shale. Mr. Shriver stated that, consistent with CBR's other borings in the area, there is no indication of radical offsets in the structural contour maps that would be present with the faults and fractures hypothesized by Dr. Kreamer.[207]

2. <u>Board Findings on Alleged CBR Misinterpretation of the Aquifer Pumping Test Data</u>

The evidentiary record before the Board establishes that CBR conducted a pumping test near the center of the MEA in May 2011 to (1) assess the hydraulic communication within the

[204] During his testimony at the hearing, Dr. Kreamer referred to well Monitor-3 as CW-3. <u>See, e.g.</u>, Tr. at 974.

[205] <u>See</u> Tr. at 937–41.

[206] <u>See</u> Tr. at 970–79.

[207] <u>See</u> Tr. at 979–82.

BC/CPF aquifer; (2) confirm the presence or absence of the BC/CPF within the MEA; (3) estimate the hydraulic properties of the BC/CPF within the pumping test's ROI; and (4) demonstrate containment (i.e., hydraulic isolation) between the production zone and the overlying Brule aquifer.[208] This MEA aquifer pumping test was a large, long-term, multiple-day test with a large ROI (8800 ft., or over 1.5 miles) that averaged the hydraulic behavior over the wide area in the middle of the MEA, minimizing the impact of small-scale anisotropy and heterogeneity encountered in most aquifers.[209]

OST contested the adequacy of CBR's analysis of the pumping test results for two primary reasons: (1) the Applicant evaluated the pumping test data with only the Theis method and that technique was inappropriate because of its inherent assumptions (e.g., homogeneity, isotropy, uniform thickness, and infinite lateral extent) and because it did not consider potential leakage from the UCU into the production zone;[210] and (2) CBR used selective data for each observation well, ignoring the early-time data, as well as employing what appears to OST to be a variable undocumented procedure for fitting the Theis type-curves to the pumping test data.[211]

a. Board Findings on the Singular Use of the Theis Method

OST criticized CBR for using only one analysis technique in its evaluation of the May 2011 pumping test data, claiming that the Applicant referenced the use of the Cooper-Jacob straight-line distance-drawdown method but did not present the results of this supplemental analysis. Regarding the latter claim, the Board finds that CBR not only presented the graphical results of the Cooper-Jacob analysis,[212] but also documented that the analysis of this figure

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[208] See CBR Initial Test. at 26, 28 (Lewis, Nelson, Pavlick).

[209] See Staff Rebuttal Test. at 26 (Back, Lancaster, Striz).

[210] See Kreamer Initial Test. at 6.

[211] See id. at 2.

[212] See Test #8 Rep. figs. app. at PDF 50 (fig. 18).

resulted in values of transmissivity and storativity (i.e., T = 737 $ft.^2/d$, S= $4.9x10^{-05}$) that are consistent with the Theis drawdown analysis.[213]

Concerning Dr. Kreamer's assertions of analysis inadequacy arising from CBR's use of only one method to evaluate the May 2011 pumping test data, we find that CBR graphically analyzed both the drawdown and recovery data to estimate aquifer transmissivity and storativity using the Theis drawdown and recovery method and the Cooper-Jacob distance-drawdown method.[214] The Board also finds that Crow Butte was prepared to use more complex analytical techniques if needed,[215] but appropriately saw no need to do so based, inter alia, on the apparent consistency of the hydraulic parameters resulting from these analyses for values that, as Dr. Kreamer acknowledged, can often vary by an order of magnitude or more.[216] The Board also notes that OST witness Wireman agreed that the use of the Theis method was a starting point for pumping test analyses (and would help to determine if more sophisticated analyses are needed),[217] and that Dr. Kreamer did not directly dispute CBR's derivation of the recovery data, which shows the same consistency for the hydraulic conductivity values as was derived from the drawdown data.[218]

We further find, as Staff witnesses noted, that CBR conducted the pumping test according to its NDEQ-approved plan using accepted industry testing and analysis procedures

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[213] See CBR Rebuttal Test. at 10 (Lewis, Nelson, Pavlick) (citing Test #8 Rep. at 12–13).

[214] See CBR Initial Test. at 29 (Lewis, Nelson, Pavlick) (citing Theis Article and Cooper-Jacob Article).

[215] See CBR Rebuttal Test. at 10 (Lewis, Nelson, Pavlick).

[216] See Test #8 Rep. tbls. app. at 10 of 10 (tbl. 8); Tr. at 485–88 (Kreamer).

[217] See Tr. at 682.

[218] See Test #8 Rep. tbls. app. at 10 of 10 (tbl. 8), figs. app. at PDF 50 (fig. 18).

that are incorporated into ASTM standards.[219] We observe as well that CBR declared that, given the great thickness, low permeability, and depth of the BC/CPF confining unit, there is no conceptual basis that would support the need for the additional aquifer test analyses called for by OST, and that the local variations in aquifer thickness and hydraulic conductivity are conceptually consistent with observed drawdown responses in a highly-confined aquifer. As such, CBR maintained, there is no conceptional support for the need to perform the hypothetical aquifer leakage analyses deemed necessary by the Intervenor.[220] We agree, noting also that Dr. Kreamer did not provide an independent estimate for the rate of leakage based on his alternative interpretation of the MEA pumping test data using any of his suggested alternative, allegedly superior methods (i.e., De Glee, Hantush-Jacob, and Walton methods) to support his call for these techniques to be implemented by Crow Butte.[221]

Regarding the use of a leaky aquifer method, CBR decided not to do such an analysis on the pumping test data, even though it appears that it would not have been difficult to do so, likely requiring only the selection of such an analysis technique available in the software used to perform the Theis/Cooper-Jacob methods analysis.[222] While we consider this lost opportunity not to be the best engineering decision (if for nothing more than to satisfy intellectual curiosity and/or avoid providing the basis for a future challenge to the MEA license application), OST has not demonstrated there is any regulatory mandate for the Applicant to have done so.

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[219] See Staff Initial Test. at 26 (Back, Lancaster) (citing ER at 3-45; Tech. Rep. at 2-82); see also ASTM Theis Analysis Standards.

[220] See CBR Rebuttal Test. at 10-11 (Lewis, Nelson, Pavlick) (citing Test #8 Rep. at 12-13).

[221] See id.

[222] See Tr. at 394–95, 495–96, 498–502, 880 (Lewis).

Furthermore, we find that the consistency of results from the Theis/Cooper-Jacob analyses provides sufficient information to meet the acceptance criteria for the MEA conceptual model.

Finally, with respect to the analysis assumptions, we concur with all the parties that all geologic strata exhibit heterogeneity and anisotropy at some scale,[223] and that application of the Theis and Cooper-Jacob techniques to these systems is routinely done in practice with an understanding of the assumptions inherent to their use.[224] Furthermore, Dr. Kreamer used the graphs in the pumping test report that are based on these solution techniques to justify his opinion that recharge boundaries indicating vertical leakage from heterogeneity were detected in some of the well data,[225] and even acknowledged that his suggested, more complex analysis methods (i.e., the De Glee, Hantush-Jacob, and Walton methods) may have the same assumptions about aquifer homogeneity, isotropy, uniform thickness, and lateral extent, so as to suffer from the same potential limitations as the Theis and Cooper-Jacob methods.[226]

b. Board Findings on CBR's Alleged Use of Selected Data

Dr. Kreamer asserted that CBR arbitrarily analyzed only selected portions of the data, choosing late-time data in some cases and middle-time data in others without a justifiable basis for analyzing only a selected portion of the pumping data rather than the test information in its entirety.[227] We find OST's claims that only selective portions of the data were analyzed, and that the report did not present an analysis of the complete data set, are unsupported.

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[223] See CBR Rebuttal Test. at 11 (Lewis, Nelson, Pavlick); NRC Rebuttal Test. at 25 (Back, Lancaster, Striz); Tr. at 491–94 (Kreamer).

[224] See NRC Rebuttal Test. at 25 (Back, Lancaster, Striz); CBR Rebuttal Test. at 11 (Lewis, Nelson, Pavlick); Kreamer Initial Test. at 6.

[225] See Kreamer Rebuttal Test. at 2; Tr. at 940–41, 1021, 1024–25 (Kreamer).

[226] See Tr. at 507–09 (Kreamer).

[227] See Kreamer Initial Test. at 2, 7.

Initially, we find that the MEA aquifer pumping test report presents drawdown and recovery response curves showing all data points for all of the observation wells used in the aquifer pumping test.[228]

The Board also finds that the rationale for analyzing the aquifer pumping test data was clearly explained by the Applicant and is consistent with recommended practice.[229] Specifically, CBR has verified that type-curve matching generally avoided the early-time data insofar as that data deviated from the type-curves,[230] which is in line with published explanation in an authority such as Driscoll as to why early-time data does not characterize the aquifer response as accurately as does mid- and late-time data.[231] In applying the Theis type-curve-fitting method (and likewise the other analysis methods advocated by Dr. Kreamer, which all seemingly share the same assumptions of homogeneity, isotropy, uniform thickness, and lateral extent), the Board finds that less weight should be given to the early-time data because that data may not closely represent the theoretical drawdown equation on which the type-curve is based.

When matching pumping results to the Theis type-curves, based on the information in the evidentiary record before us, we find that CBR correctly focused on late-time data as the most reliable indicator of overall aquifer response. We do agree that the drawdown data for wells CPW-1 and Monitor-3 (that are close to the pumping well CWP-1A) showed a late-time flattening of the curve not suitable for Theis curve fitting, whereas the drawdown data for all the other distant observation wells exhibited a more typical confined aquifer drawdown response.[232]

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[228] See Test #8 Rep. at PDF 79–96 (figs. C1 to C17); Staff Rebuttal Test. at 17 (Back, Lancaster, Striz).

[229] See Test #8 Rep. at 13.

[230] See CBR Rebuttal Test. at 4–6 (Lewis, Nelson, Pavlick).

[231] See supra note 2022.

[232] See Staff Rebuttal Test. at 19–20 (Back, Lancaster, Striz).

And while it was Dr. Kreamer's position that this isolated flattening of the curve may be indicative of encountering a recharge zone, he nonetheless failed to produce any corroborating evidence supporting his position that the UCU is leaking sufficiently to jeopardize containment or prevent CBR from controlling its production fluids during operations and restoration.

Indeed, while Dr. Kreamer maintained there is a lack of containment in the BC/CPF as demonstrated by the departure of data points from the expected Theis curve during the pumping test,[233] we find just as, if not more, credible CBR's explanation that the flattening of the curve is due to higher transmissivities encountered at distances from the pumping well.[234] We note as well that the Staff agreed with CBR's position regarding a higher transmissivity boundary, and proffered two other reasons for this flattening of the curves (i.e., additional water release from aquitard storage due to high induced stresses from overburden depths and aquifer drawdown during the pumping test, and misinterpretation of wellbore storage/near-wellbore effects), either or both of which can mimic recharge deviations in the Theis graphs.[235]

As acknowledged by OST,[236] all the parties' positions on the significance of the curve flattening are feasible hypotheses. Nonetheless, we find on the basis of the record before us that the CBR and Staff theories deserve greater consideration in that they are consistent with the many other site characteristics and observations that support the Applicant's overall position that not only will the fluids in the production zone continue to be contained to assure minimal impact on groundwater quality, but that the BC/CPF is sufficiently interconnected for CBR to control production fluids during operations and restoration.[237] In contrast, Dr. Kreamer offered

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[233] See Kreamer Rebuttal Test. at 2.

[234] See Test #8 Rep. at 13; id. app. C at PDF 80, 82 (graphs C1 & C3).

[235] See Staff Rebuttal Test. at 19–20 (Back, Lancaster, Striz).

[236] See Tr. at 565 (Wireman).

[237] See infra sections V.C, IX.A.2, and IX.B.2 for a summary of the site observations and characteristics that support BC/CPF aquifer containment.

no such corroborating evidence of other, co-existing factors supporting his position that there is localized leakage of sufficient magnitude to impact the containment properties and internal interconnections of the aquifer to control fluid migration within the BC/CPF. Accordingly, given the totality of the evidence before us, we reject his claim as lacking sufficient evidentiary support.

3. Summary of Board Findings on Misinterpretation of Aquifer Pumping Test Data

In sum, the rationale for why CBR analyzed the aquifer pumping test data as it did, both as to the use of only the Theis and Cooper-Jacob methodologies and the supposed improper data selectivity, was clearly explained by the Applicant in a manner consistent with recommended practice. Moreover, as to the judgment about what portion of the Theis type-curve to use after early-time effects have dissipated (i.e., middle- to late-time), in contrast to the Intervenor's failure to provide a sufficient evidentiary foundation to support Dr. Kreamer's opinion that significant localized aquifer leakage impacts CBR's conceptual hydrogeologic model for the MEA, we find that CBR's and the Staff's theories as to the late-time deviations detected at the two well locations are plausible and consistent with their other proffered information demonstrating the containment and connectivity characteristics of the MEA production zone.

B. Aquifer Heterogeneity and Anisotropy from Fracturing/Faulting

1. Parties' Position on Aquifer Heterogeneity and Anisotropy from Fracturing/Faulting

Intervenor witnesses alleged that faults within the MEA and other fractures associated with the Pine Ridge escarpment and other areas create heterogeneity and anisotropy in the aquifers underlying the MUs that, in turn, have the potential to allow transmission of production fluids to impact regional groundwater and surface water resources. Before discussing this topic in detail, we first note that OST witness Dr. LaGarry, without contradiction, defined a "fracture" as a crack in the geologic structure, a "fault" as a fracture that has displaced the strata in some direction, and a "joint" as a series of nondisplacement fractures oriented in parallel sets.[238] While we refer to named faults as such in this decision, in other instances we will use the term "fracture" to include faults, joints, or, for that matter, any other cracking, as subsets of this generic term.

a. Fracturing/Faulting Underlying the MEA

The Staff in its EA indicates that the relevant geologic literature, including a 1985 article by James B. Swinehart, et al., reports two postulated faults near the MEA: the Pine Ridge fault, which is reportedly located along the northern edge of the Pine Ridge escarpment, approximately five miles north of the northern MEA boundary; and the Niobrara River fault, which is reported to run parallel to the river along the southern margin of the MEA.[239] Citing the Swinehart article, which relies on large-scale (i.e., regional-level) cross-sections, as well as a 1994 article by R.F. Diffendal, which was based on a lineament analysis of linear landscape features as possible expressions of an underlying geological structure such as a fault, Dr. LaGarry asserted that these potential faults north and south of Marsland may allow production fluids to travel upward into the overlying aquifers and laterally into adjacent areas to the west and east.[240] In this regard, referencing Figure 1 of his initial testimony that shows a geologic cross-section of far western Nebraska, including the MEA site, Dr. LaGarry noted that the Niobrara River fault and the Pine Ridge fault are among those that were large enough to be documented by the Swinehart article in compiled data from approximately 12,500 drilling

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[238] See Tr. at 787–88.

[239] See EA at 3-11 (citing Ex. NRC012 (James B. Swinehart, et al., Cenozoic Paleogeography of Western Nebraska (1985) [hereinafter Swinehart Article])).

[240] See Ex. OST010 at PDF 5–6 ([Hannon E. LaGarry] Expert Opinion on the Environmental Safety of In-Situ Leach Mining of Uranium Near Marsland, Nebraska (2013) (citing Swinehart Article; Ex. NRC013 (R.F. Diffendal, Jr., Geomorphic and structural features of the Alliance 1° x 2° Quadrangle, western Nebraska, discernible from synthetic-aperture radar imagery and digital shaded-relief maps, 30 Univ. of Wyo. Contributions to Geology (Dec. 1994) [hereinafter Diffendal Article])) [hereinafter LaGarry Initial Test.].

records in western Nebraska and by drilling new boreholes at five-mile intervals along the transect shown on the figure.[241]

In response, Staff witnesses Back and Lancaster testified that neither the large-scale regional interpretation or lineament analyses cited by Dr. LaGarry as proof of permeable pathway faults are persuasive when compared with the analysis performed by CBR of site-specific cross-sections created with geophysical log data and drill cuttings from the MEA site.[242] And regarding the lineaments analysis in the Diffendall article, which involved observations based on large-scale mapping and the premise that a lineament represents a subsurface geologic fault, fracture, or joint, these Staff witnesses declared this approach to be speculative until field verification (i.e., "ground truthing") is performed,[243] a characterization with which Dr. LaGarry seemingly concurred.[244] Staff witnesses Back and Lancaster asserted that the lineaments described in the Diffendal article have not been verified to be anything more than linear alignments of ground surface features so that subsurface exploration (as CBR has conducted on the MEA site) would be essential in determining the existence, extent, and possible impacts on containment of any fault or fracture.[245]

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[241] See id. at PDF 4 (fig.1), PDF 5–6. Figure 1 is an annotated version of cross-section A-A' in Figure 5 of the 1985 Swinehart, et al., article. Compare id. at PDF 4, with Swinehart Article at 214. According to Dr. LaGarry, of the five faults shown on Figure 1 (which are designated by vertical black lines with offset arrows at the base of the cross-section), the Niobrara fault is the second line from the left and the Pine Ridge fault is represented by the rightmost line. See Tr. at 825.

[242] See Staff Initial Test. at 34.

[243] See id.

[244] Dr. LaGarry described a lineament as an "unexplained straight line feature visible in remotely sensed imagery" (such as aerial photography) and noted that whether a lineament is a fracture can only be verified by a site investigation. Tr. at 794–95.

[245] See Staff Initial Test. at 34–35; see also id. at 24–25 (Back, Lancaster) (describing the CBR MEA site characterization program that included drilling 1600 boreholes, creating cross-sections to cover the entire site based on geophysical logs and drill cuttings from 57 boreholes, supplemented with geophysical logs from oil and gas exploration wells previously

While acknowledging CBR employed geophysical logging of boreholes and constructed cross-sections to demonstrate the absence of faulting in the region, Dr. LaGarry declared that such methods do not delineate faults unless there is significant displacement. According to Dr. LaGarry, better techniques would have included electrical resistivity, seismic reflection and seismic reflection techniques, or possibly ground penetrating radar.[246] But CBR witness Lewis noted that fault offsets would have a specific signature in the geophysical logs that would suggest the presence of vertical displacements, yet none of these signatures were found in the 1600 logs for the site made by CBR, thereby confirming that CBR's geological investigations did not encounter any sign of faulting across the MEA.[247]

Applicant witnesses Lewis, Nelson, Pavlick, and Shriver did concede, however, that faults may exist at a regional level, but declared there is no evidence of any significant faulting within the MEA that will affect containment or transmit production fluids based on the data from the large number of boreholes and wells drilled on the site to date, or any other surficial or subsurface geological information that exists.[248] In this regard, CBR witnesses Lewis, Pavlick, and Shriver pointed to regional cross-sections that extend from south of the Niobrara River, northward through the MEA, across the existing CBR ISR facility and the proposed North Trend Expansion Area (NTEA), with each cross-section passing the presumed location of the Niobrara

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drilled near the MEA, as well as isopach maps and structure contour maps based on borehole data).

[246] See Ex. OST016-R, at 2 (Rebuttal Opinion Testimony of Hannan LaGarry (rev. Oct. 3, 2018)) (citing Ex. OST019 (Mark R. Lewis & F.P. Haeni, The Use of Surface Geophysical Techniques to Detect Fractures in Bedrock—An Annotated Bibliography, U.S. Geological Survey (USGS) Circular 987 (1987)).

[247] See Tr. at 805–06.

[248] See CBR Rebuttal Test. at 23.

River fault and Pine Ridge fault and none displaying a significant discontinuity of the BC/CPF aquifer.[249]

And by way of example, these CBR witnesses stated that none of the cross-sections (including an additional five cross-sections associated with the proposed Three Crow Expansion Area (TCEA) west of the current CBR ISR facility)[250] substantiate a large north-side-down vertical displacement across the area of the Pine Ridge escarpment. They noted additionally that in two of the cross-sections the top of the Pierre Shale surface elevations decrease southward, which they maintained is contradictory to a north side down vertical displacement. While these witnesses could not rule out the possibility of a small offset, they nonetheless concluded that the results from the boring logs demonstrate that there is not a large offset fault across the MEA that could act as a boundary for groundwater flow and movement that, in turn, could impact MEA operations.[251]

Moreover, as Dr. LaGarry acknowledged, the cross-section in Figure 1 of his initial testimony, which was taken from cross-section A-A' of Figure 5 of the Swinehart article and intersects both the Niobrara River and Pine Ridge faults,[252] is located 30 miles to the west of the MEA.[253] As was noted during the hearing, cross-section B-B' of Figure 5 of the Swinehart article is closer, albeit still 7.5 miles to the east of the MEA, and intersects the Pine Ridge fault but

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[249] See id. at 17; see also Tech. Rep. at 2-58 to -59; Tech. Rep. Figs. at 88–91 (figs. 2.6-21 to -24).

[250] See CBR Rebuttal Test. at 17 (citing Ex. CBR039, at PDF 3–4 (Tech. Rep. app. Z) (figs. 2 & 3) [hereinafter Three Crow Cross-Sections]).

[251] See id.

[252] See supra note 2411.

[253] See Tr. at 826.

does not encounter the Niobrara River fault.[254] Because this cross-section showed that the Niobrara River fault ceases or deviates somewhere between 30 miles west and 7.5 miles east of the MEA, while the Pine Ridge fault runs to the north of the MEA, Dr. LaGarry conceded that, as is the case with the Pine Ridge fault, the Niobrara River fault likely does not underlie the MEA.[255] Additionally, CBR witness Shriver observed in connection with cross-section B-B' that the Whitney Ash marker bed in the White River Group (i.e., the Brule Formation and the underlying Upper and Middle Chadron units) is shown as a dotted line, which in CBR's analysis continues beneath the MEA without any structural offset, implying that no faults exist in the production area — a point that Dr. LaGarry agreed was "well taken."[256]

Staff witnesses Back and Lancaster were also critical of Dr. LaGarry for relying on the Swinehart article's large-scale, regional-level cross-sections derived from widely spaced (i.e., five-mile interval) boreholes.[257] In contrast to this referenced regional study, these witnesses testified, the Staff's EA and SER provide a thorough discussion of the existence of reported faults near the MEA. That discussion, they maintained, concludes there is no evidence of vertical offsets indicative of faults and provides the reasons why, even if such faults exist, their potential impacts on the hydrogeologic behavior of the underlying strata beneath the site would not lead to significant adverse environmental impacts to surface water or groundwater as a result of MEA operations.[258] In this regard, while acknowledging reports that the Pine Ridge and Niobrara River faults transect the MEA, the EA indicates the Staff concluded these reports are

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[254] See Tr. at 830 (Lancaster); see also Staff Initial Test. at 35 (Back, Lancaster).

[255] See Tr. at 833–34.

[256] See Tr. at 835–36.

[257] See Staff Initial Test. at 34.

[258] See id. at 32–33 (citing EA at 3-11 to -14; SER at 33–36).

false based on extensive independent review of available literature on these faults (including cross-sections provided in the literature), CBR's site-specific and regional cross-sections, and CBR's site-specific and regional structure contour maps.[259]

Regarding other fractures not associated with faults, Dr. LaGarry stated that his work over the past 25 years has shown that there are likely hundreds more fractures.[260] While CBR witnesses Lancaster, Nelson, Pavlick, and Shriver acknowledged that faults and other fractures may exist at a regional level, they stated they knew of no evidence of any fracturing within the MEA that would have any effect on the proposed ISR activities and further asserted that any undetected fractures will have no hydrologic effect based on the wealth of other evidence confirming containment of the BC/CPF.[261] Moreover, these witnesses asserted that if any minor fractures were to appear, they would close up quickly as a result of overburden stress from the weight of the overlying strata.[262]

CBR witnesses Lancaster, Nelson, Pavlick, and Shriver concluded that there is no evidence of a fault or fracture in the MEA that could serve as a potential contaminant pathway. And, based on the undisputed evidence that the BC/CPF is a confined aquifer, they further stated it is highly unlikely the MEA contains a fault or a connected pathway of faults in the UCU that is capable of transmitting contaminants. Finally, according to these CBR witnesses, given the strong, downward hydraulic gradient between shallow aquifer and the BC/CPF sandstone,

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[259] See EA at 3-11 to -14.

[260] See LaGarry Initial Test. at PDF 6.

[261] See CBR Rebuttal Test. at 23.

[262] See id.

migration of fluids along any fault or fracture in the system would likely be downward, precluding any impacts to surficial aquifers.[263]

OST nonetheless posed the question of what would happen if faults or significant transmissive fracturing did exist within the MEA, with Dr. LaGarry observing:

> Of greatest concern is [the MEA's] proximity to the Niobrara River (a National Scenic River), which is used for recreation by thousands of people each year. Unfortunately, if the High Plains Aquifer were to become contaminated, the effects would be irreversible and catastrophic for the local agricultural economy . . . [and] would likely lead to the depopulation of the region.[264]

Acknowledging that it is more uncertain whether the Niobrara River fault underlies the southern portion of the MEA, as opposed to the Pine Ridge fault that is well north of the MEA, the Staff's EA indicates that even if these faults do exist beneath the MEA, their presence would not lead to significant adverse environmental impacts because (1) ambient groundwater flow in the BC/CPF sandstone aquifer is to the northwest and away from the reported Niobrara River fault; (2) once uranium recovery begins, groundwater flow would be inward toward the MUs (as required by License Condition 10.1.6) and away from both the Pine Ridge and Niobrara River faults; (3) based on groundwater velocity estimates provided in the EA, it would take at least 500 years for groundwater to migrate from the MEA to the reported Pine Ridge fault, during which time any constituents of the lixiviant would attenuate through sorption and dilution; (4) the ambient hydraulic gradients are strongly downward from the overlying aquifers of the Brule Formation and Arikaree Group into the BC/CPF sandstone aquifer and, therefore, production fluids would not be able to migrate upward through any preferential pathways; (5) the downward gradient would become even more pronounced during restoration operations; and (6) CBR will

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[263] See id. (citing Ex. CBR012 (Tech. Rep. app. AA-3 (Letter to Doug Pavlick & Larry Teahon, Cameco Resources, from Robert Lewis, AquiferTek (Dec. 17, 2014)) [hereinafter Hydraulic Containment Report]).

[264] LaGarry Initial Test. at PDF 6.

conduct additional aquifer pumping tests in each MU to identify hydraulic boundaries, including those caused by faulting.[265]

b. Hydrogeological Effects of the Pine Ridge Escarpment

Also with regard to aquifer heterogeneity and anisotropy, OST witness Wireman argued that, in addition to those factors affecting regional groundwater flow, CBR's characterization of northwest Nebraska structural geology is insufficient to develop an acceptable conceptual model of MEA site hydrology that is adequately supported by site data, particularly as it relates to the potential effects of the Pine Ridge escarpment on the MEA hydrogeology. Because CBR concluded that faulting does not exist beneath the MEA, Mr. Wireman claimed that Crow Butte improperly failed to discuss how structures like the Pine Ridge escarpment affect groundwater flow in the Arikaree and White River Groups.[266] It was his position that the Pine Ridge escarpment occurred prior to the deposition of the Chadron Formation and, as a result, was uplifted prior to the deposition of the BC/CPF, which would then be impacted by the significant discontinuity of the escarpment feature. And according to Mr. Wireman, CBR's conclusion that the BC/CPF is not affected by the Pine Ridge escarpment cannot be correct if the uplift predates the BC/CPF.[267]

In response to Mr. Wireman's concern about whether CBR's characterization of the Pine Ridge escarpment is sufficient to conceptually model this feature's effects on BC/CPF aquifer groundwater flow, CBR witnesses Lewis, Pavlick, and Shriver noted that Mr. Wireman did not discuss how his view of the structural geology in the area between the existing CBR ISR facility and the MEA can be reconciled with the hydraulic data at those sites. According to these witnesses, if there were a significant discontinuity in the BC/CPF along the Pine Ridge

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[265] See EA at 3-14 (citing ER at 3-49; SER at 139–40).

[266] See Wireman Initial Test. at 3.

[267] See id.

escarpment, no hydrogeological conceptual model can be constructed that would be consistent with the CBR-measured northwestward groundwater flow in the BC/CPF aquifer between the MEA and the existing CBR ISR facility. As a result, these witnesses indicated, Mr. Wireman's conclusions regarding the impacts of the Pine Ridge escarpment, rather than CBR's geological analysis, must be in error.[268]

In support of this view, CBR witnesses Lewis, Pavlick, and Shriver added that none of the regional cross-sections prepared from actual field data substantiate a large north-side-down vertical displacement across the Pine Ridge fault that should exist under Mr. Wireman's Pine Ridge escarpment hypothesis. For two of the cross-sections, these CBR witnesses claimed the top of the Pierre Shale surface elevations decreases southward, which is contradictory to such a north-side-down vertical displacement.[269] While admitting they cannot rule out the possibility of a short/small offset, they nonetheless asserted that the data demonstrate there is not a large offset fault that could act as a boundary for groundwater flow and movement that could impact production operations at the MEA. Overall, these CBR witnesses concluded, nothing in Mr. Wireman's general and speculative assertions relating to the preferential flow path indicated any errors in the discussion of structural geology.[270]

In rebuttal, Mr. Wireman stated that there is significant uncertainty about groundwater flow in the BC/CPF downgradient of the MEA caused by the unknown effect of the Pine Ridge escarpment on these flow paths, given that this escarpment functions as a groundwater divide in the Arikaree and Brule aquifers. As a result, he declared CBR should conduct additional

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[268] See CBR Rebuttal at 16–17; see also EA at 3-29 (fig. 3-8).

[269] See CBR Rebuttal at 17 (citing Tech. Rep. Figs. at 87–90 (figs. 2.6-21 to -24); Three Crow Cross-Sections at PDF 3–4).

[270] See id.

investigations to reduce these uncertainties, including hydrogeologic mapping to locate and characterize the suggested discharge areas, to provide necessary support for the Applicant's position that groundwater flow is not affected by the Pine Ridge escarpment.[271]

Staff witnesses Back, Lancaster, and Dr. Striz expressed support for the CBR position that Mr. Wireman's structural model is not correct. They based their assertion on regional cross-sections confirming that the BC/CPF is a continuous and essentially flat feature (from the MEA to beneath the Pine Ridge escarpment and on through to the existing CBR ISR license area), a pattern repeated with the overlying Chadron, Brule and Arikaree Formations (from north of the Pine Ridge escarpment to the southern boundary of the MEA). Based on this stratigraphic mapping from explorations and geophysical logging, these Staff witnesses concluded that these formations were deposited without any apparent interruption from the Pine Ridge escarpment.[272] And they went on to point out that the groundwater flow in the BC/CPF aquifer is to the northwest from the MEA toward the existing CBR ISR facility — an unlikely flow pattern if there were a groundwater flow divide in the BC/CPF caused by uplift related to the Pine Ridge escarpment.[273] These Staff witnesses also noted that the field data clearly shows that the Brule and Arikaree formations have been significantly eroded on the north side of the Pine Ridge escarpment away from the MEA, as compared with the south side where the MEA is proposed, which, in their view, is stratigraphic evidence supporting the position that these formations were deposited before the erosion occurred along the escarpment.[274]

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[271] See Ex. OST015-R, at 2 (Rebuttal Test. of [Michael] Wireman (rev. Oct. 3, 2018)) [hereinafter Wireman Rebuttal Test.].

[272] See Staff Rebuttal Test. at 4.

[273] See id. at 4–5 (citing EA at 3-29 (fig. 3-8)).

[274] See id. at 4.

c. Fracture Analyses

Relative to the aquifer heterogeneity and anisotropy-related issue of fracture analysis, OST witness Dr. LaGarry expressed concerns about secondary porosity in the form of fractures that have the potential to transmit leaks and excursions through preferential pathways in the Chadron Formation, calling for, among other things, a fracture analysis to help evaluate the extent of these features.[275] When queried about the techniques for a fracture analysis, Dr. LaGarry suggested an inexpensive pedestrian survey of surficial outcrops, claiming that, even with exposure to weathering and no overburden stress, bedrock observed at the surface will, in his opinion, be representative of what the bedrock will look like when buried several hundred feet below the surface and protected from weathering.[276] Dr. LaGarry's approach was rejected by both CBR witness Shriver and Staff witness Lancaster, with Mr. Shriver stating that any undetected fractures at depth are more compressed by the large overburden stresses and less able to transmit fluid. Mr. Shriver also noted that no fractures were observed in the borehole coring within the MEA.[277]

And when asked about what else would be needed to conduct a fracture analysis, OST's witnesses seemed to differ among themselves to a degree. Dr. LaGarry suggested a lineament analysis and surface geophysics to provide confidence in assessing the impact that the fractures have on the containment of the production zone underlying the MEA.[278] OST witness Dr. Kreamer, while calling for the same geophysics and lineament analysis of the surface features as first steps, also championed the usefulness of down-hole TV monitoring for

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[275] See LaGarry Rebuttal Test. at 1; Tr. at 583.

[276] See Tr. at 681, 804.

[277] See Tr. at 805–07.

[278] See Tr. at 681.

determining aperture size and orientation, satellite information, high-altitude photography, and hydraulic packer testing to estimate the hydraulic characteristics of a detected fracture.[279]

Dr. Kreamer also made the point that a fracture analysis was not performed by CBR, nor required by the Staff, adding that heterogeneous fracture flow, if it were occurring, would diminish the value of spatially limited monitoring wells in the shallow Brule Formation because their interpretation depends on homogeneous layers and the exclusion of discrete fractures.[280] CBR witnesses Lewis, Nelson, and Pavlick, and Staff witnesses Back and Lancaster, on the other hand, argued that the presence of the thick UCU indicating confinement of the BC/CPF Formation was supported by laboratory analysis of two core samples showing that this confining layer possesses an average laboratory vertical hydraulic conductivity of 1.3×10^{-7} cm./sec.[281]

Using the premise that the pumping test analysis shows departure from the Theis type-curve consistent with vertical leakage, Dr. Kreamer likewise emphasized that neither CBR nor the Staff even considered the possibility of fracture flow.[282] At the same time, Dr. LaGarry and Mr. Wireman acknowledged that the mere presence of fractures is not the controlling factor, because the impacts from such an alleged hydraulic heterogeneity depend upon whether the fractures are sufficiently transmissive to provide a preferential pathway for groundwater flow significant enough to adversely impact the containment properties of the BC/CPF.[283] Simply

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[279] See Tr. at 521–23.

[280] See Kreamer Rebuttal Test. at 2.

[281] See CBR Initial Test. at 36–37; NRC Initial Test. at 28–29.

[282] See Kreamer Rebuttal Test. at 3.

[283] See LaGarry Rebuttal Test. at 2; Tr. at 677 (Wireman).

said, as Dr. LaGarry confirmed, the magnitude of fault displacement is immaterial to whether or not a joint, fracture, or fault will transmit fluids.[284]

In this regard, Crow Butte provided evidence indicating that as the hydraulic property of fractures that is derived from the pumping test results discussed in the preceding section, the transmissivity values are indicative of the lack of widespread fractured flow and consistent with the geophysical logging of over 1600 boreholes showing a lack of offsets associated with a fault.[285] In his rebuttal testimony, however, Dr. Kreamer stated that CBR's conclusions and the Staff's analyses rely on the presumption that chemical transport processes, including hydrodynamic dispersion and diffusion, are insignificant relative to the velocity or advective movement of groundwater.[286] According to Dr. Kreamer, their reference to chemical transport processes discussing hydrodynamic dispersion and diffusion also contain the a priori assumption of homogeneous isotopic flow through a non-fractured medium. As the MEA site is dominated entirely by hard-rock strata, Dr. Kreamer asserted, the omission of any analysis of the possibility of fracture flow typically associated with hard-rock geology is inconsistent with normal hydrogeological and engineering practice.[287]

2. Board's Findings on Aquifer Heterogeneity and Anisotropy from Fracturing/Faulting

Although it often is not apparent whether the Intervenor is referencing the BC/CPF aquifer, the UCU, the Brule Formation, or all of these geologic structures, OST clearly claimed that faulting/fracturing is a major cause for the alleged heterogeneity and anisotropy of

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[284] See LaGarry Rebuttal Test. at 2.

[285] See Tech. Rep. at 2-58 to 2-59, 3-7; see also Tech. Rep. at 87–90 (figs. 2.6-21 to -24); Three Crow Cross-Sections at PDF 3–4 (figs. 2 & 3).

[286] See Kreamer Rebuttal Test. at 3 (citing CBR Initial Test. at 15, 22, 36–38 (Lewis, Nelson, Pavlick); NRC Initial Test. at 28–29, 42–43 (Back, Lancaster)).

[287] See id.

transmissivity in the geologic strata underlying the MEA, and that these strata characteristics demonstrate that the Brule aquifer is not hydraulically isolated from the production zone in the BC/CPF. In this regard, OST pointed to lithologic and hydraulic data included in the TR, in conjunction with deviations from the Theis type-curve for the May 2011 pumping test, as proof of such heterogeneities.[288]

As was noted above, Dr. Kreamer's rebuttal testimony alleged that CBR has not considered the use of a fracture analysis and claimed that the omission of such a "robust" analysis typically associated with hard-rock geology is inconsistent with normal hydrogeological and engineering practice.[289] But while CBR's position is supported by numerous other observations demonstrating the integrity of the BC/CPF for containing the operational fluids injected into the production zone,[290] the Board finds that he, as well as Dr. LaGarry (who also called for a fracture flow analysis for the site),[291] failed to provide any evidence of widespread fracturing of the UCU that would suggest the need to conduct a fracture analysis. We find that to perform this evaluation would be a complex, time-consuming, and expensive endeavor that is hard to justify given the lack of any evidence of substantial fracturing of the geologic strata. Common sense dictates that even a simple pedestrian survey to map known geologic outcrops within the MEA, as was suggested by Dr. LaGarry,[292] would be of marginal usefulness in assessing the extent of fracture flow given that the similarities in the characteristics of the cracks

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[288] See Wireman Initial Test at 4; Kreamer Rebuttal Test. at 1–3; Tr. at 342, 345, 347, 416, 494, 520–25 (Kreamer).

[289] See Kreamer Rebuttal Test. at 2–3.

[290] See infra section V.C for a discussion of BC/CPF containment.

[291] See LaGarry Rebuttal Test. at 2.

[292] See Tr. at 681 (LaGarry).

(e.g., frequency, aperture dimensions, opening, fill/gouge)[293] in surficial bedrock exposed to weathering when compared to those of fractured rock buried under hundreds of feet of overburden stress and protected from weathering would likely be coincidental.

In support of fractures in the MEA, OST also relied heavily on the Diffendal and Swinehart articles, both of which, the Board concludes, contain scientific limitations. Given OST's agreement that a lineament study only detects an unconfirmed linear feature in the surface geography that must be field-verified to confirm the presence of a fault rather than some other straight-line anthropogenic feature,[294] we find that Diffendal's lineament analysis, not having been field-verified within the MEA, is of limited use in detecting or establishing fault locations.[295]

Regarding the evaluations in the Swinehart article, although they were derived from field borings (albeit made at five-mile spacings), cross-section A-A' in that publication (which was used as the basis for Figure 1 in Dr. LaGarry's initial testimony) was 30 miles west of the MEA.[296] Additionally, cross-section B-B' in that publication is still 7.5 miles to the east of the site, and shows that neither the Pine Ridge nor the Niobrara River faults underlie the MEA,[297] a fact consistent with CBR's conclusion reached after reviewing over 1600 geophysical logs of the subsurface conditions at the site.[298] And besides showing that the Pine Ridge and Niobrara River faults do not cross the MEA, the Swinehart and Diffendal articles are stratigraphic reports

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[293] See Tr. at 521–23 (Kreamer).

[294] See Tr. at 794–95 (LaGarry).

[295] See Staff Initial Test. at 34–35 (Back, Lancaster).

[296] See Tr. at 826 (LaGarry), 829–30 (Lancaster).

[297] See Tr. at 829–35 (LaGarry).

[298] See CBR Rebuttal Test. at 23 (Lewis, Nelson, Pavlick, Shriver); Tech. Rep. at 3-7.

that do not include any information on the transmissivity or preferential flow patterns through these fractures.[299]

Moreover, OST's arguments about the value of physical evidence of faulting and the steps that need to be taken to quantify the degree of fracturing at the MEA are eclipsed by the Intervenor's own acknowledgement that the important factor is not the mere presence of these fractures, but their transmissivity.[300] In this regard, we find that OST provided no evidence to demonstrate that there are sufficient preferential flows by any means (including fractured flow) to the degree necessary to undermine the CBR and Staff showings that containment within the BC/CPF provides isolation of the Arikaree/Brule aquifer from the production zone, and that the BC/CPF is internally interconnected to allow CBR to control operational fluids injected into this strata during ISR operations and restoration. In addition, CBR and the Staff have proffered substantial evidence supporting the conclusion that the processing lixiviant will be contained within the production zone, thus providing defense in depth for minimizing the environmental impact of ISR activities at the Marsland site.[301]

Regarding the hydrogeologic parameters of the MEA, OST countered CBR's laboratory test data, which shows that the UCU consists of more than 90 percent claystone having an average laboratory hydraulic conductivity of 1.3×10^{-7} cm./sec.,[302] by stating that CBR does not even consider the possibility of fracture flow, which OST concludes is evident based on its analysis of the May 2011 pumping test that shows a departure from the Theis type-curve that OST asserts is consistent with vertical leakage.[303] As was noted in section V.A above, CBR

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[299] See Tr. at 793 (LaGarry).

[300] See Tr. at 677 (Wireman).

[301] See infra section V.C.2.

[302] See CBR Initial Test. at 36–37 (Lewis, Nelson, Pavlick).

[303] See Kreamer Rebuttal Test. at 3.

assumed homogeneity/isotropy for the pumping test, and then reviewed the actual test results to detect if data discrepancies indicated these assumptions were inappropriate and found none. And based on a review of aquifer pumping test results, we find that there is no compelling evidence that there were widespread, significant deviations that would call into question the assumptions of homogeneity and isotropy so as to require more complex “leaky aquifer” analyses. Nor has OST presented any evidence of gross heterogeneity and anisotropy that might establish an error in the Applicant’s and the Staff’s conclusions regarding the hydraulic connectivity within the BC/CPF and containment of the production fluids within this strata.

The Board thus finds relative to what the Intervenor surmises is a heterogeneous groundwater flow through fractures in the UCU that the preponderance of the evidence establishes that the deviations in the pumping test data performed in the BC/CPF aquifer resulted from other causes, i.e., localized variations in hydraulic conductivity of the layering, increased localized transmissivity from increased aquifer thickness, and water squeezed from the UCU.[304]

Dr. Kreamer did point to the range of hydraulic conductivity values derived from the pumping tests as proof of the heterogeneity of the BC/CPF. Based on the evidence before us, however, the Board does not find Dr. Kreamer’s analysis convincing as the range of values from the pumping test is relatively consistent for both the drawdown and recovery analyses. As presented in the Test # 8 report, hydraulic conductivity for the drawdown analysis varied from 6 ft./d to 45 ft./d (with 1 high value, 1 low value, and 6 very consistent values) with an average hydraulic conductivity of 22 ft./d, and with the recovery analysis showing hydraulic conductivity varied from 6 ft./d to 62 ft./d (with 1 high value, 1 low value, and 7 relatively consistent values),

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[304] See Test #8 Rep. at 13; Staff Rebuttal Test. at 18–20 (Back, Lancaster, Striz); supra section V.A.2.b.

for an average hydraulic conductivity of 28 ft./d.[305] As we discuss in more detail later,[306] we find these values consistent given the wide range over which hydraulic conductivity can vary.

Further, concerning the preferential flow path OST asserted is present in the area of well Monitor-3,[307] while feasible, we find that the preponderance of the evidence indicates no significant offsets associated with fracturing in this area. Again, with OST failing to provide any corroborating evidence for widespread aquifer leakage, we find that any fractures that may exist in the area of well Monitor-3 will not significantly affect the containment and control of fluids in the production zone.

There is also the issue of the impact of the Pine Ridge escarpment on the hydrogeology of the MEA, which is based on Mr. Wireman's claim that significant uncertainty remains about whether the groundwater flow in the BC/CPF downgradient of the MEA is affected by the Pine Ridge escarpment so as to require additional studies to support CBR's position that groundwater flow is not affected by this structure. The Board finds that OST's claim must be rejected based on a number of field-verified observations from explorations, geophysical logging, and water level measurements, as identified by the Staff. These include (1) the field data-derived structure contour maps showing a nearly level BC/CPF from the MEA to beneath the Pine Ridge escarpment and on through to the existing CBR ISR facility;[308] (2) the groundwater potentiometric maps based on measured water levels that were used to establish the contour flow map that documents constant northwest flow in the BC/CPF aquifer along the

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[305] See Test #8 Rep. tbls. app. at 10 of 10 (tbl. 8); Tech. Rep. Tbls. at 73 (tbl. 2.7.3).

[306] See infra section VII.D.2.

[307] See Tr. at 520–25 (Kreamer).

[308] See Staff Rebuttal Test. at 4 (Back, Lancaster, Striz) (citing Tech Rep. Figs. at 87–90 (figs. 2.6-21 to -24); Three Crow Cross-Sections at PDF 3–4 (figs. 2 & 3)).

axis of the MEA;[309] and (3) the erosion surface contours illustrating that the Brule and Arikaree formations have been significantly eroded on the north side of the Pine Ridge escarpment, as compared with the south side where the MEA is proposed, yielding stratigraphic evidence that supports the view that these formations were deposited before this erosion occurred along the escarpment.[310] The Board thus concludes there is an overwhelming body of field data supporting the northwest flow of groundwater in the BC/CPF — from south of the Niobrara River, through the proposed MEA and existing CBR ISR facility toward Crawford and the White River — such that the OST's argument that CBR needs to conduct an additional study because of the Pine Ridge escarpment's impact on MEA hydrology is not substantiated.

3. Summary of Board Findings on Aquifer Heterogeneity and Anisotropy from Fracturing/Faulting

The Board concludes that while there is likely some degree of structural fracturing of the geologic strata underlying the MEA, the mere presence of fractures is not the issue. Instead, the transmissivity of the strata is the critical factor. Regarding the heterogeneity and anisotropy in the rate and directions of groundwater flow within the MEA, we conclude there is no evidence in the hydrogeologic data before us that conclusively supports the presence of extensive, transmissive, heterogeneous pathways that would provide a preferential flow for contaminants to migrate uncontrollably into the adjacent Brule and Arikaree aquifers, much less into neighboring surface waters, including the Niobrara and White Rivers. And just as importantly, in the unlikely event that detrimental, transmissive fracturing were encountered during ISR activity within the MEA, the Board finds that the presence of such fracturing would not lead to unsafe conditions or significant adverse environmental impacts because (1) the lack of any vertical

[309] See id. at 4–5 (citing EA at 3-29 (fig. 3-8)).

[310] See id. at 4 (citing Tech Rep. Figs. at 87–90 (figs. 2.6-21 to -24); Three Crow Cross-Sections at PDF 3–4 (figs. 2 & 3)).

preferential pathways due to the strongly downward ambient hydraulic gradients from the overlying aquifers into the BC/CPF, in conjunction with the increased inward gradients toward the MUs required by License Condition 10.1.6,[311] would prevent contaminant migration into the adjacent aquifers; (2) in accordance with License Condition 11.3.4, CBR is required to conduct additional aquifer pumping tests designed to identify hydraulic boundaries, including those caused by faulting; (3) the BC/CPF groundwater flow is to the northwest and away from the Niobrara River such that the lixiviant would attenuate by sorption and dilution during the many decades it would take groundwater to migrate from the MEA toward the northwest discharge points;[312] and (4) if uncontrolled migration of production fluids occurred and the operations were deemed to be unsafe, operations would cease and, under License Condition 9.4, CBR would be required to submit a license amendment (which is subject to a hearing opportunity) that would provide a plan for safe operations in those conditions.[313]

The Board finds there is no evidence of excessive transmissive fracturing or faulting causing sufficient heterogeneity and anisotropy in the MEA geologic strata to refute the CBR and Staff showings of aquifer interconnectivity and containment of processing fluids that are required for safe, environmentally sound ISR activities in the proposed area. Additionally, we find that the preponderance of the evidence in the record supports a determination that there are no known faults or significant fracturing underlying the MEA that might cause heterogeneity and anisotropy of the underlying geologic strata. As a result, there is no need for CBR to augment its TR or the Staff to alter its EA to further address heterogeneity/anisotropy impacts due to fracturing.

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[311] See Tr. at 550 (Wireman).

[312] See EA at 3-14 (citing ER at 3-47 to -50).

[313] See Tr. at 443–44, 551–55 (Lancaster).

C. Allegedly Reduced Containment of the BC/CPF Aquifer

Details of OST's allegations challenging containment of the BC/CPF aquifer and the CBR and Staff responses are interwoven into the four "Concerns" associated with OST's contention, as amplified in the OST witnesses' initial and rebuttal testimony (admitted as exhibits) and their responses to Board questioning during the hearing. Much of their argument focused on the degree to which production fluids, e.g., lixiviant, are to be contained within the BC/CPF aquifer production zone during operations and restoration. Because the majority of the Intervenor's challenges rest on the alleged mischaracterization of the hydrogeologic properties of site stratification (see infra section VII), Crow Butte and the Staff highlighted multiple elements, including both natural conditions and human-engineered attributes, that support hydraulic containment of processing fluids within the production zone.

Accordingly, in the first subsection below we provide a brief review of the major disputes raised by OST relating to the containability of the BC/CPF. This is followed by a summary of CBR's and the Staff's evidence supporting containment of production fluids within the BC/CPF aquifer, which is derived from field investigations and operational experience with ISR uranium production, as impacted by regulatory requirements. Finally, the Board's findings concerning BC/CPF-provided containment conditions are presented in the last subsection below.

1. Intervenor Allegations Challenging Containment of the BC/CPF Aquifer

Through its witness Dr. Kreamer (and with support from OST witnesses Wireman and Dr. LaGarry), OST challenged showings proffered by CBR and the Staff regarding CBR's ability to manage the flow of production fluids within the BC/CPF without migration of ISR process contaminants, either vertically up through the UCU so as to impact the overlying Brule and Arikaree aquifers or laterally toward potential BC/CPF discharge locations northwest of the proposed MEA facility.[314] Relative to Intervenor's containment allegations, Dr. Kreamer implied that the results of the May 2011 pumping test indicated a lack of BC/CPF containment based on the late-time recharge zones detected in wells at two locations, CPW-1/1A and Monitor-3.[315] He stated that the flattening of the drawdown curves for these wells during the late-time period demonstrated the lack of containment associated with a detrimental flow path through the heterogeneous UCU into the BC/CPF aquifer.[316] Further, at the hearing, Dr. Kreamer attempted to show that well Monitor-3 detected a preferential pathway for groundwater flow, indicating production zone containment leakage.[317] And while Dr. Kreamer's testimony was the only direct attack by an OST witness on the lack of BC/CPF containment, the issue of reduced containment comes up repeatedly in support of numerous other Intervenor allegations.[318]

2. Summary of Staff Claims and OST Responses Regarding BC/CPF Aquifer Containment

In addressing these OST allegations, the Staff identified various items, along with the results of the May 2011 pumping test, that the Staff asserted demonstrate the containment properties of the BC/CPF aquifer so as to make this formation uniquely suited for safe and

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[314] See Kreamer Initial Test. at 2; Kreamer Rebuttal Test. at 2–3, 4; Wireman Initial Test. at 2–3; LaGarry Rebuttal Test. at 2–3.

[315] See Kreamer Initial Test. at 6.

[316] See supra section V.A.1.b.ii.

[317] See id.

[318] See, e.g., Kreamer Initial Test. at 2 (claiming Test #8 Report fails to show Cooper-Jacob analyses that could identify a recharge boundary consistent with lack of aquifer confinement); Kreamer Rebuttal Test. at 2–3, 4 (declaring possible lack of aquifer confinement not addressed by CBR and Staff assertions regarding adequacy of Theis method as sole aquifer test analysis or effectiveness of inward hydraulic gradient).

environmentally sound ISR extraction operations at the Marsland site. As compiled by the Board based principally on the Staff's testimony, these include:[319]

1. Site-specific XRD analyses, particle grain-size distribution analyses, and geophysical logging that confirm the presence of a thick (between 360 ft. and 450 ft.), laterally continuous UCU consisting of low permeability mudstone and claystone (with a measured falling-head permeameter test result for hydraulic conductivity of 1.3×10^{-7} cm./sec.) and a thick (more than 750 ft.), regionally extensive LCU composed of very low permeability black marine shale, all of which demonstrate that the hydraulic resistance to vertical flow is expected to be high due to the significant thickness of the upper and lower confining zones within the MEA.[320]

2. The results of the May 2011 aquifer pumping test demonstrate no discernable drawdown in the overlying Brule Formation observation wells.[321]

3. Large differences in the observed hydraulic head (330 ft. to 500 ft.) between the Brule Formation and the BC/CPF would not occur if the strata overlying the BC/CPF were not an effective barrier to flow.[322]

4. Potentiometric surfaces (i.e., water pressure levels) measured within the Arikaree/Brule aquifer are several hundred feet higher than those measured in the BC/CPF aquifer evidencing strong vertically downward gradients such that any amount of groundwater movement through the confining units would be downward from the Arikaree/Brule aquifer into the BC/CPF aquifer resulting in a minimal risk of naturally occurring impacts to the overlying Brule Formation.[323]

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[319] At the evidentiary hearing, both CBR and the Staff acknowledged that the list in the text that follows captures those items that best supported their positions regarding BC/CPF aquifer containment. See Tr. at 963–64 (Back, Shriver). Although CBR suggested there were two other items, one dealing with the presence of volcanic ash beds in the lower Brule aquifer that are additional vertical permeability barriers and the other concerning the use of a leaky aquifer solution relative to CBR's impact modeling, the Board indicated neither would be the subject of further discussion. See Tr. at 964–65 (Lewis).

[320] See Staff Initial Test. at 28–29 (Back, Lancaster); see also CBR Initial Test. at 36 (Lewis, Nelson, Pavlick).

[321] See Staff Initial Test. at 29–30 (Back, Lancaster); see also CBR Initial Test. at 35 (Lewis, Nelson, Pavlick).

[322] See Staff Initial Test. at 30 (Back, Lancaster); see also CBR Initial Test. at 36 (Lewis, Nelson, Pavlick).

[323] See Staff Initial Test. at 30–31 (Back, Lancaster).

5. A comparison of the major anions and cations (such as calcium, sodium, sulfate, and bicarbonate) of BC/CPF and Brule Formations shows significant historical differences in geochemical groundwater characteristics between them.[324]

6. Based on isotope age dating, the Arikaree aquifer (150,000 to 250,000 years old), Brule aquifer (250,000 to 300,000 years old) and BC/CPF aquifer (300,000 to 500,000 years old) have large groundwater age differences.[325]

7. Pressure effects from pumping at a relatively low flow rate (27 gpm) were detected at long distances over short time periods, which would only occur with containment of the aquifer.[326]

8. Calculated storativity values ranged from $1.7x10^{-3}$ to $8.3x10^{-5}$ and averaged $2.56x10^{-4}$, corresponding to storativity values for a confined aquifer that range between $5x10^{-5}$ and $5x10^{-3}$.[327]

In his initial testimony, Dr. Kreamer addressed the last item above (item 8) by asserting that the large range of these storage values and those of transmissivity (230 ft.^{2}/d to 1780 ft.^{2}/d) are not consistent with homogeneous conditions.[328] But at the hearing, Staff witness Dr. Striz pointed out that considering later time data that accounts for well effect, the largest value for storativity could be reduced from $1.7x10^{-3}$ to $1x10^{-5}$, thus yielding a narrower range of $1x10^{-5}$ to $8.3x10^{-5}$ that is more in line with other wells and indicative of a confined aquifer.[329] And with

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[324] See id. at 31 (Back, Lancaster).

[325] See Staff Initial Test. at 31 (Back, Lancaster); see also CBR Initial Test. at 36 (Lewis, Nelson, Pavlick).

[326] See Staff Rebuttal Test. at 15 (Back, Lancaster, Striz).

[327] See id. (citing Ex. NRC015, at 45–46 (David Keith Todd, Groundwater Hydrology (2d ed. 1980) [hereinafter Todd Text])).

[328] See Kreamer Initial Test. at 6.

[329] See Tr. at 502–05 (referencing Test #8 Rep. app. C at PDF 82 (graph C3)).

regard to the range of transmissivity values, Dr. Kreamer agreed that these values can often vary by an order of magnitude or more.[330]

Further, in his rebuttal testimony, Dr. Kreamer challenged another three of these Staff-identified items: item 1, dealing with the UCU's ability, both in terms of quantity and quality, to restrict vertical groundwater flow; item 2, whether the results of the May 2011 aquifer pumping test demonstrated no discernable drawdown in the overlying Brule Formation observation wells; and item 5, concerning water quality chemical characteristic differences between the BC/CPF and the Arikaree/Brule aquifer. On these three points, Dr. Kreamer countered that (1) for item 1, the UCU may be breached by potential fracturing of the intervening strata between the upper and lower aquifers as indicated by the departure of the May 2011 pumping test data from the Theis type-curve consistent with vertical leakage;[331] (2) for item 2, the efficacy of no discernable drawdown in the Brule observation wells during the May 2011 pumping test as support for containment is diminished by the fact that the results from these area-restricted, shallow monitoring wells, instead of demonstrating site containment, indicated leakage into the BC/CPF;[332] and (3) for item 5, chemical characteristic differences between the BC/CPF and the Arikaree/Brule aquifer are invalid in that (a) chemical transport processes, including hydrodynamic dispersion and diffusion, are insignificant relative to the velocity of the hydraulic movement of groundwater, (b) downward groundwater flow would be expected to naturally change chemical composition, and (c) current water quality differences noted by CBR are under unstressed conditions rather than conditions associated with production pumping and injection.[333]

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[330] See Tr. at 485–88.

[331] See Kreamer Rebuttal Test. at 2–3.

[332] See id. at 1–2.

[333] See id. at 3.

When given the opportunity at the hearing to comment further on the Staff-identified items supporting aquifer containment at the MEA,[334] Dr. Kreamer initially addressed the alleged competency of the UCU as demonstrating BC/CPF containment by discussing in detail the data from the May 2011 pumping test showing a flattening of the drawdown curve from the Theis type-curve for wells CPW-1/1A and Monitor-3. Dr. Kreamer noted the deviations of the data from the Theis type-curve, alleging that "[t]his change in the level of water from the Theis curve is consistent with a lack of confinement of the aquifer."[335] Then, as we noted previously, at the hearing Dr. Kreamer further attempted to show that well Monitor-3 detected a preferential pathway for groundwater flow indicating leakage in the containment of the production zone.[336] Specifically, as it related to aquifer isolation, Dr. Kreamer claimed that the depression of the Pierre Shale and the upper surface of the BC/CPF was indicative of "possible fractures" and additional leakage at this location.[337] In response, CBR witness Shriver claimed this depression was merely a low area in the erosional surface of the Pierre Shale and the BC/CPF deposit by pointing out that, in the relevant geologic cross-sections, there is no offset in the formations through this area.[338]

Relative to item 3 regarding the lack of discernable drawdown in the overlying Brule Formation observation wells, Dr. Kreamer responded that a leaky aquifer can still exhibit a large difference in potentiometric levels between aquifers, as has been measured between the

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[334] See Tr. at 965–99.

[335] Kreamer Initial Test. at 6.

[336] See supra section V.A.1.b.

[337] See Tr. at 971, 977–79 (citing Test #8 Rep. at PDF 41–42 (figs. 9 & 10)).

[338] See Tr. at 979–82 (citing Test #8 Rep. figs. app. at PDF 38 (fig. 6)); Tech. Rep. Figs. at 52 (fig. 2.6-3d).

Arikaree/Brule aquifer and the BC/CPF aquifer.[339] And regarding item 4 concerning the strong downward gradients between the Arikaree/Brule aquifer and the BC/CPF, Dr. Kreamer claimed that this downward flow has an environmental impact associated with a possible loss of water in the Arikaree/Brule aquifer and so indicated nothing about lateral movement of groundwater in the BC/CPF.[340] For item 5 relating to chemical characteristic differences between the BC/CPF and the Arikaree/Brule aquifer, Dr. Kreamer indicated that the complexity of potential geochemical interactions during groundwater flow through geologic strata makes such differences a poor measure of aquifer isolation.[341]

Addressing the difference in the ages of the groundwater in the three aquifers referenced in item 6, Dr. Kreamer opined that because the water samples tend to be integrated and the individual ages of the groundwater in the different aquifers tend to have wide, overlapping ranges, there possibly was communication between these aquifers.[342] Regarding item 7, it was Dr. Kreamer's opinion that with a large ROI for a well pumping at a relatively low rate, a large influence can exist and still have localized leakage in the aquifer.[343] For item 8 (concerning the storativity values derived from the May 2011 aquifer pumping tests falling within the range indicative of a confined aquifer), Dr. Kreamer declared that while this statement would be true for a homogeneous aquifer, it would not be true for a heterogeneous aquifer such as the BC/CPF.[344]

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[339] See Tr. at 990–91 (Kreamer).

[340] See Tr. at 991–93.

[341] See Tr. at 951–56.

[342] See Tr. at 993–94.

[343] See Tr. at 994–95.

[344] See Tr. at 995–96.

Finally, Dr. Kreamer was questioned about whether he was proffering extreme/rare situations supporting aquifer leakage to address each of the eight Staff-identified items, any one of which may or may not happen, but all of which apparently would have to fail for the Staff's non-leaking containment analysis to be rejected. In response, he cautioned that only one preferential flow path leakage from the MEA facility could cause devastating results and called again for a robust fracture analysis to better characterize the BC/CPF aquifer's status.[345]

3. Board Findings on BC/CPF Aquifer Containment

Initially, the Board notes that each of the eight Staff-identified items asserted to demonstrate aquifer containment are independent of the others. Moreover, five of the eight are independent of the May 2011 pumping test, i.e., quantity and quality of the UCU (item 1); large differences in head between the Arikaree/Brule aquifer (the first overlying aquifer) and the BC/CPF aquifer (item 3); strong vertically downward gradients existing between the Arikaree/Brule and the BC/CPF aquifers (item 4); differences between the geochemical characteristics of the BC/CPF and Arikaree/Brule aquifer (item 5); and varying ages of the water between the Arikaree/Brule and the BC/CPF aquifers (item 6). The other three items relate to the May 2011 pumping test data, i.e., no discernable drawdown observed in any of the three Brule aquifer observation wells monitored during the May 2011 pumping test (item 2); the long ROI of over 1.5 miles for a modest pumping rate of 27 gpm (item 7); and calculated storativity values indicative of a confined aquifer (item 8). In the Board's view, with one exception discussed below, these Staff-identified items provide strong evidentiary support for the sound containment properties of the BC/CPF's upper and lower confining units.

During the hearing Dr. Kreamer was offered an opportunity to comment on each of these eight signs of containment.[346] The Board finds that Dr. Kreamer provided persuasive evidence

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[345] See Tr. at 996–99.

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[346] See Tr. at 960–67, 990–96.

for discounting one of the eight items: item 5, concerning water quality differences between the upper and lower aquifers. In addressing this issue, Dr. Kreamer emphasized the complexity of potential geochemical interactions during groundwater flow through geologic strata.[347] The Board agrees that differing water quality between the BC/CPF and Arikaree/Brule aquifer can occur from a variety of mechanisms and that the resulting water quality between these two formations may not necessarily be the sole result of isolation of the upper aquifers from the Chadron Formation. Therefore, we place very little weight on the observation of differing water quality as definitive proof of aquifer containment –- a position that was acknowledged to some degree by CBR witness Lewis.[348]

But we disagree with the hypotheses raised by Dr. Kreamer in refuting the other seven Staff-identified items showing aquifer containment.[349] As previously stated,[350] the report on the May 2011 pumping test provides a detailed discussion and explanation regarding how the data generated was used to characterize the aquifer response. That report also documents that no drawdown was observed in any of the three Brule Formation observation wells during the test period.[351] This well array for the Brule being adequate for its intended purpose, we find that, by itself, the pump test supports the conclusion that adequate containment exists between the overlying Brule Formation and the BC/CPF production zone. The test also shows, based on the

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[347] See Tr. at 951–56.

[348] See Tr. at 956.

[349] In addition to these containment findings, we note that Board findings relative to Dr. Kreamer's responses regarding these items that appear relevant to MEA site characteristics associated with each of the Contention 2 concerns are presented within the individual sections regarding those concerns.

[350] See supra section V.A.1.b.

[351] See Test #8 Rep. at 1; see also Tech. Rep. Tables at 72 (tbl. 2.7-2) (describing three Brule observation wells monitored during the pumping tests).

character of the drawdown versus time graphs that were plotted for each observation well, that the resulting hydraulic storativity values analytically calculated from these plots place the BC/CPF within the range of values associated with a confined aquifer, i.e., the calculated range of storativity values of 1.7×10^{-3} to 8.3×10^{-5}, as compared to the values of 5×10^{-3} to 5×10^{-5} that scientifically reliable technical literature indicates is expected for a confined aquifer.[352] Given this substantial evidentiary support, and faced with the absence of any corroborating evidence from OST supporting Dr. Kreamer's position that the BC/CPF aquifer lacks containment, we reject OST's conclusion that the May 2011 pumping test data provides confirmation of a significant lack of aquifer containment.[353]

With regard to the more general containment issues concerning the BC/CPF, we note that OST's testimony for the most part addressed the inadequacy of the CBR characterization of data from the May 2011 pumping test while pointing to little specific evidence indicating that containment of production fluids within the BC/CPF is not achievable. On that score, we provided our findings regarding the adequacy of the aquifer pumping test in section V.A supra, and the potential for fracturing causing heterogeneity/anisotropy in section V.B supra. And in this section, we address the validity of other information CBR and the Staff offered to demonstrate containment, with other matters regarding containment adequacy raised by OST in the context of Concerns 1 to 4 addressed infra in sections VI to IX, so that they will not be repeated here.

Of the seven Staff-identified items we consider convincing evidence of BC/CPF containment, four are independent of the May 2011 pumping test. Relative to Contention 2, these multiple independent lines of evidence, separate from the aquifer pumping test, are a

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[352] See id. at 13; Staff Rebuttal Test. at 15 (Back, Lancaster, Striz) (citing Todd Text at 45–46 (stating that storativity values for a confined aquifer range between 5×10^{-5} and 5×10^{-3})).

[353] See Test #8 Rep. at 13; id. app. C at PDF 80, 82 (graphs C1 & C3).

significant testament to the validity of CBR's assessment of the degree of containment provided by the BC/CPF sandstone aquifer. Moreover, while none of Dr. Kreamer's hypothetical rebuttals are infeasible, the fact remains that given what the evidentiary record reflects is a thick UCU, the only way containment can be breached sufficiently to jeopardize UCU integrity is if essentially all of Dr. Kreamer's hypotheses come to fruition to nullify each of the remaining seven Staff-identified containment items. On the other hand, any one or more of these seven Staff-identified items would provide a reasonable basis for concluding that the BC/CPF is isolated so as to prevent that aquifer from impacting the overlying Arikaree/Brule aquifer. In the face of the strong evidentiary basis for each of these seven Staff-identified containment items, we find it is highly unlikely that any of Dr. Kreamer's hypotheses will come to pass and we therefore discount these responses in favor of the Staff's and CBR's evidence supporting aquifer containment.

Therefore, based on the evidentiary record before us, we conclude that the allegations raised by Dr. Kreamer do not indicate a significant loss of containment for, or demonstrate the connectivity properties of, the BC/CPF aquifer to the extent that the safe operation of the Marsland ISR facility or environmental impacts from the proposed extraction operations at the Marsland site would be adversely affected in any meaningful way. The Board also finds that the multiple lines of additional support for BC/CPF aquifer containment, four of which are independent of the May 2011 pumping test, are compelling and consistent with the Applicant's interpretation of the pumping test analyses. In contrast, nothing approaching that level of support has been proffered by OST to augment the Intervenor's central assertion that the BC/CPF is not contained because of the discontinuities (i.e., late-time curve flattening of the drawdown curves) in the pumping test data for two of the eight monitoring wells (i.e., CPW-1/1A, Monitor-3). At the same time, evidence presented by the Staff and CBR effectively refuted

OST's claims that such discontinuities can be attributed to factors that are unrelated to a loss of containment.[354]

The Board thus finds that the weight of the evidence is heavily in favor of the Applicant's and Staff's conclusions that the BC/CPF will adequately contain contaminants generated by CBR's MEA mining activities.

VI. CONCERN 1: INADEQUATE DESCRIPTION OF AFFECTED ENVIRONMENT

Having addressed the overarching issues concerning hydrological conditions raised by OST regarding Contention 2, we turn now to consideration of the more specific matters raised in the context of Contention 2's four concerns. As was noted previously, Concern 1 challenges "the adequacy of the descriptions of the affected environment for establishing the potential effects of the proposed MEA operation on the adjacent surface water and groundwater resources."[355] Based on the OST witness testimony addressing this concern, the focus of this concern involves two subjects, i.e., stratigraphy and possible contaminant pathways, and affected surface and subsurface environments. We address each in turn.

A. Concern 1A – Stratigraphy and Contaminant Pathways

1. Stratigraphy of Water-Bearing Rocks in Northwestern Nebraska

The stratigraphy of northwestern Nebraska has been documented in a previous proceeding regarding the license renewal for CBR's existing ISR facility,[356] which has

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[354] See Staff Rebuttal Test. at 19–20 (Back, Lancaster, Striz) (indicating late-time curve flattening could be caused, as CBR suggests, either by increase in transmissivity away from the pumping well, release of water from storage in the first several feet of aquitard, or wellborne/near-wellborne storage effects).

[355] LBP-18-3, 88 NRC at 53.

[356] See Crow Butte Res., Inc. (In Situ Leach Facility, Crawford, Nebraska), LBP-16-13, 84 NRC 271, 287–302 (2016), petition for review denied, CLI-18-8, 88 NRC __, __–__ (slip op. at 4–6 (Nov. 29, 2018).

contributed to the stipulated understandings of the geology and hydrogeology of the MEA presented supra in sections IV.B and IV.C. The parties' positions and the Board's findings on stratification issues beyond those stipulations are the subject of this section.

a. Parties' Positions on Disputed Stratigraphy in Northwestern Nebraska

OST witnesses Wireman and Dr. LaGarry provided testimony regarding the disputed issues associated with the stratigraphy in northwestern Nebraska, with an emphasis on the strata underlying the MEA. Mr. Wireman stated in his initial testimony that the structural geologic setting in northwest Nebraska is more complex than previously reported by CBR. He asserted as well that there is a specific disagreement between CBR and previous researchers about the existence of two major east-west trending faults — the Pine Ridge fault to the north of the Pine Ridge escarpment and the Niobrara River fault, which trends parallel to the Niobrara River — and other fracturing associated with these two faults. According to Mr. Wireman, CBR concluded that the faults do not exist in the MEA and, therefore, provided no discussion about whether these structures affect groundwater flow in the Arikaree/Brule and the BC/CPF aquifers.[357]

Dr. LaGarry claimed in his direct and rebuttal testimony that these potential faults north and south of Marsland may allow production fluids to travel upward into the overlying aquifers and laterally into adjacent areas to the east and west.[358] Referencing Figure 1 of his initial testimony, Dr. LaGarry stated that the Niobrara River and Pine Ridge faults are among those that were large enough to be discovered by other researchers who compiled data from

[357] See Wireman Initial Test. at 3.

[358] See LaGarry Initial Test. at PDF 5–6 (citing Swinehart Article & Diffendal Article); LaGarry Rebuttal Test. at 1.

approximately 12,500 borehole records in western Nebraska and had drilled new boreholes at five-mile intervals along the transect shown in Figure 1.[359]

Staff witnesses Back and Lancaster testified that regional interpretation of the strata provided by the Swinehart article, and the lineament analyses in the Diffendall article (both of which Dr. LaGarry relied upon as sources for his claim of permeable pathway faults), pale in comparison to the analysis performed by the Applicant, who used site-specific cross-sections created with geophysical log data and drill cuttings from the MEA site.[360] CBR witnesses Lewis, Nelson, Pavlick, and Shriver did concede that faults may exist at a regional level, but testified that none seemed sufficient to affect confinement or transmit production fluids. Furthermore, based on the undisputed evidence that the BC/CPF is a confined aquifer, they stated it is highly unlikely the MEA contains a fault or a connected pathway of faults in the UCU that is capable of transmitting contaminants.[361]

Also, as we have detailed previously, the parties disputed the location and potential impact on the MEA of both the Pine Ridge and Niobrara River faults.[362] Additionally, disputed party positions concerning Mr. Wireman's challenges regarding structural geology characterization are presented later in this decision.[363]

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[359] See LaGarry Initial Test. at PDF 4–6. As we indicated previously, see supra note 2411, Figure 1 of Dr. LaGarry's initial testimony is an annotated version of cross-section A-A' of the Swinehart article.

[360] See Staff Initial Test. at 34.

[361] See CBR Rebuttal Test. at 23 (citing Hydraulic Containment Report).

[362] See supra section V.B.

[363] See infra section VI.B.2.

c. Board Findings on Disputed Stratigraphy in Northwestern Nebraska

In connection with the dispute over stratigraphy within the MEA region, the Board's findings regarding the issue of aquifer heterogeneity and anisotropy from fracturing/faulting that previously was discussed in detail in section V.B.2 and the disagreement regarding Mr. Wireman's structural geology characterization concerns as set forth below in section VI.B.2 are detailed in those sections and will not repeated here. Concerning the potential effects of fracturing within the MEA, however, as a general matter, the Board observes that OST relied heavily on the lineament study in the Diffendal article, which has not been field-verified within the MEA, and the Swinehart article, the geologic cross-sections from which cover western Nebraska areas that do not pass through the Marsland site, but rather lie more than seven miles east and 30 miles west of the MEA. As a consequence, neither study establishes that the Pine Ridge or Niobrara River faults transect the MEA.[364] The absence of these faults in the MEA is consistent with CBR's assertion that there is little fracturing and faulting of the BC/CPF within the MEA, a conclusion derived from studying over 1600 geophysical logs of subsurface conditions at the site.[365] Moreover, besides failing to show that these faults cross the MEA, Dr. LaGarry confirmed that both the Diffendal and Swinehart articles, are stratigraphic reports that do not include any information on the transmissivity or preferential flow patterns through fractures, which are the critical factors for demonstrating whether there is contaminant flow between the aquifers.[366]

2. <u>LaGarry's Position on Contaminant Pathways</u>

Dr. LaGarry stated in his initial testimony that an ISR facility at the Marsland site would likely release toxic heavy metal contaminants, including but not limited to uranium, through three

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[364] <u>See</u> Staff Initial Test. at 33–35 (Back, Lancaster); Tr. at 794–95 (LaGarry), 829–35 (Lancaster, LaGarry).

potential pathways: surface leaks and spills, underground leaks and spills, and lack of containment. Furthermore, referencing Figure 1 in that testimony, Dr. LaGarry claimed that once these contaminants are in the aquifer, they would migrate laterally through porous, permeable sandstones to the White and Niobrara rivers.[367] Based on these potential pathways for toxin migration, it was Dr. LaGarry's assertion that CBR's application for an MEA ISR facility should be denied because groundwater contamination of the Arikaree/Brule aquifer would result in irreversible and catastrophic impacts to local agriculture and the Niobrara River — a National Scenic River used for recreation by thousands of people each year — that he declared would likely lead to depopulation of the region.[368] Each of these facets of Dr. LaGarry's testimony is discussed in the following sections.

a. Surface Leaks and Spills Pathways

i. Parties' Positions on Surface Leaks and Spills Pathways

In his initial testimony, Dr. LaGarry expressed a concern about surface leaks and spills, asserting that the soils in western Nebraska are thin and lie directly over permeable, porous sandstone bedrock. Citing Figure 1 in his initial testimony that he indicated showed the interval of the aquifer vulnerable to surface leaks and spills, Dr. LaGarry maintained that any leaks or spills of production fluids would be transmitted directly into the unconfined Arikaree/Brule aquifer "within a few years."[369]

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[365] See Tech. Rep. at 3-7, Tr. at 805–06 (Lewis); CBR Rebuttal Test. at 23 (Lewis, Nelson, Pavlick, Shriver).

[366] See Tr. at 793 (LaGarry).

[367] See LaGarry Initial Test. at PDF 5.

[368] See id. at PDF 6.

[369] Id. at PDF 5.

Staff witnesses Back and Lancaster agreed with Dr. LaGarry that spills or leaks of production fluids or wastewater at the MEA could impact surface waters or the Arikaree/Brule aquifer.[370] They observed, however, that the Staff in its EA concludes that such impacts to surface water and groundwater from spills and leaks would be "SMALL" because of the extensive operational controls, procedures, and monitoring that CBR will have in place at the MEA to prevent and detect spills and leaks and minimize any possible impacts should such spills occur.[371] The Staff also indicates in its EA that, in addition to CBR's Safety, Health, and Environment Quality Management System (SHEQMS) to ensure workers and crew exercise due diligence in addressing environmental, health, and safety matters, the Applicant has complementary plans in place, including (1) a Spill Prevention, Control, and Countermeasure (SPCC) plan to manage accidental discharge (including requirements for reporting, spill response, and cleanup measures); and (2) a Storm Water Pollution Prevention Plan (SWPPP) requiring the Applicant to develop a storm water management and spill response plan that identifies personnel responsible for implementing the SWPPP along with an employee education program to ensure effective plan implementation.[372] Finally, according to the Staff's EA, CBR has committed to following best management practices (BMPs) to control erosion, minimize disturbance, and facilitate reclamation as described in its MEA TR.[373]

Based on all this, the Staff concludes in its EA that the design and engineering controls for the proposed MEA facility will collect and properly dispose of any potentially contaminated stormwater runoff or snowmelt during facility construction and operation. And in addition to the

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[370] See Staff Initial Test. at 36–37.

[371] See id. (citing EA at 4-10 to -13, 4-22 to -23).

[372] See EA at 4-9, 4-11.

[373] See id. at 4-9.

engineering and procedural controls contained in the SWPPP, SHEQMS, and SPCC plan, the Staff notes in the EA that CBR's NDEQ-issued National Pollutant Discharge Elimination System (NPDES) permit requires CBR to remediate spills of petroleum products or hazardous chemicals that may enter surface waters or related habitats.[374]

CBR witnesses Lewis, Nelson, Pavlick, and Shriver also disputed Dr. LaGarry's claim that surface leaks and spills at Marsland could be transmitted to the Arikaree/Brule aquifer "within a few years," declaring that Dr. LaGarry's claim is speculation and not supported by any evidence or transport analysis. According to these witnesses, data from boreholes and geophysical well logs of surficial soils and shallow subsurface sediments at the MEA indicate the site is underlain by 30 ft. to something over 100 ft. of unsaturated sediments between the ground surface and the underlying water table, including layering of low permeability materials. As a result, they maintained, much of the Arikaree/Brule aquifer has a limited lateral extent and is interbedded with low-permeability siltstones, claystones, and mudstone units. In their view, the significant thickness of the unsaturated zone and the presence of low permeability materials would reduce the likelihood of downward migration of any spilled processing solutions into the underlying water table. From this, these CBR witnesses concluded that in the unlikely scenario of a surface spill migrating through unsaturated sediments into Arikaree/Brule aquifer, the leak would be extremely limited in extent, both laterally and vertically.[375]

ii. Board Findings on Surface Leaks and Spills Pathways

In addressing Dr. LaGarry's concerns regarding surface leaks and spills, the Board finds significant that, as is described in the Staff's EA, the Applicant is to follow the engineering and procedural controls contained in the SWPPP, SHEQMS, and SPCC that are designed to detect,

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[374] See id. at 4-9, 4-10 to -11.

[375] See CBR Rebuttal Test. at 21.

isolate, and remediate such accidents should they occur, as well as to remediate spills of petroleum products or hazardous chemicals into surface waters or related habitats in accordance with CBR's NPDES permit.[376] And while Dr. LaGarry maintained that surface spills will reach the Arikaree/Brule aquifer within a few years, we find this timing estimate unlikely due to the extensive depth of unsaturated strata, including a significant thickness of low permeability material across much of the site. Similarly, the Board finds that in the unlikely event of a surface spill migrating through unsaturated sediments into the Arikaree/Brule aquifer, the seepage would be extremely limited in extent, both laterally and vertically.[377]

Given the evidentiary record establishing the controls and requirements of CBR's SHEQMS, SWPPP, and SPCC plans, as well as CBR's NDEQ-issued NPDES permit, all designed to ensure that surface leaks and spills will not be a source of contaminant release, we conclude that Dr. LaGarry's concern that spilled contaminants will have any appreciable impact on surface or groundwater resources lacks a sufficient evidentiary basis.

b. Underground Leaks and Spills Pathways

i. Parties' Positions on Underground Leaks and Spills Pathways

Regarding potential underground (as opposed to surface) leakage, Dr. LaGarry pointed out in his initial testimony that to reach the uranium in the BC/CPF, wells will need to be drilled through the Arikaree/Brule aquifer, creating a potential interconnection between these aquifers. Likewise, referencing his initial testimony Figure 1 as showing the interval of this aquifer that is vulnerable to impact, Dr. LaGarry asserted that contamination into the shallow unconfined

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[376] See EA at 4-9, 4-10 to -11.

[377] See CBR Rebuttal Test. at 21 (Lewis, Nelson, Pavlick, Shriver).

Arikaree/Brule aquifer from underground leaks and spills attributable to such wells would be catastrophic because such contaminants would quickly spread throughout the aquifer.[378]

Disputing Dr. LaGarry's allegation regarding possible Arikaree/Brule aquifer contamination due to leaking buried well piping, CBR witnesses Lewis, Nelson, Pavlick, and Shriver testified that CBR has evaluated potential underground spills and the subsequent migration of fluids to overlying aquifers, and has established controls to prevent such an occurrence. To seal off aquifer communication between the Arikaree/Brule and BC/CPF aquifers caused by borehole drilling, these Crow Butte witnesses testified that CBR plugs all exploration holes to maintain the isolation of the mineralized zone and prevent commingling of groundwater with the Arikaree/Brule aquifer. Regarding well casing breaches, these witnesses declared that mechanical integrity tests (MIT) will be performed prior to placing a well into service, as required by NDEQ's underground injection control (UIC) program that ensures all wells are constructed properly and are capable of maintaining pressure without leakage. In addition, these CBR witnesses noted that monitoring wells located in the overlying Arikaree/Brule aquifer will be tested every two weeks during operations to detect the presence of lixiviant.[379]

CBR witnesses Lewis, Nelson, Pavlick, and Shriver also stated that Dr. LaGarry's underground leakage concern is hypothetical and ignores the Applicant's other operational practices, well-construction requirements, and site-specific conditions that will help to prevent unwanted contamination from buried pipe leaks. According to these witnesses, besides plugging abandoned wells, pressure testing well casings, and monitoring the upper aquifer for production fluids, Crow Butte will take other steps to minimize the potential for leaks and spills. These include continuous, around-the-clock flow monitoring by control room operators using

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[378] See LaGarry Initial Test. at PDF 5.

[379] See CBR Rebuttal Test. at 21–22.

visual and audible alarms triggered by a significant piping failure, thereby allowing flow to be stopped to prevent any significant migration of process fluids. In this same vein, these CBR witnesses indicated that wellfield buildings are equipped with wet alarms for early detection of leaks and explained as well that piping from the wellfield will be buried, minimizing the possibility of an accident.[380] Additionally, these CBR witnesses identified site-specific conditions, including the strong downward hydraulic gradients and the large thickness of the confining units at the Marsland site, that they contended help in preventing upward travel of processing solutions into the overlying Arikaree/Brule aquifer.[381]

Endorsing CBR's efforts in this regard, Staff witnesses Back and Lancaster reiterated that CBR will install monitoring wells in the shallowest Arikaree/Brule aquifer at a density of one well per four acres and, as required by License Condition 11.1.5, to detect leakage CBR will sample these monitoring wells every 14 days for indicators of lixiviant.[382] The Staff also indicates in its EA that, in response to the Staff's request,[383] to assess potential impacts from a leaky pipe on the only irrigation well within the MEA license area and the facility's area of review (AOR) (albeit outside the MEA itself), CBR analyzed the potential hydrologic impacts that might be occasioned by a hypothetical shallow casing leak from a processing well in the nearest MU to this irrigation well.[384] To achieve this, in 2013 CBR simulated groundwater flow in the shallow

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[380] See id. at 22.

[381] See id. at 22–23 (citing Hydraulic Containment Report).

[382] See Staff Initial Test. at 39–40 (citing EA at 2-6, 6-2; CBR License Amend. 3, at 17).

[383] See Tr. at 840 (Back).

[384] See EA at 4-22; see also Ex. CBR010 (Tech. Rep. app. AA-1 (Letter from Robert L. Lewis, Aqui-Ver, Inc., to Doug Pavlick, CBR (Dec. 10, 2013) [hereinafter Initial Well Impact Analysis]; Ex. CBR011 (Tech. Rep. app. AA-2 (Letter from Robert L. Lewis, AquiferTek, to Doug Pavlick & Larry Teahon, CBR (May 11, 2016) [hereinafter Revised Well Impact Analysis]. The CBR TR indicates that the MEA license area is approximately 4622.3 acres that encompasses the 11 MUs, while the AOR conforms to the NDEQ requirement as the area at a 2.25 mile radius from these MUs that is utilized for assessing land and water use surrounding the MEA.

Arikaree/Brule aquifer at the MEA by employing a numerical groundwater flow model that used particle-tracking techniques and a worse-case capture zone scenario, which was done to illustrate the 30-year capture zone of the irrigation well and assess whether a hypothetical shallow casing leak from the MEA wellfields could potentially impact the quality of the irrigation water.[385] In 2016, a revision to the initial 2013 modeling was performed to correct the location of the irrigation well. Initially, this revision calibrated the existing groundwater flow model using 2014 irrigation water-level data, and then re-calculated the calibrated 30-year capture zone of the irrigation well.[386]

According to the revised CBR well impact analysis, the results of this modeling demonstrate that MEA wellfields are not located within the capture zone of this sole nearby irrigation well, meaning that, under similar operating conditions, a shallow casing leak within the MEA wellfields will not impact the irrigation well at any time in the future. Further, using the same worse-case capture zone scenario as the 2013 analysis, the revised well impact analysis concludes that no other wells outside the MEA boundary will be impacted by a potential release of MEA lixiviant to the shallow aquifer given the location of other irrigation and domestic wells in the area.[387] As a result, CBR maintains that the current MEA shallow groundwater monitoring network is adequate to ensure the protection of human health and environment.[388]

See Tech. Rep. at 2-3, 8-3; Tech. Rep. Figs. at 9, 11 (figs. 2.2-1, 2.2-3); see also Tr. at 590 (Pavlick).

[385] See Initial Well Impact Analysis at 3–4.

[386] See Revised Well Impact Analysis at 1.

[387] See id. at 3 (citing id. at 6 (fig. 4)).

[388] See Tech. Rep. at 2-118 to -119; see also Revised Well Impact Analysis at 3.

ii. Board Findings on Underground Leaks and Spills Pathways

While Staff witnesses Back and Lancaster agreed with Dr. LaGarry that underground leaks and spills at the MEA from buried piping and well casing failures could impact groundwater from the Arikaree/Brule aquifer,[389] based on the evidentiary record the Board finds that Crow Butte will institute multiple initiatives that should adequately minimize the potential for adverse impacts from underground leaks and spills. These include (1) implementing a comprehensive monitoring program (including a monitoring well ring and corrective actions) to detect and mitigate any leaks or spills should they occur; (2) installing all wells using standard techniques, leak-testing all piping before placing the piping into service, and burying piping from the wellfield to minimize the possibility of a pipe-failure-inducing accident and a related release of processing solutions; (3) monitoring production flows 24 hours a day/7 days a week using visual and audible alarms that sound in the event of a pipe failure and allowing for the shut-off of process flow to prevent any significant migration of process fluids; and (4) equipping wellfield buildings with wet alarms for early detection of leaks. Also, we find that the strong downward hydraulic gradients between the Arikaree/Brule aquifer and the BC/CPF, along with the extensive thickness and low permeability of the UCU at Marsland, will prevent upward movement of ISR solutions into the overlying aquifers.[390]

The Board finds further that CBR adequately assessed potential impacts of a leaky pipe on the only irrigation well within the MEA's AOR by modeling groundwater flow in the shallow Arikaree/Brule aquifer at the MEA to evaluate whether a hypothetical shallow casing leak from

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[389] See Staff Initial Test. at 36.

[390] See CBR Rebuttal Test. at 22–23 (Lewis, Nelson, Pavlick); see also Hydraulic Containment Report at 1–2.

the MEA wellfields could potentially impact the quality of the irrigation water.[391] The results of this numerical analysis indicate that MEA wellfields are not located within the capture zone of this sole nearby irrigation well,[392] leading us to conclude that a shallow casing leak within the MEA wellfields is unlikely to impact this irrigation well in the future, if operating under similar conditions to those used in this modeling. The Board also finds that, based on CBR's 2013 and 2016 well impact modeling analyses, it was reasonable for CBR and the Staff to conclude that no other wells outside the MEA boundary will be impacted by a potential release of MEA lixiviant to the shallow aquifer, and the current MEA shallow groundwater monitoring network is adequate to ensure the protection of human health and the environment.[393]

c. Possible Containment Pathways

i. Parties' Positions on Possible Containment Pathways

Dr. LaGarry raised another concern regarding containment pathways by claiming that BC/CPF containment is lacking due to bedrock fracturing in the Marsland area that will allow leaks or excursions that might occur to migrate through these openings. This same issue has already been considered more generally supra as part of sections V.B and V.C, and that discussion will not be repeated in its entirety here. But to summarize, Dr. LaGarry's allegation of a lack of BC/CPF containment due to fracturing is based primarily on the works of Diffendal, showing several potential faults in the Marsland area, and the Swinehart article showing (per the previously discussed Figure 1 of his initial testimony) known faults both north and south of the proposed Marsland facility that may allow the transmission of production fluids to travel upward

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[391] See Initial Well Impact Analysis at 1–5; Revised Well Impact Analysis at 1–3; see also EA at 4-22.

[392] See Revised Well Impact Analysis at 3 (citing id. at 6 (fig. 4)).

[393] See Tech. Rep. at 2-118 to -119; see also Revised Well Impact Analysis at 3.

into the Arikaree/Brule aquifer and laterally into adjacent areas to the west and east.[394] And in addition to these identified faults, Dr. LaGarry stated that, based on his work over the past 25 years as supported by other referenced literature,[395] there are likely hundreds more BC/CPF fractures in both Nebraska and South Dakota that are too small to be shown on a diagram such as that in his initial testimony, but that nonetheless will transmit leaks and spills.[396]

Staff witnesses Back and Lancaster were critical of Dr. LaGarry, however, for relying on studies based on Diffendal's lineament analysis and the Swinehart article's large-scale (regional-level) cross-sections, which are derived from widely spaced boreholes placed at five-mile intervals.[397] Specifically, these Staff witnesses stated that Diffendal's analysis of lineaments involved observations based on large-scale mapping, and they further asserted that any claim that a lineament represents a subsurface geologic fault, fracture, or joint is speculative until field verification is performed.[398] On this count, Dr. LaGarry concurred that lineaments are not necessarily fractures with hydrogeologic performance, which can only be verified by a site investigation.[399] But according to these Staff witnesses, no investigation has been done for the lineaments described in the Diffendal article,[400] and, in any event, none of the

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[394] See LaGarry Initial Test. at PDF 5–6.

[395] See LaGarry Rebuttal Test. at 1 (citing Ex. OST017 (Harmon Maher, Jr. & Robert D. Shuster, Poster, Significance of an ESE Fracture Direction in Tertiary Strata of South Dakota and Nebraska? (2012)); Ex. OST018 (Harmon D. Maher, Jr., Theoretical Framework for Great Plains Fracture Generation – Ver. 2 (draft Mar. 2012))).

[396] See LaGarry Initial Test. at PDF 6.

[397] See Staff Initial Test. at 33–34.

[398] See id. at 34–35.

[399] See Tr. at 795 (LaGarry).

[400] See Staff Initial Test. at 34–35 (Back, Lancaster).

evidence submitted by the Tribe indicated that such verification investigations have been completed in the area of the MEA.[401]

Regarding his other main technical source, Dr. LaGarry agreed that the Swinehart article, cross-section A-A', which intersects both the Pine Ridge Niobrara River faults and is used in Figure 1 of his initial testimony, is located 30 miles to the west of the MEA, while cross-section B-B' of the Swinehart article, which intersects the Pine Ridge fault but not the Niobrara River fault, is 7.5 miles to the east of the MEA.[402] Because these two cross-sections show that the Niobrara River fault ceases or deviates from the MEA somewhere between them, Dr. LaGarry conceded that, as with the Pine Ridge fault, the Niobrara River fault likely does not underlie the MEA.[403]

In contrast to the more general nature of Dr. LaGarry's referenced studies, Staff witnesses Back and Lancaster testified that the Staff's EA and SER provided a thorough discussion about reported MEA-area faults and their potential impacts on the hydrogeologic behavior of the underlying strata.[404] Based on its review of available literature and other data on such faults, as well as CBR's site-specific and regional cross-sections and CBR's site-specific and regional structure contour maps, in the EA the Staff indicates there is no evidence of vertical offsets indicative of faults within the MEA.[405]

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[401] During the hearing, Dr. LaGarry made reference to a master's degree thesis study in which a student from Chadron State College in northwestern Nebraska had field-checked a few lineaments and used statistics to corroborate the rest, but indicated he could not speak to the results because it had been sometime since he read the thesis. See Tr. at 795.

[402] See Tr. at 717, 826, 830–35.

[403] See Tr. at 833–34.

[404] See Staff Initial Test. at 32–33 (citing EA at 3-11 to -14; SER at 33-36).

[405] See EA at 3-11 to -14.

And as for the other fractures that Dr. LaGarry indicated he encountered over the past 25 years,[406] while CBR witnesses Lewis, Nelson, Pavlick, and Shriver acknowledged these features likely exist at a regional level, they maintained there is no evidence of a fault or fracture in the MEA that is sufficiently transmissive to serve as a conduit for potential contaminant migration.[407] Rather, based on what they asserted is the undisputed evidence of containment of the BC/CPF, they declared it is highly unlikely the MEA contains a fracture or a connected pathway of fracturing in the UCU that is hydraulically capable of transmitting contaminants.[408]

Finally, regarding Dr. LaGarry's claim that excursions from the MEA production zone into the Arikaree Group are a possible contamination pathway, Staff witnesses Back and Lancaster indicated that the pathway Dr. LaGarry describes is a vertical excursion from the BC/CPF sandstone aquifer into the overlying Arikaree/Brule aquifer. Yet, these Staff witnesses asserted, such excursion events are unlikely given the multiple bases establishing there is adequate vertical containment at the MEA, including (1) the plugging of all the abandoned exploratory drill holes at the MEA; (2) all the well casings installed at the MEA being subject to MIT initially and every five years thereafter; (3) the strong downward gradient at the MEA that would prevent upward migration of contaminants from the production zone to the overlying Arikaree/Brule aquifer; and (4) the thick, continuous UCU between the BC/CPF sandstone aquifer and the Arikaree/Brule aquifer, which is composed of clays, mudstones, and siltstones with very low hydraulic conductivity that would prevent vertical excursions.[409]

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[406] See LaGarry Initial Test. at PDF 5.

[407] See CBR Rebuttal Test. at 23.

[408] See id. (citing Hydraulic Containment Report).

[409] See Staff Initial Test. at 36–40 (citing EA at 3-32 to -34, 4-23, 5-2; SER at 36-37; CBR License Amend. 3, at 10–11 (License Condition 10.1.4)).

ii. Board Findings on Possible Containment Pathways

In support of his argument that fractures in the MEA-area bedrock will result in pathways through containment to the Arikaree/Brule aquifer, Dr. LaGarry relied heavily on the Diffendal and Swinehart articles, both of which we conclude contain significant limitations relative to our consideration of OST's containment pathways claim. Specifically, we find Diffendal's analysis is based on a lineament study that has not been field-verified within the MEA,[410] a concern that Dr. LaGarry recognized as well in his acknowledgement that lineament studies only detect a linear feature in the surface geography that must be field-verified to confirm that the feature indicates the presence of a fracture with hydrogeologic performance rather than some straight-line anthropogenic feature.[411] And while the evaluations in the Swinehart article were derived from field borings (albeit made at five-mile spacing intervals), we find that cross-section A-A' in that publication (used as Figure 1 in Dr. LaGarry's initial testimony) was 30 miles west of the MEA while cross-section B-B' was 7.5 miles to the east of the site.[412] Given the location of each of these cross-sections, the Board concludes these sections show that neither the Pine Ridge nor the Niobrara River faults likely underlie the MEA, a point that was conceded by Dr. LaGarry.[413] This is also consistent with CBR's reached conclusion after it studied over 1600 geophysical logs of subsurface conditions at the MEA site.[414] We also agree with Dr. LaGarry that the Swinehart article, like the Diffendal article, is a stratigraphic report that omits any information on

[410] See id. at 34–35.

[411] See Tr. at 794–95.

[412] See Tr. at 717, 826 (LaGarry), 829–35 (Lancaster, LaGarry).

[413] See Tr. at 833–34.

[414] See CBR Rebuttal Test. at 23 (Lewis, Nelson, Pavlick, Shriver); Tech. Rep. at 3-7.

the transmissivity or preferential flow patterns through these fractures, which is the critical factor in assessing potential contamination travel.[415]

Regarding the question of the significance of other fractures that Dr. LaGarry indicated he encountered over the past 25 years,[416] the Board agrees with CBR that faults and other fractures likely exist at a regional level, but concludes there is no evidence of a fault or fracture in the MEA with sufficient transmissivity to serve as a potential contaminant pathway.[417] Further, based on the essentially undisputed evidence of containment within the BC/CPF aquifer,[418] we agree with CBR that it is highly unlikely that the MEA contains a fracture or a connected pathway of fractures in the UCU capable of transmitting meaningful volumes of contaminants.[419]

Lastly, we find that Dr. LaGarry's claims about the prospect of vertical excursions from the BC/CPF sandstone aquifer into the overlying Arikaree/Brule aquifer fail to be persuasive in the face of the evidence presented by CBR and the Staff on this issue. Specifically, to preclude borings and wells from becoming potential conduits for contaminant flow, CBR has plugged and abandoned all exploratory drill holes at the MEA. In addition, all wells installed at the MEA will be subject to MIT initially and at subsequent five-year intervals.[420] Further, the weight of the evidence presented by CBR and the Staff, including the presence of strong downward gradients during MEA operation and the thick, continuous, low permeability UCU (composed of clays,

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[415] See Tr. at 792–93.

[416] See LaGarry Initial Test. at PDF 5.

[417] See CBR Rebuttal Test. at 23 (Lewis, Nelson, Pavlick, Shriver).

[418] See supra section V.C.3.

[419] See CBR Rebuttal Test. at 23 (Lewis, Nelson, Pavlick, Shriver).

[420] See Staff Initial Test. at 38–39 (Back, Lancaster) (citing EA at 4-23, 5-2; SER at 36–37; CBR License Amend. 3, at 10–11 (License Condition 10.1.4)).

mudstones and siltstones) between the Arikaree/Brule aquifer and the BC/CPF, demonstrates there will be adequate vertical containment of production fluids within the BC/CPF at the MEA site.[421]

d. Lateral Migration

i. Parties' Positions on Lateral Migration

As a final contamination pathway concern, Dr. LaGarry posited that once contaminants are in the underground aquifers, they will move laterally and, within a few years, could be drawn up to the surface by domestic and irrigation wells, springs (such as those that feed the White River), and the groundwater-fed Niobrara River. He contended that the resulting contamination would migrate eastwards (down gradient) to contaminate both the White River, which supplies the towns of Glenn, Crawford, Whitney, and Pine Ridge with water, as well as the Niobrara River, which is a National Scenic River used by thousands of people for recreation every year.[422] And in his rebuttal testimony, in response to the Staff's initial testimony questioning his positions on containment pathways, Dr. LaGarry reproduced a list of alleged facts from the hydrogeologic studies performed on portions of the Niobrara River by Hallum, et al.[423] At the hearing, he clarified that he adopted as his testimony only certain points of the Hallum studies

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[421] See CBR Rebuttal Test. at 22–23 (Lewis, Nelson, Pavlick); Staff Initial Test. at 39 (Back, Lancaster) (citing EA at 3-32 to -34).

[422] See LaGarry Initial Test. at PDF 6.

[423] See LaGarry Rebuttal Test. at 2–3 (citing Ex. OST020 at 2–3 (Douglas R. Hallum, et. al, Project Completion Report: Hydrogeologic Framework Studies of Portions of the Niobrara River (Mar. 2018))).

that were within his area of expertise,[424] albeit without clarifying how these adopted statements are relevant to his opinions on Contention 2.[425]

Disputing Dr. LaGarry's assertions that ISR contamination would migrate laterally into the White and Niobrara rivers, CBR witnesses Lewis, Nelson, Pavlick, and Shriver declared that his statements are hypothetical, speculative, and unsupported by data or other evidence.[426] They further stated that Dr. LaGarry's alleged migration pathways to the White and Niobrara rivers from the Marsland site are not plausible, given the MEA site conditions, CBR ISR facility operational practices, and the lack of any transport calculations or historical evidence as the basis for his claims.[427] CBR witnesses Lewis, Nelson, and Pavlick also declared that Dr.

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[424] See Tr. at 1004–10. At the hearing, Dr. LaGarry adopted the following four points from the seven listed in his rebuttal testimony (which are designated below by their rebuttal testimony numbers):

> 1. White River Group that outcrops along the valley margins create the impression and subsequent misconception (when analyzed regionally) that the reach lacks hydraulic connection between surface water and groundwater. This is not the case locally. See Tr. at 1004.
>
> 2. There is sufficient near-surface alluvium to conduct water between the stream and groundwater wells. See Tr. at 1005–06.
>
> 4. Irrigation wells in the aquifer absent area near the Niobrara River are hydraulically connected to the High Plains aquifer and/or alluvial fill of the Niobrara River valley. See Tr. at 1007.
>
> 6. At larger scales, it becomes apparent that the reach is in contact with sediments capable of conducting water, and that the formation's ability to conduct water will likely be affected by the available thickness of conductive sediments and the physical configuration of said sediment. See id.

[425] See Tr. at 1006. At the hearing, Dr. LaGarry also corrected his testimony relating to the direction from the MEA to the headwaters of the White River, changing the direction from east of the MEA to northwest of the MEA. Compare Tr. at 725 (east), with Tr. at 847 (northwest).

[426] See CBR Rebuttal Test. at 20–21.

[427] See id.

LaGarry's assertion that contaminated water could be drawn into agricultural wells, released into rivers, or migrate more than 15 miles to the White River are highly unlikely hypothetical events that rely on erroneous technical conclusions not backed by any data-driven or other evidentiary facts.[428] These CBR witnesses also testified that Dr. LaGarry's claim of a rapid contamination of the Niobrara River is without technical basis and implausible given the physical processes of dispersion, attenuation, and chemical dilution that would both retard any transmission and reduce the concentration of radioactive contaminants.[429]

Additionally, regarding the impacts of facility operations on irrigation wells near the MEA, CBR witnesses Lewis, Nelson, and Pavlick indicated that Crow Butte's groundwater flow modeling that derived the 30-year capture zone of a nearby irrigation well demonstrated that the MEA wellfields are not located within the capture zone of irrigation wells in the vicinity of the MEA. As such, they contended, a shallow casing leak within the MEA production wellfields will not impact area irrigation wells at any time in the future, given expected operating conditions.[430]

Also on this score, in its EA the Staff discusses the potential impacts of horizontal excursions (i.e., lateral migration of ISR production fluids within the BC/CPF sandstone aquifer) and concluded that any potential long-term impacts on groundwater quality would be "SMALL."[431] Furthermore, Staff witnesses Back and Lancaster explained that while lateral migration of production fluids is possible, such movements should be infrequent and the impacts minor for the previously highlighted reasons that (1) the wellfields are required by License

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[428] See id. at 24.

[429] See id.

[430] See id. at 24–25 (citing Tech. Rep. at 2-118).

[431] See EA at 4-21 to -22.

Condition 10.1.6 to be under an inward hydraulic gradient to contain process fluids;[432] and (2) the BC/CPF aquifer will be monitored by a ring of wells surrounding each wellfield that, in accordance with License Condition 11.1.5, will be tested on a biweekly basis. If migration is confirmed, these Staff witnesses explained, CBR is to take corrective actions (e.g., adjusting wellfield extraction and injection rates to draw fluids back into the wellfield) and initiate more frequent weekly sampling from the ring of monitoring wells.[433]

And relative to Dr. LaGarry's assertion that contaminates could escape via lateral migration into the Arikaree/Brule aquifer, Staff witnesses Back and Lancaster stated that both the vertical containment at the MEA and the downward gradient between the overlying aquifers and the BC/CPF sandstone aquifer in the vicinity of the MEA would prevent such fluids from moving up to any of the locations Dr. LaGarry identified.[434]

ii. Board Findings on Lateral Migration[435]

The Board finds that Dr. LaGarry's claim that contaminated groundwater in the BC/CPF aquifer would be drawn up to the surface within "a few years" is speculation that lacks any reasonable hypothesis about the mechanisms or timing needed for this event as well as any supporting transport calculations, consistency with site data, or backing from historical data. We conclude as well that Dr. LaGarry's statement regarding contamination escaping into the Arikaree/Brule aquifer (and migrating to both the White and the Niobrara rivers) contains no viable explanation about how the contamination would manage to migrate from the BC/CPF into

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[432] See Staff Initial Test. at 40 (citing EA at 2-8, 4-16; CBR License Amend. 3, at 11 (License Condition 10.1.6)).

[433] See id. (citing EA at 4-21; CBR License Amend. 3, at 17 (License Condition 11.1.5)).

[434] See id. at 41 (citing EA at 3-34).

[435] For a more detailed discussion of the associated issue of groundwater flow see infra section VI.B.1.a.

the Arikaree/Brule aquifer in the first place, particularly given the lack of record evidence demonstrating the presence of transmissive fracturing in the area of the MEA.

We also find that Dr. LaGarry's claim that the degraded groundwater in the High Plains aquifer "would likely migrate eastwards (down gradient) and contaminate the White River"[436] is in error as "eastward" is not the down gradient direction of groundwater flow for the Arikaree/Brule aquifer, which has an established southeasterly flow across the MEA.[437] And while, in an attempt to bolster his testimony, Dr. LaGarry adopted some alleged facts concerning the hydrogeologic studies performed on portions of the Niobrara River (limiting his selection to those factors within his area of expertise),[438] we assign no weight to these facts in our decision, because Dr. LaGarry failed to clarify how these adopted statements are relevant to his opinions on Contention 2.

In responding to Dr. LaGarry's assertions about potential lateral migration, Crow Butte stated that its groundwater flow modeling of the 30-year capture zone of the only irrigation well near the MEA demonstrated that the MEA wellfields are not located within the capture zone of local irrigation wells.[439] The Board finds that CBR's modeling does not necessarily fully negate Dr. LaGarry's claim because, while we agree this modeling shows that a shallow casing leak within the MEA wellfields will not impact irrigation wells in the vicinity of the MEA, it does not address Dr. LaGarry's broader concern that contaminants anywhere in the Arikaree/Brule aquifer (not just at locations of failed well casings) might be picked up by other irrigation wells. Nonetheless, CBR's not having prevailed in toto on this particular point is not significant to our

[436] LaGarry Initial Test. at PDF 6.

[437] See CBR Rebuttal Test. at 14 (Lewis, Nelson, Pavlick).

[438] See Tr. at 1004–10.

[439] See CBR Rebuttal Test. at 24–25 (citing Tech. Rep. at 2-118).

findings regarding lateral migration given Dr. LaGarry's more telling failure, in the face of the CBR and Staff evidence regarding BC/CFP containment,[440] to provide any specific evidence or a defensible hypothesis explaining the migration of the contaminants from the BC/CPF to the Arikaree/Brule aquifer, other than his already-rejected assumption of structural fracturing in the MEA's geologic strata.[441]

The Board further finds Dr. LaGarry's testimony that a contaminated Arikaree/Brule aquifer could impact supply wells within a few hours, that the groundwater in this aquifer flows eastward, and that contaminates will migrate more than 15 miles to the White River is conjecture that is not supported by any available data in the record of this proceeding and lacks any technical foundation. And concerning lateral migration within the BC/CPF, we find that because the BC/CPF groundwater flow is to the northwest and away from the Niobrara River, we agree with the Staff's estimate that, should it occur, any lateral excursion of MEA production fluids would attenuate by sorption and dilution during the many decades it would take for groundwater to migrate from the MEA toward the reported Pine Ridge fault and northwest discharge points.[442] As a final matter, we state our agreement with CBR's assessments that Dr. LaGarry's brief description of contaminant transport pathways to the White and Niobrara rivers from the Marsland site is not reasonable given MEA site conditions (e.g., strong downward gradients from the Arikaree/Brule aquifer through the thick UCU to the BC/CPF aquifer) and operational mandates at the ISR facility (e.g., maintaining inward gradients within each MU

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[440] See supra section V.C.

[441] See supra section VI.A.

[442] See EA at 3-14 (citing ER at 3-47 to -50).

during operations), and the fact that Dr. LaGarry's claims are not based on any reasonable transport calculations.[443]

B. Concern 1B – Affected Surface and Subsurface Environment

In his initial testimony, OST witness Wireman provided what he characterized as five "opinions" stating his criticisms of the CBR and Staff characterizations of the MEA area subsurface environment that he alleges would be affected by the planned operation of the Marsland ISR facility. Mr. Wireman's concerns address uncertainties in regional hydrogeology and groundwater flow, deficiencies in the assessment of the structural geology, misinterpretation of the aquifer pumping test, confusion regarding groundwater restoration standards, and inadequacies with the wastewater disposal design. Each of these topics are discussed in the sections that follow.

1. Wireman Opinion 1 – Regional Hydrogeology and Groundwater Flow

In his Opinion 1, Mr. Wireman stated that there is still too much uncertainty regarding groundwater flow in the BC/CPF aquifer. While noting that hydraulic characteristics associated with the Marsland site have been quantified via the May 2011 aquifer pumping test that provided data deemed necessary for ISR operations, he nonetheless concluded that there are no data to support the Applicant and/or Staff claims regarding (1) recharge and discharge to the BC/CPF; (2) downgradient MEA groundwater flow; (3) lack of perimeter groundwater monitoring wells; (4) absence of a surface water hydrology discussion; and (5) lack of baseline restoration well monitoring.[444] Each of these, a so-called "basis" for his Opinion 1, is outlined below, along with responses from CBR and the Staff to his claims and the Board's findings on each topic.

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[443] See CBR Rebuttal Test. at 20–21 (Lewis, Nelson, Pavlick, Shriver); Tr. at 819 (LaGarry).

[444] See Wireman Initial Test. at 2–3. Mr. Wireman also included an inadequate selection of meteorological data as a basis for his Opinion 1, which the Board struck from his testimony as not being within the scope of the contention. See Board In Limine Ruling at 7.

a. Wireman Opinion 1, Basis 1 – Recharge Sources and Discharge Locations of the BC/CPF Aquifer

i. Parties' Positions on Wireman Opinion 1, Basis 1 – Recharge/Discharge

As Basis 1, Mr. Wireman asserted that CBR has failed to include any information in its TR on sources of groundwater recharge in the BC/CPF and on the primary pathways that deliver water to the deep, confined aquifer. In addition, he stated that the only reference to discharge from the BC/CPF aquifer provided by CBR is a TR statement that the aquifer discharge occurs at a point east of Crawford where the formation is exposed.[445] Mr. Wireman asserted that CBR should conduct hydrogeologic mapping to locate and characterize the recharge and discharge areas for the BC/CPF. Mr. Wireman also stated in his rebuttal testimony that the lack of specific information regarding the groundwater flow system in the BC/CPF aquifer is apparent in that CBR's TR contains no data-based information on the areas where sources of recharge occur or on the definition of the primary pathways that deliver recharge to the deep, confined aquifer.[446]

Regarding this basis, CBR states in its TR that, based on confined groundwater flow conditions indicated by the potentiometric maps and cross-sections of the BC/CPF sandstone, the recharge zone for the BC/CPF is most likely located west or southwest of the MEA at a minimum elevation of 3715 ft. above mean sea level (amsl).[447] CBR also notes in the TR that the top of the basal sandstone of the BC/CPF occurs at much lower elevations within the MEA, ranging from approximately 3210 ft. to 3290 ft. amsl.[448] Also, according to Crow Butte's TR,

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[445] See Wireman Initial Test. at 2 (citing Tech. Rep. at 2-86).

[446] See Wireman Rebuttal Test. at 1–2.

[447] See Tech. Rep. at 2-86 (citing Tech. Rep. Figs. at 49–62 (figs. 2.6-3a to -3n), 113–16 (figs. 2.9-6a to -6d)).

[448] See id. (citing Tech Rep. Figs. at 49–62 (figs. 2.6-3a to -3n)).

groundwater flow in the BC/CPF in the vicinity of the MEA is predominantly to the northwest toward the White River at a lateral hydraulic gradient of 0.0004 feet per foot (ft./ft.).[449] And Crow Butte's TR indicates, based on regional water level information, that a discharge point at an elevation of at least as low as 3700 feet amsl (or below) is located east of Crawford, presumably at a location where the BC/CPF is exposed.[450]

Also relative to this basis, the Staff in its EA states that while the Pine Ridge escarpment acts as a groundwater divide for the Arikaree/Brule aquifer, this is not the case for groundwater flow in the BC/CPF where groundwater south of the Pine Ridge escarpment flows in a northerly direction.[451] According to the Staff's EA, groundwater within the BC/CPF aquifer flows from recharge areas farther south of Dawes County, northward through the MEA and the existing CBR ISR facility, and then discharges where erosion has exposed this formation on the land surface north of Crawford.[452] Reportedly, at one discharge location the BC/CPF crops out about 20 miles northwest of Crawford in Sioux County, Nebraska.[453]

CBR witnesses Lewis, Nelson, Pavlick, and Shriver also pointed out that, as illustrated by a conceptual diagram showing areas of recharge and discharge of the BC/CPF, recharge to the BC/CPF occurs as direct infiltration of precipitation where the formation is exposed at distant locations west and south of the existing CBR ISR facility and the MEA, and also may occur as a small amount of downward groundwater flow from the overlying confining unit.[454] Furthermore

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[449] See id.

[450] See id.

[451] See EA at 3-27.

[452] See id.

[453] See id.

[454] See CBR Rebuttal Test. at 13 (citing Ex. CBR021 (Conceptual Groundwater Flow Diagram, Basal Chadron Aquifer) (per Tr. at 595, this is the same figure as that in the EA

with respect to the recharge, CBR witness Lewis testified at the hearing that previous CBR geologic studies (including field checks of geologic mapping of the area) indicated that the BC/CPF outcropped regionally at distant locations (e.g., 60 miles southeast of Scottsbluff and other recharge areas a significant distance to the west) where there were some outcrop areas believed to be local recharge to the BC/CPF aquifer.[455] Mr. Wireman, however, questioned recharge 60 miles away because of a geologic feature he concluded blocked any recharge and prevented groundwater from getting into the portion of the BC/CPF underlying the MEA. It was his opinion, therefore, that the recharge has to be local.[456]

CBR witnesses claimed as well that discharge from the BC/CPF currently occurs primarily through the pumped wells at the existing CBR ISR facility and from flowing wells located near the town of Crawford. They also indicated that prior to the installation of flowing wells and the development of the existing CBR ISR facility, discharge from the BC/CPF occurred in drainages and by evapotranspiration in areas east and north of Crawford where the formation is exposed at and near the surface.[457]

CBR witness Lewis further clarified at the hearing that flowing well #123 and flowing well #97, which are located northeast of Crawford as shown in EA Figure 3-8,[458] have been flowing at about 40 gpm since at least the 1980s, and that pumping from the BC/CPF aquifer at the existing CBR ISR facility discharges 200 gpm to 240 gpm for a total of 280 gpm to 300 gpm

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at 3-29 (fig. 3-8), which apparently was provided to the Staff by CBR in an April 2016 open issues response, see EA at 10-1) [hereinafter Conceptual Flow Model Diagram])).

[455] See Tr. at 609–10.

[456] See Tr. at 612.

[457] See CBR Rebuttal Test. at 13 (Lewis, Nelson, Pavlick, Shriver).

[458] See EA at 3-29.

from both sources.[459] He added that there is no discharge from the BC/CPF aquifer into the White River because the formation does not outcrop in the White River, and that the elevation of the BC/CPF potentiometric surface is substantially below the elevation of the White River, thus precluding any discharge from this aquifer into the White River.[460]

Mr. Lewis thus offered his geologic interpretation that prior to development, discharge of the BC/CPF would have taken place in the tributaries north of Crawford, noting as well that the red dashed line in EA Figure 3-8, labeled “Extent of Basal Chadron Sandstone,” is an outcrop area for the BC/CPF. Mr. Lewis added that this hypothesis is backed by old aerial photographs from the 1960s and 1970s (prior to mineral extraction operations) showing that lush vegetation existed in these tributaries where now they are dry, meaning that prior to development of CBR’s existing main facility, discharge from the aquifer took place north of Crawford.[461] Furthermore, it is the Applicant’s claim that the distance of the recharge and discharge areas from the MEA are such that they will not affect the behavior of the BC/CPF aquifer at the MEA.[462]

ii. Board Findings on Wireman Opinion 1, Basis 1 – Recharge/Discharge

While Mr. Wireman stated that CBR’s TR failed to include any information on sources of recharge/discharge of groundwater in the BC/CPF,[463] the Board finds that recharge and discharge locations for the BC/CPF are in fact discussed in the CBR TR. Additionally, we find such information is included in CBR’s initial and rebuttal testimony and in the Staff’s EA and

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[459] See Tr. at 608, 620.

[460] See Tr. at 608.

[461] See Tr. at 608–09; see also CBR Rebuttal Test. at 13 (Lewis, Nelson, Pavlick, Shriver); Tr. at 598–99 (Lewis) (correcting rebuttal answer to indicate referenced town is Crawford rather than Chadron).

[462] See CBR Rebuttal Test. at 13 (Lewis, Nelson, Pavlick, Shriver).

[463] See Wireman Initial Test. at 2.

rebuttal testimony. Further, we find that the general locations of the discharge and recharge areas are described and shown on a CBR conceptual map that pictorially represents the groundwater flow regime from south of the MEA toward the northwest.[464]

We also find that CBR's description is based on the potentiometric maps and geologic cross-sections of the BC/CPF sandstone derived from actual field data. The Board concludes that CBR's claim regarding BC/CPF recharge and discharge sources is persuasive, including its supporting positions that (1) recharge to the BC/CPF occurs as direct infiltration of precipitation (at a minimum elevation of 3715 feet amsl) where the formation is exposed at distant locations west and south of the existing CBR ISR facility and the MEA; (2) discharge from the BC/CPF currently occurs primarily from wells being pumped at the existing CBR ISR facility and from flowing wells located near the town of Crawford; and (3) prior to ISR development and the installation of flowing wells, discharge of the BC/CPF took place in the tributaries north of Crawford and by evapotranspiration in drainages east and north of Crawford where the formation is exposed at or near the surface. The Board also agrees with the Applicant that the distances of the recharge and discharge areas from the MEA are such that they will not affect the behavior of the BC/CPF aquifer at the MEA.[465]

Mr. Wireman advocated more investigations, including hydrogeologic mapping, to refine the recharge and discharge locations of the BC/CPF. We find, however, that in the face of the CBR and Staff evidence regarding recharge/discharge, he failed to justify the need for such supplemental studies, providing no evidence indicating that the results of these proposed studies would have any measurable impact on the conclusions about recharge and discharge locations reached in CBR's TR and the Staff's EA. While such studies would no doubt be useful

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[464] See Conceptual Flow Model Diagram; Tech. Rep. at 2-86; CBR Initial Test at 33–34 (Lewis, Nelson, Pavlick); CBR Rebuttal Test. at 13 (Lewis, Nelson, Pavlick, Shriver), 14 (Lewis, Nelson, Pavlick); EA at 3-27 to -29, 10-1; NRC Rebuttal Test. at 2–3 (Back, Lancaster, Striz).

[465] See CBR Rebuttal Test. at 13 (Lewis, Nelson, Pavlick, Shriver).

in better understanding the regional hydrogeology at some distance from the MEA, we find it hard to understand how any additional definition of the discharge and recharge zones for the BC/CPF, beyond that proffered by CBR and the Staff as summarized in the previous section, would have much bearing on any assessment of the interconnectivity and containment properties of the BC/CPF. Nor do we see the acceptance criteria in NUREG-1569 section 2.7 or the requirements of NEPA mandating a higher level of detail on the discharge and recharge zones of the production aquifer than has already been provided by the Applicant. As a result, we find that CBR's TR description and the Staff's EA assessment of discharge and recharge zones are supported by substantial evidence that is adequate to meet the applicable AEA and NEPA standards of review.

b. Wireman Opinion 1, Basis 2 – Downgradient MEA BC/CPF Groundwater Flow

i. Parties' Positions on Wireman Opinion 1, Basis 2 – BC/CPF Groundwater Flow

As the second basis supporting his Opinion 1, Mr. Wireman stated that there is significant uncertainty about groundwater flow in the BC/CPF downgradient of the MEA, in part because of the claim in the Staff's EA that groundwater flow in this aquifer is not affected by the Pine Ridge escarpment. According to Mr. Wireman, there is no discussion to support this Staff EA statement even though this escarpment functions as a groundwater divide in the Arikaree/Brule aquifer.[466]

Citing to published references, the Staff's EA states that the Pine Ridge escarpment acts as a groundwater divide for the Arikaree/Brule aquifer, but does not act as a divide for groundwater flow within the BC/CPF. According to the EA, groundwater within the BC/CPF aquifer flows from recharge areas farther south of Dawes County northward through the MEA

[466] See Wireman Initial Test. at 2.

and the existing CBR ISR facility, until discharging north of Crawford.[467] Additionally, referencing regional and local hydraulic gradient data presented in potentiometric maps, CBR witnesses Lewis, Nelson, and Pavlick confirmed these EA statements by noting that this charting (created using field data) indicates that the Pine Ridge escarpment does not influence the groundwater flow in the BC/CPF and, therefore, no flow divide exists in this aquifer. They also stated that these observations are consistent with the CBR conceptual model of groundwater flow indicating no significant recharge to the BC/CPF along the Pine Ridge escarpment, a condition they assert is not unexpected given the substantial depth of the BC/CPF below the escarpment and the significant thickness of the UCU that isolates the BC/CPF from the Arikaree/Brule aquifer.[468]

According to these CBR witnesses, these observations are also consistent with the groundwater flow aspects of CBR's conceptual flow model that show consistent north to northwest flow in the BC/CPF underlying the MEA, which is in line with the pre-development and current regional flow direction observed in and around the existing CBR ISR facility north of Marsland.[469] Also, they maintained, consistent with the conceptual flow model, the groundwater flow in the overlying Arikaree/Brule aquifer is northwest through the existing CBR ISR facility, while being southeasterly beneath MEA. This observation, they asserted, clearly indicates that a flow divide exists between the existing facility and the MEA in the Arikaree/Brule aquifer due to significant recharge to the shallow formations exposed along the Pine Ridge escarpment.[470]

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[467] See EA at 3-27.

[468] See CBR Rebuttal Test. at 14 (citing Tech Rep. Figs. at 105–08 (figs 2.9-4a to -4d) (Arikaree aquifer), 109–12 (figs. 2.9-5a to -5d) (Brule aquifer), 113–16 (figs. 2.9-6a to -6d) (BC/CPF aquifer).

[469] See id. at 14 (citing Conceptual Flow Model Diagram).

[470] See id.

Furthermore, when Mr, Wireman expressed doubts at the hearing about CBR's position that the escarpment affects the Brule and Arikaree formations but not the BC/CPF,[471] CBR witness Shriver responded that the BC/CPF is nearly flat across the escarpment from the south, where the Niobrara River flows, through the Marsland site, across the Pine Ridge escarpment, through the existing CBR ISR facility, and northwesterly to the discharge zones. Mr. Shriver also claimed that, as the regional geologic cross-sections indicate, only minimal (if any) dip is present in the geologic structure of the BC/CPF, and that the Arikaree/Brule aquifer are recharged at the Pine Ridge escarpment where there is a groundwater divide with southern flow to the south of the escarpment and north-northwestern flow to the north of this feature.[472]

When asked about the geologic theory that justifies this allegedly mysterious dichotomy between the groundwater flows in the two strata as a result of the Pine Ridge escarpment, CBR witness Shriver opined that the BC/CPF, middle and upper Chadron, Brule, and Arikaree formations were deposited during the same time period as the structural deformation associated with the Pine Ridge escarpment. As a result, any structural upheaval that occurred did not affect the deposition of the BC/CPF and the overlying formations. And according to Mr. Shriver, subsequent erosion of the upper deposits occurred on the north side of the escarpment, but not to any degree on the south side, creating the flow divide now observed in the Arikaree/Brule aquifer.[473]

Staff witness Dr. Striz indicated she concurred with CBR's claims, referencing the detailed regional geological cross-section in Figure 2.6-23 of the CBR TR that spans the Pine Ridge fault, which is indicated by a green line, and the Cochran Arch, which is indicated by a

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[471] See Tr. at 616–17.

[472] See Tr. at 617–18.

[473] See Tr. at 618–20.

red line. Dr. Striz maintained that this cross-section is consistent with the CBR conceptual flow model and demonstrated only a minor dip in the BC/CPF aquifer, which is confirmed by the intact marker beds of Whitney ash within the Chadron Formation.[474] And with regard to the northern and southern groundwater flow in Arikaree/Brule aquifer on either side of the escarpment, Dr. Striz testified that the Pine Ridge escarpment is the northern boundary of these aquifers and is a well-known erosional escarpment with sediments eroded to the north, but not so much to the south. Dr. Striz thus concluded that CBR had made its case that both the BC/CPF and the Arikaree/Brule aquifer were not offset by any activity at the Pine Ridge escarpment.[475] Finally, CBR witness Shriver emphasized that the existence of the intact upper and lower Whitney ash layers made a compelling case that there is not displacement across the escarpment, adding that there are no offsets shown on the geophysical logs making up the geologic cross-sections.[476]

According to OST witness Dr. LaGarry, however, this CBR position refutes 70 years of geological literature that says otherwise.[477] And with regard to OST's criticism of general groundwater flow in the BC/CPF, Mr. Wireman testified that the CBR and Staff reports "are very confusing with respect to the direction of flow" and that the CBR conceptual flow model indicates that the groundwater flow in the BC/CPF is highly variable "from the north, from the northwest, from the west, from the southwest, from the south."[478] In his view, this is "very qualitative information, somewhat inconsistent and not supported by actual data."[479] And when

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[474] See Tr. at 621–24 (citing Tech. Rep. at 90 (fig. 2.6-23)).

[475] See Tr. at 624–25

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[476] See Tr. at 629–30.

[477] See Tr. at 625–27.

[478] Tr. at 601.

[479] Wireman Rebuttal Test. at 1.

queried during the hearing about whether these directions vary as a function of the flow lines for the groundwater in the BC/CPF, Mr. Wireman seemed to agree in part, but still alluded to numerous allegedly unexplained directions of groundwater flow for BC/CPF,[480] before finally agreeing that the BC/CPF flow is primarily from the south to north and northwest across the MEA.[481] Likewise, relative to its conceptual flow model, CBR states in its TR that groundwater flow in the BC/CPF in the vicinity of the MEA is predominantly to the northwest toward the White River at a lateral hydraulic gradient of 0.0004 ft./ft.[482]

ii. Board Findings on Wireman Opinion 1, Basis 2– BC/CPF Groundwater Flow

Basis 2 of Mr. Wireman's first opinion stated that there is no discussion to support the CBR and Staff statements that groundwater flow in the BC/CPF aquifer is not affected by the Pine Ridge escarpment even though this escarpment functions as a groundwater divide in the Arikaree/Brule aquifer.[483] We find, however, that Mr. Wireman erred in this instance, as the TR clearly stated that potentiometric maps and cross-sections of the BC/CPF indicated that confined groundwater flow in the vicinity of the MEA is predominantly to the northwest at a lateral hydraulic gradient of 0.0004 ft./ft., and that regional water level information for the Brule aquifer within the MEA (as depicted in potentiometric maps) shows that groundwater in the Brule Formation generally flows to the southeast across the entire MEA toward the Niobrara River at a lateral hydraulic gradient of 0.011 ft./ft.[484] The Board also finds that the referenced

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[480] See Tr. at 602–05.

[481] See Tr. at 601, 604–05, 616.

[482] See Tech. Rep. at 2-86.

[483] See Wireman Initial Test. at 2.

[484] See Tech. Rep. at 2-86 (citing Test #8 Rep.; Tech. Rep. Figs. at 49–62 (figs. 2.6-3a through 2.6-3n), 109–12 (figs. 2.9-5a to -5d), 113–16 (figs. 2.9-6a to -6d)).

potentiometric mapping provided in CBR's TR clearly shows these contrasting flow directions in these two aquifers,[485] and that OST provided no evidence to the contrary.

Mr. Wireman continued to state that the groundwater flow directions in the BC/CPF are uncertain, repeating at the hearing his rebuttal testimony position implying that CBR's licensing information shows unexplained indications of flow from "the north, from the northwest, from the west, from the southwest, from the south. It's unclear."[486] But with CBR's explanation of the discharge occurring at the flowing wells north of Crawford and from the active pumping at the existing CBR ISR facility, we find that both the conceptualized flow diagram[487] and the plots of potentiometric levels in the BC/CPF[488] show that the flow across the MEA is to the northwest, a position with which Mr. Wireman agrees.[489] We also find that the other arrows that point to differing flow directions presented in the EA are a function of the groundwater flow paths shown on this figure, which are caused by the discharge of BC/CPF at the flowing wells near Crawford and the ongoing restoration activities at the existing CBR ISR facility.

In addition, the Board notes that the Staff's EA cites to published references indicating that while the Pine Ridge escarpment acts as a groundwater divide for the Arikaree/Brule aquifer, it does not create the same divide for groundwater flow within the BC/CPF, which has a consistent northwesterly groundwater flow both north and south of the Pine Ridge escarpment.[490] This cited material has not been made a part of the evidentiary record, however,

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[485] See Tech Rep. Figs. at 105–08 (figs 2.9-4a to -4d) (Arikaree aquifer), 109–12 (figs.2.9-5a to -5d) (Brule aquifer), 113–16 (figs. 2.9-6a to -6d) (BC/CPF aquifer).

[486] Tr. at 601.

[487] See EA at 3-29 (fig. 3-8); see also Conceptual Flow Model Diagram.

[488] See Tech. Report Figs. at 113–16 (figs. 2.9-6a to -6d).

[489] See Tr. at 601.

[490] See EA at 3-27 (citing T.W. Gjelsteen & S.P. Collings, Relationship between Groundwater Flow and Uranium Mineralization in the Chadron Formation, Northwest Nebraska,

and so cannot, in and of itself, be relied upon as support for the Staff's EA statement.[491] Nonetheless, based on the information that is in the evidentiary record, it seems reasonable to us, as the Staff's EA statement citing this material indicates, that groundwater within the BC/CPF aquifer flows from recharge areas farther south of Dawes County northward through the MEA, until historically discharging where erosion has exposed this formation on the land surface north of Crawford.[492] We likewise conclude that CBR's references to regional and local hydraulic gradient data presented in potentiometric maps is correct in stating that the lack of a flow divide in the BC/CPF aquifer beneath the Pine Ridge escarpment is not unexpected, given the significant depth of the BC/CPF below the escarpment, and the significant thickness of the UCU that separates this aquifer from the Arikaree/Brule aquifer.[493]

The Board further finds that this evidence is consistent with CBR's conceptualized flow model showing southeast flow in the overlying Arikaree/Brule aquifer through the MEA, but northerly flow in these aquifers north of the Pine Ridge escarpment, while flow in the BC/CPF is north-northwest from the Niobrara River through the MEA and the existing CBR ISR facility to the north of Crawford. These observations clearly indicate there is a flow divide between the

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Wyo. Geological Ass'n Guidebook, 39th Annual Field Conference 271–84 (1988); S.P. Collings & R.H. Knode, Geology and Discovery of the Crow Butte Uranium Deposit, Proceeding of the Practical Hydromet '83, 7th Annual Symposium on Uranium & Precious Metals, Littleton, Colo., Amer. Inst. of Mining, Metallurgical, and Petroleum Eng'g (1984)).

[491] See Licensing Board Memorandum and Order (Providing Administrative Directives Associated with Evidentiary Hearing and Limited Appearance Sessions) (July 27, 2018) at 3 n.4 (unpublished).

[492] See EA at 3-27.

[493] See CBR Rebuttal Test. at 14 (citing Tech Rep. Figs. at 105–08 (figs 2.9-4a to -4d) (Arikaree aquifer), 109–12 (figs.2.9-5a to -5d) (Brule aquifer), 113–16 (figs. 2.9-6a to -6d) (BC/CPF aquifer)).

existing CBR ISR facility and MEA in the shallow aquifers due to significant recharge to the shallow formations exposed along the Pine Ridge escarpment.[494]

And in response to Mr. Wireman's doubts about the escarpment affecting the Brule Formation but not the BC/CPF,[495] the Board finds credible CBR witness Shriver's explanation that the BC/CPF is nearly flat across the escarpment (as documented by the regional geologic cross-sections) such that the structural upheaval associated with the Pine Ridge escarpment did not affect the deposition of the BC/CPF and the overlying formations, because the BC/CPF, middle and upper Chadron, Brule, and the Arikaree formations were deposited during the same time period as the structural deformation. Consequently, we find that erosion occurring on the north side created the different flow directions in the Arikaree/Brule aquifer while maintaining the northwesterly flow in the deeper BC/CPF aquifer.[496] The Board further concludes that CBR's and the Staff's position is supported by the existence of flat, intact upper and lower Whitney ash layers — marker beds within the Chadron Formation that were not displaced across the escarpment as shown on the geophysical logs making up the geologic cross-sections.[497]

Finally, the Board rejects Mr. Wireman's claim that CBR's conceptualization of groundwater flow[498] indicates that groundwater flow in the BC/CPF comes from all directions, is inconsistent, and was not supported by actual data.[499] It seems apparent to us that these varying directions are a function of, and consistent with, the flow lines for the groundwater in the

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[494] See id. (citing Conceptual Flow Model Diagram).

[495] See Tr. at 616.

[496] See Tr. at 619–20.

[497] See Tr. at 629–30.

[498] See EA at 3-29 (fig 3-8); see also Conceptual Flow Model Diagram.

[499] See Wireman Rebuttal Test. at 1.

BC/CPF near the proffered discharge area north of Crawford. While it would be illuminating to know more precisely the pathway for flow in the BC/CPF aquifer than what is represented by this conceptualization of flow, we nonetheless find that the representation in the EA is consistent with CBR's field data and provides a sufficient understanding of the groundwater flows in the BC/CPF to resolve the issues raised in Contention 2 as they are relevant in determining the interconnectivity and containment properties of the BC/CPF.

c. Wireman Opinion 1, Basis 3 – Perimeter Groundwater Monitoring Wells

i. Parties' Positions on Wireman Opinion 1, Basis 3 – Groundwater Monitoring Wells

Because of a concern that CBR has not installed any of the perimeter monitoring wells in the BC/CPF upgradient or downgradient of the MEA licensed area, in Basis 3 to his first opinion Mr. Wireman declared that these wells are necessary to provide the data required to fully evaluate downgradient impacts to the BC/CPF aquifer. He claimed that "[t]hese impacts include potential perturbation of the potentiometric surface downgradient of the mine units and potential contamination of downgradient groundwater that may result from groundwater restoration operations."[500]

In response to these allegations, CBR witnesses Lewis, Nelson, and Pavlick confirmed that a perimeter ring of BC/CPF monitoring wells will be installed inside the licensed area surrounding ISR production and injection wells as part of the monitoring for each MU. According to these witnesses, "[t]hese monitoring wells will be used to ensure hydraulic containment and provide the necessary monitoring of groundwater quality downgradient (and in all directions) from active mining areas," but will not be installed prior to operations as there is no need to do so.[501] Consistent with this CBR representation regarding perimeter monitoring

[500] Wireman Initial Test. at 2–3; see Wireman Rebuttal Test. at 2.

[501] CBR Rebuttal Test. at 14–15.

well installation, the Staff's EA states that "CBR would place monitoring wells in the overlying aquifer and in perimeter rings surrounding all mine units to detect vertical and horizontal" migration.[502]

In its TR, CBR states that these perimeter monitoring wells will be installed in both the BC/CPF aquifer to detect lateral migration and in the Arikaree/Brule aquifer for the detection of vertical migration.[503] The CBR TR also indicates that the lateral monitoring wells are to be completed in the same aquifer and zone as the injection and production wells and that this placement is consistent with its NRC-issued license and NDEQ Class III underground injection control (UIC) permit for the existing CBR ISR facility, i.e., BC/CPF aquifer wells will be located no more than 300 ft. from the nearest mineral production wells and no more than 400 ft. from each other.[504] For the vertical monitoring wells, the TR declares that CBR will monitor for potential migration into the overlying Arikaree/Brule aquifer using shallow monitoring wells that are located within the wellfield boundary at a density of one well per four acres.[505] And the Staff's EA indicates that these perimeter monitoring wells will be sampled biweekly for approved indicators as required by License Condition 11.1.5, adopted by the MEA-related amendment to CBR's current license that authorizes operation of the existing CBR ISR facility.[506]

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[502] EA at 4-21.

[503] See Tech. Rep. at 5-56.

[504] See id. at 7-45; CBR License Amend. 3 at 10 (License Condition 10.1.3).

[505] See Tech. Rep. at 7-46. Although the Staff's SER states that CBR is only required to space these wells at one per every five acres, see SER at 138, this disparity was clarified at the hearing by Staff witness Lancaster, who indicated that CBR has a stricter commitment to place wells at a spacing of one for every four acres, which is now reflected in a license condition. See Tr. at 639, 641; see also CBR License Amend. 3, at 3–4 (License Condition 9.2), 16 (License Condition 11.1.3(A)).

[506] See EA at 4-22; CBR License Amend. 3, at 2 (cross-reference table for Amendment 3), 17 (License Condition 11.1.5).

In addition to these perimeter wells, as reflected in another license condition for the Marsland ISR facility, two additional BC/CPF wells are to be installed inside of the MEA licensed area but outside of the operational monitoring well ring and downgradient of the perimeter monitoring wells. Water levels from these wells will be measured by CBR semi-annually to better track the cone of depression for aquifer drawdown during operations.[507]

ii. Board Findings on Wireman Opinion 1, Basis 3 – Groundwater Monitoring Wells

In Basis 3 to his first opinion, Mr. Wireman declared that because CBR does not have any BC/CPF monitoring wells upgradient or downgradient of the MEA license area, these wells must be installed to provide the data needed to fully evaluate downgradient water quality impacts to the BC/CPF aquifer.[508] As was described above, the Applicant will install perimeter monitoring wells in the BC/CPF and in the Arikaree/Brule aquifer to detect potential lateral and vertical migration of production fluids along with two additional monitoring wells further downgradient of the perimeter wells to measure water levels needed to track drawdown in the mineralized zone, albeit in conjunction with each MU becoming operational.

In championing the need for such monitoring wells prior to facility licensing, Mr. Wireman is correct that the record shows the upgradient and downgradient monitoring wells are only to be installed by CBR as the ISR extraction process extends to each new MU. But the record does not indicate that installing such monitoring wells prior to licensing is either a part of the agency's regulations, a criterion under NUREG-1569 for assessing the adequacy of the hydrologic conceptual model for the MEA, or a requirement memorialized in the several license conditions adopted in the Marsland-associated license amendment to the current license for the existing CBR ISR facility that provide for the establishment and operation of these monitoring

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[507] See Tr. at 639–41, 642–43 (Lancaster, Nelson); CBR License Amend. 3, at 21 (License Condition 11.3.3).

[508] See Wireman Initial Test. at 2–3.

wells. And for his part, Mr. Wireman neither explained why the wells need to be installed as part of the licensing process nor showed how waiting for their installation until the post-operational period has any real effect on the ability of the wells to perform their important functions of detecting changes in the potentiometric surface downgradient of its respective MU or the presence of potential contamination of downgradient groundwater. We thus find no basis for requiring the installation and operation of such monitoring wells prior to licensing.

The evidentiary record also shows that these perimeter monitoring wells will be installed in both the BC/CPF and Arikaree/Brule aquifer at specific spacing to detect production fluid migration and they will be sampled on a required schedule, pursuant to the Marsland facility's license conditions.[509] The Board finds that these commitments memorialized in CBR's license, along with those discussed above regarding the establishment of such wells, provide a firm evidentiary basis for concluding that CBR's program for perimeter monitoring well installation and sampling is environmentally sound, and will be sufficient, if installed as planned, to identify potential vertical and lateral migration of production fluids and assess inward hydraulic gradient during facility operation and restoration.

d. Wireman Opinion 1, Basis 4 – Surface Water Hydrology

i. Parties' Positions on Wireman Opinion, 1 Basis 4 – Surface Water Hydrology

Relative to the fourth basis for his first opinion, Mr. Wireman identified in his initial testimony (and later reiterated in his rebuttal testimony) three concerns: (1) no data or information on surface water hydrology was included in the TR or the EA; (2) the two southward flowing ephemeral streams traversing the MEA should be sampled when ephemeral flow is

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[509] See CBR License Amendment 3, at 10 (License Condition 10.1.3), 17 (License Condition 11.1.5), 21 (License Condition 11.3.3).

occurring; and (3) the Dooley Spring, located within the MEA, should be sampled for a baseline and investigated.[510]

According to CBR and the Staff,[511] the CBR TR and the Staff EA each do discuss surface water hydrology in some detail, stating, among other things, that no surface water impoundments, lakes, or ponds have been identified within the MEA.[512] Likewise each of these documents indicates there is no known persistent stream flow, as evidenced by Dooley Spring, Willow Creek, and other ephemeral streambeds, all of which lack defined banks, are usually dry, and are only expected to carry water during significant precipitation events and snowmelt.[513]

With respect to CBR's surface water characterization efforts, CBR witnesses Lewis, Nelson, and Pavlick testified that it has characterized surface-water bodies and drainages within the licensed area and affected surroundings in accordance with the acceptance criteria of NUREG-1569, including providing maps identifying the location, size, shape, hydrologic characteristics, and uses of surface-water bodies, as well as likely surface drainage areas, near its proposed site.[514] As a result of this characterization work, CBR determined that the only significant water body near the MEA is the Niobrara River, which flows easterly through a point approximately 0.4 miles south of the southernmost MEA MU (i.e., MU-F).[515]

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[510] See Wireman Initial Test. at 3; Wireman Rebuttal Test. at 3.

[511] See CBR Rebuttal Test. at 15 (Lewis, Nelson, Pavlick); Staff Rebuttal Test. at 7 (Back, Lancaster, Striz).

[512] See Tech. Rep. at 2-77 to -78, 2-119 to -123, 2-128, 5-57 to -58; EA at 3-18 to -23; see also ER at 3-41 to -42; SER at 59–60.

[513] See Tech. Rep. at 2-105, 7-28; EA at 3-19; see also ER at 3-66; SER at 60.

[514] See CBR Initial Test. at 19–20 (citing Tech. Rep. at 2-77 to -78).

[515] See Tech. Rep. at 2-77.

And as Staff witnesses Back and Lancaster indicated,[516] gathering flow and/or water quality information about the Niobrara River, in addition to establishing its own water sampling locations on the river, CBR utilized information from several existing Nebraska programs including the Nebraska Department of Natural Resources' (NDNR) Niobrara River Ambient Stream Monitoring Program; the NDEQ Niobrara River Ambient Stream Monitoring Program, that provides water quality sampling data for the Niobrara River above and below the Box Butte Reservoir, as well as the Box Butte Reservoir itself, which is located some three miles to the east of the MEA; and the United States Bureau of Reclamation's (or USBR) Box Butte Reservoir Storage Content program. Moreover, with regard to the two CBR-established water quality sampling locations on the Niobrara River, one sampling point (N-1) is upstream (west) of the MEA license boundary, and one point (N-2) is downstream (east) of the license boundary (which CBR indicated was moved closer to the MEA to co-locate with the USGS/NDNR and NDEQ gaging stations).[517]

As the CBR TR indicates, the two sampling points are located to detect potential impacts from either of the two major ephemeral drainages referenced by Mr. Wireman, both of which drain the MEA from northwest to southeast and connect to the Niobrara River between the two sampling points.[518] Also, the Staff's EA indicates that CBR initially collected samples from these two locations for baseline water quality analysis for nonradiological (quarterly) and radiological (monthly) parameters from January 2011 through March 2013. The results of these analyses indicated that background levels of radioactivity were low, with the majority of the results at or

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[516] See Staff Initial Test. at 26.

[517] See id. at 2-119 to -123; see also EA at 3-21 to -23.

[518] See Tech. Rep. at 2-122 to -123 (citing Tech Rep. Figs. at 95 (fig. 2.7-4)).

below detection limits.[519] Furthermore, for nonradiological parameters, the majority of the results for dissolved metals were reported at or below the detection limit. A qualitative comparison indicates that the concentrations at N-1 and N-2 appear to be similar so as to provide an existing water quality baseline in the area.[520]

Responding to Mr. Wireman's assertion that Crow Butte omitted discussion of, and should include baseline sampling for, ephemeral streams and should further investigate Dooley Spring located within the MEA, CBR in its rebuttal testimony declared that (1) Dooley Spring is not located within the MEA, but is located approximately 1.5 miles west of the MEA boundary; (2) site investigations found no surface water impoundments within the MEA; (3) the lack of water flow in the two ephemeral drainages in the MEA prevented collection of surface water samples; and (4) rainfall runoff occasionally creates temporary small pools in a few places on the MEA site, but there is no evidence of persistent streamflow in recent times.[521] CBR also indicates in its TR that seven sediment and surface runoff sampling locations (MED-1 to MED-7) in these drainages have been established and, if at any time prior to operation water flow becomes available in the two ephemeral drainages at any of the sampling points set up along

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[519] See EA at 3-22. The Staff's EA, which indicates that the term "detection limit" refers to the lower limit of detection as outlined in Regulatory Guide 4.14, goes on to explain that Regulatory Guide 4.14 defines the lower limit of detection as the smallest concentration of a material sampled that has a 95 percent probability of being detected, with only a 5 percent probability that a blank sample will yield a response interpreted to mean that the material is present. See id. at 3-22 n.14. The EA indicates as well that for radioactive material, "detection" means that it yields an instrument response that leads the analyst to conclude that activity above the system background is present. See id. (citing Office of Standards Dev., NRC, Regulatory Guide 4.14,"Radiological Effluent and Environmental Monitoring at Uranium Mills" at 4.14-21 (rev. 1, Apr. 1980) (ADAMS Accession No. ML003739941)).

[520] See EA at 3-22.

[521] See CBR Rebuttal Test. at 15 (Lewis, Nelson, Pavlick) (citing Tech. Rep. at 2-78, 2-105, 2-120).

those drainages, CBR will collect baseline water samples.[522] CBR did, however, collect sediment samples at the designated locations, and those analytical results are presented in CBR's TR.[523]

And with regard to future operational and restoration monitoring, CBR in its TR indicates that samples will be collected at the two locations in the Niobrara River on a quarterly basis, and from the main drainage channel at the seven designated locations whenever sufficient flow is available for sampling in the two ephemeral drainages. Surface water monitoring results will be submitted in the semi-annual environmental and effluent reports to the NRC.[524]

Finally, in its rebuttal testimony the Staff indicated that its EA provides an extensive description of surface water hydrology, including ephemeral drainages and Dooley Spring, based on descriptions and supporting information in CBR's TR.[525] In that regard, the Staff's EA also provides an assessment of the potential impact of the MEA ISR on surface water quality, including the Niobrara River. According to the Staff's EA, surface water quality impacts will be "SMALL" because CBR had committed to control stormwater runoff during construction and operation of the MEA by implementing an SWPPP, applying BMPs, and following the NPDES program per CBR's existing stormwater discharge permit issued by NDEQ.[526]

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[522] See Tech. Rep. at 2-128. On this score, the Staff stated that CBR's commitment to sample ephemeral drainages if water is available during the pre-operational period was not required by Staff guidance because, given the quantity of this kind of water flow, the quality is not representative of any average value, so that the Applicant's commitment is over and above what is required by the Staff. See Tr. at 653 (Striz).

[523] See SER at 59 (citing Tech. Rep. Tbls. at 192–94 (tbl. 2.9-39)).

[524] See Tech. Rep. at 5-57 to -58.

[525] See Staff Rebuttal Test. at 7 (Back, Lancaster, Striz) (citing EA at 3-18 to -22, 3-72, 4-6 to -9; Tech. Rep. at 2-8 to -9, 2-77 to -78).

[526] See EA at 4-12 to -14.

ii. Board Findings on Wireman Opinion 1, Basis 4 – Surface Water Hydrology

The evidence adduced in this proceeding does not support Mr. Wireman's Basis 4 of his first opinion, i.e., that neither the CBR TR nor the Staff EA contain data or information on surface water hydrology at MEA, including information regarding two ephemeral streams and Dooley Spring.[527] To the contrary, the Board finds that the Applicant's TR and the Staff's EA, as well as CBR's ER and the Staff's SER, provide extensive information on MEA-related surface water hydrology. In addition to thoroughly describing CBR's efforts to characterize the existence of, and facility impacts on, surface water associated with the MEA site, including studies on the Niobrara River performed by NDNR and NDEQ, these documents summarize the hydrology of the river and outline CBR's baseline sampling and the monitoring program CBR intends to utilize during ISR activities on the site.[528]

Specifically, the Board finds that CBR has appropriately characterized surface-water bodies and drainages within the licensed area and affected surroundings, and provided maps identifying the location, size, shape, hydrologic characteristics, and uses of surface-water bodies near the area. Based on this evidence, we conclude that the only significant water body near the MEA is the Niobrara River.[529] Further, we find that in addressing the circumstances surrounding the only waterway in the vicinity of the MEA, CBR provided a detailed discussion concerning the Niobrara River and existing monitoring programs for this surface water body.[530] In that regard, CBR has established two water quality sampling locations on the Niobrara River

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[527] See Wireman Initial Test. at 3; Wireman Rebuttal Test. at 3.

[528] See Tech. Rep. at 2-77 to -78, 2-119 to -123, 2-128, 5-57 to -58; EA at 3-18 to -23; see also ER at 3-41 to -42; SER at 59–60.

[529] See Tech. Rep. at 2-77 to -78.

[530] See id. at 2-77 to -78, 2-119 to -123.

located to detect potential impacts from either of the two major ephemeral drainages that drain the MEA (from northwest to the southeast) and connect into the Niobrara River between the two sampling points. Moreover, CBR has collected samples from these locations for baseline water quality analysis for both nonradiological (quarterly) and radiological (monthly) parameters from January 2011 through March 2013.[531] Notwithstanding Mr. Wireman's assertion that Crow Butte omitted discussion of ephemeral streams located within the MEA, the evidentiary material provided by CBR establishes that (1) there are two major ephemeral drainages traversing the MEA license area from north to south; (2) CBR selected seven channel-bottom sampling points for these drainages to measure radiological concentrations in the sediment; and (3) in the face of insufficient water flow to permit sampling, CBR sampled sediments from these drainages twice for baseline values. Moreover, CBR in its TR indicates that since water was not present in the ephemeral drainage system during the previous sampling sessions so that no baseline water samples were collected, if water flow becomes available prior to the startup of the MEA ISR facility, CBR will collect baseline water samples as well.[532]

In sum, based on the evidentiary record, the Board has determined that sample analysis of both the Niobrara River, and the sediment in the dry ephemeral drainages provides a baseline of existing water and sediment quality in the area, and finds no basis for Mr. Wireman's concerns the CBR TR and the Staff EA posed possible surface water hydrology-associated deficiencies relative to the MEA.

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[531] See EA at 3-22.

[532] See Tech. Rep. at 2-128.

e. Wireman Opinion 1, Basis 6 – Groundwater Baseline Restoration Wells

The final basis for OST witness Wireman's Opinion 1, Basis 6, deals with the absence of pre-licensing selection of, and sampling from, baseline restoration wells.[533]

i. Parties' Positions on Wireman Opinion 1, Basis 6 – Groundwater Baseline Restoration Wells Selection and Sampling

In Basis 6 of his Opinion 1, Mr. Wireman challenged CBR's failure, as reflected in its TR, to select and install groundwater baseline restoration monitoring wells and to obtain data regarding background concentrations for applicable constituents.[534] According to Crow Butte, Mr. Wireman's concern is groundless. Specifically, CBR maintained that restoration monitoring wells will be established on an MU-by-MU basis as required by License Condition 11.1.3, which addresses the sampling necessary to establish baseline groundwater quality data for the ore zone and overlying aquifers. Further, according to CBR, the sampling results will then be used to define the background groundwater protection standards for restoration in accordance with 10 C.F.R. Part 40, app. A, criterion 5B(5).[535] In that regard, the CBR TR indicates that prior to starting the ISR process at an MU, a minimum of six baseline restoration wells will be installed per MU and that each of those wells will be sampled four times.[536] And at the hearing CBR witness Nelson maintained that the standards for baseline restoration wells will be established consistent with the above-referenced NRC license condition and in compliance with the NDEQ Class III permit that will be required before installing these wells. He also confirmed that these

[533] Basis 5 for Mr. Wireman's Opinion 1, regarding whether additional meteorological data should be collected, was stricken by the Board as outside the scope of Contention 2. See Board in Limine Ruling at 7.

[534] See Wireman Initial Test. at 3.

[535] See CBR Rebuttal Test. at 16 (Lewis, Nelson Pavlick) (citing CBR License Amendment 3, at 16 (License Condition 11.1.3)).

[536] See Tech. Rep. at 6-5.

restoration wells will be installed on an MU-by-MU basis, so that for each future MU the wells are to be installed and baseline water quality then established to determine the restoration parameters for that area.[537]

On this score, the Staff's rebuttal testimony declared that the installation and testing of baseline restoration wells cannot occur until after the site is licensed and each wellfield is constructed. The Staff's testimony emphasized that because these wells are to be used for restoration, there is no need for them to be installed during the licensing process since potential impacts of operation have previously been satisfactorily assessed, i.e., CBR has already provided sufficient water quality data from installed wells to establish a pre-operational water quality baseline of the BC/CPF aquifer.[538]

CBR witness Nelson and Staff witness Dr. Striz were asked about the possibility of water quality in an undeveloped MU being affected by ISR production activities that already occurred in an existing MU. Both expressed confidence that the perimeter monitor wells around each operating MU would detect any migration of production fluids, which would ensure that CBR could undertake preventive measures to protect those MUs outside of the areas of active wellfield operation from exposure before CBR could establish baseline conditions.[539] Dr. Striz further noted that as part of the wellfield package associated with starting a new MU, CBR will use these baseline water quality conditions, including a statistical analysis of those constituent levels, to establish the restoration standard for each MU. Moreover, if there is an unusual value, CBR will subject the sample to outlier tests to evaluate whether it should be included in the data

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[537] See Tr. at 654–55.

[538] See Staff Rebuttal Test. at 11 (Back, Lancaster, Striz) (citing Tech. Rep. Figs. at 6 (fig. 2.7-6); Tech. Rep. Tbls. at 136–41 (tbl. 2.9-11)).

[539] See Tr. at 656 (Nelson), 658 (Striz).

set, along with an explanation as to why such an unusual value occurred.[540] And if there are indications that the water quality of an adjacent undeveloped MU may have been tainted by production fluids from an existing MU, Dr. Striz testified that the Staff has the option to modify any constituent concentration to better reflect a restoration value indicative of background conditions had the migration of production fluids not occurred.[541]

Consistent with his initial testimony, at the hearing Mr. Wireman indicated that all baseline sampling should be conducted before any ISR operational extraction occurred at Marsland. In his view, baseline is "pre-mining," i.e., before any operations have begun anywhere within the MEA, because once lixiviant has been injected into the first MEA MU, the BC/CPF chemistry (specifically oxidation levels) has been altered and there are no longer "background" levels in the aquifer.[542] He further stated he had a hard time accepting the premise that "where the mine unit that's already been mined and water quality has been altered, that none of that water gets into the next mine unit."[543] He was, however, encouraged by the Staff's testimony that, in appropriate situations, the Staff has the ability to modify constituent values that will be used as the benchmark in assessing restoration efforts.[544]

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[540] See Tr. at 665–66.

[541] See Tr. at 659–60. As an analogous example of this occurring, Dr. Striz spoke of a company that conducted a pilot ISR study on a very small footprint of one well pattern. When this area was then advanced into commercial operation, the baseline restoration wells detected elevated values for uranium in the vicinity of the study area. In that case, the elevated value for uranium was considered to be an outlier and, as such, the measured concentration was not used in calculating a restoration value. Dr. Striz indicated that this example demonstrates that the Staff has the ability to adjust the baseline values if any outlying, elevated constituent levels were deemed not to be representative of background conditions. See Tr. at 659–60, 683–84.

[542] See Tr. at 661–63.

[543] Tr. at 662.

[544] See Tr. at 664–65.

But Dr. Striz challenged Mr. Wireman's statements suggesting that there would be movement of production fluids between the MEA MUs once any operations began. He was in error, she stated, because each MU is required to have an inward hydraulic gradient to prevent such a migration of fluids. She added that the water quality in the perimeter wells is monitored every two weeks to detect any indication of uncontrolled fluid movements, and corrective action is to be taken to control any migration if it did occur. In her opinion, it is implausible for constituents to be freely moving downgradient into other ISR units given the required inward gradient at operating MUs. She also rejected the notion that the constituents mobilized by the ISR process could move by chemical transportation rather than by hydraulic gradients, stating that constituents cannot overcome and move out by chemical diffusion against the strong groundwater flow established by the required inward hydraulic gradients.[545]

ii. Board Findings on Wireman Opinion 1, Basis 6 – Groundwater Baseline Restoration Wells Selection and Sampling

Regarding Mr. Wireman's baseline restoration well selection and sampling claims,[546] while he is correct that the wells for baseline monitoring have not been selected and no data points are provided regarding background concentrations for applicable constituents, the Board finds that Mr. Wireman failed to provide any evidence justifying the installation of such restoration wells at this time. It is at best questionable that water quality data should be

[545] See Tr. at 666–67.

[546] As part of their initial testimony regarding Mr. Wireman's Opinion 1, Basis 6, CBR witnesses Lewis, Nelson, and Pavlick sought to raise a legal issue, asserting that his claims were not within the scope of Contention 2. See CBR Rebuttal Test. at 16. This was resolved in the context of the Staff's prehearing in limine motion in which the Staff sought to strike this same statement. There we concluded that the testimony was within the confines of Contention 2's concerns "because establishing baseline groundwater quality is relevant to the Contention 2 issue regarding impacts the MEA would impose on surface and groundwater quality, especially to the issue of groundwater restoration." Board In Limine Ruling at 8.

obtained before ISR operations begin.[547] Moreover, we find that CBR and the Staff have proffered sufficient evidence to support their position that it is suitable to wait to install and sample these restoration wells as each MU is developed.

Concerning the potential for adjacent MUs to impact the groundwater baseline of the next area to be developed as an MU, CBR witness Nelson and Staff witness Dr. Striz agreed that the perimeter monitoring wells surrounding active MUs, which are monitored every two weeks, would detect any changes in groundwater quality and so would alert CBR to the need to implement corrective measures before any impacts could occur to the baseline water quality of an MU prior to the unit becoming operational. Based on the evidentiary record, we agree with this conclusion, and in particular, based on Dr. Striz's testimony, we find that before initiating operation of a new MU, CBR is obliged to submit a wellfield package to the NRC demonstrating all perimeter monitoring well completions and locations to assure they are placed so that contaminant migration is detected before it can migrate to a new MU area.[548]

We also find that CBR's wellfield package will include water quality information for all constituents with a statistical analysis to identify any outliers. And if there is any indication that the baseline water quality underlying the new MU has been impacted by previous ISR activity, the record establishes that the Staff has the ability to adjust the documented baseline values to be used after the MU is depleted to assess the effectiveness of restoring the aquifer — a capability supported by Mr. Wireman.[549]

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[547] See Strata Energy, Inc. (Ross In Situ Uranium Recovery Project), CLI-16-13, 83 NRC 566, 583–84 (2016), petition for review denied sub nom. Nat. Res. Def. Council, 879 F.3d at 1214.

[548] See Tr. at 656–58 (Nelson, Striz), 660 (Striz).

[549] See Tr.at 660 (Striz), 665–66 (Wireman, Striz).

Finally, we agree with Dr. Striz's assertion that movement of production fluids between the developed and undeveloped MUs is not plausible due to the required inward hydraulic gradients that prevent such fluid migration. And in this regard, nothing has been provided in the record demonstrating that the chemical transportation of constituents in the ISR process can overcome the strong inward groundwater hydraulic gradients sufficiently to allow migration away from an active MU by chemical diffusion.[550]

2 Wireman Opinion 2 – Structural Geology Characterization

In Opinion 2 of his initial testimony, Mr. Wireman challenged CBR's characterization of the structural geology in northwestern Nebraska as insufficient to develop an acceptable conceptual model of site hydrology that is adequately supported by site data. More specifically, he claimed that the area's structural geologic setting is more complex than previously reported by CBR, with numerous significant structural features including (1) the Black Hills and Chadron uplifts in northwest Nebraska; (2) the Pine Ridge escarpment to the north; (3) an east-west graben (i.e., a sunken elongated block of bedrock lying between two faults) south of Marsland; and (4) two major east-west trending faults (i.e., the Pine Ridge fault to the north of the Pine Ridge escarpment and the Niobrara River fault that trends parallel to the Niobrara River).[551] In his rebuttal testimony, Mr. Wireman asserted that there is significant uncertainty about groundwater flow in the BC/CPF downgradient of the MEA caused by the unknown effect of the Pine Ridge escarpment on these flow paths, given that this escarpment functions as a groundwater divide in the Arikaree and Brule aquifers.[552]

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[550] See Tr. at 666–67 (Striz).

[551] See Wireman Initial Test. at 3.

[552] See Wireman Rebuttal Test. at 2.

The Board has addressed these matters as one of the overarching issues in section V.B above.[553] The CBR and Staff responses to Mr. Wireman's claims, his rebuttal to those responses, and the Board findings on these issues presented therein need not be repeated here. But to summarize the findings in this decision pertinent to structural geology characterization as that issue is raised by Mr. Wireman in his Opinion 2, we conclude that:

1. While there is likely some degree of structural fracturing of the geologic strata underlying the MEA, the mere presence of fractures is not the issue. Rather, the transmissivity of such a feature is the critical factor.

2. With regard to the potential impacts of heterogeneity and anisotropy on the rate and directions of groundwater flow within the MEA, there is no evidence in the hydrogeologic data that conclusively supports the presence of extensive, transmissive, heterogeneous pathways that would provide a preferential flow for contaminants to uncontrollably migrate into the adjacent Brule and Arikaree aquifers or into the neighboring surface waters, including the Niobrara and White Rivers, and thus there is insufficient OST evidence to refute the evidentiary showings of CBR and the Staff regarding the containment of processing fluids and the lack of aquifer interconnectivity as demonstrating CBR's ability to conduct safe, environmentally-sound ISR activities in the proposed area.

3. OST's hypothesis regarding the impacts associated with the Pine Ridge escarpment is rejected based on

    a. Structure contour maps derived from field data showing a nearly level BC/CPF from below the MEA, to beneath the Pine Ridge escarpment, and on through to the existing CBR ISR Facility, without any apparent interruption by the Pine Ridge escarpment;[554]

    b. Groundwater potentiometric maps based on measured water levels establishing the contour flow maps documenting constant northwest flow along the axis of the MEA;[555] and

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[553] See supra section V.B.1.b.

[554] See Staff Rebuttal Test. at 4 (Back, Lancaster, Striz) (citing Tech. Rep. Figs. at 87–90 (figs. 2.6-21 to -24)); Three Crow Cross-Sections at PDF 3–4 (figs. 2 & 3)).

[555] See Staff Rebuttal Test. at 3, 4–5 (Back, Lancaster, Striz) (citing EA at 3-29 (fig.3-8)).

c. Surface contours illustrating that the Brule and Arikaree formations have been significantly eroded on the north side of the Pine Ridge escarpment as compared to the south side where the MEA is proposed, yielding stratigraphic evidence that supports the view that these formations were deposited before this erosion occurred along the escarpment.[556]

Contrary to Mr. Wireman's claim that there is insufficient characterization of the structural geology as well as uncertainty about groundwater flow in the BC/CPF downgradient of the MEA, the Board finds that there is an overwhelming quantity of reliable field data supporting the northwest flow of groundwater in the BC/CPF (from south of the Niobrara River, through the proposed MEA and the existing CBR ISR facility towards Crawford and the White River) and that this data largely refutes the essentially hypothetical postulates advanced by Mr. Wireman.

In conclusion, we find that the evidentiary record before the Board supports a determination that there are no known faults or significant fracturing underlying the MEA that might cause heterogeneity and anisotropy of the underlying geologic strata. As a result, there is no need for CBR to augment its TR or the Staff to alter its EA to address heterogeneity/anisotropy impacts due to fracturing.

3. Wireman Opinion 3 – MEA Aquifer Testing

a. Parties' Positions on Wireman Opinion 3 – MEA Aquifer Testing

In Opinion 3 to his initial testimony, Mr. Wireman echoed OST witness Dr. Kreamer's criticisms of CBR's aquifer testing conducted at the MEA, stating that this test was inadequate for developing an acceptable site-wide conceptual hydrologic model and does not adequately characterize the subsurface heterogeneity. Much of the material Dr. Kreamer provided in his opinion has been addressed as part of the section V.A overarching issue of misinterpretation of aquifer pumping test data, including Mr. Wireman's criticism that only one aquifer test has been conducted for the entire MEA, resulting in only a small part of the BC/CPF being tested. But Mr.

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[556] See id. at 4 (citing Tech. Rep. Figs. at 87–90 (figs. 2.6-21 to -24); Three Crow Cross-Sections at PDF 3–4 (figs. 2 & 3)).

Wireman also testified that lithologic and hydraulic data included in the TR for the Arikaree and Brule aquifers indicate significant heterogeneity and that this heterogeneity is further increased by structural deformation of the sedimentary rocks that comprise the aquifers, with the resulting heterogeneities affecting groundwater flow and well yields.[557]

Although additional details regarding the heterogeneity challenges raised by Dr. Kreamer are discussed infra in section VII.D, Mr. Wireman was in agreement with his OST colleague that the May 2011 pumping test, as the only aquifer test that was conducted at the MEA, was limited to obtaining data to assess the hydraulic properties of the BC/CPF. As a result, and alluding to the fact that no pumping test was performed on the Arikaree/Brule aquifer, he concluded that "[a]quifer testing conducted at the MEA is inadequate for developing an acceptable site-wide conceptual hydrologic model and does not adequately characterize the subsurface heterogeneity."[558] To support his argument, he stated that the lithologic and hydraulic data included in the CBR TR for the Arikaree and Brule aquifers indicated significant heterogeneity. Further, he hypothesized that sediment comprising these formations was deposited in a variety of fluvial environments resulting in changes in the characteristics of the sedimentary rock within the formation.[559]

This heterogeneity, according to Mr. Wireman, allegedly affects groundwater flow and well yields and is further increased by structural deformation of the sedimentary rocks that comprise the aquifers. He concluded that aquifer testing, monitoring, and flow modeling of these aquifers must consider the heterogeneity, claiming that the aquifer test data indicated that

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[557] See Wireman Initial Test. at 4.

[558] Id.

[559] See id.

hydraulic conductivity and transmissivity of the BC/CPF near the pumping well is an order of magnitude lower than at the outlying monitoring wells.[560]

CBR witnesses Lewis, Nelson, and Pavlick, acknowledging that within the MEA the BC/CPF is not homogeneous and isotropic on a local scale, nonetheless stated that CBR's assumptions of homogeneity and isotropy are reasonably satisfied over the scale of the BC/CPF pumping test. As a result, these CBR witnesses declared, with Staff witnesses Back, Lancaster, and Dr. Striz agreeing, that the BC/CPF Formation underlying the MEA can be treated as homogeneous and isotropic for analytical purposes.[561]

In response to Mr. Wireman's assertion that the aquifer testing at the MEA was inadequate, CBR witnesses Lewis, Nelson, and Pavlick referenced their responses to a similar challenge by Dr. Kreamer,[562] and noted that the May 2011 aquifer pumping test was sufficient to characterize the portions of the site that would be affected by development of the first four MUs at Marsland, given that such testing was consistent with industry practice and NRC guidance relative to these four MUs and that additional site-specific pumping tests would be performed, as required, as additional MUs are added.[563] These CBR witnesses also disagreed with Mr. Wireman's characterization that transmissivity and hydraulic conductivity near the pumped well is an order of magnitude lower than the outlying monitor wells. Rather, these CBR witnesses claimed that those values were within a factor of two to four (with the exception of well Monitor-3, which is two to nine times lower than other monitor well locations), thus suggesting

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[560] See id.

[561] See CBR Rebuttal Test. at 11–12 (citing Test #8 Rep. at 11); Staff Rebuttal Test. at 30.

[562] See CBR Rebuttal Test. at 7–8, 18; see also infra section VII.A.5.a.

[563] See id. at 18.

relative homogeneity.[564] Finally, these CBR witnesses asserted there is no evidence of the hypothetical structural heterogeneities cited by Mr. Wireman.[565]

Staff witnesses Back, Lancaster, and Dr. Striz likewise disputed OST's subsurface characterization of the BC/CPF, testifying that methodologies such as core examination and geophysical logging show there are no major impermeable or permeable features that would indicate significant heterogeneity at the MEA to the extent these features would impact the aquifer test analysis results.[566] According to these Staff witnesses, the lack of significant heterogeneity is also reflected in the potentiometric surface of the BC/CPF aquifer, which is smooth and essentially has a flat and relatively constant hydraulic gradient that indicates there are no significant changes in transmissivity that would impact the BC/CPF aquifer groundwater flow.[567]

b. Board Findings on Wireman Opinion 3 – MEA Aquifer Testing

In his critique of CBR's aquifer pumping test, Mr. Wireman called for more aquifer testing, stating that "[l]ithologic and hydraulic data included in the TR for the Arikaree and Brule aquifers indicate significant heterogeneity."[568] We find, however, that CBR in its TR defines the groundwater levels in the unconfined Arikaree and Brule aquifers,[569] noting that groundwater flow in these overlying strata is northwest near the existing CBR ISR facility area and southeast near the MEA. This observation clearly indicates that a flow divide exists between the existing

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[564] See id.

[565] See id.

[566] See Staff Rebuttal Test. at 27 (citing Test #8 Rep. at 5).

[567] See id. (citing Tech. Rep. Figs. at 113–16 (figs. 2.9-6a to -6d)).

[568] Wireman Initial Test. at 4.

[569] See Tech. Rep. Figs. at 105–08 (figs. 2.9-4a to -4d), 109–12 (figs. 2.9-5a to -5d).

CBR ISR facility area and MEA in the shallow aquifers due to significant recharge to the shallow formations exposed along the Pine Ridge escarpment.[570] Given this characterization, we find that Mr. Wireman in his Opinion 3 failed to provide sufficient contradictory evidence to justify the need for additional hydrogeologic detail regarding the surficial, unconfined Arikaree and Brule aquifers, nor did he justify how any additional definitions of the hydraulic properties of the Arikaree and Brule aquifers would reveal relevant information about the containment properties of the BC/CPF, which is located hundreds of feet below the ground surface and the Brule and Arikaree aquifers.

The Board also finds that Crow Butte has adequately established that the single May 2011 aquifer pumping test is sufficient to characterize the portions of the site that would be affected by development of the first four MEA MUs.[571] This is particularly so because not only must an additional pumping test be conducted prior to the opening of each new MU, but CBR's pumping test plan must be submitted for Staff review and verification 60 days before performing the aquifer pumping test, and those pumping test results must, in turn, be part of the wellfield package submitted for Staff verification 90 days prior to the planned start of lixiviant injection at each new MU.[572]

With regard to the heterogeneity of the aquifers, the Board finds that CBR's subsurface characterization of the BC/CPF (using the examination of cores and geophysical logging) shows there are no major impermeable or permeable features that would indicate significant heterogeneity at the MEA to the degree that these features would impact the aquifer test

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[570] See CBR Rebuttal Test. at 14 (Lewis, Nelson, Pavlick).

[571] See id. at 18; see also infra section VII.A.5.a.

[572] See CBR Rebuttal Test. at 7–8 (Lewis, Nelson, Pavlick); Tr. at 438–39 (Shriver); CBR License Amend. 3, at 21 (License Condition 11.3.4)).

analysis results.[573] We also agree with the Staff that the lack of significant heterogeneity is reflected in the potentiometric surface of the BC/CPF aquifer, which the evidence indicates is smooth and has an essentially flat and relatively constant hydraulic gradient.[574]

The Board agrees with the Staff as well that, at some scale, all formations are heterogeneous.[575] And more specifically, we agree with the Staff and CBR that the BC/CPF is not homogeneous and isotropic on a local scale.[576] But for reasons documented elsewhere in this decision,[577] we also find that the assumptions of homogeneity and isotropy are reasonably satisfied over the scale of the BC/CPF pumping test and conclude that the BC/CPF Formation underlying the MEA can be treated as homogeneous and isotropic for analytical purposes.[578]

Finally, we find no credible evidence supporting the hypothetical structural heterogeneities cited by Mr. Wireman,[579] and conclude that transmissivity and hydraulic conductivity near the May 2011 pumping test well is within a factor of 2 to 4 lower than the outlying monitor wells (with the exception of well Monitor-3, which is 2 to 9 times lower than other monitor well locations), thus suggesting relative homogeneity.[580]

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[573] See Staff Rebuttal Test. at 27 (Back, Lancaster, Striz) (citing Test #8 Rep. at 5).

[574] See id. (citing Tech. Rep. Figs. at 113–16 (figs. 2.9-6a to -6d)).

[575] See id. at 25 (Back, Lancaster, Striz).

[576] See id. at 30 (Back, Lancaster, Striz); CBR Rebuttal Test. at 12 (Lewis, Nelson, Pavlick) (citing Test #8 Rep. at 11).

[577] See supra section V.A; infra section VII.D.

[578] See Test #8 Rep. at 11.

[579] See CBR Rebuttal Test. at 18 (Lewis, Nelson, Pavlick).

[580] See id. at 18.

4. Wireman Opinion 4 – Applicable Groundwater Restoration Standards

In his initial testimony outlining his Opinion 4, Mr. Wireman questioned the applicable groundwater restoration standards for the MEA, which he asserted were confusing. In lieu of CBR's proposed standards, Mr. Wireman suggested additional investigation is required to establish appropriate restoration monitoring requirements and compliance standards.[581]

a. Parties' Positions on Applicable Groundwater Restoration Standards

In explaining his confusion, Mr. Wireman started by noting that both the CBR TR and the Staff EA state that the primary goal of the MEA groundwater restoration program is to return groundwater affected by uranium recovery operations to pre-injection baseline values on a mine-unit average, as determined by the baseline water quality sampling program, and that this goal invokes NRC regulatory requirements set forth in Criterion 5B(5) of Appendix A to 10 C.F.R. Part 40,[582] which states:

> At the point of compliance, the concentration of a hazardous constituent must not exceed—
>
> (a) The Commission approved background concentration of that constituent in the groundwater;
>
> (b) The respective value given in the table in paragraph 5C if the constituent is listed in the table and if the background level of the constituent is below the value listed; or
>
> (c) An alternate concentration limit [(ACL)] established by the Commission.[583]

Mr. Wireman alleged that CBR is skipping the first Criterion 5B(5) standard by assuming that restoration efforts will not achieve background concentrations for some constituents

[581] See Wireman Initial Test. at 5.

[582] See id. (citing Tech Rep. at 6-4; EA at 2-9).

[583] 10 C.F.R. Part 2, app. A, criterion 5B(5)(a)–(c).

because the Applicant (1) provided sample restoration tables for MU-1 in anticipation of using restoration values set by NDEQ for Class III UIC permits rather than background values;[584] and (2) indicated it will continue to provide tables for each of the other 11 MEA MUs that include the baseline average, the range for all restoration parameters, and the NDEQ restoration standards.[585] Mr. Wireman also noted CBR's commitment to apply "diligent application of best [practicable] technology [(BPT)]" to achieve baseline values and to meet the NDEQ compliance standards if restoration efforts are unable to achieve background conditions.[586] As a result, Mr. Wireman questioned whether NDEQ standards will be considered ACLs that allow for public involvement and require NRC approval, as well as what criteria will be used to determine when BPT is achieved.[587] And thereafter at the hearing, Mr. Wireman summarized his confusion as mainly dealing with whether NDEQ standards are applicable as restoration standards at the MEA and, if so, whether they essentially comprise an ACL.[588]

At the hearing, both CBR witness Pavlick and Staff witness Dr. Striz confirmed that initially the Applicant is required to attempt to meet background water quality, unless background water quality is lower than the water quality standard values (i.e. maximum contaminant levels) provided in the Criterion 5C table in Appendix A to 10 C.F.R. Part 40, in which case the higher Criterion 5C table value controls, i.e., CBR is not required to meet groundwater quality values lower than the maximum contaminant levels in the Criterion 5C

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[584] See Wireman Initial Test. at 5 (citing Tech. Rep. at 6-4).

[585] See id. (citing Tech. Rep. at 6-5).

[586] See id. (citing Tech. Rep. at 6-4). The Board notes that Mr. Wireman misquoted the CBR TR by stating "best available technology" instead of "best practicable technology," the phrase used in CBR's TR.

[587] See id.

[588] See Tr. at 687.

table.[589] With regard to Criterion 5B(5)(b), the Staff's EA states that under EPA requirements, groundwater restoration at ISR facilities must meet Uranium Mill Tailings Radiation Control Act (UMTRCA) standards rather than those associated with the Safe Drinking Water Act or analogous state regulations, and that those UMTRCA standards are reflected in the Criterion 5C table's maximum values for groundwater protection.[590] CBR witnesses Lewis, Nelson, and Pavlick added that the groundwater quality standards in 10 C.F.R. Part 40, Appendix A, Criterion 5B(5) for all restored aquifers conform to the standards promulgated by the EPA in 40 C.F.R. § 192.32(a)(2).[591]

Providing further clarification, Dr. Striz stated that the Criterion 5C table lists the NRC's maximum values for groundwater protection, which is reflected in CBR's TR Table 6.1-1 under the column heading "NRC UMTRCA Groundwater Protection Standards."[592] CBR's TR Table 6.1-1 also lists NDEQ's maximum concentration limits (MCLs) in the column headed "NDEQ Title 118 Groundwater Standard."[593] As NDEQ restoration standards exist separate and apart from NRC requirements,[594] CBR witnesses Pavlick and Nelson and Staff witness Dr. Striz testified that CBR is required to meet the more restrictive of the NRC Criterion 5C table UMTRCA standards or NDEQ's Title 118 MCL groundwater standards.[595] Based on these CBR and Staff representations that Crow Butte is required to meet the lowest value of these two

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[589] See Tr. at 694–95.

[590] See EA at 2-9 (citing 40 C.F.R. Part 192).

[591] See CBR Rebuttal Test. at 18–19.

[592] See Tr. at 689–90; Tech. Rep. Tbls. at 227 (tbl. 6.1-1).

[593] See Tech. Rep. Tbls. at 227 (tbl. 6.1-1).

[594] See CBR Rebuttal Test. at 19 (Lewis, Nelson, Pavlick).

[595] See Tr.at 691–93.

regulations for each individual constituent, Mr. Wireman expressed satisfaction that this concern had been addressed.[596]

Dr. Striz also indicated that prior to requesting agency approval to use ACL restoration standards in accordance with Criterion 5B(5)(c), a licensee is required to show that it has made practicable efforts using all reasonable technologies available to achieve either NRC-approved background or the maximum contaminant levels in the Criterion 5C table, whichever is higher.[597] CBR witnesses Lewis, Nelson, and Pavlick testified that the NRC will assess whether a licensee has employed the best available technology as part of the review process for determining if an MU is restored or eligible for consideration for an ACL. Furthermore, according to these CBR witnesses, the outcome of that review will depend on the efforts undertaken to restore the aquifer once mining ends, and the need for an ACL may not even be necessary depending on the status of restoration efforts.[598]

But if restoration efforts have not achieved the higher of background levels or the lowest of either NRC's UMTRCA Criterion 5C table levels or NDEQ's standards using BPT so that an ACL is necessary, CBR witnesses Lewis, Nelson, and Pavlick indicated, Crow Butte must submit an application to the NRC to use an ACL that addresses all the factors listed under Criterion 5B(6) of 10 C.F.R. Part 40, Appendix A, and then obtain NRC approval of that application pursuant to Criterion 5B(5)(c).[599] Further, Dr. Striz testified that when she reviews an ACL application, she looks to see if enough restoration effort has been made using the reasonable technologies that are available to demonstrate that no further decrease can be

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[596] See Tr. at 693.

[597] See Tr. at 699.

[598] See CBR Rebuttal Test. at 19.

[599] See id.

achieved for the constituent value at issue, i.e., until the value is as low as reasonably achievable (ALARA).[600]

On a related matter, Mr. Wireman pointed out that NRC and NDEQ have different standards regarding MU restoration stability, noting that NRC regulations require that regulated constituent concentrations be stable for four consecutive quarters before closure can occur, while NDEQ regulations require monthly sampling for only six months prior to declaring stabilization.[601] And in that regard, CBR's TR agrees with Mr. Wireman, noting that CBR's NDEQ Class III UIC permit requires that the specified ore zone monitoring wells be sampled once a month for a minimum of six months to demonstrate successful restoration, and that CBR's NRC-issued license requires that the wells be sampled once each quarter until stabilization is deemed complete, which occurs when the most recent four consecutive quarters indicate there is no statistically significant increasing trend for all constituents of concern.[602]

To mesh the two different requirements, CBR witnesses Lewis, Nelson, and Pavlick indicated the Applicant will conduct stability sampling to meet both NDEQ and NRC regulations regarding stabilization phase monitoring, which will result in some concurrent sampling to meet both criteria.[603] Specifically, CBR witness Nelson clarified that there is six months of monthly sampling to meet NDEQ requirements, which includes the quarterly sampling for NRC

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[600] See Tr. at 697, 699–700.

[601] See Wireman Initial Test. at 5.

[602] See Tech. Rep. at 6-10 to -11. The TR also states that "[t]he sampling frequency will be one sample every other month for four quarters, and if the six samples show that the restoration values for all wells are maintained during the stabilization period with no significant increasing trends, restoration shall be deemed complete." Id. at 6-11. Because this statement is in conflict with the other information in that TR section, as well as with the testimony of CBR witnesses Pavlick and Nelson at the hearing, see Tr. at 702–03, we accept the statements of the hearing witnesses, which are consistent with the balance of the TR section, as reflecting the actual tabilization monitoring schedule that CBR will follow.

[603] See CBR Rebuttal Test. at 19.

requirements.[604] At the conclusion of the six months of monthly sampling, CBR performs two more quarters of quarterly sampling, which will end stabilization monitoring if constituent levels meet the trend requirements. Staff witness Dr. Striz concurred, noting that this sampling is over and above what NRC requires, but welcomed the additional data points to establish the trend of CBR's stabilization efforts.[605]

b. Board Findings on Applicable Groundwater Restoration Standards

Based on the parties' testimony clarifying the restoration standards that must be adhered to by CBR regarding applicable hazardous constituents,[606] the Board finds that in accordance with Criterion 5B(5), using diligent application of best practicable technologies and efforts, the Applicant must first attempt to return a constituent in the BC/CPF aquifer to the NRC-approved background concentration for that constituent,[607] or, if background concentrations are less than the UMTRCA levels in the Criterion 5C table, meet the groundwater protection standard listed for that constituent in the Criterion 5C table.[608] CBR then is further required to meet NDEQ's Title 118 MCL groundwater standards. As a result, the Board concludes that after exhausting BPT to restore to the NRC-approved background level for that constituent, CBR must meet the

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[604] See Tr. at 702–03.

[605] See Tr. at 702.

[606] In connection with Mr. Wireman's allegations that there is excessive uncertainty regarding applicable groundwater restoration standards, CBR also labeled this issue outside the scope of Contention 2 because, it alleged, restoration standards are not relevant to any of the concerns in Contention 2. See CBR Rebuttal Test. at 18 (Lewis, Nelson, Pavlick). As we noted in our September 2018 in limine ruling, we disagree with this assertion, finding that Mr. Wireman's Opinion 4 dealing with groundwater restoration standards is within the scope of the contention given that any residual groundwater quality degradation after restoration has environmental impacts that might need to be assessed by the Staff as part of its NEPA responsibilities. See Board In Limine Ruling at 9.

[607] See Tr. at 699 (Striz).

[608] See Tr. at 697 (Striz) (citing 10 C.F.R. Part 40, App. A, Criteria 5B(5), 5B(6), and 5C).

lowest value of either NRC's UMTRCA groundwater protection standard in the Criterion 5C table or NDEQ's Title 118 groundwater standard for that constituent.[609]

If, after exhausting this effort, CBR cannot meet either of these two standards, it may seek NRC approval for an ACL, as provided in Criterion 5B(5). In assessing the adequacy of the effort in establishing an ACL under that regulation, however, the Staff requires a licensee to achieve a value that is "as low as reasonably achievable, after considering practicable corrective actions,"[610] by using all reasonable technologies available with sufficient sampling and analysis required to reach ALARA levels.[611] Further, in making its determination about whether to approve a site-specific ACL for a groundwater constituent, the Staff considers whether the constituent will pose a substantial present or potential future hazard to human health or the environment. And in making this constituent hazard finding, the Staff will consider the nine factors regarding potential adverse effects on groundwater quality and the ten factors relating to potential adverse effects on hydraulically-connected surface water quality that are listed in Criterion 5B(6).[612]

Additionally, as Staff witness Dr. Striz indicated, a CBR request for an ACL would need to be submitted as a license amendment that would, in turn, trigger the opportunity for a public adjudicatory hearing. As Dr. Striz explained, this is a detailed process that receives the same extensive technical review that is given to every license amendment.[613] Moreover, as Dr. Striz observed, CBR would be free in such an amendment request to propose values for an ACL that

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[609] See Tr. at 691–93 (Pavlick, Nelson, Striz); see also Tech. Rep. at 6-4; Tech Rep. Tbls. at 227 (tbl. 6.1-1).

[610] 10 C.F.R. Part 40, App. A, Criterion 5B(6).

[611] See Tr. at 699–700 (Striz).

[612] See Tr. at 697 (Striz) (citing 10 C.F.R. Part 40, App. A, Criterion 5B(6)).

[613] See Tr. at 697–98.

would be the same as the NDEQ Title 118 water quality standards so long as the request is found to meet all the requirements of Criterion 5B(6).[614]

Relative to Mr. Wireman's concern about stabilization monitoring of an MU, the NDEQ requires that the specified ore zone monitoring wells be sampled once a month for a minimum of six months to demonstrate restoration success, while NRC mandates that the wells be sampled once each quarter until there is no statistically significant increasing trend for constituents of concern for four consecutive quarters.[615] Per its representations before the Board, we find that CBR will meet both NDEQ and NRC regulations regarding stabilization phase monitoring. CBR will conduct six months of monthly sampling to meet NDEQ requirements that, concurrently, include the quarterly sampling mandated by NRC requirements, followed by two more quarters of quarterly sampling so as to be able to complete stabilization monitoring if constituent levels meet the trend requirements.[616]

In sum, in accordance with Criterion 5B(5), the Board finds that CBR must restore an MEA groundwater constituent to a concentration that does not exceed (1) an NRC-approved background groundwater concentration for that constituent; (2) the lowest constituent value given in either the NRC's UMTRCA groundwater protection standards table in Criterion 5C or NDEQ's Title 118 groundwater standards if the constituent is listed and if the constituent's NRC-approved background level is below the NDEQ's Title 118 value; or (3) an ACL established by the agency through a license amendment, subject to a public hearing opportunity. Further, we agree with Dr. Striz that CBR must show that it has made practicable efforts to restore a specific hazardous constituent to the highest of either the agency-approved

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[614] See Tr. at 696.

[615] See Tech. Rep. at 6-10 to -11.

[616] See CBR Rebuttal Test. at 19 (Lewis, Nelson, Pavlick); Tr. at 702–03 (Pavlick, Nelson, Striz).

groundwater concentration background level or the maximum contaminant level. The maximum contaminant level is the lowest of either NRC's requirements (i.e., Criterion 5C table UMTRCA levels) or NDEQ's requirements (i.e., Title 118 levels).[617] Finally, to meet both NDEQ and NRC requirements, the Board finds that CBR will undertake stabilization monitoring of an MU by conducting six months of monthly sampling to meet NDEQ requirements, which concurrently includes NRC quarterly sampling requirements, followed by two more quarters of quarterly sampling to complete stabilization monitoring if constituent levels meet the trend requirements.

5. Wireman Opinion 5 – Wastewater Disposal

In his Opinion 5, Mr. Wireman claimed that there is inadequate information regarding CBR's planned disposal of wastewater at the MEA and, more specifically, CBR's plans to use deep disposal wells (DDWs) to dispose of the waste fluids from the ISR process.[618]

a. Parties' Positions on Wastewater Disposal

As support for OST's claims that there is inadequate information regarding disposal of wastewater at the MEA, Mr. Wireman stated that CBR proposes to use one or two DDWs to inject waste fluids comprised primarily of bleed water and groundwater restoration wastewater. According to Mr. Wireman, however, CBR's TR does not include any water quality data or hydrogeologic information about the geologic formations into which CBR proposes to dispose of waste fluids. This lack of information on these disposal wells, Mr. Wireman asserted, raises questions about whether any of these formations are a Federal Safe Drinking Water Act (FSDWA)[619]-defined underground source of drinking water (USDW). If so, Mr. Wireman contended, the Applicant will need to either demonstrate that there are no USDWs below the

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[617] See Tr. at 699 (Striz); see also Tech. Rep. Tbls. at 227 (tbl. 6.1-1).

[618] See Wireman Initial Test. at 6.

[619] See 42 U.S.C. §§ 300f–300j-27.

proposed disposal area or request an aquifer exemption.[620] Mr. Wireman concluded that the appropriate hydrogeologic and water-quality data needs to be included in CBR's TR and the Staff's EA.[621]

CBR witnesses Lewis, Nelson, and Pavlick sought to address his concern, testifying that Crow Butte currently has two non-hazardous DDWs at the existing CBR ISR facility that for the past 15 years have operated with excellent results under an NDEQ-issued Class I UIC permit,[622] and the CBR already has prepared a permit application for the use of DDWs at Marsland in accordance with NDEQ regulatory requirements.[623]

These CBR witnesses also testified that the Lower Dakota, Morrison, and Sundance Formations are the geologic strata that will serve as the injection zones for receiving the waste fluids,[624] a fact the Staff acknowledged in its EA.[625] Moreover, information regarding the siting, construction, and operation of the proposed DDWs, including the hydrogeology of the Lower Dakota, Morrison, and Sundance Formations, is provided in CBR's TR and in the Staff's EA and SER.[626] CBR witnesses Lewis, Nelson, and Pavlick testified that those formations, which are the same formations currently in use at the existing CBR ISR facility,[627] are located below the

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[620] See Wireman Initial Test. at 6 (citing Tech. Rep. at 7-22).

[621] See id.

[622] See CBR Rebuttal Test. at 20; see also ER at 3-99.

[623] See CBR Rebuttal Test. at 20; see also ER at 3-99.

[624] See CBR Rebuttal Test. at 20.

[625] See Staff Rebuttal at 12 (Back, Lancaster, Striz) (citing EA at 3-30; ER at 3-99; Tech. Rep. at 4-11, 7-20).

[626] See Tech. Rep. at 3-23 to -25, 4-10 to -12, 7-20, 7-22 to -24; EA at 3-3, 4-20 to -21, 4-23 to -24, 5-19; SER at 90–92, 93, 95–96.

[627] See Tech. Rep. at 3-24.

lowermost USDW and exhibit water quality that is not considered to be a drinking water compliant source under state and federal regulations due to measured concentrations of total dissolved solids (TDS).[628]

In its TR, CBR confirms that DDWs will be used in the management of liquid wastewaters generated at the MEA site during production and restoration. The primary sources of liquid waste will be well-development water, process bleed fluids to maintain inward gradients, concentrated brine produced during aquifer restoration, and other generated process liquid wastewater (e.g., laundry water and plant washdown water).[629] Furthermore, the Staff's EA indicates that CBR will monitor the quality of injected water in the Morrison and Sundance formations on a daily or weekly basis, depending on the parameter, so that water quality in the deep injection formations will not be adversely affected beyond that permitted for DDW operations.[630] The Crow Butte TR also states that the two DDWs will be the only wastewater disposal option at the MEA site for the first five years of operation, whereupon CBR will assess the need for additional disposal options (e.g., additional DDWs, surge tanks, surge/evaporation ponds) to handle increased wastewater volumes during groundwater restoration, and only then will CBR submit a request for an amendment to its NRC license and/or NDEQ permit as needed to implement any chosen option.[631]

Noting that DDW licensing and regulation is not within NRC's jurisdiction, Staff witnesses Back, Lancaster, and Dr. Striz further stated that Crow Butte has applied to NDEQ for a

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[628] See CBR Rebuttal Test. at 20; see also ER at 3-99; EA at 4-23; Tech. Rep. at 4-11.

[629] See Tech. Rep. at 3-23 to -24; see also EA at 5-19.

[630] See EA at 5-19.

[631] See Tech. Rep. at 8-7 to -8; see also CBR License Amend. 3, at 15 (License Condition 10.3.4).

separate Class I UIC permit to construct and operate DDWs at the MEA.[632] And to manage wastewater generation over the life of the project, besides including a specific permit request for the first two wells to accommodate wastewater generated during initial operations, Crow Butte's application seeks an area permit to install and operate up to six Class I UIC DDWs within the MEA license boundary over the expected multi-year life of the project [633]

Referencing provisions of the EA, SER, ER, and TR, Staff witnesses Back, Lancaster, and Dr. Striz testified that these injection zone formations are separated from the BC/CPF sandstone aquifer by several thousand feet of low-permeability units, including at least 750 ft. of Pierre Shale, a regional aquitard with a very low hydraulic conductivity (on the order of $1x10^{-10}$ cm./sec.).[634] Specifically, in its TR Crow Butte states that the two MEA DDWs will be completed into the injection zone at an approximate depth of 4000 ft. to 5000 ft. and will be isolated from any underground source of drinking water by approximately 1800 ft. of shale (i.e., Pierre and Graneros shales).[635] The receiving formations of the proposed MEA injection zone are the same ones used by DDWs at the existing CBR ISR facility.[636] While the Staff's EA indicates that injection of the MEA wastewater will increase pressures within these units, it also notes that the Morrison Formation has demonstrated a capacity to accept large volumes of an injected waste stream over an extended period at the existing CBR ISR facility.[637]

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[632] See Staff Rebuttal Test. at 13 (citing ER at 3-99).

[633] See Tech. Rep. at 4-11; EA at 2-5.

[634] See Staff Rebuttal Test. at 13 (citing EA at 3-29 to -30, 3-32, 5-19; SER at 52–53; Tech. Rep. at 2-52 to -53, 7-20; ER at 7-24).

[635] See Tech. Rep. at 8-7; see also EA at 4-23.

[636] See Tech. Rep. at 3-24.

[637] See EA at 5-19.

The Staff's EA also states that the MEA DDWs would be separated by at least six miles from those at neighboring existing and proposed ISR areas (i.e., the existing CBR ISR facility, the NTEA, and the TCEA).[638] Although CBR in its TR recognizes there may be some overlap in pressure responses within the Lower Dakota, Morrison, or Sundance formations from MEA DDW injections, it also declares (and the Staff's EA agrees) that the subsurface geologic characteristics beneath the proposed expansion areas would prevent injected disposal fluids from impacting the overlying fresh-water Arikaree/Brule and BC/CPF aquifers.[639]

Between the lowermost BC/CPF and the injection zone formations resides a separating aquitard of more than 2500 ft. of sediments primarily consisting of low permeability shale that both CBR's TR and the Staff's EA agree protects against vertical migration of injected fluids to the overlying Brule and Chadron Formations. Shales above and below the injection zone will encase the disposal fluids within the receiving formations, and CBR has identified no structural elements (i.e., faults or fractures) with the potential to disrupt the natural vertical containment.[640] As a result, both the CBR TR and the Staff EA maintain that liquid discharges to the DDWs are expected to have little to no potential impact on water resources because they would be isolated from any USDW by hundreds of feet of low permeability shale.[641]

With respect to the wastewater wells themselves, CBR in its TR indicates that because the primary environmental concerns with DDWs are the potential release of injection fluid into drinking water aquifers or into the production zone, these disposal wells are double cased into the Pierre Shale Formation with continuous pressure and flow monitoring of the injection fluid,

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[638] See id.

[639] See Tech. Rep. at 7-24 to -25; EA at 5-19.

[640] See Tech. Rep. at 7-20; EA at 5-19.

[641] See Tech. Rep. at 7-24 to -25; EA at 4-24.

pressure monitoring in the casing annulus, and MIT testing every two years. And to further minimize the potential impacts from surface spills, pipe failure, or casing failures, the DDW system components are continuously monitored and alarmed to quickly detect and respond to leakage incidents. This combination of controls, the CBR TR asserts, will effectively control the potential impacts of DDW operations to the environment.[642]

And according to the Staff analysis in its SER, as a result of the DDW monitoring required under the NDEQ UIC permit to ensure the health and safety of workers and the public, there are no safety concerns associated with the proposed MEA DDW waste disposal system that were not previously reviewed.[643] Furthermore, based on the required well MIT testing, implementation of the leak detection system, and hydraulic isolation of the injection zone from the overlying aquifers, the Staff in its EA concludes that the potential long-term impacts on groundwater quality from wastewater disposal into the DDWs would be "SMALL."[644]

Relative to the water quality within the Lower Dakota, Morrison, and Sundance injection formations and their eligibility to serve as injection zones, CBR witnesses Lewis, Nelson, and Pavlick stated that those formations exhibit water quality that under state and federal regulations would not be considered USDW due to measured TDS concentrations. They also declared that those formations are located below the lowermost USDW.[645] Further in that regard, Staff witnesses Back, Lancaster, and Dr. Striz indicated that CBR's TR estimates the TDS concentrations within the injection zone to be in excess of 10,000 mg/L,[646] and the Applicant did

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[642] See Tech. Rep. at 4-11.

[643] See SER at 93.

[644] See EA at 4-24.

[645] See CBR Rebuttal Test. at 20.

[646] See Staff Rebuttal Test. at 12 (citing Tech. Rep. at 4-11, 7-20).

not expect any harmful or reactive incompatibility between the formation brine and the constituents of the wastewater.[647] In its EA, the Staff states that the TDS levels observed in the Morrison and Sundance formations at the existing CBR ISR facility varied from approximately 24,000 mg/L to 40,000 mg/L, respectively, while the EPA secondary drinking water standard for TDS is 500 mg/L.[648] CBR witness Pavlick also testified that because an aquifer with a TDS reading of over 10,000 mg/L is not considered a potential source of drinking water, as the formations in the MEA injection zone are in excess of this value, none of those formations have the potential to serve as a USDW as defined by the FSDWA.[649]

Mr. Wireman raised questions about the water quality suitability of the planned MEA injection formations, however, stating that based on his experience in the Rocky Mountains, the Madison Formation, a well-known regional aquifer occurring below the injection zone formations has TDS well below 10,000 mg/L so as to require USDW consideration in connection with overlying injection formations.[650] Dr. Striz testified, however, that the existing CBR ISR facility and the MEA just 11 miles to the south contain different characteristics. She posited that with the DDWs for the MEA being placed in the same formations as those DDWs currently in use at the existing ISR facility for which CBR has NDEQ permits, there are no lower USDW formations in the Marsland area consistent with NDEQ DDWs permitting requirements at the existing CBR ISR facility. Otherwise, Dr. Striz claimed, NDEQ would not have issued the Class I UIC permit

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[647] See id. (citing Tech. Rep. at 4-11, 7-20; ER at 3-99).

[648] See EA at 4-23.

[649] See Tr. at 708.

[650] See Tr. at 709.

for the existing facility DDWs, which CBR is required as a condition to its NRC license to have in order to operate.[651]

Finally, the Staff's EA concludes that the vertical hydraulic separation of the DDW injection zone from overlying aquifers and the low permeability of the LCUs, in conjunction with compliance monitoring, helps ensure that the MEA DDW system will not cause significant impacts to natural resources. Therefore, the Staff in its EA indicates that when the potential incremental impacts from amending the CBR license to include the MEA are added to other past, present, and reasonably foreseeable future actions, cumulative impacts from liquid wastes would not be significant.[652]

b. Board Findings on Wastewater Disposal

Mr. Wireman's concerns in his Opinion 5 regarding an alleged inadequate description by CBR and the Staff of wastewater disposal by deep well injection is based primarily on his claims that (1) CBR failed to provide any geologic and hydrogeologic information on the formations that will be used as the injection zone for the MEA DDWs; and (2) the existence of the regional Madison Formation aquifer raises a question whether a useable source of drinking water exists in a strata below the formations that are to be used for the MEA DDWs.[653]

With regard to Mr. Wireman's allegations that CBR does not provide any information on the geologic formations and aquifers into which CBR proposes to inject waste fluids,[654] CBR

[651] See Tr. at 711. As part of that dialogue, Staff witness Lancaster noted that License Conditions 10.3.4 and 12.5 require CBR to have that NDEQ Class I UIC permit. See Tr. at 711; see also CBR License Amend. 3, at 15, 22.

[652] See EA at 5-19.

[653] See Wireman Initial Test. at 6; Tr. at 709.

[654] We also note that CBR again used its written testimony in this regard to make the legal claim that Mr. Wireman's Opinion 5 is outside the scope of Contention 2. See CBR Rebuttal Test. at 20 (Lewis, Nelson, Pavlick). We disagree for the reasons previously stated in

plans to drill into the same formations that have been used for the DDWs at its existing ISR facility, i.e., the Lower Dakota, Morrison, and Sundance Formations.[655] And as CBR witness Pavlick confirmed, License Condition 10.3.4 stipulates that the Applicant obtain NDEQ authorization to drill a minimum of two DDWs for the Marsland area, which will be at depths of between 3400 ft. and 3600 ft. into these formations.[656] Mr. Pavlick also testified that the MEA injection zone is located below the lowermost underground source of drinking water and exhibits water quality that, due to the measured concentration of TDS, is not considered to be a USDW under state and federal regulations.[657] Based on this information, in conjunction with the other material in the evidentiary record supporting CBR's assertion that the lowermost drinking water source is isolated from the injection zone by more than 2500 ft. of sediments primarily consisting of low permeability shale (including at least 750 ft. of Pierre Shale aquitard),[658] we find that the overlying Arikaree/Brule and the BC/CPF aquifers are protected by these aquitards against vertical migration of injected wastewater fluids.

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our ruling on the Staff's in limine motion in which a similar challenge was raised. As we observed there,

> [b]ecause DDWs can impact surrounding groundwater quality, testimony questioning the MEA DDWs' locale and use during operations and restoration are within the scope of this contention so long as they are restricted to the topics of groundwater quality. Furthermore, the fact that the NRC is not the permitting agency for DDWs does not place this discussion of the topic outside of Contention 2's scope.

Board In Limine Ruling at 10.

[655] See Tech. Rep. at 3-24.

[656] See Tr. at 707.

[657] See Tr. at 707, 737.

[658] See, e.g., Tech. Rep. at 2-53, 2-85, 7-24 to -25, 8-7.

The evidentiary record also establishes that to ensure the health and safety of workers and the public, CBR monitoring of the MEA DDWs will be required by CBR's NDEQ UIC permit, which includes continuous flow and pressure monitoring of the injection fluid, pressure monitoring in the casing annulus, and biannual MIT testing of the well casings. And to further minimize the potential impacts from DDW-associated surface spills, pipe failure, or casing failures, the DDWs are continuously monitored and alarmed to quickly detect and respond to leakage incidents.[659] We note in addition that CBR will monitor the quality of disposed water in the injection zone on a daily or weekly basis (depending on the parameter) and, as a result, water quality in the deep injection formations would not be adversely impacted beyond that allowed by permit for DDW operation.[660] The Board concludes that the combination of natural isolation of the deep, non-potable injection zone formations and the DDW monitoring program will effectively control the potential impacts to the environment,[661] and will help ensure that no safety concerns are posed by the MEA's DDW waste disposal system.[662]

And while CBR did not conduct a detailed hydrogeologic investigation for each of the Lower Dakota, Morrison, and Sundance Formations, the Board finds that the level of understanding of the hydraulic behavior of these layers and their interactions, in conjunction with the detailed hydrogeologic understanding that exists of these formations' overlying strata (which are consistent throughout the existing CBR ISR facility to the southwest extent of the MEA), and the successful deployment of this disposal technique currently at the existing CBR

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[659] See id. at 4-11.

[660] See EA at 5-19.

[661] See id.

[662] See SER at 93.

ISR facility to the north,[663] is sufficient to conclude that its use can be replicated safely for the MEA DDWs.

As to Mr. Wireman's allegation, first raised at the hearing, that based on his experience in the Rocky Mountains, the well-known regional Madison Formation aquifer raises questions about whether there is a USDW below the planned MEA injection zone,[664] the Board finds that his concern lacks evidentiary support. Consistent with statements in CBR's TR and ER and the Staff's EA that the TDS levels observed in the injection zone formations at the existing CBR ISR facility varied from approximately 24,000 mg/L to 40,000 mg/L,[665] CBR witness Pavlick testified at the hearing that the MEA injection zone formations have TDS values in excess of 10,000 mg/L, thereby eliminating these strata as a potential source of drinking water and confirming that none of these injection zone formations have the potential to serve as an FSDWA USDW.[666] In addition, Mr. Pavlick declared that there are no aquifers that meet the USDW definition below the Lower Dakota/Morrison/Sundance injection zone.[667] Further, as Staff witness Dr. Striz indicated, NDEQ currently allows these same Lower Dakota, Morrison, and Sundance Formations to house Class I UIC injection wells at the existing CBR ISR facility just 11 miles to the north of the MEA, an activity that NDEQ would not have allowed if the TDS levels in these geologic layers were below 10,000 mg/L or there were USDW formations below this level.[668] In the face of Mr. Wireman's essentially unsupported speculation about the

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[663] See id. at 91–92.

[664] See Tr. at 709

[665] See Tech. Rep. at 7-20; ER at 4-11; EA at 4-23.

[666] See Tr. at 708, 737.

[667] See Tr. at 737.

[668] See Tr. at 711.

possible existence of a USDW source beneath the planned MEA injection zone formations, we find that the preponderance of the evidence establishes Mr. Wireman's USDW-related concern is without merit.[669]

Accordingly, the Board finds that Crow Butte has provided sufficient geologic and hydrogeologic characterization of the injection zone aquifers in the area of the existing CBR ISR facility and proposed MEA. We also find that the preponderance of the evidence compels the conclusion that there is no USDW formation below the injection zone, and that the TDS is more than 10,000 mg/L in the formations proposed for DDW use at Marsland, which disqualifies the Lower Dakota, Morrison, and Sundance Formations as USDWs and makes them eligible as DDW injection zones. We also agree with the Staff's assertion that the vertical hydraulic separation of the DDW injection zone from overlying aquifers and the low permeability of the confining units, in conjunction with compliance monitoring, helps ensure no significant impacts to the environment from DDW operations. Finally, we agree with the Staff's claim that when the potential incremental impacts from amending the CBR license (to include the MEA) are added to other past, present, and reasonably foreseeable future actions, the cumulative impacts from liquid wastes are not likely to be significant.[670]

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[669] In this regard, we note as well that the question of whether an NDEQ Class I UIC injection well permit has been or could be properly issued is a matter that would need to be raised with the NDEQ. See N. States Power Co. (Tyrone Energy Park, Unit 1), ALAB-464, 7 NRC 372, 375 (1978) (indicating requirements of state law are matters for state regulatory bodies).

[670] See EA at 5-19.

VII. CONCERN 2 – ABSENCE OF SITE HYDROGEOLOGY DESCRIPTION

The second major concern expressed by OST in the context of its Contention 2 involves the safety implications of the lack of a sufficient description of MEA site hydrogeology. In this regard, in his initial testimony OST witness Dr. Kreamer presented seven “opinions” indicating why, in his view, the Applicant failed to meet the standards of professional hydrogeological practice in characterizing the MEA site. In Opinion 1 of his initial testimony, Dr. Kreamer listed eight deficiencies with MEA hydrogeologic characterization associated with the aquifer pumping test data. Specifically, he raised challenges that included the adequacy of the initial pumping test attempt, data selectivity, appropriate use of the Cooper-Jacob methodology, proper analysis of monitoring wells 2 and 8, insufficient MEA coverage from a single pumping test, the impact of off-site influences, the effect of variations in aquifer thickness, and issues with monitoring wellscreen intervals. In his other six opinions, Dr. Kreamer asserted there were additional problems, including an insufficient description of the site hydrogeology relative to the previous pumping test analyses for the existing CBR ISR facility, an improper use of alternative pumping test methods, questionable homogeneity/anisotropy assumptions, improper analysis for anisotropy, discontinuities in how BC/CPF thickness was used as the basis for calculating transmissivity, and selective analysis of pumping test data.[671]

Each of these facets of Concern 2 are reviewed in this section, with reference to the overarching issues previously discussed in section V above, as appropriate.

A. Kreamer Opinion 1 - Mischaracterization of the Hydrogeologic Environment

Dr. Kreamer first opined generally that there are several deficiencies with CBR’s MEA hydrogeologic characterization as it relates to the report on the May 2011 pumping test, declaring that much of the collected pumping test data was selectively ignored, the solitary

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[671] See Kreamer Initial Test. at 2, 7; Kreamer Rebuttal Test. at 1.

pumping test covered only a portion of the MEA site while leaving the majority of the site hydrogeologically undefined, and the analysis of the single pumping test was influenced by conditions outside the site boundary.[672] Moreover, as support for these characterization inadequacy claims, Dr. Kreamer proffered eight specific "bases" (labelled A through H) to establish that CBR, with the Staff's blessing, mischaracterized the hydrogeologic environment underlying the MEA.[673]

But before addressing these points, we note that, as we previously discussed (see supra sections V.A. and V.B), Dr. Kreamer claimed that CBR failed to recognize (1) the failings of the aquifer pumping test (resulting in an inaccurate interpretation of the data obtained by this test); and (2) the presence of fractures ignored by CBR and the Staff and the contribution of these structures to heterogeneity and anisotropy that allegedly creates a lack of containment in the BC/CPF aquifer. As we have already addressed these two criticisms, we will not repeat our findings here, other than to observe that relative to CBR's interpretation of the pumping test data, we found on the basis fo the evidentiary record that CBR provided adequate justification for its approach to analyzing the aquifer pumping test data. We also found that the Intervenor failed to provide any corroborating evidence to support its position that significant localized aquifer leakage adversely impacts the efficacy of CBR's conceptual hydrogeologic model for the MEA. Thus, we determined that the Applicant's pumping test analysis was not only plausible, but consistent with other evidentiary elements demonstrating the containment and connectivity characteristics of the BC/CPF production zone (see supra section V.C). And with regard to the second issue of fracturing, we found that there was no evidence of excessive transmissive faulting or fracturing that would cause sufficient heterogeneity and anisotropy in the MEA geologic strata to refute the evidence in the record establishing the validity of the CBR and Staff

[672] See Kreamer Initial Test. at 1 (citing Test #8 Rep.).

[673] See id. at 1–2.

conclusions regarding containment of processing fluids and the lack of aquifer interconnectivity required for safe ISR activities in the MEA proposed production area.

Against this background, we turn to our consideration of the eight bases underlying Dr. Kreamer's Opinion 1.

1. Kreamer Opinion 1, Basis A: Initial Pumping Test Attempt

a. Parties' Positions on Kreamer Opinion 1, Basis A: Initial Pumping Test Attempt

As an initial Basis A allegation supporting his Opinion 1, Dr. Kreamer noted that the report for the May 2011 pumping test failed to include data from one of the two tests actually done at the MEA. Allegedly, data from an initial 19-hour test, which CBR characterized as "failed," was not presented or discussed in its TR. Dr. Kreamer maintained that additional insight into the subsurface hydrogeological conditions could be gained from that initial test and that CBR did not adequately explain the "pump failure" cited as a justification for the termination of the test.[674] And in this same vein, OST witness Dr. LaGarry in his rebuttal testimony suggested CBR had improperly suppressed data and claimed that Dr. Kreamer's rebuttal testimony regarding unreported pumping tests indicated there was a lack of containment in the MEA.[675]

CBR's pumping test report stated that, in accordance with an NDEQ-approved plan, on November 18, 2010, an initial attempt at a pumping test was performed in the MEA on well CPW-1, but that this test was terminated after only 19 hours of operation due to "pump failure."[676] CBR's pumping test report did not discuss the causes for this problem nor did it analyze the data that was collected prior to terminating this first attempt. In its rebuttal

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[674] See id. at 2 (citing Test #8 Rep. at 6).

[675] See LaGarry Rebuttal Test. at 2.

[676] See Test #8 Rep. at 3, 6; see also CBR Rebuttal Test. at 4 (Lewis).

testimony, CBR indicated that in addition to pump issues, there were problems with well installation of the CPW-1 pumping well, specifically that it was shown to be very inefficient with abnormally large drawdown values that prevented more ideal, higher pumping rates.[677]

The Staff in its rebuttal testimony stated that this issue was discussed in CBR's March 2011 proposal to change the pumping test plan because of the poor hydraulic connection between the pumping well and the aquifer during the initial attempted CPW-1 test.[678] Finally, at the hearing CBR witness Lewis clarified that other problems were encountered during the first pumping attempt, i.e., it was impossible to control the pumping rates properly during the test due to both a pump problem and a well installation problem.[679]

CBR acknowledged that it did not formally analyze the hydrogeologic data, but asserted that it did gain information from the failed test that caused CBR to modify its plans and procedures associated with the second attempt at conducting a pumping test in the CPW-1 area. These changes were reflected in the March 2011 revised pumping plan, which also was approved by NDEQ and included modifications to the projected pumping rates, the expected ROI, and the selection of wells for monitoring during the second attempt.[680]

In its rebuttal testimony, the Staff stated that any data from the first attempt would not yield any materially different, useful information because the initial pumping well, CWP-1, was not hydraulically connected to the aquifer.[681] And in its rebuttal testimony, CBR agreed that an

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[677] See CBR Rebuttal Test. at 4 (Lewis).

[678] See Staff Rebuttal Test. at 15–16 (Back, Lancaster, Striz) (citing Ex. CBR023, at 1 (Letter from Robert Lewis, Worley Parsons, to Lee Snowhite, CBR (Mar. 16, 2011)) [hereinafter Revised Pumping Test Plan]).

[679] See Tr. at 377.

[680] See CBR Rebuttal Test. at 6–7 (Lewis); Tr. at 377 (Lewis); see also Revised Pumping Test Plan at 1.

[681] See Staff Rebuttal Test. at 17 (Back, Lancaster, Striz).

analysis of the failed pumping test data from the limited 19-hour period would not have been useful or insightful because the less-than-one-day run-time was a small fraction of the duration (i.e., four days are required to reach the drawdown targets that would trigger test termination) needed to measure significant drawdown in more distant wells.[682]

Given the limited data from the first attempt at CPW-1, CBR endeavored to rectify the situation by installing CPW-1A, a new well located approximately 67 ft. west-southwest from former pumping well CPW-1, and by running a second testing attempt using the revised pumping plan.[683] The replacement pumping test on the new well was successfully conducted over a 4.3-day pumping period from May 16 to May 20, 2011, followed by the collection of recovery data.[684]

b. Board Findings on Kreamer Opinion 1, Basis A: Initial Pumping Test Attempt

Contrary to the Dr. Kreamer's claim,[685] CBR's failure to report its first attempt to conduct a pumping test in the MEA was not done to conceal that the initial November 2010 attempt "failed" and was terminated after only 19 hours of operation.[686] Furthermore, although the data from this test attempt was not formally analyzed, the test clearly was used to modify the pumping test plan for the second attempt that resulted in a successful pumping test.[687]

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[682] See CBR Rebuttal Test. at 4 (Lewis).

[683] See Revised Pumping Test Plan at 1; Staff Rebuttal Test. at 16 (citing Test #8 Rep. at 9 of 10 (tbl. 7)).

[684] See Test #8 Rep. at 8.

[685] See Kreamer Initial Test. at 2 (citing Test #8 Rep. at 6).

[686] See Test #8 Rep. at 6.

[687] See id.; see also Revised Pumping Test Plan at 1.

Dr. Kreamer also asserted that CBR did not provide any details of the “pump failure” that were adequate to justify labeling the test as “failed.”[688] While the Applicant’s terse description in the pumping test report of a “pump failure” as the cause of the problem did not provide a particularly useful explanation, any deficiency in that regard was corrected by CBR’s additional rebuttal and hearing testimony made clear there was indeed a testing failure, as opposed to an attempt to conceal unfavorable test results.[689]

With regard to obtaining hydrogeologic insight from the initial pumping test attempt, CBR admits that while it did not formally analyze the data, information gained from the failed test resulted in a revised pumping plan with modifications approved by NDEQ that, after the installation of a new pumping well, resulted in a successful, long-term pumping test.[690] As Staff witness Back indicated, it is not unusual to encounter installation difficulties with well casings placed so deeply below the surface.[691] Moreover, the usefulness of the early data from this initial test likely would be limited.[692] It thus is not surprising, realizing that the 19-hour running time of the first attempt was a fraction of the time needed to measure the necessary drawdown in the more distant wells (as is illustrated by the second attempt that lasted over 100 hours), that CBR did not include the data.[693]

And while Dr. LaGarry suggested CBR engaged in the suppression of adverse data,[694] we are unable to conclude there was any untoward motivation associated with the absence of

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[688] See Kreamer Initial Test. at 2.

[689] See CBR Rebuttal Test. at 4 (Lewis); Tr. at 377 (Lewis).

[690] See Revised Pumping Test Plan at 1–2; Test #8 Rep. at 3, 6–7; Tr. at 377 (Lewis).

[691] See Tr. at 376.

[692] See supra section V.A.1.b.i.

[693] See CBR Rebuttal Test. at 4 (Lewis).

[694] See LaGarry Rebuttal Test. at 2.

the drawdown data in the pumping test report from the first test attempt, particularly given that the first attempt was revealed (albeit somewhat succinctly) in the report. Furthermore, although Dr. Kreamer opined that the unreported pumping test results showed a lack of containment, we were unable to locate any mention in Dr. Kreamer's testimony of a relation between the data from the first pumping test attempt and a lack of containment in the hydrogeology of the BC/CPF at the MEA.

We find, therefore, that CBR identified sufficiently the unsuccessful first attempt to conduct a pumping test in a portion of the MEA, which was replaced by a successful second attempt in the same area. While the details of the problem that caused the first attempt to fail were not well defined in the pumping test report, we find that the basis for the failure was sufficiently detailed in CBR's rebuttal and hearing testimony. With the replacement test essentially duplicating the data from the first 19-hour test and extending the data collection for an additional 80-plus hours followed by recovery analyses,[695] we have no reason to believe that the analysis of the failed pumping test data would have provided any pertinent information or changed any of the conclusions that were derived from CBR's analyses of the data collected during the second, successfully-completed long-term pumping test.

2. Kreamer Opinion 1, Basis B: Data Selectivity

Also as support for his challenge to the adequacy of the May 2011 pumping test, in Basis B for his Opinion 1 Dr. Kreamer asserted that CBR arbitrarily analyzed only selected portions of the resulting data (choosing late-time data in some cases and middle-time data in others), adding that there was no justifiable basis for analyzing only a selected portion of the pumping data that, if analyzed in toto, might demonstrate lack of containment of the BC/CPF.[696] Because this issue seemed to apply to several of the concerns raised as the bases for

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[695] See Staff Rebuttal Test. at 16–17 (Back, Lancaster, Striz).

[696] See Kreamer Initial Test. at 2; 7.

Contention 2, we have addressed it as an overarching issue imbedded within OST's allegations that the Applicant and the Staff have misinterpreted the aquifer pumping test (see supra section V.A). Specifically, the parties' positions addressing Dr. Kreamer's claims that CBR did not consider the entire test data are presented in detail above in section V.A.1.b and need not be repeated here.

And in this regard, section V.A.2.b above details our findings that (1) Dr. Kreamer's claims about data selectivity are unsupported because all data points for all of the observation wells used in the MEA aquifer pumping test are presented in the drawdown and recovery response curves;[697] (2) CBR's rationale for analyzing the portions of the aquifer pumping test data was clearly explained by the Applicant and is consistent with recommended practice;[698] (3) less weight should be given to the early data because it may not closely represent the theoretical drawdown equation due to, among other things, inconsistency in well discharge and the effects of wellbore storage and near-wellbore effects;[699] (4) the late-time deviation responses in the drawdown of two wells (attributed to a lack of containment within the BC/CPF by Dr. Kreamer) could have been the result of other causes (i.e., higher transmissivities at distances from the pumping well, additional aquitard storage-water release, or misinterpretation of wellbore storage/near-wellbore effects) that could mimic the same response in the graphs;[700] and (5) while the CBR and Staff theories are consistent with the many other site observations and characteristics that support the Applicant's position that production zone fluids will be

[697] See Test #8 Rep. at PDF 79–96 (figs. C1 to C17); Staff Rebuttal Test. at 17 (Back, Lancaster, Striz).

[698] See Test #8 Rep. at 13.

[699] See CBR Rebuttal Test. at 4–6 (Lewis, Nelson, Pavlick).

[700] See Test #8 Rep. at 13; id. app. C at PDF 80, 82 (graphs C1 & C3); Staff Rebuttal Test. at 19–20 (Back, Lancaster, Striz).

contained,[701] Dr. Kreamer provided no corroborating evidence to support his position that UCU leaks of sufficient magnitude exist to either jeopardize containment or prevent CBR from controlling its production fluids during facility operation and restoration.

3. Kreamer Opinion 1, Basis C: Cooper-Jacob Methodology

Contesting the adequacy of the May 2011 pumping test analysis on another front, Dr. Kreamer in Basis C to his Opinion 1 criticized CBR for not including in the pumping test report an assessment employing the Cooper-Jacob technique, an analytical tool that can identify a recharge boundary that is consistent with a lack of confinement of an aquifer.[702] As with Basis B just discussed, this matter applies to several of OST's Contention 2-supporting Concerns so that it has been addressed in the context of the overarching issue of OST's allegations that the Applicant and Staff have misinterpreted the aquifer pumping test (see supra section V.A) and will not be repeated in detail here.

But briefly summarizing, the parties' positions regarding Dr. Kreamer's assertion that CBR did not analyze the pumping data using the Cooper-Jacob distance-drawdown method and the resulting Board findings are presented above in sections V.A.1.a and V.A.1.b. Regarding his allegations that CBR did not analyze the pumping test data using the Cooper-Jacob distance-drawdown method, we found that (1) CBR analyzed the pumping test data using both the Theis drawdown and recovery methods and the Cooper-Jacob distance-drawdown methods;[703] and (2) in the pumping test report CBR not only presented the graphical results of

[701] See supra section V.C and infra sections IX.A.2 and IX.B.2 for a summary of the site observations and characteristics that support BC/CPF aquifer containment.

[702] See Kreamer Initial Test. at 2 (citing Test #8 Rep. at 11).

[703] See CBR Initial Test. at 29 (Lewis, Nelson, Pavlick).

the Cooper-Jacob analysis but also analyzed the data to derive the hydraulic parameters of transmissivity and storativity.[704]

4. Kreamer Opinion 1, Basis D: Analysis of Monitor-2 and Monitor-8 Wells

a. Parties' Positions on Kreamer Opinion 1, Basis D: Analysis of Monitor-2 and Monitor-8 Wells

Also in support of his position that the May 2011 pumping test analysis was inadequate, Dr. Kreamer in Basis D for his Opinion 1 stated that the pumping test report did not include an analysis of data from water-level changes in wells Monitor-2 or Monitor-8 as part of CBR's evaluation of the aquifer response to pumping, even though these wells were reported to be within the ROI of the pumped well.[705]

In response, CBR witnesses Lewis, Nelson, and Pavlick testified that wells Monitor-2 and Monitor-8 were not part of the formal monitoring well network because, in developing the revised pumping test plan, CBR estimated these wells would have less than the NDEQ drawdown criteria of 0.5 ft. for inclusion into the network. Consequently, water-level changes from those wells were not going to be used to define the ROI relative to CBR's second aquifer pumping test. But because they showed drawdown of 0.42 ft. and 0.76 ft., respectively, at the end of the test, the data from these wells were analyzed along with the other monitoring wells and the results presented in Table 8 of the testing report.[706]

Staff witnesses Back, Lancaster, and Dr. Striz further clarified that, because the initial attempt to perform a pumping test failed (as is discussed supra section VII.A.1), CBR refined the test design and, among other things, designated two different wells (Monitor-6 and

[704] See CBR Rebuttal Test. at 10 (Lewis, Nelson, Pavlick); Test #8 Rep. figs. app. at PDF 50 (fig. 18).

[705] See Kreamer Initial Test. at 2.

[706] See CBR Rebuttal Test. at 7; Tr. at 431 (Lewis); Revised Pumping Plan at PDF 3 (tbl.1 note); Test #8 Rep. at 7, tbls. app. at 9 of 10 (tbl. 7), 10 of 10 (tbl. 8, n.1), app. C at PDF 81 (graph C2), PDF 87 (graph C8), PDF 90 (graph C11), PDF 96 (graph C17).

Monitor-7) as the farthest wells for the purpose of formally estimating the ROI. But, according to these Staff witnesses, Monitor-2 and Monitor-8 were still monitored and analyzed as described in the original aquifer pumping test plan.[707] These Staff witnesses further noted that the data collected from these most-distant observation wells identified measurable drawdown in excess of 0.4 ft. due to pumping, which CBR concluded were sufficiently reliable data to calculate aquifer parameters.[708]

b. Board Findings on Kreamer Opinion, 1 Basis D: Analysis of Monitor-2 and Monitor-8 Wells

We find that the allegations in Dr. Kreamer's Opinion 1, Basis D, are baseless. Even though wells Monitor-2 and Monitor-8 were officially not going to be included in the formal monitoring network for the second pumping test (as they were predicted to have less than the 0.5 ft. of drawdown required by NDEQ) and so were replaced with wells Monitor-6 and Monitor-7, CBR continued to monitor wells Monitor-2 and Monitor-8. And because wells Monitor-2 and Monitor-8 measured drawdown of 0.42 ft. and 0.76 ft., respectively, their data was later analyzed along with all the other wells to estimate their hydraulic parameters.[709]

As Dr. Kreamer acknowledged at the hearing, the data for the Monitor-2 and Monitor-8 wells were presented in the pumping test results,[710] and we thus find Basis D for Dr. Kreamer's Opinion 1 without merit.

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[707] See Staff Rebuttal at 16 (citing Test #8 Rep. at 1 of 1 (tbl. 3, n.1)), 21–22 (citing Test #8 Rep. at 14, app. C at PDF 81 (graph C2), PDF 87 (graph C8), PDF 90 (graph C11), PDF 96 (graph C17)).

[708] See id. at 21–22 (citing Test #8 Rep. at 14).

[709] See CBR Rebuttal Test. at 7 (Lewis, Nelson, Pavlick) (citing Test #8 Rep. app. C at PDF 81 (graph C2), PDF 87 (graph C8), PDF 90 (graph C11), PDF 96 (graph C17)).

[710] See Tr. at 431.

5. Kreamer Opinion 1, Basis E: MEA Coverage from Single Pumping Test

a. Parties' Positions on Kreamer Opinion 1, Basis E: MEA Coverage from Single Pumping Test

Because of their similarity, we consider together the claims of OST witnesses Wireman and Dr. Kreamer, as outlined in Basis E of Dr. Kreamer's Opinion 1, that CBR employed only a single pumping test that did not encompass the entire MEA. As a result, they contended, the hydrogeological response to pumping for a large portion of the MEA remains unknown or not adequately characterized, a paucity of coverage that is poor professional practice.[711] CBR's single pumping test for the MEA had an ROI of 8800 ft.,[712] for a total coverage length of 3.2 miles, which is less than half of the 7.3-mile long site.[713] And, as reflected earlier in this decision (see supra section VI.A.1), Mr. Wireman claimed that this limited data does not adequately characterize the subsurface heterogeneity and is inadequate for developing an acceptable site-wide conceptual hydrologic model.[714] Furthermore, according to Dr. Kreamer, it is unclear why CBR undertook only one test, given that the geologic strata in the MEA lack consistent thickness and are not entirely horizontal. To properly assess the hydraulic conditions of the subsurface consistent with normal professional practice, he maintained, it is necessary to conduct several pumping tests across the untested majority of the property area, and then undertake duplicate testing to determine the repeatability of the results.[715]

Disputing Dr. Kreamer, CBR witnesses Lewis, Nelson, and Pavlick testified that, with respect to Marsland, the pumping test was run only for the limited purpose of characterizing the

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[711] See Kreamer Initial Test. at 2; Wireman Initial Test. at 4; see also Tr. at 437 (Wireman).

[712] See Tech. Rep. at 2-82; EA at 3-31.

[713] See Tr. at 435 (Shriver); Staff Rebuttal at 23 (Back, Lancaster, Striz) (citing Text #8 Rep. figs. app. at PDF 33 (fig. 1), PDF 48 (fig. 16)).

[714] See Wireman Initial Test. at 4.

area of the first four MUs to be developed. They testified as well that additional pumping tests of the other MUs at this time would provide little incremental value given the quality and reliability of existing data and analyses. They based this claim not only on the existing pumping test results, but on other evidence that demonstrates there was a strong basis for concluding there is containment across the site.[716] As a result, relative to the MEA site as a whole, it is their opinion that there is a substantial basis for concluding that containment exists even without additional pumping test data and analysis.[717]

Staff witnesses Back, Lancaster, and Dr. Striz agreed with CBR, stating that, based on the ROI of 8800 ft. covering more than three miles of the approximately 7.5-mile length of the MEA site, there is no need to assess the response of the entire MEA site to pumping because the site geology is not complicated and cross-sections demonstrate the uniformity of hydrostratigraphic units and the continuity of the BC/CPF aquifer across the MEA.[718]

Regarding the claims of Mr. Wireman and Dr. Kreamer that performing a single pumping test that covered only a portion of the site is not consistent with professional practices, CBR witnesses Lewis, Nelson, and Pavlick responded that their approach was consistent with practice in other recent ISR proceedings and with the Staff's NUREG-1569 guidance that "[a]ny of a number of commonly used aquifer pumping tests may be used including single-well drawdown and recovery tests, drawdown versus time in a single observation well, and drawdown versus distance pumping tests using multiple observation wells."[719] Making clear that

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[715] See Kreamer Rebuttal Test. at 1.

[716] See CBR Rebuttal Test. at 7–8 (citing Hydraulic Containment Report).

[717] See id. at 8.

[718] See Staff Rebuttal Test. at 23–24.

[719] CBR Rebuttal Test. at 7 (quoting NUREG-1569, at 2-24).

the one pumping test covering a portion of the site does not end its responsibilities relative to the balance of the site, CBR witness Shriver verified at the hearing that another site-specific pumping test will be performed for each new MU as it is slated for startup operations.[720] The additional pumping tests are required under License Condition 11.3.4, which indicates that as part of developing its wellfield packages for any new MUs at the MEA, CBR must perform an aquifer pumping test for each new area.[721]

Mr. Wireman, however, declared that it was important now, upfront as part of the licensing process, to conduct these additional pumping tests covering the remaining portion of the MEA. He emphasized that, while subsequent aquifer pumping tests will give CBR the hydraulic parameters for each new MU, such tests will not characterize the groundwater flow of the MU for licensing consideration and will not assist in evaluating the recovery operation risk of unwanted movement of contaminated groundwater needed for the Staff's EA assessments.[722]

Staff witness Back challenged Mr. Wireman's claim, maintaining that there is a wealth of other characterization data already available to achieve this goal in the form of actual borehole data, geophysical logs, and field water-level measurements that were gathered from the entire MEA area. This data, he asserted, supports the similarity of hydrogeologic conditions throughout the entire site.[723]

Mr. Wireman responded that notwithstanding this additional data, there still is insufficient information on the characteristics of the Brule aquifer, i.e., potentially water could be moving from one formation to the other. Such a circumstance, he declared, can best be assessed by

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[720] See Tr. at 439.

[721] See CBR Rebuttal Test. at 7–8 (Lewis, Nelson, Pavlick) (citing CBR License Amend. 3, at 21 (License Condition 11.3.4)).

[722] See Tr. at 441.

[723] See Tr. at 442.

aquifer pumping tests that could demonstrate either drawing water downward from the Brule aquifer or, given the aquifer's heterogeneities, the presence of pathways that would allow water to flow upward from the BC/CPF aquifer into the Brule aquifer. In Mr. Wireman's view, it remains critical for the additional aquifer tests to be completed as part of the license application review process.[724]

Finally, regarding the aquifer pumping test being only one of several lines of evidence demonstrating containment of the BC/CPF aquifer at the MEA, as we noted previously (see supra section V.C), in its initial testimony the Staff described several circumstances unrelated to the aquifer pumping test that support the conclusion ISR production fluids will be adequately contained within the BC/CPF underlying the MEA.[725] Moreover, the Staff confirmed in its rebuttal testimony that to further define and verify the site conceptual model, CBR is required by License Condition 11.3.4 to perform an aquifer pumping test for each wellfield as part of the wellfield packages that will be submitted prior to the startup of each MU.[726]

And when asked at the hearing what would happen if a future pumping test analysis associated with an MU indicated that previously undetected breaches in the containment of the BC/CPF would result in CBR being unable to control production fluids from undesired vertical or lateral migration, the Staff responded that CBR would be required to assess the situation, develop a plan for safe operations under those newly discovered conditions, and submit a license amendment (which would be subject to a hearing request) to address this unexpected situation and demonstrate it is safe to operate in that MU.[727]

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[724] See Tr. at 443.

[725] See Staff Initial Test. at 28–31 (Back, Lancaster).

[726] See Staff Rebuttal Test. at 14 (Back, Lancaster, Striz) (citing CBR License Amend. 3, at 21 (License Condition 11.3.4)).

[727] See Tr. at 444, 551–54 (Lancaster).

b. Board Findings on Kreamer Opinion 1, Basis E: MEA Coverage from Single Pumping Test

The evidentiary record establishes that the May 2011 single pumping test covered almost half of the MEA, monitoring the test impacts on nine wells in the BC/CPF and three wells in the overlying Brule aquifer. While contributing to the conceptual hydrogeologic model, we conclude that this single pumping test was never intended to be the sole source of information for that characterization. Rather, the information from the pumping test was augmented with site-specific hydrogeologic data including geological cross-sections and hydrogeologic isopach, structural contour, and potentiometric contour mapping based on the stratigraphic cuttings and geophysical logging of over 1600 boreholes drilled within the MEA.

While agreeing that there are multiple lines of evidence to support containment across the MEA site, independent of the pumping test results (see supra section V.C.3), we find that the additional pumping test prior to the operational start of each MU is still necessary to verify the absence of major preferential pathways for fluid migration at each location, and that the installation of the wells and performance of these additional pumping tests is assured by License Condition 11.3.4.

Mr. Wireman raised an important issue relating to the current need to characterize the hydraulic properties of the aquifers over the entire site with additional pumping tests to help verify the absence of major preferential pathways and to assist in evaluating the risk of the recovery operation with respect to unwanted movement of contaminated water. On the basis of the evidentiary record before us, however, we find that OST has not provided sufficient evidence to establish the need during the pre-licensing phase to place the large financial and time burden on the Applicant to perform the pumping tests for all 11 of the MEA MUs, as opposed to the four covered by the May 2011 test.[728] This is particularly so given the strong

[728] During the hearing, Mr. Wireman made the point that while there are tradeoffs in putting together such a data investigation, with cost being a factor, having the correct

evidence of strata consistency displayed by the borehole information, geophysical logging, water-level measurements, and hydrogeological mapping, backed by the fact that, pursuant to License Condition 11.3.4, the desired pumping information relative to the opening of future MUs will be collected and assessed incrementally, albeit as a prerequisite to operating each MU rather than during the licensing process as desired by the Tribe. By the same token, should a previously undetected hydrogeologic anomaly be encountered during MEA operation that has the potential to prevent Crow Butte from controlling the migration of production fluids into neighboring surface waters and groundwater, to avoid having to cease operations in that mine unit, under License Condition 9.4 CBR would be required to assess the situation, develop a plan for safe operations in those conditions, and submit a license amendment (which is subject to a hearing request) to address this situation and demonstrate it is safe to continue operations.

6. Kreamer Opinion 1, Basis F: Off-Site Influences

a. Parties' Positions on Kreamer Opinion 1, Basis F: Off-Site Influences

In his Opinion 1, Basis F, Dr. Kreamer focused on the purported pumping test impacts of the elongated nature of the MEA in its northwest to southeast direction.[729] Dr. Kreamer claimed in his initial testimony that this configuration resulted in hydrogeologic off-site influences impacting the CBR pumping test because of the ROI-associated cone of depression for this test extending significantly off-site, well past the boundaries of the narrow portion of the property. According to Dr. Kreamer, the pumping test withdrew water from these off-site locations, which

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design/scope of work for a characterization study is critical and "that's not just a cost factor." Tr. at 592. While we agree with Mr. Wireman regarding the importance of establishing the proper scope for any characterization study, based on the evidentiary record before us we are unable to conclude that CBR has acted inappropriately in that regard so as to warrant the additional pre-licensing aquifer testing sought by the Tribe.

[729] See Tech. Rep. Figs. at 2 (fig. 1.3-1).

was significant because much of the resulting analysis selectively addressed only late-time data that is more influenced by off-site factors.[730]

Contesting Dr. Kreamer's assertion, CBR witnesses Lewis, Nelson, and Pavlick in their rebuttal testimony responded that the aquifer properties derived from the test results are representative of average aquifer conditions for the BC/CPF over the test ROI, which includes all monitoring wells that were evaluated as part of the test. According to these witnesses, the fact that the ROI extends to the east and west of the MEA boundary is irrelevant to the testing results.[731] And providing further clarification on this issue at the hearing, CBR witness Lewis and OST witness Dr. LaGarry agreed that the BC/CPF pinches out approximately seven miles to the west and three miles to the east of the MEA boundary, meaning that the test ROI remained within the limits of the BC/CPF.[732]

Staff witnesses Back, Lancaster, and Dr. Striz took issue with Dr. Kreamer's claim, stating that he neither elaborated on the off-site hydrogeological influences to which he referred nor explained how the pumping test conclusions would be adversely impacted. Furthermore, according to these Staff witnesses, the late-time data observed in the aquifer response curves from the more distant observation wells did not indicate there were any off-site influences significantly different from those observed in the middle-time data.[733]

Additionally, these Staff witnesses claimed Dr. Kreamer's allegation that "water was drawn from offsite" misconstrues the actual groundwater flow dynamics when pumping a confined aquifer like the BC/CPF aquifer. They asserted that the changes to the potentiometric

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[730] See Kreamer Initial Test. at 2.

[731] See CBR Rebuttal Test. at 8.

[732] See Tr. at 448–49.

[733] See Staff Rebuttal Test. at 23.

surface (i.e., drawdowns) observed in the farthest monitoring wells were a response to the decrease in pressure caused by the pumping well and are unrelated to water movement from off-site.[734] And with regard to Dr. Kreamer's claim that offsite water was removed from the BC/CPF aquifer by the May 2011 pumping test, Staff witness Back clarified at the hearing that groundwater removal from a confined aquifer like the BC/CPF is not indicative of the withdrawal of water from the aquifer pore space, but rather suggests an expansion of the water and compression of the aquifer matrix caused by the pressure released during pumping, which, in turn, is reflected in the drop of the potentiometric levels that creates the ROI-defining cone of depression.[735] Dr. Kreamer, however, indicating he did not agree with the Staff's representation of water removal when pumping a confined aquifer, declined to alter his position that BC/CPF groundwater was coming from off-site during the pumping test.[736]

Finally, at the hearing CBR witness Lewis stated that the ROI of an MU production well during MEA operations is likely to be between 75 ft. and 100 ft. because, with the reinjection of the fluids, the amount of net water drawn off is small, i.e., one-half percent or less.[737]

b. Board Findings on Kreamer Opinion 1, Basis F: Off-Site Influences

Relative to Dr. Kreamer's concern about off-site influences affecting the pumping test results, the Board finds that the ROI for the May 2011 test remained within the boundaries of the BC/CPF such that the results were not affected by the hydraulic characteristics of any other formation, e.g., the Pierre Shale. Furthermore, based on the evidentiary record, there does not appear to be any widespread influence from zonal variations within those portions of the

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[734] See id.

[735] See Tr. at 453–55; see also EA at 4-16. As we noted previously, all the parties have agreed that the BC/CPF is a confined aquifer. See supra section IV.C.2; see also Joint Stipulation at 9; Tr. at 451–52.

[736] See Tr. at 453, 455.

[737] See Tr. at 456–57.

BC/CPF that lie beyond the MEA site boundary that differed significantly from the response within the portion of this formation underlying the MEA.

Regarding the debate about the source of fluid pumped during the test, all parties agreed that the BC/CPF is a confined aquifer and no party disputed that confined groundwater comes from expansion of the groundwater and compression of the geologic formation. While removal of water during the pumping test occurred as the pore water expanded and the aquifer formation compressed from the pressure release during pumping, the resolution of this argument has little bearing on our decision as we conclude it is evident that the limits of the BC/CPF extend beyond the boundary of the MEA, which helps assure that the water removed during the pumping test is coming from the BC/CPF aquifer and not from other off-site sources.

7. Kreamer Opinion 1, Basis G: Variations in Aquifer Thickness[738]

a. Parties' Positions on Kreamer Opinion 1, Basis G: Variations in Aquifer Thickness

The sole allegation in Basis G of Dr. Kreamer's Opinion 1 is that the aquifer pumping test report did not make clear whether the actual aquifer thickness, or only the average aquifer thickness, was used to calculate transmissivity.[739] CBR witnesses Lewis, Nelson, and Pavlick responded in their rebuttal testimony that, as was stated throughout the pumping test report, an average net sand thickness of 40 ft. was used to calculate transmissivity of the BC/CPF sandstone at Marsland.[740] These CBR witnesses added that the production zone (i.e., where

[738] Dr. Kreamer raised a similar contested issue in his Opinion 6. See infra section VII.F.

[739] See Kreamer Initial Test. at 2.

[740] See CBR Rebuttal Test. at 9 (citing, e.g., Test #8 Rep. at 5, 13, 14, tbls. app. at 10 of 10 (tbl. 8)).

ore-grade uranium deposits exist underlying the MEA) is located in the BC/CPF where average thickness is 50 ft. with an average net sand thickness of 40 ft.[741]

And while they acknowledged there is some variability in the aquifer thickness, these CBR witnesses claimed that the assumption of a uniform effective aquifer thickness is "reasonably satisfied over the test area."[742] Concerning Dr. Kreamer's allegation regarding the thickness used to calculate transmissivity, Staff witnesses Back, Lancaster, and Dr. Striz noted that aquifer thickness is not needed to calculate transmissivity because transmissivities are obtained directly from aquifer pumping test data.[743]

b. Board Findings on Kreamer Opinion 1, Basis G: Variations in Aquifer Thickness

The aquifer pumping test report states numerous times that an average "net sand" thickness of 40 ft. was used when calculating the hydraulic conductivity of the BC/CPF aquifer based on the transmissivity values obtained from analyzing the drawdown and recovery data from the May 2011 MEA pumping test.[744] Using "net sand" thickness accounted for the low permeability claystone stringers within the BC/CPF and so provided a better estimate of the effective transmissivity of the BC/CPF aquifer than would have been the case had CBR used the full thickness of this layer.[745] Moreover, we do not consider CBR's recognition there is some

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[741] See id. at 5. CBR witness Lewis clarified that net sand thickness is the difference between the total thickness of the BC/CPF (determined from the boreholes and geophysical logs) and an estimation of the claystone thickness within the formation as projected from the geophysical logs. Because the claystone does not contribute appreciably to the aquifer's transmissivity, Mr. Lewis opined that using this correction accounts for these low permeability layers and is better than underestimating transmissivity using the full thickness of the BC/CPF aquifer. See Tr. at 458–59.

[742] See CBR Rebuttal Test. at 9 (quoting Test #8 Rep. at 11).

[743] See Staff Rebuttal Test. at 22 (citing Staff Initial Test. at 19–20).

[744] See Test #8 Rep. at 5, 13, 14, tbls. app. at 10 of 10 (tbl. 8).

[745] See Tr. at 458–59 (Lewis).

variability in the aquifer thickness as refuting the soundness of its showing that the assumption of a uniform effective aquifer thickness is reasonably satisfied over the test area.

With CBR's definition of its method for selecting aquifer thickness thus clarified, we find that OST witness Dr. Kreamer's Opinion 1, Basis G aquifer thickness claim is resolved in favor of the Applicant.[746]

8. Kreamer Opinion 1, Basis H: Monitoring Well Screen Intervals

a. Parties' Positions on Kreamer Opinion 1, Basis H: Monitoring Well Screen Intervals

In Basis H, the final basis supporting his Opinion 1, Dr. Kreamer raised the possibility that the monitoring wells used in the May 2011 pumping test may not have spanned the entire thickness of the BC/CPF aquifer. His conclusion was based on his assertion that the thickness of the BC/CPF sandstone varied from 21 ft. to 91 ft. across the site while the screened intervals of the monitoring wells varied from 22 ft. to 50 ft., per Figure 2.6-9 of the CBR TR.[747]

In their rebuttal testimony, CBR witnesses Lewis, Nelson, and Pavlick clarified that the monitoring wells used in the pumping test spanned all or nearly all of the BC/CPF thickness, such that there was sufficient penetration to characterize the full thickness of the aquifer. These CBR witnesses further stated that "given the relatively large distances from the pumped well to monitoring wells, partial penetration effects in observation wells are negligible."[748]

During the hearing, CBR witness Shriver concurred in this response with a correction, stating that the observation wells in the Brule aquifer were not fully penetrating, while some of the wells in the BC/CPF were fully or nearly fully penetrating.[749] He clarified as well that the few

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[746] A more detailed discussion regarding discontinuities in the thickness of the BC/CPF aquifer is provided infra in section VII.F.

[747] See Kreamer Initial Test. at 2 (citing Tech. Rep. Figs. at 75 (fig. 2.6-9)).

[748] CBR Rebuttal Test. at 9.

[749] See Tr. at 473–74.

monitoring wells that did not completely screen the entire interval of the BC/CPF were located where there was a sand layer, followed by a shale layer, at the top of the BC/CPF. In those instances, he indicated, the well screen was placed a few feet below what is considered to be the uppermost level of the BC/CPF.[750]

In their rebuttal testimony, Staff witnesses Back, Lancaster, and Dr. Striz declared that Dr. Kreamer's assertions regarding pumping test penetration of the entire BC/CPF aquifer thickness were not valid, notwithstanding the fact that the range of the well screen intervals for the monitoring wells differed from the thickness of the BC/CPF. These Staff witnesses explained that the BC/CPF thickness ranges of 21 ft. to 91 ft. do not reflect the thicknesses at the locations of the aquifer pumping test observation wells, as evidenced by comparing the BC/CPF thickness contours with the locations of the BC/CPF observation wells.[751] Based on their review of these figures, they claimed that, except for well Monitor-5, all the observation wells were in areas where the thickness shown in CBR TR Figure 2.6-9 was less than 50 ft.[752] Moreover, these NRC witnesses stated that the completion reports provided in Appendix A of the aquifer pumping test report indicate that the BC/CPF observation wells were fully screened across the BC/CPF aquifer.[753]

When asked at the hearing about the potential impacts on the pumping test results of a slight partial penetration of the monitoring wells, Dr. Kreamer stated that some of the wells may be over-penetrating into either the UCU or the LCU,[754] indicating that, while not necessarily the

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[750] See Tr. at 477–79.

[751] See Staff Rebuttal Test. at 24–25 (citing Tech. Rep. Figs. at 75 (fig. 2.6-9) (BC/CPF thickness contours), 97 (fig. 2.7-7) (observation wells)).

[752] See id. at 25.

[753] See id. (citing Test #8 Rep. app. A at PDF 53–65).

[754] See Tr. at 475 (citing Tech, Rep. at 2-49 to -50).

case for pumping tests, the use of such wells is a poor monitoring technique for what he called "contaminant hydrology."[755]

b. Board Findings on Kreamer Opinion 1, Basis H: Monitoring Well Screen Intervals

Regarding Dr. Kreamer's Basis H allegation that the monitoring wells used by CBR in the May 2011 pumping test may either be partially penetrating or over-penetrating, the Board finds that the preponderance of the evidence indicates that while a small number of the wells were not fully penetrating, those that were not fully penetrating have a high percentage of partial penetration. We find as well that no evidence has been submitted by the Intervenor demonstrating any potential adverse effects from the partial well screen intervals on the pumping test analysis results, leading us to conclude that the impacts, if any, from the few partially penetrating wells are negligible, particularly given the relatively large distances between the pumped well and the observation wells. Also, in line with Dr. Kreamer's observation that the monitoring technique used by CBR was not unacceptable for pumping tests,[756] we find that no evidence has been submitted by the Intervenor demonstrating any potential adverse effects on the pumping test analysis results as a consequence of well screening interval issues.

[755] Tr. at 476. "Contaminant hydrology" is a term that Dr. Kreamer used for the first time at the hearing in connection with the use of screened monitoring wells associated with production pumping, such as aquifer pumping tests, and in discussing aquifer heterogeneity. See Tr. at 463, 464, 476, 866, 867, 869, 873, 890, 918, 997, 998. Given his isolated use of this term so late in the proceeding and the fact that the Intervenor's bases and written testimony regarding Contention 2 deal primarily with the hydraulic description and development of the conceptual hydrogeologic model of MEA site hydrology, and only peripherally with constituent transport through fractures, see supra sections V.B.1.c and V.B.2, and geochemical differences between the BC/CPF and the overlying Arikaree/Brule aquifer, see supra sections V.C.2 and V.C.3, we saw no need to explore further the definition of this term or its relevance to this hearing.

[756] See Tr. at 476.

B. Kreamer Opinion 2 – Previous Pumping Test Analyses for the Renewal Site

1. Parties' Positions on Kreamer Opinion 2 – Previous Pumping Test Analyses for the Renewal Site

In Opinion 2 of his initial testimony, Dr. Kreamer claimed that the summary of historical testing results provided for the existing CBR ISR facility mischaracterizes the BC/CPF hydrogeological test results for that facility. In particular, Dr. Kreamer maintained that the Pumping Test # 8 report erroneously states that "[r]esults of previous testing indicate the [BC/CPF] is relatively homogeneous and isotropic."[757] He then reiterated the concerns he expressed about the pumping tests that were conducted in conjunction with the renewal of the existing CBR ISR facility license. During the 2015 adjudication for that license renewal request, he claimed that, among other things, CBR reported aquifer leakage in five of the ten aquifer tests that were performed at or near the existing facility. Dr. Kreamer also stated that the Staff questioned CBR's use of a non-leaky analysis method for pumping test data that showed a significant deviation from the Theis type-curves, and that examination of the drawdown-time graphs for the observation wells indicated that some leakage from the BC/CPF occurred during the pumping tests.[758]

Dr. Kreamer's testimony for the existing CBR ISR facility license renewal proceeding presented annotated figures for some of the pumping tests as examples to show departure from the classic Theis type-curve consistent with leakage. Claiming that the same departure historically observed at the existing facility is evident in the MEA data, he re-submitted these figures as part of his initial testimony for this hearing.[759] Referencing this previous analysis, Dr.

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[757] See Kreamer Initial Test. at 3 (quoting Test #8 Rep. at 6).

[758] See id.

[759] See id. at 3–5.

Kreamer claimed that the analytical mathematical approaches used for interpreting the MEA data are the same as the ones for the license renewal proceeding and, in both cases, CBR assumed homogeneity and isotropy. Instead, Dr. Kreamer maintained, such CBR assumptions were debunked in the renewal hearing by the quantification of anisotropy in the pumping tests.[760]

CBR witnesses Lewis, Nelson, and Pavlick responded that the same homogeneous and confined nature of the Basal Chadron aquifer that was discussed in the license renewal hearings for the existing CBR ISR facility extends to the BC/CPF at the MEA, which is also relatively homogeneous, isotropic, and confined for purposes of aquifer characterization.[761] And concerning Dr. Kreamer's testimony during the renewal proceeding, these CBR witnesses stated that his presentation was not relevant to the Marsland site as the drawings he provided in conjunction with his testimony are specific to the pumping tests performed at the existing CBR ISR area, not the pumping test performed at the MEA.[762]

In their rebuttal testimony, Staff witnesses Back, Lancaster, and Dr. Striz agreed that the BC/CPF can be treated as homogeneous and isotropic for analytical purposes and that Dr. Kreamer has repeated arguments he made in the Crow Butte Renewal Site proceeding regarding the presence of recharge boundaries based on his re-analysis of the aquifer pumping test data to match early-time data. In the estimation of these Staff witnesses, however, it was inappropriate for Dr. Kreamer to use such early-time data.[763] These witnesses also stated that

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[760] See id. at 5.

[761] See CBR Rebuttal Test. at 9–10 (citing Renewal Site, LBP-16-13, 84 NRC at 330).

[762] See id. at 10. These CBR witnesses also pointed out that Dr. Kreamer's concerns about the purported misuse of early-time data in reanalyzing the aquifer pumping test in the main license area was rejected by the licensing board in the license renewal proceeding. See id. (citing Renewal Site, LBP-16-13, 84 NRC at 330).

[763] See Staff Rebuttal Test. at 30–31.

Dr. Kreamer's only reference to the MEA test data as part of his Opinion 2 was his assertion that the MEA response curves show departures from the Theis curve that are consistent with leakage, another allegation they addressed previously in their rebuttal testimony.[764] Lastly, these Staff witnesses stated that it is not clear how Dr. Kreamer's statement about the hydrogeologic conditions at the existing Crow Butte ISR facility were relevant to the interpretation of the results of the MEA aquifer pumping test and, more generally, to the demonstration of BC/CPF aquifer confinement at the MEA.[765]

2. Board Findings on Kreamer Opinion 2 – Previous Pumping Test Analyses for the Renewal Site

Given the fact that the Board in this initial decision is called upon to address the homogeneity and isotropy associated with the pumping test in the BC/CPF underlying the MEA,[766] relative to his Opinion 2 concern, the Board finds that Dr. Kreamer's re-analysis of aquifer pumping test data for the renewal of the existing CBR ISR facility license has no bearing on the issues in this case regarding the interpretation of the MEA aquifer pumping test or BC/CPF confinement at the MEA. Regarding Dr. Kreamer's evaluation of pumping test data initially provided in the 2015 license renewal hearing, the Board finds that these challenges to the hydrogeologic characterization of the BC/CPF underlying the existing CBR ISR facility have already been adjudicated and Dr. Kreamer has failed to provide any justification for applying that information to the MEA site. We find no reason to revisit the issues that have already been resolved by another licensing board and the Commission.[767]

[764] See id. at 31 (citing id. at 18–21).

[765] See id. at 31.

[766] See supra section V.B; infra sections VII.D.2 and VII.E.2.

[767] See Renewal Site, LBP-16-13, 84 NRC at 329–30, aff'd, CLI-18-8, 88 NRC at __–__ (slip op. at 37–39).

Indeed, on the issues of the adequacy of the MEA pumping test analysis and BC/CPF confinement at the MEA, the application of regionally-based information to site-specific matters seems untoward, as the hydrogeologic performance in the main facility 11 miles north of the MEA has little, if any, bearing in establishing whether CBR can control processing fluids circulated in the operation and restoration of the MEA.[768] The hydraulic characteristics and hydrogeological conceptual model for the MEA must be established on its own merit, regardless of the past performance of the existing CBR ISR facility — a position that was accepted by all the parties at the hearing.[769]

Thus, the adjudication for the renewal of the existing CBR ISR facility license is not controlling regarding site-specific, fact-based disputes concerning the adequacy of CBR's Marsland application. While the same geologic strata generally underlie each area, hydrogeologic performance may vary between sites and, as such, CBR must demonstrate safe facility operation and restoration for each site. Likewise, the Staff must prepare a NEPA-compliant assessment of environmental impacts from the licensing action for the MEA area. Therefore, were Dr. Kreamer to apply the techniques used in the renewal case, it would have been necessary for him to use the site-specific data from the pumping test conducted at the MEA. Dr. Kreamer's analysis, while interesting, simply carries no evidentiary weight as it fails to demonstrate any connection to the hydrogeologic behavior of the BC/CPF within the MEA. Rather, we address the issues of homogeneity/anisotropy raised by Dr. Kreamer in his Opinion 2 elsewhere in this decision as specifically applicable to the pumping test and other hydrogeologic data gathered within the MEA.[770]

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[768] This same conclusion seemingly would apply to any of the other proposed CBR recovery sites in the region, e.g., the NTEA and the TCEA.

[769] See Tr. at 407–12.

[770] See supra section V.B.2; see also infra sections VII.D.2 and VII.E.2.

C. Kreamer Opinion 3 – Utilization of Alternative Pumping Test Methods

As previously discussed,[771] Dr. Kreamer claimed that CBR is derelict for not considering other forms of pumping test analyses such as the De Glee, Hantush-Jacob, or Walton methods, and that the Staff is equally deficient in not requiring more scientifically appropriate analyses that consider the leakage into or out of the confined aquifer.[772] In this same vein, in his Opinion 3 Dr. Kreamer specifically criticized CBR for using only the Theis method for analyzing the aquifer pumping test data. He also noted, as he had done in Opinion 1, Basis C, that while CBR referred to using the Cooper-Jacob technique, CBR nonetheless failed to present the results of this supplemental analysis, which might identify a recharge boundary that could, in turn, indicate a lack of BC/CPF aquifer containment.[773]

The parties' positions and Board findings on the utilization of alternative pumping test methods were discussed earlier and need not be repeated here.[774] But summarizing our findings: (1) CBR conducted the pumping test according to its NDEQ-approved plan using the Theis drawdown/recovery and the Cooper-Jacob Distance-Drawdown methods, which are accepted industry testing and analysis procedures that are incorporated into ASTM standards;[775] (2) CBR analyzed both the drawdown and recovery data to estimate aquifer transmissivity and storativity and saw no need to use a more complex method based on the apparent consistency of the hydraulic parameters resulting from these analyses;[776] (3) the need

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[771] See supra sections V.A.1.a and V.A.2.a.

[772] See Kreamer Rebuttal Test. at 2–3.

[773] See Kreamer Initial Test. at 6; see also id. at 2.

[774] See supra section V.A.1.a.

[775] See Staff Initial Test. at 26 (Back, Lancaster) (citing ER at 3-45; Tech Rep. at 2-82); see also ASTM Theis Analysis Standards.

[776] See CBR Rebuttal Test. at 10 (Lewis, Nelson, Pavlick); Tr. at 485–88.

to perform hypothetical aquifer leakage analyses demanded by the Intervenor has no conceptual support;[777] (4) OST witness Dr. Kreamer did not provide an independent estimate for the rate of leakage based on his alternative interpretation of the Marsland pumping test data using the suggested alternative, allegedly superior methods (i.e., De Glee, Hantush-Jacob, and Walton Methods) to support his call for these techniques to be implemented at the MEA by Crow Butte;[778] and (5) Dr. Kreamer conceded that his suggested, more complex analysis methods may employ the same assumptions of aquifer homogeneity, isotropy, uniform thickness, and lateral extent as do the Theis and Cooper-Jacob methods.[779]

D. Kreamer Opinion 4 – Homogeneity and Isotropy Assumptions

1. Parties' Positions on Kreamer Opinion 4 – Homogeneity and Isotropy Assumptions

Dr. Kreamer in his Opinion 4 maintained that the major requirement inherent in the Theis approach used to evaluate the MEA pumping test data lies in the assumptions that the BC/CPF sandstone aquifer must be "homogeneous and isotropic, and of uniform effective thickness over the area influenced by pumping."[780] Dr. Kreamer then asserted that the data and evidence shows these foundational assumptions have been violated. Dr. Kreamer claimed that the

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[777] See CBR Rebuttal Test. at 10–11 (Lewis, Nelson, Pavlick) (citing Test #8 Rep. at 12–13).

[778] See id.

[779] See Tr. at 507–08.

[780] Kreamer Initial Test. at 6 (quoting Test #8 Rep. at 11). Dr. Kreamer's claims about the impact of the homogeneity and isotropy assumptions are discussed in this section, while the thickness of the BC/CPF referenced in the quoted language will be addressed in section VII.F, infra, dealing with Dr. Kreamer's Opinion 6 regarding discontinuities in the thickness variations within the BC/CPF. The potential for heterogeneity/anisotropy caused by fractures and faults has already been reviewed, see supra section V.B, a discussion that need not be reiterated at this point.

allegedly wide range of transmissivities (i.e., 230 $ft.^2/d$ to 1780 $ft.^2/d$) and storage coefficients ($1.7x10^{-3}$ to $8.32x10^{-5}$) are not consistent with homogeneous conditions.[781]

Further, with regard to these assumptions and the overlying Arikaree/Brule aquifer, Dr. Kreamer claimed that the limited monitoring well array in the heterogeneous Brule Formation is insufficient to adequately measure the hydrogeological response to production pumping and injection in the BC/CPF, and that the extrapolation of observations from isolated, widely-spaced wells over many square miles of the property is inconsistent with good professional practice.[782] According to Dr. Kreamer, data analysis of the May 2011 pumping test indicates BC/CPF aquifer leakage that refutes the Applicant's position, adopted by the Staff, that the Brule Formation is homogeneous.[783]

As a consequence, at the hearing Dr. Kreamer, along with OST witness Wireman, again advanced the need to further characterize the homogeneity of the BC/CPF within the MEA by conducting additional pumping tests to address the containment properties of this strata.[784]

Also with regard to the Brule aquifer, Mr. Wireman indicated his agreement with Dr. Kreamer, stating that the only aquifer test that was conducted at the MEA was limited to obtaining data to assess the hydraulic properties of the BC/CPF and that no pumping test was performed on the Arikaree/Brule aquifer. As a result, Mr. Wireman asserted, "[a]quifer testing conducted at the MEA is inadequate for developing an acceptable site wide conceptual hydrologic model and does not adequately characterize the subsurface heterogeneity."[785] He

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[781] See Kreamer Initial Test. at 6.

[782] See Kreamer Rebuttal Test. at 1–2.

[783] See id. (citing CBR Initial Test. at 31, 35 (Lewis, Nelson, Pavlick); Staff Initial Test. at 30 (Back, Lancaster)).

[784] See Tr. at 436–37, 440–41; supra section VII.A.5.

[785] Wireman Initial Test. at 4; see Tr. at 442–43.

further supported this argument by declaring that the lithologic and hydraulic data included in CBR's TR for the Arikaree/Brule aquifer indicates significant heterogeneity. Additionally, he stated that sediment comprising these formations was deposited in a variety of fluvial environments resulting in changes in the characteristics of the sedimentary rock within the formations.[786]

Furthermore, according to Mr. Wireman, this heterogeneity affects groundwater flow and well yields and is further increased by structural deformation of the sedimentary rocks that comprise the aquifers. Consistent with Dr. Kreamer's position that the MEA aquifer testing was inadequate, Mr. Wireman concluded that aquifer testing, monitoring, and flow modeling of these aquifers must take into consideration that heterogeneity, claiming that the aquifer test data indicate that hydraulic conductivity and transmissivity of the BC/CPF near the pumping well used in the May 2011 test is an order of magnitude lower than at the outlying monitoring wells.[787]

Disputing Mr. Wireman's assertions that the MEA aquifer testing was inadequate, Crow Butte witnesses Lewis, Nelson, and Pavlick testified that CBR previously established the technical sufficiency of the aquifer pumping test to characterize the portions of the site that would be affected by development of the first four mine units at Marsland.[788] These CBR witnesses also disagreed with Mr. Wireman's characterization of transmissivity and hydraulic conductivity near the pumped well as being an order of magnitude lower than the outlying monitoring wells, claiming that these values were within a factor of two to four (with the exception of well Monitor-3, which is two to nine times lower than other monitoring well

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[786] See Wireman Initial Test. at 4.

[787] See id.

[788] See CBR Rebuttal Test. at 17–18; see also supra section VII.A.5.a.

locations) and so as to suggest relative homogeneity.[789] Finally, these CBR witnesses claimed there is no evidence of the hypothetical structural heterogeneities cited by Mr. Wireman.[790]

Regarding the well Monitor-3 issue, Dr. Kreamer proffered a specific claim regarding heterogeneity by attempting to show that during the May 2011 pumping test, well Monitor-3 detected a preferential pathway for groundwater flow that indicated leakage in the containment of the production zone.[791] In his Opinion 3, Dr. Kreamer backed this claim by referencing the fact that the drawdown data for both the pumping well (i.e., CWP-1A) and the observation wells that are close to the pumping well (i.e., CPW-1 and Monitor-3) show a late-time flattening of the curve not suitable for Theis type-curve fitting. According to Dr. Kreamer, this isolated flattening of the curve may be indicative of leakage in the containment of the production zone.[792]

Staff witnesses Back, Lancaster, and Dr. Striz disagreed with Dr. Kreamer, testifying that the subsurface characterization of the BC/CPF using the examination of cores and geophysical logging shows that there are no major impermeable or permeable features that would indicate significant heterogeneity at the MEA to the extent such features would impact the aquifer test analysis results.[793] According to the Staff, the lack of significant heterogeneity is also reflected on the potentiometric surface of the BC/CPF aquifer, which is smooth and has an essentially flat and relatively constant hydraulic gradient.[794]

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[789] See CBR Rebuttal Test. at 17–18.

[790] See id.

[791] See Kreamer Initial Test. at 6; see also supra section V.A.1.b.

[792] See Kreamer Initial Test. at 6.

[793] See Staff Rebuttal Test. at 27 (citing Test #8 Rep. at 5).

[794] See id. (citing Tech. Rep. Figs. at 113–16 (figs. 2.9-6a to -6d)).

Additionally, Staff witness Dr. Striz indicated that she re-analyzed the data from well Monitor-3 because it is close to the pumping well (i.e., within 100 ft.) and likely was impacted from well effects, phenomena Mr. Wireman agreed should not be ignored when selecting the portion of the drawdown curve to be evaluated.[795] Her re-analysis resulted in the appearance of well effects for approximately 800 minutes, followed by fully developed radial flow that is necessary to be able to use the Theis solution. Fitting the type-curve to the later time data of this test because of the early-time well effects, Dr. Striz estimated transmissivity of 700 $ft.^2/d$ (a value that is in line with the results from the other wells), and a storage coefficient of $1x10^{-5}$ (a value that indicates a confined aquifer).[796]

Further, in disputing Dr. Kreamer's claim regarding MEA site homogeneity, Staff witnesses Back, Lancaster, and Dr. Striz cited Driscoll, a well-established reference volume known to all the parties,[797] for that text's discussion of the need for homogeneity of the hydraulic parameters and uniform aquifer thickness in the analytical solutions provided to determine aquifer properties. With regard to how close these homogeneity and thickness constraints need to be satisfied to obtain meaningful results, as referenced by the Staff,[798] this portion of Drisoll states

> These assumptions appear to limit severely the use of the [Theis] equations. In reality, however, they do not . . . [because while] uniform hydraulic conductivity is rarely found in a real aquifer, . . . average hydraulic conductivity [values,] as determined from pumping tests[, have] proved to be reliable for predicting well performance. In confined aquifers where the well is fully penetrating and open to the formation, the assumption of no stratification is not an important limitation.

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[795] Tr. at 565–66.

[796] See Tr. at 502–05, 530.

[797] See Tr. at 462 (Kreamer), 465 (Back), 480 (Lewis).

[798] See Staff Rebuttal Test. at 26 (citing Driscoll Text at 214).

> Assumption of constant thickness is not a serious limitation because variation in aquifer thickness within the cone of depression in most situations is relatively small, especially in sedimentary rocks.[799]

Although acknowledging his familiarity with Driscoll, Dr. Kreamer asserted that text refers to the use of fully penetrating screened monitoring wells for monitoring pumping.[800] And while Dr. Kreamer affirmed the application of Driscoll's comments to well production from screened monitoring wells, he implied that it is inappropriate to apply Driscoll's guidance to "contaminant hydrology."[801]

2. Board Findings on Kreamer Opinion 4 – Homogeneity and Isotropy Assumptions

With respect to the homogeneity and isotropy analysis assumptions that Dr. Kreamer challenged, while we concur with the parties that all geologic strata exhibit heterogeneity and anisotropy at some scale,[802] we find that the Theis and Cooper-Jacob techniques are routinely applied in practice with an understanding of the homogeneity and isotropy assumptions inherent to their use.[803] Thus, the CBR pumping test acknowledged that within the MEA, the BC/CPF is not homogeneous and isotropic on a local scale, but concluded that the assumptions of homogeneity and isotropy are reasonably satisfied over the scale of the BC/CPF pumping test.[804] And the Staff agreed that the CBR pumping test analysis demonstrated that the BC/CPF

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[799] Driscoll Text at 214.

[800] See Tr. at 463, 464.

[801] See Tr. at 463, 464.

[802] See CBR Rebuttal Test. at 11 (Lewis, Nelson, Pavlick); Staff Rebuttal Test. at 25 (Back, Lancaster, Striz); Tr. at 491–94 (Kreamer).

[803] See Staff Rebuttal Test. at 25 (Back, Lancaster, Striz); CBR Rebuttal Test. at 11 (Lewis, Nelson, Pavlick).

[804] See Test. #8 Rep. at 11.

formation underlying the MEA can be treated as homogeneous and isotropic for analytical purposes.[805] We agree as well, noting that even Dr. Kreamer used the graphs in the pumping test report, which are based on the Theis and Cooper-Jacob solution techniques, to support his conclusion that recharge boundaries indicating vertical leakage from heterogeneity were detected in some of the well data.[806]

OST witness Dr. Kreamer also claimed that the allegedly wide range of transmissivities (i.e., 230 ft.^{2}/d to 1780 ft.^{2}/d) and storage coefficients ($1.7\text{x}10^{-3}$ to $8.32\text{x}10^{-5}$) from the May 2011 pumping test are not consistent with homogeneous conditions.[807] We disagree, based on the apparent consistency of the hydraulic parameters resulting from the pumping test analyses,[808] which are for values that OST agrees can often vary by an order of magnitude or more.[809] We also observe that the derived storativity values from the pumping test are within the range expected for a confined aquifer,[810] and agree with the Staff that the smoothness of the potentiometric surface, as shown in the pumping test results, indicates there are no significant changes in transmissivity that impact the groundwater flow in the BC/CPF aquifer.[811] It seems clear to us also that well Monitor-3, which is only 100 ft. from the pumping well for the May 2011 pumping test, was impacted by well effects. Consequently, we are persuaded by Dr. Striz's

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[805] See Staff Rebuttal Test. at 30 (Back, Lancaster, Striz) (citing Test #8 Rep. at 11).

[806] See Kreamer Rebuttal Test. at 2; Tr. at 940–41, 1021, 1024–25.

[807] See Kreamer Initial Test. at 6.

[808] See Test #8 Rep. tbls. app. at 10 of 10 (tbl. 8).

[809] See Tr. at 485–88 (Kreamer).

[810] See Staff Rebuttal Test. at 15 (Back, Lancaster, Striz) (citing Todd Text at 45–46 (stating that storativity values for a confined aquifer range between $5\text{x}10^{-5}$ and $5\text{x}10^{-3}$)).

[811] See Staff Rebuttal Test. at 27 (citing Test #8 Report figs. app. at PDF 48 (fig. 16)).

re-analysis of the information by matching with the later time data, which reflected values of transmissivity and a storage coefficient that are more in line with the other wells and indicative of a confined aquifer.[812]

Concerning Dr. Kreamer's specific claim that well Monitor-3 detected a preferential pathway for groundwater flow indicating leakage in the containment of the production zone,[813] we find the drawdown data for distant observation wells exhibited a more typical confined aquifer drawdown response than did the drawdown data for the pumping well (i.e., CWP-1A) or the observation wells that are close to the pumping well (i.e., CPW-1 and Monitor-3) and that these results show a late-time flattening of the drawdown data.[814] While it is Dr. Kreamer's position that this isolated flattening of the curve may be a recharge boundary indicative of leakage in the containment of the production zone, he presented no corroborating evidence supporting his position that the UCU is leaking sufficiently to jeopardize containment or prevent CBR from controlling its production fluids during operations and restoration. Certainly, as the Staff indicated, if there were a significant recharge boundary as alleged by Dr. Kreamer, it would be unlikely that the drawdown would have reached out to 8800 ft. during the short period of time that the well was pumped.[815]

We also find that OST has provided no convincing evidence disputing the Staff's showing that well Monitor-3 was impacted by well effects during the early-time period, an effect OST agrees should not be ignored when selecting the portion of the drawdown curve to be evaluated.[816] We thus find that Staff witness Dr. Striz's re-analysis matching the Theis

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[812] See Tr. at 502–05, 530.

[813] See supra section V.A.1.b; Kreamer Initial Test. at 2.

[814] See Staff Rebuttal Test. at 19–20 (Back, Lancaster, Striz).

[815] See Tr. at 502 (Striz).

[816] See Tr. at 565–66 (Wireman).

type-curves to the later time data was warranted and that the resulting transmissivity and storage coefficient values, as revised, are more in line with the other wells so as to be even more representative of a confined aquifer.[817]

Also, in its rebuttal testimony the Staff cited the Driscoll text in concluding that it is not necessary for the analytical assumptions in the Theis and Cooper-Jacob methods to be strictly met. We find the aquifer pumping test data provides no suggestion that any diversions existed sufficient to impact significantly the results and conclusions in the Applicant's conceptual model of the BC/CPF aquifer at the MEA such that CBR should not have employed the assumptions made during its pumping tests.[818] Furthermore, we observe that the May 2011 MEA aquifer pumping test was a multi-day test with a large ROI, which prompts us to concur with the Staff that this aquifer test averages the hydraulic behavior over the ROI, thereby minimizing the impact of small scale anisotropy and heterogeneity.[819]

When asked during the hearing to comment about the Staff's citation to Driscoll with regard to how well the homogeneity and isotropy assumptions need to be verified, Dr. Kreamer stated that he was familiar with the reference but indicated that Driscoll's comments are only relevant to well production from screened monitoring wells.[820] We find that his suggested criteria for applying Driscoll's comments is consistent with CBR's use of screened monitoring wells in gathering and analyzing the data from the May 2011 aquifer pumping test at the MEA.[821] And based on Driscoll, we conclude that CBR's calculation for the average hydraulic

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[817] See Tr. 502–05, 530.

[818] See Staff Rebuttal Test. at 26 (Back, Lancaster).

[819] See id.

[820] See Tr. at 463.

[821] See supra note 7536 and accompanying text.

conductivity, as determined by the transmissivity derived from an analysis of the monitoring wells during the May 2011 pumping test, has proved reliable for predicting well performance. In addition, we find that the assumption of no stratification is not an important limitation in the confined BC/CPF aquifer with the fully or nearly fully penetrating monitoring wells that are open in the formation.[822]

Also at the hearing, Dr. Kreamer claimed there is a need to further characterize the homogeneity of the BC/CPF within the MEA with additional pumping tests to address the containment properties of this strata,[823] but he failed to explain how additional pumping tests in the production zone would generate this data. As a result, we find that Dr. Kreamer failed to provide any evidence to support this position nor did he show why or how efforts at an additional definition of homogeneity would demonstrably change CBR's understanding of the containment behavior of the MEA during operation and restoration.

Finally, we observe that there are two matters dealt with elsewhere in this decision that bear some relationship to the issues raised in the context of Dr. Kreamer's Opinion 4. Regarding the previously discussed impact of faults/fracturing on the homogeneity/isotropy of the BC/CPF,[824] the Board found that (1) there is likely some degree of structural fracturing of the geologic strata underlying the MEA; (2) the mere presence of fractures is not the issue, rather the transmissivity of this feature is the critical factor; (3) there is no evidence in the hydrogeologic data that conclusively supports the presence of extensive, transmissive,

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[822] See supra section VII.A.8. We note as well that, because there is no evidence in the record indicating any attempt to apply Driscoll's comments in the context of Dr. Kreamer's "contaminant hydrology," we conclude that Driscoll's comments about the success of using the Theis method to evaluate heterogeneous/anisotropic aquifers seems to be in agreement with the Staff's acceptance of CBR's analysis of pumping test data at the MEA.

[823] See Tr. at 436–37, 440–41; supra section VII.A.5.

[824] See supra section V.B.

heterogeneous fractures that would provide a preferential flow for contaminants; and (4) in the unlikely event that detrimental, transmissive fracturing were encountered during ISR activity within the MEA, the presence of such features would not be significant enough to lead to unsafe conditions based on the multiple signs of containment presented above.[825]

Similarly, Mr. Wireman's Opinion 3 alleging inadequacies with CBR's aquifer pumping test discussed previously,[826] can be summarized as follows: (1) Mr. Wireman failed to justify how more detailed hydrogeologic characterization with an additional pumping test of the surficial, unconfined Arikaree and Brule aquifers relates to the containment properties of the BC/CPF located hundreds of feet below the ground surface; (2) Crow Butte has addressed the basis for concluding that the aquifer pumping test is sufficient to characterize the portions of the site that would be affected by development of the first four mine units at Marsland,[827] and that additional pumping tests will be conducted within the MEA prior to opening new MU;[828] (3) there is no evidence of the hypothetical structural heterogeneities cited by Mr. Wireman, while the transmissivity and hydraulic conductivity near the pumped well is within a factor of two to four lower than the outlying monitor wells (with the exception of well Monitor-3, which is two to nine times lower than other monitor well locations) so as to suggest relative homogeneity;[829] (4) the subsurface characterization of the BC/CPF using the examination of cores and geophysical logging shows that there are no major features that would indicate significant heterogeneity at

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[825] See supra sections V.B.2 and V.B.3.

[826] See supra section VI.B.3.a.

[827] See CBR Rebuttal Test. at 17–18 (Lewis, Nelson, Pavlick); see also supra section VII.A.5.a.

[828] See CBR Rebuttal Test. at 7–8 (Lewis, Nelson, Pavlick); Tr. at 438–39 (Shriver); CBR License Amend. 3, at 21 (License Condition 11.3.4)).

[829] See CBR Rebuttal Test. at 17–18 (Lewis, Nelson, Pavlick).

the MEA to the extent that they would impact the aquifer test analysis results, and the lack of significant heterogeneity is also reflected on the potentiometric surface of the BC/CPF aquifer, which is smooth and has an essentially flat and relatively constant hydraulic gradient.[830]

E. Kreamer Opinion 5 – Analysis for Anisotropy

1. Parties' Position on Kreamer Opinion 5 – Analysis for Anisotropy

Dr. Kreamer in his Opinion 5 stated that "[r]igorous analyses for anisotropy were not demonstrated or undertaken for the EA or hydrologic report, and the nature of directional hydraulic conductivity differences remains undefined and not quantified, particularly in the vertical direction."[831] Dr. Kreamer further argued that CBR's claim (supposedly accepted in the Staff's EA) that no anisotropy has been shown to exist in the MEA is flawed because it is based on the questionable results of the analysis presented in Figure 16 of the pumping test report.[832] According to Dr. Kreamer, rather than being a standard, serious, data-based evaluation, this figure used a technique not consistent with professional practice by incorporating two-dimensional hand-drawn contours derived from only a few data points to visually represent isotropy indicated by the uniform horizontal flow to the pumping well.[833]

Disputing Dr. Kreamer's assertion in their rebuttal testimony, CBR witnesses Lewis, Nelson, and Pavlick clarified that drawdown data from all 11 monitoring wells was used to

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[830] See Staff Rebuttal Test. at 27 (Back, Lancaster, Striz) (citing Test #8 Rep. at 5; Tech. Rep. Figs. at 113–16 (figs. 2.9-6a to -6d)).

[831] Kreamer Initial Test. at 7.

[832] See id. Although Dr. Kreamer cited to "[EA] at 70 & 255" as support for his statement that the Staff accepted CBR's argument of no anisotropy in the MEA, id., assuming the citation is to PDF pages, we have been unable to find anything on those pages to support his statement. Also we note that because Concern 2 is limited to the consideration of safety matters, see supra note 5 and accompanying text, we consider Dr. Kreamer's Opinion 5, to the degree it is based on EA references, in that context.

[833] See id.

create the cone of depression at the end of the pumping test that is shown in the referenced figure.[834] Furthermore, CBR witness Lewis explained at the hearing that the contour lines in Figure 16 showing flow in a horizontal plane are not hand-drawn and are non-biased, having been created with the commercially-available computer contouring program SURFER.[835] CBR's conclusion was that more detailed analyses of horizontal anisotropy are not necessary given the lack of a conceptual basis in the geometry of the drawdown cone.[836]

Along these lines, Staff witnesses Back, Lancaster, and Dr. Striz noted in their rebuttal testimony that if there were a significant anisotropy within the production zone, the aquifer test would have shown elliptical drawdown curves, a shape not apparent in the plot from the MEA aquifer pumping test results.[837] At the hearing, Dr. Kreamer agreed that if one considered the pump test data used to create the figure is sound, the figure does illustrate consistent isotropy in the horizontal plane.[838]

And in addition to declaring Dr. Kreamer provided no support for his assertion that further analysis of anisotropy is necessary to meet the aquifer pumping test's objectives, Staff witnesses Back, Lancaster, and Dr. Striz observed that anisotropy (and heterogeneity for that matter) is unrelated to the vertical containment of a production zone aquifer and is only important in meeting one of the objectives of the MEA aquifer pumping test, i.e., to show interconnectivity as it may affect the ability of the operator to balance the wellfields and maintain an inward gradient. In fact, according to these Staff witnesses, if there is any vertical anisotropy

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[834] See CBR Rebuttal Test. at 12.

[835] See Tr. at 537–39.

[836] See CBR Rebuttal Test. at 12 (Lewis, Nelson, Pavlick).

[837] See Staff Rebuttal Test. at 29.

[838] See Tr. at 539–40.

in the production zone aquifer, it would benefit ISR operations by creating a preferred horizontal flow within the sandstone aquifer.[839]

2. Board Findings on Kreamer Opinion 5 – Analysis for Anisotropy

In his Opinion 5, Dr. Kreamer asserted that (1) directional differences in hydraulic conductivity for the BC/CPF remain undefined and not quantified, particularly in the vertical direction; and (2) CBR's claim of no anisotropy is based on a crude plot of limited pumping test data presented on a hand-drawn visual representation of isotropy that violates professional practice.[840] We cannot agree on either count. Figure 16 of the CBR pumping test analysis was created using the monitoring well network data and software-generated contours to create the non-biased horizontal flow patterns displayed in this figure from the pumping test result.[841] As shown, the drawdown contours from the May 2011 aquifer pumping test presented in the MEA aquifer pumping test report are far from the elliptical shape that would indicate significant directional hydraulic conductivity from lateral anisotropy.[842] With no dispute from Dr. Kreamer about what Figure 16 shows as drawn,[843] the plot illustrates near circular contour lines of potentiometric levels indicative of isotropic flow in a horizontal plane of the BC/CPF.[844] As a consequence, we find that CBR is justified in stating that, given lack of conceptual basis in the geometry of the drawdown cone, more detailed analyses of horizontal anisotropy are not

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[839] See Staff Rebuttal Test. at 29.

[840] See Kreamer Initial Test. at 7.

[841] See CBR Rebuttal Test. at 12 (Lewis, Nelson, Pavlick); Tr. at 537–39 (Lewis).

[842] See Staff Rebuttal Test. at 27 (Back, Lancaster, Striz).

[843] See Tr. at 539–40.

[844] See Staff Rebuttal Test. at 29 (Back, Lancaster, Striz).

necessary.[845] Dr. Kreamer, on the other hand, failed to provide any reasonable indication, to say nothing of concrete evidence, that supports his assertion that anisotropy is not defined or quantified and that this lack of definition has a significant impact on the safe operation of the proposed Marsland ISR.

The Board also finds that the necessity of having horizontal isotropic conditions for safe MEA operation has not been justified by the Intervenor. We recognize that isotropy is likely needed to assure hydraulic interconnectivity to give a facility operator the ability to balance the wellfields and maintain an inward gradient. But we also find that anisotropy of the BC/CFP is unrelated to vertical confinement of the production zone aquifer controlled by the hydraulic characteristics of the UCU and LCU.[846] Staff witnesses were unchallenged when they noted that any vertical anisotropy that might exist within the BC/CPF sandstone aquifer will likely be beneficial for ISR operations because it creates the preferred horizontal flow.[847] Indeed, we find this Staff position consistent with Dr. Kreamer's recognition that with sandstones, there is usually greater hydraulic conductivity in the horizontal direction than in the vertical direction so as to result in preferential horizontal flow that is beneficial to CBR in controlling the vertical migration of production fluids.[848]

Given that anisotropy of the BC/CPF plays, at best, a minor role in the determination of the containment properties of the production zone (and may even help the operator control production fluids during operations and restoration), when combined with the Intervenor's scant evidence supporting its position that the Applicant needed to define directional differences in the hydraulic conductivity of the production zone to a greater degree, we conclude that the results of

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[845] See CBR Rebuttal Test. at 12 (Lewis, Nelson, Pavlick).

[846] See Staff Rebuttal Test. at 29 (Back, Lancaster, Striz).

[847] See id.

[848] See Tr. at 544–46.

the May 2011 pumping test as reflected in the record before us were sufficient to indicate manageable anisotropy of the BC/CPF.

F. Kreamer Opinion 6 – Discontinuities in BC/CPF Thickness and Infinite Extent

1. Parties' Position on Kreamer Opinion 6 – Discontinuities in BC/CPF Thickness and Infinite Extent

According to Dr. Kreamer's Opinion 6 (and the related portions of his Opinions 3 and 4),[849] both the Theis and Cooper-Jacob mathematical solutions employed in the MEA pumping test report require the same assumption that the BC/CPF sandstone aquifer is "of uniform effective thickness over the area influenced by pumping,"[850] and is "confined and has apparent infinite extent."[851] He claimed that these foundational requirements are not consistent with the data and evidence.[852]

a. Thickness Variations

Looking first at alleged variations in aquifer thickness, Dr. Kreamer testified that there are significant discontinuities in the thickness of the BC/CPF sandstone aquifer because the formation is not entirely horizontal nor of equal thickness and, like heterogeneity and anisotropy, these differences invalidate the Theis/Cooper-Jacob approach used to characterize the BC/CPF's hydrological properties of transmissivity and storage coefficient.[853]

In their rebuttal testimony, Staff witnesses Back, Lancaster, and Dr. Striz contradicted Dr. Kreamer's suggestion that the local geology is complex with significant discontinuities, stating that, based on CBR's subsurface investigations, there is ample evidence that the local

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[849] See supra sections VII.C and VII.D.

[850] Kreamer Initial Test. at 6 (quoting Test #8 Rep. at 11).

[851] Id. (quoting Test #8 Rep. at 11).

[852] See id.

[853] See id. at 7.

stratigraphy around the MEA is relatively uniform and uncomplicated.[854] In particular, according to these Staff witnesses, the site-specific and regional cross-sections provided by CBR show that the stratigraphic units, and specifically the BC/CPF, are relatively uniform in thickness over the site.[855] Furthermore, these Staff witnesses maintained that if there were significant heterogeneities, such as large variations in aquifer thickness over short distances, these variations would be apparent from the potentiometric surface mapping, which instead showed smooth contours that indicate relative homogeneity.[856]

In his review of CBR's geologic cross-sections, Dr. Kreamer concluded that while the lower boundary of the BC/CPF is rather flat, the upper boundary of the BC/CPF changes elevation repeatedly and fairly abruptly, causing these impermissible changes in aquifer thickness. [857] And according to Dr. Kreamer, the notable difference between the upper and lower boundary of the BC/CPF is not adequately explained by the Staff's conjecture in its EA that the lack of continual thickness of the BC/CPF Formation is due to the creation of paleo

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[854] See Staff Rebuttal Test. at 29 (citing Staff Initial Test. at 10–11, 24–25 (summarizing CBR's subsurface investigations)).

[855] See id. at 29 (citing Staff Initial Test. at 12–13; Tech. Rep. Figs. at 49–62 (figs. 2.6-3a to -3n), 87–90 (figs. 2.6-21 to -24)). Relative to the cited TR figures 2.6-21 to 2.26-24 that present the geophysical logs of a series of wells that lie on a designated section line, the Board notes that these are drawn to a vertical exaggeration of 10. As other TR figures present the same information, albeit not at a constant exaggeration, see Tech. Rep. Figs. at 35–40 (figs. 3–8), 49–62 (figs. 2.6-3a to -3n), 68–70 (figs. 2.6-3r to -3t), this was likely done for figures 2.6-21 to 2.6-24 to better show the vertical stratification and geophysical information. While the vertical depths of the logs are to scale, upon closer inspection the wells are placed horizontally next to each other with the numeric interval distance labels between the logs, but with no apparent attempt to maintain any true scale of the horizontal distances between each well. As a result, there is still a vertical exaggeration, but it is not constant for these figures.

[856] See Staff Rebuttal Test. at 27, 29; see also Tech. Rep. Figs. at 113–17 (figs 2.9-6a to -6d) (potentiometric surface maps).

[857] See Kreamer Initial Test. at 6 (citing Tech. Rep. Figs. at 67–69 (figs. 2.6-3s to -3u); Test #8 Rep. at PDF 35–40 (figs. 3–8)).

channels as the sediment was being deposited.[858] Staff witnesses Back, Lancaster, and Dr. Striz responded that Dr. Kreamer must have misunderstood the EA because his reference says nothing about the variation in thickness of the BC/CPF sandstone at (or near) the MEA.[859] According to these Staff witnesses, another section of the EA, which describes the thickness of the BC/CPF sandstone as ranging from 20 ft. to 90 ft. over the MEA, indicates these figures are based on site-specific cross-sections and geophysical logging.[860] This level of variation, these Staff witnesses asserted, is expected in sedimentary systems and, as pointed out by Driscoll, will not preclude obtaining reliable results from an aquifer pumping test because the assumption of constant thickness is not a serious limitation given that the variation in aquifer thickness within the cone of depression in most situations is relatively small, especially in sedimentary rocks such as the BC/CPF.[861]

In his rebuttal testimony, Dr. Kreamer repeated his claim that the MEA geologic strata are not of consistent thickness, nor are they entirely horizontal.[862] But when given the opportunity at the hearing to point out the cross-sections on which he based his opinion that there were abrupt changes in the upper boundary of the BC/CPF that led to thickness variations, Dr. Kreamer could not recollect what he used to reach this opinion.[863]

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[858] See id. (citing EA at 3-28).

[859] See Staff Rebuttal Test. at 28.

[860] See id. (citing EA at 3-10).

[861] See id. at 26–27, 28 (citing Driscoll Text at 214); see also supra note 799799 and accompanying text.

[862] See Kreamer Rebuttal Test. at 1.

[863] See Tr. at 469–71.

b. Confinement and Lateral Extent

Staff witnesses Back, Lancaster, and Dr. Striz also challenged Dr. Kreamer's allegations regarding the aquifer's lack of confinement and lateral extent by noting that the BC/CPF aquifer is a confined aquifer by definition because its potentiometric surface rises above the top elevation of the aquifer.[864] At the hearing, Dr. Kreamer agreed that the BC/CPF is a confined aquifer, albeit, in his view, a leaky one.[865] Regarding the assumption of apparent infinite lateral extent, it was these Staff witnesses' opinion that the site-specific and regional cross-sections that are based on borehole data and geophysical logging demonstrate that the BC/CPF aquifer is present over the entire MEA site and well beyond.[866] This conclusion is also supported by the lack of boundary conditions observed during the aquifer pumping test, especially in the most distant observation wells.[867]

2. Board Findings on Kreamer Opinion 6 – Discontinuities in BC/CPF Thickness

Dr. Kreamer alleged that the foundational requirements necessary for a Theis and Cooper-Jacob solution, i.e., a confined aquifer with uniform thickness over an apparent infinite extent, are violated at the MEA site.[868] Based on the evidentiary record before us, this Board finds that not to be the case.

a. Thickness Variations

We agree with the Staff's position that there is ample evidence that the local stratigraphy around the MEA is relatively uniform and uncomplicated and, specifically, that the site-specific

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[864] See Staff Rebuttal Test. at 27 (citing Staff Initial Test. at 30).

[865] See Tr. at 451.

[866] See Staff Rebuttal Test. at 28 (citing Tech. Rep. Figs. at 49–62 (figs. 2.6-3a to -3n), 87–90 (figs. 2.6-21 to -24)).

[867] See id. (citing Test #8 Rep. at 13).

[868] See Kreamer Initial Test at 6–7.

and regional cross-sections provided by CBR show the BC/CPF is relatively uniform in thickness over the site.[869] We also find that if there were significant variations in aquifer thickness, there would be some signs of deviations not evident from the smooth uniform contours presented in CBR's potentiometric surface maps.[870] While Dr. Kreamer in his Opinion 6 stated there are significant discontinuities in the thickness of the BC/CPF sandstone aquifer, he did not point to any specific examples of such discontinuities in those geologic cross-sections, other than his general reference to the geologic cross-sections presented in the CBR TR and pumping test report.

In citing cross-sections in the CBR TR and the pumping test report, Dr. Kreamer did indicate as part of his initial testimony that the upper boundary of the BC/CPF changes elevation repeatedly and fairly abruptly, causing impermissible variations in aquifer thickness for the purpose of employing the Theis and Cooper-Jacob methodologies. Yet, he offered this opinion without reference to specific locations on the geologic cross-sections where he considered the variation in BC/CPF thickness to exist.[871] Moreover, Dr. Kreamer's opinion in this regard did not address the effect vertical exaggeration in these cross-sections might have played in his conclusion that there were abrupt changes in the upper boundary of the BC/CPF, even when given the opportunity to do so at the hearing.[872]

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[869] See Staff Rebuttal Test. at 29 (Back, Lancaster, Striz).

[870] See id.

[871] See Kreamer Initial Test. at 6 (citing Tech. Rep. Figs. at 67–69 (figs. 2.6-3s to -3u); Test #8 Rep. at PDF 35-40 (figs. 3–8)).

[872] See Tr. at 467–71 (Shriver, Kreamer). While we find that the visual representations on the geologic cross-sections in question may at times illustrate an apparent abrupt change in the upper surface of the BC/CPF, we also conclude that it is reasonably likely this is an artifact of the exaggerated scales of these graphs. See supra note 8555. If drawn to true vertical and horizontal scale, the boundaries would appear flat and the thickness of the BC/CPF extremely thin, in some places possibly just the width of a pencil line. See Tr. at 468 (Shriver).

In contrast, the Staff's SER describes the thickness of the BC/CPF sandstone as ranging from 20 ft. to 90 ft. over the MEA based on site-specific cross-sectional data and geophysical logging,[873] a level of variation expected in sedimentary systems consistent with Driscoll.[874] We thus conclude that this range of aquifer thickness will yield reasonably reliable results from an aquifer pumping test, such as that conducted in May 2011, because the assumption of constant thickness associated with the Theis and Cooper-Jacob distance drawdown methods is not a serious limitation, given that the variation in aquifer thickness within the cone of depression appears to be relatively small in the area of the BC/CPF aquifer pumping test.[875]

b. Confinement and Lateral Extent

Consistent with the definition of a "confined aquifer" recognized by Dr. Kreamer,[876] we conclude that the BC/CPF aquifer is a confined aquifer because its potentiometric surface rises above the top elevation of the aquifer.[877] Also, with respect to the issue of lateral extent, we find that the BC/CPF aquifer is present over the entire MEA site, and in fact goes well beyond the site limits, based on the site-specific regional cross-sections derived from borehole data and geophysical logging that is consistent with the lack of definitive boundary conditions observed during the aquifer pumping test.[878]

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[873] See SER at 29.

[874] See Staff Rebuttal Test. at 28 (Back, Lancaster, Striz).

[875] See id. at 26–27 (Back, Lancaster, Striz).

[876] See Tr. at 451–52.

[877] See Staff Rebuttal Test. at 27 (Back, Lancaster, Striz) (citing Staff Initial Test. at 30).

[878] See id. at 28 (Back, Lancaster, Striz) (citing Test #8 Rep. at 13; Tech. Rep. Figs. at 67–69 (figs. 2.6-3s to -3u); Test #8 Rep. figs app. at PDF 35–40 (figs. 3–8)).

G. Kreamer Opinion 7 – Analysis of Selected Pumping Test Data

In his Opinion 7, Dr. Kreamer claimed that CBR had no justifiable basis for analyzing only a selected portion of the pumping data, which can bias the results by only considering a small area of the site through an arbitrary selection process. The Board finds that Opinion 7 is repetitive of the same allegation presented in Dr. Kreamer's Opinion 1, Basis B,[879] which, in turn, was a subject in our detailed discussion of the overarching issue regarding CBR's alleged misinterpretation of aquifer pumping test data.[880] Details of the parties' positions and the Board's findings on Dr. Kreamer's claim that CBR selected only portions of the pumping data during its analysis are provided above in sections V.A.1.b and V.A.2.b, respectively.

H. Summary of Board Findings Regarding Concern 2 – Absence of Site Hydrogeology Description

Exclusively as a safety matter, the Board reviewed all the initial and rebuttal testimony, as well as the hearing transcripts, relating to the absence of an adequate description of the site hydrogeology that is the subject of OST's Contention 2-associated Concern 2. Our detailed findings on each of Dr. Kreamer's seven Concern 2-related opinions (the first of which contains eight bases), which deal specifically with the May 2011 pumping test performed within the MEA and various test-related hydraulic characteristics of the BC/CPF aquifer, can be found in individual subsections of our Concern 2-related discussion. Within these findings, each of the eight bases proffered for Dr. Kreamer's first opinion dealing with the mischaracterization of the hydrogeologic description from the pumping test results is also addressed. As to each of the major topics, in summary we find that:

1. The challenge to CBR's efforts to properly define the MEA site hydrogeology, expressed in Dr. Kreamer's seven opinions (with Opinion 1 comprised of eight bases), covers several issues, including the aquifer pumping test, geologic cross-sections

[879] See supra section VII.A.2.

[880] See supra section V.A.

derived from site-specific investigations (including numerous borings, geophysical logs, and water level readings), and structural, potentiometric contour, and isopach mapping derived from CBR's field measurements.[881]

2. Although there is likely some degree of structural fracturing of the geologic strata underlying the MEA, the mere presence of fractures is not the issue; instead, the transmissivity of this feature is the critical factor and, in this regard, no evidence has been provided by OST demonstrating that there are sufficient preferential flow paths from any cause (including fractured flow) sufficient to alter the CBR and Staff conclusions that (a) containment within the BC/CPF provides isolation of the Arikaree/Brule aquifer from the production zone; (b) the BC/CPF is internally interconnected to allow CBR to control operational fluids injected into this strata during ISR operations and restoration; and (c) multiple pieces of evidence support the containment of the processing lixiviant within the production zone.[882]

3. Crow Butte's May 2011 regional aquifer pumping test was performed to address several objectives, including (a) demonstrating hydraulic communication (connection) within the BC/CPF Sandstone aquifer (production zone); (b) assessing the hydrological characteristics of the BC/CPF sandstone aquifer; (c) evaluating the presence or absence of hydraulic boundaries in the BC/CPF sandstone aquifer within the test area; and (d) demonstrating sufficient vertical containment to isolate the overlying Arikaree/Brule aquifer from the BC/CPF sandstone aquifer.[883]

4. The goals of the pumping test were achieved, with the pumping test report (a) providing the bases for demonstrating containment (i.e., hydraulic isolation) between the production zone and the overlying Arikaree/Brule aquifer as no drawdown was observed in the overlying Brule Formation observation wells during the test period; and (b) presenting drawdown data vs. time plots for each observation well, which determined that confined aquifer analytical methods were appropriate for the analysis of pumping test data.[884]

5. OST's claims that only selective portions of the data were analyzed are unsupported because all data points for all of the observation wells were presented in the

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[881] See supra note 671 and accompanying text.

[882] See supra sections V.B and VI.B.2.

[883] See supra section V.A; see also CBR Initial Test. at 28 (Lewis, Nelson, Pavlick); Tech. Rep. at 2-82; EA at 3-31.

[884] See supra sections V.A and VI.B.3; see also CBR Rebuttal Test. at 4–6 (Lewis, Nelson, Pavlick).

drawdown and recovery response curves, while CBR's rationale for analyzing the aquifer pumping test data was clearly explained by the Applicant in that, consistent with recommended practice, less weight should be given to the early-time pumping data for lack of theoretical representation due to well effects and the late-time deviation responses in the drawdown of two wells (attributed by OST to a lack of containment within the BC/CPF) could have been a result of three other causes (outlined in item 6 below) that would mimic the same response in the plots.[885]

6. While OST provided no corroborating evidence supporting its position that leakage through the UCU is of sufficient magnitude to jeopardize containment or prevent CBR from controlling its production fluids during operations and restoration, the CBR pumping test data, in conjunction with the CBR and Staff explanations about the source of late-time deviations detected at two well locations (i.e., higher transmissivities encountered at distances from the pumping well, additional water release from aquitard storage, and misinterpretation of wellbore storage/near-wellbore effects, all of which mimic recharge deviations in the Theis graphs), verified other multiple lines of evidence demonstrating the containment and connectivity properties of the BC/CPF.[886]

7. OST failed to provide credible evidence or expert opinion refuting the CBR conclusion (supported by the Staff) that the lack of a response in the Brule aquifer observation wells during the pumping test is evidence of containment within the BC/CPF aquifer provided by the thick, low permeability UCU.[887]

8. OST failed to justify the need for any additional pre-licensing pumping testing efforts.[888]

9. The single pumping test in May 2011, which covered almost half of the MEA by monitoring nine wells in the BC/CPF and three wells in the overlying Brule aquifer, was never intended to be the sole source of site characterization information given (a) additional pumping tests will be performed prior to the startup of each MU; and (b) the information from the existing test is backed by other site-specific hydrogeologic data, including geological cross-sections and hydrogeologic isopach, structural contour,

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[885] See supra section V.A.2.b.

[886] See supra section V.A.2.b; see also section V.C and infra sections IX.A.2 and IX.B.2 for a summary of the site observations and characteristics that support BC/CPF aquifer containment.

[887] See supra section V.C.3.

[888] See supra section VII.A.5.b.

and potentiometric contour mapping based on the stratigraphic cuttings and geophysical logging of over 1600 boreholes drilled within the MEA.[889]

10. While all geologic strata exhibit heterogeneity and anisotropy at some scale, application of the Theis and Cooper-Jacob techniques is routinely done in practice with an understanding of the assumptions of homogeneity and isotropy inherent to their use, and CBR acknowledged that within the MEA, the BC/CPF is not homogeneous and isotropic on a local scale, but the assumptions of homogeneity and isotropy are reasonably satisfied over the scale of the BC/CPF pumping test.[890]

11. With the BC/CPF conforming to the definition of a confined aquifer, the assumptions of homogeneity, isotropy, and lateral extent of the BC/CPF aquifer underlying the MEA are reasonably satisfied and, consistent with Driscoll, can be treated for analytical purposes as homogeneous, isotropic, and of uniform thickness with infinite lateral extent.[891]

12. Offering no corroborating evidence of co-existing factors supporting its position that there is localized leakage of sufficient magnitude to impact the containment properties and internal interconnections of the aquifer so as to significantly impede CBR ability to control fluid migration within the BC/CPF, OST's claim that the flattening of the pumping test drawdown curve detected in two close wells indicates a recharge boundary from vertical leakage is not consistent with site observations, particularly given that other scenarios proffered by CBR and NRC Staff are consistent with many other MEA characteristics that support the Applicant's position that the fluids in the production zone are contained.[892]

VIII. CONCERN 3 – UNACCEPTABLE SITE HYDROLOGIC CONCEPTUAL MODEL (HCM)

Concern 3 of OST Contention 2, as both a safety and environmental issue, deals with the alleged failures of (1) the Applicant to develop an acceptable HCM based on site characterization data; and (2) the Staff to evaluate properly, from an environmental perspective,

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[889] See id.

[890] See supra section VII.D.2.

[891] See supra sections VII.A.7.b, VII.D.2, and VII.F.2.

[892] See supra section V.C and infra sections IX.A.2 and IX.B.2 for a summary of these site observations and characteristics that support BC/CPF aquifer containment.

the adequacy of this model in accordance with section 2.7 of NUREG-1569.[893] According to this concern, an acceptable model is one that demonstrates (with scientific confidence) that the MEA's surface water hydrology and groundwater hydrogeology assures containment of extraction fluids and expected operational and restoration performance.[894]

OST witness Wireman challenged the adequacy of CBR's HCM directly in section 1 of his rebuttal testimony, as well as in a passing reference in his initial testimony, when challenging the specific structural geologic characterization of fractures/faults and the interpretation of aquifer pumping test results.[895]

This portion of our initial decision summarizes Mr. Wireman's initial and rebuttal testimony for Concern 3 that directly applies to the adequacy of CBR's HCM, the associated

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[893] At the hearing, the Board's questions to the parties went beyond the HCM to encompass other models CBR used to help create the initial design of the site and to document the procedures necessary for safe and environmentally sound operation and restoration of the MEA ISR facility. See Tr. at 875–928 (Lewis, Shriver, Back, Lancaster, Kreamer). Specifically, in support of its development of the HCM, CBR also created a geologic stratification model, see supra section 4.2 for the undisputed geologic stratification model, and several numerical models to assist with analyzing (1) the potential impact from well casing leaks on irrigation water quality, see Tech. Rep. at 2-117 to -119, 3-25 to -27; (2) hydrologic containment under normal and extended facility shut-down scenarios, see Hydraulic Containment Report at 4; Tech. Rep. at 3-26 to -27; and (3) the impact of aquifer drawdown on surface and groundwater resources, see Ex. CBR017 (Tech. Rep. app. GG (AquiferTek, Re: Drawdown Impact Assessment, [MEA] (May 11, 2016)) [hereinafter Drawdown Impact Assessment]. While OST witnesses did not provide any written initial or rebuttal testimony regarding these numerical models, the Board asked questions at the hearing regarding the HCM and the details of the numerical models to better understand their use in the development of the Marsland license amendment application. Most, but not all, of the questions were directly related to the HCM, but those that were not nonetheless assisted the Board in acquiring background information to better understand CBR's process for preparing its application for this site. As the numerical models were not specifically contested in the Intervenor's initial or rebuttal written testimony for Concern 3, this decision only discusses the testimony proffered for these numerical models to the degree any of those models had an impact on the HCM as a mathematical aid in integrating HCM-related concepts.

[894] See LBP-18-3, 88 NRC at __ (slip op. at 43).

[895] See Wireman Rebuttal Test. at 1–2; Wireman Initial Test. at 3, 4. OST's other two witnesses, Dr. Kreamer and Dr. LaGarry, did not address the HCM, instead focusing on OST's claims regarding the aquifer pumping test, see supra section VII, and stratigraphic characterization, see supra section VI, respectively.

initial and rebuttal testimony from the Applicant and the Staff, and pertinent testimony from the evidentiary hearing.

A. Parties' Positions on HCM

Mr. Wireman directly contested CBR's HCM by alleging that (1) characterization of the structural geology is insufficient to develop an acceptable conceptual model of site hydrology that is adequately supported by site characterization data, primarily as a result of the Applicant's disregard for the fractures and faults within the stratigraphy underlying the MEA;[896] (2) the May 2011 aquifer pumping test conducted at the MEA is inadequate for developing an acceptable site-wide conceptual hydrologic model as it does not adequately characterize the subsurface heterogeneity;[897] and (3) neither CBR's TR nor the Staff's EA contain sufficient data and information to develop an adequate conceptual model of site hydrology.[898] In addition to Mr. Wireman's testimony on this topic, CBR and the Staff also submitted initial, rebuttal, and hearing testimony describing their positions on the extent to which the Applicant's HCM meets the acceptance criteria of section 2.7.3 of NUREG-1569.[899]

Most, if not all, of the issues associated with the creation of the CBR's HCM were previously addressed as part of our Concern 1 discussion dealing with OST's allegations of an inadequate description of the affected environment for the Marsland site.[900] As context for this discussion of the HCM, presented below are the parties' positions regarding the generic

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[896] See Wireman Initial Test. at 3.

[897] See id. at 4.

[898] See Wireman Rebuttal Test. at 1–2.

[899] See CBR Initial Test. at 25–26, 38 (Lewis, Nelson, Pavlick); CBR Rebuttal Test. at 6–17 (Lewis, Pavlick, Shriver), 26 (Lewis, Nelson, Pavlick, Shriver); Staff Initial Test. at 22–41 (Back, Lancaster, Striz).

[900] See supra section VI.B.

components of HCM and a summary of MEA hydrology at issue in Contention 2, followed by the parties' positions relating to each of Mr. Wireman's opinions dealing with Concern 3.

1. Parties' Positions on HCM Components and MEA Hydrology

According to Staff witnesses Back, Lancaster, and Dr. Striz, a hydrologic conceptual model that is consistent with NUREG-1569 guidance includes descriptions of both surface water and groundwater hydrology. The description of the surface water hydrology includes the presence, characteristics, and behavior of regional and local surface water bodies, while the groundwater hydrogeology description discusses the presence and behavior of regional and local groundwater aquifers within the geologic setting of the proposed ISR facility.[901]

For surface water hydrology, the conceptual model includes watersheds and drainages; surface water feature types (e.g., streams, impoundments); size, and morphology (e.g., stream cross-sections); peak flow rates at storm recurrence intervals; flooding potential; typical seasonal ranges of surface water levels; seasonal surface water quality; and past, current, and anticipated surface water use. For groundwater hydrogeology, the conceptual model describes, among other things, regional and local groundwater aquifers, which includes hydrostratigraphy (i.e., depth and thickness of aquifers and aquitards); hydraulic properties of the aquifers/aquitards; aquifer potentiometric surfaces and hydraulic gradients; aquifer groundwater flow directions and magnitudes; preferential flow pathways; aquifer recharge/discharge areas; aquifer water quality; and past, current, and anticipated groundwater use.[902]

As is relevant to Contention 2, surface water hydrology for the HCM focused on identification of ephemeral drainages and a detailed description of the Niobrara River as the

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[901] See Staff Initial Test. at 22–23 (citing NUREG-1569, at 2-20 to -26).

[902] See id.

only significant water body in the region of the MEA, with no surface water impoundments, lakes, ponds, or other rivers identified within the proposed MEA license area.[903]

With regard to the hydrogeology of the MEA for the HCM, CBR in its TR presents the regional and local stratigraphic columns beneath the MEA that listed the aquifers at the site, including the shallow unconfined Arikaree/Brule aquifer and the deeper confined BC/CPF aquifer.[904] Within the MEA, the UCU for the BC/CPF includes up to 450 ft. of clay-rich mudstone and siltstones of the middle and upper Chadron,[905] and as a result, the unconfined Arikaree/Brule aquifer is vertically and hydraulically isolated from the underlying BC/CPF aquifer. The LCU of the BC/CPF in the vicinity of the MEA consists of 750 ft. or more of black marine shale deposits of the Pierre Shale, a non-water-bearing unit that exhibits very low permeability and is considered a regional aquiclude that hydraulically isolates the BC/CPF from underlying sandstones.[906]

In addition to this hydrostratigraphy, the Staff stated that the groundwater HCM includes an assessment of preferential flow paths, aquifer recharge/discharge, and aquifer water quality.[907] In this regard, the CBR TR references a potentiometric map and cross-sections of the BC/CPF as indicating a confined groundwater flow as a result of an elevated recharge zone that most likely is located west or southwest of the MEA.[908] In the vicinity of the MEA,

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[903] See Tech. Rep. at 2-77 to -78; 2-119 to -123; 2-128; 5-57 to -58; EA at 3-18 to -23; SER at 59–60.

[904] See Tech. Rep. at 2-84 (citing Tech. Rep. Tbls. at 62–63 (tbls. 2.6-1 to -2)).

[905] See id. (citing Tech. Rep. Figs. at 49–62 (figs. 2.6-3a to -3n), 74 (fig. 2.6-8)).

[906] See id. at 2-84 to -85.

[907] See Staff Initial Test. at 22–23 (Back, Lancaster).

[908] See Tech. Rep. at 2-86 (citing Tech. Rep. Figs. at 49–62 (figs. 2.6-3a to -3n), 113–16 (figs. 2.9-6a to -6d)).

groundwater flow in the basal sandstone of the Chadron Formation is predominantly to the northwest toward the White River drainage at a lateral hydraulic gradient of 0.0004 ft./ft. Regional water-level information for the BC/CPF sandstone of the Chadron Formation suggests a discharge point located past Crawford, presumably at a location where the basal sandstone of the Chadron Formation is exposed.[909]

In contrast, the CBR TR indicates the groundwater of the Arikaree/Brule Formation generally flows to the southeast across the entire MEA toward the Niobrara River at a lateral hydraulic gradient of 0.011 ft./ft. Though the Arikaree/Brule aquifer is the primary groundwater supply in the vicinity of the MEA, low production rates indicate that the discontinuous sandstone lenses may not be fully connected hydraulically. Recharge to the Arikaree/Brule likely occurs directly within the MEA, as the unit is overlain by 0 to 30 ft. of unconsolidated alluvial deposits. At the MEA, groundwater elevations for the Arikaree/Brule aquifer are distinctly different from those of the BC/CPF.[910] The available water-level data suggest hydrologic isolation of the BC/CPF with respect to the overlying water-bearing intervals in the MEA.[911]

According to Staff witnesses Back and Lancaster, the above descriptions of the conceptual models for surface water hydrology and groundwater hydrogeology are consistent with the regulatory guidance of NUREG-1569.[912] Of these components, Mr. Wireman's testimony focused on (1) characterization of the structural geology relating to fractures and faults within the stratigraphy underlying the MEA; (2) the May 2011 aquifer pumping test conducted at the MEA; and (3) characteristics of regional hydrology associated with sources of

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[909] See id.

[910] See id. (citing Tech. Rep. Figs. at 49–62 (figs. 2.6-3a to -3n); Tech. Rep. Tbls. at 114 (tbl. 2.9-7)).

[911] See id.

[912] See Staff Initial Test. at 16–17.

groundwater recharge and discharge, groundwater flow in the BC/CPF underlying the MEA, perimeter groundwater monitoring wells, description of surface water hydrology, and groundwater baseline restoration wells.[913]

Seeking to counter Mr. Wireman's allegation that the Applicant failed to develop an HCM based on site characterization data and that the Staff failed adequately to consider the HCM in its EA for the proposed MEA license amendment, CBR quotes portions of NUREG-1569 section 2.7.3 in setting forth the six criteria that must be met for acceptance as an adequate HCM.[914] Of those six criteria, Mr. Wireman's testimony challenging CBR and Staff attempts to show compliance with these regulatory guidance items seems to rely primarily to two criteria: (1) Criterion 1, stating that the Applicant is to characterize surface-water bodies and drainages within the proposed facility and affected surroundings and identify the interconnection between surface water and groundwater; and (2) Criterion 3, stating that the Applicant will describe the local and regional hydraulic gradient and hydrostratigraphy, including, but not limited to, (a) subsurface water-level measurements; (b) potentiometric maps presenting hydraulic gradient data, potentiometric levels, and water-surface elevations; (c) hydrogeologic cross-sections for illustrating the interpreted hydrostratigraphy; and (d) hydraulic parameters.

The parties' positions and the Board's findings on Mr. Wireman's claims regarding these criteria as they relate to Concern 1 were already covered in detail above, supra section VI.B. References explaining how these positions may apply to Concern 3 are presented in the next section. After offering our findings on CBR's and the Staff's attempts to show that the NUREG-1569 acceptance criteria for an HCM have been met relative to CBR's application, in subsequent sections we present our findings on NUREG-1569 Criteria 1 and 3.

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[913] See Wireman Initial Test. at 3, 4; Wireman Rebuttal Test. at 1–2.

[914] See CBR Initial Test. at 9–11 (Lewis, Nelson, Pavlick) (quoting NUREG-1569, at 2-23 to -26).

2. Parties' Positions on HCM – Structural Geology Characterization

Mr. Wireman presented his position dealing with the characterization of the structural geology in Opinion 2 of his initial testimony and in his rebuttal testimony, which have already been discussed in this decision in section VI.B.2, referencing the overarching issue of heterogeneity from fracturing/faulting in section V.B, and is not repeated here.

3. Parties' Positions on HCM – Aquifer Pumping Test

Mr. Wireman presented his position dealing with the May 2011 aquifer pumping test in Opinion 3 of his initial testimony and in his rebuttal testimony, which have already been discussed, along with the CBR and Staff initial and rebuttal testimony and the parties' hearing testimony, in this decision in section VI.B.3., as it references the overarching issue of misinterpretation of aquifer pumping test data in section V.A, and so is not repeated here.

4. Parties' Positions on HCM – CBR and Staff Insufficient Data and Information on Regional Hydrogeology and Groundwater Flow

Other issues raised by the Intervenor regarding regional hydrogeology and groundwater flow aspects of the Applicant's HCM were already discussed in this decision in section VI.B relative to Mr. Wireman's Concern 1B and include:

- Recharge sources and discharge locations of the BC/CPF aquifer (section VI.B.1.a);
- Downgradient MEA BC/CPF groundwater flow (section VI.B.1.b);
- Perimeter groundwater monitoring wells (section VI.B.1.c);
- Surface water hydrology (section VI.B.1.d); and
- Groundwater baseline restoration wells (section VI.B.1.e).

Mr. Wireman's position, as well as those of CBR and the Staff, are delineated in each of the above referenced sections and so will not be repeated herein.

B. Board Findings on HCM

As was noted above, in its initial testimony CBR quotes portions of NUREG-1569 section 2.7.3 that it asserts set forth the review and acceptance criteria to be met for providing an adequate HCM.[915] Of the six acceptance criteria, Mr. Wireman's testimony challenging CBR and Staff compliance with this regulatory guidance appears to apply only to two criteria: Criterion 1, which establishes that the Applicant is to characterize surface-water bodies and drainages within the proposed facility and affected surroundings and identify the interconnection between surface water and groundwater; and Criterion 3, which indicates that the Applicant will describe the local and regional hydraulic gradient and hydrostratigraphy including, but not limited to, (a) subsurface water-level measurements; (b) hydraulic parameters; (c) potentiometric maps presenting hydraulic gradient data; potentiometric levels, and water-surface elevations; and (d) hydrogeologic cross-sections for illustrating the interpreted hydrostratigraphy.[916] After offering below our general findings on the CBR and Staff attempts to meet the acceptance criteria for an HCM, in the subsequent sections we present our findings about each of the contested criteria.

1. Board Findings on Addressing NUREG-1569 Acceptance Criteria

As a general matter, relative to Contention 2, Concern 3, the Board finds that CBR and the Staff have provided sufficient information to meet the NUREG-1569 section 2.7.3 acceptance criteria regarding the adequacy of site geology and hydrogeology descriptions as they relate to the containment properties of the BC/CPF aquifer and the aquifer's ability to control the groundwater flow of production fluids. This is apparent from the extensive presentation concerning the Applicant's conceptual model of site hydrology presented in

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[915] See CBR Initial Test. at 9–11 (Lewis, Nelson, Pavlick) (quoting NUREG-1569, at 2-23 to -24).

[916] See id. at 9–10 (Lewis, Nelson, Pavlick)

section 2.7.2.3 of its TR, which also was discussed in section 2.4 of the Staff's SER and was summarized in CBR's initial and rebuttal testimony.[917] Besides the Staff's SER description of CBR's HCM, we find that most of section 3.2, "Geology, Soils, and Seismology," and section 3.3 "Water Resources," in the Staff's EA provide the fundamental understanding of the site's geology, hydrology, and hydrogeology that is foundational to the MEA HCM as challenged by OST in Contention 2.[918] The Board also concludes that CBR's HCM is supported by a plethora of site characterization data provided in its TR's tables,[919] maps,[920] and appendices.[921]

As the Staff noted, an applicant must provide sufficient information in its HCM to demonstrate containment of the production zone aquifer.[922] In meeting the regulatory guideline acceptance criteria, the Board finds that a key aspect of the Staff's safety and environmental reviews for ISR facilities is the applicant's demonstration of the containment and

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[917] See Tech. Rep. at 2-84 to -87; SER at 45–58; CBR Initial Test. at 25–26 (Lewis, Nelson, Pavlick); CBR Rebuttal Test. at 16–17 (Lewis, Shriver, Pavlick).

[918] See EA at 3-5 to -36.

[919] See, e.g.,Tech. Rep. Tbls. at 62–63 (tbls. 2.6-1 to-2) (presenting MEA-vicinity regional and local stratigraphic columns).

[920] See, e.g., Tech. Rep. Figs. at 48–69 (figs. 2.6-2a to -3u) (MEA geologic structural cross-sections), 72–75 (figs. 2.6-6 to -9) (isopach thickness contour maps), 76–79 (figs. 2.6-10 to -13) (structural surface elevation contour maps), 87–90 (figs. 2.6-21 to -24) (regional geologic cross-sections), 109–16 (figs. 2.9-4a to -6d) (MEA potentiometric surface elevations).

[921] See, e.g., Initial Well Impact Analysis; Revised Well Impact Analysis; Hydraulic Containment Report; Ex. CBR015 (Tech. Rep. app. EE (Kozeny-Carman Calculations)); Test #8 Rep.; Drawdown Impact Assessment; Ex. CBR018 (Tech. Rep. app. HH (J. Shriver, Final Report, Deep Brule Monitor Well Installation Program, MEA, Dawes Cty., Neb. (May 3, 2017))); Ex. CBR019 (Tech. Rep. app. K-1 (Arcadis, U.S., Inc., Hydrologic and Erosion Study, MEA (Apr. 12, 2012))); Ex. CBR020 (Tech. Rep. app. K-2 (Arcadis, U.S., Inc., Hydrologic and Flood Study, MEA (May 2013))); Ex. CBR031 (Tech. Rep. app. G-1 (Mineralogy, Inc., Test Rep. (June 6, 2011)) (providing mineralogical and particle size distribution test results)); Ex. CBR032 (Tech. Rep. app. G-2 (Letter. from Michael Mark Brady, PTS Labs., Inc., to Wade Beins, CBR (Oct. 10, 2013)) (providing mineralogical and particle size distribution test results)).

[922] See Staff Initial Test. at 27–28 (Back, Lancaster, Striz).

interconnectivity of the production zone aquifer. In the Staff's safety review, an applicant's demonstration of containment directly impacts its ability to ensure that production fluids can be controlled within the production zone of the host aquifer, while in the Staff's environmental review, the demonstration of containment directly influences the evaluation of potential impacts to surface water and groundwater resources.[923]

In its review of the MEA application, the Staff concluded that CBR's hydrologic conceptual model for the MEA is supported by extensive and reliable site characterization data from CBR's comprehensive subsurface investigation of the MEA. These data include geophysical logs and observations of drill cuttings that provide data on the thickness, extent, and continuity of stratigraphic units; cross-sections covering the entire MEA site constructed using data from 57 boreholes; isopach maps and structure contour maps created using borehole data; and physical and chemical properties of the overlying aquifers, upper and lower confining units, and production zone aquifer based on drill cuttings and analysis of core samples from over 1600 boreholes drilled within the MEA, and over 2100 boreholes drilled within the 2.25-mile radius of the MEA's AOR.[924]

Based on this extensive volume of work and the pertinent data amassed, the Board finds that CBR has provided the necessary hydrologic and hydrogeologic characterization of the MEA based on the extensive field data necessary for a scientifically sound HCM of the MEA and that the Staff has appropriately incorporated this model into its assessment of potential environmental impacts from operation and restoration of the MEA site.

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[923] See id.

[924] See id. at 24–26 (Back, Lancaster) (citing Tech. Rep. at 3-7; ER at 3-6).

2. Board Findings on Structural Geology Aspects of Fractures/Faults

Detailed discussion of the Board's findings dealing with the structural geology aspects of fractures/faults and the impacts of the Pine Ridge escarpment on groundwater flow beneath the MEA have been presented previously,[925] and will not be repeated here except as the following summary of the findings that relate to the HCM: (1) there is likely some degree of structural fracturing of the geologic strata underlying the MEA, but the mere presence of fractures is not the issue, the transmissivity of such features being the critical factor; (2) based on structure contour maps derived from field data and groundwater potentiometric maps that used measured water levels to establish the contour flow maps documenting a constant northwest flow along the axis of the MEA, the Pine Ridge escarpment impacts groundwater flow in the Arikaree/Brule aquifer, but not in the deep BC/CPF aquifer; and (3) erosion surface contours illustrate that the surficial formations have been significantly eroded on the north side of the Pine Ridge escarpment as compared to the south side where the MEA is proposed.

Based on these conclusions and others presented in the above-referenced sections, we find that the Intervenor failed to establish that CBR's characterization of the MEA's structural geology and subsurface heterogeneity is insufficient. Rather, a clear preponderance of the evidence demonstrates that CBR's conceptual model of site hydrology is sufficiently supported by the MEA-acquired site characterization data (including that related to the structural geologic aspects of fractures/faults generally and, more specifically, the impacts of the Pine Ridge escarpment on groundwater flow) to establish an acceptable site-wide HCM.

3. Board Findings on MEA Aquifer Pumping Test

Detailed discussion of the Board's findings dealing with the MEA aquifer pumping test have been presented previously,[926] and again are not repeated here except as the following

[925] See supra section VI.B.2 (citing section V.B).

[926] See supra section VI.B.3 (citing section V.A).

summary of the findings that relate to the HCM: (1) CBR has adequately explained why the May 2011 aquifer pumping test was sufficient to characterize the portions of the site that would be affected by development of the first four MUs at Marsland;[927] (2) in its call for more pre-licensing testing for the Arikaree/Brule aquifer, because of what the Tribe asserted are the indications of significant heterogeneity, OST failed to justify how the such additional definition of the hydraulic properties of the Arikaree/Brule aquifer relates to the containment properties of the BC/CPF located hundreds of feet below the ground surface; (3) additional pumping tests will be conducted by CBR within the MEA prior to opening each new MU;[928] (4) subsurface characterization of the BC/CPF using the examination of cores and geophysical logging shows that there are no major impermeable or permeable features that would indicate significant heterogeneity at the MEA;[929] and (5) lack of significant heterogeneity is also reflected by a consistently smooth, nearly flat hydraulic gradient of the BC/CPF aquifer's potentiometric surface.[930]

The Board concludes that while the BC/CPF may not be homogeneous and isotropic on a local scale,[931] the assumptions of homogeneity and isotropy are reasonably satisfied over the scale of the BC/CPF pumping test.[932] Based on these factors, the Board concludes that the

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[927] See CBR Rebuttal Test. at 17–18 (Lewis, Nelson, Pavlick); see also supra section VII.A.5.a.

[928] See CBR Rebuttal Test. at 7–8 (Lewis, Nelson, Pavlick), Tr. at 438–39 (Shriver); see also CBR License Amend. 3, at 21 (License Condition 11.3.4).

[929] See Staff Rebuttal Test. at 27 (Back, Lancaster, Striz) (citing Test #8 Rep. at 5).

[930] See id. (citing Tech. Rep. Figs. at 113–16 (figs. 2.9-6a to -6d)).

[931] See id. at 30 (Back, Lancaster, Striz); Test #8 Rep. at 11.

[932] See supra sections V.A and VII.D.

BC/CPF formation underlying the MEA can be treated as homogeneous and isotropic for analytical purposes.[933]

4. Board Findings on Regional Groundwater Flow

Our previous findings on regional groundwater flow focused on OST's indirect challenges dealing with issues that include recharge sources and discharge locations of the BC/CPF aquifer; downgradient MEA BC/CPF groundwater flow; perimeter groundwater monitoring wells; surface water hydrology; and groundwater baseline restoration wells. Because each of these topics is associated with Concern 3 relative to its potential effect on the development of the HCM, we address each in the sections below.

a. Board Findings on Recharge/Discharge Zones

Detailed discussion of the Board's findings dealing with the recharge sources and discharge locations of the BC/CPF aquifer has been presented above,[934] and is not repeated here except as the following summary of the findings that relate to the HCM: (1) contrary to OST's claim that CBR failed to discuss this topic in its application,[935] sources of recharge/discharge of groundwater in the BC/CPF are presented in CBR's TR as well as in the Staff's EA;[936] (2) locations of the discharge and recharge areas were based on the potentiometric maps and geologic cross-sections of the BC/CPF derived from actual field data and backed by a conceptual map that pictorially represents the flow regime from south of the MEA toward the northwest;[937] (3) CBR's theory of BC/CPF recharge and discharge plausibly

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[933] See Test # 8 Rep. at 11.

[934] See supra section VI.B.1.a.ii.

[935] See Wireman Initial Test. at 2.

[936] See Tech. Rep. at 2-86; EA at 3-23 to -24.

[937] See Tech. Rep. at 2-86; EA at 3-23 to -24, 3-29 (fig. 3-8); CBR Initial Test. at 33–34 (Lewis, Nelson, Pavlick); CBR Rebuttal Test. 13–14 (Lewis, Nelson, Pavlick, Shriver); Staff Rebuttal Test. at 2–3 (Back, Lancaster, Striz).

claims that recharge occurs as direct infiltration where the formation is exposed above an elevation of 3715 ft. amsl at distant locations west and south of the MEA, that discharge currently occurs from pumped wells at the existing CBR ISR facility and to flowing wells located near the town of Crawford, and that, prior to the existing CBR ISR facility's development, discharge occurred to the tributaries north of Crawford and by evapotranspiration in drainages east and north of Crawford where the BC/CPF is exposed at or near the surface;[938] and (4) confined conditions exist at the MEA as a result of an elevated recharge zone most likely located west or southwest of the MEA,[939] but such distant recharge and discharge areas will not affect the behavior of the BC/CPF aquifer at the MEA.[940]

While OST advocated for more refinement of the recharge and discharge locations of the BC/CPF, the Board finds that OST has not justified the need for such supplemental studies because it has failed to provide any evidence indicating that the refinement would have any impact on the conclusions reached in the CBR TR and the Staff EA. Furthermore, the acceptance criteria in NUREG-1569 do not require a higher level of detail on the discharge and recharge zones of the production aquifer than what has already been provided by the Applicant. As a result, based on the evidentiary record before us, we conclude that CBR's description of discharge and recharge zones in its TR is adequate to meet the applicable NUREG-1569 criteria and that CBR's definition of recharge and discharge areas of the BC/CPF is sufficiently supported by the site characterization data acquired at the MEA to establish an acceptable site-wide HCM.

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[938] See CBR Rebuttal Test. at 13 (Lewis, Nelson, Pavlick, Shriver).

[939] See CBR Initial Test. at 33 (Lewis, Nelson, Pavlick).

[940] See CBR Rebuttal at 13 (Lewis, Nelson, Pavlick, Shriver).

b. Board Findings on Downgradient BC/CPF Flow

A detailed discussion of the Board's findings addressing the downgradient BC/CPF flow has been presented previously,[941] and is not repeated here except as the following summary of the findings that relate to the HCM: (1) while OST stated that there is no discussion supporting the lack of effect by the Pine Ridge escarpment on groundwater flow in the BC/CPF aquifer,[942] both the conceptual map[943] and the plots of potentiometric levels and cross-sections of the BC/CPF[944] clearly indicate uniform northwesterly BC/CPF groundwater flow from recharge areas farther south of Dawes County, then northwesterly through the MEA and the existing CBR ISR facility until historically discharging where erosion has exposed this formation on the land surface north of Crawford;[945] (2) groundwater in the Arikaree/Brule aquifer flows to the southeast across the MEA toward the Niobrara River at a lateral hydraulic gradient of 0.011 ft./ft.,[946] while groundwater in the BC/CPF flows to the northwest through the MEA at a lateral hydraulic gradient of 0.0004 ft./ft.,[947] a showing about which OST provides no conflicting evidence; (3) notwithstanding OST's doubts that the Pine Ridge escarpment affects the Brule formation but not the BC/CPF,[948] the structural upheaval associated with the Pine Ridge escarpment did not affect the deposition of the BC/CPF and the overlying formations because the BC/CPF, middle and upper Chadron, and Brule and Arikaree formations were deposited during the same period of time as the structural deformation and, subsequently, erosion occurred on the north side to create the different flow directions in the Arikaree/Brule aquifer while maintaining the northwesterly flow in the deeper BC/CPF aquifer;[949] and (4) the lack of impact from the Pine Ridge escarpment is backed by the existence of nearly flat, intact upper and lower Whitney ash layers, which are marker beds within the Chadron Formation that were not displaced across the escarpment as shown on the geophysical logs making up the geologic cross-sections.[950]

The field evidence of differing groundwater flow directions in the Arikaree/Brule and BC/CPF is consistent with CBR's conceptual model showing southeast flow in the overlying

Arikaree/Brule aquifer through the MEA, but northerly flow in these aquifers north of the Pine Ridge escarpment, while flow in the BC/CPF is north-northwest from the Niobrara River through the MEA and the existing CBR ISR facility to north of Crawford. These observations clearly indicate a flow divide exists between the existing facility and the MEA in the shallow aquifers due to significant recharge to the shallow formations exposed along the Pine Ridge escarpment.[951]

As a consequence, we find that the CBR TR description of downgradient flow in the BC/CPF is adequate to meet the applicable NUREG-1569 criteria, and is sufficiently supported by the site characterization data acquired at the MEA to establish an acceptable site-wide HCM.

c. Board Findings on Perimeter Groundwater Monitoring Wells

A detailed discussion of the Board's findings addressing the perimeter groundwater monitoring wells has been presented above,[952] and is not repeated here except as the following summary of the findings that relate to the HCM: (1) before the start of operations in each MU, perimeter monitoring wells will be installed in the BC/CPF and in the Arikaree/Brule aquifer to detect potential lateral and vertical migration of production fluids;[953] (2) two additional monitoring wells will be placed further downgradient of the perimeter wells to measure water levels needed to track drawdown in the mineralized zone;[954] and (3) while the upgradient and downgradient monitoring wells will only be installed as the ISR extraction process extends into a new MU, no OST evidence was proffered on the need to install the wells as part of the licensing process or

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[951] See CBR Rebuttal Test. at 14 (Lewis, Nelson, Pavlick) (citing Conceptual Flow Model Diagram; EA at 3-29 (fig. 3-8)).

[952] See supra section VI.B.1.c.ii.

[953] See CBR Rebuttal Test. at 14–15 (Lewis, Nelson, Pavlick).

[954] See EA at 4-22; CBR License Amend. 3, at 2 (cross-reference table for Amendment 3), 17 (License Condition 11.1.5).

how the use of the monitoring wells is diminished by waiting to install them until the pre-operational period.

The Board finds that delaying the installation of monitoring wells until just prior to the start of each MU will have no real effect on their ability to (a) detect changes in the potentiometric surface downgradient of the MUs; (b) indicate unwanted changes in aquifer discharge; or (c) quantify potential contamination of downgradient groundwater. With the installation and sampling of the perimeter monitoring wells dictated by several license conditions imposed by the Staff, the Board finds that these perimeter monitoring wells will be sufficient to identify potential vertical and lateral migration of production fluids, and to assess inward hydraulic gradients during the operation and restoration of the facility. As a result, we find that CBR's description of perimeter groundwater monitoring wells in the BC/CPF in its TR is adequate to meet the applicable NUREG-1569 criteria so as to establish an acceptable site-wide HCM.

d. Board Findings on Surface Water Hydrology

A detailed discussion of the Board's findings addressing CBR's description of surface water hydrology has been presented previously,[955] and is not repeated here except as the following summary of the findings that relate to the HCM: (1) while OST claimed there was no data or information on surface water hydrology at MEA in the Marsland license application,[956] the CBR TR, and the Staff EA and SER provide extensive information relating to surface water hydrology at the MEA, with the narrative provided by the Applicant and the Staff characterizing surface-water bodies and drainages within the MEA licensed area and affected surroundings, and providing maps identifying the location, size, shape, hydrologic characteristics, and uses of

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[955] See supra section VI.B.1.d.ii.

[956] See Wireman Initial Test. at 3.

surface-water bodies near the MEA area,[957] which resulted in the conclusion that the only significant water body near the MEA is the Niobrara River;[958] (2) CBR thoroughly reviewed surface water studies on the Niobrara River performed by NDNR and NDEQ and summarized the hydrology of this river, as well as CBR's baseline sampling and proposed monitoring program during MEA ISR activities;[959] (3) in contrast to OST's allegations, the two major ephemeral drainages that traverse the MEA license area north to south were discussed, seven sampling points in the channel bottom were selected on these drainages to measure radiological concentrations in the sediment, and sediments from these collection points were sampled twice for baseline values;[960] (4) water was not present in the ephemeral drainages, thus preventing water sample collection, but if water flow becomes available prior to MEA startup, baseline water samples will be collected;[961] (5) a detailed discussion of Niobrara River and existing monitoring programs on this surface water body was provided in CBR's TR;[962] (6) two water quality sampling locations were located on the Niobrara River to detect potential impacts from either of the two major ephemeral drainages as they drain the MEA and connect to the Niobrara River between the two drainage points;[963] (7) quarterly water quality samples of the Niobrara River will be taken at the two designated locations, as will samples from the main

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[957] See Tech. Rep. at 2-77 to -78, 2-119 to -123, 2-128, 5-57 to -58; EA at 3-18 to -23; SER at 59–60.

[958] See Tech. Rep. at 2-77.

[959] See id. at 2-120 to -122.

[960] See id. at 2-128.

[961] See id.; Tr. at 645–47 (Pavlick, Back, Lancaster); see also CBR License Amend. 3, at 20 (License Condition 11.2.3).

[962] See Tech. Rep. at 2-77 to -78, at 2-119 to -123.

[963] See id. at 2-122 to -123 (citing Tech. Rep. Figs. at 94 (fig. 2.7-4)).

drainage channel at the seven designated locations of the ephemeral drainages whenever sufficient flow is available for sampling.[964]

As a result of these and other findings on surface water hydrology, the Board concludes that CBR's description of surface water hydrology in its TR is adequate to meet the applicable NUREG-1569 criteria so as to establish an acceptable site-wide HCM.

e. Board Findings on Baseline Restoration Wells

Detailed discussion of the Board's findings dealing with the baseline restoration wells have been presented previously,[965] and so are not repeated here except as the following summary of the findings that relate to the HCM: (1) as OST asserted, wells for baseline monitoring have not been selected and no data is provided by CBR or the Staff regarding background concentrations for applicable constituents;[966] (2) the baseline monitoring wells will be installed before initiating operations of a new MU,[967] and there has been no convincing evidence or testimony presented justifying why these wells should be installed at an earlier date; (3) before each new MU begins operation, a wellfield package will be provided for Staff review that must illustrate all well completions and show the locations of the perimeter monitoring wells so that contaminant migration is detected before being transported into any new MU area;[968] (4) alleviating the concern that the active MU may impact the groundwater quality of the downgradient area proposed for the next MU, perimeter monitoring wells surrounding the active MUs will detect any changes in groundwater quality, and provide the warning to implement corrective measures prior to any impact on baseline water quality for the downgradient

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[964] See id. at 5-57 to -58.

[965] See supra section VI.B.1.e.ii.

[966] See Wireman Initial Test. at 3.

[967] See Tr. at 656–58 (Nelson, Striz), 660 (Striz).

[968] See Tr. at 656–58 (Nelson, Striz), 660 (Striz).

proposed MU;[969] (5) CBR's wellfield package includes water quality for all constituents with a statistical analysis to uncover any outliers that would help indicate impacted baseline water quality;[970] (6) if outliers are detected, NRC has the ability to adjust the documented values to better reflect baseline levels that will be used after the MU is depleted to assess the effectiveness of restoring the aquifer;[971] (7) movement of production fluids between the MUs is not plausible due to the required inward hydraulic gradients that prevent such migrations of fluids and the perimeter monitoring that provides early detection and correction for potential wayward constituents;[972] and (8) it is not likely that chemical transportation of ISR mobilized constituents could overcome the strong inward groundwater hydraulic gradients.[973]

As a result, we find that CBR's description of baseline restoration wells in the BC/CPF in its TR is adequate to meet the applicable NUREG-1569 criteria so as to establish an acceptable site-wide HCM.

C. Summary of Board Findings on HCM

As we have noted in addressing above the items of concern raised by OST regarding the Applicant's HCM, CBR in its TR[974] and the Staff in its EA[975] have described in detail the surface water and groundwater HCM for the MEA. For surface water, these include descriptions of watersheds and drainages; seasonal surface water quality; and the detailed

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[969] See Tr. at 656–58 (Nelson, Striz), 660 (Striz).

[970] See Tr. at 665–66 (Striz).

[971] See Tr. at 660, 665–66 (Striz).

[972] See Tr. at 666–67 (Striz).

[973] See Tr. at 666–67 (Striz).

[974] See Tech. Rep. at 2-77 to -91, 2-115 to -123, 2-127 to -128.

[975] See EA at 3-5 to -18, 3-18 to -36.

hydrology of surface water features of the two ephemeral streams transecting the MEA licensed area, the Niobrara River about a half mile south of the most southern MEA MU, and the local Box Butte Reservoir located approximately three miles to the east of the southeast corner of the MEA license boundary.[976] Groundwater hydrogeology includes the identification of aquifers; descriptions of the upper and lower confining units; hydrologic conditions in the production zone of the BC/CPF and overlying Arikaree/Brule aquifer; groundwater occurrence and flow direction; aquifer and aquitard properties; a regional aquifer pumping test that was used to determine hydraulic properties of the production zone aquifer; and a summary of the lines of evidence demonstrating adequate confinement of the BC/CPF Sandstone aquifer.[977] These descriptions are augmented with discussions of water-level measurements and groundwater geochemistry of the production zone and overlying aquifers,[978] the hydrologic conceptual model for the MEA,[979] and baseline sediment sampling.[980]

The Board finds that CBR submitted a wealth of hydrologic data and analyses supporting its HCM,[981] while the Intervenor's witnesses merely made repeated calls for more investigations and analyses based on allegations that had little or no support justifying these additional efforts. OST not having provided any specific, supported rationale as to how the existing CBR program for licensing the MEA fails to meet NUREG-1569 acceptance criteria and why the additional work sought will achieve such a goal, the Board rejects OST's demands.

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[976] See Tech. Rep. at 2-77 to -78, 2-119 to -123, 2-128, 5-55 to -58.

[977] See id. at 2-78 to -84.

[978] See id. at 2-115 to -119.

[979] See id. at 2-84 to -87; see also Staff Initial Test. at 23–24 (Back, Lancaster).

[980] See Tech. Rep. at 2-127 to -128.

[981] See Staff Initial Test. at 23–24 (Back, Lancaster) (outlining sections of Staff review documents that describe HCM).

Crow Butte asserts relative to its HCM that it has provided information meeting all of the NUREG-1569 section 2.7 acceptance criteria, as confirmed by the Staff's review. The Board finds that no evidence has been proffered by the Intervenor demonstrating that CBR has not met these criteria. At the same time, based on our review of the evidentiary record, the Board has no difficulty determining that the CBR TR contains sufficient data and information to create an adequate site-wide conceptual model of site hydrology that meets the requirements of NUREG-1569 or that the Staff was justified in using that HCM as the basis for resolving both the safety and environmental aspects of the CBR license amendment application.

The Board thus finds relative to OST Concern 3 that in its TR and supporting documents CBR has developed an HCM for the MEA that demonstrates, with scientific confidence, that MEA hydrology and hydrogeology, including horizontal and vertical hydraulic conductivity, assures containment of extraction fluids and anticipated operational and restoration performance, and that the Staff appropriately used this model in deriving its EA and SER for the MEA site.

IX. CONCERN 4 – UNSUBSTANTIATED ASSUMPTIONS REGARDING BC/CPF AQUIFER ISOLATION

Concern 4, dealing with the unsubstantiated assumptions regarding BC/CPF aquifer isolation, relates to specific analysis assumptions as well as more general assumptions associated with the analytical bases that the Applicant and the Staff used to assess the containment and interconnectivity properties of the BC/CPF aquifer — bases that are necessary to both assure the safe operation and restoration of the MEA facility and assess the environmental impacts of ISR activity in the MEA.

A. Parties' Positions on Unsubstantiated Assumptions Regarding BC/CPF Aquifer Isolation

Regarding this concern, OST witnesses Wireman and Dr. Kreamer claimed that CBR used several analysis assumptions in evaluating the May 2011 aquifer pumping test of the BC/CPF aquifer that were not consistent with the data and other evidence gathered relative to this formation. Consequently, in their view, the main foundations of CBR's analytical calculations are not representative of the hydrogeologic conditions at the MEA. In addition to their concern about these analytical assumptions, they also claimed that CBR and the Staff misinterpreted observations, resulting in the erroneous conclusion that the aquifers underlying the MEA are isolated and will remain so during facility operation and restoration.[982]

1. Parties' Positions on Analysis Assumptions

According to Mr. Wireman and Dr. Kreamer, CBR made faulty assumptions in its analysis of pumping test data relating to homogeneity, isotropy, transmissivity, storativity, infinite lateral extent, and thickness.[983] Mr. Wireman claimed that the CBR and Staff mischaracterizations of the BC/CPF aquifer hinged on the assumption that groundwater flow could be characterized as Darcian porous media flow with no significant structural disturbance (e.g., fractures/faults) causing preferential flow paths.[984] Mr. Wireman also alleged that the aquifer pumping test analysis assumed no spatial variability in the aforementioned parameters in deriving the hydraulic properties of the BC/CPF aquifer from the pumping test data. Further, he maintained that these assumptions led to a mischaracterization of the hydrogeology of the area by failing to recognize the increased heterogeneity from structural deformation. Mr. Wireman thus asserted that CBR failed to consider properly the impact of variable heterogeneity, anisotropy, thickness, and lateral extent on groundwater flow and well yields, and to identify significant preferential flow paths within the BC/CPF aquifer and overlying strata.[985]

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[982] See Kreamer Initial Test. at 6–7; Wireman Initial Test. at 4; Kreamer Rebuttal Test. at 1–2, 3, 4; Wireman Rebuttal Test. at 3.

[983] See Kreamer Initial Test. 6–7; Wireman Initial Test. at 4.

[984] See Wireman Rebuttal Test. at 3 (citing CBR Initial Test. at 7, 14, 35–41; Staff Initial Test. at 42–44).

[985] See Wireman Initial Test. at 4; Wireman Rebuttal Test. at 3.

The allegedly incorrect and invalid assumptions highlighted by Dr. Kreamer include fundamental assumptions inherent in the Theis and Cooper-Jacob analytical solutions for analyzing aquifer pumping test results, starting with the assumption that the aquifer is confined and of apparent infinite extent, followed by the assumptions of homogeneity, isotropy, infinite lateral extent, and uniform effective thickness.[986] As Concern 4 involves primarily a coalescing of selected testimony from Concerns 1 and 2, the parties' positions regarding the identified unsubstantiated assumptions leading to the CBR/Staff conclusion about BC/CPF aquifer containment were already discussed in detail in previous sections of this decision. Narrated references to these sections are presented below, organized by each individual assumption.

a. Sole Use of the Theis and Cooper-Jacob Methodologies

The parties' positions regarding CBR's singular use of the Theis and the Cooper-Jacob methodologies to interpret the May 2011 aquifer pumping test were discussed previously,[987] and will not be repeated here. But summarizing the discussion relating to the assumptions associated with those analyses in the context of Concern 4, Dr. Kreamer criticized CBR for using the Theis method for analyzing the aquifer pumping test data as well as claimed that CBR referred to using the Cooper-Jacob technique, but then failed to present the results of this supplemental analysis.[988] In response, Staff witnesses Back, Lancaster, and Dr. Striz confirmed that CBR's pumping test report clearly states that the Applicant used both the Theis drawdown and recovery method and the Cooper-Jacob distance-drawdown method to analyze the aquifer

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[986] See Kreamer Initial Test. at 6.

[987] See supra section V.A.1.a.

[988] See Kreamer Initial Test. at 6.

pumping test data, and presented the graphical results from both analyses for the entire duration of the aquifer pumping test in the MEA aquifer pumping test report.[989]

Dr. Kreamer also testified that CBR did not address the omission of, nor did the Staff require, other pumping test analysis methodologies that consider aquifer leakage (e.g., De Glee, Hantush-Jacob, Walton).[990] And in support of his criticism of CBR's use of only one type of analysis solution, Dr. Kreamer declared that both the Theis and Cooper-Jacob mathematical forms of analysis are considered the simplest forms of aquifer pumping test analyses and require the same fundamental assumptions (e.g., aquifer homogeneity, isotropy, uniform thickness, lateral extent) to be considered appropriate at the aquifer for accurate results.[991]

CBR witnesses Lewis, Nelson, and Pavlick responded in rebuttal testimony that "Crow Butte used appropriate analytical techniques for such aquifers, but nevertheless was prepared to use more complex analytical techniques had it been necessary. It was not."[992] These witnesses indicated that the need to perform hypothetical aquifer leakage analyses had no conceptual support because of the great thickness and low permeability of the UCU and the depth of the BC/CPF sandstone, which precludes the OST-asserted need for additional aquifer test analyses.[993]

Staff witnesses provided support for the Applicant's position, noting that the May 2011 pumping test was conducted according to a plan approved by the NDEQ and employed

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[989] See Staff Rebuttal Test. at 21 (citing Test #8 Rep. at 11, figs. app. at PDF 50 (fig. 18)).

[990] See Kreamer Rebuttal Test. at 2–3.

[991] See Kreamer Initial Test. at 6.

[992] CBR Rebuttal Test. at 10.

[993] See id. at 10–11 (citing Test #8 Rep. at 12–13).

accepted industry testing and analysis procedures.[994] Staff witnesses also explained that the Theis and Cooper-Jacob methods are widely used and accepted techniques that have been adopted into ASTM standards and that there was no evidence in the aquifer pumping test data to suggest that the assumptions underlying those methodologies were inappropriate for the BC/CPF aquifer at the MEA.[995] They noted as well that these methods have been successfully applied to heterogeneous, anisotropic aquifers.[996] Furthermore, Dr. Kreamer acknowledged that the more complex analysis methods he suggested (i.e., De Glee, Hantush-Jacob, Walton methods) have the same assumptions of aquifer homogeneity, isotropy, uniform thickness, and lateral extent as the Theis and Cooper-Jacob methods.[997]

b. Lack of Preferential Flow Paths Associated with Fracturing/Faulting

The parties' positions regarding the lack of preferential flow paths associated with fracturing/faulting were discussed previously in detail,[998] and are not repeated here. But with regard to Concern 4, in summary Mr. Wireman claimed that there may be significant preferential flow paths within the BC/CPF aquifer and overlying strata that are the result of structural and lithologic conditions.[999]

CBR witness Lewis testified that none of the specific geophysical log signatures that would indicate significant structural displacements were found in the 1600 logs made at the site,

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[994] See Staff Initial Test. at 26 (Back, Lancaster) (citing ER at 3-45; Tech. Rep. at 2-82).

[995] See Staff Rebuttal Test. at 25–26 (Back, Lancaster, Striz) (citing ASTM Theis Analysis Standards).

[996] See id. at 25 (Back, Lancaster, Striz).

[997] See Tr. at 507–08.

[998] See supra sections V.B.1 and VI.B.2.

[999] See Wireman Rebuttal Test. at 3.

which confirmed that these extensive field investigations did not encounter any sign of significant faulting across the MEA.[1000] Furthermore, it is CBR's position that, based on extensive field data, there is no evidence of any significant faulting within the MEA that will affect confinement or transmit production fluids.[1001]

OST witness Dr. LaGarry stated that his work over the past 25 years had shown that there are several, likely hundreds, more fractures.[1002] While CBR witnesses Lewis, Nelson, Pavlick, and Shriver admitted that faults and other fractures may exist at a regional level, it is Crow Butte's position that if any minor fractures were to appear, they would close up quickly as a result of overburden stress from the weight of overlying strata.[1003] And they further declared that CBR knows of no evidence of any fracturing within the MEA that will have any effect on the proposed activity, asserting that any undetected fractures will have no hydrologic impact based on the wealth of other evidence confirming containment of the BC/CPF.[1004]

But even if the faults do exist beneath the MEA, their presence would not lead to significant adverse environmental impacts, according to the Staff's EA, because (1) ambient groundwater flow in the BC/CPF sandstone aquifer is to the northwest and away from the reported Niobrara River fault; (2) once uranium recovery begins, groundwater flow would be inward toward the MUs (as required by License Condition 10.1.6)[1005] and away from both the Pine Ridge and Niobrara River faults; (3) based on groundwater velocity estimates provided in

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[1000] See Tr. at 805–06; see also Tech. Rep. at 3-7.

[1001] See CBR Rebuttal at 23.

[1002] See LaGarry Initial Test. at PDF 5.

[1003] See CBR Rebuttal Test. at 23 (Lewis, Nelson, Pavlick, Shriver).

[1004] See id.; see also supra section V.C.2 (discussing other containment-confirming evidence).

[1005] See CBR License Amend. 3, at 11 (License Condition 10.1.6).

the EA, it would take at least 500 years for groundwater to migrate from the MEA to the reported Pine Ridge fault, during which time any constituents of the production fluids would attenuate through sorption and dilution; (4) the ambient hydraulic gradients are strongly downward from the overlying aquifers of the Arikaree/Brule into the BC/CPF aquifer such that production fluids would not be able to migrate upward through any preferential pathways; (5) the downward gradient would become even more pronounced during restoration operations; and (6) CBR will conduct additional aquifer pumping tests in each MU to identify hydraulic boundaries, including those caused by faulting.[1006]

c. Aquifer Confinement and Apparent Infinite Extent

Regarding aquifer confinement, Staff witnesses Back and Lancaster testified that by definition, the BC/CPF sandstone aquifer is a confined aquifer because the potentiometric surface of the BC/CPF rises above the top elevation of the aquifer.[1007] These Staff witnesses, along with Dr. Striz, also noted that the majority of the data collected during the aquifer pumping test fall on the classic Theis type-curve, further indicating that the BC/CPF aquifer is confined.[1008] Ultimately, no party disputed that the BC/CPF is not a confined aquifer under the potentiometric surface definition.[1009]

The parties' positions about the assumption of apparent infinite extent was discussed previously in detail,[1010] and are not repeated here. But summarizing the discussion concerning the infinite extent assumption in the context of Concern 4, Staff witnesses Back, Lancaster, and

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[1006] See EA at 3-14 (citing ER at 3-47; SER at 139).

[1007] See Staff Initial Test. at 30.

[1008] See Staff Rebuttal Test. at 27 (citing Test #8 Rep. app. C at PDF 80–95 (graphs C1 to C16)).

[1009] See Staff Initial Test. at 30; Test #8 Rep. at 11; Tr. at 50–51 (Kreamer).

[1010] See supra section VII.F.1.

Dr. Striz posited that the site-specific and regional cross-sections, based on boreholes and geophysical logging, demonstrate that the BC/CPF sandstone aquifer is present over the entire MEA site and beyond.[1011] This conclusion is also supported by the lack of boundary conditions observed during the aquifer pumping test, especially in the most distant observation wells.[1012]

d. Homogeneity and Isotropy

The parties' positions concerning the assumption of BC/CPF homogeneity and isotropy was discussed previously in detail as well,[1013] and are not repeated here. But summarizing the discussion relating to the homogeneity and isotropy assumptions in the context of Concern 4, Dr. Kreamer argued that the BC/CPF is heterogeneous and anisotropic over the area influenced by pumping.[1014] CBR witnesses Lewis, Nelson, and Pavlick pointed out that while actual hydrogeological conditions always vary from ideal conditions in natural systems so that, realistically, the BC/CPF within the MEA is not homogeneous and isotropic on a local scale, the assumptions of homogeneity and isotropy nonetheless are reasonably satisfied over the scale of the BC/CPF pumping test.[1015]

As a result, these CBR witnesses asserted, and Staff witnesses Back, Lancaster, and Dr. Striz agreed, that the BC/CPF Formation underlying the MEA can be treated as homogeneous and isotropic for analytical purposes.[1016] Furthermore, these Staff witnesses indicated that homogeneity and isotropy exist on the scale of the ROI of the pumping test as a

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[1011] See Staff Rebuttal Test. at 28 (citing Tech. Rep. Figs. at 49–62 (figs. 2.6-3a to -3n), 87-90 (figs. 2.6-21 to -24)).

[1012] See Test #8 Rep. at 13.

[1013] See supra section VII.D.1.

[1014] See Kreamer Initial Test. at 6.

[1015] See CBR Rebuttal Test. at 11–12 (citing Test #8 Rep. at 11).

[1016] See id.; Staff Rebuttal Test. at 27.

result of fairly uniform hydraulic conductivity, indicating a lack of significant stratification of the BC/CPF aquifer underlying the MEA. It was their position as well that the homogeneity/isotropy premise is supported by the subsurface characterization (e.g., core inspection, geophysical logging) demonstrating that there are no major impermeable or permeable features that would indicate significant heterogeneity or anisotropy to the extent that it would impact CBR's analysis of the aquifer test analysis results.[1017]

At the hearing, Dr. Kreamer again advanced the need to further characterize the homogeneity of the BC/CPF with additional pumping tests to address the containment properties of this strata,[1018] having claimed that the allegedly wide range of transmissivities (i.e., 230 $ft.^2$/day to 1780 $ft.^2$/day) and storage coefficients ($1.7x10^{-3}$ to $8.32x10^{-5}$) are not consistent with homogeneous conditions.[1019] Mr. Wireman was in agreement, concluding that aquifer testing, monitoring, and flow modeling of these aquifers must consider the heterogeneity, noting that the aquifer test data indicate that hydraulic conductivity and transmissivity of the BC/CPF near the pumping well was an order of magnitude lower than at the outlying monitoring wells.[1020]

Relative to these concerns, Staff witness Dr. Striz testified that well Monitor-3, which was only 100 ft. from the pumping well, was impacted by well effects, and she also indicated that when she corrected for this effect by re-analyzing the information to match with the later time data, the resulting transmissivity (700 $ft.^2$/d) and storage coefficient ($1x10^{-5}$) values were more in line with the other wells and indicative of a confined aquifer.[1021] Nonetheless, Dr. Kreamer

[1017] See Staff Rebuttal Test. at 27 (citing Test #8 Rep. at 5, figs. app. at PDF 48 (fig. 16)).

[1018] See Tr. at 344–45.

[1019] See Kreamer Initial Test. at 6.

[1020] See Wireman Initial Test. at 4.

[1021] See Tr. 502–05, 530.

continued to claim the existence of a preferential pathway indicating leakage in the containment of the production zone, backed by references to the drawdown data for the pumping well (i.e., CWP-1A) and the observation wells that are close to the pumping well (i.e., CPW-1 and Monitor-3). Because these, in his estimation, showed a late-time flattening of the drawdown curve that made them unsuitable for Theis type-curve fitting, Dr. Kreamer maintained that this isolated flattening of the curve may be indicative of leakage in the containment of the production zone.[1022]

Staff witnesses Back, Lancaster, and Dr. Striz disagreed with this analytical approach, testifying that the lack of significant heterogeneity is also reflected on the potentiometric surface of the BC/CPF aquifer, which is smooth and has an essentially flat and relatively constant hydraulic gradient. In addition, they asserted, the aquifer drawdown from the May 2011 aquifer pumping test indicates that there is no evidence of significant directional conductivity from lateral anisotropy. According to these Staff witnesses, the smooth appearance of these mapping contours indicates that there are no significant changes in transmissivity that impact the groundwater flow in the BC/CPF sandstone aquifer.[1023]

Also, these same Staff witnesses referenced the Driscoll text, stating that the assumption of homogeneity does not limit the use of the Theis equations because average hydraulic conductivity values, as determined from pumping tests, have proven to be reliable for predicting well performance even though uniform hydraulic conductivity is rarely found in a real aquifer. They also noted that Driscoll concluded that in confined aquifers where the well is fully

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[1022] See Tr. at 937–42; see also Kreamer Initial Test. at 6; Kreamer Rebuttal Test. at 1–2.

[1023] See Staff Rebuttal Test. at 27 (citing Test. #8 Rep. figs. app. at PDF 48 (fig. 16); Tech. Rep. Figs. at 113–16 (figs. 2.9-6a to -6d)).

penetrating and open to the formation, which they asserted is the case with the BC/CPF, the assumption of no stratification is not an important limitation.[1024]

Dr. Kreamer, who acknowledged familiarity with Driscoll, maintained that Driscoll referenced the use of fully penetrating screened monitoring wells for monitoring pumping,[1025] and asserted that assuming homogeneity and isotropy “wrongly implies the local geology is simple.”[1026] Staff witnesses Back, Lancaster, and Dr. Striz, on the other hand, indicated that, based on CBR’s subsurface investigation, there is ample evidence that the local stratigraphy around the MEA is relatively uniform and uncomplicated. In particular, they indicated that the site-specific and regional cross-sections provided by CBR show that the stratigraphic units, and particularly the BC/CPF sandstone, are essentially flat.[1027]

e. Uniform Effective Aquifer Thickness

The parties’ positions about the assumption of uniform effective aquifer thickness were discussed previously in detail,[1028] and are not repeated here. But summarizing the discussion in the context of Concern 4, Dr. Kreamer claimed that the BC/CPF aquifer is not of uniform effective thickness over the area influenced by the May 2011 pumping aquifer test and thus this formation is not homogeneous.[1029]

[1024] See Tr. at 465 (Back); Staff Rebuttal at 26 (Back, Lancanster, Striz) (citing Driscoll Text at 214).

[1025] See Tr. at 462, 463–64.

[1026] Kreamer Initial Test. at 5.

[1027] See Staff Rebuttal Test. at 29 (citing Tech. Rep. Figs. at 49–62 (figs. 2.6-3a to -3n), 87–90 (figs. 2.6-21 to -24)).

[1028] See supra sections VII.A.7.a and VII.F.1.

[1029] See Kreamer Initial Test. at 6 (citing EA at 3-28; Test #8 Rep. at 11), 7.

But CBR witnesses Lewis, Nelson, and Pavlick stated that the local variations in aquifer thickness are conceptually consistent with observed drawdown responses in the highly confined aquifer.[1030] Supporting CBR, Staff witnesses posited that there is ample evidence that the local stratigraphy around the MEA is relatively uniform and uncomplicated, pointing out that the site-specific and regional cross-sections provided by CBR show that the stratigraphic units, and particularly the BC/CPF sandstone, are relatively uniform in thickness over the site.[1031]

With respect to the Staff's assessment of the BC/CPF sandstone thickness, Dr. Kreamer asserted that the EA contains "conjecture" about the reason for a "lack of continual thickness."[1032] As a counterpoint to this statement, Staff witnesses Back, Lancaster, and Dr. Striz noted that, based on site-specific cross-sections and geophysical log data, the BC/CPF aquifer transitions to less permeable silts and clays (zero sandstone thickness) approximately nine miles to the east and 12 miles to the west of the MEA,[1033] while the EA indicates the aquifer has a thickness ranging from approximately 20 ft. to 90 ft. (and averaging about 55 ft.) with the thickest sections occurring in the western portions of the MEA.[1034] These Staff witnesses maintained that this level of variation is expected in sedimentary systems and, per the Driscoll

[1030] See CBR Rebuttal Test. at 10–11 (citing Test #8 Rep. at 12–13).

[1031] See Staff Rebuttal Test. at 29 (Back, Lancaster, Striz) (citing Tech. Rep. Figs. at 49–62 (figs. 2.6-3a to -3n), 87–90 (figs. 2.6-21 to -24)).

[1032] Kreamer Initial Test. at 6 (citing EA at 3-28). According to the Staff, Dr. Kreamer's statement reflects a misunderstanding of what was written in the EA. Further, the Staff asserted, the only reference to aquifer thickness at the EA page Dr. Kreamer cites states that the BC/CPF sandstone was deposited in a fluvial stream environment within a regional channel, which represents two separate concepts and, more importantly, says nothing about the variation in thickness of the BC/CPF sandstone at (or near) the MEA, whereas the EA at page 3-10 describes the thickness of the BC/CPF sandstone. See Staff Rebuttal Test. at 28 (Back, Lancaster, Striz). In this decision, we assume Dr. Kreamer was referring to the EA at page 3-10 relative to his concern about the thickness of the BC/CPF aquifer.

[1033] See Staff Rebuttal Test. at 28 (citing EA at 3-28).

[1034] See EA at 3-10.

text, is not a serious limitation given that the variation in aquifer thickness within the cone of depression in most situations is relatively small, especially in sedimentary rocks, so as not to preclude obtaining reliable results from the May 2011 aquifer pumping test for the MEA.[1035]

f. Range of Transmissivity and Storage Coefficient Values

The parties' position about the alleged wide range of values for transmissivity and storage coefficients as a demonstration of heterogeneity/anisotropy was discussed previously in detail.[1036] As stated therein, Dr. Kreamer claimed that transmissivities, ranging from 230 $ft.^2/d$ to 1780 $ft.^2/d$ with values of storage coefficients ranging from 1.7×10^{-3} to 8.3×10^{-5} are not consistent with homogeneous conditions.[1037]

According to CBR witnesses Lewis, Nelson, and Pavlick, the cited variability in aquifer transmissivity and storativity is not unusual, is relatively small, and is well within the expected range of variability of a sandstone aquifer. In their view, the observed variation in subsurface conditions at the MEA does not preclude analysis of the data using analytical models with ideal boundary conditions.[1038] And Staff witness Dr. Striz, looking more closely at the circumstances that generated the values of concern to Dr. Kreamer, testified that well Monitor-3, which was close to the pumping well CPW-1A, was impacted by well effects. When the pertinent information was re-analyzed to match with the later time data, she declared the resulting values of transmissivity (700 $ft.^2/d$) and storage coefficient (1×10^{-5}) changed the range for the storage coefficient from 1.7×10^{-3} to 8.3×10^{-5} to 1×10^{-5} to 8.3×10^{-5}, which is more in line with the other wells and indicative of a confined aquifer.[1039]

[1035] See Staff Rebuttal Test. at 27–28 (citing Driscoll Text at 214).

[1036] See supra section VII.D.1.

[1037] See Kreamer Initial Test. at 6.

[1038] See CBR Rebuttal Test. at 11–12.

[1039] See Tr. at 502–05, 530.

g. Anisotropy

The parties' positions as to the alleged anisotropy of the BC/CPF was discussed previously in detail,[1040] and again are not repeated here. But summarizing the discussion regarding anisotropy in the context of Concern 4, Dr. Kreamer claimed that neither CBR nor the Staff performed an analysis for anisotropy and that the nature of directional hydraulic conductivity differences remains undefined and not quantified, particularly in the vertical direction.[1041] In lieu of any anisotropy model analysis, he maintained that the CBR and Staff claims that no anisotropy exists within the May 2011 aquifer pumping test's ROI are inadequate, because they are based on a hand-drawn visual rendering using very few data points rather than a standard data-based evaluation.[1042]

CBR witnesses Lewis, Nelson, and Pavlick clarified that drawdown data from all monitoring wells were used to create the cone of depression at the end of the May 2011 pumping test,[1043] while CBR witness Lewis explained that the drawdown contour lines are non-biased as they were created with a commercially available computer contouring program SURFER.[1044] According to these CBR witnesses, a more detailed analysis of horizontal anisotropy was not necessary given the lack of a conceptual basis in the geometry of the drawdown cone.[1045]

[1040] See supra section VII.E.1.

[1041] See Kreamer Initial Test. at 7.

[1042] See id. (citing Test #8 Rep. at 14, figs. app. at PDF 48 (fig. 16); EA at 3-30, A-22).

[1043] See CBR Rebuttal Test. at 12.

[1044] See Tr. at 537–39.

[1045] See CBR Initial Test. at 12.

Additionally, Staff witnesses Back, Lancaster, and Dr. Striz indicated that if there was significant anisotropy within the production zone, the aquifer test would show elliptical drawdown curves, a shape not apparent in the plot from the MEA aquifer pumping test results.[1046] And for his part, Dr. Kreamer agreed that if the data is accepted as sound, the graph does illustrate consistent isotropy in the horizontal plane.[1047] Moreover, Staff witnesses Back, Lancaster, and Dr. Striz also claimed that if there is any vertical anisotropy in the production zone aquifer, it would be beneficial for ISR operations by creating a preferred horizontal flow within the sandstone aquifer.[1048]

Finally, these Staff witnesses claimed that Dr. Kreamer provided no support for his assertion that further analysis is necessary because anisotropy (and heterogeneity for that matter) are unrelated to the vertical containment of a production zone aquifer and are only important in meeting one of the objectives of the MEA aquifer pumping test, i.e., to show interconnectivity as it may affect the ability of the operator to balance the wellfields and maintain an inward gradient.[1049]

2. Parties' Positions on Challenges to Evidence of Hydrogeologic Containment of BC/CPF

The parties' positions regarding OST's challenges to the evidence proffered by CBR and the Staff dealing with the alleged hydrogeologic containment of the BC/CPF were discussed previously in detail,[1050] and will not be not repeated here. But to summarize the discussion concerning BC/CPF hydrogeologic containment in the context of Concern 4, both CBR and the

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[1046] See Staff Rebuttal Test. at 29.

[1047] See Tr. at 539–40.

[1048] See Staff Rebuttal Test. at 29.

[1049] See id.

[1050] See supra sections V.C.1 and V.C.2.

Staff referred to what they considered extensive evidentiary support demonstrating the containment properties of the BC/CPF aquifer that, in their view, make this formation fit for safe and environmentally-sound ISR uranium extraction. Their evidence relating to containment was summarized by the Staff and presented as eight independent observations that demonstrated isolation of the overlying Arikaree/Brule aquifer from the production zone within the BC/CPF aquifer.[1051]

The Staff-referenced evidence included the following items: (1) the presence of a thick (360 ft. to 450 ft.), laterally continuous UCU consisting of low permeability mudstone and claystone and an uncontested, thick (more than 750 ft.), regionally extensive LCU of Pierre Shale; (2) the results of the May 2011 aquifer pumping test demonstrating no discernable drawdown in the overlying Brule Formation observation wells; (3) the large differences in observed hydraulic head (330 ft. to 500 ft.) between the Arikaree/Brule aquifer and the BC/CPF aquifer that could only occur with a large hydraulic resistance to vertical flow due to the significant thickness of the UCU within the MEA; (4) the strong vertical downward gradients between the Arikaree/Brule aquifer and the BC/CPF aquifer; (5) the significant historical differences in geochemical groundwater characteristics between the BC/CPF and the Arikaree/Brule aquifer; (6) the large groundwater age differences between the BC/CPF, the Brule Formation, and the Arikaree aquifer (oldest to youngest) based on age dating of isotopes; (7) the detection of pressure effects at long distances over short time periods from pumping at a relatively low flow rate (27 gpm), which could only occur from confinement of the aquifer; and (8) the calculated storativity values (ranging from 1.7×10^{-3} to 8.3×10^{-5}) indicative of a confined aquifer, the values for which range between 5×10^{-3} and 5×10^{-5}.[1052]

[1051] See supra section V.C.2; see also Staff Initial Test. at 28–31 (Back, Lancaster) (outlining six items); Staff Rebuttal Test. at 15 (Back, Lancaster, Striz) (indicating two items).

[1052] See Staff Initial Test. at 28–31 (Back, Lancaster); Staff Rebuttal Test. at 15 (Back, Lancaster, Striz).

In his rebuttal testimony, Dr. Kreamer challenged three of the Staff-identified items above, i.e., items one, two, and five, stating, respectively, that (a) the quantity and quality of the UCU may be breached by potential fracturing of the intervening strata; (b) the well array in the Arikaree/Brule aquifer was not sufficient to discern drawdown; and (c) geochemical transport is too complex to use as a demonstration of aquifer containment.[1053] Furthermore, when given the opportunity at the hearing to comment on aquifer containment at the MEA,[1054] Dr. Kreamer raised the issue of the flattening of the drawdown curve from the Theis type-curve for wells CPW-1/1A and Monitor-3, implying that these results are associated with late-time recharge zones indicating a lack of containment.[1055] In addition, during the hearing Dr. Kreamer presented his hypothesis countering the following Staff-identified items: (a) the strong downward gradients between the Arikaree/Brule aquifer and the BC/CPF (item 4); (b) the difference in the ages of the groundwater (item 6); (c) the large ROI for a well pumped at relatively low rate (item 7); and (d) the range of storativity values indicative of containment (item 8).[1056] Moreover, when asked whether, in addressing these items, he was identifying unusual situations that would all need to occur to establish a lack of containment, Dr. Kreamer cautioned that it would take only leakage from one preferential flow path to cause devastating results and again called for a robust fracture analysis.[1057]

[1053] See Kreamer Rebuttal Test. at 1–2 (Kreamer item 2 responding to Staff item 2), 3 (Kreamer items 7 and 8 responding to Staff item 5), 5 (Kreamer item 10 responding to Staff item 1).

[1054] See Tr. at 965–99.

[1055] See Tr. at 968–85 (Kreamer, Shriver); see also Kreamer Initial Test. at 6.

[1056] See Tr. at 993–96.

[1057] See Tr. at 996–98.

B. Board Findings on Unsubstantiated Assumptions of BC/CPF Aquifer Isolation

1. Board Findings on Analysis Assumptions

As Concern 4 is primarily a coalescing of selected testimony regarding Concerns 1 and 2, most of the Board findings regarding the purported unsubstantiated analysis assumptions improperly underpinning the conclusion of BC/CPF aquifer isolation were already discussed in detail in previous sections of this decision. Below, references to those sections are provided, along with a brief summary of the most relevant findings.

a. Analytical Solution Analogues to the Use of the Theis and Cooper-Jacob Methodologies

Board findings regarding CBR's purported misuse of the Theis and the Cooper-Jacob methodologies in interpreting the May 2011 aquifer pumping test were previously discussed in detail,[1058] but are summarized here as relevant to Concern 4. As an initial matter, we found that CBR graphically analyzed data using Theis drawdown and recovery methods and the Cooper-Jacob distance-drawdown method.[1059] The Board also noted that OST agreed that the use of the Theis method was a starting point for pumping test analyses, and would help to determine if more sophisticated analyses are needed.[1060] We found as well that CBR was prepared to use more complex analytical techniques if needed,[1061] but we agreed with CBR and the Staff that there was no need to do so based on record evidence demonstrating the apparent consistency of the resulting hydraulic parameters with established values that OST agrees can often vary by an order of magnitude or more.[1062] Nor did the Intervenor directly dispute CBR's

[1058] See supra section V.A.2.a.

[1059] See CBR Initial Test. at 29 (Lewis, Nelson, Pavlick).

[1060] See Tr. at 682 (Wireman).

[1061] See CBR Rebuttal Test. at 10 (Lewis, Nelson, Pavlick).

[1062] See supra note 216 and accompanying text.

derivation of the recovery data, which shows the same consistency in the hydraulic conductivity values generated as those that were derived from the drawdown data.[1063]

The Board further found that CBR conducted the pumping test according to its NDEQ-approved plan, using accepted industry testing and analysis procedures that are incorporated into ASTM standards.[1064] In contrast, OST did not provide any independent estimate for the rate of leakage based on a separate interpretation of the Marsland pumping test data using its suggested alternative, allegedly superior methods that consider a leaky aquifer (i.e., De Glee, Hantush-Jacob, and Walton methods) to support its demand that these techniques be implemented by Crow Butte,[1065] despite acknowledging that these more complex analysis methods may have the same assumptions of aquifer homogeneity, isotropy, uniform thickness, and lateral extent, and thus the same potential limitations, as the Theis and Cooper-Jacob methods.[1066]

Dr. Kreamer also maintained there is a lack of containment in the BC/CPF as demonstrated by the departure of data points from the expected Theis type-curve during the May 2011 pumping test.[1067] The Board found, however, that CBR and the Staff presented other hypotheses for these deviations that are consistent with the many other site characteristics and observations while Dr. Kreamer offered no corroborating evidence of co-existing factors supporting his position there is localized leakage of sufficient magnitude to negatively impact the

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[1063] See Test #8 Rep. tbls. app. at 10 of 10 (tbl. 8).

[1064] See Staff Initial Test. at 26 (Back, Lancaster) (citing ER at 3-45; Tech. Rep. at 2-82); see also ASTM Theis Analysis Standards.

[1065] See CBR Rebuttal Test. at 10–11 (Lewis, Nelson, Pavlick).

[1066] See Tr. at 507–09 (Kreamer).

[1067] See Kreamer Rebuttal Test. at 2.

containment properties and internal interconnections of the BC/CPF to control fluid migration within the aquifer.[1068]

b. Lack of Preferential Flow Paths Associated with Fracturing/Faulting

The Board's findings regarding the lack of preferential flow paths associated with fracturing/faulting were discussed previously in detail,[1069] and are summarized here as is relevant to Concern 4. We found it likely that there is some degree of structural fracturing of the geologic strata underlying the MEA, but that transmissivity, not the mere presence of fractures, is the critical issue. In this regard, we concluded that there is no evidence of extensive, transmissive, heterogeneous pathways that would provide a preferential flow for contaminants to uncontrollably migrate into the adjacent aquifers or into the neighboring Niobrara and White Rivers.[1070]

c. Aquifer Confinement and Apparent Infinite Extent

The Board found that there was no disagreement that the BC/CPF aquifer meets the definition of a confined aquifer, because its potentiometric surface rises above the top elevation of the aquifer.[1071] Moreover, the Board's related findings regarding the apparent infinite extent assumption were discussed previously.[1072] Therein we found that, with respect to the issue of lateral extent, as it is relevant to Concern 4, the BC/CPF aquifer is present over the entire MEA site and goes well beyond these limits based on the lack of definitive boundary conditions

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[1068] See supra section V.A.2.b.

[1069] See supra sections V.B.2 and VI.B.2.

[1070] See supra section V.B.3.

[1071] See Staff Initial Test. at 30 (Back, Lancaster); Text #8 Rep. at 11; Tr. at 450–51 (Kreamer).

[1072] See supra section VII.F.2.

observed during the aquifer pumping test, backed by site-specific regional cross-sections derived from borehole data and geophysical logging.[1073]

d. Homogeneity and Isotropy

The Board's findings relating to the homogeneity and isotropy assumptions were discussed previously in detail,[1074] and are not repeated here other than to note that, in Dr. Kreamer's estimation, the assumption that the BC/CPF is homogeneous and isotropic is inconsistent with data and evidence in the record, as is the asserted premise of uniform effective thickness over the area influenced by pumping. The Board agreed with CBR and the Staff that actual hydrogeological conditions always vary from ideal conditions in natural systems,[1075] but if the Theis and other aquifer analysis methods were only utilized when the assumptions are strictly adhered to, the methods would never be employed because no hydrogeologic system could meet them.[1076] The Board also concurred with the parties that all geologic strata exhibit heterogeneity and anisotropy at some scale,[1077] noting that application of the Theis and Cooper-Jacob techniques to these systems is routinely done in practice with an understanding of the assumptions inherent to their use.[1078] And we found further that, at the relevant scale for licensing, the Applicant assumed homogeneous, isotropic responses, and then looked to the actual test results to show whether there were significant deviations from the

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[1073] See Staff Rebuttal Test. at 28 (Back, Lancaster, Striz) (citing Test #8 Rep. at 13; Tech. Rep. Figs. at 49–62 (figs. 2.6-3a to -3n), 87–90 (figs. 2.6-21 to -24)).

[1074] See supra section VII.D.2.

[1075] See CBR Rebuttal Test. at 11–12 (Lewis, Nelson, Pavlick).

[1076] See Staff Rebuttal Test. at 25 (Back, Lancaster, Striz).

[1077] See CBR Rebuttal Test. at 11 (Lewis, Nelson, Pavlick); Staff Rebuttal Test. at 25 (Back, Lancaster, Striz); Tr. at 491–94 (Kreamer).

[1078] See CBR Rebuttal Test. at 11 (Lewis, Nelson, Pavlick); Staff Rebuttal Test. at 25 (Back, Lancaster, Striz).

assumed homogeneity and isotropy that, in turn, would establish the need for the use of more complex analysis methods. Moreover, we agreed with CBR's conclusion, based on the preponderance of the evidence in the record before us, that no such additional testing or analysis was necessary here.[1079]

Finally, the Board found that the evidence points to the fact that there are no known faults or significant fracturing underlying the MEA that might cause heterogeneity and anisotropy of the underlying geologic strata. As a result, there is no need for CBR to augment its TR or for the Staff to alter its EA to address heterogeneity/anisotropy impacts due to fracturing.

e. Uniform Effective Aquifer Thickness

The Board's findings concerning uniform aquifer thickness were discussed previously in detail,[1080] and are not repeated here except as they are relevant to Concern 4.

Dr. Kreamer testified that the upper boundary of the BC/CPF changes elevation repeatedly and fairly abruptly, causing impermissible changes in aquifer thickness.[1081] But we found that he proffered these points without providing references to specific locations on the geologic cross-sections where he believed the variation in BC/CPF thickness to exist, thus failing to point to examples of these allegedly numerous discontinuities other than by general reference to geologic cross-sections.

We also found that the record provided ample evidence that the local stratigraphy around the MEA is relatively uniform and uncomplicated and, specifically, that the site and regional cross-sections provided by CBR show that the BC/CPF is relatively uniform in

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[1079] See CBR Rebuttal Test. at 11 (Lewis, Nelson, Pavlick).

[1080] See supra sections VII.A.7.b and VII.F.2.

[1081] See Kreamer Initial Test. at 6 (citing Tech. Rep. Figs. at 67–69 (figs. 2.6-3s to -3u); Test #8 Rep. at PDF 35–40 (figs. 3–8)).

thickness over the site.[1082] Furthermore, the Staff's EA describes the thickness of the BC/CPF sandstone as ranging from 20 ft. to 90 ft. over the MEA based on site-specific cross-sectional data and geophysical logging,[1083] which the Staff asserted is a level of variation expected in sedimentary systems.[1084] We agreed with the Staff as well that, based on Driscoll,[1085] this range of thicknesses will not affect the analysis results significantly, thus yielding reasonably reliable hydraulic parameters from the use of the Theis and Cooper-Jacob methodologies for the solution of the aquifer pumping test data.[1086] And while the visual representations of the geologic cross-sections may, in some locations, appear to illustrate an apparent abrupt change in the upper surface of the BC/CPF, the Board found that this is likely an artifact of the exaggerated scales of these graphs.[1087]

f. Range of Transmissivity and Storage Coefficient Values

The Board's findings regarding the allegedly wide range of values for transmissivity and storage coefficients were discussed previously in detail.[1088] While Dr. Kreamer claimed that the allegedly wide range of transmissivities (i.e., 230 $ft.^2/d$ to 1780 $ft.^2/d$) and storage coefficients ($1.7x10^{-3}$ to $8.32x10^{-5}$) are not consistent with homogeneous conditions,[1089] we disagreed based on the apparent consistency of the hydraulic parameters resulting from the pumping test

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[1082] See Staff Rebuttal Test. at 29 (Back. Lancaster, Striz) (citing Staff Initial Test. at 10–11, 12–13, 24–25; Tech. Rep. Figs. at 49–62 (figs. 2.6-3a to -3n), 87–90 (figs. 2.6-21 to -24)).

[1083] See EA at 3-10.

[1084] See Staff Rebuttal Test. at 28 (Back, Lancaster, Striz).

[1085] See Driscoll Text at 214, 218.

[1086] See NRC Rebuttal Test. at 26–27 (Back, Lancaster, Striz).

[1087] See Tr. at 468 (Shriver).

[1088] See supra section VII.D.2.

[1089] See Kreamer Initial Test. at 6.

analyses,[1090] values that OST agreed can often vary by an order of magnitude or more.[1091] We also noted that the derived storativity values are within the range expected for a confined aquifer.[1092] Also, it seems clear to us that well Monitor-3, which was only 100 ft. from the pumping well, was impacted by well effects, and concur with the Staff's re-analysis of the information to match with the later time data, which resulted in values of transmissivity and storage coefficients that are more in line with the other wells and indicative of a confined aquifer.[1093]

g. Anisotropy

The Board's findings as to anisotropy were discussed previously in detail,[1094] and therefore are not repeated here other than to reiterate that it is OST's opinion that directional differences in hydraulic conductivity for the BC/CPF remains undefined and not quantified.[1095] Dr. Kreamer claimed that CBR's position of no anisotropy is based on a crude plot of limited pumping test data.[1096] We disagreed, finding that Figure 16 in the pumping test report[1097] was generated using the monitoring well network data and software-generated contours to create the non-biased horizontal flow patterns derived from the pumping test results and displayed in

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[1090] See Test #8 Rep. tbls. app. at 10 of 10 (tbl. 8).

[1091] See Tr. at 485–88 (Kreamer).

[1092] See Staff Rebuttal Test. at 15 (Back, Lancaster, Striz) (citing Todd Text at 45–46 (stating that storativity values for a confined aquifer range between $5x10^{-5}$ and $5x10^{-3}$)).

[1093] See Tr. at 502–05, 530 (Striz).

[1094] See supra section VII.E.2.

[1095] See Kreamer Initial Test at 7.

[1096] See id. (citing EA at 70, 255; Test #8 Rep. figs. app. at PDF 48 (fig. 16)).

[1097] See Test #8 Rep. figs. app. at PDF 48 (fig. 16).

this figure.[1098] And we pointed out that the drawdown contours are far from the elliptical shape that would indicate significant directional hydraulic conductivity from lateral anisotropy.[1099] With OST not disputing what the contour lines represent if they are based on accurate data,[1100] we found that the plot illustrates near circular contour lines indicative of isotropic flow in a horizontal plane of the BC/CPF. As a result, we concluded that CBR was justified in its determination that more detailed analyses of horizontal anisotropy are not necessary given the lack of conceptual basis in the geometry of the drawdown cone. The Board also found that Dr. Kreamer failed to provide any concrete evidence or even reasonable indications of observations that supported his opinion that anisotropy is not defined or quantified, or that this lack of definition has any significant safety impact on the proposed Marsland ISR facility.

The Board concluded that the alleged necessity of having horizontal isotropic conditions in the BC/CPF has not been justified by the Intervenor because it is unrelated to the vertical containment of a production zone aquifer that is controlled by the hydraulic characteristics of the UCU and LCU.[1101] And as far as vertical anisotropy is concerned, OST did not challenge the Staff's persuasive argument that vertical anisotropy in the BC/CPF sandstone aquifer will likely be beneficial for ISR operations because it creates the preferred horizontal flow that increases the interconnectivity of the BC/CPF, thus helping the operator to balance the wellfields and maintain an inward gradient.[1102]

[1098] See CBR Rebuttal Test. at 12 (Lewis, Nelson, Pavlick).

[1099] See Staff Rebuttal Test. 27 (Back, Lancaster Striz) (citing Test #8 Rep. figs. app. at PDF 48 (fig. 16)).

[1100] See Tr. at 539–40 (Kreamer).

[1101] See Staff Rebuttal Test. at 29 (Back, Lancaster, Striz).

[1102] See id.; Tr. at 544–46 (Kreamer).

2. Board Findings on Challenges to Evidence of Hydrogeologic Containment of BC/CPF

A detailed discussion of the Board's findings addressing the challenges to the Staff's list of evidence of the hydrogeologic containment of the BC/CPF aquifer has been presented above,[1103] and is not repeated here except to present a summary of the findings as is relevant to Concern 4. The Board found that CBR and the Staff presented extensive data and analysis supporting multiple lines of evidence establishing that the production zone is hydrologically isolated from the overlying aquifers. Overall, we found that the information in the CBR ER and TR, as well as the Staff's EA and SER, demonstrated the isolation of the BC/CPF aquifer within the MEA. We thus concluded that most of the independent observations of containment provided by CBR and the Staff strongly demonstrate that the BC/CPF has the hydraulic properties to contain processing fluids and to control lateral migration within the aquifer.

According to the Staff, Dr. Kreamer appeared to be suggesting that if the Theis analyses show deviations consistent with a recharge boundary, it follows that a significant volume of water may be flowing from the overlying aquifer into the BC/CPF sandstone aquifer, which would indicate a lack of containment.[1104] We found that Dr. Kreamer's explanation is not likely because the Intervenor provided no convincing evidence for this volume of flow and, as the Staff summarized in its initial written testimony,[1105] other multiple, independent lines of evidence showed a high degree of containment so as to preclude a preferential vertical flow (as championed by the Intervenor) that would jeopardize the containment properties of the BC/CPF aquifer.

[1103] See supra section V.C.3.

[1104] See Staff Rebuttal Test. at 19 (Back, Lancaster, Striz) (citing Kreamer Initial Test. at 2, 6).

[1105] See id. (citing Staff Initial Test. at 28–31) (Back, Lancaster)).

Given the opportunity to address each of the items that the Staff presented as evidence of containment of production fluids within the BC/CPF, Dr. Kreamer provided persuasive arguments that the purported complexity of potential geochemical interactions during groundwater flow through geologic strata was not a basis supporting the BC/CPF containment.[1106] The Board agreed with the Intervenor that the resulting difference between the water quality of the upper Arikaree/Brule aquifer and that of the BC/CPF aquifer is unlikely to be solely a result of isolation of the upper aquifers from the Chadron Formation. As a result, we place very little weight on the observation of differing water quality as definitive proof of aquifer containment, a position that is acknowledged to some degree by CBR witness Lewis.[1107]

Relative to Dr. Kreamer's comments on each of the remaining seven signs of containment,[1108] however, the Board finds that the preponderance of the evidence supports the validity of the Staff's seven other observations, noting that the presence of any one of these items provides a significant demonstration of the containment properties of the BC/CPF aquifer. While OST's hypotheses in rebuttal are not infeasible, the Board nonetheless found there is insufficient contrary evidence to show a likelihood that containment will be breached by ISR operations sufficiently to jeopardize the integrity of the thick UCU. This is particularly so given all seven of the Staff-identified items would have to prove insufficient to establish containment, a situation that is highly unlikely to occur.

Ultimately, the central focus of Dr. Kreamer's arguments regarding a lack of hydrogeologic containment was his premise that there is fracturing of the geologic strata that had the potential to create a preferential pathway for groundwater flow such that a robust

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[1106] See Tr. at 951–56 (Lewis, Kreamer).

[1107] See Tr. at 956 (Lewis).

[1108] See Tr. at 965–67, 990–96 (Kreamer).

fracture analysis is required to quantify this possible structural disturbance.[1109] Yet, all the parties agreed to a greater or lesser degree that in assessing a facility such as the MEA, it is not the mere presence of a fracture that is important but its transmissivity. And in this regard, OST has failed to provide convincing evidence of the existence of such a preferential path that has groundwater flow capacity sufficient to negate the CBR and Staff persuasive showings regarding the seven items supporting a containment finding.

To be sure, in his initial testimony, Dr. Kreamer alleged that the large range of storativity and transmissivity values from the May 2011 pumping test were not consistent with homogeneous conditions at the MEA. But based on the evidentiary record, the Board found that these values fall within the range expected for a confined aquifer. Furthermore, at the hearing Staff witness Dr. Striz clarified that the largest value for storativity should be reduced by nearly two orders of magnitude, yielding a narrower range that is more in line with other monitoring wells and even more indicative of a confined aquifer. Thus, regarding transmissivity and the analogous parameter of hydraulic conductivity, we find the results fall within the containment parameters that even Dr. Kreamer agreed can often vary by an order of magnitude or more.[1110]

C. Summary of Unsubstantiated Assumptions of BC/CPF Aquifer Isolation

For Concern 4, the Board reached findings on what OST asserted are unsubstantiated assumptions of BC/CPF aquifer isolation used for both the Theis and Cooper-Jacob aquifer analyses, as well as to assess the BC/CPF aquifer containment and interconnectivity properties that are considered necessary to assure the safe operation and restoration of the facility and to assess the environmental impacts from ISR activity in the MEA. A summary of our findings follows.

[1109] See Tr. at 998.

[1110] See Tr. at 485–88.

1. Summary of Unsubstantiated Assumptions with Aquifer Pumping Test Analyses

The assumptions underlying the analytical analyses concern several topics, including the use of the Theis and Cooper-Jacob methodologies, the lack of preferential flow paths associated with fracturing/faulting, aquifer confinement and apparent infinite extent, homogeneity and isotropy, uniform effective aquifer thickness, range of transmissivity and storativity, and anisotropy assessments.

Regarding the assumptions associated with the use of the Theis and Cooper-Jacob methodologies in interpreting the May 2011 aquifer pumping test, the Board found that CBR graphically analyzed both the drawdown and recovery data using the Theis drawdown and recovery method and the Cooper-Jacob distance-drawdown method.[1111] Additionally, while prepared to use more complex analytical techniques if needed, the Applicant concluded, and we agreed, that there was no need to do so based on the apparent consistency of the resulting hydraulic parameters for values that,[1112] as OST acknowledged, can often vary by an order of magnitude or more.[1113] The Board also found that CBR conducted the pumping test according to its plan approved by NDEQ, using accepted industry testing and analysis procedures that are incorporated into ASTM standards.[1114] We found further that Dr. Kreamer conceded that the more complex analysis methods he suggested may have the same assumptions of aquifer homogeneity, isotropy, uniform thickness, and lateral extent as do the Theis and Cooper-Jacob methods.[1115]

[1111] See CBR Initial Test. at 29 (Lewis, Nelson, Pavlick).

[1112] See CBR Rebuttal Test. at 10 (Lewis, Nelson, Pavlick).

[1113] See Tr. at 485–88 (Kreamer).

[1114] See Staff Initial Test. at 26 (Back, Lancaster) (citing ER at 3-45; Tech. Rep. at 2-82); Staff Rebuttal Test. at 25 (Back, Lancaster, Striz) (citing ASTM Theis Analysis Standards).

[1115] See Tr. at 507–09.

As to the assumptions associated with the lack of preferential flow paths associated with fracturing/faulting, the Board found that there is likely some degree of structural fracturing of the geologic strata underlying the MEA, but that transmissivity, rather than the mere presence of fractures, is the critical issue. In this regard, we found that there is no evidence of extensive transmissive, heterogeneous pathways that would provide a preferential flow for contaminants to uncontrollably migrate into the adjacent aquifers or into the neighboring Niobrara River and the more distant White River.

Concerning the assumptions associated with aquifer confinement and apparent infinite extent, the Board found the parties in agreement that the BC/CPF aquifer meets the definition of a confined aquifer because its potentiometric surface rises above the top elevation of the aquifer.[1116] And with respect to lateral extent of the aquifer, we concluded that the BC/CPF aquifer is not only present over the entire MEA site, but goes well beyond these limits based on site-specific regional cross-sections derived from borehole data and geophysical logging and the lack of definitive boundary conditions observed during the May 2011 aquifer pumping test.[1117]

We also found that at some scale, all geologic strata are heterogeneous and anisotropic.[1118] Furthermore, we acknowledged that when analyzing pumping test data, application of the "simplistic" Theis equations to these strata is routinely done in practice with an understanding of the assumptions inherent to their use.[1119] And at the relevant scale for

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[1116] See Staff Initial Test. at 30 (Back, Lancaster); Test #8 Rep. at 11; Tr. at 450–51 (Kreamer).

[1117] See Staff Rebuttal Test. at 28 (Back, Lancaster, Striz) (citing Test #8 Rep. at 13; Tech. Rep. Figs. at 49–62 (figs. 2.6-3a to -3n), 87–90 (figs. 2.6-21 to -24)).

[1118] See CBR Rebuttal Test. at 11 (Lewis, Nelson, Pavlick); Staff Rebuttal Test. at 25 (Back, Lancaster, Striz); Tr. at 491–94 (Kreamer).

[1119] See Staff Rebuttal Test. at 25 (Back, Lancaster, Striz); CBR Rebuttal Test. at 11 (Lewis, Nelson, Pavlick).

licensing, we noted that the Applicant assumed homogeneous, isotropic responses and then concluded from the consistent test results supporting the applicability of those assumptions to the MEA that additional analysis complexity was unnecessary.[1120] The Board also found there was no need for CBR to augment its TR or for the Staff to alter its EA to address this issue given that the evidence in the record supports a finding that there are no known faults or significant fracturing underlying the MEA that might cause heterogeneity and anisotropy of the underlying geologic strata.

For the assumptions associated with uniform effective aquifer thickness, the Board found that the Staff referenced ample evidence that the local stratigraphy around the MEA is relatively uniform and uncomplicated and, specifically, that the site-specific and regional cross-sections provided by CBR show that the BC/CPF is relatively uniform in thickness over the site.[1121] Moreover, while the visual representations of the CBR geologic cross-sections may, in spots, illustrate an apparent abrupt change in the upper surface of the BC/CPF, the Board found that it is likely an artifact of the exaggerated scales of these graphs.[1122]

Regarding the assumptions associated with the range of transmissivity and storativity, the Board found consistency among the hydraulic parameters resulting from the May 2011 pumping test analyses for values that, as OST acknowledged, can often vary by an order of magnitude or more.[1123] And we found as well that the derived storativity values are within the range expected for a confined aquifer.[1124]

[1120] See CBR Rebuttal Test. at 11 (Lewis, Nelson, Pavlick).

[1121] See Staff Rebuttal Test. at 29 (Back, Lancaster, Striz) (citing Staff Initial Test. at 10–11, 12–13, 24–25; Tech. Rep. Figs at 49–62 (figs. 2.6-3a to -3n), 87–90 (figs. 2.6-21 to -24)).

[1122] See Tr. at 468 (Shriver).

[1123] See Test #8 Rep. tbls. app. at 10 of 10 (tbl. 8); Tr. at 485–88 (Kreamer).

[1124] See Staff Rebuttal Test. at 15 (Back, Lancaster, Striz) (citing Todd Text at 45–46).

Finally, concerning the assumptions associated with anisotropy, the Board found that potentiometric drawdown was created using the monitoring well network and software-generated contours to create non-biased horizontal flow patterns,[1125] and that the analysis results indicated isotropic flow in a horizontal plane of the BC/CPF.[1126] As a result, we found that CBR was justified in stating that more detailed analyses of horizontal anisotropy are not necessary given the lack of conceptual basis in the geometry of the drawdown cone.[1127] As far as vertical anisotropy is concerned, OST did not dispute the Staff's assertion that vertical anisotropy creates the preferred horizontal flow in the BC/CPF sandstone aquifer and therefore will likely be beneficial for ISR operations.[1128]

2. Summary of Unsubstantiated Assumptions with BC/CPF Aquifer Containment

Regarding the assumptions associated with the containment of the BC/CPF aquifer, the Board found that CBR and the Staff presented extensive data and analyses to support the conclusions in the CBR TR, as well as in the Staff EA and SER, that the ore-bearing zones are hydrologically isolated. We also found that a Staff-identified list of independent observations of containment, in general, strongly established that the BC/CPF has the hydraulic properties to contain processing fluids and to control lateral migration within the aquifer.[1129]

The Board concluded as well that for one of the Staff-identified items purportedly evidencing containment, i.e., the complexity of potential geochemical interactions during groundwater flow through geologic strata, OST provided persuasive arguments as to why that

[1125] See CBR Rebuttal at 12 (Lewis, Nelson, Pavlick).

[1126] See Staff Rebuttal Test. at 29 (Back, Lancaster, Striz).

[1127] See CBR Rebuttal Test. at 12 (Lewis, Nelson, Pavlick).

[1128] See Staff Rebuttal at 29 (Back, Lancaster, Striz), Tr. at 544–46 (Kreamer).

[1129] See supra section V.C.1.

element failed to demonstrate BC/CPF aquifer containment.[1130] On the basis of the evidentiary record, and contrary to the Staff's assertions, we concluded that the resulting difference between the water quality of the upper Arikaree/Brule aquifer and that of the BC/CPF aquifer was unlikely to be solely a result of isolation of the upper aquifers from the Chadron Formation. As a result, we place very little weight on the observation of differing water quality as proof of aquifer containment, a position with which CBR did not disagree.[1131] That being said, we found the seven other Staff-identified items supporting BC/CPF containment to be valid, emphasizing that any one provides a significant demonstration of the BC/CPF aquifer's containment properties.

We also observed that, while not infeasible, OST's hypotheses challenging the BC/CPF aquifer's containment properties nonetheless have a low probability of occurrence and would all need to come to pass for containment to be breached sufficiently to jeopardize the integrity of the thick UCU, a highly unlikely situation. Accordingly, OST's attempts to refute the Staff's seven other lines of evidence supporting BC/CPF containment deserve little weight.[1132]

We find little substance in particular in the proposition upon which Dr. Kreamer placed the main weight of his arguments, i.e., the premise that there is fracturing of the geologic strata that creates a preferential pathway for groundwater flow, a structural disturbance that he asserted requires quantification via a robust fracture analysis.[1133] Although all the parties agreed that it is not the mere presence of a fracture, but the fracture's transmissivity, that is important, OST failed to provide substantial evidence indicating that such a preferential path

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[1130] See Tr. at 951–56 (Lewis, Kreamer).

[1131] See Tr. at 956 (Lewis).

[1132] See Tr. at 965–67, 990–96 (Kreamer).

[1133] See Tr. at 998 (Kreamer).

exists with sufficient flow to affect the other indications of aquifer containment. In contrast, we found that the hydraulic parameter values of storativity and transmissivity evidenced by the May 2011 pumping test fell within those values expected for a confined aquifer, with a consistency in magnitude for parameters that, as OST acknowledged, can often vary by an order of magnitude or more.[1134]

X. CONCLUSIONS OF LAW

Relative to OST Contention 2, which involves both AEA safety issues and, with regard to Concerns 1, 3, and 4, NEPA issues, we conclude, as a matter of law, that the preponderance of evidence before the Board establishes that the CBR application, including its TR, and the Staff EA provide sufficient information regarding (1) the geological setting of the MEA so as to meet the AEA safety requirements in 10 C.F.R. Part 40, including Appendix A, Criterion 5(B)(2), the NEPA-implementing requirements in 10 C.F.R. Part 51, and the review criteria of NUREG-1569, section 2.6; and (2) the potential effects of the MEA project on the adjacent surface and groundwater resources so as to meet the NEPA-implementing requirements of 10 C.F.R. Part 51, and the review criteria of NUREG-1569, section 2.7.

Additionally, relative to Contention 2, the Board concludes that (1) the MEA application, including the CBR TR, provides a description of hydraulic conductivity, hydraulic gradient, effective porosity, transmissivity, and storativity as is necessary to demonstrate CBR's ability to conduct ISR operations and groundwater restoration in accordance with NRC regulations in 10 C.F.R Part 40 and the review criteria of NUREG-1569, section 2.7; (2) the CBR TR and the Staff EA both adequately describe the hydrologic conceptual model for the MEA in that (a) the conceptual model as set forth in the CBR TR is supported by extensive site characterization data and demonstrates with scientific confidence that there will be adequate confinement of ISR production fluids at the MEA, and (b) the Staff EA satisfied the NEPA "hard look" requirement in

[1134] See Tr. at 485–88 (Kreamer).

its consideration of CBR's hydrologic conceptual model, site characterization data, and evidence of confinement when assessing potential impacts to adjacent surface water and groundwater resources at the MEA; and (3) the CBR TR and the Staff EA do not contain unsubstantiated assumptions related to isolation of aquifers at the MEA.

Accordingly, as to the matters at issue in OST Contention 2, we conclude as a matter of law that the MEA application, including CBR's TR, demonstrates that (1) CBR will comply with the requirements of the AEA and the applicable NRC safety regulations in 10 C.F.R. Part 40; and (2) the Staff's environmental review, including its EA and FONSI, comply with the requirements of NEPA and the agency's environmental regulations in 10 C.F.R. Part 51.

We thus resolve OST Contention 2 in favor of the Staff and CBR.

Accordingly, it is this twenty-eighth day of February 2019, ORDERED, that:

A. Intervenor OST's Contention 2, including associated Concerns 1–4, are resolved on the merits in favor of CBR and the Staff, and the proceeding before this Board is <u>terminated</u>.

B. In accordance with 10 C.F.R. § 2.1210, this initial decision will constitute a final decision of the Commission 120 days from the date of issuance (or the first agency business day following that date if it is a Saturday, Sunday, or federal holiday, <u>see</u> 10 C.F.R. § 2.306(a)), i.e., on <u>Friday, June 28, 2019</u>, unless a petition for review is filed in accordance with 10 C.F.R. § 2.1212, or the Commission directs otherwise. Any party wishing to file a petition for review on the grounds specified in 10 C.F.R. § 2.341(b)(4) must do so within twenty-five (25) days after service of this initial decision. Unless authorized by law, the filing of a petition for review is mandatory for a party to have exhausted its administrative remedies before seeking judicial review. Within 25 days after service of a petition for review, parties to the proceeding may file an answer supporting or opposing Commission review. Any petition for review and any answer shall conform to the requirements of 10 C.F.R. § 2.341(b)(2)–(3).

THE ATOMIC SAFETY
AND LICENSING BOARD

/RA/

G. Paul Bollwerk, III, Chairman
ADMINISTRATIVE JUDGE

/RA/

Richard E. Wardwell
ADMINISTRATIVE JUDGE

/RA/

Thomas J. Hirons
ADMINISTRATIVE JUDGE

Rockville, Maryland

February 28, 2019

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of CROW BUTTE RESOURCES, INC. In-Situ Leach Uranium Recovery Facility, Crawford, Nebraska (License Renewal)	))))))))	Docket No. 40-8943-OLA

CERTIFICATE OF SERVICE

I hereby certify that copies of the foregoing **INITIAL DECISION (Ruling on Intervenor Oglala Sioux Tribe's Contention 2) (LBP-19-2)** have been served upon the following persons by Electronic Information Exchange, and by electronic mail as indicated by an asterisk.

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[Original signed by Clara Sola]
Office of the Secretary of the Commission

Dated at Rockville, Maryland
The 28th day of February, 2019