CAMECO RESOURCES
CROW BUTTE OPERATION

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For placement in Section 2.7.2.3

Confining Layers

Upper confinement for the basal sandstone of the Chadron Formation within the MEA is represented by 650 to 710 feet of smectite-rich mudstone and siltstones of the upper Chadron and middle Chadron (**Figures 2.6-3a** through **2.6-3n, 2.6-7, and 2.6-8**). Particle grain-size analyses of six core samples from the upper confining layer within the MEA indicate the samples were predominately siltstone. (**Appendix G-1 and G-2**). All MEA core samples were laboratory tested using ASTM D4464 methods for determining particle-size distributions by laser light scattering. The procedure is a modification of ASTM D4464-85 used to measure particle sizes of catalytic material. The procedure has been extended to include measurement of unconsolidated soils and sediments, and is recognized as an alternative to ASTM D422 (hydrometer) and the pipette method. X-Ray Diffraction (XRD) analyses indicate that the chemical compositions of core samples from the middle Chadron 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 (**Appendix G-1**).

The estimated hydraulic conductivities for the upper confining units were developed using the Kozeny-Carmen method (Appendix ???) based on particle grain-size distribution data from the six core samples collected from the upper Chadron and middle Chadron. Use of the Kozeny-Carmen method is acceptable for developing hydraulic conductivity estimates for sands and silts, but not for cohesive clayey soils with a high degree of plasticity. Results of the particle size distribution analyses (Appendix G-1, Appendix G-2) indicate sediments dominated by silts and fine sand with less than 25% clay. Estimated hydraulic conductivities of the four core samples collected within the upper Chadron ranged from 4.3 x 10-5 to 5.9 x 10-5 cm/sec. Estimated hydraulic conductivities of the two core samples collected within the middle Chadron ranged from 1.7 x 10-5 to 2.9 x 10-5 cm/sec. The vertical hydraulic conductivity across the upper and lower confining layers is likely to be even lower due to vertical anisotropy. Additionally, hydraulic resistance to vertical flow is expected to be high due to the significant thickness of the upper confining zone within the MEA, which ranges between 650 and 710 ft. As a result, the Brule Formation and Arikaree Group are vertically and hydraulically isolated from the underlying aquifer proposed for exemption.

Lower confinement for the basal sandstone of the Chadron Formation in the vicinity of the MEA is represented by approximately 750 to more than 1,000 feet of black marine shale deposits of the Pierre Shale. Additional low permeability confining units are represented by the underlying Niobrara Formation, Carlile Shale, Greenhorn Limestone, and Graneros Shale. Together with the Pierre Shale, these underlying low-permeability units hydraulically isolate the basal sandstone of the Chadron Formation from the underlying “D”, “G”, and “J” sandstones of the Dakota Group by more than 1,000 vertical feet (**Table 2.6-1**). The Pierre Shale is not a water-bearing unit, exhibits very low permeability, and is considered a regional aquiclude.

The Pierre Shale consists primarily of illite and smectite clays as indicated by x-ray diffraction of CBR core samples collected in 2011 and 2013 (**Appendix G-1** and **G-2**). The swelling nature of these clays in the presence of water makes it unlikely that any fractures or penetrations within the Pierre would provide a pathway for loss of confinement through this thick unit. Regional estimates of hydraulic conductivity for the Pierre Shale range from 10^{-7} to 10^{-12} cm/sec (Neuzil and Bredehoeft 1980; Neuzil et al. 1982; Neuzil 1993). The Pierre Shale has a measured vertical hydraulic conductivity at the CPF of less than 1 x 10^{-10} cm/sec (WFC 1983), which is consistent with other studies in the region. Particle grain-size analyses of two samples collected from the Pierre Shale within the MEA indicate low permeability silty clay compositions. Kozeny-Carman estimated hydraulic conductivities for the seven core samples collected within the Pierre Shale were not reported due to significant levels (up to 76 weight percent) of clay.

The upper surface of the Pierre Shale illustrated on **Figure 2.6-10** and cross-section A-A’ (**Figure 2.6-3a**) is a gentle, southeasterly-sloping surface consistent with that described by DeGraw (1971). This sloping surface rises northwesterly to the axial crest of the Cochran Arch north of the MEA. Cross-section A-A’ does not show evidence of major folding across the axis of the Cochran Arch that could have created significant vertical fractures within the Pierre Shale. Regional studies also indicate that there is no observed transmissivity between vertical fractures in the Pierre Shale, which if present, are short and not interconnected (Neuzil et al. 1982). All oil and gas wells in the area of review which penetrate the Pierre Shale were abandoned in accordance with accepted regulatory practices at that time. Oil and gas well plugging records are provided as **Appendix D-1**.