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**EXPERT OPINION ON THE POTENTIAL CONTAMINATION OF SURFACE WATERS
IN WESTERN SOUTH DAKOTA BY UNCONFINED ISL URANIUM MINE LIXIVIANANT
AND HISTORICAL OPEN PIT MINING**

I, the undersigned, Hannan E. LaGarry, Ph.D., an individual, residing at 526 Chapin Street in Chadron NE 69337, hereby provide the following EXPERT OPINION ON THE POTENTIAL CONTAMINATION OF SURFACE WATERS IN SOUTH DAKOTA BY UNCONFINED ISL URANIUM MINE LIXIVIANANT AND HISTORICAL OPEN PIT MINING. These written comments are provided in addition to the Inductively Coupled Plasma - Optical Emission Spectrometry (ISP-OES) analytical results of 16 water samples in western South Dakota obtained by the Lakota Peoples Law Project and analyzed by SDSU's Water and Environmental Engineering Laboratory, SCEH 112, PO Box 2219, Brookings SD 57007 (Dr. Beverly Klein, Senior Chemist, 605-688-6308).

EXECUTIVE SUMMARY

South Dakota has been mined for uranium, a highly toxic heavy metal, since the late 1930s. From its inception through the late 1960s this mining was done primarily in open pits that have not yet been reclaimed. Beginning in the 1980s, uranium mining resumed using in situ leach (ISL) methods, and continues to this day. The Lakota Peoples Law Project sampled and tested surface waters at 16 locations in western South Dakota and the Pine Ridge Reservation (Oglala Sioux Tribe) in an attempt to identify contaminants produced exclusively by uranium mining. Altogether, 26 toxic and benign metals were analyzed by inductively coupled plasma optical

emission spectrometry at South Dakota State University. This analysis shows that: 1) 14 of 16 samples tested, including the Missouri River at the intake for the Mni Wiconi Coreline, were above the EPA maximum contaminant level for uranium; 2) all 16 samples analyzed were above the US EPA maximum contaminant level of 15 pCi/L for alpha radiation (which includes uranium); 3) 7 of 16 samples, including the Missouri River at the intake for the Mni Wiconi Coreline and the tap water at Potato Creek, were above the EPA maximum contaminant level for mercury, another highly toxic heavy metal; and 4) at least 5 other toxic metals are at or near EPA health advisory levels for children weighing less than 10 kg (about 22 lbs). Others were found to be potential hazards for livestock and wildlife. My attempt to confirm that the historical and ongoing uranium mining produced these contaminants were inconclusive due to incomplete baseline data reported by the uranium mines and insufficient testing of other potential sources of toxic contaminants. In addition to the chemical toxicities mentioned the 14 samples that exceeded EPA maximum contaminant levels for alpha radiation, which include the Missouri River at the intake for the Mni Wiconi Coreline, pose an increased chance of causing cancer.

Therefore, it is my expert opinion that surface waters in western South Dakota are an unacceptable alternative to the continued use of dwindling supplies of already highly contaminated groundwater currently being relied upon to meet municipal, residential, and agricultural needs in western South Dakota and the Pine Ridge Reservation.

INTRODUCTION

I have served as an expert witness for local private landowners and the Oglala Sioux Tribe in support of ongoing legal interventions against local uranium mining since 2008, and I have provided numerous expert opinions for both the Crow Butte Resources (CAMECO) and Dewey-Burdock (Powertech/Azarga) ISL uranium mining license interventions. In my prior opinions (LaGarry 2008a, 2008b, 2010, 2012, 2014a, 2014b, 2014c, 2014d, 2015a, 2015b, 2015c, 2015d, 2015e), I provided reviews of stratigraphy, geological structures, lineaments, secondary porosities, artesian flow, and potential contaminant migration pathways at both mines. In each

case, I challenged mine operators' assertions of confinement of pregnant lixiviant within the producing aquifer(s).

In addition, I led a team that conducted an ASLB ordered examination of the data recovered from Powertech's belatedly disclosed borehole data purchased from the Tennessee Valley Authority (TVA) following the initial licensing hearings in 2015 (LaGarry 2015b). We observed that in the 1970s, the drillers of the TVA boreholes documented uncased holes, improperly plugged holes, artesian water escaping from boreholes, breccia pipes and caves, and faults crossing boreholes at varying depths. I opined that the secondary porosities in the Dewey-Burdock area are such that loss of containment and the escape of pressurized fluids from ISL mining and underground waste injection are almost a certainty should either mining or injection be allowed. One of the conclusions we drew from this review was that these boreholes had been allowed to serve as pathways of contaminant migration for decades before Powertech/Azarga sought a license to renew mining operations.

In my prior opinions (cited above) provided to both the Crow Butte Resources (CAMECO) and Dewey-Burdock (Powertech/Azarga) ISL uranium license interventions, I argued that secondary porosities, primarily in the form of joints and faults, needed to be investigated prior to determining if mining should be allowed to proceed. The consequences of not doing so would be unmitigated transmission of mining fluids and contaminated ore water into surface water and groundwater. Recent (January 2020) surface water sampling across western South Dakota by the Lakota Peoples Law Project and subsequent ICP-OES quantitative analysis of these samples heavy metals at South Dakota State University Water and Environmental Engineering Laboratory has provided an opportunity to test this hypothesis and opine whether or not contamination may have occurred.

In this document, I describe these recent analyses of surface waters in western South Dakota and interpret the potential for contamination of South Dakota's surface waters by historical open-pit uranium mining in South Dakota and ongoing ISL mining for uranium in Nebraska. It should be

noted that this is a preliminary analysis based on pilot data, and all errors, omissions, and misinterpretations of scientific data are exclusively my own.

PROFESSIONAL BACKGROUND

I have 25 years of experience studying the rocks and fossils of northwestern Nebraska. From 1988-1991, I collected fossils from northern Sioux County for my dissertation work. From 1991-1996, I led field parties from the University of Nebraska State Museum while mapping the fossils and geology of the Oglala National Grassland in Sioux and Dawes Counties. From 1996-2006, I led a teams of geologists from the Nebraska Geological Survey that mapped in detail the surficial geology of most of northwestern Nebraska (a total of 80 1:24,000 quadrangles). This mapping included the entire Pine Ridge area and the area between Crawford, Nebraska and Pine Ridge, South Dakota. These maps, including digital versions (ArcInfo) and supporting field notes, are available from the University of Nebraska-Lincoln School of Natural Resources and the United States Geological Survey. As a direct consequence of this mapping, I have published peer-reviewed articles on the Chadron Formation (Terry & LaGarry 1998), the Brule Formation (LaGarry 1998), and the mapping of surficial deposits (Wysocki & others 2000, 2005) and local faults (Fielding & others 2007). Stratigraphic studies intended to revise and reclassify the remaining rocks and surficial sediments of northwestern Nebraska and adjacent South Dakota are ongoing.

In addition to my ongoing stratigraphic work in South Dakota (LaGarry & Sanovia 2014), I led teams of students and faculty at Oglala Lakota College that studied the geology, groundwater, surface water, and heavy metal contaminants of southwestern South Dakota and the Pine Ridge Reservation. From 2012-2018, our research was funded by the National Science Foundation's Tribal Colleges and Universities Program (NSF TCUP) and the Experimental Program for Stimulating Competitive Research (NSF EPSCoR), and the USDA National Institute for Food and Agriculture (NIFA) Tribal College Equity Program. We worked in close partnerships with Chadron State College, the South Dakota Geological Survey, the South Dakota School of Mines and Technology, South Dakota State University, the University of Illinois Urbana-Champaign,

the University of Illinois Center for Advanced Materials Purification of Water Systems, the Department of Nuclear Engineering and Radiological Sciences at the University of Michigan - Ann Arbor, the University of Washington Native American Research Center for Health, and the Technological University of Darmstadt, Germany. I have authored or coauthored reports detailing the preliminary results of studies describing toxic heavy metal contamination of drinking water on the Pine Ridge Reservation (Salvatore & others 2010, Botzum & others 2011), characteristics of our local aquifers (Gaddie & LaGarry 2010, LaGarry & others 2012), potential uranium contamination risk to communities on the Pine Ridge Reservation (LaGarry & Yellow Thunder 2012), the transmission of uranium-contaminated water along regional faults (Bhattacharyya & others 2012), levels of ionizing background radiation in Oglala Lakota County (Garnette & others 2017), and the contamination potential of soils derived from uraniferous bedrock (Vasek & others 2017), among others.

MATERIALS AND METHODS

The 16 surface water samples used in this opinion were collected by the Lakota Peoples Law Project from 3-7 January 2020 (Fig. 1). Samples were collected by hand using a 2L plastic pitcher rinsed in the water to be sampled prior to sample collection. The sampled water was then transferred to 100 ml plastic containers provided by the SDSU Water and Environmental Engineering Research Center (WEERC). These containers were pre-prepared with 5 ml of nitric acid (HNO₃) to prevent adsorption of metals to the inside of the container, and chain of custody was maintained throughout the sampling expedition (Fig. 2). Samples were photographed, their GPS locations recorded, and kept refrigerated until provided to the WEERC on 7 January 2020. The results of WEERC's ICP-OES metals quanti-scan analyses were provided on 14 January 2020. An initial draft of this report was prepared and submitted on 18 February 2020.



Figure 1. Map of western South Dakota and adjacent Nebraska showing sample locations used in this study. Figure prepared by Lakota Peoples Law Project.

RESULTS AND DISCUSSION

The ICP-OES metals quanti-scan analysis provided by WEERC included uranium, silver, aluminum, gold, boron, barium, calcium, cesium, copper, iron, mercury, potassium, lanthanum, lithium, magnesium, manganese, molybdenum, sodium, phosphorus, sulfur, silicon, strontium, titanium, vanadium, zinc, and zirconium. Results were reported in mg/L and subsequently converted to parts per billion (ppb) where appropriate (see attached data).



Figure 2. Photograph and embedded field data of sample 1 collected at site CR2020. Photograph by Lakota Peoples Law Project.

On the question of heavy metal contamination of surface waters

The contaminants observed in the samples examined here were derived from at least seven (7) sources; three (Pierre Shale, White River Group, Rosebud Formation) are naturally occurring, and four are the result of mining and its effluents (historical open-pit mining in Fall River County SD, historical open-pit mining in Harding County SD, the Dewey-Burdock site in Fall River County SD, and ongoing ISL mining at Crow Butte Resources near Crawford, Dawes County NE). However, these sources likely do not contribute equally to all samples, and these differences in levels of contamination are addressed below. This list of potential sources does not include contributions from specific aquifers where they contribute to surface waters through seepage or springs. In the following discussion, numbers in parentheses correspond to the sample numbers in Figure 1. The groundwater mentioned below is likely the result of continental glaciers melting 26,000 years ago that, at that time, seeped into its current position through secondary porosities. In my earlier expert opinions, I opined that these secondary porosities also allow contaminated groundwater, under artesian conditions, to flow in reverse and contaminate surface waters.

The Pierre Shale is a marine deposit rich in the accumulated salts and decay products it derived from the shallow tropical sea that deposited it. It contains high amounts of arsenic, sulfur, vanadium, and selenium, and is known to contribute these to groundwater and surface waters, along with the plants and animals that drink the water and eat the plants. The Pierre Shale likely contributed contaminants to the northernmost samples, which includes Cherry Creek (15), and the Belle Fouché (12), Grand (13), Moreau (14), Cheyenne (1), and Missouri rivers (16). The Missouri River sample (16) is at the intake of the Mni Wiconi Coreline, and therefore by extension the Pierre Shale ultimately contributes to the contaminants in the tap water at Potato Creek (11).

The White River Group consists of volcanic ash deposits and contains the uranium-bearing Chamberlain Pass Formation at its base. It is exposed to surface waters in Fall River, Custer, westernmost Pennington, and Oglala Lakota counties. It is known to contribute calcium, silicon, and uranium to groundwater and surface waters along with the plants and animals that consume these waters both directly and indirectly. The Chamberlain Pass Formation is mined at the Crow Butte Resources ISL facility near Crawford, a highly contaminated aquifer (see below), a prerequisite for ISL mining. The Chamberlain Pass Formation is exposed to surface waters in Sioux, Dawes, and Keya Paha counties in Nebraska, and Harding, Fall River, Custer, western Pennington, and Oglala Lakota counties in South Dakota. Therefore, White River Group/Chamberlain Pass Formation contaminants are likely found at the Whiteclay Dam (5) and in the Cheyenne (1), White (2, 3, 4), Belle Fouché (12), Grand (13), Moreau (14), and Missouri (16) rivers. The Missouri River sample (16) is at the intake of the Mni Wiconi Coreline and therefore by extension the White River Group/Chamberlain Pass Formation ultimately contributes to the tap water at Potato Creek (11). If Mni Wiconi Coreline recharge wells are sourced in the Chamberlain Pass Formation once it reaches the Reservation, the Chamberlain Pass Formation will contribute heavily to the contaminants in the tap water at Potato Creek (11).

The Rosebud Formation is part of the Arikaree Group and consists, like the White River Group, of highly weathered volcanic ash deposits. However, these rocks are derived from a different, younger volcanic field having different chemistry. The Rosebud Formation is known to contaminate groundwater and surface waters with high amounts of barium and calcium. The extent to which barium bioaccumulates in plants and animals locally is, to the best of my knowledge, unknown at this time. The Rosebud Formation is exposed to surface waters in Cherry, Keya Paha and Ainsworth counties in Nebraska, and Oglala Lakota, Bennet, Jackson, and Todd counties in South Dakota. Therefore, The Rosebud Formation likely contributes contaminants to the Little White River (6) and Wounded Knee (7), White Horse (8), Porcupine (9), and No Flesh (10) creeks. If Mni Wiconi Coreline recharge wells are sourced in this formation, it will contribute heavily to the contaminants in the tap water at Potato Creek (11).

Uranium was discovered south of the Black Hills in Fall River County, South Dakota in 1938, and was mined in open pits through the late 1960s (see Klepper and Wyant 1957 for descriptions of mining in the early years). These abandoned open pits and talus piles, some up to 20 m high, cover many square miles and continue to be exposed to the elements to this day. These open pits include the Dewey-Burdock site, but because of its subsequent history is considered separately here. The uranium in these open pits was likely derived, like the Chamberlain Pass Formation, from devitrified volcanic ash of the White River Group that subsequently migrated through secondary porosities into underlying marine shales. Therefore, the suite of contaminants likely combines those of the Pierre Shale and White River Group mentioned above, and includes arsenic, sulfur, selenium, uranium, and probably iron from the weathering of concretions. These contaminants likely are restricted to the Cheyenne River (1), and by extension the Mni Wiconi intake at the Missouri River (16) and the tap water at Potato Creek (11).

Like the open-pit mines in Fall River County, uranium was discovered north of the Black Hills in Harding County, South Dakota in the late 1930s and was mined in open pits through the late 1960s. Also, just as in Fall River County, these abandoned open pits and talus piles, some as high as 10 m, are still exposed to the elements and continue to weather unchecked to this day. In some

cases, such as at Ludlow SD, the uranium ore was on the tops of buttes and was mined simply by pushing ore over the side of the butte to the ground below where it was loaded directly into trucks. In 2009 I went to Ludlow with OST tribal members and a faculty-led student field party from UM Ann Arbor where we directly measured ionizing background radiation of 1776 microR/hr about 300 m uphill from the Ludlow Elementary School playground. Like Fall River County, the Harding County open pit mines combine the contaminant loads of the Pierre Shale and White River Group, including contaminants from rocks equivalent to the Chamberlain Pass Formation. These contaminants include, but are not limited to, uranium, arsenic, vanadium, selenium, silicon, and iron, and impact surface waters including the Belle Fouche (12), Grand (13), Moreau (14), and Missouri (16) rivers, and Cherry Creek (15). The Missouri River sample (16) is at the intake of the Mni Wiconi Coreline, and therefore by extension the Harding County open pit mines ultimately contribute to the tap water at Potato Creek (11).

The Dewey-Burdock site in northwestern Fall River County, South Dakota was mined for uranium in tunnels and open pits through the late 1960s. However, in the 1970s, and subsequently under Powertech/Azarga, the site was extensively drilled with exploratory drill holes. This drilling had many unresolved issues that I opined extensively about in 2015. In summary, 7,600+ boreholes were produced, with as many as 10% of that total number improperly plugged, poorly documented, or redacted and unavailable for review. These included several that were documented as being artesian (like a fountain) or in direct contact with secondary porosities in the form of faults or joints, breccia pipes, or caves. In subsequent decades these improperly plugged or problematic boreholes have allowed contaminated waters to migrate unconfined into adjacent aquifers. Although the site closely resembles the circumstances present at the open pits elsewhere in Fall River County, the unconfined mine fluids pose a contaminant risk similar to that of the Chamberlain Pass Formation, in that contaminants have been allowed to accumulate and concentrate over time. The situation is marginally worse in that many unplugged bore holes are open at the surface enabling rainwater and acidic surface waters (sulfur in the rock + water = sulfuric acid under pressure from above) into the contaminated aquifers, increasing the likelihood of artesian discharge to the surface. Therefore, the suite of contaminants likely

combines those of the Pierre Shale and White River Group mentioned above, and includes arsenic, sulfur, selenium, uranium, and probably iron from the weathering of concretions. Like the open pit mines elsewhere in Fall River County, these contaminants likely are restricted to the Cheyenne River (1), and by extension the Mni Wiconi intake at the Missouri River (16) and the tap water at Potato Creek (11).

In-situ leach (ISL) uranium mining began adjacent to the White River in Crawford, Dawes County, Nebraska in 1989 and continues to the present day. And although no new mining at the primary facility will occur and parts of the mine have entered their restoration and remediation phase, satellite expansions north, northwest, and southwest of the main facility are being pursued with one of these, the Marsland Expansion, already licensed in 2018. The Crow Butte Resources ISL mine draws exclusively from the Chamberlain Pass Formation (Evans and Terry 1994). Secondary porosity in the form of faults and joints as indicated by lineaments visible from near-Earth orbit were mapped in detail by Diffendal (1994) and Vasek & LaGarry (2017). Despite unconfined flow and contamination as a direct result of mining at Crow Butte Resources has not yet been detected by monitoring wells, pregnant lixiviant was reported by a local landowner to be flowing from exploratory wells on their property north of Crawford. Also, artesian water contaminated with high amounts of uranium has been directly observed seeping from the Whiteclay Fault on the Pine Ridge Reservation west of Pine Ridge some 50 miles to the northeast of the mine. In my earlier opinions I discussed how it would take less than a decade for contaminants to traverse the distance if consistent with measurements elsewhere in Nebraska (see LaGarry 2015a).

The Chamberlain Pass Formation is known to host an extensive suite of accessory toxic heavy metal contaminants in addition to uranium (see opinions cited above), and if my opined hypotheses were demonstrated to be correct, the Chamberlain Pass Formation would directly contaminate surface waters including, but not limited to, the White River (2) and its tributaries (3, 4) and the Whiteclay Dam (5). After flowing northeast across the Pine Ridge Reservation, the White River flows through extensive exposures of White River Badlands (of which it's the

namesake for) in and around Badlands National Park with includes the most extensive outcrops of the Chamberlain Pass Formation. Therefore, the relative contribution of the Crow Butte ISL mine's contributions to White River's contaminant load when it reaches its confluence with the Missouri River cannot be reasonably inferred at this time. It should be noted however, that the extensive network of secondary porosities mapped by Diffendal (1994) strongly suggests that pregnant lixiviant, if leaking, could occur in virtually any waterway north of the Pine Ridge along the Nebraska/South Dakota border at any time.

On the question of contaminant toxicity

Many of the contaminants reported in the attached analyses are toxic to varying degrees and some are federally regulated. Irrespective of their point(s) of origin, these contaminants are a serious concern and should be mitigated if possible. In the following section, I'll briefly discuss each of the reported elements, its toxic effects, and the surface waters impacted by the particular contaminant. When discussing metal toxicity and radiation, it is important to keep in mind that the effects are cumulative and compounded, with emergent toxicities depending on the particular combination of elements. An exhaustive discussion of emergent toxicities is, however, beyond the scope of this opinion. Finally, this analysis does not isolate the various forms each element might take, but is a cumulative measure of all chemical forms, including undissolved solids, present in a sample. All descriptions of standards and toxicities discussed below are from the US EPA National Primary Drinking Water Standards (and related documents on [EPA.gov](https://www.epa.gov) accessed on 2/18/2020).

Uranium- Uranium is both toxic and radioactive, and it is dangerous as a consequence of both conditions. In order for either effect to be harmful to human health, the uranium must either be inhaled as dust or consumed in ingested through food or water. Uranium bioaccumulates in plants and animals, and where present in high amounts in surface water and soils, locally sourced foods become an additional pathway into the body. In addition to being present as insoluble sediment and nanoparticles, uranium forms many different chemical species, both organic and inorganic, and detailed discussions of these can be found in Fetter & others (1999).

Typically, uranium toxicity impacts the kidneys causing renal failure. However, the cumulative doses required for acute renal failure and death are quite high (50 - 100 mg/L), and moderately high doses (25-40 mg/L) are required before damage can be observed in the form of dead kidney cells in the urine. The doses recorded in these samples are much lower, but the toxic effects accumulate over time and can fully manifest after years of continuous exposure. The toxic effects of uranium will eventually heal if exposure is eliminated. Fourteen of the sixteen samples exceeded the EPA MCL for uranium (Fig. 3), with the highest levels of contamination found in tributaries of the White River (3, 4) west of Pine Ridge. This analysis corroborates prior studies in this area by Botzum & others (2011) and Battacharrya & others (2012).

In terms of radiation risk, uranium is an alpha emitter, and increases the risk and severity of cancer, along with an increased incidence of rare cancers. Cancers associated with uranium typically develop in the body where blood filtering occurs or where fine capillaries or tubes are found. These include the kidneys, the liver, the pancreas, and in the blood-brain barrier (brain tumors). The EPA MCL for total alpha emitters (including uranium) is 15 pCi/L. When converted from mg/L to pCi/L ($\text{mg/L} \times 675.7 = \text{pCi/L}$ (Fig. 3), all 16 samples exceed the EPA MCL with lowest value being from the Grand River (16.9 pCi/L) and the highest being from a tributary of the White River west of Pine Ridge (72.9 pCi/L).

Uranium is also a well-known cause of early fetus birth defects and can cause both internal and external deformities such as mottled skin, missing or shortened fingers and toes, and missing or malformed internal organs and structures (Irwin 1997).

Sample #	Date Sampled	Sample Type	Uranium	Uranium	Uranium
			mg/L	ppb	pCi/L
01062020-00001	01/03/20	CR2020-1	0.055	55.4	37.5
01062020-00002	01/03/20	WR2020-2	0.064	63.9	43.2
01062020-00003	01/03/20	WR2020-3	0.107	107.0	72.3
01062020-00004	01/03/20	WR2020-4 ^{HEL}	0.108	108.2	73.1
01062020-00005	01/03/20	WC2020-5	0.038	38.2	25.8
01062020-00006	01/03/20	LWR2020-6	0.032	32.4	21.9
01062020-00007	01/03/20	WK2020-7	0.042	41.9	28.3
01062020-00008	01/03/20	WH2020-8	0.050	50.1	33.8
01062020-00009	01/04/20	PC2020-9	0.047	46.7	31.5
01062020-00010	01/04/20	NF2020-10	0.033	32.5	22.0
01062020-00011	01/04/20	POT2020-11	0.028	27.7	18.7
01062020-00012	01/04/20	BF2020-12	0.049	49.1	33.2
01062020-00013	01/05/20	GR2020-13	0.025	24.7	16.7
01062020-00014	01/05/20	MOR2020-14	0.045	45.5	30.7
01062020-00015	01/05/20	CCR2020-15	0.053	53.3	36.0
01062020-00016	01/06/20	MW2020-16	0.031	30.5	20.6

Figure 3. Uranium concentrations measured in the 16 samples discussed in this paper in mg/L (milligrams per liter) and ppb (parts per billion), and radioactivity in pCi/L (picocuries/liter). The US EPA maximum contaminant level for uranium toxicity is 0.030 mg/L or 30 ppb. The US EPA maximum contaminant level for alpha radiation (which includes uranium) is 15 pCi /L.

Silver- Silver occurs as both salt and inorganic sediment and nanoparticles. Silver has a secondary EPA MCL of 0.10 mg/L (100 ppb), and if ingested above this concentration can lead to skin discoloration. The highest levels of silver in the analyzed samples are from the Belle Fouche River (1.9 ppb) and Cherry Creek (1.2 ppb) and is not a regulatory or health concern.

Aluminum- Aluminum has a secondary EPA MCL of 0.05 to 0.2 mg/L (50-200 ppb) at which point it discolors water and has a metallic taste. In the samples analyses reported here, the highest levels of aluminum were from the Cheyenne River (1.9 ppb) and the Little White River (2.4 ppb), and therefore aluminum is not a regulatory or health concern.

Gold- There is no EPA MCL for gold. In general, gold is not toxic in its metallic form, although it can be harmful in extremely rare dissolved chemical forms. The analysis described here cannot distinguish individual chemical forms. The highest concentrations are from the tributaries of the White River (sample 3 had 11.2 ppb, sample 4 had 39.7 ppb) with the majority of samples having less than 6.5 ppb. With no MCL, gold is not a regulatory concern. At these low concentrations, it is also not a health concern.

Boron- There is no EPA MCL for boron, and it is generally not an element of regulatory concern. However, doses of over 2 mg/L (2000 ppb) are known to cause health problems in children <10 kg. Boron is toxic to plants, however, and in large amounts is a strong defoliant. The analyses presented here show that Cherry Creek (229 ppb) and the Moreau River (207 ppb) have the highest levels of this contaminant, but are 1/10th of the amount needed to be concerned for human or small animal health.

Barium- Barium has an EPA MCL of 2 mg/L (2000 ppb) or 0.7 mg/L (700 ppb) for children under 10 kg. Exposures to the MCLs of barium can cause an increase in blood pressure. Similar doses of barium carbonate can induce vomiting, abdominal pain, and watery diarrhea. All of the sites sampled passing through or over the Rosebud Formation have the highest levels of barium, including the Little White River (0.34 mg/L), Wounded Knee Creek 0.26 mg/L), White Horse Creek (0.24 mg/L), Porcupine Creek 0.25 mg/L), and No Flesh Creek 0.29 mg/L). One of the tributaries of the White River (0.26 mg/L) and the Whiteclay Dam (0.28 mg/L) had similarly high levels of barium. While below the 0.7 mg/L level of concern for children, these levels are high enough to justify additional study, especially in standing water like the Rosebud Reservoir in Rosebud, South Dakota (the formation takes its name from rocks there).

Calcium- There is no EPA MCL for calcium, and it is generally not considered toxic to plants or animals. However, in high concentrations it can cause kidney and liver stones. The highest levels observed in these samples was 185 mg/L from a tributary of the White River (sample 3), and it's known to be ubiquitous in the rocks, soils, and water of this region. It is not a regulatory concern and is not a health concern.

Cesium- There is no EPA MCL for cesium, and it is generally considered non-toxic. It has negative health effects at 2.3 g/Kg similar to those of sodium chloride and potassium chloride, two common components of table salt. In the samples described here, the highest concentration was in Whiteclay Dam (0.018 mg/L), far below the levels where health is impacted. It is not a regulatory concern, and not a health concern.

Copper- Copper has an EPA MCL of 1.3 mg/L (1300 ppb) dangerous in large doses to children and people with certain metabolic disorders. The highest observed level in the samples described here were in the Cheyenne River (0.0046 mg/L), a tributary of the White River (sample 3 at 0.0049 mg/L), and the tap water at Potato Creek (0.049). Its noteworthy that the tap water at Potato Creek has 10x the copper of the highest surface water and warrants additional study.

Iron- There is no EPA MCL for iron, and ingestion of less than 20 g/Kg are considered non-toxic. The highest concentration observed in the samples described here is 0.53 mg/L. Therefore, iron is not a regulatory or health concern in the samples described here.

Magnesium- There is no EPA MCL for magnesium, and it is only toxic at high doses (5000 mg/day) in adults but is problematic at much lower doses in small children (65 mg/day). Toxic effects include hypotension, nausea, vomiting, facial flushing, urine retention, ileus, depression, lethargy, and muscle weakness. In the very young and very old, high doses of magnesium causes hypermagnesemia, which can be fatal. The highest concentrations observed here were at Cherry Creek (26.0 mg/L) and the Moreau River (26.5 mg/L), and although not overly high at this level, ingest 3L of contaminated level would put a young child at the threshold of potential health consequences.

Manganese- Manganese does not have an EPA MCL, although there is a health advisory level of 1 mg/L for children under 10 kg. Health effects include irritability, aggressiveness, and hallucinations a lower doses, and permanent neurological damage that manifests as tremors, difficulty walking, and facial muscle spasms at higher doses. The highest levels observed here was at the easternmost tributary of the White River (2.28 g/L), which is over twice the advisory

level for children. The next highest was at the western tributary of the White River (0.606 mg/L). The source of these high manganese concentrations should be studied further.

Mercury- Mercury has an EPA MCL of 0.002 mg/L and is highly toxic. Its health effects include muscle weakness, loss of coordination, numbness in the hands and feet, skin rashes, anxiety, memory loss, trouble speaking, trouble hearing, and trouble seeing. Concentrations equal to or exceeding the EPA MCL were measured in both tributaries of the White River (0.0036 mg/L and 0.0021), White Horse Creek (0.0167 mg/L), Porcupine Creek (0.002 mg/L), the Potato Creek tap water (0.0031 mg/L), Cherry Creek (0.0027 mg/L), and the Mni Wiconi intake at the Missouri River (0.002 mg/L). Several others are just below the threshold, including the White River (0.0019 mg/L), White Clay Dam (0.0019 mg/L), No Flesh Creek (0.0019 mg/L), and the Belle Fouche River (0.0019 mg/L). White Horse Creek is 8x the EPA MCL, and is of immediate concern, as are the Mni Wiconi intake on the Missouri River and the tap water at Potato Creek because they're public water supplies. All of the sites exceeding the EPA MCL should be sampled again, the mercury hazard more clearly defined, and the source of the Mercury identified.

Molybdenum- There is no EPA MCL for molybdenum, but there is an establish health advisory of 0.08 mg/L for children <10 Kg. Molybdenum toxicity causes impaired copper metabolism and deficiency in humans. In high doses molybdenum causes stunted growth, kidney failure, infertility, and diarrhea in animals. The highest level observed in these samples was in the western tributary of the White River (0.0497 mg/L), with the next closest being the eastern tributary of the White River (0.0142 mg/L). While well below the advisory level, long-term or high consumption (like swimming in it every day) can approach toxic levels in children.

Potassium- There is no EPA MCL for potassium, and it is generally considered non-toxic. It has negative health effects at 2.3 g/Kg similar to that of sodium chloride, or common table salt. At these levels, common symptoms include nausea, vomiting, cramps, and diarrhea. In the samples described here, the highest levels were in the White River tributaries (27.7 mg/L and 26.1 mg/L), far below the levels where health is impacted. It is not a regulatory or health concern.

Lanthanum- Lanthanum has no biological role in humans, is non-toxic, and therefore has no EPA MCL.

Lithium- There is no EPA MCL and is generally considered non-toxic in environmental doses. However, 900-1200 mg/day are used to treat depression and suppress suicidal tendencies. In the samples described here, the highest levels were in Cherry Creek (0.7669 mg/L), far below the therapeutic dose, and is therefore not a health concern.

Sodium- There is no EPA MCL for sodium, and it is generally considered non-toxic. It has negative health effects at 2.3 g/Kg. At these levels, common symptoms include nausea, vomiting, cramps, and diarrhea. In the samples described here, the highest levels were in the Cheyenne River (117 mg/L), the White River (107 mg/L) and its tributaries (115 mg/L and 110 mg/L), and the Grand River (113 mg/L), well below the levels where the health of an individual with normal kidney function is impacted. It is not a regulatory concern, and likely not a health concern.

Phosphorus- Phosphorus has no EPA MCL, and is generally considered to be non-toxic in people with healthy kidneys, producing nausea, vomiting, and diarrhea in high doses. However, in people with severely compromised kidneys, or in people who can't properly metabolize calcium, it can cause hardening of the organs and soft tissues. The highest observed concentrations were in the Little White River (0.456 mg/L) and White Horse Creek (0.154 mg/L), and is not a health concern.

Sulfur- Sulfur (sulfate) does not have an EPA MCL. However, it does have a Secondary Drinking Water Regulation limit of 250 mg/L (largely to control odor) and is generally considered non-toxic in people (indigestion and diarrhea at the worst). In animals, however, it is toxic and can be fatal. The highest levels measured were in the Cheyenne River (190 mg/L), tributaries of the White River (219 mg/L and 131 mg/L), the Belle Fourche River (169 mg/L), the Grand River (131 mg/L), the Moreau River (276 mg/L), and Cherry Creek (493 mg/L). Ranchers in these areas should closely monitor their livestock and local wildlife.

Silicon- Silicon has no EPA MCL, is thought to be chemically inert within human physiological limits, and is therefore considered non-toxic.

Strontium- Strontium does not have an EPA MCL, but it does have a Health Advisory limit of 25 mg/L for children <10kg. It is considered stable at surface temperatures and pressures and within human physiological limits. However, it has highly radioactive isotopes that will accumulate in the bones of small children and cause cancer. The highest concentration observed in these samples was in the Belle Fouché River (4.63 mg/L), but it is low enough to be unlikely to cause health concerns. It should be noted that like uranium, strontium's radioactive isotopes can accumulate in the body over time, and the risk increases with age and continued consumption. As with all radionuclides, there is a risk for early fetus birth defects.

Titanium- Titanium has no EPA MCL, can be tolerated by the human body, and is therefore considered to be non-toxic. It occurs in very small amounts (0.0005-0.0078 mg/L) in the sampled surface water, and none was detected in the Cheyenne River.

Vanadium- Vanadium has no EPA MCL, can be tolerated by the human body when ingested, and is therefore considered to be non-toxic. It occurs in very small amounts (0.0008-0.0087 mg/L) in the sampled surface water.

Zinc- Zinc does not have an EPA MCL but does have a Health Advisory limit of 6 mg/L for children <10 kg. Toxic exposure of over 50 mg has been observed during overdoses of dietary supplements, and results in acute deficiency of other essential nutrients like iron and copper. Otherwise, it is considered non-toxic in people. It is toxic, however, to bacteria, plants, invertebrates, and fish.

Zirconium- There is no EPA MCL for zirconium, and it is generally considered non-toxic by ingestion. If powdered and inhaled, however, it is a corrosive lung irritant.

On the question of escaped lixiviant and other mining fluids

The in-situ leach mining process requires an underground uraniferous aquifer sandwiched between two intact aquicludes (at best) or aquitards (at worst). Typically, the uranium in this aquifer is in a mineral form (often a sulfide) that has reached a stable equilibrium within the aquifer. That is to say that although the water within the uraniferous aquifer is saturated with uranium and other minerals, most of the uranium and minerals (called accessory or co-occurring minerals) exist as a solid mineral crust within the pore spaces of the grains that make up the aquifer. The mining process introduces a simple chemical, usually hydrogen peroxide or sodium bicarbonate (called lixiviant), that quickly oxidizes (rusts) the uranium and co-occurring minerals into a finely granular oxide that can be drawn out through boreholes (called pregnant lixiviant) for minimal processing on site.

One of the drawbacks of this process is that it also indiscriminately oxidizes many of the co-occurring minerals that are also in the aquifer, and these are also drawn out with the uranium. They are excluded during processing and typically remain in solution. They are continuously recycled through the extraction system until they reach saturations that interfere with the processing, at which point they are separated and discarded as toxic waste. However, any pregnant mining fluids that escape confinement also contain these co-occurring minerals, and in some cases, it may be possible to measure these escaped co-occurring minerals and tie them back to their mined source (Fetter & others 1999).

Uranium is typically formed in igneous and volcanic rocks such as granites, rhyolites, and volcanic ashes. It accumulates as a chemically precipitated sediment after extensive weathering of its igneous or volcanic source rock. In the case of the uranium deposits mined at Crow Butte and Dewey-Burdock, it is generally accepted that they are the result of the devitrification and weathering of the uranium-bearing volcanic ash (think of it as silt-sized granite and rhyolite particles) of the White River Group. Volcanic ashes are often hydrophilic (having an affinity for water) and readily dissolve in acidic groundwater or surface water. The uranium-laden acid water releases the uranium once it soaks into a host rock and comes in contact with alkali conditions.

This process produces roll-front deposits of uranium, like those assumed to be at Crow Butte and Dewey-Burdock. However, many other elements occur in mineral suites associated with the igneous and volcanic source rocks. Report suites of elements associated with uranium include phosphorous-titanium-zirconium-thorium (Klepper & Wyant 1957) and titanium-copper-vanadium-manganese-nickel-chromium-cobalt-molybdenum-phosphorus (Kohn 2003) associations. Using these known associations, and the fact that ISL mining typically liberates these elements from the mined orebody along with the mined uranium, we can look for traces of these suites of elements in groundwater and surface water.

In this section I'll examine the surface water analyses, the scientific literature, and the self-reported co-occurring mineral profiles provided by the licensing documents provided to the Nuclear Regulatory Commission for Crow Butte Resources (CAMECO) and the Dewey-Burdock Site (Powertech/Azarga).

Crow Butte Resources- The Crow Butte Resources ISL uranium mine is situated directly adjacent to tributaries of the White River east of Crawford, Nebraska, about 30 miles southwest of the southwestern corner of the Pine Ridge Reservation, west of the town of Pine Ridge, South Dakota (Fig. 1). The White River, after flowing northeast past Crawford and the Crow Butte ISL mine, flows directly northeast onto the Pine Ridge Reservation. It then continues to flow northeast across the reservation, exiting it near the northeastern corner near the town of Kadoka, South Dakota. In my earlier expert opinions in support of local landowners' and the Oglala Sioux Tribe's interventions, I opined that surface spills and undetected excursions could potentially toxify and render the Pine Ridge Reservations primary source of surface water unusable. Large surface spills resulting in fines and suspected discharges resulting in license conditions have been well documented (Issues at Operating Uranium Mines and Mills - USA on wise-uranium.org accessed on 2/19/2020), and first-hand (but unverified) observations of undetected excursions have been reported by local landowners (a dentist's tap water in town and an exploratory well 5 miles north of the monitoring wells circling the site's perimeter). However,

no verified excursions of pregnant lixiviant have yet been reported to the NRC or discovered by the public.

My comparison of the elemental contaminants in the sample surface waters described here to those recorded at Crow Buttes Resources is hampered by the poor baseline data provided by Crow Butte Resources. In the ongoing intervention against Crow Butte's ongoing mining, the inadequacy of the baseline data provided to the general public has been the source of several contentions and has been opined about expensively by Robert Moran, David Kreamer, Mikel Wireman, Linsey McLean, and myself. Crow Butte reported baseline levels of arsenic, barium, boron, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, potassium, radium 226, selenium, silica, sulfur, vanadium, and zinc. However, the detection limits of the analytical equipment is much higher (they used AA MS) than the ICP-MS used here, and in this case arsenic, cadmium, chromium, lead, nickel, selenium and radium were not analyzed.

Despite these omissions from this analysis, the remaining elements, including mercury, are present in the surface waters sampled. While the data is incomplete and I am unable to definitively connect these surface water contaminants to mining at Crow Butte, there is enough overlap within the two contaminant profiles that I cannot rule it out either. I recommend resampling and analysis of the missing elements, and an exhaustive attempt be made to eliminate other potential contaminants. For example, if no other potential source for mercury could be identified, then it becomes more likely that the high amounts of mercury in the environment derive from escaped pregnant lixiviant.

Dewey-Burdock Site- The Dewey-Burdock Site is situated directly adjacent to tributaries of the Cheyenne River, and surface spills are carried by high-flow runoff events directly from the site to the river. Also, based on groundwater flow mapping by the United States Geological Survey (Driscoll and others 2002), water in the vicinity of the Dewey-Burdock site flows S/SE along the southern edge of the Black Hills, and once into greater Fall River County, groundwater flow is due east. This report makes no mention of a groundwater divide or other circumstance that would

indicate isolation of groundwater within the Dewey-Burdock vicinity. The flow from north of Dewey-Burdock to the SW has been measured at 591 feet/day, but flow south of the site has been measured at 7,393 feet/day. Once eastward flow is established, it's been measured at 4,349 feet/day to the east at the SD-WY state line, then 1,463 feet/day to the east in northern Fall River County and 732 feet/day to the east in central and southern Fall River County. On average, flow from Dewey-Burdock towards Edgemont, Hot Springs, Buffalo Gap, Oelrichs, and the western border of the Pine Ridge Reservation is about 3,484 feet/day. The Pine Ridge Reservation (Oglala Lakota County) is 46 miles from the Dewey-Burdock site, which means contaminated water from Dewey-Burdock could travel to the Pine Ridge Reservation in 70 days. Edgemont would be affected in weeks, and Hot Springs would be reached in as little as 35 days (see LaGarry 2015a).

The Dewey-Burdock Project final EIS (accessed on [NRC.gov](http://www.nrc.gov) on 2/21/2020) lists several baseline contaminant concentrations in local surface waters and groundwater. The Dewey-Burdock final EIS reports extremely high values of sulfate, chloride, arsenic, and selenium, and radionuclides including uranium, radium 226, lead 210, polonium 210, and thorium 230. Of these, sulfur (sulfate) can be directly compared to our samples, but in this context sulfur is too ubiquitous to make a meaningful comparison. For their reported groundwater baseline contamination, the EIS states that 28 of 31 measured contaminants exceed EPA MCLs, but only directly reports values for arsenic, lead, uranium, radium 226, and gross alpha. These data are also insufficient to tie contaminants reported herein to the mine, but also does not preclude the possibility that leakage from this mine is contaminating the surface water I address herein. In order to make meaningful comparisons, I would need the measured values for all 31 contaminants recognized by the Dewey-Burdock Project. This incomplete reporting of baseline was opined about during the initial licensing hearing in 2015 (see citations of opinions cited above). It may be possible to use alpha spectrometry or a related method to link the particular radioactive isotopes reported in the EIS to the surface waters described here if we were able to directly measure the Dewey-Burdock mine fluids and compare them to directly measured isotopes in surface waters in western South Dakota.

DISCUSSION AND CONCLUSIONS

Based on my examination of the newly acquired surface water data accompanying this opinion and a review of the pertinent scientific literature (including ISL licensing documents for the Crow Butte Resources ISL mine near Crawford and the proposed ISL mine at the Dewey-Burdock site near Edgemont), I can draw the following conclusions:

- 1. The majority of the surface waters analyzed and describe here (14 of 16 sites) exceed the EPA MCLS for uranium, including all the major rivers and the Min Wiconi Coreline. In addition to being radioactive, uranium is also extremely toxic. Uranium alpha decay causes increased instances and severities of cancer primarily at blood-filtering or capillary-dense locations within the body, primarily the kidneys, pancreas, liver, and membranes surrounding the brain. Uranium toxicity attacks the kidneys, leading to renal failure and potentially death, and is a major cause of debilitating and potentially fatal birth defects (Irwin 1997).**
- 2. The majority of the surface waters analyzed and described here (11 of 16 sites), including the Mni Wiconi intake from the Missouri River and the Mni Wiconi tap water at Potato Creek, closely approach, equal, or exceed the EPA MCL for mercury. Mercury is extremely toxic, can lead to renal failure and possibly death, and has profound and debilitating effects on the human versus system.**
3. Several of the waterways examined here contain levels of barium, copper, magnesium, manganese, molybdenum, and strontium that approach health advisory levels for small children and require additional study and quantification.
4. Several of the major waterways north of the Black Hills have levels of sulfur that pose a danger to livestock and wildlife and require additional study and quantification.
5. A general lack of detailed reporting of baseline data necessary for meaningful evaluation of the potential risk of mining was one of the primary contentions through the ongoing intervention against which I and others opined about and provided testimony to the ASLB

for. Baseline data reported by Crow Butte Resources (Received renewal application on [NRC.gov](https://www.nrc.gov) accessed 2/22/2020) partially matches the elements analyzed in the samples reported here, including several of the problematic contaminants mentioned above including mercury. Additional research needs to be done to eliminate consideration of non-mining sources for these elements before mining at Crow Butte Resources can be tied to the observed contaminant levels reported here. Likewise, the partial list of elements omitted from this study cannot exclude escaped mine waste from being the source of these contaminants.

6. Baseline data reported by the Dewey-Burdock Project is incomplete (Environmental Impact Statement for the Dewey-Burdock Project in Custer and Fall River Counties, South Dakota: Supplement to the Generic Environmental Impact Statement for In-Situ Leach Uranium Milling Facilities [Chapters 1 to 5] on [NRC.gov](https://www.nrc.gov) accessed 2/21/2020), and a complete suite of elemental analyses (31 according to their EIS) is needed before meaningful comparison can be made. Historical mining and contemporary borehole drilling at Dewey-Burdock can therefore be neither confirmed nor ruled out as being contributors to the contaminant loads described here. However, the Dewey-Burdock EIS provides data for uranium, radium 226, lead 210, polonium 210, and thorium 230, which presents an opportunity for isotopic fingerprinting and detection of excursions of toxic mining fluids migrating from Dewey-Burdock into the surface waters of greater South Dakota.

BROADER IMPLICATIONS

The new data reported here is especially concerning, as it reveals how widespread uranium and mercury contamination are in South Dakota's surface waters. South Dakota DENR and the US NRC do not monitor uranium, but instead compile data from studies such as this one when formally published. The South Dakota DENR reported that, for the 2018 testing cycle, nearly all South Dakota lakes tested failed the EPA limit of 0.3 mg/kg for mercury in fish tissue (SD DENR 2018). Furthermore, their report attributes the high mercury concentrations to atmospheric fallout resulting from global industrial emissions. This assertion can be confirmed or refuted by comparing South Dakota's surface water mercury contamination to adjacent states.

In any case, toxic levels of uranium and mercury in surface waters impact the entire resident population of the state and are a burgeoning public health crisis.

I'm particularly concerned for the residents of western South Dakota and the Pine Ridge Reservation, because surface water use is seen by many as an alternative to contaminated groundwater. Large areas of western South Dakota where the Pierre Shale is at the land surface are entirely reliant of surface water supplies and shallow, thin floodplain deposits in direct contact with contaminated waterways. For these areas the reality is stark. The only accessible water is contaminated (LaGarry & Sanovia 2014).

The situation is, some ways, even worse for the areas of northwestern Nebraska and the Pine Ridge Reservation north of the Pine Ridge Escarpment for three reasons:

1. **Sources of fresh, clean water from local springs that feed the perennial rivers are decreasing and not being replaced and will eventually disappear altogether.** The Pine Ridge Escarpment marks the northernmost edge of the High Plains (formerly Ogallala) Aquifer. The springs along this escarpment represent leakage from the High Plains Aquifer and are the headwaters for the vast majority of the Reservation's rivers and creeks. This includes Ash Creek, Whiteclay Creek, Chadron Creek, White River, Porcupine Creek, Wounded Knee Creek, White Horse Creek, the Little White River, and No Flesh Creek). As agricultural operations continue into the future, water levels within the High Plains Aquifer will continue to drop in Nebraska (40% consumed) just as they have in Texas (90% consumed), Oklahoma (75% consumed), and Kansas (60% consumed). Tributaries of Chadron Creek, Ash Creek, and Hat Creek have already stopped flowing altogether for this reason (Balmat & others, Butterfield & others 2008).
2. **The vast majority of available groundwater is located in contaminated shallow alluvial aquifers and the Chamberlain Pass Formation, which is mined for uranium.** Most of western South Dakota apart from the Black Hills and Pine Ridge Reservation are underlain by the Pierre Shale, which is an aquiclude — it neither contains water nor allows water to

soak through. At the Nebraska border its thickness is estimated at about 2000 feet but is even thicker in the central part of the state, as it is significantly closer to the Black Hills. In most cases, municipalities and residences cannot drill through it hoping to find water even deeper underground. In fact, the Pierre Shale is so thick and isolated from aquifers below it, vaults are built deep within it to store radioactive medical waste, and in some places deep underground toxic chemical waste disposal wells. In the case of the Pine Ridge Reservation, if a community or residence is at or below the level of the sandstone cliffs of the Pine Ridge Escarpment, drilling downwards for water first passes through the Brule and Chadron formations, which are aquitards (sometimes contains a little water, or allows a little to soak through), followed by the uraniumiferous aquifer called the Chamberlain Pass Formation, followed by the 2000-foot thick aquiclude, the Pierre Shale. To the best of my knowledge, this is true across the entire region underlain by these formations (Swinhart & others 1985).

3. **Underground aquifers are being mined and not replenished, and as a result, contaminant concentrations are increasing.** Based on all available evidence, most groundwater on the Great Plains, including the High Plains Aquifer, is having its water pumped out at rates far faster than its being replenished. For example, in 2007, water levels in the High Plains Aquifer near Alliance, Nebraska were lowered as much as 26 feet. In the same year, rainfall recharged the aquifer in that area only a few tenths of an inch. The only notable exceptions are the Sand Hills in Nebraska (they reach into South Dakota a few tens of miles in some places), and narrow, ribbon-like shallow alluvial aquifers in direct contact with contaminated rivers. Unfortunately, in western South Dakota and the Pine Ridge Reservation, a large percentage of the land surface is underlain by aquicludes and aquitards, and even minimal recharge is impossible without significant amounts of secondary porosity (Balmat & others 2008, Butterfield & others 2008).
4. **Natural exchanges of water between the surface and groundwater, which might dilute contaminants, cannot help if both are contaminated.** Many state and local governments maintain the outdated and disproven view that surface water and groundwater are isolated from each other and should be managed separately, or rely on “as needed” basis. In reality, aquifers are rocks, and rocks in tectonically active areas (in this case, the Rocky Mountain

ranges and the Black Hills) are fractured and faulted. Also, areas with large caves have large numbers of tiny caves (called breccia pipes). Collectively, these are called “secondary porosity” (Fetter & others 1999). Secondary porosity allows recharge of groundwater by surface water, and recharge of surface water by groundwater by artesian conditions or when the surface water is down gradient from the groundwater. For the Pine Ridge Reservation, this is a conundrum. If the ISL uranium mines are correct, and the Chamberlain Pass Formation is confined by aquitards, it is essentially cut off from freshwater recharge and is an underground storage tank saturated with toxic metals and radionuclides. If the Chamberlain Pass Formation is unconfined, like I have repeatedly opined in the past, then surface recharge may be happening, but only exacerbating the contaminant problem. Also, if my past opinions are correct, there’s a strong possibility that artesian flow is bringing contaminants up to the surface and polluting surface waters like it does along the Whiteclay Fault west of Pine Ridge (Botzum & others 2011, Bhattacharrya & others 2012).

5. **Drilling additional wells into the same contaminated aquifers simply provides more opportunities for more people’s health to be eventually compromised.** I call this “the illusion of potable water” because in most cases, and as is the case where I live in Nebraska, initial flows from a contaminated aquifer may test below EPA MCLs, but within a short time the clean water is drawn off and replaced by deeper, more contaminated water. Without uncontaminated recharge, contaminant concentrations slowly rise over a few years to toxic MCL levels. Toxic contaminant will continue to increase until equilibrium with the mineral contaminants in the rock or continue to increase until the water is saturated with toxic contaminants and can’t dissolve more (Fetter & others 1999).
6. **Local tectonism opens and closes secondary porosity in ways we are unable to predict.** In 2007 a 3.1 magnitude earthquake, lasting 30 seconds, opened up a fracture that had previously been closed, and the entire perennial flow of Chadron Creek disappeared into the ground. This effectively “turned off” Chadron’s surface water supply, and the community of 5,800 people had to find an alternate source of water. Chadron now uses a set of abandoned irrigation wells on the Hartville Table 20 mile south of town and pipes the water in. In many of my prior opinions, and in testifying before the Atomic Safety and Licensing Board, I have

opined that a similar situation could occur with any additional earthquake (there are 3-4 each and every year) anywhere in the region, with the potential for transmission of water in either direction (up or down). Water transported up will almost certainly be contaminated (Botzum & others 2011, Bhattacharyya & others 2012).

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SIGNATURE

The information contained herein is true and correct to the best of my knowledge at the time of this writing on 24 February, 2020.

A handwritten signature in black ink, reading "Hannan LaGarry". The signature is written in a cursive style with a large, looping initial 'H' and a long, sweeping tail on the 'y'.

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Quanti-scan :

Sample #	Date Sampled	Sample Type	Uranium mg/L	Uranium ppb	Silver mg/L	Aluminum mg/L	Gold mg/L	Boron mg/L	Barium mg/L	Calcium mg/L	Cesium mg/L
01062020-00001	01/03/20	CR2020-1	0.055	55.4	0.0010	0.0019	0.0046	0.1321	0.0903	141	0.0157
01062020-00002	01/03/20	WR2020-2	0.064	63.9	0.0006	0.0005	0.0044	0.1642	0.2570	108	0.0107
01062020-00003	01/03/20	WR2020-3	0.107	107.0	0.0009	0.0008	0.0112	0.1716	0.0587	185	0.0069
01062020-00004	01/03/20	WR2020-4 ^{HEL}	0.108	108.2	0.0006	0.0009	0.0397	0.4896	0.0793	106	0.0148
01062020-00005	01/03/20	WC2020-5	0.038	38.2	0.0002	0.0014	0.0025	0.0450	0.2831	75.2	0.0184
01062020-00006	01/03/20	LWR2020-6	0.032	32.4	0.0002	0.0024	0.0021	0.0422	0.3445	72.8	0.0232
01062020-00007	01/03/20	WK2020-7	0.042	41.9	0.0003	0.0011	0.0010	0.0413	0.2641	75.9	0.0059
01062020-00008	01/03/20	WH2020-8	0.050	50.1	0.0005	0.0011	0.0088	0.0740	0.2402	87.3	0.0103
01062020-00009	01/04/20	PC2020-9	0.047	46.7	0.0006	0.0012	0.0062	0.0594	0.2466	72.2	0.0203
01062020-00010	01/04/20	NF2020-10	0.033	32.5	0.0000	0.0016	0.0011	0.0637	0.2949	77.2	0.0148
01062020-00011	01/04/20	POT2020-11	0.028	27.7	na	0.0015	0.0023	0.0902	0.0595	63.5	0.0183
01062020-00012	01/04/20	BF2020-12	0.049	49.1	0.0019	0.0013	0.0032	0.1015	0.0656	166	0.0143
01062020-00013	01/05/20	GR2020-13	0.025	24.7	0.0004	0.0018	0.0022	0.2751	0.0787	49.5	0.0178
01062020-00014	01/05/20	MOR2020-14	0.045	45.5	0.0010	0.0017	0.0065	0.2073	0.0856	92.3	0.0173
01062020-00015	01/05/20	CCR2020-15	0.053	53.3	0.0012	0.0008	0.0031	0.2296	0.0695	151	0.0082
01062020-00016	01/06/20	MW2020-16	0.031	30.5	0.0000	0.0014	0.0039	0.0794	0.0720	63.3	0.0090

Sample #	Date Sampled	Sample Type	Copper mg/L	Iron mg/L	Mercury mg/L	Potassium mg/L	Lanthanum mg/L	Lithium mg/L	Magnesium mg/L	Manganese mg/L	Molybdenum mg/L
01062020-00001	01/03/20	CR2020-1	0.0046	0.0186	0.0008	13.8	0.0635	0.1487	23.8	0.0431	0.0058
01062020-00002	01/03/20	WR2020-2	0.0029	0.2278	0.0019	15.2	0.0582	0.1376	15.8	0.2543	0.0058
01062020-00003	01/03/20	WR2020-3	0.0049	0.5310	0.0036	27.7	0.0665	0.2222	21.9	0.6061	0.0497
01062020-00004	01/03/20	WR2020-4 ^{HEL}	0.0033	0.1074	0.0021	26.1	0.0559	0.2013	17.5	2.2845	0.0142
01062020-00005	01/03/20	WC2020-5	0.0026	0.1049	0.0019	9.14	0.0524	0.0517	8.24	0.0299	0.0011
01062020-00006	01/03/20	LWR2020-6	0.0023	0.4904	0.0008	20.2	0.0541	0.0556	9.72	0.2570	0.0002
01062020-00007	01/03/20	WK2020-7	0.0014	0.0945	0.0014	12.0	0.0508	0.0490	7.68	0.0363	0.0013
01062020-00008	01/03/20	WH2020-8	0.0020	0.0907	0.0167	17.6	0.0534	0.1025	10.0	0.3651	0.0029
01062020-00009	01/04/20	PC2020-9	0.0019	0.2948	0.0020	11.3	0.0521	0.0704	9.65	0.2470	0.0019
01062020-00010	01/04/20	NF2020-10	0.0016	0.1064	0.0019	9.61	0.0534	0.0448	6.38	0.0876	0.0005
01062020-00011	01/04/20	POT2020-11	0.0493	0.0176	0.0031	6.22	0.0455	0.0964	14.6	0.0303	0.0019
01062020-00012	01/04/20	BF2020-12	0.0012	0.1770	0.0019	6.57	0.0648	0.1086	24.6	0.0854	0.0081
01062020-00013	01/05/20	GR2020-13	0.0036	0.0589	0.0016	14.0	0.0369	0.0758	19.0	0.0376	0.0073
01062020-00014	01/05/20	MOR2020-14	0.0041	0.2053	0.0004	11.0	0.0535	0.4061	26.0	0.2214	0.0038
01062020-00015	01/05/20	CCR2020-15	0.0026	0.1278	0.0027	16.3	0.0644	0.7669	26.5	0.2055	0.0005
01062020-00016	01/06/20	MW2020-16	0.0044	0.0728	0.0020	6.13	0.0460	0.0970	14.8	0.2411	0.0019

Sample #	Date Sampled	Sample Type	Sodium mg/L	Phosphorus mg/L	Sulfur mg/L	Silicone mg/L	strontium mg/L	Titanium mg/L	Vanadium mg/L	Zinc mg/L	Zirconium mg/L
01062020-00001	01/03/20	CR2020-1	117	na	190	4.83	3.30	na	0.0030	0.0020	0.0007
01062020-00002	01/03/20	WR2020-2	107	0.0355	76.7	27.8	1.95	0.0019	0.0067	0.0022	0.0027
01062020-00003	01/03/20	WR2020-3	115	0.0964	219	20.6	2.98	0.0005	0.0038	0.0195	0.0016
01062020-00004	01/03/20	WR2020-4 ^{HEL}	110	0.0415	131	25.2	2.37	0.0012	0.0037	0.0014	0.0006
01062020-00005	01/03/20	WC2020-5	33.9	0.0165	6.63	29.8	1.12	0.0031	0.0087	0.0021	0.0002
01062020-00006	01/03/20	LWR2020-6	71.2	0.4561	18.2	34.2	0.6890	0.0078	0.0071	0.0048	0.0048
01062020-00007	01/03/20	WK2020-7	38.7	0.0880	9.50	32.1	0.8545	0.0037	0.0041	0.0011	0.0010
01062020-00008	01/03/20	WH2020-8	86.2	0.1543	22.9	40.1	1.38	0.0012	0.0015	0.0010	0.0004
01062020-00009	01/04/20	PC2020-9	75.0	0.0836	13.1	31.9	1.24	0.0029	0.0074	0.0024	0.0009
01062020-00010	01/04/20	NF2020-10	73.3	0.0925	7.02	34.7	0.8434	0.0026	0.0041	0.0019	0.0012
01062020-00011	01/04/20	POT2020-11	80.9	na	46.9	3.37	0.9523	0.0006	0.0024	0.0073	0.0003
01062020-00012	01/04/20	BF2020-12	85.3	0.0036	169	5.26	4.63	0.0015	0.0039	0.0014	0.0004
01062020-00013	01/05/20	GR2020-13	113	0.0012	131	0.2455	1.01	0.0025	0.0048	0.0018	0.0014
01062020-00014	01/05/20	MOR2020-14	98.8	0.0034	276	4.26	1.91	0.0028	0.0020	0.0056	0.0013
01062020-00015	01/05/20	CCR2020-15	96.1	0.0041	493	3.31	3.44	0.0013	0.0026	0.0012	0.0015
01062020-00016	01/06/20	MW2020-16	81.4	na	48.5	3.64	0.9735	0.0009	0.0008	0.0020	0.0003

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 2/27/20