Memo

Date: Sunday, July 28, 2024

To: Lori Myott, Lansing Board of Water & Light

From: Lara Zawaideh, HDR Michigan, Inc.

Subject: Erickson Power Station CCR Units

Ash and Groundwater Isotope Investigation

The U.S. Environmental Protection Agency's (EPA) final Coal Combustion Residuals (CCR) Rule 40 CFR §257 and Michigan's Part 115 Solid Waste Management, of the Natural Resources and Environmental Protection Act, 1994 PA 451 (Part 115), establishes a comprehensive set of requirements for the management and disposal of CCR (or coal ash) in surface impoundments by electric utilities. The Lansing Board of Water & Light (BWL) Erickson Power Station (Erickson) contains a single coal-fired generator that was capable of producing 165 megawatts of electricity. It was permanently shut down November 2022. Erickson has three regulated CCR impoundments: the Forebay, Retention Basin, and Clear Water Pond (CWP) (**Figure 1**). The three CCR impoundments are currently inactive. The BWL is in the process of investigating the groundwater impacts from the CCR Impoundments and evaluating corrective measures alternatives for Erickson.

BWL has completed numerous tasks to further characterize the potential impact to groundwater for the assessment of corrective measures at Erickson. In 2023, one of those tasks was the sampling and analysis of isotopes in groundwater and ash to evaluate if isotopes could help distinguish naturally occurring boron from ash impacted groundwater. There is groundwater literature for the Lansing area that has demonstrated the presence of naturally occurring boron associated with the shale groundwater aquifer (Rowe, 1999; Rowe et al., 2021; Rowe, 2022; Slayton, 1982; Ravenscroft and McArthur, 2004). The bedrock aquifer beneath Erickson Station and also in the area of private wells that were sampled by BWL has shale and sandstone lithology. The isotopic signature of boron coming from coal ash is typically different from naturally occurring boron, which means it has the potential to be used as a tracer (Ruhl et al, 2014). Knowing that there is potential for the boron concentrations observed in bedrock groundwater to be from naturally occurring sources and not the CCR impoundments, the waters were analyzed for isotopic ratios to evaluate if there was a different isotopic signature of naturally occurring boron in the shale of the Saginaw aquifer versus boron in the shallow groundwater from the Erickson CCR impoundments.

This data was first presented in the July 2023 Erickson Power Station Semiannual Progress Report for Selection of Remedy per 40 CFR §257.97(a); however, after receipt of comments from EGLE, this memo provides more detail for the isotope analyses.

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Figure 1. CCR Units and Monitoring Wells

Methods

BWL sampled monitoring wells in February 2023 for assessment monitoring and the boron concentrations from that sample event were used for the data table and graphing in **Table 1** and **Figure 2**. The assessment monitoring groundwater is analyzed by Merit Laboratory. The laboratory reports are attached as **Attachment A**. Additionally in March 2023, 12 wells plus two duplicate samples were sampled to collect groundwater for isotope analysis and submitted to Covalent Metrology of Sunnyvale, California. Wells chosen to be sampled were collected from select glacial wells and bedrock background wells to represent the different conditions at the site, glacial versus bedrock groundwater, background groundwater, and wells that have been observed to be impacted by the CCR impoundment versus (e.g. downgradient of the CCR impoundments and multiple CCR constituents of interest with statistically significant exceedances of groundwater protection standards):

- Glacial Background Groundwater: MW-11, MW-12
- Glacial Impacted Groundwater: MW-2, MW-7, MW-7C
- Glacial Unimpacted Groundwater: MW-16A, MW-16B
- Bedrock Background Groundwater: MW-11B, MW-12B
- Bedrock Groundwater: MW-7B, MW-16C, MW-16D

In March 2023 ash was sampled from the Forebay and CWP CCR impoundments before impoundment closure was initiated. Two water samples were prepared from the ash from each impoundment, one leachate was prepared via Synthetic Precipitate Leaching Procedure (SPLP, SW-846 Method 1312), and one was prepared via centrifuge to capture pore water from the ash sample. Ash samples were submitted to Merit Laboratory for leachate/pore water preparation before submittal to the isotope laboratory. Due to miscommunication with the laboratory, the leachate and pore water samples were not analyzed for boron prior to shipment to Covalent. Therefore, the boron concentrations used in Table 1 are from the solids analysis of ash from the Forebay and CWP. Three ash samples from the Forebay had total boron concentrations ranging between 123 and 150 milligrams per kilogram (mg/kg), with an average of 132.7 mg/kg; and three ash samples from the CWP had concentrations of boron between 40.9 and 48.7 mg/kg with an average of 44.7 mg/kg. In order to convert the total solid concentration to a maximum leachate concentration, the “Rule of 20” is used where the leachate from a solid is typically assumed to be approximately 20 times less the solid concentration. Using the average total boron ash concentration and the “Rule of 20”, the Forebay and CWP coal ash leachate was estimated to be 6,630 and 2,240 ug/L, respectively (**Table 1**).

Groundwater and ash leachate and pore water samples were submitted under Chain of Custody to Covalent Metrology of Sunnyvale, California. Samples were analyzed for ^{7}Li, ^{11}B, ^{87}Rb, ^{86}Sr, $^{11}B/^{10}B$, and $^{87}Sr/^{86}Sr$. This memorandum is focusing on the boron isotopic results because there is more literature available regarding the boron isotopes in CCR than the lithium and strontium

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results. Covalent used calibration against Inorganic Ventures 71A standard, a 43 element ICP calibration standard, with a boron isotope distribution of 4.089. The B10 and B11 ratios were calibrated by ion counts on the respective m/z lines given the total boron concentration of the standard and the isotope distribution. Covalent Laboratory boron isotope results are in **Table 1** and the laboratory report is included in Attachment A. Samples identified as MWF-12B and MWT-16-A in the covalent report are field duplicate samples for groundwater samples from MW-12B and MW-16A. The reported $^{11}B/^{10}B$ ratios are included in **Table 1** as are the δ11B values. Boron isotopic composition is typically reported as $\delta^{11}B$, which is the $^{11}B/^{10}B$ ratio of a sample relative to the $^{11}B/^{10}B$ ratio of the laboratory standard. The δ11B calculation is:

$$\delta^{11}B=\{[(^{11}B/^{10}B)_{sample}-(^{11}B/^{10}B)_{standard}]/(^{11}B/^{10}B)_{standard}\}*1000$$

These **Table 1** reported values are graphed in **Figure 2**.

Table 1. Boron Isotope Results and Boron Concentrations

Sample I.D.	Covalent Lab I.D.	Aquifer or Impoundment	^{11}B (ng/ml)	($^{11}B/^{10}B$) (ng/ml)	δ(11B)	Boron Concentration February 2023 (ug/L)
Boron Standard		--	--	4.089	--	--
MW-2	MW-2 3-22-23 1140	Glacial Impacted	4180	4	-21.77	5100
MW-7	MW-7 3-21-23 1732	Glacial Impacted	1720	4.02	-16.87	1360
MW-7B	MW-7B 3-21-23 1830	Bedrock	3110	4.15	14.92	3000
MW-7C	MW-7C 3-21-23 1926	Glacial Impacted	6440	4.03	-14.43	6460
MW-11 (Bckg)	MW-11 3-22-23 1304	Glacial Background	143	4.06	-7.09	200
MW-11B (Bckg)	MW-11B 3-22-23 1404	Bedrock Background	1100	4.11	5.14	820
MW-12 (Bckg)	MW-12 3-22-23	Glacial Background	71.9	4.12	7.58	70
MW-12B (Bckg)	MW-12B 3-22-23 1019	Bedrock Background	3610	4.16	17.36	3330
MW-16A	MW-16A 3-21-23 1108	Glacial Unimpacted	111	4.08	-2.20	210
MW-16B	MW-16B 3-21-23 1444	Glacial Unimpacted	153	4.09	0.24	120
MW-16C	MW-16C 3-21-23 1317	Bedrock	464	4.08	-2.20	400
MW-16D	MW-16D 3-21-23 1406	Bedrock	5040	4.14	12.47	4650
FB Ash 2 Pore Water	L303223-01A	Forebay	618	3.77	-78.01	6630
CWP Ash 2 Pore Water	L303223-02A	Clear Water Pond	1110	4.04	-11.98	2240
FB Ash 1 SPLP	L30322-01A	Forebay	1350	4.02	-16.87	6630
CWP Ash 1 SPLP	L30322-02A	Clear Water Pond	129	4.01	-19.32	2240

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Results

As shown in **Figure 2**, the CCR leachates had lower $\delta^{11}B$ (<-10‰), which is consistent with the literature study on boron isotopic characterization of CCR that showed CCR leachate were lower (Ruhl et al, 2014). Also shown in **Figure 2**, the $\delta^{11}B$ at glacial wells impacted by the CCR impoundments (MW-2, MW-7, and MW-7C) are also lower (<-10‰). Background wells (MW-11, MW-11B, MW-12, and MW-12B) and unimpacted glacial wells (MW-16A and MW-16B) have higher $\delta^{11}B$ (>10‰). Therefore, the data indicate that $\delta^{11}B$ higher than -10‰ appear to indicate naturally occurring boron. All of the bedrock wells sampled had $\delta^{11}B$ greater than -10 and had the highest measured $\delta^{11}B$ (-2.2 and 17.4‰) indicating that the boron isotopes in the bedrock groundwater are more similar to background groundwater and unimpacted groundwater than to coal ash pore water or leachate and impacted groundwater from the CCR units.

The $\delta^{11}B$ values reported in this study for shale bedrock groundwater (-2.2 and 17.4‰) are consistent with those reported by Noireaux et al., 2021 (between 2.2 and 17.4‰). It is recognized that this study did not use the same standards as those used in the cited studies and that may be a limitation in the direct comparison; however relative comparisons with this study and Ruhl show consistent results.

Ruhl et al., 2014 found that the $\delta^{11}B$ increased with depth in pore water at a CCR impacted lake, likely because ^{10}B may preferentially adsorb onto sediment as contamination moves through pores. Therefore, in addition to boron source, depth, distance from source, and lithology is also considered. For example, the positive $\delta^{11}B$ signal in MW-7B should be considered for increasing ^{10}B sorption with increasing depth, rather than a different source of boron.

MW-7C is screened in glacial silt above the bedrock and has a boron concentration (6.46 mg/L) that is elevated and appears to be elevated due to impact from the CCR impoundments, given that it also has high concentrations of other constituents of concern from the CCR, including calcium, lithium, molybdenum, sulfate, and TDS. Given the high boron concentration at MW-7C, if ^{10}B sorption were increasing with depth, it would be expected that the $\delta^{11}B$ value would be higher at MW-7C, which is not the case, the $\delta^{11}B$ value is the same as that from the ash leachate and appears to be further indication that the boron at MW-7C is from the CCR. Additionally, well MW-7B, which is at the same distance from the impoundments and is screened deeper in the shale bedrock has a boron concentration of 3.00 mg/L. If that boron were from the CCR impoundments rather than the shale, the $\delta^{11}B$ values would be unusually low (e.g. <-10‰), which is not the case. The $\delta^{11}B$ value at MW-7B is high, measured as the second highest $\delta^{11}B$ value measured at 14.9‰.

If an observed positive $\delta^{11}B$ signal could be due to increasing adsorption of ^{10}B to clay minerals in the shale or glacial materials, with depth and distance from the CCR source, it would be expected that there would be a difference between the upgradient and downgradient $\delta^{11}B$ signals in bedrock wells, which is not the case. All five of the bedrock wells had quite similar $\delta^{11}B$ values, regardless of their location upgradient or downgradient of the CCR impoundments, and regardless of the distance from the CCR impoundments. The $\delta^{11}B$ values were consistently the highest $\delta^{11}B$ values measured at Erickson and were between -2.2 and 17.4‰.

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Further, the two bedrock wells with the lowest $\delta^{11}B$ value also have the least shale in the well screened interval and the three wells with the highest $\delta^{11}B$ values (>12.5‰) also have the most shale in the well screened interval (80 to 100% of the screen is in shale).

Based on the groundwater flow direction flowing east under the impoundments and then turning north to follow Carrier Creek Drainage and not flow towards wells MW-16A-D, it is inappropriate to compare those wells with distance from the impoundments. But even if groundwater could get to MW-16D from the impoundments, and the boron concentration at MW-16D (4.65 mg/L) was from the CCR impoundments, it would be expected that other CCR constituents of concern would also be observed at MW-16D along with the boron, including calcium, lithium, molybdenum, sulfate, and TDS, which is not the case. These other CCR parameters are not observed at MW-16D, and the $\delta^{11}B$ at MW-16D is quite high, 12.4‰, similar to the glacial background wells, bedrock background wells, and unimpacted glacial wells. The only distance from the impoundments to the wells that could be compared would be MW-2 and MW-7, which are from approximately zero to approximately 370 feet from the Former Impoundment. Both of these wells have elevated concentrations of boron and additional CCR constituents of concern, making groundwater at both wells appear to be impacted from the CCR. Both MW-2 and MW-7 have negative $\delta^{11}B$ values, -21.8 and -16.9 respectively, similar to ash leachate (-12.0 to -78.0‰). The closer well to the impoundment (MW-2) has the higher concentrations of boron and the more negative $\delta^{11}B$ value (-21.8‰). With only two points it is difficult to determined if the slightly higher $\delta^{11}B$ value at MW-7 is the result of increasing adsorption of ^{10}B to clay minerals with distance from the CCR source.

The results of the isotope analysis at Erickson are generally consistent with the Ruhl et al. (2014) and show negative isotopic ratios in for coal ash leachate and known coal ash impacted groundwater. Based on this, the positive boron isotopic ratios reported in the bedrock wells support the hypothesis that the boron in the shale aquifer is naturally occurring.

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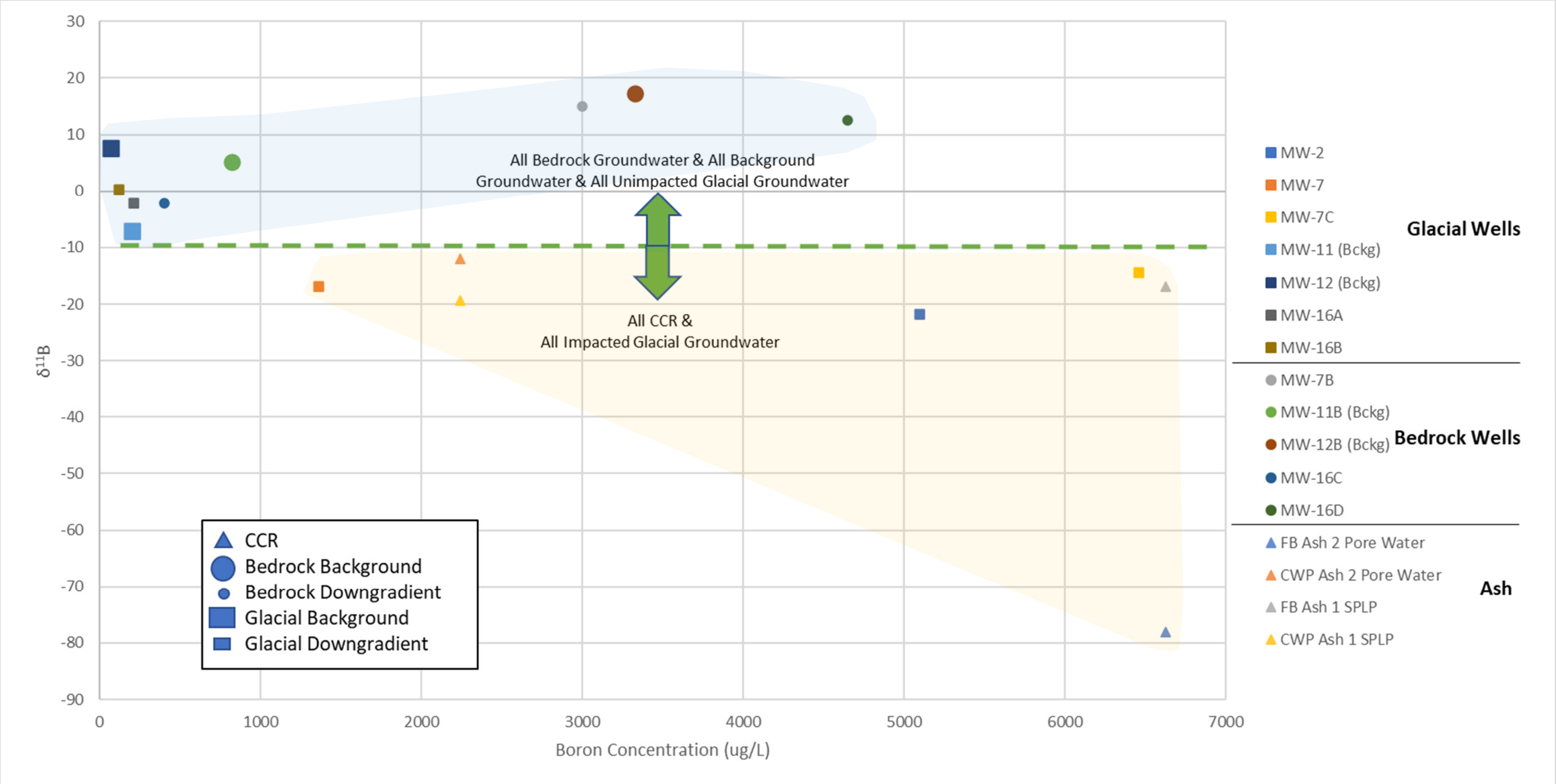

Figure 2. Boron Concentrations and Boron Isotope Ratios of Impoundment CCR, Groundwater from Erickson Wells in the Glacial Aquifer in Areas Known to be Impacted and Unimpacted by the CCR Impoundments, and Groundwater from the Bedrock Aquifer

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Attachment A

Laboratory Reports