Conceptual Site Model and Assessment of Corrective Measures

for Compliance with the Coal Combustion Residuals (CCR) Rule

Erickson Power Station

Prepare for: Lansing Board of Water and Light

Prepared by: HDR Michigan, Inc., Ann Arbor, Michigan

November 5, 2021

Contents

Appendices

Figures

Tables

Certification

Erickson Station Assessment of Corrective Measures Report

I hereby certify to the best of my knowledge that this assessment of corrective measures for the Erickson Power Station impoundments is an accurate demonstration of the potential corrective measures under consideration for the impoundments and is in general compliance with 40 CFR Part §257 of the Federal Coal Combustion Residuals (CCR) Rule.

I am duly licensed Professional Engineer under the laws of the State of Michigan.

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License Renewal Date 02/03/2024

1 Introduction

This assessment of corrective measures (ACM) was performed for groundwater conditions at the Lansing Board of Water & Light (BWL) Erickson Power Station (site, plant, station or Erickson) in Lansing, Michigan (Figure 1-1). The purpose of the assessment was to identify and evaluate potential groundwater corrective measures for the Forebay, Retention Basin and Clear Water Pond (CWP) bottom ash impoundments, showing benefits and limitations associated with each alternative. The corrective measure alternatives are evaluated with the goal of implementation to reduce groundwater concentrations to levels below the groundwater protection standards (GPS) developed for the site.

In accordance with 40 Code of Federal Regulations (CFR) §257.96(c), this assessment of corrective measures includes a preliminary analysis of the feasibility of potential corrective measures in meeting the requirements and objectives of the remedy as described under 40 CFR §257.97. Seven potential corrective measure alternatives were evaluated for the Coal Combustion Residuals (CCR) impoundments.

In order to assess the potential effectiveness and time to complete the remedy of each corrective measure alternative for the impoundments, HDR is developing a numerical groundwater flow and transport model for the site. The conceptual site model (CSM) is a narrative description of the hydrologic flow system that forms the basis of the numerical groundwater flow and transport model. This report describes the CSM for the site, the model objectives, model construction, and the model will be used to develop predictive simulations for each of the corrective measure alternatives being evaluated.

The purpose of numerical groundwater flow and transport modeling is to predict the groundwater flow and constituent transport that will occur as a result of different corrective measure alternatives at the impoundments. The study for the impoundments consists of three main activities:

- Development of a calibrated steady-state flow model of current conditions,
- Development of a transport model for constituents identified as constituents of interest (COIs),
- Preliminary simulation of transport for multiple corrective measure scenarios.

BWL is currently completing the calibration of the flow model as discussed herein and the flow and transport model will be calibrated before model simulations may be used to further analyze the alternatives and later select the appropriate remedies.

Figure 1-1. Erickson Power Station Vicinity Map

2 Background

Erickson Power Station has three CCR units that are the subject of this assessment: the Forebay, Retention Basin, and Clear Water Pond (CWP). These impoundments/ponds will be referenced together as the CCR Impoundments. (Figure 2-1).

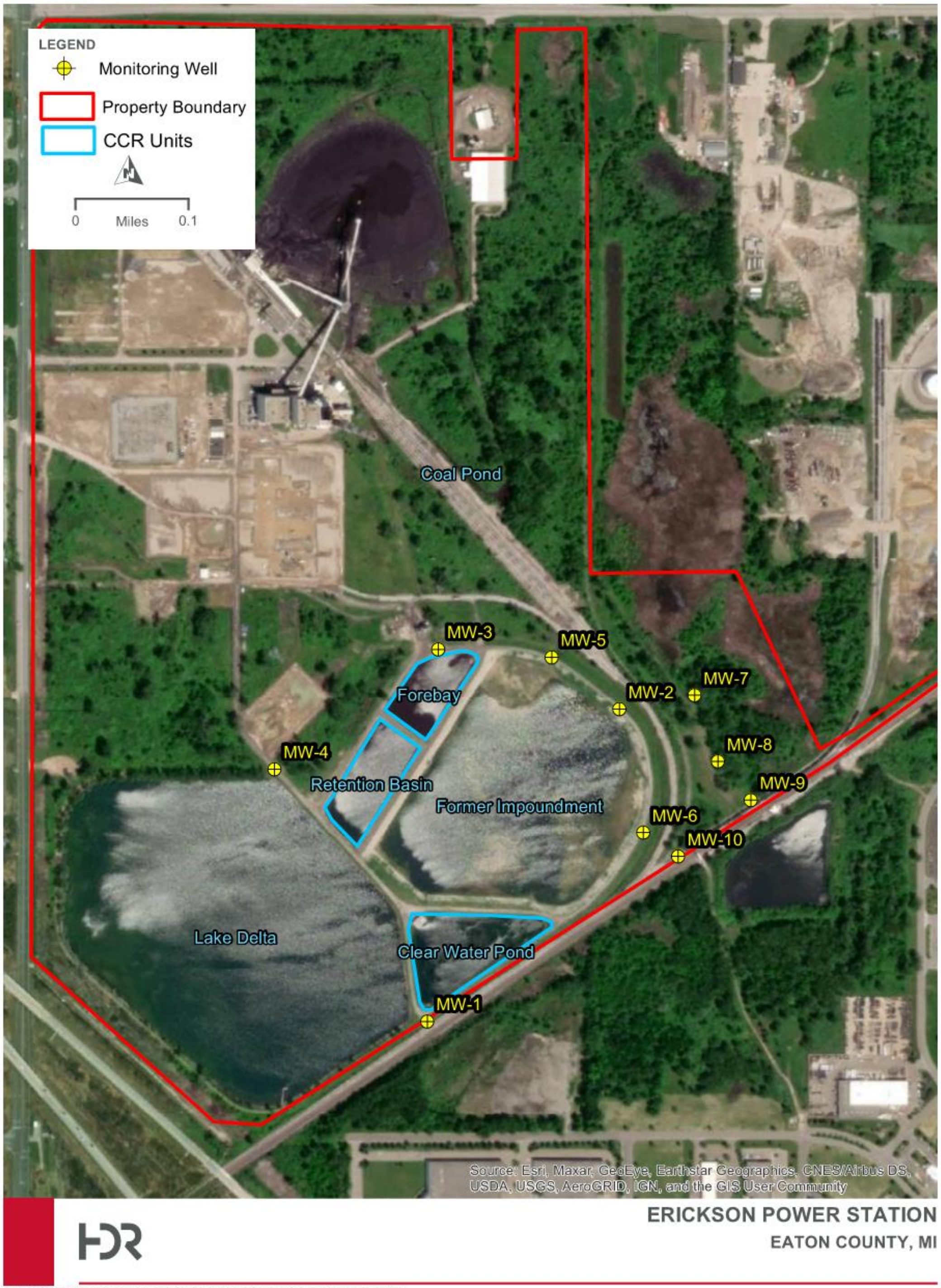
2.1 CCR Impoundments

For the CCR Impoundments detection monitoring water quality data collected in October 2020 were compared against the background threshold values (BTVs) as specified under CCR Rule §257.94, and statistically significant increases (SSIs) were identified. Groundwater monitoring was subsequently conducted for assessment monitoring as specified under 40 CFR §257.95 and Michigan Rule R 299.4441. GPS were established for the Michigan and Federal CCR compliance programs. Downgradient wells were found to have concentrations of lithium at statistically significant levels (SSLs) above the GPS for the federal groundwater compliance program, and boron, calcium, sulfate, total dissolved solids, lithium, and molybdenum at SSLs above the GPS for the Michigan groundwater compliance program. BWL will select, design, and implement a remedy for the impoundments based upon the corrective measures assessment herein.

From 1970 to 2014, fly ash and bottom ash were sluiced from the plant to a 33-acre impoundment. Water flowed to the CWP before returning to the plant for use. The 33-acre impoundment was physically closed in 2014 (CCR was removed from the impoundment and disposed off-site) and the Forebay and Retention Basin were installed within its footprint, leaving a 28-acre inactive area currently described as the Former Impoundment on Figure 2-1 and Figure 3-1. Currently, bottom ash from the coal-fired boiler is sluiced from the plant to dewatering tanks (hydro-bins). The dewatered bottom ash is trucked to a sanitary landfill and the decant water is hydraulically fed through the Forebay, Retention Basin, and then to the CWP to allow the minimal remaining CCR particles to settle out before returning to the plant. Fly ash is handled dry and collected in on-site silos. In addition to the flow from the hydro-bins, the CCR impoundments also receive non-CCR wastewater, including flows from the coal pile runoff sump and plant sumps.

The interior embankments and floors of both the Forebay and Retention Basin are lined with a layer of geosynthetic clay overlain with a 40-millimeter-thick flexible polyvinylchloride membrane liner (FML). Each FML is protected with geofabric and a 6- to 12-inch layer of sand. The tops of the embankments that are subject to wave action are protected with an additional layer of geofabric and 6 to 12 inches of stone riprap (MD&E, 2018). The tops of the interior embankments of the CWP are protected with approximately 6 inches of stone riprap. The CWP is lined with compacted clay. There are no regulated outfalls associated with the impoundment system. In addition to the three active CCR impoundments (Forebay, Retention Basin, and CWP), the site is bordered by Lake Delta on the southwest side (Figure 2-1).

These three active CCR impoundments, the Forebay, Retention Basin, and CWP, are subject to the U.S. Environmental Protection Agency's (EPA) CCR Rule (40 CFR Part §257) and Michigan Part 115 Solid Waste Regulations. In accordance with §257.91 and Michigan Part 115, BWL installed a groundwater monitoring network composed of ten monitoring wells around the CCR impoundments (Figure 2-1). Wells MW-1, MW-3, and MW-4 serve as background/upgradient wells and MW-2 and MW-5 through MW-10 serve as downgradient wells.



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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Figure 2-1. Erickson Power Station—CCR Units and Certified Monitoring Well Network

3 Conceptual Site Model

The CSM is a narrative description of the groundwater flow system that forms the basis of the numerical groundwater flow and transport model. The purpose of the CSM is to identify relevant hydrogeologic components of the local groundwater system, including inflows and outflows, to later translate this information into a numerical model that is representative of the physical processes within the groundwater system.

3.1 Climate

In the Tri-County region of Lansing (Clinton, Eaton, and Ingham counties) precipitation is the source of groundwater and surface water resources. In the region, mean precipitation ranges from a maximum of about 41.5 inches per year (in/yr) to about 22 in/yr (National Oceanic and Atmospheric Association (NOAA) Climate Database). Table 3-1 provides key climate characteristics such as temperature and precipitation by month. Precipitation is consistently distributed throughout the year; May is the month of highest mean precipitation (4.18 in), and February is the month of lowest mean precipitation (1.78 in). The Tri-County region averages about 40 in/yr of snowfall.

The groundwater model will use net recharge, which is a combination of rainfall and evaporation as one model variable. Typically, the net recharge is approximately 10% to 50% of rainfall. However, the net recharge variable may be modified to calibrate the model to actual measured monitor well water levels.

Table 3-1. Key Climate Characteristics at Erickson Power Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Average Temperature[1]	22.0	23.2	32.6	45.5	56.9	66.5	70.7	68.6	61.2	49.6	37.5	26.7
Monthly Average Precipitation[1]	1.98	1.78	2.06	2.97	4.18	3.99	2.89	3.48	2.88	3.45	2.50	2.02

[1] NOAA Online Weather Data (NOWData): https://w2.weather.gov/climate/xmacis.php?wfo=grr

3.2 Conceptual Site Model

3.2.1 Topography

The groundwater flow and transport model require a digital elevation model (DEM) file (or similar) to reflect the top boundary of the model. A topographic surface from a 2016 United States Geological Survey (USGS) survey was acquired from the USGS National Mapper Online Database. The USGS DEM was augmented with 2021 data from a bathymetric survey by Affiliated Researchers, Inc. to create a combined topographic surface. Once the combined topographic surface was completed, it was verified with the surveyed ground surface elevations at the onsite monitor wells. The surveyed elevations matched within tolerance to be appropriate for the geological and groundwater flow and transport model surface elevation.

3.2.2 Geology

The Tri-County region is underlain by unconsolidated clay, silt, sand, and gravel of glacial origin which rest upon about 10,000 feet of consolidated sediments deposited in ancient seas. The consolidated sediments are bedrock composed of limestone, shale, siltstone, sandstone, salt, and gypsum. The glacial deposits and the upper bedrock layers are important sources of fresh water in the region (Vanlier and others, 1969). Descriptions of the ash and soil fill and bedrock materials are presented below:

Glacial Deposits: The glacial deposits are composed of coarse alluvial and outwash deposits. The most extensive area of buried outwash deposits is in the northeastern part of Eaton County, where the Erickson Station is located. These areas of buried outwash the source of groundwater supply for wells; however, most wells in these areas are completed in deeper, bedrock aquifers because of the better-quality water available. **Appendix A** contains cross sections that summarizes the lithologic depths observed in onsite monitoring well drilling. The depth to the uppermost aquifer under the impoundments is determined to be approximately 6 to 20 feet below surface. Given the bedrock surface between 36 and 61 feet below surface, the upper glacial aquifer thickness at the Site is approximately between 16 and 47 feet thick. This data was used in the development of the model layer thicknesses.

Jurassic “Red Beds”: The Jurassic “red beds” separate bedrock from glacial deposits in some areas of the Lower Peninsula. The “red beds” consist of primarily clay, mudstone, siltstone, sandstone, shale, and gypsum and are relatively impermeable and considered a confining unit impeding vertical flow of water between glacial and bedrock aquifers (Westjohn and others, 1994). According to Westjohn and others (1994), this confining unit is entirely absent or only marginally present in the Tri-County region. Based on the site production well logs and geotechnical reports there is no evidence suggesting the presence of a confining unit separating the Saginaw aquifer from the shallow glacial aquifer on the site; therefore, in the groundwater flow model no confining unit will be modeled between the units of the glacial deposits and the Saginaw Formation

Bedrock: The glacial deposits of Pleistocene age overlie Pennsylvanian and Mississippian bedrock units in Eaton County. The Jurassic “red beds” which separate Pennsylvanian rocks from glacial deposits in some areas of Michigan are relatively impermeable and are considered a confining unit; however, the “red beds” are mostly absent in this region (Westjohn and others, 1994). The Pennsylvanian bedrock is composed of sandstone, shale, coal, and limestone in units that have been formally subdivided into two formations. The uppermost massive, coarse-grained sandstones form the Grand River Formation; remaining Pennsylvanian rocks are considered part of the underlying Saginaw Formation (Westjohn and others, 1994).

In Eaton County, erosion removed most of the Grand River Formation, and as a result only a few large remnants remain (Vanlier and others, 1973). These assignments between formations are somewhat uncertain, however, because no lithologic differences or stratigraphic horizons mark a change from one formation to the next (Westjohn and Weaver, 1996a). The Pennsylvanian bedrock unit ranges in thickness from 0 to over 400 feet.

HDR reviewed available boring logs from geotechnical studies and boring logs from well installations. HDR reviewed available studies, gathered and interpreted the boring logs to consolidate the logged lithologies into units for use in developing the conceptual site model and framework for the groundwater model in MODFLOW. In addition to existing boring logs from monitoring well installation, HDR reviewed geotechnical borings completed on the property, and an additional eleven wells from the Michigan well database to confirm the accuracy of the large-scale geologic interpretations (Table 3-1).

Geologic cross sections through the CCR Impoundments were prepared in ArcMap. The geologic interpretations presented on the cross sections are based on the subsurface conditions encountered in exploratory borings, historical descriptions of the construction of the impoundments, measurements of the cover fill berms, and review of aerial photographs. The cross sections provided in Appendix A represent lithologies that have been consolidated into hydrostratigraphic units for groundwater modeling.

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 3-1. Geotechnical and Monitoring Well Borings Containing Lithologic Data for Use in Developing the Geologic Framework for the Groundwater Model

3.2.3 Groundwater Flow System

Water level data has been collected in monitoring wells since October 2019. With the addition of four new wells in June 2021, water level data was collected by BWL staff in monitoring wells within the CCR monitoring network June 2021 (Table 3-2).Figure 3-2 provides Monitoring Wells Hydrographs and Figure 3-3 provides the potentiometric surface under the CCR Impoundments. The groundwater flow direction is east-northeast.

Water levels in Lake Delta have been measured in the past by BWL staff and will be collected weakly for the foreseeable future. In July of 2021 the water elevation was observed at 882 ft above mean sea level (AMSL).

Table 3-2. Water Elevation Data Collected in Monitoring Wells Within the Modeling Boundaries

Well ID	June 2021 (ft amsl)
MW-1	872.87
MW-2	865.16
MW-3	869.80
MW-4	871.07
MW-5	866.59
MW-6	864.77
MW-7	863.81
MW-8	864.43
MW-9	863.99
MW-10	865.03

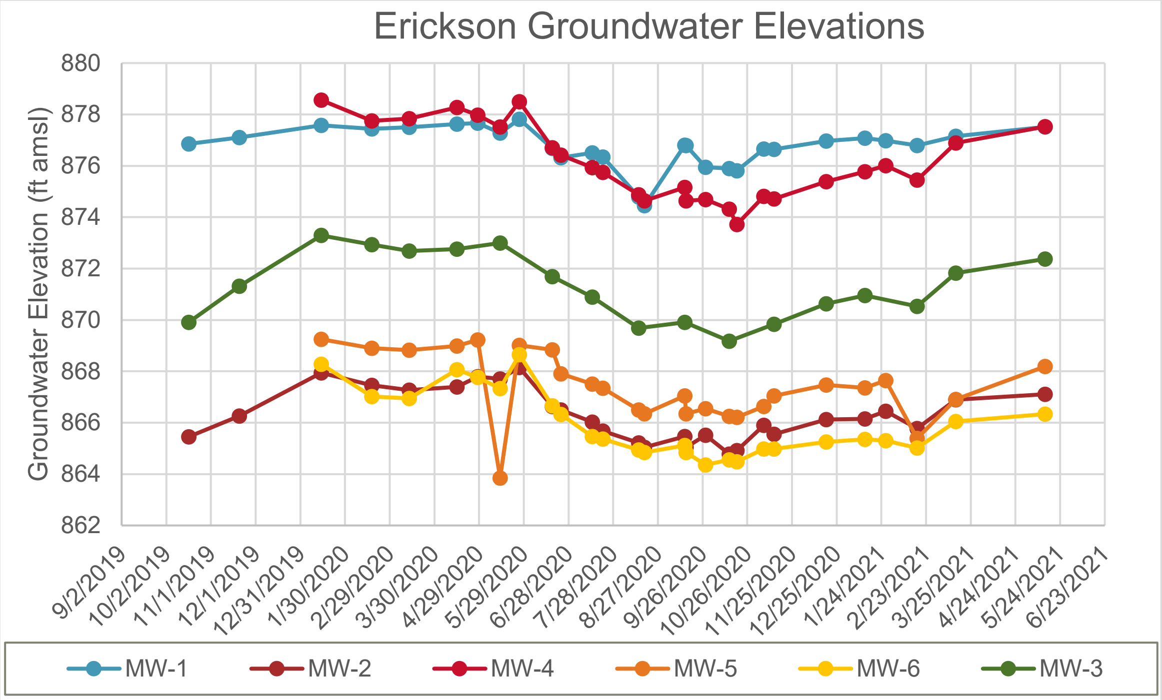

Figure 3-2. Erickson Power Station Monitoring Well Hydrographs

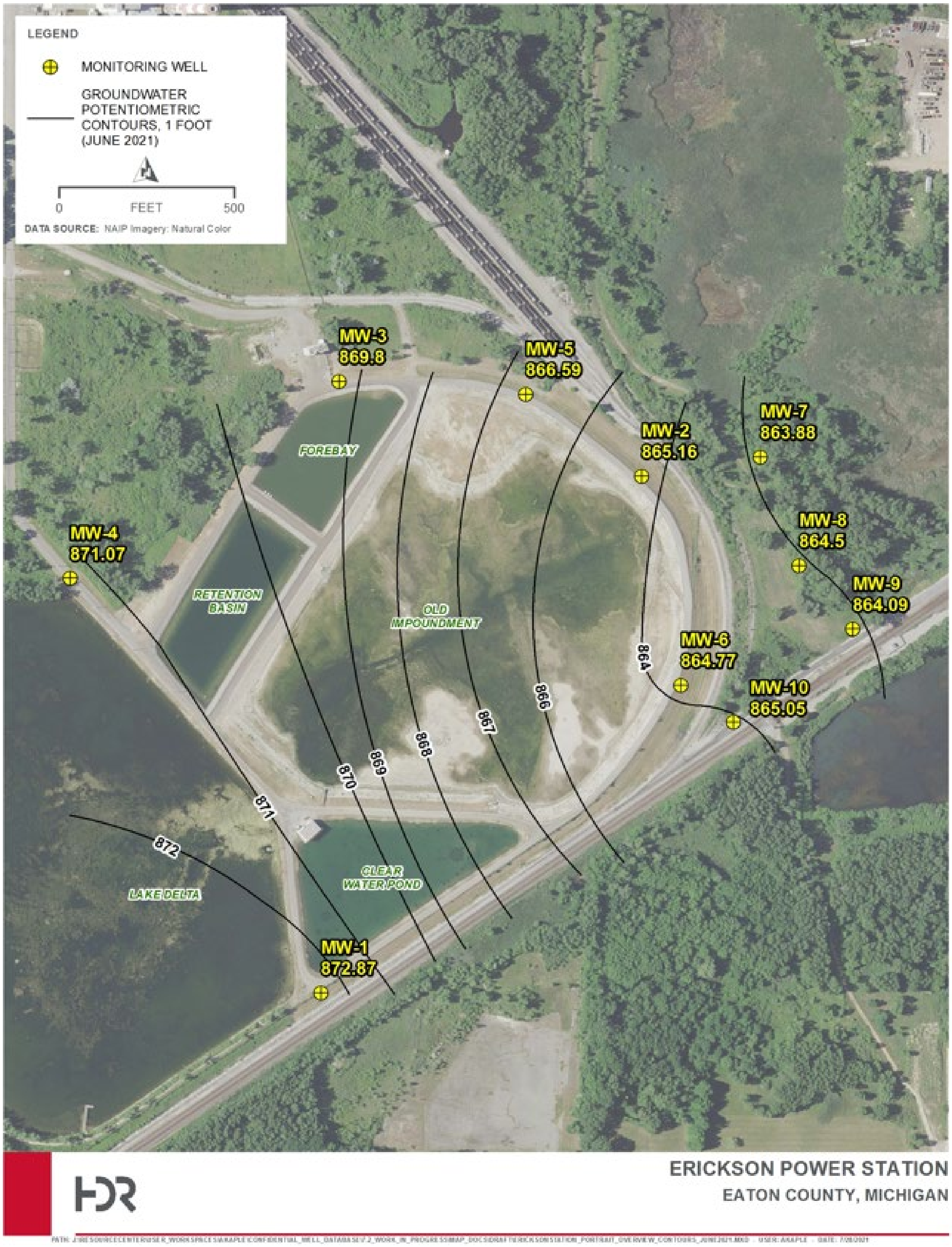

Figure 3-3. Erickson Power Station Potentiometric Surface

During installation of the on-site monitoring wells, the uppermost groundwater was found to be in the glacial deposits and therefore monitoring wells are screened at the top of the saturated glacial units. The depth to the uppermost aquifer under the impoundments was determined to be approximately 14 to 20 feet below surface. Given the bedrock surface between 36 and 61 feet below surface, the upper glacial aquifer thickness at the Site is approximately between 16 and 47 feet thick; however hydraulic connectivity of the glacial aquifer to the bedrock below is unknown.

The hydraulic conductivity for the bottom of each impoundment and the embankments surrounding the impoundments was derived from the construction as-built information where available. Table 3-2 summarizes on-site hydraulic conductivity values gathered from slug testing done on the groundwater monitoring wells and data from the impoundment construction reports.

The center of the embankments for the Forebay, Retention Basin and CWP are constructed with clay-rich engineered fill with hydraulic permeabilities less than 10^{-7} centimeter per second (cm/sec) (MD&E, 2018). The flanks of the embankments also consist of clay-rich engineered fill. The base grade elevation of both the Forebay and Retention Basin is 871.5 feet above geodetic datum (agd). The base grades of the CWP range from 871 to 874 feet agd (MD&E, 2018). The interior embankments and floors of both the Forebay and Retention Basin are lined with a layer of geosynthetic clay overlain with a 40-millimeter-thick FML. Each FML is protected with geofabric and a 6- to 12-inch layer of sand. The tops of the embankments that are subject to wave action are protected with an additional layer of geofabric and 6 to 12 inches of stone riprap (MD&E, 2018). The tops of the interior embankments of the CWP are protected with approximately 6 inches of stone riprap. The CWP is lined with compacted clay. Data from the monitoring wells and geotechnical borings is weighted heavily in the determination of site-specific hydraulic conductivity values for each of the geologic and hydrogeologic layers. Literature values for the overburden materials are being noted but aren't relied on these determinations. Calculated hydraulic conductivity are provided in Table 3-3**.**

Two 8-inch diameter wells are located at Erickson that are screened within the Saginaw aquifer, both with a small pump installed. The wells have pump capacities of 80 and 94 gallons per minute and were only used for emergency water supply, though the wells have not been utilized since before 2010. According to the well logs, pump testing showed there was drawdown of 212 feet in the pumping well after 8 hours of pumping at 48 gallons per minute (gpm) in one well and 157 feet in the pumping well after 10 hours of pumping at 35 gpm in the second well. This is the only site-specific data available for the Saginaw aquifer.

Analyses of aquifer test data in literature indicate a wide range of transmissivities within the Saginaw aquifer. Wood (1969) reported that pumping tests indicated a relatively constant horizontal hydraulic conductivity in the Saginaw Formation of about 100 gallon per day per square foot (gpd/ft2) (13 ft/d). The horizontal hydraulic conductivity of the shale (still part of the Saginaw aquifer) is more variable, ranging from 0.01 to 1.0 gpd/ft2 (0.001 to 0.13 ft/d) (Wood, 1969). Transmissivities that range from 130 to 2,700 ft2/d were reported for the Saginaw aquifer for the Tri-Counties by Vanlier and Wheeler (1968). This range in transmissivities reflects variations in the thickness of the sandstone and variations in the permeability of the sandstone. According to the Public Water Supply database, the estimated transmissivity for wells completed in the Saginaw aquifer in Eaton County ranges from approximately 840 to 3,240 feet squared per day. Measured effective porosities and matrix-controlled vertical hydraulic conductivities range from 4 to 34 percent and 0.0001 to 55 ft/day, respectively (Westjohn and Weaver, 1996a).

The hydraulic conductivity of sandstone bedrock was estimated to be 7.5 ft/d based on local aquifer-test results (Holtschlag, et al., 1996). Initial estimates of transmissivity range from 50 to 2,300 ft2/d. Transmissivity is highest in the central part of the Tri-County area and lowest along the west, south, and east. Water is assumed to move slower through the shales and other tight materials than through the sandstone. The summarization of hydraulic characteristics of the glacial deposits and Saginaw Formation based on literature are in Table 3-4. These values will be considered when determining the appropriate hydraulic conductivity for the bedrock and glacial deposits within the flow model.

Table 3-3. Calculated Hydraulic Conductivity Values for Subsurface Materials at the Impoundments

Well I.D.	Depth of Screened Interval (feet below surface)	Screened Interval Lithology	Hydraulic Conductivity (cm/sec)	Data Source
MW-1	20	Clayey sand to silty sand	1.11E-03	HDR, 2021
MW-2	24	Clayey sand to silty sand	1.69E-04	HDR, 2021
MW-3	24	Clayey sand to silty clay	1.14E-03	HDR, 2021
MW-4	18	Sandy lean clay and clayey sand	2.82E-03	HDR, 2021
MW-5	19	Sandy lean clay	4.78E-04	HDR, 2021
MW-6	18	Fine to coarse sand and sandy lean clay	4.09E-03	HDR, 2021
MW-7	5	Fine to medium silty sand	3.27E-03	HDR, 2021
MW-8	7	Fine to coarse sand and clayey sand	1.95E-03	HDR, 2021
MW-9	6.5	Fine to coarse silty sand	3.26E-03	HDR, 2021
MW-10	7.5	Fine to medium sand	2.59E-03	HDR, 2021

Well I.D.	Depth of Screened Interval (feet below surface)	Screened Interval Lithology	Hydraulic Conductivity (cm/sec)	Data Source
Impoundment Embankments	N/A	Clay core with coarse fill layered over	1.00E-07	MD&E, 2015
Forebay / Retention Basin Liner	N/A	Geosynthetic clay (GCL) (thickness unknown) overlain with a 40-ml-thick flexible polyvinylchloride membrane	5.00E-09	MD&E, 2015
Clear Water Pond Liner	N/A	Compacted clay (thickness unknown)	5.00E-09	MD&E, 2015

Table 3-4. Regional Hydraulic Conductivity Values

Stratigraphic Unit	Lithology at Erickson	Thickness at Erickson (feet)	Hydraulic Conductivity (cm/s)	Porosity (%)	Effective Porosity (%)
Glacial Deposit	sandy clay, silt, clayey sand, sand, and sand with gravel	10-61	2.19E-5[1]	30-47[2]	15[3]
Saginaw Formation	sandstone and siltstone containing interbedded layers of coal, shale, and dolomite	Unknown (0-400 regionally)	4.6E-05[4] 4.6E-03[4] 2.7E-03[5]	21-27[6] 5-40[7]	15[3] 4-34[6]

[1] Site specific slug tests
[2] Based on published data for approximately 1200 soils (5,000 horizons) from 34 states (Rawls, et al., 1983)
[3] Estimated through particle tracking analysis (Holtschlag, et al 1996)
[4] Wood, 1969
[5] Holtschlag, et al 1996
[6] Measured in geophysical logs (Westjohn and Weaver, 1996)
[7] Table in Ohio EPA, 2006 citing Bouwer, 1978; Todd, 1980; Freeze and Cherry, 1979; Sevee, 2006.

3.2.4 Groundwater Recharge

The groundwater model will use net recharge, which is a combination of precipitation and evaporation as one model variable. An initial recharge value of approximately 10% of precipitation will be used. However, the net recharge variable may be modified to calibrate the model to actual measured monitor well water levels.

3.2.5 Groundwater Withdrawal and Potential Receptor Wells

According to the Michigan well database and Erickson well logs, two 8-inch diameter production wells are located at Erickson that are screened within the Saginaw aquifer, both with a small pump installed. The wells have pump capacities of 80 and 94 gallons per minute and were only used for emergency water supply, though the wells have not been utilized since before 2010. According to the well logs, pump testing showed there was drawdown of 212 feet in the pumping well after 8 hours of pumping at 48 gpm in one well and 157 feet in the pumping well after 10 hours of pumping at 35 gpm in the second well. This is the only site-specific data available for the Saginaw aquifer. Currently, the wells are not capable of being monitored for water level due to the pump and wiring in the well and BWL is looking into equipment removal. In one well the top 79 feet of subsurface was logged as clay and gravely clay, representing the glacial deposits, overlying sandstone and shale bedrock down to 420 feet below grade, representing the Saginaw Formation. The second Site well geologic boring log indicates the top 36 feet are glacial deposits (clay, gravel, sand) overlying 345 feet of shale and sandstone of the Saginaw Formation. Static water levels were recorded as 21 and 26 feet below grade on the logs. This equates to a groundwater elevation of approximately 856 feet, which is approximately 10 feet lower than the groundwater elevation observed in the glacial aquifer wells onsite; however, the measured times are decades apart and the surface elevation at the wells is not accurate. No groundwater withdrawal wells are located within or near the model domain.

Appendix Bs the map and list of wells within 1-mile from the property boundary from the Michigan Wellogic Database, which also provides the closest receptor wells. These wells appear to be screened in the Saginaw aquifer. The closest receptor wells that appear to be screened in the glacial aquifer are two public supply wells owned by BWL that are approximately one mile east of the property boundary. There are four residential wells within 0.5-mile that could potentially be considered potential receptor wells, and 58 wells within 1-mile that could potentially be considered potential receptor wells; however, these wells are all considerably deeper, constructed in the Saginaw aquifer.

Well log groundwater elevation data from offsite wells listed in Table 3-5 are between 837 and 861 feet, and groundwater flow is to the east. These elevations are approximately 10-20 feet lower than the glacial aquifer monitoring wells at Erickson; however the measurements for the offsite wells are measured over several decades and the groundwater elevations are estimated using Google Earth or DEM files to estimate the surface elevation based on the location provided on the well log. Therefore, the estimated elevations for offsite wells could be off by 10 or more feet elevation. The groundwater elevation in the glacial and Saginaw aquifers appears similar enough that it appears likely the two aquifers are vertically hydraulically connected. The absence of a confining unit between the glacial aquifer and the Saginaw Formation allows for the use of the Wellogic log groundwater elevations as a data source for the groundwater elevations west (upgradient) and east (downgradient) of the groundwater flow model. These groundwater elevations are in Table 3-5 and will be used to help determine the model boundary conditions (e.g. constant head values at the east and west boundaries).

3.2.6 Water Quality

BWL has two compliance programs, the Federal CCR Rule Groundwater Compliance Monitoring Program (Federal) and the Michigan Part 115 Groundwater Compliance Monitoring Program (State). The two groundwater monitoring programs have concurrent monitoring events and constituents of interest from each program that are overlapping. Both compliance programs are in Assessment Monitoring; however, there are different GPS for the site based on the Federal and State CCR requirements.

In accordance with the Hydrogeologic Monitoring Plan (HMP) submitted to Michigan Department of Environment, Great Lakes, and Energy (EGLE) in compliance with the State CCR compliance program, and in compliance with the Federal CCR Rule, eight rounds of groundwater sampling for background monitoring were conducted on wells MW-1, MW-2, MW-4, MW-5, and MW-6 between April and October 2020. The water quality collected from the monitoring wells located upgradient of the CCR unit has been compiled and statistically analyzed to develop BTVs for each COI. The Background Water Quality Statistical Certification documents the background sampling and describes the data evaluation performed to select the appropriate statistical method in the background data (HDR, 2020).

During background monitoring, groundwater was sampled for detection and assessment monitoring COIs. In accordance with Michigan Statute 324.11511a and the federal CCR Rule groundwater was sampled for detection monitoring COI on October 19, 2020. Concentrations of detection monitoring COIs from each downgradient monitoring well were compared against the BTVs and COIs were shown to have a concentration that is a statistically significant increase (SSI) over BTVs (Table 3-5).

Table 3-5. Detection Monitoring SSIs over BTVs in Downgradient Wells

MW-2	Retention Basin	boron, calcium, chloride, sulfate, total dissolved solids (TDS)
MW-5	Forebay	boron, calcium, sulfate, TDS
MW-6	Clear Water Pond	boron, sulfate, TDS

These SSIs trigger the assessment monitoring program for the impoundments. The first round of assessment monitoring for compliance with the Federal CCR Rule was sampled on November 6, 2020. The initial assessment requires samples be analyzed for CCR Rule Appendix IV parameters only; however, BWL analyzed for Appendix III, Appendix IV, and total suspended solids. Assessment monitoring data was statistically evaluated, and under the Federal compliance program concentrations of lithium were identified at an SSL above the GPS at MW-2, MW-5, and MW-6 (HDR, 2020b). Under the CCR Rule compliance program the GPS for each constituent of interest is either the 1) federal Maximum Concentration Limits (MCLs), as established under 40 CFR §141.62 and 141.66; or 2) background concentrations developed in accordance with 40 CFR §257.91, whichever is greater.

On May 4, 2021 BWL staff completed the first assessment monitoring sample event for compliance with the State compliance program and the Assessment Monitoring Plan approved by EGLE. On June 7-8, 2021 BWL installed four new monitoring wells (MW-7 though MW-10) to comply with BWL Response Action Plan (RAP), to delineate groundwater plume of concentrations that exceed GPS. These new wells are located as close to the downgradient facility boundary (eastern and southern) as was feasible given the presence of wetlands, seasonal inundation and county drainage structures. Following the installation of MW-7 though MW-10 the first round of sampling was completed in those wells on June 15, 2021. This June 15, 2021 sample event at the new wells is a continuation of the May 2021 assessment monitoring event (first assessment monitoring event) completed on MW-1 through MW-6. Downgradient well concentrations from the January and May/June 2021 assessment monitoring events were compared against background values, and some concentrations were found to be above background values and were found to exceed GPS. The following exceedances have been noted; MW-2: Boron, Calcium, Sulfate, TDS, and Lithium. MW-3 a one-time exceedance of Boron, Calcium, Sulfate, TDS, Lithium, and Molybdenum. MW-5: Boron, Calcium, Sulfate, TDS, and Lithium. MW-6: Boron and Lithium. MW-7 a one-time exceedance of Boron, Lithium, and Molybdenum. Note MW-7 though MW-10 have only been sampled once since installation in early June 2021. Well MW-3 water quality results from the single sample event (May 2021) may indicate that the well location is not appropriate as a background well because its concentrations are more similar to downgradient wells concentrations than upgradient well concentrations. However, it was a one-time sample event and BWL intends to continue to monitor the data for additional events prior to making such determination. Well MW-3 has been sampled once because it was previously not monitored prior to EGLE request for inclusion in the monitoring network as a background well. The May/June 2021 sample event represents the first assessment monitoring for the state compliance program and the second event was conducted in early August 2021. The second assessment monitoring event will analyze detected COIs from the first assessment monitoring event. After the second assessment monitoring event, the statistical analysis will be completed following the Statistical Procedures Plan in the HMP and the Assessment Monitoring Plan.

This Assessment of Corrective Measures is intended to support both the federal and state compliance programs and therefore is assuming that the constituents of concern for groundwater include the constituents with SSLs over federal program GPS and constituents that appear to have GPS exceedances over the state program GPS (though final statistical analysis of the second state assessment monitoring event are anticipated in October 2021), all listed below:

- Boron
- Calcium
- Lithium
- Molybdenum
- Sulfate
- TDS

3.2.7 Surface Water Quality

Lake Delta is a private lake located in the southwest Erickson Station, owned by BWL, and leased to Delta Township for recreational fishing. According to the bathymetry survey completed in July 2021 Lake Delta is between five and ten feet deep. Water from Grand River is fed to the lake by the Erickson's River Pump House located on the Grand River to maintain lake levels to be utilized for cooling tower make-up water and for recreation. In May 2021 surface water samples were taken from each of the impoundments and Lake Delta. These results will be used in the calibration of the numerical groundwater transport model.

4 Constituents of Concern in Groundwater

4.1 Constituents Exceeding the Groundwater Protection Standard

In accordance with CCR Rule §257.95(e) and with Michigan R 299.4441(5,6,7), downgradient well concentrations from assessment monitoring are compared against background values, and some concentrations were found to be above background values. Detected Appendix IV COI concentrations in downgradient wells were compared against GPS and some were found to exceed GPS. Therefore, downgradient well concentrations are statistically evaluated to determine "if one or more constituents in appendix IV to this part are detected at SSL above the groundwater protection standard." To determine if an exceedance of a GPS was statistically significant, the 95% lower confidence limit (95LCL) was calculated for each of the downgradient wells for each of the detected COIs. The data set used to calculate the lower confidence limit (LCL) included samples collected at these wells since the establishment of the groundwater monitoring system. The LCL results that exceeded their respective GPS are provided in Table 4-1 and Table 4-2.

In the latest round of sampling May/June 2021 for wells MW-1 though MW-10, Table 4-1 provides the constituents observed exceeding federal compliance program GPS.

Table 4-1. Federal Groundwater Protection Exceedances

MW-2	Lithium
MW-3	Lithium, Molybdenum
MW-5	Lithium
MW-6	Lithium
MW-7	Lithium, Molybdenum

In the latest round of sampling May/June 2021 for wells MW-1 though MW-10 Table 4-2 provides the constituents observed exceeding State GPS.

Table 4-2. State Groundwater Protection Exceedances

MW-2	Boron, Calcium, Sulfate, Lithium, TDS
MW-3	Boron, Calcium, Sulfate, Lithium, Molybdenum, TDS
MW-5	Boron, Calcium, Sulfate, Lithium, TDS
MW-6	Boron, Lithium
MW-7	Boron, Lithium, Molybdenum

These parameters will be considered constituents of concern (COCs). After the groundwater flow model is built and calibrated, a transport model will be calibrated for COCs. A specific date of concentrations from wells onsite will be chosen for calibration (August 2021 sample event). Values will not be averaged over time (nor statistical values such as the LCL). The background water quality data is helpful to review for seasonal effects and reasonableness of the model during calibration.

4.2 Constituents of Concern Source Areas

The plant was constructed in 1970 and historically the fly ash and bottom ash were sluiced from the plant to the 33-acre impoundment system. From the impoundment, the water then flowed hydraulically to the Clear Water Pond. Water from Clearwater was sent back to the plant for use. Due to the connection between the old ash impoundment and the CWP, the CWP contains historic ash. From 2009 through 2014, the ash was removed from the 33-acre impoundment, and a new system was installed, which is currently in use.

Currently, bottom ash from the coal-fired boiler is sluiced from the plant to dewatering tanks (hydro bins). The dewatered bottom ash is trucked to a sanitary landfill and the decant water is hydraulically fed through the impoundment system, which consists of a series of three impoundments: the Forebay, Retention Basin and CWP. The Forebay and Retention Basin were constructed in 2014 and the CWP was constructed in 1970. Water in the CWP is sent back to the plant. Recycled plant water used from the CWP is returned via sluice to the hydro bins and overflows to the Forebay. There are no regulated outfalls associated with the impoundment system and it is designed to operate as a closed loop. The 5-acre, 2014 Forebay and Retention Basin were installed within the footprint of the excavated 33-acre impoundment (now referred to as the Former Impoundment), reducing the excavated, former impoundment down to 28-acres.

As indicated in the Location Restriction Report, the base grade elevation of each of the impoundments is less than five feet from the uppermost groundwater, and in some cases appears to be in contact with the water table (MD&E, 2018). As described in the HDR HMP, the source of contamination appears to be one or multiple CCR impoundments (HDR, 2021a). Geotechnical engineers determined that the embankments between the impoundments is not suitable for monitoring well installation; therefore, given the well placement relative to the impoundments and groundwater flow directions it is not possible to differentiate the four impoundments as source to groundwater other than to assume the direct groundwater flow direction from each pond to the most direct downgradient well. For example, well MW-3 appears to have the Forebay and Retention Basin as likely source(s); and the Former Impoundment or CWP as less likely sources given the configuration of the impoundments relative to the groundwater flow direction. Similarly, MW-5 appears to have the Forebay, Retention Basin, and Former Impoundment as likely source(s); and the CWP less likely as a source. However this approach does not account for the possibility of preferential flow paths or transport time. Therefore, it will be assumed three CCR impoundments have the equal potential to be contaminant sources. For initial modeling efforts the Former Impoundment will not be a source because of the lack of ash since 2014; however, this will continue to be under consideration as the model is calibrated.

4.3 Source Characterization

For the transport model of the COCs in groundwater beneath the CCR Impoundments, a source (higher concentrations of the COC) for the COCs needs to be identified and concentrations applied to the source area. For the Erickson transport model, it is assumed at this time that source concentrations of COCs will be applied to the three CCR impoundments. As a starting point for the model calibration, it will be assumed three CCR impoundments have the equal potential to be contaminant sources, and source loading will be distributed over the three impoundments in the transport model calibration. Should there be difficulty calibrating the concentrations in wells based on applying source to the three CCR impoundments, an alternative source application to the Former Impoundment will be studied as an alternative source area. No sediment samples from the floor of the Former Impoundment have been collected. No settled ash samples have been collected in the CCR units. A settled ash sample could be submitted to a laboratory for analysis of ash leachate that could provide the actual source concentrations from the ponds to groundwater. An ash sample will be collected from the hydro bins. The ash will be submitted to a laboratory for Synthetic Precipitation Leaching Procedure (SPLP) and the leachate analyzed for COCs. This tested leachate will be representative of impoundment water in contact with and leaching settled ash prior to infiltration to groundwater.

5 Groundwater Flow and Transport Model

The groundwater flow and transport models are the numerical representation of the CSM. Lithologic layers were created from studying boring log data. The lithologic data along with USGS DEM, well construction data, and the June 2021 water levels were used to develop cross sections. Based on the lithologic data and slug test analysis, the lithologic units were combined into hydrogeologic layers for the groundwater flow modeling (Appendix A). The numerical groundwater flow and transport model uses the graphical user interface (GUI) Groundwater Vistas Version 7 (Environmental Simulations, Inc., 2017) as the pre- and post- processor for the groundwater flow code MODFLOW-NWT and the transport code MT3DMS.

The specific MODFLOW code chosen for the study is MODFLOW-NWT, a Newton formulation of MODFLOW-2005 that is specifically designed to improve the stability of solutions involving drying and re-wetting under conditions present at the water table (Niswonger et al. 2011). The numerical code selected for the transport model is MT3DMS (Zheng and Wang 1999). MT3DMS is a multi-species three-dimensional (3D) mass transport model that can evaluate advection, dispersion/diffusion, and chemical reaction of COIs in groundwater flow systems, and has a package that provides a link to the MODFLOW codes. The MODFLOW-NWT and MT3DMS input packages used to create the groundwater flow and transport models, as well as a brief description of their use, are provided in Table 5-1.

Table 5-1. MODFLOW and MT3DMS Input Packages Utilized

MODFLOW Input Package	**Description**
Name (NAM)	Contains the names of the input and output files used in the model simulation and controls the active model program
Basic (BAS)	Specifies input packages used, model discretization, number of model stress periods, initial heads and active cells
Discretization (DIS)	Contains finite-difference grid information, including the number and spacing of rows and columns, number of layers in the grid, top and bottom model layer elevations and number of stress periods
Specified Head and Concentration (CHD)	Specifies a head and/or a concentration that remains constant throughout the simulation
Recharge (RCH)	Simulates areal distribution of recharge to the groundwater system
Newton Solver (NWT)	Contains input values and the Newton and matrix solver options
Upstream Weighting (UPW)	Replaces the LPF and/or BCF packages and contains the input required for internal flow calculations
Flow Transfer Link File (LMT)	Used by MTDMS to obtain the location, type, and flow rates of all sources and sinks simulated in the flow model
MT3DMS Input Package	Description
Flow Transfer Link File (FTL)	Reads the LMT file produced by MODFLOW
Basic Transport Package (BTN)	Reads the MODFLOW data used for transport simulations and contains transport options and parameters
Advection (ADV)	Reads and solves the selected advection term
Dispersion (DSP)	Reads and solves the dispersion using the explicit finite- difference formulation
Source and Sink Mixing (SSM)	Reads and solves the concentration change due to sink/source mixing using the explicit finite-difference formulation
Chemical Reaction (RCT)	Reads and solves the concentration change due to chemical reactions using the explicit finite-difference formulation
Generalized Conjugate Gradient (GCG) Solver	Solves the matrix equations resulting from the implicit solution of the transport equation

5.1 Modeling Objectives

The primary modeling objectives are to simulate the rate of movement, potential pathway(s) and the potential offsite migration of COCs within the local groundwater system. Predictive simulations will simulate the movement of COCs over a pre-determined time period and determine if offsite migration is likely or unlikely. Simulation of source control alternatives and treatment alternatives will be performed.

5.2 Model Domain and Grid

The 3D groundwater flow model was built in Groundwater Vistas, Version 7, which is the pre- and post-processor for the groundwater modeling software used to simulate groundwater flow (MODFLOW) and contaminant transport (MT3DMS). The model layers that represent different hydrostratigraphic units include top and bottom elevations of each layer beginning at ground surface to a pre-determined bottom, which represents the top elevation of the bedrock. The geologic units identified in the boring logs are not always continuous across the site and may be modeled as one or more layers with different hydraulic conductivity values to designate discontinuities and spatial changes of geologic units.

The model domain encompasses the CCR units, Former Impoundment, Lake Delta, monitoring wells, the BWL property boundary in the direction of groundwater flow, and some surrounding properties (Figure 5-1). The model domain has a grid consisting of uniform 10-foot grid cells in 8 layers. The contact between the glacial deposits and the underlying bedrock is the bottom of the model, which equates to an average thickness of 100 feet.

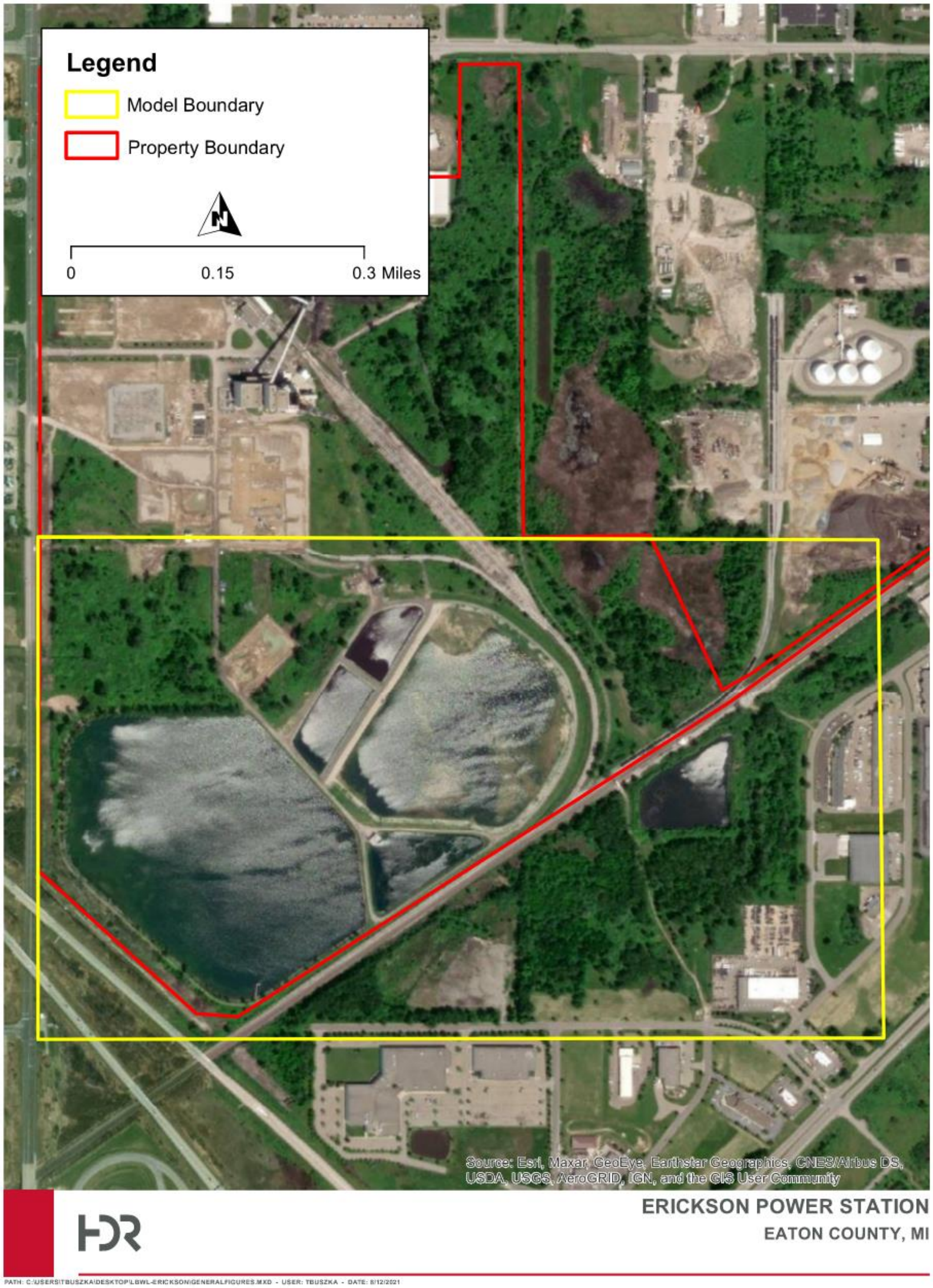

Figure 5-1. Model Boundary

5.3 Hydraulic Parameters

Horizontal hydraulic conductivity and the ratio of horizontal to vertical hydraulic conductivity, which are specific for each hydrostratigraphic unit, are the primary determinants of groundwater flow for a given configuration of boundary conditions and sources and sinks, including recharge. Field measurement of these parameters have been performed through slug testing of onsite monitor wells and are included in consultant reports completed shortly after drilling. MODFLOW does not simulate flow in unsaturated sediments, so does not use the hydraulic conductivity of unsaturated units in the flow and transport computation. However, values were assigned to the unsaturated units for completeness.

Values assigned to the model, with a comparison of literature and measured values are provided in Table 5-2.

Table 5-2. Summary of Hydraulic Conductivity Values to be Used in the Model

Model Layer	Lithology	Hydraulic Conductivity (cm/s)	Data Source
Layer One	Impoundment Embankments	1.00E-07	MD&E, 2015
Layer Two	Geosynthetic liner, PVC Membrane	5.00E-09	MD&E, 2015
Layer Three	Fine to medium grained silty sand	1.14E-03	HDR, 2021
Layer Four	Poorly graded clean fine to medium grained sand	3.34E-03	HDR, 2021
Layer Five	Topsoil	N/A	N/A
Layer Six	Lean clay, layers of completely weathered shale	1.00E-10	Freeze and Cherry, 1979
Layer Seven	Lean clay, sandy clay, silty clay with sand	4.78E-04	HDR, 2021
Layer Eight	Bedrock – Saginaw Frm. Sandstone and shale	4.60E-05	Wood, 1969

5.4 Boundary Conditions

The outer model boundary is simulated with Constant Head boundary conditions set to elevations that approximately represent mid-2021 water level elevations that align with the water level contours developed for the site (Figure 5-2). Constant Head boundaries were used to represent the observed water levels at most upgradient extent of the monitoring well network, also considering the water level elevation of Lake Delta. The water table elevation was approximately 871.5 feet in June 2021.

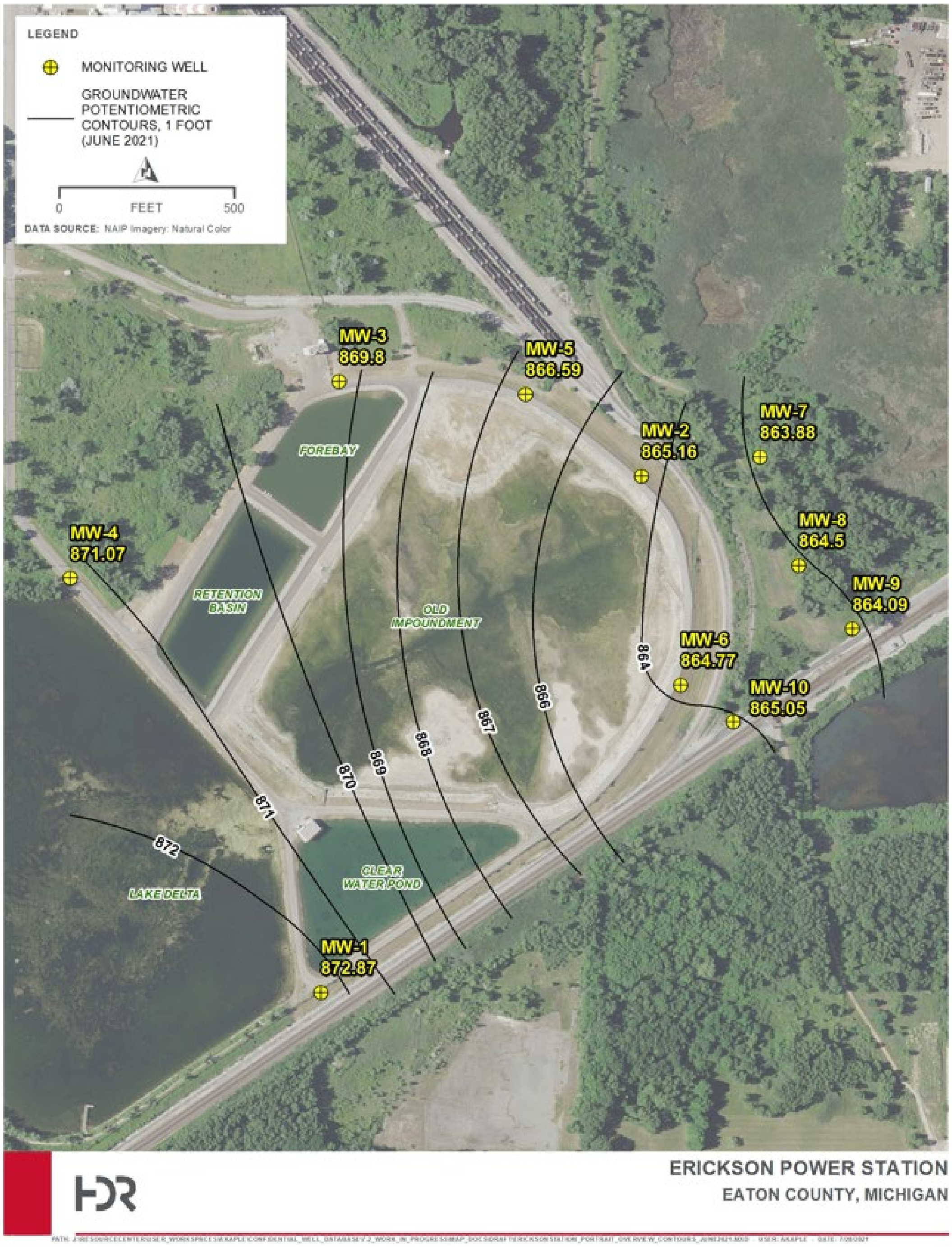

Figure 5-2. Erickson Power Station Water Level Contours (June 2021)

The groundwater flow model is currently being calibrated at the time of the report. This ACM will be updated to reflect calibration, transport model properties, plume evaluation and the potential for offsite transport as the model if further progressed.

5.5 Data Gaps

The following limitations, based on necessary assumptions, will be inherent within the completed groundwater flow and transport model. Where data was unavailable, use of published literature values, appropriate assumptions and professional judgment are routinely employed in modeling and are assumed to be sufficient to perform the model.

- The geological interpretation of boring logs has been completed by multiple people from different engineering companies over a 16-year period. It's possible that geological interpretations are not uniform.
- Lake Delta water levels can affect boundary conditions on the eastern side of the model area, this data is necessary for proper calibration.
- The development of the geological model requires interpolation of geologic units between boreholes that may be inaccurate despite professional judgment and reasonable interpretations.
- Hydraulic conductivity values are sparse and are likely not representative of each entire geological unit underlying the site, as most geological units are heterogeneous.
- Site-specific aquifer recharge is not known, and testing has not been conducted.
- Dispersion or dispersivity of a contaminant within the subsurface is difficult to quantify.
- Site-specific effective porosity values are not known. However, literature values are extensive and can be correlated to known site specific soil characteristics.
- The model will represent stead-state conditions and does not account for transient impacts, such as aquifer storage or fluctuations of water level gradients over time.
- The model will predict groundwater flow and transport onsite, and predicts the direction and velocity of flow, but does not evaluate the extent or velocity of offsite movement beyond the model boundaries.

5.6 Plume Evaluation and Potential for Offsite Transport

Based on the current understanding of the site hydrogeology, water quality sampling and preliminary model simulations, groundwater is impacted by boron, calcium, sulfate, TDS, lithium, and molybdenum downgradient of the CCR impoundments.

Water quality sampling and preliminary model simulations demonstrate that there is limited potential for concentrations of COCs to move offsite at the eastern property boundary. This potential for offsite transport was confirmed by COC concentrations at MW-7; however, COCs did not have concentrations above the GPS at MW-8, MW-9, or MW-10. The potential for COC mass flux at the downgradient property boundary will be quantified after the model is updated.

6 Corrective Measures Alternatives

Consideration of corrective measure alternatives to address CCR related impacts to groundwater at the impoundments is discussed in this section. The alternatives include source removal of CCR, monitored natural attenuation, and groundwater treatment alternatives.

Table 6-1 provides brief descriptions of seven potential corrective measure alternatives for consideration at the Erickson impoundments to address CCR-related impacts to groundwater. The selection of the remedy will take into consideration each of the COCs identified, the sources, and the transport pathways identified in the model once completed. Of the alternatives reviewed, the one that appears to be feasible will be carried forward. Certain natural site-specific characteristics are common to multiple alternatives and will factor in the effectiveness, feasibility, and timeliness of each, and therefore require additional evaluation, but do not eliminate the alternatives from further considerations. The alternatives are briefly discussed in the sections below.

6.1 Alternative 1—CCR Source Removal

Description. The ash removal alternative assumes that ash from the three impoundments will be excavated and moved offsite for disposal or beneficial use. This alternative was described as the closure path for the impoundments in the Demonstration of Site-Specific Alternate to Initiation of Closure Due to Lack of Capacity 40 CFR §257.103(f)(1), submitted to EPA in November 2020. for closure extension. CCR removal would be overseen by a Professional Engineer (PE) and confirmation samples would be collected from the impoundments after CCR removal and statistically evaluated to demonstrate that "…all areas affected by releases of CCR…" are removed. A preliminary report documenting the closure by removal would be prepared and certified by the oversight PE. The closure report would be finalized once COC concentrations in groundwater are confirmed to meet the GPS according to the requirements of the CCR Rule. This process will be required for both the State and Federal CCR compliance programs. After the CCR material has been completely removed from the former impoundment concentrations of CCR constituents in groundwater are expected to decrease through natural attenuation. Groundwater monitoring at the impoundments after CCR removal would represent post-corrective action, and upper confidence limits for each COC would be used to compare to the GPS to show the corrective measure or remedy was successful.

Considerations. Closure by CCR removal is the most significant corrective action that could be taken to mitigate impacts to groundwater. Removal of the ash will take time and monitored natural attenuation (MNA) may prove slow to meet GPS because the groundwater transmissivity is low. However, this alternative drastically decreases or removes the source of COCs to groundwater.

Additional Data Needs. No additional date is anticipated.

6.2 Alternative 2—Monitored Natural Attenuation

Description. Monitored natural attenuation (MNA) is well accepted as an appropriate mitigation factor that should be considered when evaluating passive and active remedial options (USEPA, 1999, 2007a, b). The USEPA has established a tiered series of steps to determine whether MNA would sufficiently lower concentrations of COIs on an appropriate timescale, and whether there is system capacity and stability for MNA mechanisms (USEPA, 1999, 2007a, b). Natural attenuation mechanisms include adsorption of COIs, ion exchange, precipitation of COI-containing minerals, and dispersion. In addition to adsorption to soil, clay particles, and organic matter, iron and manganese oxides that commonly precipitate down-gradient of CCR disposal sites will, in turn, remove other COIs by adsorption. While model predictions can simulate long-term attenuation using a soil-water partitioning coefficient to estimate adsorption, natural conditions will dictate how COIs migrate through the strata and how much is removed en route. Empirical data are good indicator of natural attenuation mechanisms, but long-term groundwater monitoring is required. (EPRI, 2015; USEPA, 1999, 2007a, b). Dispersion of COCs should also be fully considered, modeled, and if possible, validated using naturally present ions like chloride and sulfate that are generally not affected by interactions with soil, clay particles, and mineral precipitates.

Considerations. MNA as an alternative is primarily carried forward as a comparative tool to evaluate concentrations of COC without source control or groundwater treatment. The CCR Rule recognizes that "…as part of attaining this (*statistically meet background level or MCL, sic)* standard…contaminants left in the subsoils (i.e., contaminated groundwater left in subsoils below the impoundments)…(*that, sic*) will not impact environmental media…" may remain in place. Given that the bottom of the impoundments was sampled and confirmed to meet soil background levels, the relatively low mobility of the adjacent groundwater, and relatively low COC concentrations, this may be an acceptable outcome.

Additional Data Needs. No additional date is anticipated. Assessment monitoring would continue until constituent concentrations are reduced to levels which allow unit closure, and ultimately attainment of GPS for three consecutive years.

6.3 Alternative 3—Permeable Reactive Barrier

Description. A Permeable Reactive Barrier (PRB) is a form of in-situ groundwater treatment that can be constructed to remove contaminants. Constructed by excavating a trench that penetrates the saturated zone perpendicular to the direction of groundwater flow, which is keyed into an underlying barrier to groundwater movement. The trench is then backfilled with reactive material while maintaining a transmissivity greater than the surrounding subsurface so that groundwater continues to flow through, rather than around the PRB. Reactive material may be media that adsorbs COCs or forms precipitates with COCs to reduce concentrations. The design of a PRB can involve the use of multiple types of reactive material depending on the specific COCs to treat. Depending on the COCs, multiple types of reactive material may be mixed together to create a single reactive zone or sequentially so that the groundwater passes through several different reactive zones. Example reagents for Erickson include zero valent iron (ZVI) and ZVI-carbon to sorb selenium and arsenic, and apatite (phosphate) to precipitate lithium.

A variation of the conventional PRB is a trenchless PRB, which involves the injection of reactive components, in a starch medium that subsequently breaks down, leaving the reactive components behind. The reactive components are injected into a fracture that is created at the desired depth(s) using a series of wells.

Considerations. Space is limited for construction between the downgradient edge of the impoundments, downgradient wells, and downgradient wetlands. In addition, the depth to bedrock ranges from approximately 36 to 61 feet below ground surface. The combination of limited surface area and required depth of trench within that area, may limit feasibility. The trenchless PRB would have fewer space constraints, and has several other potential advantages for this site. First, a trenchless PRB can be installed to depths greater than that achievable using traditional trenching technologies. A funnel-and-gate system can be used to channel the contaminant plume into a gate that contains the reactive material (Obiri-Nyarko et al., 2014). The funnels are non-permeable (e.g., slurry wall), and the simplest design consists of a single gate with walls extending from both sides. The main advantage of the funnel-and-gate system is that a smaller reactive zone can be used to treat the plume, thereby, potentially reducing costs.

Additional Data Needs. Geochemical, bench-scale, and possible pilot-scale testing will be required to evaluate the optimal reactive media composition, PRB lifespan, selection of an appropriate reagent(s), and to evaluate potential additional contaminate mobilization.

6.4 Alternative 4—In-Situ Solidification

Description. Injection of Portland cement or other binding agent to physically bind ash below the localized water table via creation of a monolith. The mixture is intended to encapsulate the source material resulting in the COCs becoming inert. This is accomplished through bench testing of the ash and surrounding soils with potential binding agents to determine the effectiveness of the mixture in immobilizing the COCs. Multiple injection techniques are available depending on the binding agent used.

Considerations. In-situ solidification is a potential option to immobilize COCs in the source below the water table rendering it inert. It may not be sufficient as a sole remedy and may need to be paired with source control or other alternatives. Given the relatively minor amount of ash in the three impoundments, this alternative would likely surpass costs expected of an equally effective ash removal.

Additional Data Needs. Additional groundwater flow modeling would be needed to evaluate potential changes to the physical setting. Geochemical, bench-scale, and possible pilot-scale testing will be required to evaluate the optimal binding agent.

6.5 Alternative 5—Slurry Wall

Description. Excavation of a trench system coupled with injection of a high slump slurry that when solidified forms an impermeable cutoff wall to prevent groundwater flow from off-site to beneath the impoundments and become in contact with ash. The slurry is typically a combination of the excavated trench soils, bentonite, and other potential additives. The slurry mixture forms into a material similar to a soft, clayey soil. This method typically results in a cutoff wall with a permeability ranging from $1x10^{-6}$ to $1x10^{-8}$ cm/sec.

Considerations. Could have some benefit along the east perimeter of the impoundments; however space is very limited with Lake Delta. The wall may result in groundwater mounding as the gradient changes to flow around the wall. Potential impacts of mounding on the adjacent property and Lake Delta would need to be evaluated. Also, depth to bedrock would need to be keyed into bedrock.

Additional Data Needs. This alternative will require modeling scenarios to be run and would need to be paired with other alternative(s).

6.6 Alternative 6—Cover in Place

Description. This alternative would require the surface water to be decanted from the impoundments, CCR remains in place, and fill and cover material imported is from offsite to cover the ash according to §257.102(d) (permeability no greater than 1 × 10-5 cm/sec). Model simulations would be run for multiple final cover systems for the impoundments including a geosynthetic cover and an evapotranspirative/water balance cover. These cover systems could be installed to prohibit vertical migration of precipitation into ash to cut off the continued source of COCs to groundwater. After the cover is installed, MNA will occur, and groundwater monitoring will continue to evaluate the predicted decrease in COCs leaching to groundwater.

Considerations. Covering the impoundments will substantially decrease or eliminate infiltration of surface water through the ash thereby significantly decreasing leaching of COCs into groundwater. This alternative would not address the areas of ash that may remain below the water table. If the groundwater elevation does not lower around the impoundments after the cessation of waste disposal and decant of the surface water, this alternative may not be approved by EGLE.

Additional Data Needs. Different scenarios of the impoundments cover would be modeled, including targeting cover in certain portions of the impoundments, and varying the recharge rates (including zero recharge) based on cover type and thickness.

6.7 Alternative 7—Groundwater Extraction and Treatment (Pump and Treat)

Description. As an alternative to in-situ groundwater treatment methods, impacted groundwater could be pumped to the surface and treated above grade in order to provide hydraulic containment and prevent the COC from migrating. Groundwater capture approaches are utilized to provide hydraulic control to reduce or prevent the mobility of COCs from migrating offsite and/or to receptors. Capture of groundwater can be accomplished through the use of a conventional vertical groundwater pumping well network screened within the water bearing zone(s) or recovery trenches used to intercept groundwater flow. Extraction typically includes wells, pumps, electrical feed, well vaults, flow meters, and other miscellaneous appurtenances, and a treatment and discharge option for extracted groundwater. The efficiency of each alternative is dependent on contaminant and hydrogeologic conditions. A groundwater extraction system, if designed, installed, operated, and maintained appropriately in conjunction with source removal could offer an effective remediation solution for Erickson impoundments.

Due to the expected complexity of trench construction near surface water features or wetlands, capital costs associated with trench construction would likely surpass costs expected of an equally effective groundwater extraction well system.

A groundwater extraction system is expected to be highly effective at capturing groundwater prior to venting to surface water, thus protecting potential receptors. However, this alternative has high capital and long-term costs due to the installation and ongoing operation and maintenance of the groundwater extraction system. Reliability of a groundwater capture/control system is high but may be less reliable than an impermeable barrier due to operation and maintenance. Additionally, there is uncertainty associated with the treatment of the extracted groundwater, which would need to be treated on site or transported off site for discharge. The effectiveness of a groundwater capture system would need to be monitored, and a routine system inspection and maintenance program would be required.

Considerations. Design and construction of a groundwater extraction system would take longer to implement than other alternatives. Design and operation of a system shall consider COC migration control, potential changes in oxidation state within water bearing zones that could cause unwanted scale formation or bacteria in well screens and/or extraction equipment. Use of sorbents for chemical fixation of the COC or use of reverse osmosis is a well-established method to reduce COC concentrations in groundwater. However, this method has never been used for lithium or at CCR sites. While the operation of a groundwater extraction system would effectively provide hydraulic containment of impacted groundwater, it is anticipated that a groundwater extraction and treatment system would have to operate into perpetuity unless source control was also implemented.

Additional Data Needs. Geochemical modeling to evaluate reduction in COC concentrations. Bench-scale screening and treatability testing would be required.

Table 6-1. Summary of the Corrective Measure Alternatives

Alternative	Description	Performance/ Reliability	Additional Data Needs	Relative Ease of Implementation 1 = easy 2 = moderately easy 3 = moderate 4 = moderately difficult 5 = difficult)	Potential Impacts of the Remedy (Safety, cross-media impacts, exposure to residual contamination)	Relative Time Required for Implementation/Remedy 1 = 1-5 yrs 2 = 5-10 yrs 3 = 10-50 yrs 4 = 50-100 yrs 5 = 100+ yrs	Institutional Requirements (Permits or other environmental or public health requirements	Recommended for Further Evaluation
CCR Source Removal	Removal of all CCR and all areas affected by releases of CCR	• Source removal. • Ease of implementation. • Does not address existing COCs in groundwater.	No additional date is anticipated.	2	No additional impacts	1	Approval by State.	Yes
Monitored Natural Attenuation (MNA)	Well accepted by state and federal regulators as an appropriate mitigation factor that should be considered when evaluating passive and active remedial options (USEPA, 1999, 2007a, b). Natural attenuation mechanisms include adsorption of COIs, ion exchange, precipitation of COI-containing minerals, and dilution/dispersion. In addition to adsorption to soil, clay particles, and organic matter, iron and manganese oxides that commonly precipitate downgradient of CCR disposal sites will, in turn, remove other COIs by adsorption	• Accepted as a valid remedial approach. COC concentrations in groundwater should decrease over time since the CCR source has been removed. • O&M is limited to performance monitoring and would not require operation or periodic maintenance of engineered systems. • COC concentrations in groundwater are relatively low and are bounded by the adjacent reservoir.	No additional date is anticipated.	1	Potential for residual contamination	1-2 with source control	Approval by State. Impoundments will continue to be monitored per state regulations. May require environmental covenant if residual contamination exists	Yes
Permeable Reactive Barrier (PRB)	A form of in-situ groundwater treatment that can be constructed to remove contaminants. Constructed by excavating a trench that penetrates the saturated zone perpendicular to the direction of groundwater flow, which is keyed into an underlying barrier to groundwater movement such as bedrock. The trench is then backfilled with reactive material while maintaining a transmissivity greater than the surrounding subsurface so that groundwater continues to flow through, rather than around the PRB.	• Remedial alternative that, once installed, will prevent discharge of COCs beyond the impoundments. • Has been successfully implemented at other sites nationwide. • An evaluation is required to determine if space is available for construction between the downgradient edge of the ash and the downgradient wells. • Depth to consolidated bedrock (approximately 40-70 feet below ground surface). • Effectiveness and frequency of reactive material recharge unknown without laboratory bench-scale testing. • Conventional PRB design life is commonly based on decades; therefore, if it is anticipated that the COCs will be present long term in groundwater.	Geochemical, bench-scale and possible pilot-scale testing to evaluate the optimal reactive media composition, PRB lifespan, select the appropriate reagent(s), and evaluate potential additional contaminate mobilization. Availability and quantity of material required for the respective application locations will drive feasibility.	3-4	Addition of reagents or adjustment of pH/redox conditions may mobilize other contaminants in groundwater.	1-2/3 with source control	Approval by State. Impoundments will continue to be monitored per state regulations.	Yes
In-situ solidification	Injection of Portland cement or	• Encapsulates the source of COCs below the water table, and limits further migration	Groundwater flow	3	Groundwater mounding	1/2-3	Impoundments will	No

	other mixture to physically bind ash below the water table via creation of a monolith. Encapsulates source material and immobilizes COCs	• One time implementation with no ongoing O&M • Ease of implementation when compared to some other remedial alternatives, e.g., ash removal. • Contaminants are not destroyed or removed • Modeling simulations may show groundwater mounding potential • Modeling may show leaching of COCs still occurring from the ash above the groundwater table which is not bound in cement. • Given the relatively minor amount of ash in the three impoundments, this alternative would likely surpass costs expected of an equally effective ash removal.	modeling to evaluate potential changes in physical setting.		potential		continue to be monitored per state regulations. Selected alternative will require approval from the State.	
Slurry Wall	Cutoff wall to prevent perched groundwater flow from off-site to beneath the impoundments in contact with ash.	• Reduces recharge of groundwater, contact with CCR and leaching of COCs. • Low maintenance once installed. • Modeling simulations may show groundwater mounding potential. • Feasibility of installation should be evaluated due to depth of bedrock may be too deep as wall must be keyed into bedrock. • Modeling simulations may show incomplete diversion of groundwater flow from off-site. • Space is very limited with Lake Delta.	This alternative will require modeling scenarios to be run to evaluate degree of effectiveness and. assist in assessing potential for groundwater mounding.	3	Groundwater mounding potential	1/additional remedy dependent	Impoundments will continue to be monitored per state regulations. Selected alternative will require approval from the State.	No
Cap in Place	Impermeable cap(s) are placed over existing ash ponds. Cover could be reinforced to limit recharge to groundwater, thus limiting the ash leachate to groundwater.	• Source control/Removal. • Recharge to groundwater and leaching of COCs is reduced or eliminated from the ash above the water table. • COC concentrations in groundwater will decrease over time • Transport modeling with slow groundwater flow velocities on site may predict long term presence of elevated COCs in groundwater. Model simulations may show ash below the water table continuing to be a source of COCs to groundwater.	Additional groundwater modeling scenarios will allow for determination of most effective: • Locations for capping • Cover materials • Cover thickness	2	No additional impacts	1/5	Impoundments will continue to be monitored per state regulations. Selected alternative will require approval from the State.	Yes
Pump and Treat	Extraction of groundwater and above-ground treatment of COCs	• Does not remove the source therefore required into perpetuity, or until the COCs were completely leached out of the ash.	Geochemical, modeling and bench-scale testing to evaluate the optimal treatment train/reagents (e.g. RO), operational lifespan. Source control also required.	5	No additional impacts	1/3 with source control	Impoundments will continue to be monitored per state regulations. Will require approval from the State.	Yes

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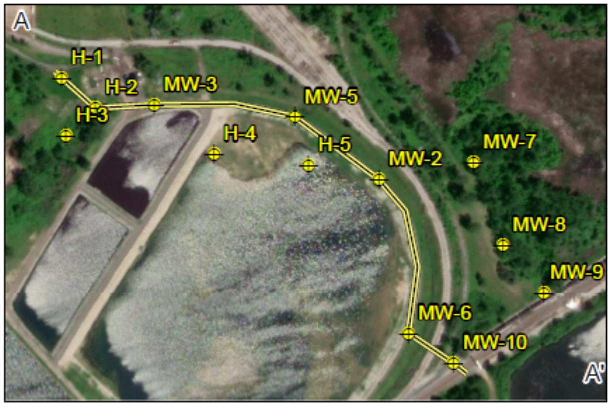
Appendix A.

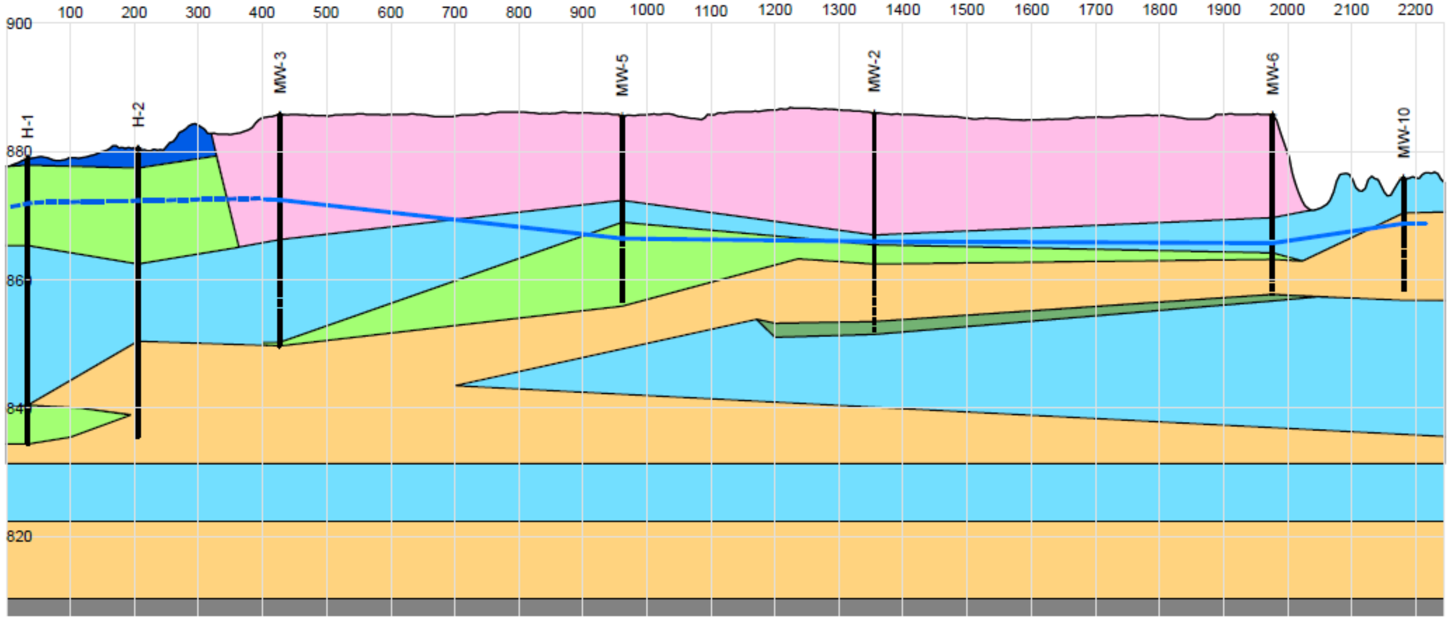
Impoundments Hydro-Stratigraphic Cross-Section

Model Layer	Lithology	Hydraulic Conductivity (cm/s)	Data Source
Layer One	Impoundment Embankments	1.00E-07	MD&E, 2015
Layer Two	Geosynthetic liner, PVC membrain	5.00E-09	MD&E, 2015
Layer Three	Fine to sedium silty sand	1.14E-03	HDR, 2021
Layer Four	Poorly graded clean fine to medium sand	3.34E-03	HDR, 2021
Layer Five	Top soil	N/A	N/A
Layer Six	Lean clay, layers of completely weathered shale	1.00E-10	Freeze and Cherry, 1979
Layer Seven	Lean clay, sandy clay, silty clay with sand	4.78E-04	HDR, 2021
Layer Eight	Bedrock - Saginaw Frm. Sandstone and shale	4.60E-05	Wood, 1969



🟪 Layer One
🟦 Layer Three
🟧 Layer Four
🟦 Layer Five
🟩 Layer Six
🟩 Layer Seven
⬛ Layer Eight
▬ Screen
— Well Boring
— Potentiometric Surface June 2021

0 0.075 0.15 Miles

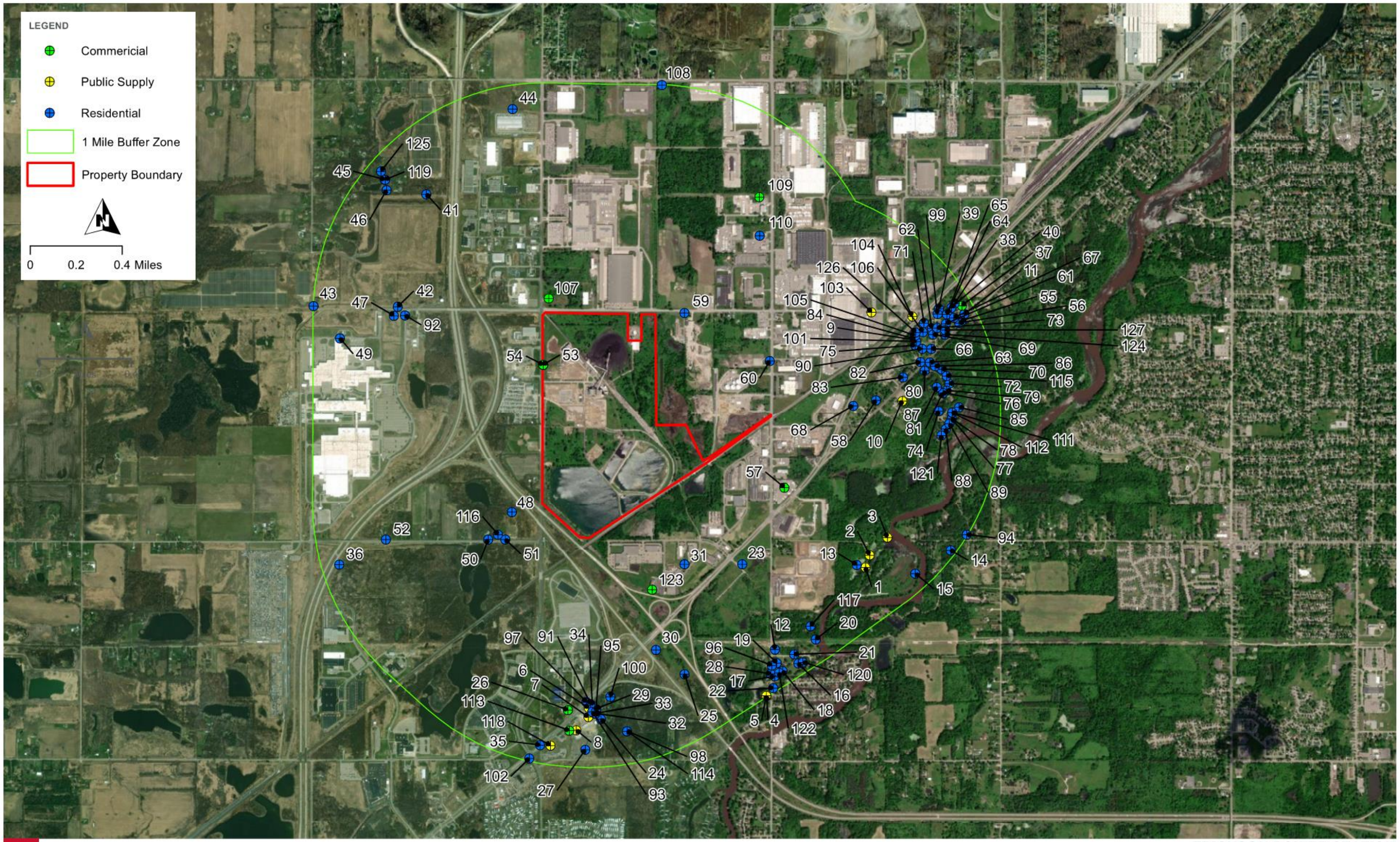


ERICKSON POWER STATION
CROSS SECTION A-A'

PATH: C:\USERS\TBUSZKA\DESKTOP\LBWL-XC\MXD\CX_GG.MXD - USER: TBUSZKA - DATE: 8/18/2021

Appendix B.

Wells Within 1-mile of Erickson Station



ERICKSON POWER STATION

EATON COUNTY, MICHIGAN

Map Reference Number	*MI Well ID*	Well Depth (ft bgs)	Date of Contstruction	Static Water Level (ft bgs)	Latitude	Longitude	Elevation (ft)	Well Type
1	*23000000063*	93	11/21/1963	Not Reported	42.681	-84.634	837	Public Supply
2	*23000000064*	85	1/17/1964	Not Reported	42.682	-84.634	837	Public Supply
3	*23000000065*	105	5/15/1964	Not Reported	42.683	-84.632	837	Public Supply
4	*23000000066*	351	1/9/1961	12	42.673	-84.643	840	Public Supply
5	*23000000067*	400	2/27/1961	12	42.673	-84.643	840	Public Supply
6	*23000000069*	Not Reported	Not Reported	Not Reported	42.672	-84.658	899	Public Supply
7	*23000000070*	180	10/29/1968	50	42.672	-84.658	899	Public Supply
8	*23000000071*	180	10/27/1967	46	42.671	-84.659	899	Public Supply
9	*23000000142*	335	6/11/1985	50	42.696	-84.630	873	Public Supply
10	*23000000143*	385	11/15/1966	44	42.692	-84.631	879	Public Supply
11	*23000000556*	425	5/16/2000	52	42.697	-84.626	876	Residential
12	*23000003745*	235	10/22/1980	49	42.676	-84.642	856	Residential
13	*23000003747*	200	1/12/1983	40	42.682	-84.635	837	Residential
14	*23000003755*	427	9/16/1988	42	42.682	-84.627	866	Residential
15	*23000003756*	305	4/28/1988	81	42.681	-84.630	837	Residential
16	*23000003761*	180	2/2/1982	10	42.675	-84.640	843	Residential
17	*23000003762*	140	6/5/1985	20	42.674	-84.642	853	Residential
18	*23000003763*	125	2/8/1972	15	42.675	-84.641	846	Residential
19	*23000003764*	140	Not Reported	10	42.675	-84.642	856	Residential
20	*23000003765*	360	10/20/1980	41	42.677	-84.639	840	Residential
21	*23000003772*	148	6/7/1997	13	42.676	-84.640	846	Residential
22	*23000003774*	155	8/19/1997	40	42.674	-84.642	843	Residential
23	*23000003775*	300	1/8/1977	10	42.682	-84.645	869	Residential
24	*23000003776*	203	10/18/1971	48	42.672	-84.657	899	Residential
25	*23000003777*	216	5/23/1989	45	42.675	-84.650	869	Residential
26	*23000003779*	180	Not Reported	50	42.672	-84.660	896	Commercial
27	*23000003780*	182	3/16/1989	57	42.670	-84.658	899	Residential
28	*23000003781*	160	2/23/1987	32	42.675	-84.642	856	Residential
29	*23000003783*	225	2/25/1994	48	42.672	-84.657	899	Residential
30	*23000003784*	175	4/22/1994	34	42.676	-84.652	886	Residential
31	*23000003785*	231	8/23/1994	25	42.682	-84.650	869	Residential
32	*23000003786*	200	8/25/1994	58	42.672	-84.657	899	Residential
33	*23000003787*	220	7/8/1998	63	42.672	-84.657	899	Residential
34	*23000003788*	220	3/21/1999	45	42.673	-84.658	899	Residential
35	*23000003790*	260	5/22/1978	32	42.670	-84.662	896	Residential
36	*23000003791*	145	11/19/1998	22	42.681	-84.679	879	Residential
37	*23000006051*	345	9/25/1984	48	42.698	-84.626	876	Commercial
38	*23000006052*	420	5/1/1974	48	42.698	-84.627	879	Residential
39	*23000006056*	400	9/16/1996	25	42.698	-84.628	879	Residential

Map Reference Number	*MI Well ID*	Well Depth (ft bgs)	Date of Contstruction	Static Water Level (ft bgs)	Latitude	Longitude	Elevation (ft)	Well Type
40	*23000006057*	426	8/18/1997	60	42.698	-84.627	879	Residential
41	*23000006065*	Not Reported	Not Reported	Not Reported	42.705	-84.672	869	Residential
42	*23000006066*	200	2/22/1996	22	42.698	-84.674	876	Residential
43	*23000006068*	141	8/2/1996	20	42.698	-84.682	863	Residential
44	*23000006071*	140	4/23/1997	15	42.710	-84.665	873	Residential
45	*23000006072*	160	9/25/1997	35	42.706	-84.675	863	Residential
46	*23000006073*	160	3/4/1999	25	42.705	-84.675	866	Residential
47	*23000006099*	191	9/9/1970	25	42.697	-84.675	876	Residential
48	*23000006100*	280	Not Reported	21	42.685	-84.665	879	Residential
49	*23000006101*	305	4/7/1995	19	42.696	-84.679	866	Residential
50	*23000006102*	325	8/29/1995	12	42.683	-84.667	873	Residential
51	*23000006103*	200	11/2/1996	29	42.683	-84.665	879	Residential
52	*23000006104*	201	10/24/1996	35	42.683	-84.675	879	Residential
53	*23000006105*	420	5/8/1996	21	42.694	-84.662	879	Commercial
54	*23000006106*	380	4/17/1998	26	42.694	-84.662	879	Commercial
55	*23000006107*	225	6/25/1984	40	42.697	-84.626	876	Residential
56	*23000006108*	200	2/5/1985	45	42.697	-84.626	876	Residential
57	*23000006109*	340	4/21/1980	36	42.686	-84.641	873	Commercial
58	*23000006110*	300	1/10/1978	40	42.692	-84.633	860	Residential
59	*23000006111*	335	6/26/1974	40	42.697	-84.650	869	Residential
60	*23000006112*	245	5/20/1974	25	42.694	-84.643	873	Residential
61	*23000006113*	370	11/13/1973	60	42.697	-84.627	876	Residential
62	*23000006114*	380	8/23/1972	0	42.696	-84.629	873	Residential
63	*23000006115*	460	9/29/1992	60	42.694	-84.629	873	Residential
64	*23000006116*	385	9/23/1992	40	42.697	-84.627	879	Residential
65	*23000006117*	Not Reported	Not Reported	Not Reported	42.697	-84.627	879	Residential
66	*23000006119*	365	8/13/1993	40	42.695	-84.629	873	Residential
67	*23000006120*	440	6/29/1993	42	42.697	-84.627	876	Residential
68	*23000006121*	260	11/18/1993	36	42.692	-84.635	869	Residential
69	*23000006123*	280	9/12/1994	40	42.696	-84.629	876	Residential
70	*23000006125*	300	2/28/1995	40	42.694	-84.628	873	Residential
71	*23000006126*	460	6/8/1995	48	42.697	-84.629	876	Residential
72	*23000006127*	200	Not Reported	50	42.693	-84.627	869	Residential
73	*23000006129*	276	11/29/1995	65	42.697	-84.628	876	Residential
74	*23000006130*	175	4/28/1996	50	42.691	-84.628	866	Residential
75	*23000006131*	400	11/5/1997	43	42.695	-84.630	873	Residential
76	*23000006132*	321	8/15/1996	58	42.692	-84.628	876	Residential
77	*23000006133*	340	1/14/1997	65	42.691	-84.627	863	Residential
78	*23000006134*	340	6/4/1997	65	42.691	-84.627	863	Residential

Map Reference Number	*MI Well ID*	Well Depth (ft bgs)	Date of Contstruction	Static Water Level (ft bgs)	Latitude	Longitude	Elevation (ft)	Well Type
79	*23000006135*	245	7/29/1997	51	42.693	-84.627	873	Residential
80	*23000006137*	460	2/2/1998	40	42.694	-84.629	873	Residential
81	*23000007120*	417	6/2/2000	46	42.692	-84.628	876	Residential
82	*23000007187*	460	5/22/2000	60	42.694	-84.630	873	Residential
83	*23000007213*	320	9/14/2001	40	42.693	-84.631	876	Residential
84	*23000007370*	360	2/13/2002	40	42.696	-84.630	876	Residential
85	*23000007379*	340	3/5/2002	35	42.692	-84.626	876	Residential
86	*23000007400*	440	4/2/2002	40	42.694	-84.628	873	Residential
87	*23000007670*	420	6/25/2002	40	42.693	-84.628	869	Residential
88	*23000007686*	400	2/12/2001	50	42.690	-84.627	873	Residential
89	*23000007754*	360	2/12/2001	50	42.690	-84.627	876	Residential
90	*23000007790*	360	8/31/2001	42	42.695	-84.629	873	Residential
91	*23000007889*	200	6/22/2001	30	42.673	-84.658	899	Residential
92	*23000007936*	340	11/13/2001	100	42.697	-84.674	873	Residential
93	*23000007942*	300	10/12/2001	40	42.672	-84.658	899	Residential
94	*23000008019*	490	9/16/2002	50	42.683	-84.626	869	Residential
95	*23000008037*	300	9/30/2002	40	42.672	-84.657	899	Residential
96	*23000008085*	180	4/19/2002	30	42.675	-84.642	860	Residential
97	*23000008178*	220	10/31/2001	54	42.673	-84.658	899	Residential
98	*23000008266*	200	12/9/1999	30	42.671	-84.655	899	Residential
99	*23000008339*	396	10/16/2002	56	42.697	-84.628	879	Residential
100	*23000008356*	290	12/23/2002	62	42.673	-84.656	899	Residential
101	*23000008364*	360	2/20/2003	40	42.696	-84.630	873	Residential
102	*23000008365*	140	2/20/2003	38	42.669	-84.663	892	Residential
103	*23000008664*	Not Reported	Not Reported	Not Reported	42.697	-84.634	869	Public Supply
104	*23000008675*	Not Reported	Not Reported	Not Reported	42.697	-84.630	879	Public Supply
105	*23000008817*	340	10/6/2003	45	42.696	-84.630	869	Residential
106	*23000009043*	396	2/24/2004	25	42.696	-84.629	873	Residential
107	*23000009147*	270	Not Reported	60	42.698	-84.661	879	Commercial
108	*23000009148*	200	7/8/1971	35	42.712	-84.652	869	Residential
109	*23000009149*	321	8/21/1973	56	42.705	-84.643	869	Commercial
110	*23000009150*	290	6/16/1976	50	42.702	-84.643	869	Residential
111	*23000010028*	400	11/16/2005	30	42.691	-84.627	866	Residential
112	*23000010030*	400	11/16/2005	40	42.691	-84.627	869	Residential
113	*23000010086*	44	11/12/2005	14.6	42.671	-84.660	896	Commercial
114	*23000010321*	220	9/25/2003	30	42.671	-84.655	899	Residential
115	*23000010583*	410	8/15/2007	40	42.693	-84.627	869	Residential
116	*23000010760*	300	6/10/2008	25	42.683	-84.666	879	Residential
117	*23000010789*	356	7/30/2008	43	42.678	-84.639	853	Residential

Map Reference Number	*MI Well ID*	Well Depth (ft bgs)	Date of Contstruction	Static Water Level (ft bgs)	Latitude	Longitude	Elevation (ft)	Well Type
118	*23000011011*	190	8/31/1992	52	42.670	-84.661	896	Public Supply
119	*23000011261*	196	6/2/2010	18	42.706	-84.675	866	Residential
120	*23000011265*	180	5/24/2011	12	42.675	-84.640	840	Residential
121	*23000011444*	410	9/20/2012	45	42.690	-84.628	870	Residential
122	*23000011552*	365	9/12/2013	23	42.675	-84.642	850	Residential
123	*23000011554*	200	9/13/2013	24	42.680	-84.653	882	Commercial
124	*23000011748*	110	3/4/2009	0	42.696	-84.628	877	Residential
125	*23000011832*	200	1/23/2014	30	42.706	-84.676	859	Residential
126	*23000011846*	380	12/24/2013	40	42.696	-84.630	874	Residential
127	*23000012309*	395	4/17/2019	50	42.696	-84.628	877	Residential