Assessment of Corrective Measures

Laramie River Station
Bottom Ash Pond 1

Basin Electric Power Cooperative

Project number: 60577052

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Quality information

Prepared by	Checked by	Verified by	Approved by
Gregg Somermeyer Senior Project Manager	Geoff Webb Senior Project Manager	Dennis Connair VP, Principal Geologist	Gregg Somermeyer Senior Project Manager

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Prepared for:

Basin Electric Power Cooperative

Prepared by:

AECOM
1601 Prospect Pkwy
Fort Collins, CO 80525
aecom.com

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List of Acronyms

ACM	Assessment of Corrective Measures
bgs	below ground surface
CCR	Coal Combustion Residuals
CFR	Code of Federal Regulations
FGD	flue gas desulfurization
ft	feet
gpm	gallons per minute
GWPS	groundwater protection standard
LRS	Laramie River Station
mg/L	milligrams per liter
SSL	statistically significant level
TDS	total dissolved solids
WDEQ	Wyoming Department of Environmental Quality

1. Introduction

On behalf of Basin Electric Power Cooperative, (Basin), AECOM Technical Services, Inc. (AECOM) has completed an Assessment of Corrective Measures (ACM) for groundwater impacts associated with Bottom Ash Pond 1 at Laramie River Station (LRS) near Wheatland, Wyoming (**Figure 1-1**). This ACM was prepared in accordance with Chapter 40 of the Code of Federal Regulations (CFR) §§ 257.96 and 257.97 requirements under the Coal Combustion Residuals (CCR) Rule.

This ACM report is organized as follows:

- Chapter 1.0 provides an introduction, presents pertinent background information, and presents the corrective action objectives;
- Chapter 2.0 presents the nature and extent of impacts;
- Chapter 3.0 presents the technology/process options identification and assembly of corrective measure alternatives;
- Chapter 4.0 presents the detailed evaluation of corrective measure alternatives;
- Chapter 5.0 provides a list of references cited in the report.

Background

The CCR Rule (Chapter 40 of the Code of Federal Regulations (CFR) Part 257 Subpart D) established standards for the disposal of CCR in landfills and surface impoundments (CCR units). CCR produced at LRS includes fly ash, bottom ash, and flue gas desulfurization (FGD) waste, which is disposed in the following CCR units/multi-units:

- Bottom Ash Pond 1
- Bottom Ash Pond 2, Bottom Ash Pond 3, Ash Landfill (multi-unit)
- Emergency Holding Ponds (multi-unit)

40 CFR §§ 257.90 through 257.98 set forth groundwater monitoring and corrective action requirements for CCR units/multi-units. The groundwater monitoring provisions required the installation of a system of monitoring wells at LRS (**Figure 1-2**), periodic sampling of these wells, and analysis of the resulting data to evaluate whether hazardous constituents are identified above background levels. The CCR Rule also requires initiating a corrective action process if any hazardous constituents listed in Appendix IV of 40 CFR Part 257 are detected above background concentrations at levels exceeding groundwater protection standards (GWPSs).

GWPSs for the two CCR multi-units have not been exceeded. Groundwater assessment monitoring of Bottom Ash Pond 1 in 2018 (AECOM 2018a) identified lithium and molybdenum at statistically significant levels (SSLs) above GWPSs. Because concentrations of lithium and molybdenum were found to exceed GWPSs downgradient of Bottom Ash Pond 1, additional groundwater characterization activities were required per 40 CFR § 257.95(g)(1). The additional characterization activities were completed by AECOM in 2019 and documented in a report to Basin Electric (AECOM 2019).

The exceedance of GWPSs for Bottom Ash Pond 1 also triggers requirements for the assessment, selection and implementation of corrective measures to prevent further releases of hazardous constituents, remediate any releases and restore the affected area. Per 40 CFR § 257.97(b), the selected corrective measures shall achieve the following objectives:

- Be protective of human health and the environment;
- Attain the groundwater protection standard as specified pursuant to 40 CFR § 257.95(h);

- Control the source(s) of releases to reduce or eliminate, to the maximum extent feasible, further releases of constituents in Appendix IV to this part into the environment;
- Remove from the environment as much of the contaminated material that was released from the CCR unit as is feasible, considering factors such as avoiding inappropriate disturbance of sensitive ecosystems; and
- Comply with standards for management of wastes as specified in 40 CFR § 257.98(d).

Basin has committed to retrofit Bottom Ash Pond 1 in accordance with § 257.102 (criteria for conducting the closure or retrofit of CCR units). Because that will effectively remove the source of GWPS exceedances, this ACM focuses on identifying and evaluating groundwater corrective measures to address the dissolved lithium and molybdenum in groundwater downgradient of Bottom Ash Pond 1.

2. Nature and Extent of Impacts

Groundwater assessment monitoring of Bottom Ash Pond 1 in 2018 (AECOM 2018a) identified lithium and molybdenum at SSLs above GWPSs. The GWPS at LRS for lithium is 0.056 mg/L (the site background concentration), as specified in § 257.95(h)(3). The GWPS at LRS for molybdenum is 0.1 mg/L, as specified in 40 CFR § 257.95(h)(2). The results of past CCR groundwater monitoring of Bottom Ash Pond 1 are summarized in **Table 2-1**.

The approximate extent of impacted groundwater exceeding GWPSs downgradient of Bottom Ash Pond 1 is illustrated in **Figure 2-1**. The impacts extend from Bottom Ash Pond 1 to the north-northeast in the direction of groundwater flow. The GWPSs for lithium and molybdenum have been consistently exceeded in one monitoring well, MW-38B, the nearest CCR monitoring well downgradient of Bottom Ash Pond 1 (**Figure 2-1**). Lithium and molybdenum have been detected in other monitoring wells downgradient of Bottom Ash Pond 1, although measured concentrations do not exceed the established GWPSs (**Table 2-1**).

The vertical extent of impacts was further characterized by installing and sampling MW-38C in 2019. MW-38C is located in close proximity to MW-38B and is screened across a deeper interval. Sampling of MW-38C found concentrations of lithium and molybdenum to be less than GWPSs (**Table 2-1**). The vertical extent of impacts exceeding GWPSs therefore is limited from the top of the uppermost aquifer associated with Bottom Ash Pond 1 downwards to a depth above the screened interval of MW-38C.

The existing monitoring well network has sufficiently defined the lateral and vertical extent of lithium and molybdenum impacts for purposes of assessing corrective measures alternatives. Lithium and molydenum impacts exceeding GWPSs are confined to within the facility boundary and do not extend off-site.

3. Groundwater Corrective Measures Identification and Screening

The purpose of this chapter is to identify potentially applicable groundwater corrective measures for Bottom Ash Pond 1 to remediate the occurrence of lithium and molybdenum in groundwater above their respective GWPSs. The identified corrective measures were subjected to a screening process, after which selected technologies were assembled into corrective action alternatives and evaluated to determine their capability of achieving the corrective measures objectives specified in 40 CFR § 257.97(b).

Potentially applicable corrective measures were identified based on the nature and extent of groundwater impacts and site-specific geological and hydrogeological characteristics. The following corrective measures, to be used singly or in combination, were identified for screening to achieve the corrective action objectives:

- Natural attenuation
- Groundwater extraction (e.g., using pumping wells), followed by:
    - Surface discharge of extracted groundwater with prior treatment if necessary,
    - Underground injection of extracted groundwater, or
    - On-site reuse or disposal of extracted groundwater
- In-situ treatment
- Long-term monitoring.

Screening was performed by evaluating each corrective measure against the criteria of effectiveness, technical implementability and relative cost. Those that were deemed ineffective and/or had significant implementation concerns were rejected from further consideration. Those that passed the screening step were used to develop corrective measures alternatives, which were then subjected to detailed analysis and comparison as discussed in Chapter 4.

Natural Attenuation

Intrinsic biodegradation and volatilization cannot attenuate the constituents of concern, lithium and molybdenum, at the LRS site. However, other natural physical and chemical processes can, under favorable conditions, attenuate inorganic constituents such as lithium and/or molybdenum in groundwater with corresponding reductions in toxicity, mobility, and/or concentration. Physical attenuation processes include dispersion and dilution. Chemical attenuation processes include adsorption, ion exchange, and precipitation of target constituents.

Long-term monitoring of the site is required to track target constituent concentrations over time and to determine when site-specific corrective action goals are achieved. This natural attenuation approach is a viable option for Bottom Ash Pond 1 considering that Basin Electric plans to remove the CCR source materials, the extent of lithium and molybdenum impacts is limited, and detected concentrations marginally exceed the respective GWPSs. Natural processes such as dispersion, dilution, adsorption, and/or precipitation are expected to decrease concentrations downgradient of Bottom Ash Pond 1 over time once the impoundment is closed and CCR materials are removed. In the interim, lithium and molybdenum impacts are confined to the LRS site and continued monitoring will track progress towards achieving GWPSs.

Natural attenuation is a potentially viable corrective measure that is easily implementable, effective in achieving GWPSs without undue risk, and potentially cost effective relative to more aggressive corrective measures.

Groundwater Extraction

Groundwater extraction using one or more pumping wells is a proven technology for removing contaminated groundwater from an aquifer for subsequent treatment, discharge and/or reuse. An extraction well network would be designed and installed to capture impacted groundwater and remove contaminant mass and reduce concentrations, and/or to provide hydraulic containment and prevent further migration. The extraction well flow rates and spacing are based on aquifer hydraulic characteristics. The groundwater extraction wells would require registration with the Wyoming State Engineer.

A site-specific groundwater analytical flow model was calibrated and used to simulate groundwater pumping to capture the dissolved plume of lithium and molybdenum downgradient of Bottom Ash Pond 1. The results of modeling determined that a network of three recovery wells, each pumping at a rate of approximately 13 gallons per minute (gpm), could achieve full capture of the plume. Coupled with the planned removal of CCR source material from the impoundment, groundwater extraction could accelerate achievement of GWPSs.

Multiple alternatives exist for disposing of extracted groundwater – surface discharge or reuse, with or without pretreatment. The overall cost effectiveness of a groundwater extraction corrective measure would depend upon the selected disposal option for the extracted groundwater.

With Surface Discharge

One option for disposing of extracted groundwater would involve point source discharge to the Laramie River located north of LRS. This option would require obtaining a discharge permit from Wyoming Department of Environmental Quality (WDEQ). The permit would impose effluent limitations to ensure that the discharge does not cause exceedance of Wyoming Surface Water Quality Standards or endanger aquatic life. The permit would also require periodic monitoring and reporting to ensure compliance with effluent limitations.

While existing groundwater quality data suggests that the discharge (with no treatment) may meet surface quality standards, bioassay testing may be required to verify that the discharge would not present unacceptable toxicity to aquatic organisms. If it is determined that treatment is required to meet effluent limitations, treatment options would include pH adjustment, coagulation/chemical precipitation, or constructed wetlands. Treatment, if required, would increase the overall costs of groundwater extraction corrective measures and require installation of additional equipment, tanks, piping, instrumentation and controls, as well as periodic operator attention, maintenance, and monitoring during it operating life.

With On-Site Reuse or Disposal

The other likely alternative for disposal of extracted groundwater would involve pumping it to the plant for use as process makeup or cooling water, or disposal in one of the ash ponds. LRS average water use currently is approximately 11,000 gpm. LRS raw water quality contains approximately 500 milligrams per liter (mg/L) total dissolved solids (TDS), while groundwater samples from MW-38B contain up to 8,000 mg/L TDS. The addition of 39 gpm of extracted groundwater to the LRS raw makeup water would only increase TDS about 5 percent. The extracted groundwater would therefore likely be pumped, without treatment, directly to the makeup water pond near the eastern edge of the facility for commingling with incoming raw water prior to usage in the plant. Alternatively, the extracted groundwater would be pumped to one of the ash ponds.

In-Situ Treatment

A variety of technologies can be applied to treat impacted groundwater in-situ (i.e. in-place). In general, reactive materials or amendments are either injected into the subsurface or emplaced in a trench to form a permeable reactive barrier. The reactive materials/amendments are selected based on the chemical nature of the target constituents. Some dissolved metals, including molybdenum, may be removed by adsorption or co-precipitation onto zero-valent iron. Other reactants that have been used to remove metals by chemical reduction include ferrous sulfide and calcium polysulfide. Apatite (phosphate) has been used to stabilize metals in-situ and may be applicable for the removal of lithium.

Construction of a permeable reactive barrier downgradient of Bottom Ash Pond 1 through the underlying sandstone into groundwater to the required depth of up to 100 feet (ft) below ground surface (bgs) would be technically challenging and relatively costly. Therefore, reactive materials or amendments would most likely be introduced into the impacted groundwater zone associated with Bottom Ash Pond 1 using an injection well network designed to achieve effective contact and treatment of the dissolved constituents of concern.

Site-specific laboratory bench scale tests would be required to verify the treatment effectiveness of one or more candidate reactive materials selected to treat lithium and molybdenum to GWPSs. Pilot testing may also be required to verify that injection methods can effectively distribute the reactive materials within the aquifer. The data from these tests would be essential to supporting the detailed design of a full scale in-situ treatment system. The current uncertainties regarding the implementability and treatment effectiveness of an in-situ system, coupled with the potential costs compared to other corrective measures described above, warrants elimination of in-situ treatment from further consideration as a practicable, effective, and economical corrective measure for Bottom Ash Pond 1.

Long-Term Monitoring

Long-term monitoring of groundwater is commonly employed as an effective tool in evaluating remedial progress and attainment of corrective action objectives. During remedy implementation, groundwater is periodically sampled using standard, established procedures and equipment. The results are used to track the reduction in target constituent concentrations over time and ensure that potential further migration is being controlled. Long-term monitoring ensures that the remedy remains protective over time and provides the necessary data to determine when the remedy has achieved the desired goals.

Assembly of Groundwater Corrective Measure Alternatives

Applying the screening criteria of effectiveness, technical implementability and relative cost to the corrective measures described above eliminates in situ treatment as a viable technology for further consideration. The effectiveness of in situ treatment is currently unknown and would have to be verified, the technology may be difficult and costly to construct and maintain.

Natural attenuation, groundwater extraction, and long-term monitoring are proven effective, easily implementable and often cost-effective corrective measures, and have been retained and assembled into the following two corrective measures alternatives for further detailed evaluation:

- Alternative A: Natural Attenuation and Long-Term Monitoring
- Alternative B: Groundwater Extraction, Onsite Reuse or Disposal and Long-Term Monitoring

For Alternative B, onsite reuse or disposal has been selected as the preferred option for disposal of extracted groundwater for reasons of simplicity, reduced permitting burden, and lower cost. The results of detailed evaluation of these alternatives are discussed in the next chapter.

4. Detailed Evaluation of Groundwater Corrective Measure Alternatives

A detailed evaluation of the two groundwater alternatives developed in Chapter 3 is presented in the following subsections. Both alternatives were evaluated against the requirements specified in 40 §§ CFR 257.96 and 257.97. The alternative evaluation criteria are listed in **Table 4-1** below, and broadly categorized under the headings of effectiveness, implementability and cost.

Table 4-1. Criteria for Evaluation of Alternatives

Effectiveness
Protective of Human Health and the Environment
Attain GWPS
Control the Source of Release
Comply with Standards for Management of Wastes
Long-term Effectiveness and Permanence
Reduction of Toxicity, Mobility or Volume through Treatment
Short-term Effectiveness
Implementability
Technical Feasibility
Administrative Feasibility
Availability of Services and Materials
Cost
Capital and Operation & Maintenance Costs

Alternative A: Natural Attenuation and Long-Term Monitoring

This alternative consists of natural attenuation and long-term monitoring. Once Bottom Ash Pond 1 is retrofit, both lithium and molybdenum concentrations in monitoring wells downgradient of the pond are expected to decrease by naturally occurring processes such as adsorption, advection and dispersion. As part of natural attenuation, a long-term monitoring network would be established in the vicinity of Bottom Ash Pond 1 to document that natural attenuation is reducing lithium and molybdenum concentrations over time. Long-term monitoring would be performed using existing wells which may be supplemented by newly installed wells, if needed. At a minimum, the long-term monitoring network would include an upgradient well, the affected well (MW-38B), the deeper well adjacent to MW-38B (MW-38C), and several hydraulically downgradient wells. Groundwater samples would be collected annually and analyzed for Appendix IV constituents in accordance with the Sampling and Analysis Plan (AECOM 2018b). The long-term monitoring network would be finalized in the design phase and optimized periodically based on long-term monitoring data review. The remediation timeframes for natural attenuation to attain GWPSs were estimated using SourceDK Remediation Timeframe Decision Support System, a spreadsheet model developed by GSI Environmental and Air Force Center for Engineering and Environment. The timeframes for natural attenuation to attain GWPSs for lithium and molybdenum were calculated to be 45 years and 40 years, respectively.

The results of evaluating Alternative A against criteria of effectiveness, implementability and cost are presented in **Table 4-2**.

Table 4-2. Evaluation of Alternative A: Natural Attenuation and Long-Term Monitoring

Effectiveness	
Protective of Human Health and the Environment	Alternative A would be protective of human health and the environment. Following retrofit of Bottom Ash Pond 1, the relatively low lithium and molybdenum concentrations at monitoring well MW-38B are expected to attenuate over time to GWPSs through naturally occurring processes such as adsorption, precipitation, dilution and dispersion. Exposure to groundwater containing lithium and molybdenum above GWPSs through ingestion, inhalation, dermal contact or agricultural use is unlikely to occur at the site. The area exceeding GWPSs is distant from the facility boundary and off-site risks to human or environmental receptors is minimal. Continued long-term monitoring of groundwater quality would help ensure that the remedy remains protective until GWPSs are reached.
Attain GWPS	Once Bottom Ash Pond 1 is retrofit, natural attenuation is expected to meet the GWPSs for lithium and molybdenum after approximately 45 years. Long-term monitoring would be conducted to track groundwater quality and confirm when GWPSs are reached.
Control the Source of Release	The planned retrofit of Bottom Ash Pond 1 involving removal of CCR source materials would prevent further release of CCR hazardous constituents to groundwater.
Comply with Standards for Management of Wastes	Small quantities of purge water and non-hazardous solid waste resulting from long-term groundwater sampling activities would be managed in compliance with waste disposal rules and regulations.
Long-Term Effectiveness and Permanence	Removal of CCR materials from Bottom Ash Pond 1 during retrofit activities will prevent additional releases, and natural attenuation processes will result in the permanent reduction of lithium and molybdenum concentrations in groundwater to below GWPSs. Long-term monitoring will be performed to ensure that the remedy remains effective and permanent.
Reduction of Toxicity, Mobility or Volume through Treatment	This alternative would not result in the reduction of toxicity, mobility, or volume of lithium or molybdenum through treatment, although mobility could be reduced through chemical interaction with aquifer materials.
Short-Term Effectiveness	Implementation of Alternative A would involve groundwater sampling to monitor natural attenuation progress. Proper use of PPE and safety procedures would minimize potential risks to workers during routine groundwater sampling activities.
Implementability	
Technical Feasibility	Groundwater sampling activities involve routine environmental monitoring procedures and would be easily implemented.
Administrative Feasibility	No additional approvals and permits would be required to implement the natural attenuation groundwater corrective measure for this alternative.
Availability of Services and Materials	Natural attenuation and long-term monitoring would involve using standard environmental sampling methods and equipment. No special equipment or training would be required to implement the remedy. Certified testing laboratories are readily available to perform sample analysis.
Cost	
Total Cost	Relatively cost effective. Overall costs would increase if timeframe to achieve GWPSs increases.

For evaluation purposes, the following assumptions were made:

- The long-term monitoring network would consist of six existing wells; no new wells would be required.
- Groundwater samples would be shipped to a commercial testing laboratory for analysis of Appendix IV constituents.
- Long-term monitoring would be conducted on an annual basis for 45 years, plus 2 years of additional monitoring to ensure that groundwater quality remains below GWPSs. (The actual duration of long-term monitoring would be adjusted accordingly if GWPSs are achieved in a shorter or longer timeframe.)

Alternative B: Groundwater Extraction, Onsite Reuse or Disposal and Long-Term Monitoring

This alternative would consist of installing and operating groundwater extraction wells to recover groundwater for onsite reuse or disposal, and long-term monitoring. Groundwater extraction would be performed using multiple vertical extraction wells containing dedicated submersible pumps. The recovery wells would be placed downgradient of Bottom Ash Pond 1 along a line perpendicular to groundwater flow direction designed to provide complete capture of impacted groundwater and prevent it from flowing downgradient towards the property boundary.

The GFLOW model used to evaluate the design of a pumping system to capture the dissolved lithium and molybdenum in the bedrock (sandstone) aquifer downgradient of Bottom Ash Pond 1. GFLOW is a stepwise groundwater flow modeling system developed by Haitjema Software, a subdivision of Haitjema Consulting, Inc. It models steady state flow in a single heterogeneous aquifer based on the analytic element method, and uses particle tracking to simulate movement of groundwater particles. Model inputs included annual precipitation, recharge rate, hydraulic conductivity, aquifer thickness, and nearby river and stream elevations. The model was calibrated to actual groundwater levels measured at LRS in 2018. Using the calibrated GFLOW model, a recovery system consisting of three wells spaced approximately 330 ft apart and each pumping at a rate of 13 gpm was determined effective in capturing the plume of dissolved lithium and molybdenum downgradient of Bottom Ash Pond 1. (The optimal number of extraction wells, placement, and pumping rate would be finalized during detailed design prior to construction)

Following extraction, groundwater would be conveyed to the existing LRS makeup water pond or one of the existing CCR impoundments. If used for makeup water, the groundwater would not require treatment because of the relatively low flow rate of groundwater compared to incoming makeup water from Grayrocks Reservoir.

Long-term groundwater monitoring would be required to demonstrate hydraulic containment and reduction in lithium and molybdenum concentrations over time. Monitoring would include annual groundwater elevation measurements, groundwater sampling of six existing monitoring wells and the combined stream of extracted groundwater, and laboratory analysis of groundwater samples for Appendix IV constituents.

The remediation timeframes for groundwater extraction to attain GWPSs were estimated using SourceDK Remediation Timeframe Decision Support System. The timeframes to attain GWPSs for lithium and molybdenum were calculated to be approximately 2.4 years and 2.1 years, respectively. The extraction system would be shut off after GWPSs are achieved throughout the impacted area. Long-term monitoring would then continue on an annual basis for 2 additional years to confirm that lithium and molybdenum concentrations in groundwater do not rebound.

An evaluation of Alternative B is presented in **Table 4-3**.

Table 4-3. Evaluation of Alternative B: Groundwater Extraction, Onsite Reuse or Disposal and Long-Term Monitoring

Effectiveness	
Protective of Human Health and the Environment	Alternative B would be protective of human health and the environment. Following retrofit of Bottom Ash Pond 1, the relatively low lithium and molybdenum concentrations at monitoring well MW-38B would decline within a relatively short timeframe to GWPSs by extracting the impacted groundwater from the aquifer and reusing it within the plant. Exposure to groundwater containing lithium and molybdenum above GWPSs through ingestion, inhalation, dermal contact or agricultural use is unlikely to occur at the site because the extracted groundwater will be conveyed in a closed pumping and piping system to the makeup water pond where it will be commingled with the much larger incoming volume of makeup water from Grayrocks Reservoir. The area of the aquifer exceeding GWPSs is distant from the facility boundary and off-site risks to human or environmental receptors would be minimal to non-existent. Continued long-term monitoring of groundwater quality would ensure that the remedy remains protective until GWPSs are reached.
Attain GWPS	This alternative is expected to meet the GWPSs for lithium and molybdenum in less than 3 years. Long-term monitoring would be conducted to track groundwater quality and confirm when GWPSs are reached.
Control the Source of Release	The planned retrofit of Bottom Ash Pond 1 involving removal of CCR source materials would prevent further release of CCR hazardous constituents to groundwater.
Comply with Standards for Management of Wastes	The extracted groundwater would be beneficially reused at LRS or be disposed onsite as a waste stream. Small quantities of purge water and non-hazardous solid waste resulting from long-term groundwater sampling activities would be managed in compliance with waste disposal rules and regulations.
Long-term Effectiveness and Permanence	The retrofit of Bottom Ash Pond 1 will prevent additional releases, and groundwater extraction will result in the permanent reduction of lithium and molybdenum concentrations in groundwater to below GWPSs. Long-term monitoring will be performed to ensure that the remedy remains effective and permanent.
Reduction of Toxicity, Mobility or Volume through Treatment	This alternative would result in the reduction of toxicity, mobility, and volume of dissolved lithium or molybdenum in groundwater through extraction and reuse.
Short-term Effectiveness	Construction of a groundwater extraction system consisting of pumping wells and transfer piping would be completed using standard drilling and construction equipment in accordance with industry standard health and safety procedures and using personal protective equipment to minimize risks to workers. Fugitive dust emissions would be minimal, and air quality would not be adversely impacted. Standard environmental and health and safety procedures would be followed during operation and monitoring to minimize risk to workers and the environment.
Implementability	
Technical Feasibility	Groundwater extraction is a proven, reliable technology for containing and removing groundwater with inorganic constituents of concern and has been successfully employed at many sites. The construction methods for installing the extraction wells, pumps and piping are routinely employed during environmental remediation projects and would be easily implemented.
Administrative Feasibility	Implementation of this alternative would require coordination with construction contractors. Additional coordination and permits would be required related to transportation of contaminated groundwater to an off-site non-hazardous waste disposal facility.

Table 4-3. Evaluation of Alternative B: Groundwater Extraction, Onsite Reuse or Disposal and Long-Term Monitoring

Availability of Services and Materials	A number of qualified environmental drillers and remediation construction contractors are available to install a groundwater extraction system at LRS. The required equipment and supplies are also readily available from reputable vendors and suppliers.
Cost	
Total Cost	Relatively cost effective. Overall costs would increase if timeframe to achieve GWPSs increases.

The evaluation was prepared based on the following assumptions:

- Three extraction wells would be installed downgradient of Bottom Ash Pond 1, each with an approximate pumping rate of 13 gpm.
- The extracted groundwater would be pumped directly to the existing makeup water pond or into one of the CCR impoundments.
- No groundwater treatment is required.
- Operations would continue for 2.5 years.
- The long-term monitoring network would consist of six existing wells (no new wells would be required); the combined discharge from the extraction wells would also be sampled.
- Groundwater samples would be shipped to a commercial testing laboratory for analysis of Appendix IV constituents.
- Long-term monitoring would involve annual sampling until GWPSs are achieved, plus 2 years of additional monitoring to ensure that groundwater quality remains below GWPSs.

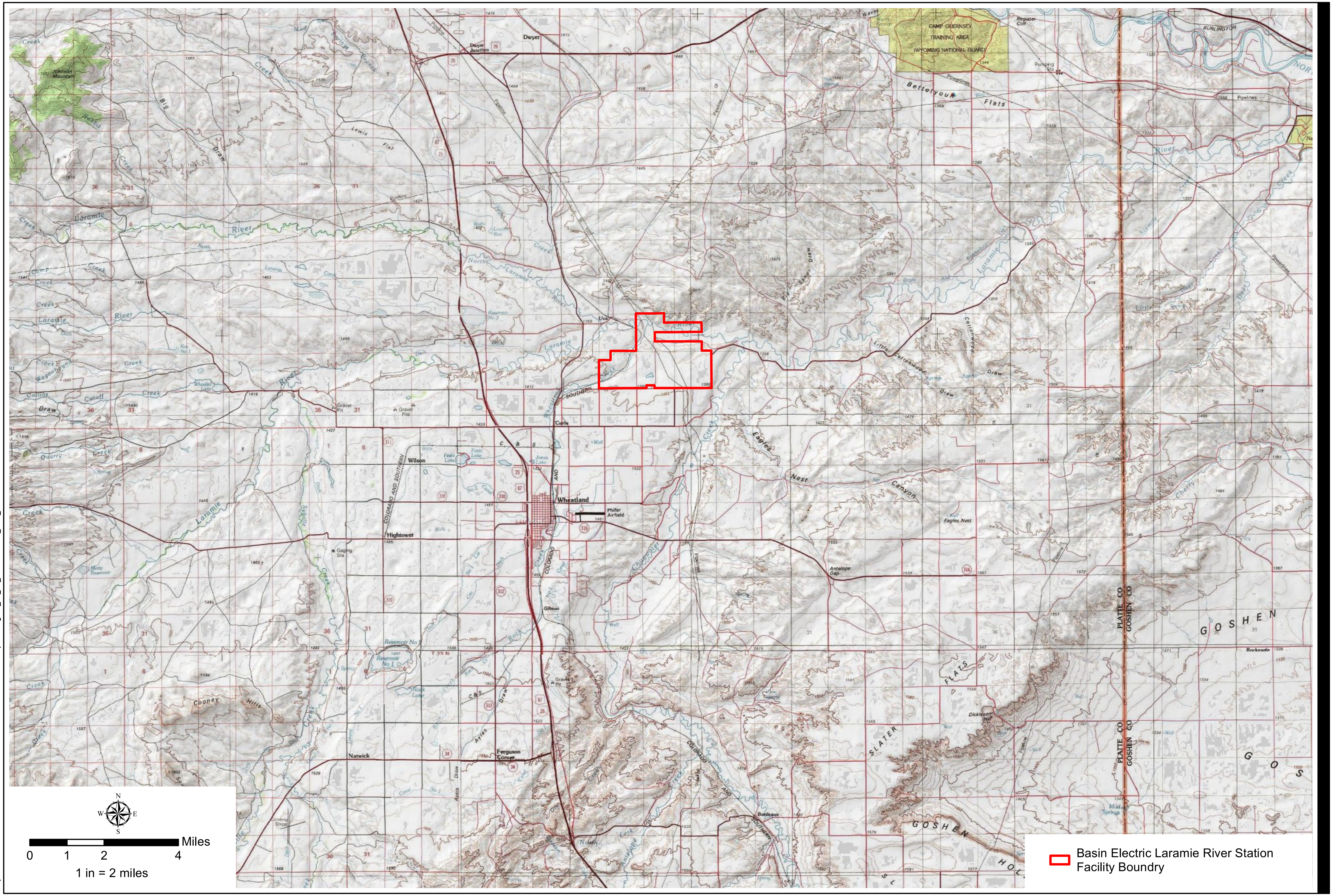
5. References

AECOM. 2018a. First Annual Groundwater Monitoring and Corrective Action Report, 2016-2017, Laramie River Station, Wheatland, Wyoming. Basin Electric Power Cooperative. January 2018.

AECOM. 2018b. Sampling and Analysis Plan, CCR Monitoring Program, Laramie River Station, Wheatland, Wyoming. Basin Electric Power Cooperative. January 2018.

AECOM. 2019. Groundwater Characterization Report, Laramie River Station, Wheatland, Wyoming. Basin Electric Power Cooperative. July 2019.

Figures



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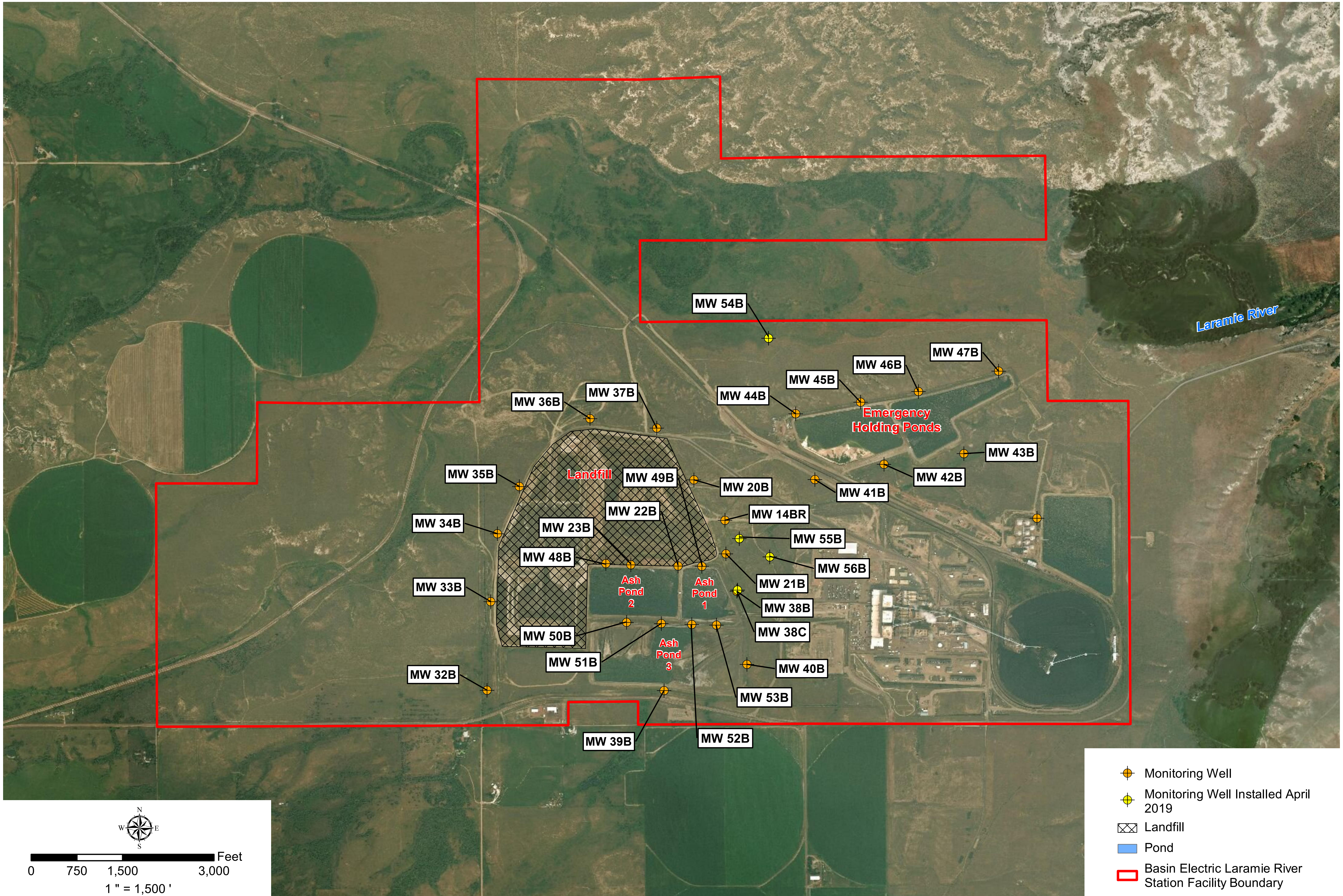
Site Location Map

AECOM

Figure: 1-1

Basin Electric
Laramie River Station
Platte County, Wyoming
Project No.: 60506860 Date: 09/28/2016



AECOM

Figure: 1-2

LRS CCR Monitoring Well Network

Basin Electric
Laramie River Station
Platte County, Wyoming
Project No.: 60577052 Date: 6/28/2019

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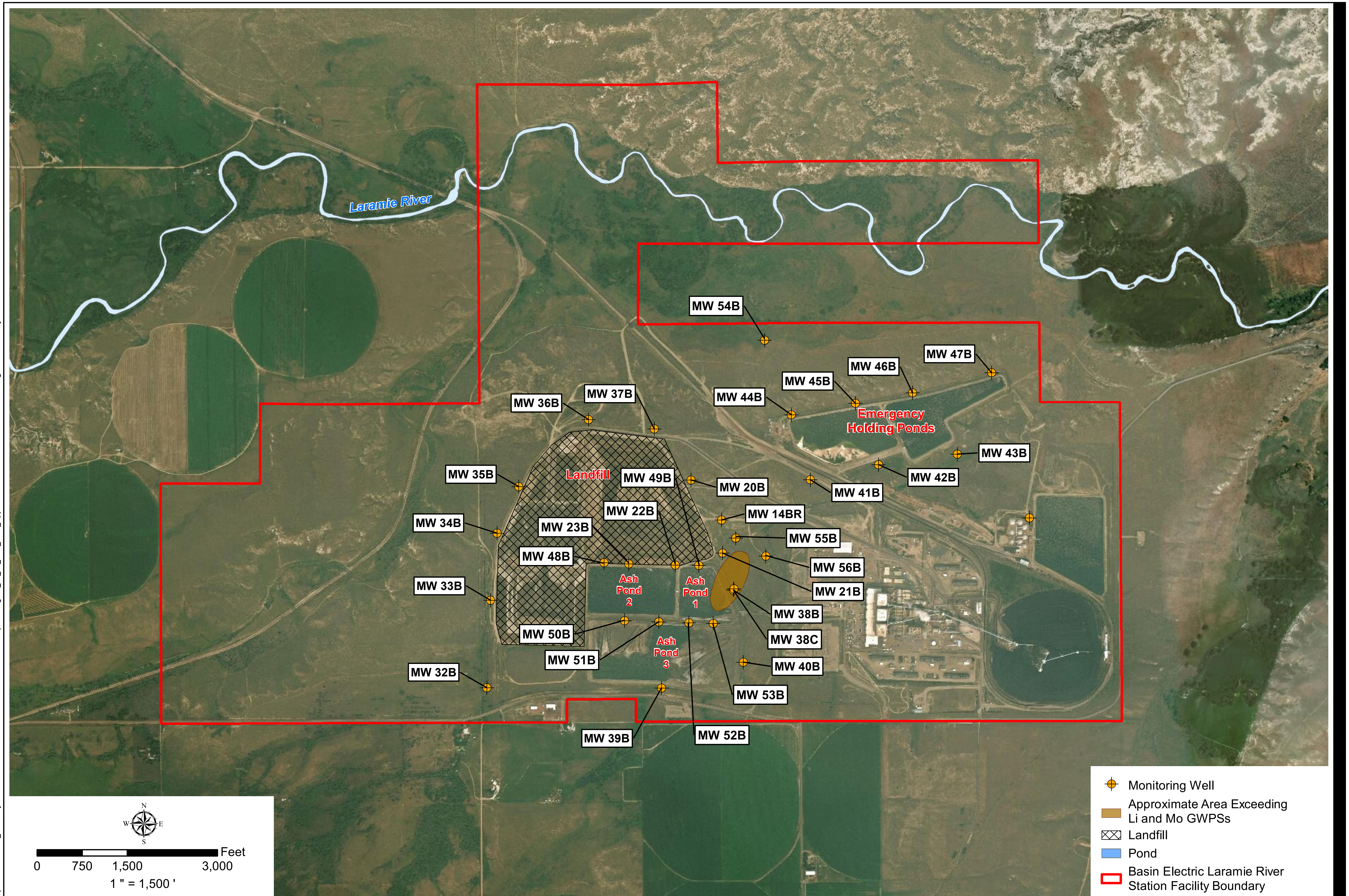

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Approximate Extent of Groundwater Exceeding Lithium or Molybdenum GWPSs

Basin Electric
Laramie River Station
Platte County, Wyoming
Project No.: 60577052 Date: 8/27/2019

Figure: 2-1

Tables

Table 2-1 Groundwater Analytical Data – Bottom Ash Pond 1

				Appendix III Constituents							Appendix IV Constituents														
		Analyte Name		Boron	Calcium	Chloride	Fluoride	pH	Sulfate	TDS	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Fluoride	Lead	Lithium	Mercury	Molybdenum	Radium 226/228	Selenium	Thallium
		Unit		mg/L	mg/L	mg/L	mg/L	SU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pCi/L	mg/L	mg/L
Relative Location	MW ID	Date	Type																						
Background	MW-52B	7/19/2017	N	0.15	120	33	0.50	7.91	370	820	0.0020 U	0.0050 U	0.130	0.0010 U	0.0010 U	0.0058	0.0014	0.50	0.0010 U	0.048	0.00020 U	0.013	0.35 U	0.0050 U	0.0010 U
		8/25/2017	N	0.16	120	41	0.50 U	7.54	410	920	0.0020 U	0.0050 U	0.120	0.0010 U	0.0010 U	0.002 U	0.0010 U	0.50 U	0.0010 U	0.039	0.00020 U	0.0094	0.903	0.0050 U	0.0010 U
		8/31/2017	N	0.16	160	41	0.50 U	7.61	420	930	0.0020 U	0.0050 U	0.240	0.0010 U	0.0010 U	0.011	0.0040	0.50 U	0.0041	0.063	0.00020 U	0.0088	1.250 U	0.0050 U	0.0010 U
		9/6/2017	N	0.17	140	41 J	0.50 U	7.61	430	980	0.0020 U	0.0050 U	0.110	0.0010 U	0.0010 U	0.002 U	0.0010 U	0.50 U	0.0010 U	0.045	0.00020 U	0.0083	1.200 U	0.0050 U	0.0010 U
		9/14/2017	N	0.16	130	43	0.50 U	7.46	430	940	0.0020 U	0.0050 U	0.120	0.0010 U	0.0010 U	0.002 U	0.0010 U	0.50 U	0.0010 U	0.049	0.00020 U	0.0071	0.482	0.0050 U	0.0010 U
		9/18/2017	N	0.15	130	41	0.50 U	7.45	420	1000	0.0020 U	0.0050 U	0.110	0.0010 U	0.0010 U	0.002 U	0.0010 U	0.50 U	0.0010 U	0.049	0.00020 U	0.0066	0.566	0.0050 U	0.0010 U
		9/27/2017	N	0.15	140	40	0.50 U	7.55	430	960	0.0020 U	0.0050 U	0.110	0.0010 U	0.0010 U	0.002 U	0.0010	0.50 U	0.0010 U	0.050	0.00020 U	0.0063	0.370 U	0.0050 U	0.0010 U
		10/3/2017	N	0.15	130	42	0.50 U	7.74	430	1000	0.0020 U	0.0050 UJ	0.096	0.0010 U	0.0010 U	0.002 U	0.0010 UJ	0.50 U	0.0010 U	0.048	0.00020 U	0.0056	0.576 UJ	0.0050 U	0.0010 U
		4/4/2018	N	----	----	----	0.50 U	----	----	----	0.0020 U	0.0050 U	0.109 J+	0.0010 U	0.0010 U	0.002 U	0.0010	0.50 U	0.0010 U	0.048	0.00020 U	0.0053	0.617 J	0.0050 U	0.0010 U
		6/27/2018	N	0.16	175	39 J+	0.50 U	7.39	499	1080	0.0020 U	0.0050 U	0.086 J+	0.0010 U	0.0010 U	0.002 U	----	0.50 U	0.0010 U	0.048	0.00020 U	0.0045	0.873 U	0.0050 U	0.0010 U
		10/24/2018	N	0.16	168	41	0.50 U	7.32	469	1100 J+	----	----	0.082	----	----	0.002 U	0.0010 U	0.50 U	----	0.039	----	0.0041	----	0.0050	----
	MW-53B	7/19/2017	N	0.10 U	95	32	0.96	8.63	220	570	0.0020 U	0.0050 U	0.100	0.0010 U	0.0010 U	0.0045	0.0010 U	0.96	0.0010 U	0.042	0.00020 U	0.0140	0.682 U	0.0060	0.0010 U
		8/25/2017	N	0.10 U	81	34	0.91	8.48	210	560	0.0020 U	0.0050 U	0.120	0.0010 U	0.0010 U	0.0038	0.0010 U	0.91	0.0010 U	0.033	0.00020 U	0.0140	1.090	0.0050 U	0.0010 U
		8/31/2017	N	0.10 U	82	33	0.88	8.72	220	540	0.0020 U	0.0050 U	0.130	0.0010 U	0.0010 U	0.0045	0.0010 U	0.88	0.0010 U	0.042	0.00020 U	0.0150	0.426 U	0.0050 U	0.0010 U
		9/6/2017	N	0.10 U	79	33 J	1.00	8.98	210	560	0.0020 U	0.0050 U	0.130	0.0010 U	0.0010 U	0.0052	0.0010 U	1.00	0.0010 U	0.035	0.00020 U	0.0150	0.407 U	0.0050 U	0.0010 U
		9/14/2017	N	0.10 U	77	33	0.93	7.79	220	590	0.0020 U	0.0050 U	0.094	0.0010 U	0.0010 U	0.0028	0.0010 U	0.93	0.0010 U	0.038	0.00020 U	0.0120	0.424 U	0.0050 U	0.0010 U
		9/18/2017	N	0.10 U	76	33	1.00	7.52	210	580	0.0020 U	0.0050 U	0.094	0.0010 U	0.0010 U	0.0033	0.0010 U	1.00	0.0010 U	0.041	0.00020 U	0.0120	0.432 U	0.0050 U	0.0010 U
		9/27/2017	N	0.10 U	78	32	1.10	7.96	220	620	0.0020 U	0.0050 U	0.070	0.0010 U	0.0010 U	0.002 U	0.0010 U	1.10	0.0010 U	0.042	0.00020 U	0.0100	0.375 U	0.0050 U	0.0010 U
		10/3/2017	N	0.10 U	78	33	1.10	7.79	220	610	0.0020 U	0.0050 UJ	0.081	0.0010 U	0.0010 U	0.0022	0.0010 UJ	1.10	0.0010 U	0.040	0.00020 U	0.0110	1.880 UJ	0.0050 U	0.0010 U
		4/4/2018	N	----	----	----	1.14	----	----	----	0.0020 U	0.0050 U	0.055 J+	0.0010 U	0.0010 U	0.002 U	0.0010 U	1.14	0.0010 U	0.042	0.00020 U	0.0070	0.370 UJ	0.0069	0.0010 U
		6/27/2018	N	0.10	102	37 J+	1.33 J+	7.62	242	691	0.0020 U	0.0050 U	0.052 J+	0.0010 U	0.0010 U	0.002 U	----	1.33 J+	0.0010 U	0.038	0.00020 U	0.0085	0.400 U	0.0064	0.0010 U
		10/24/2018	N	0.11	98	41	1.21	7.68	231	711 J+	----	----	0.053	----	----	0.002 U	0.0010 U	1.21	----	0.041	----	0.0067	----	0.0071	----
Downgradient	MW-21B	11/11/2016	N	0.16	290	250	0.76	6.63	680	1600 J	0.0020 U	0.0050 U	0.061	0.0010 U	0.0010 U	0.021	0.0010 U	0.76	0.0021	0.046	0.00020 U	0.0160	0.513	0.0350	0.0010 U
		12/15/2016	N	0.16	270	250	0.75	7.65	680	1600	0.0020 U	0.0050 U	0.068	0.0010 U	0.0010 U	0.021	0.0010 U	0.75	0.0015	0.044	0.00020 U	0.0150	0.694	0.0340	0.0010 U
		2/14/2017	N	0.16	290	250	0.77	7.66	660	1500	0.0020 U	0.0050 U	0.059	0.0010 U	0.0010 U	0.023	0.0010 U	0.77	0.0010 U	0.046	0.00020 U	0.0160	0.385 U	0.0360	0.0010 U
		4/4/2017	N	0.16	280	280	0.71	7.49	740	1700 J	0.0200 U	0.0500 U	0.053	0.0100 U	0.0100 U	0.031	0.0100 U	0.71	0.0100 U	0.049	0.00020 U	0.0200 U	0.310 U	0.0500 U	0.0100 U
		4/25/2017	N	0.16	290	290	0.73	7.53	770	1800	0.0020	0.0050	0.049	0.0050	0.0010	0.037	0.0010	0.73	0.0010	0.041	0.00020	0.0170	0.328	0.0490	0.0010
		5/16/2017	N	0.18	280	290	0.72	7.53	760	1800	0.0020 U	0.0050 U	0.049 J	0.0010 U	0.0010 U	0.041	0.0010 U	0.72	0.0010 U	0.043	0.00020 U	0.0160	0.384 U	0.0520	0.0010 U
		6/14/2017	N	0.16	290	300	0.73	7.46	760	1900	0.0020 U	0.0050 U	0.045	0.0010 U	0.0010 U	0.039	0.0010 U	0.73	0.0010 U	0.050	0.00020 U	0.0160	0.606	0.0470	0.0010 U
		7/26/2017	N	0.15	260	270	0.70	7.74	670	1600	0.0020 U	0.0050 U	0.057	0.0010 U	0.0010 U	0.038	0.0010 U	0.70	0.0010 U	0.040	0.00020 U	0.0120	0.394 U	0.0440	0.0010 U
		6/27/2018	N	----	----	----	0.83 J+	7.51	----	----	0.0020 U	0.0050 U	0.057 J+	0.0010 U	0.0010 U	0.0258	0.0010 U	0.83 J+	0.0010 U	0.042	0.00020 U	0.0164	0.345 U	0.0508	0.0010 U
		10/24/2018	FD	0.17	289	270	0.70	7.51	714	1670 J+	----	----	0.045	----	----	0.0343	0.0010 U	0.70	----	0.044	----	0.0172	----	0.0542	----
		10/24/2018	N	0.17	280	268	0.71	7.51	699	1380 J+	----	----	0.045	----	----	0.0346	0.0010 U	0.71	----	0.039	----	0.0168	----	0.0526	----
	MW-38B	9/1/2016	N	3.00	510	400	1.00 U	7.30	4600	7800	0.0020 U	0.0050 U	0.050	0.0010 U	0.0010 U	0.0042	0.0029	1.00 U	0.0010 U	0.130	0.00020 U	0.2100	0.604	0.0120	0.0010 U
		11/10/2016	N	3.00	500	500	1.00 U	7.11	4800	4800	0.0100 U	0.0050 U	0.038	0.0050 U	0.0050 U	0.0087	0.0014	1.00 U	0.0010 U	0.130	0.00020 U	0.1800	0.412 U	0.0250 U	0.0010 U
		12/15/2016	N	3.00	470	490	1.00 U	7.35	5000	7800	0.0020 U	0.0050 U	0.034	0.0010 U	0.0010 U	0.01	0.0014	1.00 U	0.0010 U	0.130	0.00020 U	0.1900	0.514	0.0120	0.0010 U
		2/14/2017	N	2.80	460	470	1.00 U	7.38	4800	7700	0.0020 U	0.0050 U	0.060	0.0010 U	0.0010 U	0.013	0.0015	1.00 U	0.0010 U	0.130	0.00020 U	0.1900	0.308 U	0.0120	0.0010 U
		4/4/2017	N	2.90	440	420	1.00 U	7.28	4700	7800	0.0200 U	0.0500 U	0.026	0.0100 U	0.0100 U	0.02 U	0.0100 U	1.00 U	0.0100 U	0.150	0.00020 U	0.1700	0.317 U	0.0500 U	0.0100 U
		5/16/2017	FD	3.00	460	410	0.50 U	7.31	4800	7700	0.0020 U	0.0050 U	0.023 J	0.0010 U	0.0010 U	0.0091	0.0010 U	0.50 U	0.0010 U	0.140	0.00020 U	0.2000	0.400 U	0.0130	0.0010 U
		5/16/2017	N	2.80	420	410	0.60	7.31	4700	8000	0.0020 U	0.0050 U	0.025 J	0.0010 U	0.0010 U	0.01	0.0010 U	0.60	0.0010 U	0.130	0.00020 U	0.2100	0.357 U	0.0130	0.0010 U
		6/14/2017	N	2.80	480	400	1.00 U	7.23	5000	8000	0.0020 U	0.0050 U	0.023	0.0010 U	0.0010 U	0.0088	0.0010 U	1.00 U	0.0010 U	0.140	0.00020 U	0.2000	0.534	0.0120	0.0010 U
		7/26/2017	FD	3.00	470	390	0.50 U	7.47	4600	7800	0.0020 U	0.0050 U	0.031	0.0010 U	0.0010 U	0.0099	0.0010	0.50 U	0.0010 U	0.140	0.00020 U	0.1900	0.336 U	0.0120	0.0010 U
		7/26/2017	N	3.00	470	390	0.50 U	7.47	4900	8000	0.0020 U	0.0050 U	0.034	0.0013	0.0011	0.011	0.0021	0.50 U	0.0018	0.130	0.00020 U	0.1900	0.671 U	0.0130	0.0010
		6/27/2018	N	----	----	----	2.50 U	7.41	----	----	0.00200 U	0.00500 U	0.0242 J+	0.00100 U	0.00100 U	0.00994	0.00104	2.50 U	0.00100 U	0.139	0.000200 U	0.239	0.788 U	0.0128	0.00100 U
		10/24/2018	N	3.60	675	328	1.00 U	7.25	3450	7800 J+	----	----	0.0139	----	----	0.00765	0.00100 U	1.00 U	----	0.116	----	0.226	----	0.0127	----
	MW-49B	7/27/2017	N	0.10 U	94	19	0.50 U	11.40	180	490	0.0020 U	0.0050 U	0.092	0.0010 U	0.0010 U	0.023	0.0010 U	0.50 U	0.0010 U	0.029	0.00020 U	0.0093	0.487 U	0.0050 U	0.0010 U
		8/25/2017	N	0.10 U	110	32	0.50 U	10.14	380	620	0.0020 U	0.0050 U	0.140	0.0010 U	0.0010 U	0.012	0.0010 U	0.50 U	0.0010 U	0.031	0.00020 U	0.0053	1.070	0.0050 U	0.0010 U
		8/31/2017	N	0.10 U	98	33	0.50 U	9.57	390	650	0.0020 U	0.0050 U	0.120	0.0010 U	0.0010 U	0.0087	0.0010 U	0.50 U	0.0010 U	0.038	0.00020 U	0.0055	0.616 U	0.0050 U	0.0010 U
		9/6/2017	N	0.11	100	32 J	0.53	9.70	390	730	0.0020 U	0.0050 U	0.120	0.0010 U	0.0010 U	0.0057	0.0010 U	0.53	0.0010 U	0.034	0.00020 U	0.0057	0.509 U	0.0050 U	0.0010 U
		9/14/2017	N	0.12	95	34	0.59	8.80	400	750	0.0020 U	0.0050 U	0.130	0.0010 U	0.0010 U	0.0031	0.0010 U	0.59	0.0010 U	0.043	0.00020 U	0.0051	0.432 U	0.0050 U	0.0010 U
		9/19/2017	N	0.12	94	34	0.50 U	8.49	400	820	0.0020 U	0.0050 U	0.140	0.0010 U	0.0010 U	0.0028	0.0010 U	0.50 U	0.0010 U	0.043	0.00020 U	0.0050	0.481 U	0.0050 U	0.0010 U
		9/27/2017	N	0.12	100	33	0.84	8.93	400	820	0.0020 U	0.0050 U	0.140	0.0010 U	0.0010 U	0.002 U	0.0010 U	0.84	0.0010 U	0.041	0.00020 U	0.0052	0.548 U	0.0050 U	0.0010 U
		10/3/2017	FD	0.12	110	32	0.69	8.76	390	830	0.0020 U	0.0050 UJ	0.120	0.0010 U	0.0010 U	0.002 U	0.0010 UJ	0.69	0.0010 U	0.042	0.00020 U	0.0049	1.970 UJ	0.0050 U	0.0010 U
		10/3/2017	N	0.12	100	32	0.69	8.76	390	830	0.0020 U	0.0050 UJ	0.120	0.0010 U	0.0010 U	0.002 U	0.0010 UJ	0.69	0.0010 U	0.039	0.00020 U	0.0043	0.573 UJ	0.0050 U	0.0010 U
		6/27/2018	N	----	----	----	0.608 J+	7.68	----	----	0.00200 U	0.00500 U	0.109 J+	0.00100 U	0.00100 U	0.00200 U	0.00100 U	0.608 J+	0.00100 U	0.0444	0.000200 U	0.00381	0.780 U	0.00500 U	0.00100 U
		10/24/2018	N	0.173	125	34.8	0.588	7.75	407	965 J+	----	----	0.100	----	----	0.00200 U	0.00100 U	0.588	----	0.0396	----	0.00448	----	0.00500	----
	MW-38C	4/16/2019	N	0.135 J-	94.3	47.2 J	0.893	7.53	320	755	----	----	0.0509 J-	----	----	0.0020 U	0.0010 UJ	0.893	----	0.0515	----	0.0268 J-	----	0.00513	----
		4/16/2019	FD	0.137 J-	97.9	92.8 J	1.67	7.53	310	796	----	----	0.0500 J-	----	----	0.00200	0.00100 UJ	1.67	----	0.0471	----	0.0254 J-	----	0.00500 U	----
	MW-54B	4/16/2019	N	0.100 UJ	44.4	17.5 J	0.918	7.69	95.6	398	----	----	0.0491 J-	----	----	0.00341	0.0010 UJ	0.92	----	0.020 U	----	0.00507 J-	----	0.00608	----
	MW-55B	4/16/2019	N	0.146 J-	106	85.3 J	0.842	7.65	320	853	----	----	0.125 J-	----	----	0.00808	0.00143 J-	0.842	----	0.0362	----	0.0164 J-	----	0.0252	----
	MW-56B	4/16/2019	N	0.100 UJ	101	37.7 J	0.963	7.60	320	789	----	----	0.0840 J-	----	----	0.00463	0.00106 J-	0.963	----	0.0345	----	0.0160 J-	----	0.0187	----

Notes:
mg/L - milligrams per liter
SU - standard units
pCi/L - picocuries per liter
U - undetected at the reporting limit/concentration
UJ - undetected, reporting limit is estimated
J - estimated concentration
J- - estimated concentration, low bias indicated
J+ - estimated concentration, high bias indicated
FD - field duplicate
N - primary sample
MW ID - monitoring well identifier