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Assessment of Corrective Measures Addendum East Pond

Bremo Power Station
Solid Waste Permit No. 618

Prepared for:

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EXECUTIVE SUMMARY

Golder Associates Inc. (Golder) prepared this *Assessment of Corrective Measures (ACM) Addendum* on behalf of Virginia Electric and Power Company, doing business as Dominion Energy Virginia (Dominion Energy), for the East Pond at the Bremo Power Station in Bremo Bluff, Virginia. Dominion Energy maintains a groundwater monitoring program for the East Pond at the Bremo Power Station in Fluvanna County, Virginia, consistent with the requirements of the Federal Coal Combustion Residuals (CCR) Rule and the Virginia Department of Environmental Quality (DEQ)-issued Solid Waste Facility Permit (SWP) No. 618. The ACM Addendum was prepared in accordance with Title 9, Virginia Administrative Code (VAC), Agency 20, Chapter 81 260 *et seq.* [9VAC20-81-260 of the Virginia Solid Waste Management Regulations (VSWMR)], and Title 40 Code of Federal Regulations (CFR) Part 257.50 *et seq.* of the Federal Disposal of Coal Combustion Residuals from Electric Utilities Rule (CCR Rule) as amended, as well as the Commonwealth of Virginia adoption of 40 CFR Part 257 Subpart D by reference [9VAC20-81-800 of the Virginia Solid Waste Management Regulations (VSWMR)].

On October 16, 2020, a new federal CCR Rule Groundwater Protection Standard (GWPS) exceedance was documented at the East Pond in the groundwater sample collected from downgradient monitoring well MW-20S for arsenic. Consistent with the timeframes for data evaluation in the VSWMR, a Virginia SWP Groundwater Protection Standard (GPS) exceedance was subsequently documented for arsenic at MW-20S on October 30, 2021. In accordance with the CFR §257.96 *et seq*. and VSWMR (9VAC20-81-260 *et seq*.), these exceedances triggered the need for an ACM Addendum for arsenic. Federal CCR GWPS exceedances for cobalt, lithium, and molybdenum were previously addressed in an ACM Report placed in the East Pond's CCR operating record on September 1, 2020. Virginia SWP GPS exceedances for boron, cobalt, lithium, and molybdenum [constituents of concern (COCs)] were previously addressed in an ACM Report submitted to the DEQ on November 10, 2020. This ACM Addendum is a supplement to the original ACM Report.

A nature and extent field investigation was completed for arsenic at the Bremo Power Station East Pond in February 2021 to support the ACM Addendum. A report summarizing the results of the field investigation is provided under separate cover (*Nature and Extent Study Addendum,* April 2021). This ACM Addendum summarizes the results of the assessment of remedial alternatives for addressing the reported federal CCR Rule GWPS and Virginia SWP GPS exceedances for arsenic based on the results of the field investigation, the site conceptual model, and a limited Risk Assessment.

As presented in the Nature and Extent Study Addendum, the arsenic concentration at MW-20S over the last four (4) years have been variable ranging from less than the laboratory method detection limit to greater than the GWPS/GPS. This observation coupled with documented upgradient construction activities associated with closure by removal of the East Pond could indicate that the observed arsenic concentration trend at MW-20S is a function of variable geochemical conditions in the aquifer resulting from a combination of Station actions. The actions that may have impacted the geochemistry of the uppermost aquifer include the removal of the CCR materials from the East Pond, the conversion of the former East Pond to a stormwater management system, and on-going remedial actions associated with the North Pond, including installation of a rain cover and active CCR material dewatering. Based on an evaluation of available geochemical data presented in the Nature and Extent Study Addendum, it is likely that the arsenic concentrations at MW-20S are not related to the North Pond. Specifically, while the bulk geochemistry for groundwater at wells MW-20S and MW-20D plots similarly to the North Pond porewater, the arsenic to boron ratio for MW-20S is significantly different from the arsenic to boron ratio for the North Pond pore water. It is expected that such ratio would be preserved if the North Pond was the source of the arsenic at MW-20S. With respect to MW-20D, the arsenic to boron ratio is similarly different and the arsenic concentration is not detected

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in this well at concentrations above the GWPS/GPS. Collectively these observations suggest that the source of GWPS/GPS exceeding arsenic concentrations in MW-20S is localized to the well. Therefore, remediation of the arsenic GWPS/GPS exceedance is not believed to be contingent upon the removal fo the North Pond CCR materials.

Consistent with the requirements of the VSWMR (9VAC20-81-260.C.3) and the CCR Rule (40 CFR Part 257.96 and 257.97), this ACM Addendum evaluated remedial alternatives for the arsenic groundwater impacts by identifying those remedial alternatives applicable to the contaminant-of-concern present in groundwater based on source, extent, and fate and transport considerations as documented in the Nature and Extent Study Addendum for arsenic. The pool of remedial alternatives was then screened with a screening matrix designed to identify the remedial alternatives most applicable to the site conditions present at the Bremo East Pond. The remedial alternatives selected for additional consideration were evaluated in detail based on criteria presented in the CCR Rule and the VSWMR, as those criteria relate to the conditions at the East Pond. Based on the findings of the NES and the ACM screening matrix, the following remedial alternatives were evaluated in detail as potential remedial strategies for the arsenic impacts at the Bremo East Pond:

- Monitored Natural Attenuation/Natural Recovery (MNA)
- *In-Situ* Aquifer Enhancement and MNA
- Hydraulic Pumping Containment (East Pond External Pumping Wells) with *Ex-Situ* Water Treatment and MNA and North Pond Wastewater Treatment Plant
- Funnel and Gate *Ex-Situ* Treatment and MNA and North Pond Wastewater Treatment Plant

Due to the lack of groundwater receptors, the incomplete exposure pathway at the East Pond, and the removal of historical CCR materials and subsoils from the East Pond, the evaluation of remedial alternatives suggests that the MNA remedy is likely the most appropriate remedial alternative for the documented impacts associated with the East Pond. The MNA remedy was also identified as the most appropriate remedy for the boron, cobalt, lithium, and molybdenum impacts addressed in the previous ACM Report. Therefore, the recommended remedy for arsenic is consistent with the previously recommended remedy for the other COCs.

Consistent with VSWMR 9VAC20-81-260.C.1.e, a public meeting must be held to discuss the results of the ACM prior to the final selection of the remedy. Due to the coronavirus pandemic, a public meeting is not feasible at this time. A public meeting and comment period will be scheduled for a future date when it is reasonable to do so with documentation of the public meeting and any associated comments completed at that time.

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1.0 INTRODUCTION

Golder Associates Inc. (Golder) has prepared this *Assessment of Corrective Measures* (ACM) *Addendum* on behalf of Virginia Electric and Power Company, doing business as Dominion Energy Virginia (Dominion Energy). The ACM Addendum was prepared for the East Pond (Unit) at the Bremo Power Station (Station) in Bremo Bluff, Fluvanna County, Virginia in response to federal and state Groundwater Protection Standard (GWPS/GPS) exceedances for arsenic. The location of the Station is shown on Figure 1. Groundwater at the downgradient point of compliance for the East Pond is currently being monitored under a modified Assessment Monitoring Program (AMP). The groundwater monitoring activities are conducted pursuant to the requirements in the June 2019 Virginia Department of Environmental Quality (DEQ)-issued Solid Waste Permit (SWP) No. 618, the Virginia Solid Waste Management Regulations (VSWMR), and Title 40 Code of Federal Regulations (CFR) Section 257.96 (40 CFR Part 257.96) of the Federal Disposal of Coal Combustion Residuals from Electric Utilities Rule (CCR Rule), as amended.

The ACM requirement was triggered during the second semi-annual 2020 compliance event on October 16, 2020, when a new federal CCR Rule GWPS exceedance for arsenic was documented at the East Pond in the sample collected from downgradient monitoring well MW-20S. Based on the data evaluation timeframe in the VSWMR, a notification of the arsenic GPS exceedance at MW-20S was submitted to DEQ and placed in the Unit's operating record on October 30, 2020, and uploaded to the publicly accessible website on November 25, 2020.

The ACM is required under 40 CFR Part 257.96 of the federal CCR Rule following the documentation of federal CCR Rule GWPS exceedance. Specifically, once a federal CCR Rule GWPS exceedance has been documented for a CCR Rule Appendix IV constituent, the CCR Rule requires the initiation of an ACM within 90 days of documenting the federal CCR Rule GWPS exceedance unless a successful Alternative Source Demonstration (ASD) is completed. Consistent with the CCR Rule, the ACM must be completed within an additional 90 days unless a demonstration for additional time based on a site-specific condition or circumstances is completed. Pursuant to section 257.96(a) of the CCR Rule, a demonstration of need for an extension was certified by a professional engineer and placed in the Station's operating record on March 12, 2021. A copy of the extension certification will be included in the East Pond's 2021 annual groundwater monitoring and corrective action report consistent with the provisions of the CCR Rule.

Similarly, when a Virginia GPS is exceeded, the VSWMR require initiation of the ACM, to include a NES, within 90 days of documenting the Virginia GPS exceedance unless a successful ASD is completed. Similar to the CCR Rule, the Station operator has an additional 90 days to complete the ACM under the VSWMR unless a demonstration for additional time based on a site-specific condition or circumstances is approved by the DEQ.

In response to the federal CCR Rule GWPS and Virginia GPS exceedances, a field investigation was completed [Nature and Extent Study (NES)] to support the ACM. The field investigation was conducted in February 2021 pursuant to the requirements in SWP No. 618 and consistent with Virginia DEQ NES and ACM guidance for solid waste facilities. The results from the field investigation are documented in a NES Addendum report under separate cover (Golder, 2021). This ACM Addendum summarizes the results of the assessment of remedial alternatives for addressing the reported federal CCR Rule GWPS and Virginia GPS exceedance for arsenic based on the results of the field investigation. This ACM Addendum is a supplement to the ACM Report that was previously prepared for the East Pond for boron, cobalt, lithium, and molybdenum in September 2020.

1.1 Purpose and Report Structure

Consistent with 9VAC20-81-260 and the CCR Rule, the purpose of the East Pond ACM Addendum is to evaluate remedial alternatives for remediating elevated concentrations (CCR Rule GWPS and Virginia GPS exceeding concentrations) of arsenic that have been detected in the groundwater downgradient from the East Pond. The evaluation of remedial options should take into consideration the nature and extent of the groundwater impacts.

As previously stated, a comprehensive summary of the field investigation completed to address the nature and extent of groundwater impacts (*i.e.,* to delineate the horizontal and vertical extents of arsenic GPS/GWPS exceedance in the vicinity of the East Pond) is provided under separate cover in the *NES Addendum* (Golder, 2021). For context with this assessment for arsenic, a summary of the NES work completed, and the key results of the field investigation is provided in Section 3.0 of this ACM Addendum. An assessment of select remedial options to address the requirements of the ACM per 9VAC20-81-260 of the VSWMR and the CCR Rule is presented in Section 4.0 of this ACM Addendum. Cost estimates associated with the evaluated remedial options are presented in Section 5.0 and Section 6.0 is reserved for a summary of the public meeting and associated public comment. Due to the Covid-19 state of emergency a public comment period for the ACM and this ACM Addendum is pending and the results (once completed) will be documented under separate cover. Limitations for the remedial alternatives assessment are presented in Section 7.0, and conclusions for the ACM Addendum are presented in Section 8.0.

2.0 STATION INFORMATION SUMMARY

Station information relevant to the ACM is summarized in the following sections.

2.1 Site Setting and Background

As shown on Figure 1, a portion of the United States Geological Survey (USGS) 7½-minute topographic map of Arvonia, Virginia, the site vicinity has moderately steep topography in the upland areas bordering the Station. The local topography is dissected by drainage swales that have developed a mix of dendritic and trellis drainage patterns reflecting an underlying structure control. Both intermittent and perennial streams characterize surface flow in the vicinity of the Station, with broad ridges and hilltops serving as topographical highs (maximum elevations of roughly 450 feet above mean sea level [AMSL] to the north of the Station). A portion of the Station, including the former generation station and the East and West Ponds, is located within the James River floodplain where topographic elevations range from 200 to 230 feet AMSL.

As presented on the aerial photograph inlay on Figure 2, the Station property consists of wooded, open, and developed land just north of the James River. The Station's northern, eastern, and western boundaries are bordered primarily by undeveloped parcels. The Station property is bordered to the south by a CSX rail line and the James River. Land use surrounding the Station is classified as "A-1 Agricultural" and consists of undeveloped wooded and agricultural properties within a rural residential setting. Other than a process water supply well that is located on the Station, there are no known water supply wells within the immediate vicinity of the Station boundary.

Power generation activities at the Station were initiated in the late 1930's. Ash from the power generation activities has historically been stored in the three on-site coal combustion residual (CCR) surface impoundments (North Pond, West Pond, and East Pond). In 2014, the Station converted from a coal-fired power plant to a natural gas-fired power plant. No newly generated CCR has been placed in these impoundments since the conversion to a gas-fired plant. The Station ceased power generation activities in 2018. Storage of existing CCR materials at the Station was consolidated to the North Pond, with removal of CCR materials formerly stored in the West Pond to the North Pond completed in 2017, and removal of CCR materials and an over excavation of a minimum of 6 inches of soil from the East Pond completed in early 2019. DEQ documented their approval of East Pond closure by removal records, including a DEQ site inspection to visually document the removal of CCR material and over-excavation of 6 inches of soil (conducted March 14, 2019), in a letter dated October 1, 2019.

2.2 Groundwater Monitoring Network

Historically, groundwater at the Station was monitored on a 5-year cycle under Virginia Pollutant Discharge Elimination System (VPDES) Permit (Permit No. VA0004138). Beginning in 2013, following installation of an updated groundwater monitoring network under VPDES Permit No. VA0004138, quarterly background sampling activities associated with VPDES monitoring at the Facility were completed between March 2013 and October 2014.

Subsequent to promulgation of the CCR Rule, background sampling activities for the East Pond under the CCR Rule were initiated in October 2017 following installation of additional monitoring wells for the unit. The East Pond background sampling activities were completed in February 2019. On June 5, 2019, SWP No. 618 was issued by DEQ with groundwater monitoring provisions for all three (3) of the Ponds at the Station. The Station currently monitors groundwater downgradient from the East Pond in accordance with the Modified Assessment Monitoring Program (AMP) as established in the SWP consistent with the AMP provisions in the CCR Rule.

As presented in Table 1 following, the East Pond compliance monitoring network includes three (3) upgradient wells and six (6) downgradient wells that are screened within the uppermost aquifer beneath the East Pond.

Table 1: East Pond Monitoring Network

Upgradient Compliance Monitoring Wells		
MW-11	MW-29S	MW-29D
Downgradient Compliance Monitoring Wells		
MW-19	MW-20S	MW-20D
MW-21	MW-22	MW-23

The monitoring wells are sampled semi-annually under the provisions of the modified AMP. The sample results from the first semi-annual 2021 compliance event, plus two (2) additional groundwater observations wells in the vicinity of the East Pond (MW-VPDES and MW-40), were used in preparation of the arsenic NES Addendum for the East Pond.

2.3 Surface Water Monitoring Network

Under Permit Module XVIII of Bremo Power Station's SWP No. 618, the Station operator is required to monitor near-shore waters of the James River to assess for potential surface water impacts that may be occurring due to potential groundwater-surface water exchanges downgradient of the active and inactive impoundments. In accordance with the Surface Water Monitoring Plan (SWMP) prepared for the Station, a total of 10 surface water samples along the north shore of the James River were collected on February 26, 2021, by EnviroScience, Inc. (EnviroScience, 2021). Although this sampling was conducted independent of the ACM investigation, the preliminary data from the February 2021 event conducted as part of this routine surface water monitoring was evaluated as part of the NES for the East Pond. Table 2 following summarizes the surface water sampling locations. A site map showing the downgradient East and North Pond surface water monitoring locations is presented in Figure 3.

Table 2: Surface Water Sampling Locations

NES Surface Water Sampling Locations – Upstream of the Facility	
JR-01	JR-02
NES Surface Water Sampling Locations – Downgradient of West Pond, Upstream of East Pond	
BR-01	BR-02
BR-03	BR-04

NES Surface Water Sampling Locations – Downgradient of East and North Pond	
BR-05	BR-06
BR-07	BR-08

3.0 NES SUMMARY

A summary of the arsenic *NES Addendum* (Golder, 2021) findings is presented herein to provide context and support for this *ACM Addendum*. The field investigation focused on understanding the nature and extent of the constituent of concern (COC; arsenic) in groundwater and surface water based on the documented state and federal GPS/GWPS exceedances for arsenic in the groundwater downgradient from the East Pond.

3.1 Constituents of Concern

The COC for the *ACM Addendum* is arsenic. Details pertaining to the physical and chemical properties of arsenic as they pertain to fate and transport characteristics and risk to human health and the environment are presented in the *NES Addendum* (Golder, 2021).

3.2 Summary of Field Program

To fulfill the requirements in SWP No. 618 and its reference to 9VAC20-81 *et seq*., and the CCR Rule as modified to be consistent with DEQ NES guidance for solid waste facilities, a field investigation was conducted to characterize the nature and extent of the arsenic impacts in the vicinity of the East Pond and to identify site conditions that could affect the remedy. To meet these requirements Golder completed a field investigation that included the following tasks:

- Collection, analysis, and evaluation of a comprehensive round of groundwater elevation measurements on February 23-24, 2021.
- Collection, analysis, and evaluation of groundwater samples from the routine compliance monitoring network as part of the first semi-annual 2021 compliance groundwater event in February 2021.
- Verification samples collected from monitoring wells MW-20D on April 16, 2021.
- Collection, analysis, and evaluation of groundwater samples from two (2) observations wells (MW-40 and MW VPDES) in the vicinity of the East Pond on February 24, 2021.
- Evaluation of the preliminary results from analysis of surface water samples collected during the routine first quarter 2021 compliance surface water event conducted by EnviroScience on February 26, 2021.
- Incorporation and evaluation of available historical cation and anion data from the January 2019 and February 2021 sampling events for groundwater and the January 2019 sampling event for North Pond pore water.
- An assessment and evaluation of potential and actual risks to human health using default exposure scenarios and actual conditions using the DEQ Virginia Unified Risk Assessment Model.

Detailed descriptions of sampling methods, analytical parameters, and analysis methodology are provided in the *NES Addendum* (Golder, 2021).

3.3 Summary of NES Addendum Results

A groundwater surface contour map for the East Pond is presented as Figure 4. As presented the direction of the interpreted groundwater flow beneath and downgradient from the East Pond is consistent with historical interpretations.

As presented in Figure 5, the NES delineated the inferred vertical and horizontal extents of arsenic concentrations in groundwater which exceed the Virginia SWP GPS and federal CCR Rule GWPS. Based on the NES results, the current exceedances for arsenic are as summarized in Table 3 following.

Table 3: Summary of NES GPS/GWPS Exceedance Results

Constituent	GPS/GWPS Concentration (µg/L)	Assessment Monitoring Well	Concentration (µg/L)
Arsenic	10.0 (GWPS/GPS)	MW-20S	13.4
		MW-20S Duplicate	7.3
		MW-20S (Average)	10.35

Notes: µg/L = Microgram per liter

Based on the information evaluated during the NES Addendum, the inferred extent of the federal CCR Rule GWPS and Virginia SWP GPS exceeding arsenic concentrations in groundwater were delineated around the compliance monitoring well MW-20S. Based on an evaluation of regional soil data, the arsenic concentrations observed at MW-20S may be related to a natural geological soil source as natural arsenic concentrations are documented in Virginia soils at concentration sufficient to account for the observed groundwater concentrations.

The arsenic concentrations at MW-20S have been variable ranging from less than the laboratory method detection limit to greater than the GWPS/GPS over the last 4 years. This observation coupled with documented upgradient construction activities could indicate that the observed arsenic concentration trend at MW-20S is a function of variable geochemical conditions in the aquifer resulting from a combination of Station actions. The actions that may have impacted the geochemistry of the uppermost aquifer include the removal of the CCR materials from the East Pond, the conversion of the former East Pond to a stormwater management system, and on-going remedial actions associated with the North Pond, including installation of a rain cover and active CCR material dewatering. Based on an evaluation of a Schoeller plot and scatter plots presented in the NES Addendum, it is likely that the arsenic concentrations at MW-20S are not related to the North Pond. While the bulk geochemistry of the water at wells MW-20S and MW-20D plot similarly to the North Pond porewater, the arsenic to boron ratio for MW-20S is significantly different from the arsenic to boron ratio for the North Pond pore water. It is expected that such ratio would be preserved if the North Pond was the source of the arsenic at MW-20S. With respect to MW-20D, arsenic is not detected in this well at concentrations above the GWPS/GPS. Collectively these observations suggest that the source of arsenic in MW-20S is localized to the well.

This localized arsenic concentration could be due to the variable geochemical conditions that are expected to have resulted from the Station actions which may have resulted in the dissolution of naturally occurring iron oxyhydroxide minerals in the aquifer resulting in the subsequent release of naturally occurring arsenic oxyanion to the groundwater. Based on the recent conversion of the East Pond to a stormwater management basin, it is expected that geochemical conditions favorable for formation of iron oxyhydroxide minerals will re-establish, likely resulting in the removal of dissolved arsenic ions from the groundwater via mineral sorption processes.

Alternatively, the arsenic detected in groundwater could also be associated with residual dissolved phase aquifer pore water impacts from the East Pond ash storage activities that are being flushed out of the aquifer system due to the refilling of the East Pond and the associated aquifer recharge that is expected in this area.

Assessment of the risk related to Virginia SWP GPS and federal CCR Rule GWPS exceedances in the vicinity of the East Pond did not identify risk above the acceptable cumulative risk threshold (1.0). While the United States Environmental Protection Agency (EPA) has classified inorganic arsenic as a human carcinogen, the calculated cumulative carcinogenic risk using the actual arsenic concentration also does not exceed the acceptable threshold (1.00E-04) for cumulative carcinogenic risk. Additionally, public access to the Station and downgradient (railroad) property is restricted, and groundwater at the Station is not used as a potable water source. Because exposure pathways associated with groundwater are not complete at the East Pond, the current COC concentrations do not pose an excessive risk to human health based on EPA and DEQ acceptable risk thresholds.

Surface water samples collected from along the north shore of the James River (located 200 to 300 feet downgradient of East Pond and thought to be the point of exchange for groundwater flowing southwest across the Station) reported no detections of the COC (arsenic). These results indicate that impacted groundwater is not reaching surface water at concentrations that could pose a risk to human health or the environment.

4.0 REMEDIAL TECHNOLOGIES

In accordance with the Station's SWP No. 618, and the CCR Rule, the owner/operator of a CCR impoundment with federal CCR GWPS exceedances must complete an assessment of potential corrective measures that could be implemented to remediate impacted groundwater. The ACM must include an analysis of the effectiveness of potential corrective measures in meeting the requirements of §257.97 and 9VAC20-81-260.C.3 of the VSWMR, including performance, reliability, ease of implementation, potential remedy impacts, residual contamination controls, time required to initiate and complete the remedy, and the institutional controls that may be required that could impact the remedy implementation. The evaluation criteria in §257.97 and 9VAC20-81-260.C.3. are comprised of some 37 "evaluation elements" that Golder has grouped into seven "evaluation categories" as follows:

- Remedy Constructability
- Remedy Institutional Controls
- Remedy Performance
- Remedy Timeframes
- Remedy Concerns
- Remedy Operations and Maintenance
- Remedy Risks

The evaluation elements in each category are summarized in Table 4 (attached) along with the relevant CCR Rule citation. Within each category, the evaluation elements were assigned a mean probability of success. These mean values were assigned based on Golder's experience with similar remediation and construction activities and the following site-specific conditions, remedial option considerations, and regulatory requirements:

- Site Conceptual Model (Geology/Hydrogeology)
- CCR Impoundment Design
- Site Geometry
- Site Geographic Location
- Contaminant Risk (Human and Environmental)
- Source Removal Regulatory Requirement
- Aquifer Geochemistry
- Constituents of Concern (Contaminants)
- Contaminant Fate and Transport Considerations
- Treatment Technology Efficacy
- Site-Specific Data Gaps

To minimize bias for one remedial option versus another, the mean probability of success for each element was limited to one of four success probability options (20%, 40%, 60%, or 80%) with each option assigned a 15% standard deviation. In general, the higher the probability of success, the more likely the remedy is to satisfy the individual ACM evaluation criterion in the CCR Rule. Some of the ACM evaluation criteria are ranked in an inverse manner (*e.g.*, the potential need for remedy replacement: a lower probability for this element correlates with a higher probability of success) and the assigned probabilities for these criteria have been accounted for in the model. Similarly, timeframe criteria are evaluated in terms of years, with short timeframes generally considered more successful. The timeframes are translated in the model to probability of success using linear regression.

To account for expected bias in the extreme tails of the assigned probability, a beta distribution was assumed for each evaluation element (with exception of the Occupational Safety and Health Administration [OSHA] compliance criterion and the Virginia Standards compliance criterion, which were assigned a uniform distribution that assumed 100% compliance for every remedy). The beta distribution follows a normal distribution for a 50% rating with an increasingly positive skewness for mean success ratings that exceed 50% and an increasingly negative skewness for mean success ratings that are less than 50%. Table 4 summarizes the assigned success probabilities for the 37 ACM evaluation elements for each potential remedial option evaluated.

The ACM evaluation elements within each category were weighted evenly such that the maximum success probability for any one category was 80%, with the minimum being 20%. The ACM categories (collections of evaluation elements) were weighted based on Golder's interpreted significance as presented in the VSWMR, the CCR Rule, the CCR Rule Preamble, and our experience with working on similar solid waste remediation projects. The assigned category weightings used for this evaluation are presented in Table 5 following.

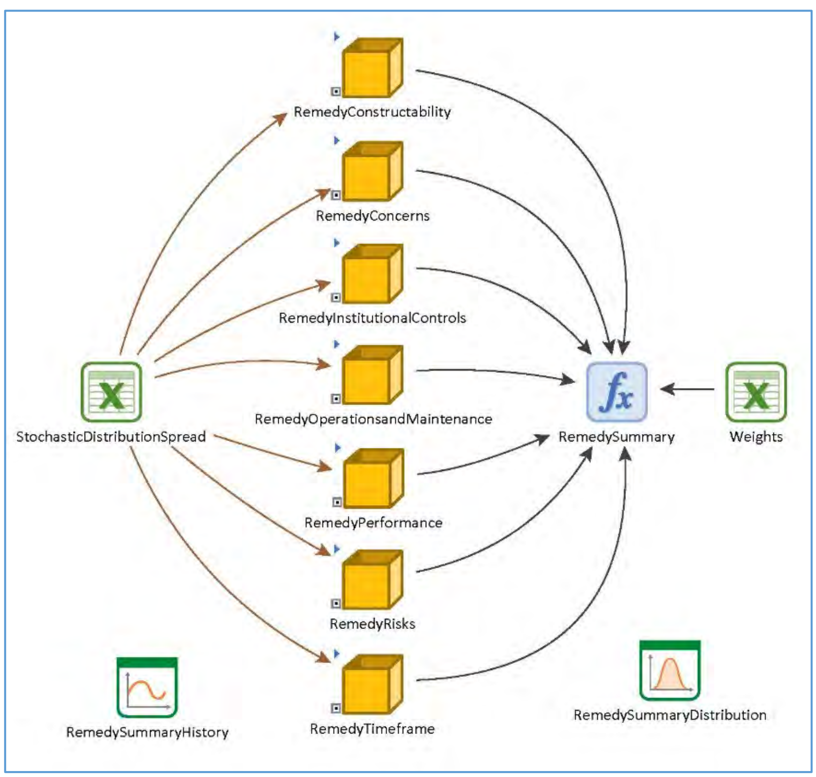
Table 5: Remedy Evaluation – Model Categories and Weights

Category	Weighting
Remedy Constructability	10%
Remedy Concerns	10%
Remedy Institutional Controls	5%
Remedy Operations and Maintenance	5%
Remedy Performance	20%
Remedy Risk	30%
Remedy Timeframe	20%
Sum of Weights:	**100%**

As presented in Table 5, the category weightings sum to 100%, such that a remedial option with a 80% probability of success in all seven categories would yield an average weighted overall probability of success score of 80%.

The assigned groupings, probabilities, distributions, and weightings for the ACM evaluation categories and evaluation elements were subsequently evaluated using an analytical model constructed within the commercially available GoldSim® Monte Carlo simulation software that is managed and maintained by the GoldSim Technology Group LLC.

After constructing the model (see inset illustration) and assigning the probabilities and distributions to the model elements within each category, the GoldSim®



software was used to simulate the probability of success for each remedial option using 1,000 simulations over the expected remedial option-specific timeframe.

Golder believes the natural recovery of groundwater beneath and downgradient from the East Pond is influenced by the natural recovery of the groundwater beneath the North Pond for the constituents of concern (COCs) presented in the September 2020 ACM (*e.g.*, boron); however, Golder also believes that the arsenic groundwater impacts at MW-20S are likely not associated with the North Pond based upon the evaluation of Schoeller plot and scatter plots presented in the NES Addendum. Based on this belief the source removal of the North Pond was not considered in this ACM Addendum. This ACM Addendum considered the following remedial alternatives:

- Monitored Natural Attenuation/Natural Recovery (MNA) - Option 1
- *In-Situ* Aquifer Enhancement and MNA – Option 2
- Hydraulic Pumping Containment (East Pond External Pumping Wells) with *Ex-Situ* Water Treatment and MNA and North Pond Wastewater Treatment Plant - Option 3
- Funnel and Gate *Ex-Situ* Treatment and MNA and North Pond Wastewater Treatment Plant – Option 4

A summary of the remedial alternatives evaluated as part of the ACM Addendum is presented in the following sections. Details regarding the consideration of the 37 evaluation elements in the VSWMR and CCR rule for each potential remedy are presented in Table 4.

4.1 Monitored Natural Attenuation/Natural Recovery (MNA)

Option 1 is comprised of excavation of the East (completed) followed by natural recovery of the groundwater system. Specifically, based on available data and limited 1-dimensional groundwater modeling, Golder believes that natural hydrogeological processes based on diffusion, dispersion, sorption, dilution, and mineralization (potential carbonate mineralization) will attenuate the federal CCR Rule GWPS and Virginia GPS concentrations of the COCs being detected in East Pond compliance wells to concentrations that are less than the applicable standard within approximately 20 to 30 years, with arsenic expected to attenuate based on modeling results from the currently observed concentration of 13.4 ug/L to less than its GPS/GWPS in 4 to 5 years assuming that the source (East Pond ash) has been removed. Future studies prior to formal remedy selection may be necessary to validate natural recovery mechanisms and timeframes.

4.1.1 Method Description

Natural attenuation requires minimal resources and relies on physical processes such as diffusion, dispersion, sorption, and mineralization (potential carbonate and iron oxyhydroxide mineralization) to remediate contaminants in groundwater. To be the sole method of remediation, three (3) tiers of evidence documenting natural attenuation are typically required, as follows:

1. Historical groundwater data that demonstrate a clear and meaningful trend of decreasing contaminant mass and/or concentration over time at appropriate monitoring points.
2. Hydrogeologic and geochemical data that can be used to demonstrate indirectly the type of natural attenuation processes active at the site, and the rate at which such processes will reduce contaminant concentrations to required levels.
3. Data from field or microcosm studies, which directly demonstrate the occurrence of a particular natural attenuation process at the site and its ability to degrade the contaminants of concern.

MNA consists of monitoring natural attenuation processes (both biological and physical) and is a proven remedial alternative for sites where biological processes are documented and a more aggressive remedy is not required (*i.e.*, the impacts do not pose an immediate or substantial risk). The physical attenuation processes (dispersion, dilution, adsorption, vaporization, abiotic degradation, *etc.*) are important parts of MNA; however, it is typically only viable if the source of contamination has been removed or isolated such that the natural attenuation processes are in equilibrium with the residual release rate for the COC (*i.e.*, steady-state conditions exist).

Under an MNA remedial alternative, a site is monitored at regular intervals to demonstrate that contaminants are attenuating at a rate sufficient to prevent potential exposures, and that the dissolved-phase contaminants are not migrating to a receptor. It may also include measurements of contaminant concentrations in soil, groundwater, or soil gas.

There is substantial guidance from the EPA concerning MNA, including the appropriateness of the remedy and cleanup levels. When restoration of groundwater is not practicable, EPA "*expects to prevent further migration of the plume, prevent exposure to the contaminated groundwater, and evaluate further risk reduction*" (EPA, 1999). Cleanup levels appropriate for the expected beneficial use "*should generally be attained throughout the contaminated plume, or at and beyond the edge of the waste management area when waste is left in place*" (EPA, 1999). The objectives for a natural attenuation groundwater remedy include the following:

- Demonstrate that natural attenuation is occurring;
- Be protective of human health and the environment;
- Monitor natural attenuation and environmental impact; and
- Restore groundwater to below state and federal GPS/GWPS.

Acceptance of this option requires a conceptual model of the site, a quantification of attenuation, and establishment of a long-term monitoring program. A conceptual model was proposed in the *NES Addendum* (Golder, 2021). The model described the groundwater flow system and characterized and delineated the arsenic plume.

The demonstration and documentation of measurable MNA processes are key in the application of minimizing risk. Typically, MNA programs indicate the status of the groundwater plume at different locations in the plume (stable, shrinking, or expanding), enable estimation of remediation rates, and warn of potential impact on sensitive receptors. Primary evidence of natural attenuation includes demonstration of a stable or shrinking plume, or a plume expanding more slowly than groundwater movement adjusted for retardation.

Downgradient wells, located within and parallel to the groundwater flow path, would be sampled periodically for measurable changes in contaminant concentrations. The monitoring frequency for MNA depends on the plume status, water table fluctuations and seasonal variability, groundwater velocity, and distance from the plume to a sensitive receptor.

4.1.2 Remedy Performance

MNA performance differs at every site and is dependent on-site conditions. Therefore, performance of MNA is typically determined by long-term monitoring for the COCs. Adsorption to sediments with negative charge sites (arsenate and arsenite) or positive charge sites (hydrogen arsenate compounds) and dilution are expected to be the most significant mechanisms that will influence the fate of COCs in water (EPA, 2004). Arsenic is known to strongly absorb to iron hydroxide minerals that are naturally present in sedimentary aquifers, such as the alluvium and saprolite aquifers observed in the vicinity of the East Pond and the extent of absorption is strong influenced by pH (EPA, 2004). It is possible that a steady-state condition may not be confirmed within the first few years of the MNA process but with time sorption and dilution should be able to reduce contaminant concentrations to acceptable levels.

4.1.3 Remedy Reliability

MNA is a proven remedial alternative, which has been used at Resource Conservation and Recovery Act (RCRA), Underground Storage Tank (UST), Superfund, Voluntary Remediation Program (VRP), and Brownfield sites to treat both impacted groundwater and soils. MNA alone is adequate when there is no identified risk, or when proactive remediation is no more effective than MNA.

4.1.4 Remedy Implementation Ease

Implementation of MNA requires a Corrective Action Monitoring Program (CAMP). Per the OSWER Directive (EPA, April 1999), "*Performance monitoring to evaluate remedy effectiveness and to ensure protection of human health and the environment is a critical element of all response actions.*" The CAMP should be designed to accomplish the following:

- Demonstrate that natural attenuation is occurring;
- Detect changes in environmental conditions that may reduce the efficacy of any of the natural attenuation processes;
- Identify any potentially toxic and/or mobile transformation products;
- Verify that the plume(s) is not expanding;
- Verify no unacceptable impact to downgradient receptors;
- Detect new releases of contaminants to the environment that could impact the effectiveness of the natural attenuation remedy;
- Demonstrate that institutional controls that were put in place to protect potential receptors are performing as desired; and
- Verify attainment of remediation objectives.

Dominion Energy would implement the CAMP program through a Corrective Action Plan (CAP) submitted to DEQ upon approval of the ACM.

4.1.5 Remedy Impacts

There are no major remediation related impacts expected with MNA. Specifically, MNA does not require any intrusive activities that could impact the unit and the COCs are attenuated via destruction, sorption, or precipitation within the uppermost aquifer beneath the unit. Minor operational impacts may include the generation of contaminated purge water, which would have to be disposed of appropriately. Potential safety impacts for commercial and industrial workers via contamination exposure would also be present on site.

4.1.6 Remedy Exposure Control

Dominion Energy has removed the CCR material from the East Pond; therefore, the potential for future COC exposure under the MNA remedy is not expected, with the exception of potential exposure during well installation and groundwater sampling activities. Provided site personnel are appropriately trained in the hazards of the COCs and that they use appropriate personal protection equipment (PPE) for onsite activities, the exposures to hazards associated with the MNA remedy can be minimized.

4.1.7 Remediation Time to Completion

Based on preliminary 1-dimensional analytical modeling Golder believes that natural hydrogeological processes based on diffusion, dispersion, sorption, dilution, and mineralization (potential carbonate mineralization) will attenuate the above federal CCR Rule GWPS and Virginia SWP GPS concentrations of the COCs including arsenic to concentrations that are less than the applicable GWPS and GPS within approximately 20 to 30 years (4 to 5 years for arsenic). Future studies prior to formal remedy selection may be necessary to validate natural recovery mechanisms and timeframes.

4.1.8 Remedy Institutional Requirements

No significant institutional requirements for implementation of the MNA remedy are required other than DEQ permitting of the remedial alternative, which will include incorporating a CAP as a permit amendment.

4.2 *In-Situ* Aquifer Enhancement and MNA

Option 2 is comprised of excavation of the East (completed) with *in-situ* aquifer enhancement treatment for the East Pond followed by natural recovery of the groundwater system. Golder believes the natural recovery of groundwater beneath and downgradient from the East Pond is influenced by the natural recovery of the groundwater beneath the North Pond, therefore the above federal CCR Rule GWPS and Virginia GPS concentrations of the COCs being detected in East Pond compliance wells (exclusive of arsenic) will likely not attenuate to concentrations that are less than the applicable standard until after the removal of the CCR materials (including the North Pond materials) is complete. Following removal of the CCR materials, attenuation to concentrations that are less than the applicable standard is expected to occur within approximately 20 to 30 years. The arsenic source is believed to be local to MW-20S and not related to the North Pond. Therefore, the arsenic concentrations are expected to attenuate based on modeling results to less than the GPS/GWPS in 4 to 5 years assuming that the source (East Pond ash) has been removed. Future studies prior to formal remedy selection may be necessary to validate *in-situ* aquifer enhancement technologies, natural recovery mechanisms and timeframes.

4.2.1 Method Description

A variety of *in-situ* aquifer enhancement technologies exist; however, based on the site conceptual model nano-iron injection coupled with air sparging (oxygen injection) is currently the most viable option for the East Pond.

In-situ zero-valent iron nano-remediation is the application of reactive nano materials for transformation and removal of COCs in the water column in the aquifer with no groundwater removal required for *ex-situ* treatment (Otto *et al.*, 2008). The nanomaterials are injected into the aquifer via an injection well, and then the nanoparticles are transported via groundwater flow to the contamination. Upon contact, the nanoparticles can bind the COCs through redox reactions, immobilize them, or attenuate them to below the GPS/GWPS (Karn *et al.*, 2009).

Air sparging is an *in-situ* remediation technology used to enhance the rate of mass removal from a COC plume through injecting air into the saturated subsurface to treat contaminated soil and groundwater (USACE, 2013). Air sparging can be used as air stripping to remove volatile contaminants by partitioning them from the aqueous phase to the vapor phase for their transfer and removal from the unsaturated zone. Air sparging can also be used as biosparging to enhance aerobic microbial degradation of contaminants in the saturated zone. Air sparging is also used to immobilize contaminants through chemical changes as proposed in this situation. Aeration increases dissolved oxygen which causes an increase in oxidation-reduction potential which can immobilize unwanted inorganic compounds or heavy metals (Marley *et al.*, 1996).

Using a combination of nano-iron injection with air sparging, the goal will be to increase the amount of iron oxyhydroxide mineralization within the aquifer matrix, which is expected to result in a combination of co-precipitation of cationic metals and sorption of cationic metals. The increased oxidation reduction potential from the air sparging may also result in metal oxide formation for immobilization of the cationic metals.

4.2.2 Remedy Performance

Nano-remediation performance is dependent upon site-specific conditions, the COCs at the site, and the nanomaterials chosen for the application. The current three leading nanomaterials are nanoscale zero-valent iron (nZVI), bimetallic nanoscale particles (BNP), and emulsified zero-valent iron (EZVI) which all perform differently under different conditions. Nano-remediation has proven successful in reducing COC concentrations of volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and heavy metals; however, specific-site performance of the selected nanoparticle would require a pilot study (EPA, 2004) to confirm the efficacy of the remedial design.

Air sparging performance is also dependent upon site-specific conditions and has not been researched fully in the removal of contaminants other than volatile contaminants. A site-specific pilot study would be required for further performance details to determine the final design of the supplemental oxygen addition system for the nano-remediation system.

4.2.3 Remedy Reliability

Nano-remediation is a more recent remedy with many remediation projects using nanoparticles just beginning or are currently ongoing, therefore performance data is limited. Scheduled injections of the appropriate nanomaterial should remain reliable though.

Air sparging can raise the redox potential to immobilize or precipitate out heavy metals; however, this technique will need to be verified in the field to ensure the effectiveness. In this case, the air sparging is proposed as a supplemental oxygen delivery mechanism for the primary nano-remediation program and therefore, the creation of metal oxides for the COCs is not the primary goal, rather the creation of iron oxyhydroxide mineralization is the primary goal.

4.2.4 Remedy Implementation Ease

The *In-situ* aquifer enhancement remedy using a combination of air sparging and nano-remediation will require significant design and pilot testing activities including bench scale testing to verify the efficacy of the design prior to a pilot test and full system deployment. Additional permitting may also be required for the injection of nanoparticles into the aquifer.

4.2.5 Remedy Impacts

There are no major remediation related impacts expected with *in-situ* aquifer enhancement; however, the technology is more recent and potential risks are less understood than other remedies. Continued use of nanoparticles in environmental remediation could possibly lead to a release of the nanoparticles into the environment (Nowack, 2008). Minor operational impacts may include the generation of contaminated purge water and possible chemical handling associated with nanoparticle injection. Potential safety impacts for commercial and industrial workers via contamination exposure would also be present on site. Under the proposed alternative, zero-valent iron nanomaterials are not expected to present any significant health risks since immobilization via oxidation is expected to occur quickly upon injection into the aquifer matrix.

4.2.6 Remedy Exposure Control

Dominion Energy has removed the CCR material from the East Pond; therefore, potential for future COC exposure under the *in-situ* aquifer enhancement remedy is not expected, with the exception of potential exposure during well installation and groundwater sampling activities. Provided site personnel are appropriately trained in the hazards of the COCs and that they use appropriate PPE for onsite activities, the exposures to hazards associated with the remedy can be minimized.

4.2.7 Remediation Time to Completion

As discussed previously, based on preliminary 1-dimensional analytical modeling Golder believes that *in-situ* aquifer enhancement and MNA will attenuate the above federal CCR Rule GWPS and Virginia SWP GPS concentrations of the COCs including arsenic to concentrations that are less than the applicable GWPS and GPS within approximately 20 to 30 years (4 to 5 years for arsenic). Future studies prior to formal remedy selection may be necessary to validate *in-situ* aquifer enhancement technologies, natural recovery mechanisms and timeframes.

4.2.8 Remedy Institutional Requirements

Possible Underground Injection Control (UIC) permits may be required from the DEQ for the injection of the aquifer treatment remedy. Additionally, DEQ permitting of the remedial alternative will be required, which will include incorporating a CAP as a permit amendment.

4.3 Hydraulic Pumping Containment (East Pond External Pumping Wells) with Ex-Situ Water Treatment and MNA and North Pond Wastewater Treatment Plant

Option 3 is comprised of excavation of the East (completed) with hydraulic pumping through pumping wells with an *ex-situ* water treatment at the North Pond wastewater treatment plant followed by natural recovery of the groundwater system. Golder believes the natural recovery of groundwater beneath and downgradient from the East Pond is influenced by the natural recovery of the groundwater beneath the North Pond, therefore the above federal CCR Rule GWPS and Virginia SWP GPS concentrations of the COCs being detected in East Pond compliance wells (exclusive of arsenic) are not likely attenuate to concentrations that are less than the applicable standard until the removal of the CCR materials is complete (including the North Pond materials). Following removal of the CCR materials, attenuation to concentrations that are less than the applicable standard is expected to occur within approximately 20 to 30 years. The source of the arsenic is believed to be localized to the MW-20S area and the arsenic concentrations are expected to attenuate based on modeling results to less than the GPS/GWPS in 4 to 5 years assuming that the source (East Pond ash) has been removed. During the North Pond CCR removal and natural recovery phase of the remedy for the COCs, hydraulic containment of the COC-impacted groundwater using a series of dewatering wells/trenches installed along the downgradient boundary of the East Pond would be used to control downgradient impacts, including arsenic. Future studies prior to formal remedy selection may be necessary to validate the design of the proposed system.

4.3.1 Method Description

Pump and treat remedies have been used for decades at contaminated sites. Pump and treat remedies are used primarily for hydraulic containment to prevent the continued expansion of the plume and for treatment to reduce the contaminant concentrations in groundwater. Groundwater pump and treat systems combine a groundwater extraction system with a treatment system to remove contaminants from the subsurface and/or to control contaminant migration. The groundwater extraction system can consist of a well field, trenches, or a pumping system which are used to capture the contaminated water. Groundwater removed from the aquifer is treated for the COC and either re-injected on-site or discharged to a surface water body on-site assuring that the effluent meets the VPDES levels. Pump and treat remedies involve pumping contaminated groundwater to the surface for treatment.

Additional site characterization activities may need to be completed to determine the effectiveness of a pump and treat remedy (EPA, 1996). Suggested site characterization activities may include:

- Contaminant conditions: physical phases, quantification of distribution between phases, extent of contamination
- Aquifer and soil conditions: particle-size distribution, sorption characteristics, and hydraulic conductivity; and
- Pumping conditions: Volume of water to be withdrawn, treatment and handling of extracted groundwater.

Groundwater monitoring would still be required to demonstrate the effectiveness of the remedy. Downgradient wells, located within and parallel to the groundwater flow path, would be sampled periodically for measurable changes in contaminant concentrations. The monitoring frequency depends on the pumping rates, plume status, water table fluctuations and seasonal variability, groundwater velocity, and distance from the plume to a sensitive receptor.

4.3.2 Remedy Performance

Success of a pump and treat remedy is not only dependent upon source and groundwater plume removal but also upon the contaminants being treated. Arsenic could be treated with anionic resins or aluminum oxide media, which removes ions from the aqueous phase by the exchange of cations between the COCs and the resin and the sorption to the aluminum oxide media. Resins will require backwash and will create a concentrated waste that will need to be managed and aluminum media require periodic replacement. Alternatively, reverse osmosis could be used for arsenic removal with carbon polishing of the periodic backwash fluids.

4.3.3 Remedy Reliability

Pump and treat remedies are one of the most widely used groundwater remediation techniques with 88% of Superfund sites and most sites where cleanup is required by RCRA using the remedy (EPA, 2002). When a pump and treat system is online, the reliability is high with the COC plume stabilizing or shrinking after the removal of the source. These remedies require substantial operation and maintenance, and therefore the reliability of the remedy is not as high as other alternative remedies.

4.3.4 Remedy Implementation Ease

Pump and treat remedies are not as simple to implement as other alternative remedies due to design, installation of wells, pumps, and piping. The construction of a specialized on-site water treatment plant may also be required due to the COCs if the North Pond Wastewater Treatment Plant cannot treat the COCs. This evaluation assumes that the treatment system being designed for the dewatering of the North Pond CCR material has sufficient capacity and design elements to remove the COCs from the wastewater stream to concentrations that are acceptable for discharge to the environment.

4.3.5 Remedy Impacts

Other than the management of treated water and possible backflush water from a reverse osmosis system, there are no major remediation related impacts expected with a pump and treat remedy. Minor impacts would include the generation of contaminated purge water and possible chemical handling or cleaning associated with the water treatment plant. There are possible safety impacts during the construction phase of the pump and treat remedy associated with the installation of wells, pumps, piping, and the construction of an on-site water treatment plant.

4.3.6 Remedy Exposure Control

Dominion Energy has removed the CCR material from the East Pond, therefore, no significant potential for future COC exposure is expected. There is a greater risk of potential exposure compared to alternative remedies due to the continual pumping of groundwater during the period of treatment, as well as during construction activities, well installation, and groundwater sampling activities. Provided site personnel are appropriately trained in the hazards of the COCs and that they use appropriate PPE for onsite activities, the exposures to hazards associated with the remedy can be minimized.

4.3.7 Remediation Time to Completion

Based on preliminary 1-dimensional analytical modeling Golder believes that hydraulic containment with *ex-situ* treatment of captured groundwater and natural recovery of the groundwater following removal of the North Pond CCR material will attenuate the above federal CCR Rule GWPS and Virginia SWP GPS concentrations of the COCs including arsenic to concentrations that are less than the applicable GWPS and GPS within approximately 20 to 30 years (4 to 5 years for arsenic).

4.3.8 Remedy Institutional Requirements

Construction permits will likely be required for the construction of the treatment plant, as well as possible Underground Injection Control (UIC) and/or VPDES permits for the re-injection (if used) of treated water, or the surface discharge of treated water depending on the final design of the system. Additionally, DEQ permitting of the remedial alternative will be required, which will include incorporating a CAP as a permit amendment.

4.4 Funnel and Gate Ex-Situ Treatment and MNA and North Pond Wastewater Treatment Plant

Option 4 is comprised of excavation of the East (completed) with funnel and gate *ex-situ* treatment for the East Pond followed by natural recovery of the groundwater system. Golder believes the natural recovery of groundwater beneath and downgradient from the East Pond is influenced by the natural recovery of the groundwater beneath the North Pond, therefore the above federal CCR Rule GWPS and Virginia SWP GPS concentrations of the COCs being detected in East Pond compliance wells (exclusive of arsenic) are not likely attenuate to concentrations that are less than the applicable standard until the removal of the CCR materials is complete (including the North Pond materials). Following removal of the CCR materials, attenuation to concentrations that are less than the applicable standard is expected to occur within approximately 20 to 30 years. The source of the arsenic is believed to be localized to the MW-20S area and the arsenic concentrations are expected to attenuate based on modeling results to less than the GPS/GWPS in 4 to 5 years assuming that the source (East Pond ash) has been removed. Future studies prior to formal remedy selection may be necessary to validate the remedy design, the natural recovery mechanisms, and the remedial timeframes.

4.4.1 Method Description

Funnel and gate systems are a passive remediation technology which uses vertical barriers (the funnel) to modify flow patterns so that groundwater flows primarily through the higher conductivity gaps (the gates). The barriers are typically walls constructed using deep trenching equipment that mix a bentonite/cement slurry to create an impermeable wall. When possible, the walls are keyed into the low-permeability soil or bedrock located at the bottom of the aquifer to control seepage under the wall. The gate typically contains a reactive substance to treat the contaminated groundwater. Due to groundwater flow in bedrock at the site, a completely stable funnel and gate system is not feasible and pumping around the East Pond would still be required in conjunction with *ex-situ* treatment of the extracted groundwater.

4.4.2 Remedy Performance

Remedy performance is dependent upon the COCs, the treatment chosen for the gate, and the treatment chosen for the wastewater treatment plant. Arsenic could be treated with an anionic resin or other readily accessible and proven technologies including activated carbon and reverse osmosis.

4.4.3 Remedy Reliability

If funnel and gate systems are constructed correctly (*i.e.* keyed into a low conductivity unit), with enough residence time in the reactive portion of the wall and a correct reactive substance to treat the contaminated groundwater, then funnel and gate systems are relatively reliable and stable. For the East Pond, with the groundwater flow also in bedrock, it is difficult to reliably control the groundwater flow path without creating a pumping low pressure to induce the upward flow of groundwater. With sufficient site characterization activities to identify the preferential flow pathways in the lower fractured bedrock, a combination of funnel and gate technology with limited pumping can be an effective remediation approach.

4.4.4 Remedy Implementation Ease

Funnel and gate systems require detailed knowledge of the groundwater flow path for construction. In addition to construction of the barriers and *in-situ* treatment this remedy also requires the design, installation of wells, pumps, and piping for *ex-situ* treatment of extracted groundwater. The construction of a specialized on-site water treatment plant may also be required due to the COCs if the North Pond Wastewater Treatment Plant cannot treat the COCs.

4.4.5 Remedy Impacts

Other than management of treated water and potential back-flush wastewater from a reverse osmosis system, there are no major remediation related impacts expected with a funnel and gate system coupled with pump and treat technology. Minor impacts would include the generation of contaminated purge water and possible chemical handling or cleaning associated with the water treatment plant. There are possible safety impacts during the construction phase of the funnel and gate system and the pump and treat remedy associated with the installation of wells, pumps, piping and the construction of an on-site water treatment plant.

4.4.6 Remedy Exposure Control

Dominion Energy has removed the CCR material from the East Pond; therefore, no potential for future COC exposure is expected. There is a greater risk of potential exposure compared to alternative remedies due to the continual pumping of groundwater during the period of treatment, as well as during construction activities, funnel and gate installation, well installation, and groundwater sampling activities. Provided site personnel are appropriately trained in the hazards of the COCs and that they use appropriate PPE for onsite activities, the exposures to hazards associated with the remedy can be minimized.

4.4.7 Remediation Time to Completion

Based on preliminary 1-dimensional analytical modeling Golder believes that the funnel and gate with *ex-situ* treatment will attenuate the above federal CCR Rule GWPS and Virginia GPS concentrations of the COCs including arsenic to concentrations that are less than the applicable GWPS and GPS within approximately 20 to 30 years (4 to 5 years for arsenic).

4.4.8 Remedy Institutional Requirements

Construction permits will be required for the construction of the funnel and gate system and of the treatment plant, as well as possible UIC or VPDES permits for the re-injection (if used) of treated water or the discharge of treated water to the surface. Additionally, DEQ permitting of the remedial alternative will be required, which will include incorporating a CAP as a permit amendment.

5.0 COST ESTIMATES

In accordance with 9VAC20-81-260.C.3.a(3) of the VSWMR an assessment of the costs of remedy implementation was completed. These costs are important for viability assessment and planning purposes. As with the ACM evaluation criteria, Golder developed probabilistic cost estimates (AACE International [formerly the Association for Advancement of Cost Engineering] Class IV type – study/feasibility level) for each viable remedial option over the remedy's expected remedial timeframe. These costs estimates include costs associated with the design and permitting, construction, operations, post-construction monitoring, and termination of the remedy once the remedial action goals are achieved. The cost estimates for the hauling efforts associated with the excavation of the East and North Ponds was not included as this activity is a regulatory required activity regardless of the selected groundwater remedy. The probabilistic costs estimates were then evaluated using 1,000 simulations of the remedy-specific analytical cost model with the GoldSim® software to generate probabilistic ranges for the remedy costs. The evaluations indicated that the upper 95% probable future value costs for the alternatives considered, based on an average inflation rate of 2.5% over the estimated remedial timeframe could range from $1.8 million USD for Option 1 to $184 million USD for Option 3.

Using the estimated costs for remediation, the alternatives from the probability-of-success evaluation were normalized for costs to generate a relative method for comparing the cost-benefit of the remedial options. The evaluation was completed by dividing the upper 95% probability of success for each remedial option by the mean cost estimate (in $100's of million USD) for the remedy. The relative cost-benefit factor was then normalized by dividing each option by the highest percentage. Table 6 below summarizes estimated remedial timeframes, mean probabilities of success, future remedy costs, and the relative cost-benefit factor for each remedial option. The evaluation indicates that the highest cost-benefit is obtained with Option 2.

Table 6: Summary of Cost Evaluation

Remedial Option		Estimated Remedial Timeframe (years)	Upper 95% Probability of Success Score (%)	Mean Future Value Remedy Cost (100,000,000's USD)	Normalized Relative Cost -Benefit Factor
1	Monitored Natural Attenuation (MNA)	7	80.45%	$0.018	100%
2	*In-Situ* Aquifer Enhancement and MNA	9	75.72%	$0.019	89%
3	Hydraulic Pumping Containment (EP External Pumping Wells) with *Ex-Situ* Water Treatment, MNA, and North Pond Wastewater Treatment Plant (NP WWTP)	9	72.62%	$1.840	1%
4	Funnel and Gate *Ex-Situ* Treatment, MNA, and NP WWTP	9	72.06%	$1.509	1%

As compared to the previous ACM Report submitted in September 2020 to address the Virginia GPS exceedances of boron, cobalt, lithium, and molybdenum (Golder, 2020), the top remedial alternatives remain the same with the most effective remedial option remaining as natural recovery. Table 7 following shows the comparison of the upper 95% probability of success score and the normalized relative cost-benefit factors between the September 2020 ACM remedial options with excavation of the North Pond included and the ACM Addendum remedial options without excavation of the North Pond.

Table 7: Comparison Summary of Evaluations

Remedial Option		September 2020 ACM - Upper 95% Probability of Success Score (%)	September 2020 ACM - Normalized Relative Cost -Benefit Factor	April 2021 ACM Addendum - Upper 95% Probability of Success Score (%)	April 2021 ACM Addendum - Normalized Relative Cost -Benefit Factor
1	Excavation with off-site disposal and Monitored Natural Attenuation (MNA)	72.90%	89%	--	--
2	Excavation with on-site disposal and MNA	71.00%	100%	80.45%	100%
3	Excavation with off-site Disposal and *In-Situ* Aquifer Enhancement and MNA	68.40%	4%	--	--
4	Excavation with on-site Disposal and *In-Situ* Aquifer Enhancement and MNA	67.10%	5%	75.75%	89%
5	Excavation with off-site Disposal and Hydraulic Pumping Containment (EP External Pumping Wells) with *Ex-Situ* Water Treatment, MNA, and North Pond Wastewater Treatment Plant (NP WWTP)	67.00%	3%	--	--
6	Excavation with on-site Disposal and Hydraulic Pumping Containment (EP External Pumping Wells) with *Ex-Situ* Water Treatment, MNA, and NP WWTP	67.60%	4%	75.62%	1%

Remedial Option		September 2020 ACM - Upper 95% Probability of Success Score (%)	September 2020 ACM - Normalized Relative Cost -Benefit Factor	April 2021 ACM Addendum - Upper 95% Probability of Success Score (%)	April 2021 ACM Addendum - Normalized Relative Cost -Benefit Factor
7	Excavation with off-site Disposal and Funnel and Gate *Ex-Situ* Treatment, MNA, and NP WWTP	66.00%	2%	--	--
8	Excavation with on-Site Disposal and Funnel and Gate *Ex-Situ* Treatment, MNA, and NP WWTP	66.60%	2%	72.06%	1%

6.0 PUBLIC COMMENTS

Consistent with VSWMR 9VAC20-81-260.C.1.e a public meeting must be held to discuss the results of the ACM process prior to the final selection of the remedy. Due to the coronavirus pandemic a public meeting is not feasible at this time. A public meeting and comment period will be scheduled for a future date when it is reasonable to do so.

7.0 LIMITATIONS

The assessment and evaluation activities presented here were performed based on limited data, the impacts of which could have a substantial bearing on the evaluation outcomes presented herein. These limitations include the following assumptions and data gaps:

- Limited understanding of the hydraulic properties of the saprolite and underlying bedrock due to known heterogeneous rock composition, geometry, and differential weathering;
- Limited understanding of the depth to competent bedrock in the vicinity of the East Pond;
- Limited understanding of the nature and extent of the existing groundwater plume that will remain following ash removal;
- Current groundwater monitoring data from existing site monitoring wells accurately reflects the nature and extent of GPS/GWPS exceedances on the study area;
- Normal and expected construction costs for routine construction activities have been assumed for the cost estimates; and
- High level estimates of non-routine specialty construction costs.

8.0 CONCLUSIONS

Consistent with 9VAC20-81-260 of the VSWMR, the CCR Rule, and based on the results presented in the *NES Addendum* (Golder, 2021), Golder identified potential remedial options to address the state and federal GPS/GWPS exceedances for arsenic in the vicinity of the East Pond. These remedial options are consistent with the September 2020 ACM; however, the remedial evaluation for arsenic is not contingent upon removal of the North Pond since the available data suggest that the source of the arsenic concentration being detected downgradient from the East Pond is not related to the North Pond.

Specifically, as discussed in the *NES Addendum*, the arsenic concentrations at MW-20S over the last four (4) years have been variable ranging from less than the laboratory method detection limit to greater than the GWPS/GPS. This observation coupled with documented upgradient construction activities associated with closure by removal of the East Pond could indicate that the observed arsenic concentration trend at MW-20S is a function of variable geochemical conditions in the aquifer resulting from a combination of Station actions. The actions that may have impacted the geochemistry of the uppermost aquifer in the vicinity of MW-20S include the removal of the CCR materials from the East Pond, the conversion of the former East Pond to a stormwater management system, and on-going remedial actions associated with the North Pond, including installation of a rain cover and active CCR material dewatering. Additionally, while the bulk geochemistry for groundwater at wells MW-20S and MW-20D plots similarly to the North Pond porewater, the arsenic to boron ratio for MW-20S is significantly different from the arsenic to boron ratio for the North Pond pore water suggesting that the source of the MW-20S arsenic is not the North Pond since it is expected that such ratio would be preserved if the North Pond was the source of the arsenic at MW-20S. With respect to MW-20D, the arsenic to boron ratio is similarly different and the arsenic concentration is not detected in this well at concentrations above the GWPS/GPS. Collectively these observations suggest that the source of GWPS/GPS exceeding arsenic concentrations in MW-20S is localized to the well and therefore, remediation of the arsenic GWPS/GPS exceedance at MW-20S is not considered to be contingent on removal of the North Pond CCR materials.

Using a robust analytical model Golder evaluated the remedial options against 9VAC20-81-260 and the CCR Rule to develop a probabilistic ranking of remedial options. Additionally, Golder developed probabilistic cost estimates for each of the remedial options over the remedy's expected remedial timeframe. These cost estimates include costs associated with design and permitting, construction, operations, post-construction monitoring, and termination of the remedy once the remedial action goals are achieved.

The success probabilities for each remedial option considered were normalized with the remedy-specific mean cost estimates to provide an overall scaled relative efficacy/cost evaluation of the remedial options. These evaluations suggest that 4 to 5 years of natural recovery monitoring would prove to be the most effective remedy option under the CCR Rule and 9VAC20-81-260 of the VSWMR ACM evaluation criteria for mitigating the currently observed arsenic groundwater impacts. This remedial option is consistent with the findings from the previous September 2020 ACM Report. Future studies prior to formal remedy selection may be necessary to validate natural recovery mechanisms and timeframes.

9.0 REFERENCES

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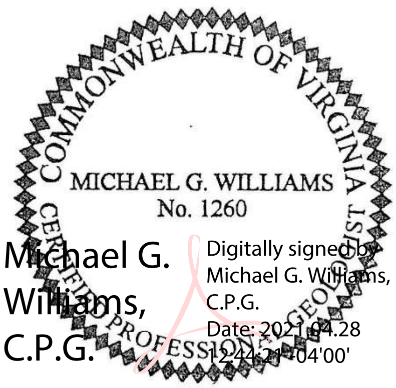
10.0 SIGNATURE SECTION

This document was prepared by Golder Associates Inc. for Dominion Energy. The document was prepared by qualified groundwater scientists and engineers who have received baccalaureate and/or post-graduate degrees in the natural sciences or engineering and who have sufficient training and experience in groundwater hydrology, engineering, and related fields as demonstrated by state professional registrations and completion of an accredited university program that enables sound professional judgments consistent with the industry standard of care for groundwater monitoring, contaminant fate and transport, environmental corrective actions, and cost estimate development.

Golder Associates Inc.



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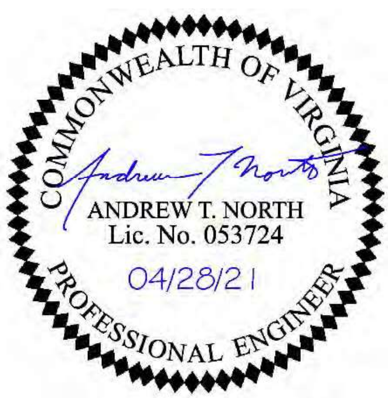

Andrew T. North, P.E.
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TABLE

Table 4
Assessment of Corrective Measures Addendum Evaluation Criteria
Bremo Power Station, Solid Waste Permit No. 618
East Pond

Class		Remedy Performance									Remedy Constructability (Ease of Implementation)				Remedy Concerns			
GoldSim Model Element		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Regulatory Citation (VSWMR)		9VAC20-81-260.D.1.a(1)	9VAC20-81-260.C.3.a(1)	9VAC20-81-260.D.1.a(2b)	9VAC20-81-260.D.1.a(1)	9VAC20-81-260.C.3.c(1b)	9VAC20-81-260.D.1.a(2); 9VAC20-81-260.D.1.a(2a); 9VAC20-81-260.C.3.c(1c)	--	9VAC20-81-260.C.3.a(4); 9VAC20-81-260.D.1.a(3c)	9VAC20-81-260.D.1.a(1h)	9VAC20-81-260.D.1.a(3a)	9VAC20-81-260.D.1.a(3b)	9VAC20-81-260.D.1.a(3d)	9VAC20-81-260.D.1.a(3e)	9VAC20-81-260.C.3.a(1)	9VAC20-81-260.C.3.a(1)	9VAC20-81-260.C.3.a(1)	9VAC20-81-260.D.1.a(6)
Regulatory Citation (CCR)		§257.96(c)(1); §257.97(c)(1); §257.97(c)(2)(i)	§257.96(c)(1); §257.97(c)(1); §257.97(c)(1)(vii); §257.97(c)(3)(ii)	§257.97(c)(2)(ii)	§257.96(c)(1)	§257.97(b)(2)	§257.96(c)(1); §257.97(b)(3)	§257.96(c)(1); §257.97(b)(4)	§257.97(c)(1)(ii)	§257.96(c)(1); §257.97(c)(1)(viii)	§257.96(c)(1)	§257.97(c)(3)(i)	§257.97(c)(3)(iv)	§257.97(c)(3)(v)	§257.96(c)(1)	§257.96(c)(1)	§257.96(c)(1)	§257.97(c)(4)
Percent Success		0% = minimal; 100% = substantial longterm effectiveness	0% = minimal; 100% = substantial longterm reliability	0% = lot of tech use; 100% = no tech use	0% = minimal; 100% = substantial shortterm effectiveness	0% = low; 100% = high ability to obtain GPS at POC	0% = minimal reduction; 100% = elimination of further releases	0% = minimal recovery; 100% = full recovery, or none required	0% = low potential for preventing; 100% = high potential for preventing future	0% = high remedy replacement potential; 100% = low remedy replacement potential	0% = hard to build; 100% = easy to build	0% = not available; 100% = available	0% = not available; 100% = available	0% = not available; 100% = available	0% = high potential safety impact; 100% = low safety impacts	0% = high cross media impact; 100% = low cross media impacts	0% = no residual contamination control; 100% = control	0% = does not address; 100% = addresses all concerns
Criteria		Long-Term Effectiveness of Remedy (%)	Long-Term Reliability of Remedy (%)	Treatment Tech Use Extent (%)	Short-Term Effectiveness (%)	Ability to Obtain the GPS at Point of Compliance (%)	Source Control to Reduce or Eliminate Further Releases (%)	Fugitive Material Recovery (%)	Potential for Future Material Releases (%)	Potential Need for Remedy Replacement (%)	Constructability (%)	Technology Availability/ Reliability (%)	Resource & Knowledge Availability (%)	Available Treatment, Storage, and Disposal Resources (%)	Potential Safety Impacts (%)	Potential Cross-Media Impacts (%)	Residual Contamination Exposure Control (%)	Community Concerns (%)
Option 1: Monitored Natural Attenuation (MNA)	Mean	60	60	80	20	60	80	80	80	20	80	80	80	80	60	60	60	80
	Assignment Notes (Relative evaluation across crierion)	Source removed coupled with limited sorption and dilution. Considering current groundwater impacts, sould be effective in controlling the release	Source removed, Natural Recovery based on sorption and dilution for COC	No tech required, just physical controls, sorption, and dilution	Source removed and full remedy effectiveness	With time, soprtion and dilution will attain goal	Source removal coupled with gradient reduction and Natural Recovery for contaminated water.	Fugitive materials recovered under parallel program	Source removed	May not be sufficent as a stand alone remedy to prevent off-site impacts above risk-based concentrations due to property line proximity	Limited construction	relatively available for this scale and type of work	experience gained every day by active providers	Treatment available	heavy equipment, source removal via over the road or rail traffic	Potential exist, contaminated groundwater could discharge to surface water. Contaminated groundwater flux reduces after source removal.	Source removed, contaminated groundwater. Potential for exposure at groundwater-surface water interface.	no active groundwater treatment
Option 2: In-Situ Aquifer Enhancement and MNA	Mean	80	80	20	40	60	80	80	80	40	40	60	60	80	40	60	60	80
	Assignment Notes (Relative evaluation across crierion)	At least as effective as removal with MNA only, effective injectants identified for metals, pilot test needed to confirm effectiveness	At least as effective as source removal and MNA alone; effective media/injectate identified to treat metals, pilot test needed to confirm effectiveness	Technology intensive remedy on top of source removal and MNA	Short term effectiveness could be enhanced with appropriate injectant, nano-carbon or other immoblizing agents	At least equal to MNA alone	Source removal coupled with gradient reduction and MNA for contaminated water.	Fugitive materials recovered under parallel program	Source removed	May not be sufficent with MNA to prevent off-site impacts above risk-based concentrations due to property line proximity	technology exists; proven; somewhat complex due to varying geology, need to find the right injectant and delivery method	injection-type providers available	some in situ work for metals done, need pilot test to confirm effectiveness	Treatment available	heavy equipment, source removal via over the road or rail traffic, injection safety	Potential exist, contaminated groundwater could discharge to surface water	Source removed, contaminated groundwater. Potential for exposure at groundwater-surface water interface.	Treamtent with contaminanted groundwater
Option 3: Hydraulic Pumping Containment (EP External Pumping Wells) with Ex-Situ Water Treatment and MNA and North Pond Wastewater Treatment Plant (NP WWTP)	Mean	80	80	20	60	80	80	80	80	80	80	80	80	80	60	40	20	80
	Assignment Notes (Relative evaluation across crierion)	More effective than removal and MNA alone, active treatment	At least as effective as source removal and MNA alone; relatively o/m needy, and power dependent, but reliably during working conditions; reliable treatment	Technology intensive remedy on top of source removal and MNA	Short term effectiveness enhanced via traditional P&T installation in less than 15 years	Expected to obtain GPS goal at point of compliance faster than MNA alone	Source removal coupled with gradient reduction and MNA for contaminated water.	Fugitive materials recovered under parallel program	Source removed	Should be sufficent with MNA to prevent off-site impacts above risk-based concentrations	technology is common; some drilling challenges expected; added wells may be expected	lots of drillers; will need a good rig and crew for the setting	lots of resources	Treatment available	heavy equipment, source removal via over the road or rail traffic	Potential exist, contaminated groundwater could discharge to surface water, source control for contaminated groundwater flux implemented quickly	Source removed, contaminated groundwater. Potential for exposure at groundwater-surface water interface and via O&M and treatment	Treamtent with contaminanted groundwater
Option 4: Funnel and Gate Ex-Situ Treatment and MNA and NP WWTP	Mean	80	80	20	60	80	80	80	80	80	60	80	80	80	60	40	20	80
	Assignment Notes (Relative evaluation across crierion)	More effective than removal and MNA alone, in-situ collection of water and ex-situ treatment: good access to medium and change-out ability; long term effectiveness may be high	At least as effective as source removal and MNA alone; reliable, simple water collection; O&M needy, reliable treatment due to ex-situ ability to change media and monitor conditions and flow	Technology intensive remedy on top of MNA	Short term effectiveness enhanced via F&G with P&T installation in less than 15 years	Expected to obtain GPS goal at point of compliance faster than MNA alone	Source removed coupled with gradient reduction and MNA for contaminated water.	Fugitive materials recovered under parallel program	Source removed	Should be sufficent with MNA to prevent off-site impacts above risk-based concentrations	technology exists; proven; somewhat complex due to varying geology	limited providers, but available	PRBs for metals confirmed effectiveness	T+O9:O14reatment available	heavy equipment, source removal via over the road or rail traffic	Potential exist, contaminated groundwater could discharge to surface water, source control for contaminated groundwater flux implemented quickly	Source removed, contaminated groundwater. Potential for exposure at groundwater-surface water interface and via O&M and treatment	Treamtent with contaminanted groundwater

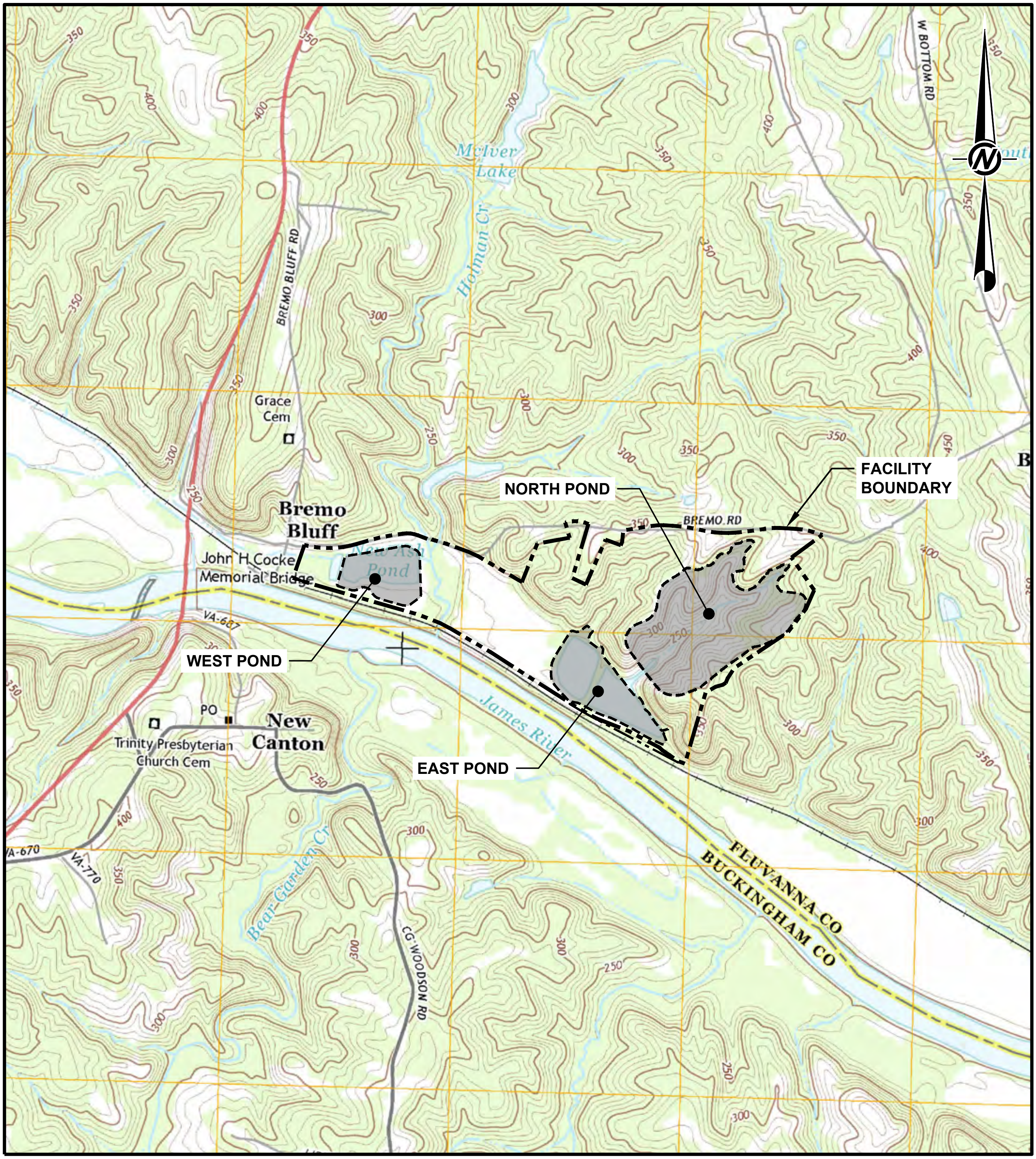
Table 4
Assessment of Corrective Measures Addendum Evaluation Criteria
Bremo Power Station, Solid Waste Permit No. 618
East Pond

Class		Remedy Institutional Controls							Remedy Risks						Remedy Operations and Maintenance			
GoldSim Model Element		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Regulatory Citation (VSWMR)		9VAC20-81-260.C.3.a(4); 9VAC20-81-260.D.1.a(3c)	9VAC20-81-260.C.3.a(4); 9VAC20-81-260.D.1.a(3c)	9VAC20-81-260.C.3.a(4); 9VAC20-81-260.D.1.a(3c)	9VAC20-81-260.D.1.a(5b)	9VAC20-81-260.C.3.c(1d)	--	9VAC20-81-260.D.1.a(1g)	9VAC20-81-260.D.1.a(1d); 9VAC20-81-260.D.1.a(1f)	--	9VAC20-81-260.D.1.a(1); 9VAC20-81-260.D.1.a(5a); 9VAC20-81-260.D.1.a(1f); 9VAC20-81-260.C.3.c(1a)	9VAC20-81-260.D.1.a(1); 9VAC20-81-260.D.1.a(5a); 9VAC20-81-260.D.1.a(1f); 9VAC20-81-260.C.3.c(1a)	9VAC20-81-260.D.1.a(1a) 9VAC20-81-260.D.1.a(2c)	9VAC20-81-260.D.1.a(1b)	9VAC20-81-260.D.1.a(1c)	9VAC20-81-260.D.1.a(1c)	9VAC20-81-260.D.1.a(1c)	9VAC20-81-260.D.1.a(1c)
Regulatory Citation (CCR)		§257.96(c)(3); §257.97(c)(3)(iii)	§257.96(c)(3); §257.97(c)(3)(iii)	§257.96(c)(3); §257.97(c)(3)(iii)	§257.97(a)	§257.97(b)(5)	§257.96(c)(3); §257.97(c)(3)(iii)	§257.96(c)(1); §257.97(c)(1)(vii)	§257.97(c)(1)(iv)	§257.97(c)(1)(iv)	§257.97(b)(1); §257.97(c)(1)(vi)	§257.97(b)(1); §257.97(c)(1)(vi)	§257.97(c)(1)(i)	§257.97(c)(1)(ii)	§257.97(c)(1)(iii)	§257.97(c)(1)(iii)	§257.97(c)(1)(iii)	§257.97(c)(1)(iii)
Percent Success		0% = Hard to get Fed Permit Required; 100% = No Fed Permit Required	0% = Hard to get State Permit Required; 100% = No State Permit Required	0% = Hard to get Local Permit Required; 100% = No Local Permit Required	0% = Out of Compliance; 100% = in compliance	0% = not in compliance; 100% = always in compliance	0% = Deed Restriction Required; 100% = Not Required	0% = Not reliable; 100% = always reliable	0% = significant community risks; 100% = no community risk	0% = significant Eco risks; 100% = no Eco risk	0% = less protective; 100% = most protective	0% = less protective; 100% = most protective	0% = little to no risk reduction; 100% = major risk reduction	0% = little to no risk reduction; 100% = major risk reduction	0% = High Management; 100% = Low Management	0% = High Monitoring; 100% = Low Monitoring	0% = High Operational; 100% = Low Operational	0% = High Maintenance; 100% = Low Maintenance
Criteria		Federal Permit Need (%)	State Permit Need (%)	Local Permit Need (%)	Compliance With OSHA, Federal, and Virginia Standards - 100% Compliance Assumed (%)	Waste Management Compliance (%)	Deed Restrictions (%)	Long Term Reliability of Controls (%)	Community Implementation Risks (transporation & disposal) (%)	Ecological Implementation Risks	Remedy Human Health Protectiveness & Waste Exposure	Remedy Environment Protectiveness & Waste Exposure	Magnitude of Existing Health Risk Reduction	Magnitude of Residual Risk for Further Releases	Relative Management Requirement (%)	Relative Monitoring Requirement (%)	Relative Operational Requirements (%)	Relative Maintenance Requirements (%)
Option 1: Monitored Natural Attenuation (MNA)	Mean	80	40	80	100	80	80	80	80	80	60	60	80	80	80	60	80	80
	Assignment Notes (Relative evaluation across crierion)	None	Solid Waste permit for closure via removal	no local permit known	In compliance	low risk for out of compliance conditions	Waste Removed, no deed restriction required for waste.	Once constructed, at steady state Natural Recovery is reliable after source removal	No construction, low concern	low risk	With source removed steady state remedy is protective provided no media transfer to surface water	With source removed steady state remedy is protective provided no media transfer to surface water	With source removed should ultimately achieve GPS, health risk reduction is goal	Source removed	No construction required, passive management	Moderate level of monitoring	Low operational requirements	Minimal maintenance requirements
Option 2: In-Situ Aquifer Enhancement and MNA	Mean	40	40	80	100	80	80	80	60	80	60	60	80	80	40	40	40	40
	Assignment Notes (Relative evaluation across crierion)	May require a Federal Underground Injection Control permit	Solid Waste permit for closure via removal	no local permit known	In compliance	low risk for out of compliance conditions	Waste Removed, no deed restriction required for waste.	Reliability of injectant for imobilizing COCs is unclear. At least as reliable as MNA alone	Some over the road or rail transport for construction of remedy	Low risk	With source removed steady state remedy is protective provided no media transfer to surface water	With source removed steady state remedy is protective provided no media transfer to surface water	With source removed should ultimately achieve GPS, health risk reduction is goal	Source removed	Moderate management during construction, moderate active management after construction	High level of monitoring during construction and moderate level of monitoring after construction is complete	High during construction, moderate if passive enplacement option selected	Minimal after construction is complete, may require follow-up enhancement applications to the aquifer system
Option 3: Hydraulic Pumping Containment (EP External Pumping Wells) with Ex-Situ Water Treatment and MNA and North Pond Wastewater Treatment Plant (NP WWTP)	Mean	40	40	80	100	60	80	80	60	40	40	60	80	80	20	20	20	20
	Assignment Notes (Relative evaluation across crierion)	May require a Federal Underground Injection Control permit	Solid Waste permit for closure via removal	no local permit known	In compliance	low risk for out of compliance conditions; treatment process will generate a waste stream	Waste Removed, no deed restriction required for waste.	High	Some over the road or rail transport for construction of remedy	moderate-high, coupled with water treatment system and permitted discharge	With source removed steady state remedy is protective provided no media transfer to surface water; some potential exposure associated with O&M of the system; expsoure potential with water treatment and discharge	With source removed steady state remedy is protective provided no media transfer to surface water; potential for impact associated with treated water discharge	With source removed should ultimately achieve GPS, health risk reduction is goal	Source removed	Moderate management during construction, significant active management after construction	High level of monitoring during construction and high level of monitoring after construction is complete	High during construction, moderate to high after with P&T and water treatment, discharge monitoring	High after construction is complete, routine O&M on the treatment system
Option 4: Funnel and Gate Ex-Situ Treatment and MNA and NP WWTP	Mean	40	40	80	100	60	80	80	60	40	40	60	80	80	20	20	20	20
	Assignment Notes (Relative evaluation across crierion)	May require a Federal Underground Injection Control permit	Solid Waste permit for closure via removal	no local permit known	In compliance	low risk for out of compliance conditions; treatment process will generate a waste stream	Waste Removed, no deed restriction required for waste.	High	Some over the road or rail transport for construction of remedy	moderate-high, coupled with water treatment system and permitted discharge	With source removed steady state remedy is protective provided no media transfer to surface water; some potential exposure associated with O&M of the system; expsoure potential with water treatment and discharge	With source removed steady state remedy is protective provided no media transfer to surface water; potential for impact associated with treated water discharge	With source removed should ultimately achieve GPS, health risk reduction is goal	Source removed	Moderate management during construction, significant active management after construction	High level of monitoring during construction and high level of monitoring after construction is complete	High during construction, moderate to high after with P&T and water treatment, discharge monitoring	High after construction is complete, routine O&M on the treatment system

Table 4
Assessment of Corrective Measures Addendum Evaluation Criteria
Bremo Power Station, Solid Waste Permit No. 618
East Pond

Class		Remedy Timeframes			Remedy Cost				
GoldSim Model Element		35	36	37	38	39	40		
Regulatory Citation (VSWMR)		9VAC20-81-260.C.3.a(2)	9VAC20-81-260.C.3.a(2)	9VAC20-81-260.D.1.a(1e) 9VAC20-81-260.D.1.a(2d)	9VAC20-81-260.C.3.a(3); 9VAC20-81-260.D.1.a(4)	9VAC20-81-260.C.3.a(3); 9VAC20-81-260.D.1.a(4)	9VAC20-81-260.C.3.a(3); 9VAC20-81-260.D.1.a(4)		
Regulatory Citation (CCR)		§257.96(c)(2)	§257.96(c)(2)	§257.96(c)(2); §257.97(c)(1)(v)	--	--	--	Upper 95% Probability of Success Score (%)	Relative Cost-Benefit Factor (% per USD)
Percent Success		Enter Years	Enter Years	Enter Years	Enter Costs	Enter Costs	Enter Costs		
Criteria		Time Required to Initiate Remedy (yrs)	Time Required to Complete Remedy Construction (yrs)	Time to Full Protection (less than GPS at Point of Compliance; yrs)	Engineering/Design Cost (USD)	Construction Cost & Construction Period O&M (USD)	Annual Post-Construction O&M Cost (USD)		
Option 1: Monitored Natural Attenuation (MNA)	Mean	1	1	5	$ -	$ 2,970,000.0	$ 198,000.0	80.45%	100%
	Assignment Notes (Relative evaluation across crierion)	Award contract and start hauling	Construct additional monitoring well network	estimate based on groundwater flow velocity, pore space flushing, and remedy construction timeframe					
Option 2: In-Situ Aquifer Enhancement and MNA	Mean	1	3	5	$ 112,500.0	$ 20,992,500.0	$ 385,000.0	75.72%	89%
	Assignment Notes (Relative evaluation across crierion)	Award contract and start hauling	delivery system construction	estimate based on groundwater flow velocity, pore space flushing, and remedy construction timeframe					
Option 3: Hydraulic Pumping Containment (EP External Pumping Wells) with Ex-Situ Water Treatment and MNA and North Pond Wastewater Treatment Plant (NP WWTP)	Mean	1	3	5	$ 82,500.0	$ 27,494,500.0	$ 1,419,000.0	72.62%	1%
	Assignment Notes (Relative evaluation across crierion)	Award contract and start hauling	wells and systems; water treatment	estimate based on groundwater flow velocity, pore space flushing, and remedy construction timeframe					
Option 4: Funnel and Gate Ex-Situ Treatment and MNA and NP WWTP	Mean	1	3	5	$ 206,250.0	$ 43,408,750.0	$ 1,364,000.0	72.06%	1%
	Assignment Notes (Relative evaluation across crierion)	Award contract and start hauling	F&G installation, Collection System and water treatment	estimate based on groundwater flow velocity, pore space flushing, and remedy construction timeframe					

FIGURES



REFERENCE

BASE MAP CONSISTS OF 7.5-MINUTE USGS TOPOGRAPHIC QUADRANGLE NAMED ARVONIA, VIRGINIA, DATED 2013.

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SCALE FEET

CLIENT
DOMINION ENERGY

PROJECT
BREMO POWER STATION
FLUVANNA COUNTY, VIRGINIA

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-03-17
DESIGNED	HDE
PREPARED	SIB
REVIEWED	MGW
APPROVED	MGW

TITLE
SITE LOCATION MAP

PROJECT NO.	REV.	FIGURE
20-13982321	0	1

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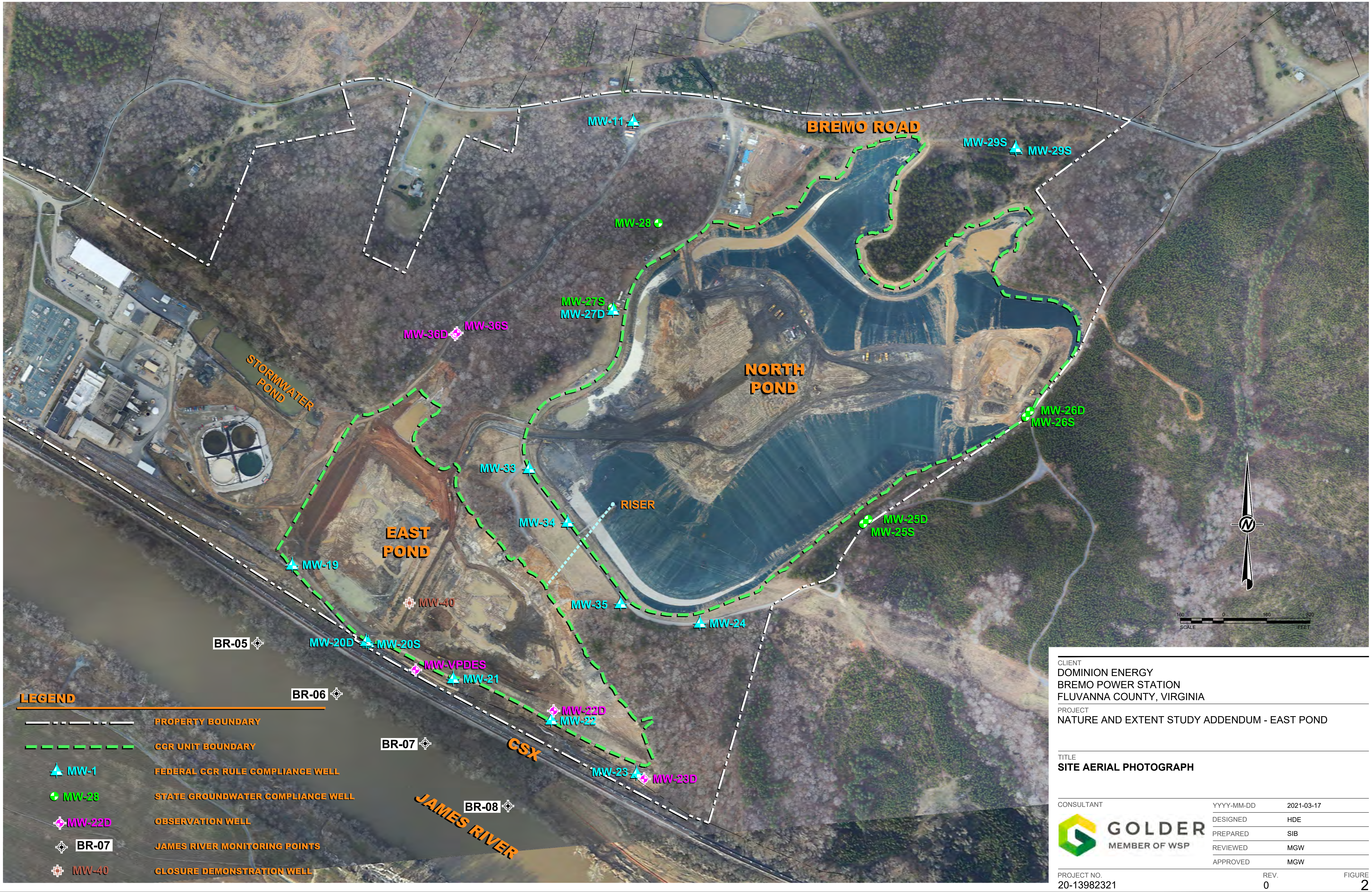

CLIENT
DOMINION ENERGY
BREMO POWER STATION
FLUVANNA COUNTY, VIRGINIA

PROJECT
NATURE AND EXTENT STUDY ADDENDUM - EAST POND

TITLE
SITE AERIAL PHOTOGRAPH

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-03-17
DESIGNED	HDE
PREPARED	SIB
REVIEWED	MGW
APPROVED	MGW

PROJECT NO. 20-13982321 REV. 0 FIGURE 2

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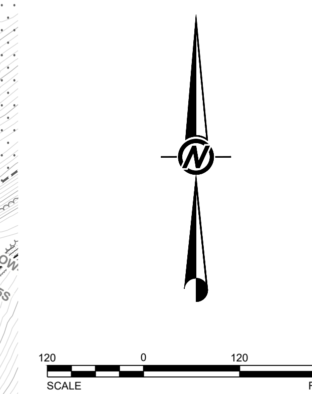

LEGEND

	APPROXIMATE PROPERTY BOUNDARY
250	EXISTING TOPOGRAPHIC CONTOURS (2' INTERVALS) (FROM AERIAL SURVEY - SEE NOTE 6)
	WETLANDS
	APPROXIMATE LIMITS OF EXISTING ASH PONDS
	APPROXIMATE LIMITS OF NORTH ASH POND FILL
	LIMITS OF 100-YR FLOOD PLAIN
MW-36S	GROUNDWATER OBSERVATION WELL LOCATION AND IDENTIFICATION
MW-21	FEDERAL CCR RULE COMPLIANCE WELL LOCATION AND IDENTIFICATION - EAST POND
MW-27S	STATE GROUNDWATER COMPLIANCE WELL LOCATION AND IDENTIFICATION
MW-2	GROUNDWATER OBSERVATION WELL LOCATION AND IDENTIFICATION
MW-9	FORMER VPDES MONITORING WELL
MW-33	FEDERAL CCR RULE COMPLIANCE WELL LOCATION AND IDENTIFICATION - NORTH POND
MW-20S	MONITORING WELL WITH FEDERAL GWPS OR VIRGINIA GPS EXCEEDANCE
BR-07	SURFACE WATER MONITORING LOCATION
MW-40	CLOSURE DEMONSTRATION WELL
★	EAST POND BASIN WATER

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BREMO POWER STATION
FLUVANNA COUNTY, VIRGINIA

PROJECT
NATURE AND EXTENT STUDY ADDENDUM - EAST POND

TITLE
EAST POND SITE PLAN

CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-03-17
DESIGNED	HDE
PREPARED	SIB
REVIEWED	MGW
APPROVED	MGW

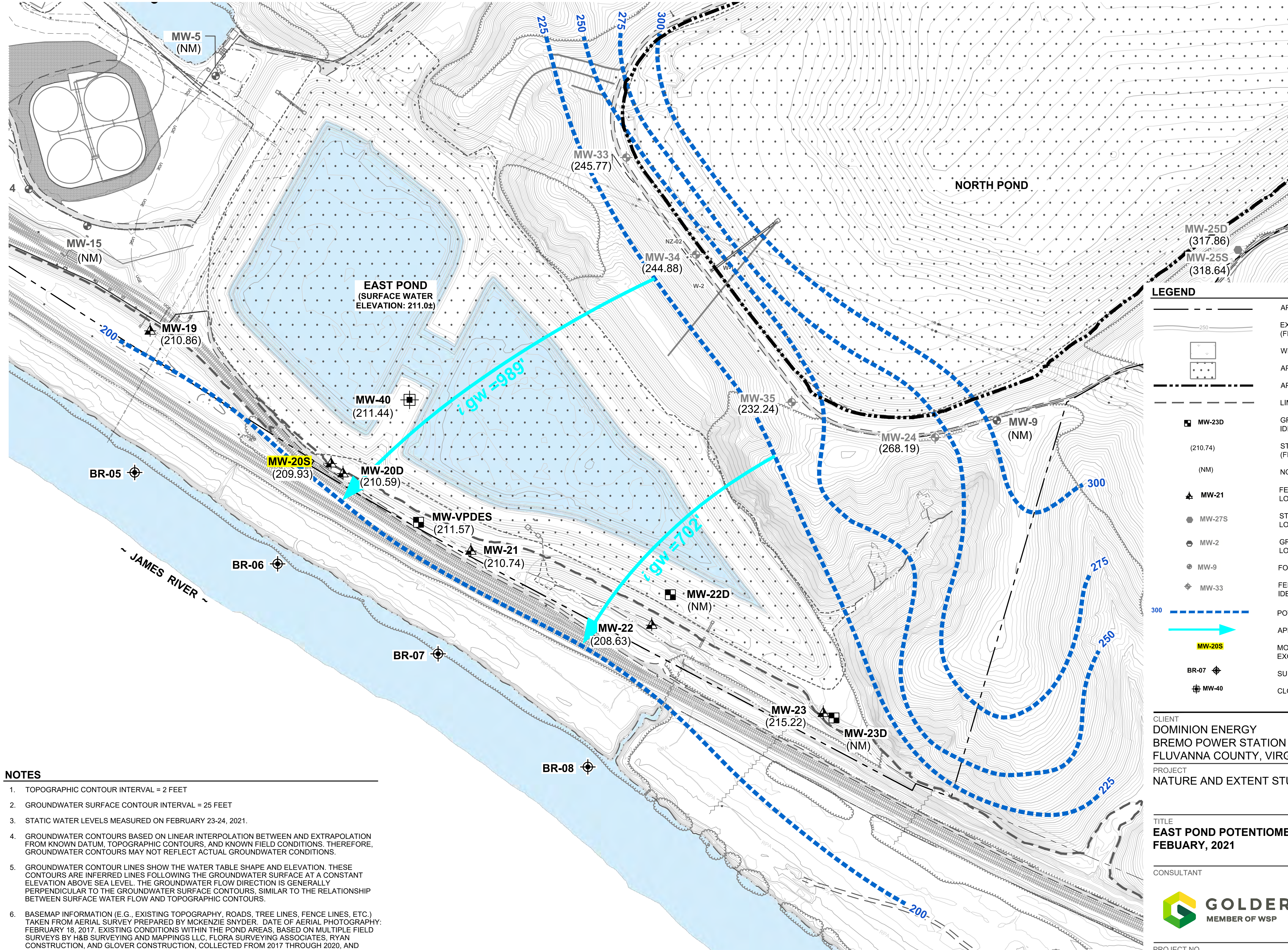
PROJECT NO.	REV.	FIGURE
20-13982321	0	3

NOTES

1. TOPOGRAPHIC CONTOUR INTERVAL = 2 FEET
2. BASEMAP INFORMATION (E.G., EXISTING TOPOGRAPHY, ROADS, TREE LINES, FENCE LINES, ETC.) TAKEN FROM AERIAL SURVEY PREPARED BY MCKENZIE SNYDER. DATE OF AERIAL PHOTOGRAPHY: FEBRUARY 18, 2017. EXISTING CONDITIONS WITHIN THE POND AREAS, BASED ON MULTIPLE FIELD SURVEYS BY H&B SURVEYING AND MAPPINGS LLC, FLORA SURVEYING ASSOCIATES, RYAN CONSTRUCTION, AND GLOVER CONSTRUCTION, COLLECTED FROM 2017 THROUGH 2020, AND COMPILED BY GOLDER ASSOCIATES.

Path: G:\Plan Production Data Files\Drawing Data Files\20-13982321\010_Bremo-ACM\Active Drawings\2013982321-03.dwg

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI D



NOTES

1. TOPOGRAPHIC CONTOUR INTERVAL = 2 FEET
2. GROUNDWATER SURFACE CONTOUR INTERVAL = 25 FEET
3. STATIC WATER LEVELS MEASURED ON FEBRUARY 23-24, 2021.
4. GROUNDWATER CONTOURS BASED ON LINEAR INTERPOLATION BETWEEN AND EXTRAPOLATION FROM KNOWN DATUM, TOPOGRAPHIC CONTOURS, AND KNOWN FIELD CONDITIONS. THEREFORE, GROUNDWATER CONTOURS MAY NOT REFLECT ACTUAL GROUNDWATER CONDITIONS.
5. GROUNDWATER CONTOUR LINES SHOW THE WATER TABLE SHAPE AND ELEVATION. THESE CONTOURS ARE INFERRED LINES FOLLOWING THE GROUNDWATER SURFACE AT A CONSTANT ELEVATION ABOVE SEA LEVEL. THE GROUNDWATER FLOW DIRECTION IS GENERALLY PERPENDICULAR TO THE GROUNDWATER SURFACE CONTOURS, SIMILAR TO THE RELATIONSHIP BETWEEN SURFACE WATER FLOW AND TOPOGRAPHIC CONTOURS.
6. BASEMAP INFORMATION (E.G., EXISTING TOPOGRAPHY, ROADS, TREE LINES, FENCE LINES, ETC.) TAKEN FROM AERIAL SURVEY PREPARED BY MCKENZIE SNYDER. DATE OF AERIAL PHOTOGRAPHY: FEBRUARY 18, 2017. EXISTING CONDITIONS WITHIN THE POND AREAS, BASED ON MULTIPLE FIELD SURVEYS BY H&B SURVEYING AND MAPPINGS LLC, FLORA SURVEYING ASSOCIATES, RYAN CONSTRUCTION, AND GLOVER CONSTRUCTION, COLLECTED FROM 2017 THROUGH 2020, AND COMPILED BY GOLDER ASSOCIATES.

LEGEND

	APPROXIMATE PROPERTY BOUNDARY
250	EXISTING TOPOGRAPHIC CONTOURS (2' INTERVALS) (FROM AERIAL SURVEY - SEE NOTE 6)
	WETLANDS
	APPROXIMATE LIMITS OF EXISTING ASH PONDS
	APPROXIMATE LIMITS OF NORTH ASH POND FILL
	LIMITS OF 100-YR FLOOD PLAIN
MW-23D	GROUNDWATER OBSERVATION WELL LOCATION AND IDENTIFICATION
(210.74)	STATIC GROUNDWATER ELEVATION (FEET ABOVE MEAN SEA LEVEL)
(NM)	NOT MEASURED
MW-21	FEDERAL CCR RULE COMPLIANCE WELL LOCATION AND IDENTIFICATION - EAST POND
MW-27S	STATE GROUNDWATER COMPLIANCE WELL LOCATION AND IDENTIFICATION
MW-2	GROUNDWATER OBSERVATION WELL LOCATION AND IDENTIFICATION
MW-9	FORMER VPDES MONITORING WELL
MW-33	FEDERAL CCR RULE COMPLIANCE WELL LOCATION AND IDENTIFICATION - NORTH POND
300	POTENTIOMETRIC SURFACE CONTOURS
	APPROXIMATE GROUNDWATER FLOW LINE
MW-20S	MONITORING WELL WITH FEDERAL GWPS OR VIRGINIA GPS EXCEEDANCE
BR-07	SURFACE WATER MONITORING LOCATION
MW-40	CLOSURE DEMONSTRATION WELL

CLIENT
DOMINION ENERGY
BREMO POWER STATION
FLUVANNA COUNTY, VIRGINIA

PROJECT
NATURE AND EXTENT STUDY ADDENDUM - EAST POND

TITLE
EAST POND POTENTIOMETRIC SURFACE PLAN
FEBUARY, 2021

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-03-17
DESIGNED	HDE
PREPARED	SIB
REVIEWED	MGW
APPROVED	MGW

PROJECT NO.	REV.	FIGURE
20-13982321	0	4

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI D

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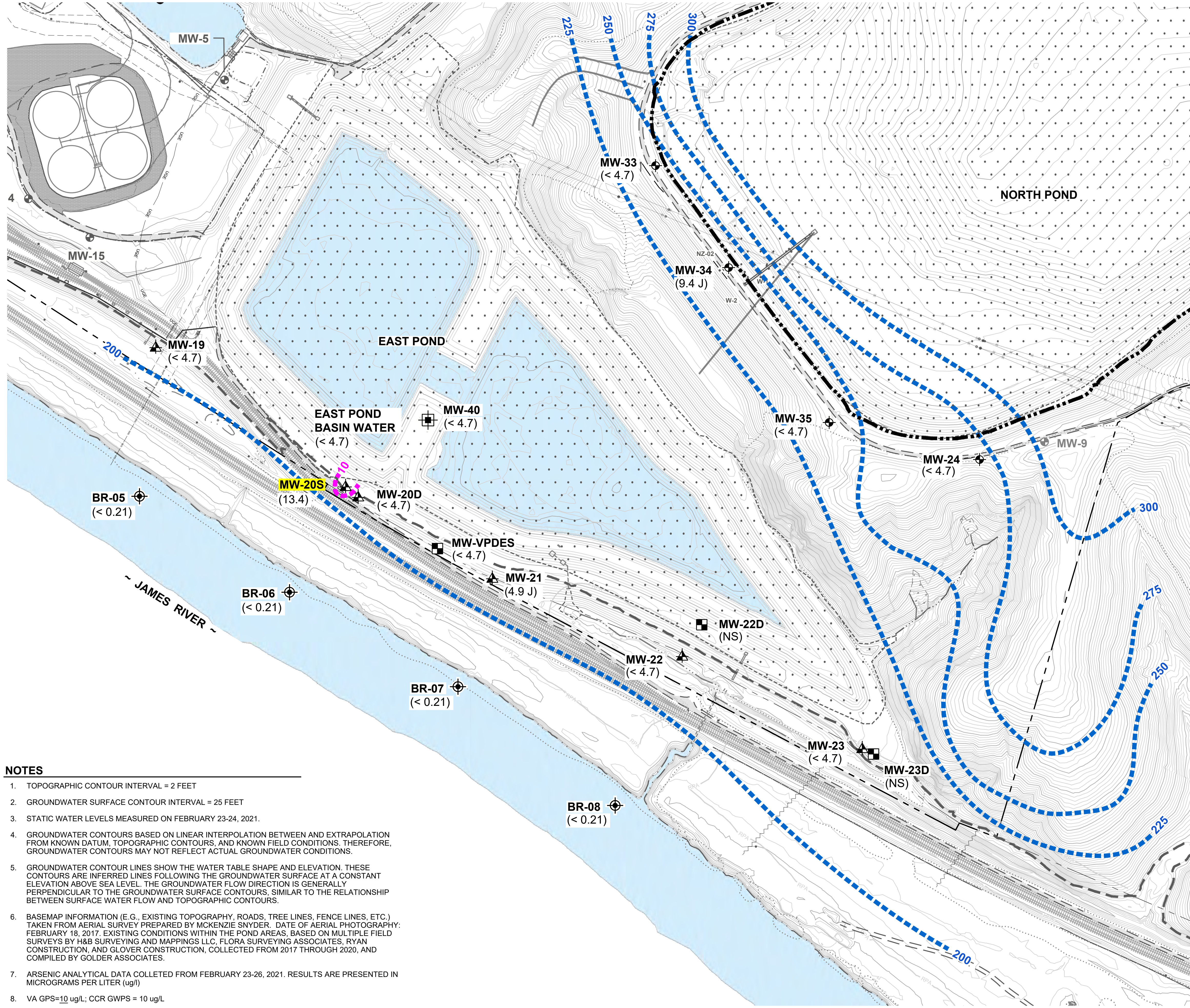

SCALE 120 0 120 240 FEET

LEGEND

- APPROXIMATE PROPERTY BOUNDARY
- EXISTING TOPOGRAPHIC CONTOURS (2' INTERVALS) (FROM AERIAL SURVEY - SEE NOTE 6)
- WETLANDS
- APPROXIMATE LIMITS OF EXISTING ASH PONDS
- APPROXIMATE LIMITS OF NORTH ASH POND FILL
- LIMITS OF 100-YR FLOOD PLAIN
- MW-23D — GROUNDWATER OBSERVATION WELL LOCATION AND IDENTIFICATION
- (13.4) — ARSENIC CONCENTRATION (ug/l)
- (NM) — NOT MEASURED
- MW-21 — FEDERAL CCR RULE COMPLIANCE WELL LOCATION AND IDENTIFICATION - EAST POND
- MW-27S — STATE GROUNDWATER COMPLIANCE WELL LOCATION AND IDENTIFICATION
- MW-2 — GROUNDWATER OBSERVATION WELL LOCATION AND IDENTIFICATION
- MW-9 — FORMER VPDES MONITORING WELL
- MW-33 — FEDERAL CCR RULE COMPLIANCE WELL LOCATION AND IDENTIFICATION - NORTH POND
- 300 — POTENTIOMETRIC SURFACE CONTOURS
- MW-20S — MONITORING WELL WITH ARSENIC GPS EXCEEDENCE
- BR-07 — SURFACE WATER MONITORING LOCATION
- MW-40 — CLOSURE DEMONSTRATION WELL
- 10 — ARSENIC ISOCONCENTRATION CONTOUR
- ★ — EAST POND BASIN WATER

NOTES

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7. ARSENIC ANALYTICAL DATA COLLETED FROM FEBRUARY 23-26, 2021. RESULTS ARE PRESENTED IN MICROGRAMS PER LITER (ug/l)
8. VA GPS=10 ug/L; CCR GWPS = 10 ug/L

CLIENT
DOMINION ENERGY
BREMO POWER STATION
FLUVANNA COUNTY, VIRGINIA

PROJECT
NATURE AND EXTENT STUDY ADDENDUM - EAST POND

TITLE
EAST POND ARSENIC ISOCONCENTRATION CONTOURS FEBRUARY - APRIL 2021

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2021-03-17
DESIGNED	ALR
PREPARED	SIB
REVIEWED	MGW
APPROVED	MGW

PROJECT NO. 20-13982321 REV. 0 FIGURE 5

GOLDER

golder.com