Corrective Measures Assessment

Miami Fort Basin A
Miami Fort Power Station
11021 Brower Road
North Bend, Ohio

Dynegy Miami Fort, LLC

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OBG
Part of Ramboll

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1 INTRODUCTION

O'Brien & Gere Engineers, Inc, part of Ramboll (OBG) has prepared this Corrective Measures Assessment (CMA) for Basin A (Basin A; CCR Unit ID 111) located at the Miami Fort Power Station (MFS) in North Bend, Ohio. This CMA report complies with the requirements of Title 40 of the Code of Federal Regulations (C.F.R.) § 257, Subpart D Standards for the Disposal of Coal Combustion Residuals (CCR) in Landfills and Surface Impoundments (CCR Rule). Under the CCR Rule, owners and operators of existing CCR surface impoundments (SIs) must initiate a CMA, in accordance with 40 C.F.R. § 257.96, when one or more Appendix IV constituents are detected at statistically significant levels (SSLs) above groundwater protection standards (GWPS) in the Uppermost Aquifer, and the owner or operator has not completed an alternate source demonstration demonstrating that a source other than the CCR unit has caused the contamination. This CMA is responsive to the 40 C.F.R. § 257.96 and § 257.97 requirements for assessing potential corrective measures to address the exceedance of the GWPS for cobalt and molybdenum in the Uppermost Aquifer.

This CMA is the first step in developing a long-term corrective action plan and has been prepared to evaluate applicable remedial measures to address cobalt and molybdenum SSLs in the Uppermost Aquifer. The results of the CMA will be used to guide whether additional site-specific data are necessary to develop a long-term corrective action plan for the Uppermost Aquifer, consistent with 40 C.F.R. § 257.96 and § 257.97 requirements.

1.1 CORRECTIVE MEASURES ASSESSMENT OBJECTIVES AND METHODOLOGY

The objective of this CMA is to begin the process of evaluating appropriate corrective measure(s) to address impacted groundwater in the Uppermost Aquifer potentially associated with Basin A at the MFS. The CMA evaluates the effectiveness of the corrective measures in meeting the requirements and objectives of the remedy, as described under 40 C.F.R. § 257.96(c), by addressing the following evaluation criteria:

- Performance
- Reliability
- Ease of implementation
- Potential impacts of appropriate potential remedies (safety impacts, cross-media impacts, and control of exposure to any residual contamination)
- Time required to begin and complete the remedy
- Institutional requirements that may substantially affect implementation of the remedy(s) (permitting, environmental or public health requirements)

The CMA provides a systematic, rational method for evaluating potential corrective measures. The assessment process documented herein: a) identifies the site-specific conditions that will influence the effectiveness of the potential corrective measures (Section 2); b) identifies applicable corrective measures (Section 3); c) assesses the corrective measures against the evaluation criteria to select potentially feasible corrective measures (Section 4); and d) summarizes the remedy selection process and future actions (Section 5).

1.2 EVALUATION CRITERIA

The evaluation criteria are defined below to provide a common understanding and consistent application. The evaluation included qualitative and/or semi-quantitative screening of the corrective measures relative to their general performance, reliability and ease of implementation characteristics, and their potential impacts, timeframes and institutional requirements. Evaluations were at a generalized level of detail in order to screen out corrective measures that were not expected to meet 40 C.F.R. § 257.97 design criteria, while retaining corrective measures that would meet the design criteria.

The evaluation does not explicitly address and document compliance with each of the specific elements included in the definitions below. Rather, the evaluation considered the elements qualitatively, applying engineering judgement, to provide a reasoned set of corrective measures that could be used, either individually or in combination, to achieve GWPS in the most effective and protective manner.

1.2.1 Performance

The performance of potentially applicable corrective measures was evaluated for the:

1. Potential to ensure that any environmental releases to groundwater, surface water, soil and air will be at or below relevant regulatory and health-based benchmarks for human and ecological receptors.
2. Degree to which the corrective measure isolates, removes or contains SSLs identified in the Uppermost Aquifer.
3. Ability of the corrective measure to achieve GWPS within the Uppermost Aquifer at the compliance boundaries.

1.2.2 Reliability

The reliability of the corrective measure is a description of its ability to function as designed until the GWPS are achieved in the Uppermost Aquifer at the compliance boundaries. Evaluation of the reliability included considering:

1. Type and degree of long-term management required, including monitoring, operation, and maintenance.
2. Long-term reliability of the engineering and institutional controls associated with the corrective measure.
3. Potential need for replacement of the corrective measure.

1.2.3 Ease of Implementation

The ease or difficulty of implementing a given corrective measure was evaluated by considering:

1. Degree of difficulty associated with constructing the corrective measure.
2. Expected operational reliability of the corrective measure.
3. Need to coordinate with and obtain necessary approvals and permits.
4. Availability of necessary equipment and specialists.
5. Available capacity and location of needed treatment, storage, and disposal services.

1.2.4 Potential Impacts of the Remedy

Potential impacts associated with a given corrective measure included consideration of impacts on the distribution and/or transport of contaminants, safety impacts (the short-term risks that might be posed to the community or the environment during implementation), cross-media impacts (increased traffic, noise, fugitive dust) and control of potential exposure of humans and environmental receptors to remaining wastes.

1.2.5 Time Required to Begin, Implement, and Complete the Remedy

Evaluating the time required to begin the remedy focused on the site-specific conditions that could require additional or extended timeframes to characterize, design, and/or field test a corrective measure to verify the applicability and effectiveness of a corrective measure. The length of time that would be required to begin and implement the remedy was considered to be the total time to: 1) verify applicability and effectiveness; 2) design and obtain permits; and 3) complete construction of the corrective measure.

The time required to complete the remedy considered the total time after the corrective measure was implemented until GWPS would be achieved in the Uppermost Aquifer at the compliance boundaries.

1.2.6 Institutional, Environmental or Public Health Requirements

Institutional, environmental and public health requirements considered state, local, and site-specific permitting or other requirements that could substantially affect construction or implementation of a corrective measure.

2 SITE HISTORY AND CHARACTERIZATION

2.1 SITE DESCRIPTION AND HISTORY

The MFS is owned and operated by Dynegy Miami Fort, LLC. The station is located in the southwest corner of the State of Ohio on the north shore of the Ohio River, at the confluence with the Great Miami River, as shown in Figure 1. The facility is located within Hamilton County, Miami Township, approximately 5 miles southwest of the village of North Bend, Ohio. The state boundary with Indiana is approximately 1,900 feet to the west of MFS and the boundary with the State of Kentucky lies just offshore to the south, within the Ohio River.

The MFS has two coal-fired units, Units 7 and 8, constructed in 1975 and 1978 with a total capacity of 1,100 megawatts (MW) and four oil-fired facilities constructed in 1971 with a total capacity of 78 MW. Basin A is located in the southwest corner of the MFS property.

Basin A is an unlined surface impoundment (SI) approximately 30 acres in size. It was originally constructed sometime prior to 1959 with a vertical expansion around 1976. Basin A receives effluent from the sluice lines, which primarily transport bottom ash products as well as FGD effluent and some fly ash and miscellaneous yard drainage (AECOM, 2017). The basin is bounded by the Veolia North America property and Brower Road to the north, the Great Miami River to west, the Ohio River to the south, Veolia's production wells to the northwest, and MFS's electric switch yard and production wells to the east. Figure 2 is a site plan showing the basin, monitoring wells, and production wells.

2.2 GEOLOGY AND HYDROGEOLOGY

The geologic units present beneath Basin A at MFS include fill, alluvial deposits, glacial outwash (Uppermost Aquifer) and bedrock, as described below:

- Fill Unit – (CCR within Basin A). The CCR consists primarily of bottom ash, fly ash, and other non-CCR waste streams. This unit also includes man made berms constructed of a variety of locally available materials.
- Alluvial Deposits - The alluvial deposits consist of clay, silt and fine sand deposited by the Ohio River floodwaters. These alluvial deposits range in depth from approximately 20 to 60 feet below the present ground surface. A silty, sandy clay layer is the primary component of the alluvial deposits. The clay ranges in elevation from 428 feet (ft) above mean sea level (msl) in the southwest near the confluence of the Ohio River and the Great Miami River to 495 ft msl beneath the northeast corner of Basin A. The clay is thin, or absent, near the valley wall and thickens towards the Ohio River. The clay is thickest beneath the southern half of Basin A, ranging in thickness from 15 ft to 48 ft. A silt layer, averaging approximately 7 ft thick, overlies the clay in several areas.
- Glacial Outwash (Uppermost Aquifer) - Deposits consisting of sands and gravels deposited during the Illinoian and Wisconsin stages of the Pleistocene. The thickness of the outwash deposits is approximately 100 feet; the outwash deposits directly overlie bedrock. A silt and fine sand layer is present locally on top of the outwash deposits and ranges in thickness from 4 ft to 30 ft; however, it is not present below all of Basin A.
- Bedrock - The bedrock consists of interbedded shales and limestones belonging to the Ordovician-aged Fairview and Kope formations (AECOM, 2017). Depth to bedrock beneath the site varies between approximately 110 to 120 feet below ground surface (bgs) dependent on proximity to the edge of the valley wall north of Basin A. Due to the relatively impermeable nature of the shales and limestones underlying this region, water yields in the bedrock are generally insufficient for domestic use.

The glacial outwash deposits (Uppermost Aquifer) underlying Basin A are part of the Ohio River Valley Fill Aquifer; a buried valley aquifer. The valley was cut into the bedrock by pre-glacial and glacial streams and subsequently back-filled with deposits of sand, gravel and other glacial drift by glacial and alluvial processes as the glaciers advanced and receded. Buried valley aquifers such as the Uppermost Aquifer are Ohio's most productive water-bearing formations. Estimates of transmissivity are in excess of 50,000 gallons per day per foot (USGS, 1997).

Regionally, yields for high-capacity wells in the Uppermost Aquifer range from 450 gallons per minute (gpm) to 3,000 gpm with one well tested as high as 6,000 gpm. (IDNR, 2006). Three production wells, located northwest of Basin B, are operated by Veolia for process (non-potable) water. The MFS operates four production wells east-southeast of Basin A for cooling water. Pumping rates measured at the cooling water production wells range from 1,000 gpm to 1,500 gpm. The majority of the water withdrawn by these wells is from induced flow from the Ohio River (ODNR, undated).

The aquifer receives most of its recharge from infiltration of precipitation on the valley floor; however, secondary recharge also comes from bank storage from the Great Miami River and Ohio River during flood stages. Recharge to the aquifer from bank storage is periodic and short-lived.

The groundwater potentiometric surface on site was encountered at depths of 25 to 55 feet bgs, approximately 455 to 460 ft msl, coincident with the approximate pool elevation of the Ohio River. Groundwater flow is generally to the west/northwest towards the Great Miami River and Veolia's production wells, and east/southeast towards MFS production wells. The hydraulic gradient across the site is very low (flat) and prone to minor changes due to changes in river stage and/or nearby production well usage (AECOM, 2017).

2.3 GROUNDWATER QUALITY

Detection monitoring in the Uppermost Aquifer, per 40 C.F.R. § 257.90, was initiated in October 2017; statistically significant increases (SSIs) of Appendix III parameters over background concentrations were detected in October 2017. Alternate source evaluations were inconclusive for one or more of the SSIs. Therefore, in accordance with 40 C.F.R. § 257.94(e)(2), an Assessment Monitoring Program was established for Basin A on April 9, 2018. Assessment Monitoring results identified statistically significant levels (SSLs) of the Appendix IV parameters cobalt and molybdenum over the GWPS of 0.006 milligrams per Liter (mg/L) and 0.10 mg/L, respectively. SSLs for total cobalt were identified in downgradient monitoring well MW-4 where concentrations ranged from 0.00503 mg/L to 0.0187 mg/L. SSLs for total molybdenum were identified in downgradient monitoring well MW-6 where concentrations ranged from 0.344 mg/L to 0.661 mg/L. No other SSLs have been identified for Basin A. Monitoring well locations are shown on Figure 2.

3 DESCRIPTION OF CORRECTIVE MEASURES

The corrective measures described below are frequently used to mitigate impacts from contaminants. The corrective measures are identified as either potential source control or groundwater corrective measures.

3.1 OBJECTIVES OF THE CORRECTIVE MEASURES

The following performance standards, per 40 C.F.R. § 257.97, must be met by the selected corrective measures:

- Be protective of human health and the environment.
- Attain the groundwater protection standards per 40 C.F.R. § 257.95(h).
- Provide source control to reduce or eliminate, to the maximum extent feasible, further releases of Appendix IV constituents.
- Remove from the environment as much of the contaminated material as feasible.
- Comply with waste management standards, per 40 C.F.R. § 257.98(d).

Site-specific considerations regarding Basin A, provided in Section 2, were used to evaluate potential corrective measures. Each of the corrective measures evaluated may be capable of satisfying the performance standards listed above to varying degrees of effectiveness. The corrective measure review process yields a set of applicable corrective measures that can be used in developing a long-term corrective action plan. The corrective measures may be used independently or may be combined into specific remedial alternatives to leverage the advantages of multiple corrective measures to meet the performance standards.

The following potential corrective measures are commonly used to mitigate groundwater impacts and were considered as a part of the CMA process:

- Potential Source Control Corrective measures
  - Closure in Place
  - Closure by Removal (Off-Site Landfill)
  - In-Situ Solidification/Stabilization
- Potential Groundwater Remedial Corrective measures
  - Monitored Natural Attenuation (MNA)
  - Groundwater Cutoff Wall
  - In-Situ Chemical Treatment
  - Permeable Reactive Barrier
  - Groundwater Extraction

3.2 POTENTIAL SOURCE CONTROL CORRECTIVE MEASURES

3.2.1 Closure in Place

Closure in place (CIP) includes constructing a cover system in direct contact with the graded CCR. Cover systems are designed to significantly minimize water infiltration into the CCR unit and allow surface water to drain off the cover system, thus reducing generation of potentially impacted water and reducing the extent of cobalt and molybdenum impact in the Uppermost Aquifer.

Construction of a cover system typically includes, but is not limited to, the following primary project components:

- Removal of free water and grading the CCR to allow cover system construction.

- Relocating and/or reshaping the existing CCR and cover material within the impoundment to achieve acceptable grades for closure. Borrow soil may be used to supplement fill volume, if necessary, to reach final design grades.
- Constructing a cover system that complies with the CCR Rule, including establishment of a vegetative cover to minimize long-term erosion.
- Constructing a stormwater management system to convey runoff from the cover system to a system of perimeter drainage channels for ultimate routing and discharge to nearby surface water.
- Ongoing inspection and maintenance of the cover system; and, stormwater and property management.

3.2.2 Closure by Removal (Off-Site Landfill)

Closure by removal (CBR) includes the following components: removal of all CCR from the CCR unit; moisture conditioning the CCR as needed to facilitate excavating, loading and transporting CCR to either an on-site or off-site landfill; and backfilling the excavation. This corrective measure would address the source of groundwater impacts by removing the CCR, but the groundwater impacts would not begin to diminish until the source is completely removed.

CBR would require transporting CCR to an off-site location for disposal, as the MFS property does not have the space required for siting a new on-site landfill. This would result in increased risk to the public, increased greenhouse gas emissions and carbon footprint, and increased potential for fugitive dust exposure. Transporting ash to an off-site landfill also presents concerns about available landfill capacity and community impacts, safety concerns and project duration.

3.2.3 In Situ Solidification/Stabilization

In situ solidification/stabilization (ISS) is a corrective measure which consists of encapsulating waste within a cured monolith having increased compressive strength and reduced hydraulic conductivity. Hazards can be reduced by both converting waste constituents into a less soluble and mobile forms and by isolating waste from groundwater, thus facilitating groundwater remediation and reducing leaching to groundwater. ISS includes solidifying all CCR from the CCR unit and encapsulating the CCR through in-place mechanical mixing with reagents in an engineered grout mixture. The grout is typically emplaced using augers, backhoes or injection grouting. ISS also improves the geotechnical stability and material strength of the CCR materials.

ISS construction technologies include vertical rotary mixed ISS, hydraulic auger mixed ISS, hydraulic mixing tool ISS, and excavator mixed ISS. ISS construction may use a combination of these technologies depending on site-specific design requirements. ISS design typically requires data on, but not limited to, the following CCR material properties; geotechnical parameters, inorganic chemical constituents, class of ash, and ash management information (*e.g.,* coal source, co-management). Due to the variability in material properties of CCR, ISS would require an extensive mix design process for assessing ISS performance. Typical design and performance parameters include but are not limited to: volume expansion (swell), leachability, permeability and unconfined compressive strength. ISS performance may be evaluated based on both civil design and remedial performance objectives.

3.3 POTENTIAL GROUNDWATER CORRECTIVE MEASURES

3.3.1 Monitored Natural Attenuation

Both federal and state regulators have long recognized that MNA can be an acceptable component of a remedial action when it can achieve remedial action objectives in a reasonable timeframe. In 1999, the USEPA published a final policy directive (USEPA, 1999) for use of MNA for groundwater remediation and described the process as follows:

- The reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods. The ‘natural attenuation processes’ that are at work in such a remediation approach include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in-situ processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants.

The USEPA has stated that source control was the most effective means of ensuring the timely attainment of remediation objectives (USEPA, 1999). Natural attenuation processes may be appropriate as a “finishing step” after effective source control implementation, if there are no risks to receptors and/or the contaminant plume is not expanding. Thus, MNA would be used in conjunction with source control measures described in Section 3.2.

The 1999 MNA document was focused on organic compounds in groundwater. However, in a 2015 companion document, the USEPA addressed the use of MNA for inorganic compounds in groundwater. The USEPA noted that the use of MNA to address inorganic contaminants: (1) is not intended to constitute a treatment process for inorganic contaminants; (2) when appropriately implemented, can help to restore an aquifer to beneficial uses by immobilizing contaminants onto aquifer solids and providing the primary means for attenuation of contaminants in groundwater; and (3) is not intended to be a “do nothing” response (USEPA, 2015). Rather, documenting the applicability of MNA for groundwater remediation should be thoroughly and adequately supported with site-specific characterization data and analysis in accordance with the USEPA’s tiered approach to MNA (USEPA 1999, 2007, and 2015):

1. Demonstrate that the area of groundwater impacts is not expanding.
2. Determine the mechanisms and rates of attenuation.
3. Determine that the capacity of the aquifer is sufficient to attenuate the mass of constituents in groundwater and that the immobilized constituents are stable and will not remobilize.
4. Design a performance monitoring program based on the mechanisms of attenuation and establish contingency remedies (tailored to site-specific conditions) should MNA not perform adequately.

Both physical and chemical attenuation processes can contribute to the reduction in mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. Physical attenuation processes applicable to CCR include dilution, dispersion and flushing. Chemical attenuation processes applicable to CCR include precipitation and coprecipitation (*i.e.*, incorporation into sulfide minerals), sorption (*i.e.*, to iron, manganese, aluminum, or other metal oxides or oxyhydroxides, or to sulfide minerals or organic matter), and ion exchange. Timeframes to achieve GWPS are dependent on site-specific conditions, actual timeframes would require detailed technical analysis.

Cobalt and molybdenum have the potential to be sorbed onto iron hydroxides or organic matter in the aquifer materials, depending on the geochemical conditions, but are typically mobile (EPRI, 2012). Physical and chemical mechanisms are available natural attenuation processes acting upon CCR constituents such as cobalt and molybdenum. The performance of MNA as a groundwater corrective measure varies based on site-specific conditions. Additional data collection and analysis may be required to support the USEPA’s tiered approach to MNA (USEPA, 2015) and obtain regulatory approval.

3.3.2 Groundwater Extraction

Groundwater extraction is a widely used groundwater corrective measure. This corrective measure includes installation of a series of groundwater pumping wells or trenches to control and extract impacted groundwater. Groundwater extraction captures and contains impacted groundwater and can limit plume expansion and/or off-site migration. Construction of a groundwater extraction system typically includes, but is not limited to, the following primary project components:

- Designing and constructing a groundwater extraction system consisting of a series of extraction wells or trenches located around the perimeter of the site and operating at a rate to allow capture of CCR impacted groundwater within the Uppermost Aquifer.

- Designing a system to manage extracted groundwater, which may include modification to the existing NPDES permit, including treatment prior to discharge, if necessary.
- Ongoing inspection and maintenance of the groundwater extraction system.

Remediation of inorganics by groundwater extraction can be effective, but systems do not always perform as expected. A combination of factors, including geologic heterogeneities, difficulty in flushing low permeability zones, and sorbed contaminants (desorption rate limited cleanup process) can inhibit effective remediation. Groundwater extraction systems require ongoing operation and maintenance to ensure optimal performance and the extracted groundwater must be managed, either by ex-situ treatment or disposal.

3.3.3 Groundwater Cutoff Wall

Since the late 1970s and early 1980s, vertical cutoff walls have been used to control and/or isolate impacted groundwater. Low permeability cutoff walls can be used to prevent horizontal off-site migration of potentially impacted groundwater. Cutoff walls act as barriers to transport of impacted groundwater and can isolate soils that have been impacted by CCR to prevent contact with unimpacted groundwater. Cutoff walls are often used in conjunction with an interior pumping system to establish a reverse gradient within the cutoff wall. The reverse gradient maintains an inward flow through the wall, keeping it from acting as a groundwater dam and controlling potential end-around or breakout flow of contaminated groundwater.

A commonly used cutoff wall construction technology is the slurry trench method, which consists of excavating a trench and backfilling it with a soil-bentonite mixture, often created with the soils excavated from the trench. The trench is temporarily supported with bentonite slurry that is pumped into the trench as it is excavated (D'Appolonia & Ryan, 1979). Excavation for cutoff walls is conducted with conventional hydraulic excavators, hydraulic excavators equipped with specialized booms to extend their reach (*i.e.*, long-stick excavators), or chisels and clamshells, depending upon the depth of the trench and the material to be excavated. In order for a cutoff wall to be technically feasible, there must be a low-permeability lower confining layer into which the barrier can be keyed, and it must be at a technically feasible depth.

3.3.4 Permeable Reactive Barrier

Chemical treatment via a Permeable Reactive Barrier (PRB) is defined as an emplacement of reactive materials in the subsurface designed to intercept a contaminant plume, provide a flow path through the reactive media, and transform or otherwise render the contaminant(s) into environmentally acceptable forms to attain remediation concentration goals downgradient of the barrier (EPRI, 2006).

As groundwater passes through the PRB under natural gradients, dissolved constituents in the groundwater react with the media and are transformed or immobilized. A variety of media have been used or proposed for use in PRBs. Zero-valent iron has been shown to effectively immobilize CCR constituents, including arsenic, chromium, cobalt, molybdenum, selenium and sulfate. Zero-valent iron has not been proven effective for boron, antimony, or lithium (EPRI, 2006).

System configurations include continuous PRBs, in which the reactive media extends across the entire path of the contaminant plume; and funnel-and-gate systems, where barrier walls are installed to control groundwater flow through a permeable gate containing the reactive media. Continuous PRBs intersect the entire contaminant plume and do not materially impact the groundwater flow system. Design may or may not include keying the PRB into a low-permeability unit at depth. Funnel-and-gate systems utilize a system of barriers to groundwater flow (funnels) to direct the contaminant plume through the reactive gate. The barriers, typically some form of cutoff wall, are keyed into a low-permeability unit at depth to prevent short circuiting of the plume. Funnel-and-gate design must consider the residence time to allow chemical reactions to occur. Directing the contaminant plume through the reactive gate can significantly increase the flow velocity, thus reducing residence time.

Design of PRB systems requires rigorous site investigation to characterize the site hydrogeology and to delineate the contaminant plume. A thorough understanding of the geochemical and redox characteristics of the plume is critical to assess the feasibility of the process and select appropriate reactive media. Laboratory studies, including batch studies and column studies using samples of site groundwater, are needed to determine the effectiveness of the selected reactive media at the site (EPRI, 2006). The main considerations in selecting reactive media are as follows (Gavaskar et al., 1998; cited by EPRI, 2006):

- Reactivity - The media should be of adequate reactivity to immobilize a contaminant within the residence time of the design.
- Hydraulic performance - The media should provide adequate flow through the barrier, meaning a greater particle size than the surrounding aquifer materials. Alternatively, gravel beds have been emplaced in front of barriers to direct flow through the barrier.
- Stability - The media should remain reactive for an amount of time that makes its use economically advantageous over other technologies.
- Environmentally compatible by-products - Any by-products of media reaction should be environmentally acceptable. For example, iron released by zero-valent iron corrosion should not occur at levels exceeding regulatory acceptance levels.
- Availability and price: The media should be easy to obtain in large quantities at a price that does not negate the economic feasibility of using a PRB.

3.3.5 In-Situ Chemical Treatment

In-situ chemical treatment technologies for inorganics are being tested and applied with increasing frequency (Evanko and Dzombak, 1997). In-situ chemical treatment includes the targeted injection of reactive media into the subsurface to mitigate groundwater impacts. Inorganic contaminants are typically remediated through immobilization by reduction or oxidation followed by precipitation or adsorption (EPRI, 2006). Chemical reactants that have been applied or are in development for application in treating inorganic contaminants include ferrous sulfate, nanoscale zero-valent iron, organo-phosphorus nutrient mixture (PrecipiPHOS™) and sodium dithionite (EPRI, 2006). Zero-valent iron has been shown to effectively immobilize cobalt and molybdenum.

In-situ chemical treatment design considerations include the following (EPRI, 2006):

- Source location and dimensions
- Source contaminant mass
- The ability to comingle the contaminants and reactants in the subsurface
- Competing subsurface reactions (that consume added reactants)
- Hydrologic characteristics of the source and subsurface vicinity
- Delivery options for the cleanup procedure(s)
- Capture of any contaminants mobilized by the procedures
- Long-term stability of any immobilized contaminants

4 EVALUATION OF POTENTIAL CORRECTIVE MEASURES

4.1 EVALUATION CRITERIA

The corrective measures described in the previous section were evaluated relative to the criteria presented in Section 1.2 and reiterated below:

- Performance
- Reliability
- Ease of implementation
- Potential impacts of appropriate potential remedies (safety impacts, cross-media impacts, and control of exposure to any residual contamination)
- Time required to begin and complete the remedy
- Institutional requirements that may substantially affect implementation of the remedy(s) (permitting, environmental or public health requirements)

These factors are presented in Table 1 with the retained corrective measures to allow a qualitative evaluation of the ability of each corrective measure to address SSLs for cobalt and molybdenum in the Uppermost Aquifer. The goal is to understand which corrective measures could be used, either independently or in combination, to protect human health and the environment by attaining GWPS, as discussed in the following report sections.

4.2 POTENTIAL SOURCE CONTROL CORRECTIVE MEASURE EVALUATION

Based on the corrective measure review presented in Section 3, the following source control corrective measures are potentially viable to address SSLs in the Uppermost Aquifer:

- Potential Source Control Corrective measures
  - Closure in Place
  - Closure by Removal (Off-Site Landfill)
  - In-Situ Solidification/Stabilization

These remedial corrective measures are discussed below relative to their ability to effectively address the SSLs for cobalt and molybdenum in the Uppermost Aquifer. To attain GWPS these source control corrective measures may be combined with groundwater corrective measures, such as MNA. Additional site-specific data collection and analyses will be required to verify the feasibility of selected corrective measures and to design the corrective measure(s), consistent with 40 C.F.R. § 257.97 requirements.

4.2.1 Closure in Place

CIP is a widely accepted corrective measure for source control of CCR and is routinely approved by the Ohio Environmental Protection Agency (OEPA). The performance of CIP as a source control corrective measure can vary based on site-specific conditions and may require additional data collection or groundwater fate and transport modeling to support the design and regulatory approval. CIP is a reliable remedial technology that does not require active systems to operate and requires limited maintenance.

Cover systems control exposure to CCR by limiting potential contact with CCR material, controlling stormwater runoff and significantly reducing infiltration of water into the CCR material. During construction of the cover system there is the potential for short term exposure.

Implementation of CIP only requires commonly performed construction and earthwork activities as described in Section 3.2 and can typically be completed in 3 to 5 years, including design, permitting and construction. CIP requires approval by the OEPA to be implemented.

4.2.2 Closure by Removal (Off-Site Landfill)

CBR is a widely accepted corrective measure with regard to source control of CCR. CBR is a reliable corrective measure that does not require active systems to operate and requires limited maintenance. CBR only requires commonly performed construction and earthwork activities as described in Section 3.2. However, dewatering and moisture conditioning of the CCR for transport can often be problematic; and, site access is limited.

CBR of Basin A could be completed in approximately 11 to 14 years, including design, permitting, and construction. During that timeframe the transport of the CCR could lead to increased risk to the public, particularly for the off-site disposal, increased greenhouse gas emissions and carbon footprint, and increased potential for fugitive dust exposure.

The regulatory approval process for constructing a new on-site landfill, if feasible, would take multiple levels of approval, including environmental permits and local authorization. Opposition to such projects and regulatory approvals would take years before construction could commence. However, most importantly, there is no available space at the MFS on which to site or construct an on-site landfill, requiring that only off-site landfill alternatives be considered.

4.2.3 In-Situ Solidification/Stabilization

Performance of ISS for application as a CCR source control corrective measure is not proven, therefore the reliability of ISS for CCR is unknown. The design of ISS as a source control corrective measure would require additional data collection. During ISS construction there would be the potential for short term exposure.

Implementation of ISS would require extensive pre-implementation testing, specialized equipment and specialized contractors. ISS construction timeframes would be dependent on application volume. Treatment of all CCR materials may not be feasible dependent upon depth and obstructions. Targeted ISS may reduce the timeframe required, however, another source control corrective measure would be required to address remaining CCR. ISS requires approval by the OEPA to be implemented.

4.3 POTENTIAL GROUNDWATER CORRECTIVE MEASURE EVALUATION

Based on the corrective measure review presented in Section 3.3, the following remedial corrective measures are considered potentially viable to address SSLs in the Uppermost Aquifer:

- Potential Groundwater Corrective measures
  - Monitored Natural Attenuation (MNA)
  - Groundwater Cutoff Wall
  - In-Situ Chemical Treatment
  - Permeable Reactive Barrier
  - Groundwater Extraction

These corrective measures are discussed below relative to their ability to effectively address the SSLs for cobalt and molybdenum in the Uppermost Aquifer. Additional site-specific data collection and analyses will be required to verify the feasibility of selected corrective measures and to design the corrective measure(s), consistent with 40 C.F.R. § 257.97 requirements.

4.3.1 Monitored Natural Attenuation

MNA is a widely accepted corrective measure for groundwater remediation and is routinely approved by state and federal regulators when paired with source control. The performance of MNA as a groundwater corrective measure can vary based on site-specific conditions and would require additional data collection to support the design and regulatory approval consistent with the USEPA's tiered approach to MNA (USEPA 1999, 2007, and 2015). MNA would be implemented as a finishing step in combination with source control corrective measures or other groundwater corrective measures described in Section 3.

MNA is a relatively reliable groundwater corrective measure because operation and maintenance requirements are limited. However, the reliability can also vary based on site-specific hydrogeologic and geochemical conditions. Additional groundwater sample collection and analyses would be required to characterize potential attenuation mechanisms as discussed above. Following characterization and approval, implementation of MNA would be relatively easy and may consist of installing additional monitoring wells. Implementation could be completed within 1 year. Time of construction could be reduced if existing groundwater monitoring well systems could be utilized for MNA.

No potential safety impacts or exposure to human health or environmental receptors are expected to result from implementing MNA. Timeframes to achieve GWPS are dependent on site-specific conditions, which require detailed technical analysis. MNA requires approval by the OEPA to be implemented.

4.3.2 Groundwater Extraction

Groundwater extraction is a widely accepted corrective measure for groundwater with a long track record of performance and reliability. It is routinely approved by state and federal regulators. The performance of a groundwater extraction system is dependent on site-specific hydrogeologic conditions and would require additional data collection and possibly groundwater fate and transport modeling to support the design and regulatory approval.

Implementation of a groundwater extraction system presents design challenges due to the significant features controlling hydraulic head and groundwater flow in the Uppermost Aquifer (*i.e.,* Ohio River and Great Miami River). Relatively high horizontal hydraulic conductivities are anticipated to require a high pumping rate to successfully control groundwater in the vicinity of Basin A. For a corrective measure using groundwater containment to effectively control off-site flow or to remove potentially contaminated groundwater, horizontal and vertical capture zone(s) must be created using pumping wells. Cutoff walls could be used in conjunction with a pumping system to control groundwater movement. Source control measures (Section 3.2) may also reduce the mass loading to the Uppermost Aquifer, thus reducing the total contaminant mass that would need to be pumped to attain GWPS. Depending on the volumetric rate of extraction required, groundwater pumping wells may require high capacity well registration. Extracted groundwater would need to be managed, which may include modification to the existing NPDES permit and treatment prior to discharge, if necessary.

There could be some impacts associated with constructing and operating a groundwater extraction system, including limited exposure to extracted groundwater. Additional data collection and analyses would be required to design an extraction system. Construction could be completed within 1 year. Time of implementation is approximately 3 to 4 years, including characterization, design, permitting and construction. Timeframes to achieve GWPS are dependent on site-specific conditions, which require detailed technical analysis. Groundwater extraction requires approval by the OEPA to be implemented.

4.3.3 Groundwater Cutoff Wall

Groundwater cutoff walls are a widely accepted corrective measure used to control and/or isolate impacted groundwater and are routinely approved by the state and federal regulators. Cutoff walls have a long history of reliable performance as hydraulic barriers provided they are properly designed and constructed. In addition, ongoing operation and maintenance would be needed to ensure performance over time. Construction of a cutoff wall extending to, and keyed into, the bedrock underlying the Uppermost Aquifer would present challenges due to the required depth (estimated thickness of the permeable valley fill at the MFS is approximately 120 feet). Additional site investigation would be required to verify the feasibility of a cutoff wall keyed into the bedrock below the Uppermost Aquifer.

Cutoff walls are designed to act as hydraulic barriers; as a result, cutoff walls inherently alter the existing groundwater flow system. These changes to the existing groundwater flow system may need to be controlled to maximize the effectiveness of the remedy; for example, groundwater extraction may be required to control build-up of hydraulic head upgradient and around the groundwater cutoff walls. The effectiveness of a cutoff wall as a hydraulic barrier also relies on the contrast between the hydraulic conductivity of the aquifer and the cutoff wall. The most effective barriers have hydraulic conductivity values that are several orders of magnitude lower than the aquifer that it is in contact with. Based on literature, and the high yield of the production wells, the hydraulic conductivity is expected to be high. The high horizontal conductivities in the upper aquifer suggest that a barrier wall would have the desired contrast in hydraulic conductivities.

Additional data collection and analyses would be required to design a cutoff wall. Construction could be completed within 2 to 3 years. Time of implementation is approximately 5 to 8 years, including characterization, design, permitting and construction. To attain GWPS, groundwater cutoff walls require a separate groundwater corrective measure to operate in concert with the hydraulic barriers. Groundwater cutoff walls are commonly coupled with MNA and/or groundwater extraction as groundwater corrective measures. Timeframes to achieve GWPS are dependent on site-specific conditions, which require detailed technical analysis. Groundwater cutoff walls require approval by the OEPA to be implemented.

4.3.4 Permeable Reactive Barrier

PRB application as a groundwater corrective measure for cobalt and molybdenum is not well established and more research is needed (EPRI, 2006), therefore, performance is unknown. PRB treatment of cobalt and molybdenum is expected to have variable reliability based on site-specific hydrogeologic and geochemical conditions. The capacity of the reactive media may be exceeded and require replacement or rejuvenation. Conservative estimates indicate iron-based reactive media are expected to require maintenance every 10 years (ITRC, 2005). Implementation of PRBs may have design challenges associated with both groundwater hydraulics and plume configuration.

Funnel-and-gate PRBs inherently alter the existing groundwater flow system. These changes to the existing groundwater flow system may need to be controlled to reduce potential impacts of the remedy. Construction of PRBs could be completed within 2 to 3 years. Time of implementation is approximately 6 to 9 years, including characterization, design, permitting and construction. Timeframes to achieve GWPS are dependent on site-specific conditions, including reactivity and maintenance (replacement or rejuvenation requirements) which require detailed technical analysis. PRBs and potentially associated groundwater cutoff walls (funnel-and-gate system) require approval by the OEPA to be implemented.

4.3.5 In-Situ Chemical Treatment

In-situ chemical treatment of cobalt and molybdenum is not well established and more research is needed (EPRI, 2006); therefore, performance is unknown. Chemical treatment of cobalt and molybdenum is expected to have variable reliability based on site-specific geochemical conditions. The capacity of the reactive media may be exceeded and require replacement or rejuvenation. Conservative estimates indicate iron-based reactive media is expected to require maintenance every 10 years (ITRC, 2005).

Implementation of in-situ chemical treatment may have design challenges associated with groundwater hydraulics.

Injections of reactive media could be completed within 1 to 2 years. Time of implementation is approximately 5 to 8 years, including characterization, design, permitting and injections. Chemical treatment alters groundwater geochemical conditions, which may result in potential impacts associated with implementation of the remedy. Timeframes to achieve GWPS are dependent on site-specific conditions, including reactivity and maintenance (replacement or rejuvenation requirements) which require detailed technical analysis. Since in-situ chemical treatment alters groundwater geochemistry implementation of the remedy may require Underground Injection Control approval (UIC).

5 REMEDY SELECTION PROCESS

5.1 RETAINED CORRECTIVE MEASURES

This CMA was prepared to address the requirements of 40 C.F.R. § 257.96. The following potentially viable corrective measures were identified based upon site-specific conditions:

- Potential Source Control Corrective measures
  - Closure in Place
  - Closure by Removal (Off-Site Landfill)
  - In-Situ Solidification/Stabilization
- Potential Groundwater Corrective measures
  - Monitored Natural Attenuation (MNA)
  - Groundwater Extraction
  - Groundwater Cutoff Wall
  - Permeable Reactive Barrier
  - In-Situ Chemical Treatment

Per 40 C.F.R. § 257.97, a remedy must be selected to address the SSLs in the Uppermost Aquifer, based on the results of the CMA. The remedy should be selected as soon as possible and must meet the following standards:

- Be protective of human health and the environment
- Attain the groundwater protection standard as specified pursuant to § 257.95(h)
- Control the source(s) of releases so as to reduce or eliminate, to the maximum extent feasible, further releases of constituents in Appendix IV to this part into the environment
- Remove from the environment as much of the contaminated material that was released from the CCR unit as is feasible, taking into account factors such as avoiding inappropriate disturbance of sensitive ecosystems
- Comply with standards for management of wastes as specified in § 257.98(d)

5.2 FUTURE ACTIONS

Semiannual reports per § 257.97 will be prepared to describe the progress in selecting and designing the remedy that addresses SSLs for cobalt and molybdenum in the Uppermost Aquifer. A final report describing the selected remedy and how it meets the standards listed above will also be prepared, per § 257.97. The corrective action plan may incorporate one or more of the corrective measures identified in this CMA to address impacts from CCR constituents in the Uppermost Aquifer.

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Tables

Table 1. Corrective Measures Assessment Matrix
Corrective Measures Assessment
Miami Fort Basin A, North Bend, Ohio
September 4, 2019

	Evaluation Factors	Performance	Reliability	Ease of Implementation	Potential Impacts of Remedy (safety impacts, cross-media impacts, control of exposure to any residual contamination)	Time Required to Begin and Implement Remedy[1]	Time to Attain Groundwater Protection Standards	Institutional Requirements (state/local permit requirements, environmental/public health requirements that affect implementation of remedy)
Source Control Corrective Measures	**Closure In Place**	Widely accepted, routinely approved; variable performance based on site-specific conditions.	Reliable technology.	Commonly performed construction and earthwork.	Controls exposure to CCR. Some potential short term exposure during construction.	3 to 5 years.	Dependent on selected groundwater remediation technology.	Requires regulatory approval processes.
	Closure By Removal (Off-Site Landfill)	Widely accepted, good performance with regard to source control.	Reliable technology.	Commonly performed earthwork. Dewatering can be problematic.	Significant exposure potential.	12 to 15 years.	Dependent on selected groundwater remediation technology.	Requires regulatory approval processes.
	In-Situ Solidification /Stabilization	Not proven in CCR applications.	Unknown.	Requires extensive preimplementation testing and specialized equipment and contractors.	Some potential short term exposure during construction.	Dependent on application volume.	Dependent on selected groundwater remediation technology.	Requires regulatory approval processes.
Groundwater Remediation Corrective Measures	**MNA**	Widely accepted, routinely approved; variable performance based on site-specific conditions.	Reliable, but dependent on site-specific conditions.	Easy.	None identified.	2 to 3 years.	Dependent on site-specific conditions.	Requires regulatory approval processes.
	Groundwater Extraction	Widely accepted, routinely approved; variable performance based on site-specific conditions.	Reliable if properly designed, constructed and maintained.	Design challenges due to groundwater hydraulics and plume configuration. Extracted groundwater would require management.	Alters groundwater flow system. Potential for some limited exposure to extracted groundwater.	3 to 4 years.	Dependent on site-specific conditions.	Extracted groundwater will require management and approval from OEPA. May require high capacity well registration.
	Groundwater Cutoff Wall	Widely accepted, routinely approved, good performance if properly designed and constructed. May not be feasible for the Uppermost Aquifer.	Reliable if properly designed and constructed (if feasible).	Widely used, established technology. May be difficult due to required depth and keying wall into bedrock.	Alters groundwater flow system.	5 to 8 years.	Needs to be combined with other remediation technology(ies). Time required to attain GWPS dependent on combined technologies.	Requires regulatory approval processes.
	Permeable Reactive Barrier	Permeable Reactive Barrier treatment not well established for cobalt or molybdenum.	Variable reliability based on site-specific groundwater hydraulics and geochemical conditions.	Design challenges associated with groundwater hydraulics and plume configuration.	Alters groundwater flow system.	6 to 9 years.	Dependent on site-specific conditions.	Requires regulatory approval processes.
	In-Situ Chemical Treatment	In-Situ treatment not well established for cobalt or molybdenum.	Variable reliability based on site-specific geochemical conditions.	Design challenges associated with groundwater hydraulics.	Alters groundwater geochemistry.	5 to 8 years.	Dependent on site-specific conditions.	May require Underground Injection Control approval.

Notes:

[1] Time required to begin and implement remedy includes design, permitting and construction.

Figures

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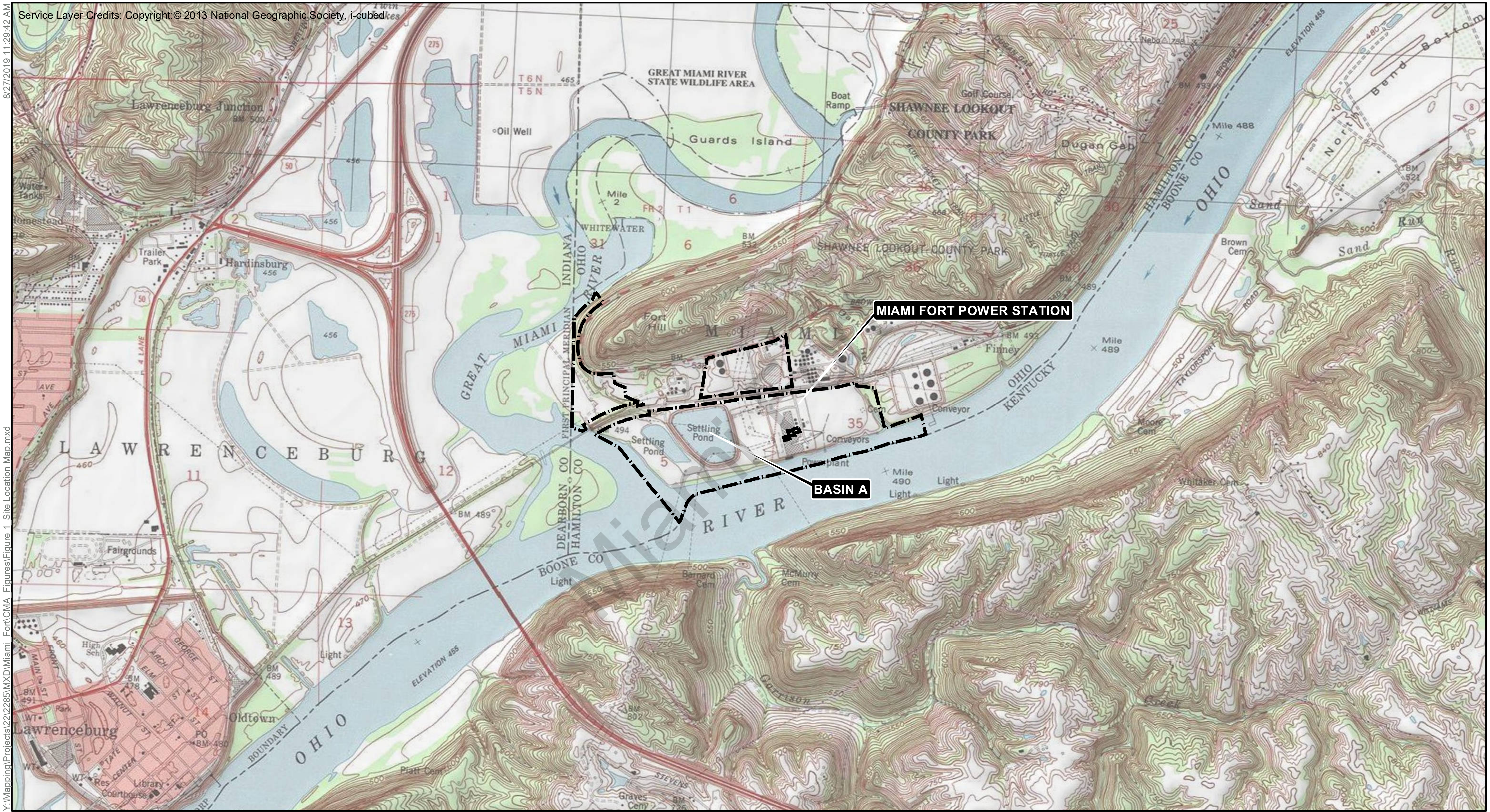

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▭ APPROXIMATE PROPERTY BOUNDARY

CORRECTIVE MEASURES ASSESSMENT
MIAMI FORT BASIN A
MIAMI FORT POWER STATION
NORTH BEND, OHIO

SITE LOCATION MAP

0 500 1,000 2,000
Feet

N

FIGURE 2

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▭ BASIN A UNIT BOUNDARY

▣ BASIN A DOWNGRADIENT MONITORING WELL

▣ BACKGROUND MONITORING WELL

▣ BASIN B DOWNGRADIENT MONITORING WELL

◈ MIAMI FORT PRODUCTION WELLS

◈ VEOLIA PRODUCTION WELLS

CORRECTIVE MEASURES ASSESSMENT
MIAMI FORT BASIN A
MIAMI FORT POWER STATION
NORTH BEND, OHIO

0 75 150 300
Feet

N

CCR GROUNDWATER
MONITORING SYSTEM

OBG
Part of Ramboll

OBG

Part of Ramboll