ASSESSMENT OF CORRECTIVE MEASURES

COAL ASH PONDS
ELMER SMITH STATION
DAVIESS COUNTY
OWENSBORO, KENTUCKY

Prepared For:
OWENSBORO MUNICIPAL UTILITIES
OWENSBORO, KENTUCKY

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1.0 INTRODUCTION

The United States Environmental Protection Agency (USEPA) issued 40 C.F.R. § 257, Subpart D, *Disposal of Coal Combustion Residuals from Electric Utilities* (CCR Rule) on April 17, 2015. The CCR Rule regulates disposal of coal combustion residuals (CCR) in new and active landfills and impoundments. Civil & Environmental Consultants, Inc. (CEC) has been engaged by Owensboro Municipal Utilities (OMU) to perform an Assessment of Corrective Measures (ACM) for the Coal Ash Ponds (aka the Site) at the Elmer Smith Station (ESS) as required by the CCR Rule as a result of constituents of concern (COCs) being identified at concentrations exceeding the Groundwater Protection Standards (GWPS). This document summarizes the potential remedies that were considered to mitigate the identified impacts to groundwater and the associated performance, reliability, feasibility, limitations, and potential impacts of implementing each remedy. This ACM also addresses the time required to begin and complete each remedy and addresses institutional requirements, such as State and local permit requirements or other environmental or public health requirements that may substantially affect implementation of each corrective measure. The ACM is not required or intended to include the selection and/or engineering design of any potential remedial alternatives. It is intended that this document will be placed in the facility operating record as required by 40 C.F.R. §257.105(h)(10), submitted to the appropriate State regulatory agency in accordance with 40 C.F.R. §257.106(h)(8) and posted on the publicly accessible website as required by 40 C.F.R. §257.107(h)(8).

2.0 SITE OVERVIEW

2.1 BACKGROUND

The Ash Pond area associated with the Site is less than 10 acres in size and consists of three separate unlined ash settling basins (Ponds 1, 2, and 3). A Site location map and a Site and vicinity aerial map showing the location of the Ash Ponds are provided as Figures 1 and 2, respectively. The basins are not used for the disposal of CCR but for temporary storage of CCR material prior to being excavated and transported off-site for disposal or beneficial re-use. Pond 1 is used for Unit 1 boiler slag; Pond 2 receives other ash and water plant blowdown (lime softening sludge); and Pond 3 receives no ash directly and is used for final settling prior to discharge to the Ohio River under an National Pollution Discharge Elimination System (NPDES) permit. Other plant discharges, including coal pile runoff, Flue Gas Desulfurization (FGD) blowdown, roof and floor drains are also conveyed through the ponds. Based on a review of aerial images, topographic contour data from the USGS National Map, Owensboro East Quadrangle, and a Site map prepared by others labeled "Structural Fill Finish Grading" dated August 28, 1962[1], the Ash Ponds appear to be incised in the native soils to a depth of approximately 8 feet below ground surface (bgs). This was confirmed by Site personnel.

CEC assisted OMU with the design and installation of a permanent groundwater monitoring system (GMS) to comply with the GMS performance standard contained within the Federal CCR Rule (Section 257.91), as documented in the GMS Certification Report dated October 17, 2017 (amended March 2019). Prior to the installation of the GMS, groundwater monitoring had not been conducted at the Site.

2.2 HYDROGEOLOGIC SETTING

Subsurface conditions encountered at the Site, as evidenced by the soil borings advanced in association with a Preliminary Hydrogeologic Investigation and the permanent GMS wells, are consistent with Quaternary-aged alluvium, and buried outwash (Tazewell age) typically found within the Ohio River Valley[2]. Variable thicknesses of fine-grained silt and clay lenses are

[1] Drawing No. S-7 "Structural Finish Grading", prepared by Black & Veatch, dated August 28, 1962.

interbedded with deposits of coarser-grained, poorly-graded sand beneath a thin veneer of topsoil, crushed stone fill, or other fill material. The near-surface fine-grained deposits are thicker near the Ohio River, and decrease in thickness away from the river towards the southeast, where sand becomes the predominant soil type. A low permeability clay layer was encountered at depths ranging from 26 to 43 feet bgs, varying in thickness from approximately 1 foot to over 16 feet, with increasing thickness towards the south/southeast. The clay layer is underlain by saturated, coarse-grained deposits that comprise the uppermost aquifer at the Site. Aquifer saturated thickness in the vicinity of the Site ranges from approximately 60 to 100 feet[2]. Based on the elevation of the groundwater table and the presumed bottom elevation of the Ash Ponds, groundwater is not in direct communication with the Ash Ponds. Boring logs for the Site are provided in the GMS Certification Report (amended March 2019). A geologic cross-section is provided as Figure 3.

2.2.1 Hydrogeologic Characteristics

Groundwater occurs within the coarse-grained deposits that constitute the uppermost aquifer at the Site. Depth to water measurements collected from the GMS monitoring well network during the 2018 sampling events ranged from 34.75 feet below top of casing (BTOC) at MW-1 to 69.37 feet BTOC at MW-7. Static groundwater elevations measured in 2018 ranged from 351.74 feet above mean sea level (AMSL) at MW-7 to 370.29 feet AMSL at MW-3. The normal pool elevation of the adjacent Ohio River in the vicinity of ESS is approximately 358 feet AMSL[3]. Potentiometric data are summarized on Table 1 and shown on Figure 4.

Groundwater elevation measurements indicate that the groundwater flow direction is to the southeast at an approximate average hydraulic gradient of 0.006. The gradient is slightly steeper near the river and gradually flattens out moving away from the river to the south and east. This flow direction is contrary to what is typically observed in this type of hydrogeologic setting, where groundwater flow is towards the surface water body. The southeasterly flow direction is the result of the pumping influence from the 11 nearby water production wells (Figure 2) associated with

[2] *Geohydrology and Simulation of Ground-Water Flow for the Ohio River Alluvial Aquifer near Owensboro, Northwestern Kentucky.* U.S. Geological Survey Water-Resources Investigation Report 96-4274. 1997. Figure 7.

[3] Ohio River Navigation Charts from Cairo, Illinois to Foster, Kentucky (June 2010). U.S. Army Corps of Engineers, Louisville District. Chart No. 53.

municipal water production operations at OMU’s Cavin Water Treatment Plant, which has a capacity of up to 10 million gallons per day. OMU also operates Water Plant A, which is located west of the Cavin Water Treatment Plant. Water Plant A has an additional total withdrawal capacity of 18 million gallons per day from the 11 water production wells. Absent the operation of the production wells, groundwater flow direction is likely to the northwest towards the Ohio River; however, some combination of pumping wells is always in operation and the observed groundwater levels measured since the installation of the GMS (Table 1) consistently indicate a southeasterly groundwater flow direction. For the purposes of this ACM, CEC has assumed that future groundwater flow direction will remain consistent with the current regime (i.e. to the south and east).

Hydraulic conductivity of the uppermost aquifer was not tested as part of the GMS installation process; however, based on published scientific reports, the Site is located in an area where horizontal hydraulic conductivity values are estimated to range from 126 to 157 feet per day[4].

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[4]*Geohydrology and Simulation of Ground-Water Flow for the Ohio River Alluvial Aquifer near Owensboro, Northwestern Kentucky.* U.S. Geological Survey Water-Resources Investigation Report 96-4274. 1997. Figure 11.

3.0 GROUNDWATER MONITORING SYSTEM

The GMS consists of eight monitoring wells. Monitoring wells MW-1 and MW-3 are used to monitor groundwater elevation, and monitoring wells MW-2, MW-4, MW-5, MW-6, MW-7, and MW-8 are utilized to monitor both groundwater elevation and groundwater quality. Refer to the GMS Certification Report for lithologic descriptions and well construction diagrams. Monitoring wells MW-2 and MW-7 were used to establish and monitor background groundwater conditions.

While MW-2 is currently hydraulically upgradient, this is an artificial condition created by the operation of the production wells. Prior to the operation of the production wells (ca. 1998) this well would have been situated in a downgradient location. Also, should the production wells cease to operate in the future, groundwater flow direction would likely be reversed toward the river and MW-2 would be in a downgradient location. Because of this unique and artificial condition, the MW-7 location was also selected to accurately represent the quality of background groundwater that has not been affected by leakage from a CCR unit. MW-7, while located hydraulically downgradient from the Ash Ponds, is placed in a location so as not to be on a direct flow path from the ponds. MW-7 is also at a sufficient distance from the ponds to be representative of background conditions for the well field aquifer.

Downgradient monitoring wells MW-4, MW-5, and MW-6 are used to monitor water quality of groundwater passing the boundary of the CCR unit. These wells were placed as close as possible to the CCR unit boundary to provide for detection of groundwater contamination in the uppermost aquifer. In the event that the well field should cease pumping operations for an extended period of time and the groundwater flow direction reverts back toward the river, monitoring wells MW-1 and MW-3 (currently used only for water level monitoring) can serve as future downgradient wells along with MW-2.

Monitoring well MW-8 was installed in December 2018 after one constituent (molybdenum) was quantified at a statistically significant level (SSL) in downgradient monitoring wells MW-5 and MW-6 (see Section 4.0) in an effort to characterize the nature and extent of the release, as required by §257.95(g)(1).

A summary of the GMS wells is provided in the table below.

CCR RULE GROUNDWATER MONITORING SYSTEM

Location	Relative Location	Well Diameter (in.)	Total Depth (ft.-bgs)	Screen Length (ft.)
MW 1	Upgradient	4	57	10
MW-2	Upgradient (Background)	4	57	10
MW-3	Upgradient	4	57	10
MW-4	Downgradient	4	59	10
MW-5	Downgradient	4	59	10
MW-6	Downgradient	4	59	10
MW-7	Downgradient (Background)	4	72	10
MW-8	Downgradient	4	63	15

4.0 GROUNDWATER CONTAMINANT DISTRIBUTION

As summarized in the 2018 Groundwater Monitoring and Corrective Action report for the Site, dated January 31, 2019, the site transitioned from Detection Monitoring to Assessment Monitoring in 2018, because concentrations of several Appendix III COCs (boron, calcium, sulfate, and total dissolved solids) represented a statistically significant increase (SSI) over background levels. Statistical analysis of the analytical results from the Assessment Monitoring sampling events conducted in 2018 quantified the presence of one COC (molybdenum) at a statistically significant level (SSL) in downgradient monitoring wells MW-5 and MW-6. Because molybdenum was not identified in upgradient and/or background monitoring wells, and the likelihood of potential sources of this constituent between the Ash Ponds and these two downgradient monitoring wells is interpreted to be very low, the source of the impact is assumed to be the Ash Ponds. Therefore, an additional downgradient monitoring well (MW-8) was installed, developed and sampled to delineate the extent of the plume. Analytical data received for MW-8 did not identify the presence of molybdenum or other COCs at concentrations exceeding their respective GWPS. Groundwater analytical data are summarized in Table 2. An interpretation of the approximate limits of the molybdenum plume is shown on Figure 4.

Molybdenum has been quantified during each of the groundwater sampling events conducted since June 2017 (baseline, detection, and assessment monitoring) but it has only been detected in two monitoring wells (MW-5 and MW-6). Concentrations of molybdenum in MW-5 have ranged from 0.34 milligrams per Liter (mg/L) to 1.3 mg/L, and concentrations in MW-6 have ranged from 1.7 mg/L to 2.8 mg/L. The average concentrations are approximately three times higher in MW-6 (2.4 mg/L) than in MW-5 (0.8 mg/L). Concentrations of molybdenum have fluctuated but appear to exhibit a downward trend. A plot of the molybdenum concentrations in these two monitoring wells versus time is provided as Figure 5.

Molybdenum has not been identified in MW-4, which is located approximately 200 feet northeast of MW-6, during the monitoring period, which indicates the plume is laterally defined perpendicular to groundwater flow direction (southeast) to the area of MW-5 and MW-6. Groundwater flow in the area to the south and west of MW-5 is controlled by the operation of multiple water production wells located at the Site (refer to Figures 2 and 3), thus limiting migration off-Site to the south/southwest.

5.0 CORRECTIVE MEASURES OBJECTIVES

Per §257.97(b)(1) through (5), the corrective measure used to mitigate a CCR release must:

- Be protective of human health and the environment;
- Attain the GWPS as specified pursuant to §257.97(h);
- Control the source(s) of release 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; and,
- Comply with standards for management of wastes as specified in §257.98(d).

The corrective measures objectives (CMOs) are based on the current and future land and groundwater use and were developed using information gathered from subsurface explorations and groundwater monitoring as well as applicable promulgated regulations and relevant guidance and will ultimately form the basis for the selected corrective measure.

The current land use is considered to be industrial and land use in the future is anticipated to continue in that capacity. Neither workers nor visitors to the ESS facility should be exposed to impacted groundwater, because access to the monitoring wells is protected by a locked steel cover. Additionally, access to the Site is controlled by perimeter fencing, locking gates, and entrances staffed with security personnel. Potential receptors that could be exposed to impacted groundwater is limited to consultants that handle groundwater monitoring duties. Personnel engaged in these activities are well-trained in sampling techniques, personal protective equipment, and incident response so as to minimize the potential for unsafe exposure.

There are no known users of groundwater in the vicinity of the Site other than OMU that, as previously mentioned, extracts groundwater from a network of production wells for the purpose of municipal supply. The production wells are screened from approximately 80 to 130 feet bgs and draw from a deeper horizon within the aquifer, while the GMS is screened from approximately 45 to 70 feet bgs. The groundwater extracted by the production wells is subject to pre-treatment and quality assurance/quality control practices that are in place prior to distribution.

Findings from the groundwater monitoring performed at the Site indicate that one constituent (molybdenum) was quantified at a SSL in excess of the GWPS (0.1 mg/L), which is the health-based level adopted by the U.S. EPA for constituents without a maximum contaminant level (MCL). In order to comply with the CCR Rule, the following CMOs were identified:

1. Reduce leaching of CCR COCs from the coal ash impoundments via infiltration of surface water and inundation of groundwater, which appears to be the primary source of the observed groundwater impacts; and,
2. Monitor performance of the selected corrective measure through continued sampling of the GMS wells to demonstrate compliance with the GWPS.

These CMOs will be used in the evaluation of the screening of the remedial options, which are described in the following section.

6.0 POTENTIAL CORRECTIVE MEASURES

The purpose of this ACM is to identify technologies that are realistic remedies that can potentially be implemented to address the groundwater impacts at the Site and to evaluate the feasibility of each option. The final remedy will be selected after careful consideration of the options by OMU along with a period of public comment.

There are numerous technologies available to remedy groundwater that has been impacted with metals; however, the selection of a successful remedy is based on the hydrogeologic and geochemical conditions as well as the potential risks associated with the release. Additionally, the type and size of the source (one that can be removed versus one that cannot be removed) and the urgency of the remedial effort, or aggressiveness, are considered when selecting a remedy. The need for an aggressive or non-aggressive remedy is usually controlled by the risk(s) associated with the release (i.e., a high risk may dictate an aggressive remedy while a low risk may allow for a less aggressive, more cost effective remedy). Additionally, the use of more than one remedy may be required to meet regulatory standards. Currently, there are no remedial activities associated with groundwater at the Site. The following is a list of the remedies that are being considered for implementation at the Site:

CORRECTIVE MEASURE
1. Monitored Natural Attenuation
2. Waste Excavation and Disposal
3. In-Situ Remediation
4. Capping
5. Pump and Treat
6. Cut-off Wall

Details regarding each of these option are provided in the following sections of this report.

6.1 SCREENING OF CORRECTIVE MEASURES

A total of six potential corrective measures were identified as candidates for implementation. The effectiveness of each corrective measures option was evaluated with respect to the areas of impact and volume of contaminated media as well as potential impacts to human health and the environment and achieving the CMOs summarized in Section 5.0. The performance, reliability, and ease of implementation for each corrective measure focused on the ability to implement each corrective measures option in conjunction with the technology necessary and the administrative feasibility. This included the required construction techniques with respect to contractors, equipment and Site conditions as well as the ability to obtain the necessary permits and approvals to perform the remedial activity. The schedule to plan, execute, and complete each remedy as well as the institutional requirements were also considered in this ACM.

Potential corrective measures options are classified as either dismissed or retained. An option was dismissed if: it did not satisfy any CMOs, it was considered to have excessive risk or be ineffective with regards to the COCs, or it was not considered feasible given Site constraints. An option was retained if it could be used, whether solely or in conjunction with one of the other options listed, to meet the CMOs. A description of each corrective measure considered for the Site and the evaluation for each screening criteria follows.

6.1.1 Corrective Measures Option 1 – Monitored Natural Attenuation

6.1.1.1 Description

Monitored Natural Attenuation (MNA) involves a variety of physical, chemical, and biological natural processes that can reduce the presence of COCs in soil and groundwater without human intervention. These processes include biodegradation, dispersion, dilution, sorption, volatilization, chemical or biological stabilization, transformation or destruction of contaminants. It may be used with other remediation processes as a finishing option or as the only remediation process if the rate of contaminant degradation is protective of human health and the environment. Reliance on these natural processes in conjunction with a monitoring program to assess remedial progress can be effective under certain conditions.

6.1.1.2 Achievement of Corrective Measure Goals

<u>Protection of Human Health and the Environment</u>: The presence of groundwater containing SSLs of molybdenum exceeding the GWPS is confined to a limited area within the OMU property between GMS wells MW-5 and MW-6, downgradient of the Ash Ponds. Groundwater to the south

of this area is extracted by OMU for treatment and distribution to the municipal drinking water network. Offsite migration of groundwater containing COCs exceeding the GWPS is not occurring and groundwater that is pumped from the production wells is subject to a rigorous pre-treatment process prior to distribution and public consumption; therefore, potential exposure to contaminants in groundwater is under control. MNA provides protection by verifying that predictions regarding future improvements to groundwater quality occur.

Attainment of GWPS: Based on the improvements in groundwater quality observed with respect to the molybdenum concentration trends, MNA should adequately address residual groundwater impacts when used in conjunction with another strategy to reduce or eliminate leaching CCR constituents to groundwater.

Controlling the Source of Releases to Reduce or Eliminate Further Releases to the Environment: MNA does not provide benefit to controlling the source of the release on its own, but when paired with another active remedy can provide supplementary value.

Removal of Contaminated Material Released from the CCR Unit, Taking into Account Factors such as Avoiding Inappropriate Disturbance of Sensitive Ecosystems: MNA does not effectively remove contaminants that have already been released, but when paired with another remedy can address residual groundwater impacts. There are no known sensitive ecosystems present at the ESS facility.

Compliance with Standards for Management of Wastes as Specified in §257.98(d): MNA would not alter the compliance status for management of wastes as specified in §257.98(d).

Performance, Reliability and Ease of Implementation: MNA is readily implemented as groundwater monitoring is already in place and has indicated improvements in groundwater quality with respect to molybdenum. Additional improvements to the groundwater quality are anticipated when coupled with a remedy to reduce or eliminate leaching of CCR constituents.

Potential Impacts: MNA does not pose impacts, because it does not involve land disturbance, construction activities, or waste generation.

6.1.1.3 Institutional Requirements

None. No permits would be required for MNA.

6.1.1.4 Schedule

As previously mentioned, MNA is readily implemented, because the groundwater monitoring network is already in place. Based on the current concentration trends for molybdenum in GMS wells MW-5 and MW-6 (see Figure 5), natural attenuation is in progress and would accelerate once an additional remedy is implemented to reduce or eliminate leaching of CCR constituents to groundwater.

6.1.2 Corrective Measures Option 2 – Waste Excavation and Disposal

6.1.2.1 Description

This option consists of excavating CCR material and transporting it to a permitted off-site facility for disposal or beneficial re-use (e.g., incorporated into manufactured products such as concrete, roofing, etc.).

6.1.2.2 Achievement of Corrective Measure Goals

Protection of Human Health and the Environment: While some short-term exposures to airborne/fugitive dust may be possible during implementation of this remedy, the long-term benefits are protective of human health and the environment as the goal is to remove as much, if not all, of the source as is practicable.

Attainment of GWPS: Source removal would greatly reduce or eliminate future leaching of COCs, which would increase the probability of compliance with the GWPS.

Controlling the Source of Releases to Reduce or Eliminate Further Releases to the Environment: Excavation of the CCR from the Ash Ponds would eliminate the source and significantly reduce further releases to the environment.

Removal of Contaminated Material Released from the CCR Unit, Taking into Account Factors such as Avoiding Inappropriate Disturbance of Sensitive Ecosystems: Excavation of the CCR will not effectively remove the contaminants that have already been released, but will remove the source of the release and reduce or eliminate of further release from the Ash Ponds. There are no known sensitive ecosystems present at the ESS facility.

Compliance with Standards for Management of Wastes as Specified in §257.98(d): Excavated CCR would need to be managed in accordance with applicable Resource Conservation and Recovery Act (RCRA) requirements.

Performance, Reliability and Ease of Implementation: Considering that the facility currently hauls CCR from the Ash Ponds for off-site disposal and/or beneficial re-use on a regular basis as part of ongoing operations and maintenance activities, implementation of this option would be fairly easy. Excavation efforts would need to be scaled up to exceed the accumulation rate within the ponds.

Potential Impacts: Potential impacts involved with excavation of CCR primarily involve land disturbances associated with typical excavation and backfill activities such as fugitive dust control, and potential impacts to the local community associated with construction activities (e.g. noise, roadway usage, etc.). In order to minimize the potential impacts associated with these activities several controls should be considered for implementation including, permit requirements for erosion and sedimentation controls, speed limit restrictions for vehicular traffic, dust suppression measures and dustfall monitoring, restrictions on construction hours of operation, odor and air monitoring, and the use of equipment muffler systems, low-volume backup alarms and noise monitoring, as described in the facility's Fugitive Dust Control Plan, dated October 13, 2015. Exposure to potential contamination would be controlled through the use of existing fencing and signage around the facility.

6.1.2.3 Institutional Requirements

A construction stormwater permit may be needed, which would potentially require erosion and sediment controls as well as regular inspections and reporting requirements.

6.1.2.4 Schedule

The excavation of CCR from the Ash Ponds can be initiated after the appropriate permits and contractor bids are obtained and evaluated for the construction/excavation work. This is estimated to take up to 6 months. It is estimated that the time required to shut down the coal-fired boilers, excavate the CCR from the Ash Ponds, and restore that excavated areas will be approximately 2 to 3 years.

6.1.3 Corrective Measures Option 3 – In-Situ Remediation

6.1.3.1 Description

In-situ remediation involves relying on naturally-occurring micro-organisms or introducing inoculated organisms (bioremediation), chemical oxidants (In-Situ Chemical Oxidation [ISCO]), or chemically-reductive agents (In-Situ Chemical Reduction [ISCR]) in the subsurface to metabolize, react with, degrade, stabilize, or immobilize COCs in groundwater. Knowledge of the COCs, the geochemistry of the aquifer, and the impacted groundwater to undergo treatment is required to successfully implement this technology.

6.1.3.2 Achievement of Corrective Measure Goals

Protection of Human Health and the Environment: This corrective measure could be effective at mitigating dissolved-phase impacts within the groundwater plume and can be implemented through the design of a remedial plan. However, concerns with injecting bio/chemical reagents in the proximity of an active municipal wellfield would need to be evaluated prior to implementing this approach.

Attainment of GWPS: While the injection of bio/chemical reagents into the subsurface is interpreted to have a high success rate at reducing impacts in groundwater to levels less than the GWPS, there is some uncertainty surrounding unintended side effects that may arise from implementing this remedy. For example, in some cases ISCO technology can oxidize metallic compounds to a more soluble form, thereby increasing their migration potential. Along the same lines, ISCR technology can biomethylate metallic compounds to a more volatile and more toxic form due to increased solubility and hydrophobicity.

Controlling the Source of Releases to Reduce or Eliminate Further Releases to the Environment: In-situ treatment would not further control or reduce releases to the environment, but would rather treat impacted groundwater as it migrates from the Ash Ponds.

Removal of Contaminated Material Released from the CCR Unit, Taking into Account Factors such as Avoiding Inappropriate Disturbance of Sensitive Ecosystems: In-situ treatment would not remove contaminants from the environment, but rather alter the form of the contaminant so that it is not mobile in groundwater. There are no known sensitive ecosystems at the facility that would be affected by implementing this remedy.

Compliance with Standards for Management of Wastes as Specified in §257.98(d): In-situ treatment would not alter the compliance status for management of wastes.

Performance, Reliability and Ease of Implementation: This option would likely perform well given what is known about the hydrogeologic conditions. The introduction of the reagents into the subsurface would take place via injection or trenching on the downgradient side of the Ash Ponds. An injection program would consist of a network of evenly spaced borings or injection wells along the downgradient edge of the impoundments installed by conventional drilling methods through which the reagent would be introduced into the subsurface. Trenching would occur using a large track hoe, one-pass excavator, or continuous trenching machine to create an open trench that could be used to facilitate the introduction of the reagents into the groundwater creating a permeable reactive barrier. However, as mentioned above, there is some uncertainty surrounding potential chemical reactions that could create an unintended result. A pilot study would be required to evaluate the performance and to identify which reagent mixture would have the greatest impact on the contaminant plume prior to going full scale with implementation.

Potential Impacts: Potential impacts associated with in-situ treatment include changing the redox and other geochemical conditions in the aquifer, which may in turn mobilize other metals or COCs. Surficial disturbance would be minimal. The public water supply may be impacted if the injectate introduced to the subsurface enters the capture zone of the production wells.

6.1.3.3 Institutional Requirements

Remedial activities associated with the addition of reagents into the subsurface would require design documentation be prepared and submitted for approval by the appropriate regulatory agencies to obtain the necessary underground injection permits.

6.1.3.4 Schedule

The pilot study could take up to 1 year to conduct with design and permitting efforts taking an additional year, depending on the response time from the regulatory agencies. Therefore, the amount of time required to implement this remedy is anticipated to be at least 2 years.

6.1.4 Corrective Measures Option 4 – Capping

6.1.4.1 Description

This corrective measure includes the closure of the Ash Ponds in place without removal of the CCR material. This option would use a final cover system designed to reduce infiltration into the CCR materials. Potential components from bottom to top of this option include a 40-mil geomembrane liner, overlaid by a geotextile cushion/drainage layer, and covered with a layer of final cover soil.

6.1.4.2 Achievement of Corrective Measure Goals

Protection of Human Health and the Environment: Capping of the Ash Ponds would be protective of both human health and the environment, because it would reduce the amount of leaching that occurs through the CCR and it would reduce the amount of fugitive emissions from the impoundments.

Attainment of GWPS: The reduction in leaching from the CCR units would translate to a reduction in impacts to groundwater.

Controlling the Source of Releases to Reduce or Eliminate Further Releases to the Environment: Capping would address the future leaching of COCs from the Ash Ponds; however, the limitation of capping is that it would not prevent groundwater with coming into contact with the CCR when a rise in the Ohio River raises groundwater levels to elevations above the bottom of the CCR units potentially mobilizing adsorbed-phase COCs.

Removal of Contaminated Material Released from the CCR Unit, Taking into Account Factors such as Avoiding Inappropriate Disturbance of Sensitive Ecosystems: Capping will not remove the impacted material that has already been released to the subsurface, but would rather control the source of the release and reduce further releases. There are no known sensitive ecosystems present at the ESS facility that would be affected by implementation of this option.

Compliance with Standards for Management of Wastes as Specified in §257.98(d): Implementation of the capping option would be in compliance with §257.98(d).

Performance, Reliability and Ease of Implementation: This corrective measure can be implemented using standard engineering design and construction techniques, which include developing a work plan and construction specifications. Part of the design would include assessing the need for active dewatering so that equipment may operate on the surface of the impoundment. It has been a proven and preferred engineering control at many solid waste disposal sites across the country to reduce surface infiltration and subsequent leaching.

Potential Impacts: Potential impacts involved with capping include some of the same that were identified in association with excavation (Option 2) and include: disturbances associated with typical site work activities such as fugitive dust control, and potential impacts to the local community associated with construction activities (e.g. noise, roadway usage, etc.). In order to reduce the potential impacts associated with these activities several controls should be considered for implementation including, permit requirements for erosion and sedimentation controls, speed limit restrictions for vehicular traffic, dust suppression measures and dustfall monitoring, restrictions on construction hours of operation, odor and air monitoring, and the use of equipment muffler systems, low-volume backup alarms and noise monitoring, as described in the facility's Fugitive Dust Control Plan, dated October 13, 2015. Dewatering operations, if necessary, would need to be evaluated for compliance with a NPDES permit.

6.1.4.3 Institutional Requirements

OMU would need to obtain a permit from the state regulatory agency for the closure-in-place of the impoundments. A construction stormwater permit will likely need to be obtained, which will require erosion and sediment controls as well as regular inspections and reporting requirements. Post-closure groundwater monitoring will also be a requirement. If dewatering is necessary, a NPDES application may be required.

6.1.4.4 Schedule

Design efforts associated with the cap are estimated to span up to one year, the permitting process is estimated to span up to one year, and the actual construction of the cap is estimated to take an additional year.

6.1.5 Corrective Measures Option 5 – Pump and Treat

6.1.5.1 Description

This option consists of installing extraction wells to intercept and extract impacted groundwater. The extracted groundwater is either then directed to a treatment system that would ultimately be discharged to surface water under a NPDES permit or to a local publically owned treatment works (POTW).

6.1.5.2 Achievement of Corrective Measure Goals

Protection of Human Health and the Environment: This goal of this option would be to reduce the concentrations of molybdenum in groundwater to concentrations less than its GWPS, thus being protective of human health and the environment.

Attainment of GWPS: Implementation of the pump and treat option would achieve the GWPS by controlling the migration of dissolved-phase molybdenum.

Controlling the Source of Releases to Reduce or Eliminate Further Releases to the Environment: The pump and treat system option would not control the source from releasing additional contaminants into the groundwater nor future releases; however, it would maintain hydraulic control in the vicinity of the Ash Ponds to capture the dissolve-phase COCs after they have been released from the Ash Ponds.

Removal of Contaminated Material Released from the CCR Unit, Taking into Account Factors such as Avoiding Inappropriate Disturbance of Sensitive Ecosystems: This option would remove the impacted groundwater that is released from the CCR unit. There are no known sensitive ecosystems at the ESS facility that would be affected by the operation of a pump and treat system.

Compliance with Standards for Management of Wastes as Specified in §257.98(d): Wastes generated as byproducts from the treatment of impacted groundwater would be managed by off-site disposal at an approved/licensed disposal facility.

Performance, Reliability and Ease of Implementation: The pump and treat option is a proven technology, especially in this type of hydrogeologic setting. It is also widely used to address groundwater impacts at many other non-CCR facilities. There would be periodic and regular operation and maintenance associated with the upkeep of the extraction wells, pumps, piping, and treatment components, but in general these would be considered low maintenance items. Some adjustments may be required to optimize long-term performance of the pump and treat system. The installation of a pump and treat system would not be complex based on our current understanding of the hydrogeologic conditions and would likely entail similar intrusive activities as those that were undertaken during the installation of the GMS (i.e. hollow stem auger drilling), accompanied by some piping installation that would occur at the surface.

Potential Impacts: Potential impacts associated with installation of pump and treat systems include surface disturbance for the installation of infrastructure such as pumping wells, buried pipelines, a treatment plant, and electrical service. Treated water would be discharged to surface water under a NPDES permit. Sludges generated at the treatment plant would require trucking and offsite disposal. Altered groundwater flows may impact the production wells.

6.1.5.3 Institutional Requirements

Installation of a pump and treat system would require permit approval for the discharge of the treated water. Additional permits may be required for the construction of a treatment plant, such as storm water/erosion, sediment control, and construction permits.

6.1.5.4 Schedule

Investigations to collect data to design a pump and treat system would require at least 1 year to complete. Design and permitting for the system could take another 1 to 2 years, depending on agency response and review. Construction may also take 1 to 2 years, including construction of a treatment plant and installation of electric service, and would be dependent on treatment plant size and complexity. Therefore, the total amount of time to implement this remedy is anticipated to be approximately 5 years.

6.1.6 Corrective Measures Option 6 – Cut-Off Wall

6.1.6.1 Description

This corrective measure assumes that Ash Ponds would be closed in place and engineering controls such as grout curtain, slurry wall, or sheet piling wall would be constructed surrounding the Ash Ponds to create a low permeability barrier that would reduce the migration of COCs in groundwater. Groundwater extraction wells would also be required to control the head such that groundwater down not simply pass around or under the physical barrier. The extracted groundwater would then require processing and treatment through a constructed treatment system.

6.1.6.2 Achievement of Corrective Measure Goals

Protection of Human Health and the Environment: The cut-off wall option could be protective of human health and the environment by limiting or preventing further migration of dissolved-phase COCs.

Attainment of GWPS: The cut-off wall option would seek to attain the GWPS by reducing the further migration of dissolved-phase impacts.

Controlling the Source of Releases to Reduce or Eliminate Further Releases to the Environment: The cut-off wall option would not control the source from releasing additional contaminants into the groundwater nor future releases; however, it would reduce or limit the dissolved-phase plume by creating a barrier to flow and capture the COCs after they have been released from the Ash Ponds.

Removal of Contaminated Material Released from the CCR Unit, Taking into Account Factors such as Avoiding Inappropriate Disturbance of Sensitive Ecosystems: This option would reduce or eliminate the dissolved-phase plume and remove the impacted groundwater via extraction wells. There are no known sensitive ecosystems at the ESS facility that would be affected by the operation of a pump and treat system.

Compliance with Standards for Management of Wastes as Specified in §257.98(d): Wastes generated during the installation of the cut-off wall and byproducts from the treatment of impacted groundwater would be managed by off-site disposal at an approved/licensed disposal facility.

Performance, Reliability and Ease of Implementation: A groundwater cut-off wall would offer a long-term containment measure for the management of impacted groundwater. It would need to be installed along a sufficient length and depth to control the movement of impacted groundwater and capture the groundwater for transfer to a treatment plant. Groundwater extraction wells would need to be sufficiently sized to control the groundwater head on the cut-off wall. This technology has been utilized successfully for a number of applications with similar hydrogeologic conditions. Implementation of this option would be invasive with excavations being required to accommodate the placement of the barrier wall. If sheet piling were used, the feasibility would be dependent upon subsurface material being suitable for driving piles (i.e., no boulders, cobbles, large slag, etc.).

Potential Impacts: Potential impacts associated this option include surface disturbance for the installation of both the cut-off wall itself as well as the supporting infrastructure such as pumping wells, buried pipelines, a treatment plant, and electrical service. Groundwater flow will also be altered, which may impact the uptake of production wells.

6.1.6.3 Institutional Requirements

Extracted groundwater may require treatment prior to discharging to a surface water body, which would require a NPDES permit.

6.1.6.4 Schedule

This option could take between one and two years to design and an additional one to two years for the installation. A NPDES permit for the discharge of extracted water may take another year.

7.0 PREFERRED APPROACH

Section 6.0 provided an assessment of potential corrective measures that could be implemented to meet the requirements of 40 CFR § 257.96 and § 257.97. Six potential corrective measures were evaluated for their ability to reduce concentrations of molybdenum in groundwater downgradient from the Ash Ponds. The results of this assessment are summarized below:

Potential Corrective Measure	Status
1. MNA	Retained
2. Excavation	Retained
3. In-Situ Treatment	Dismissed
4. Capping	Dismissed
5. Pump and Treat	Retained
6. Cut-Off Wall	Dismissed

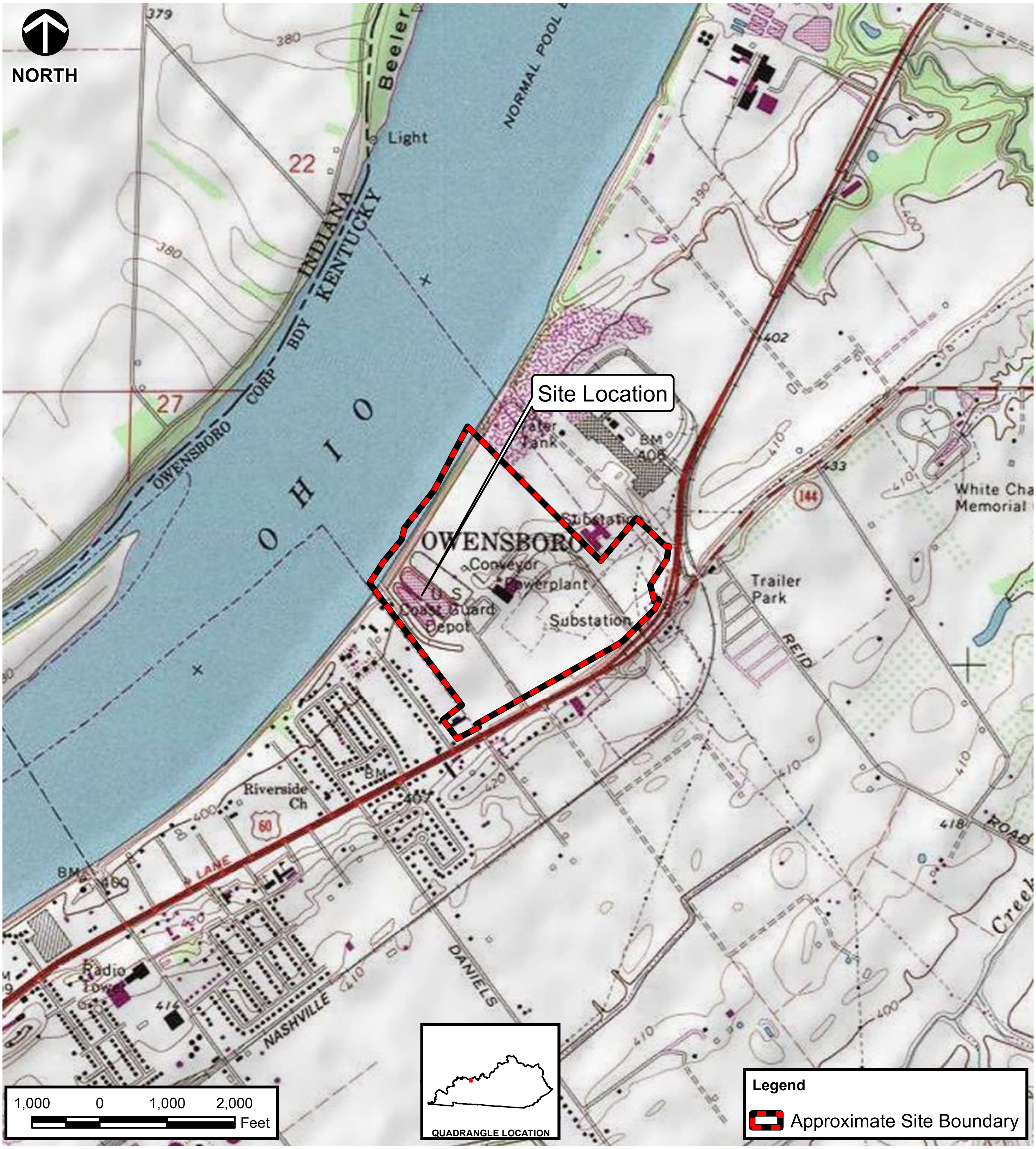
The remedy at the OMU ESS Ash Ponds will be selected following public meetings and comment in accordance with §257.96. However, the preferred approach is to excavate and dispose of the CCR (Option 2). MNA will also be performed to monitor the performance of the applied remedy. OMU has outlined the preliminary approach for implementing this remedy in their Initial and Post Closure Plan for the facility, dated October 17, 2016 (revised October 19, 2017). As indicated in Section 6.0, this option provides protection of human health and the environment and a high level of confidence that further releases of COCs from the Ash Ponds will not occur. The MNA will serve to monitor the performance of the excavation remedy, while the pump and treat option will serve in a backup capacity in the event that the excavation does not perform as expected.

8.0 FUTURE ACTIVITIES

Upcoming activities for the upcoming year include the following:

- Continued groundwater monitoring in accordance with the Assessment Monitoring program (40 CFR §257.97(b)),
- Post this report to the publicly-available internet website and notify the Kentucky Department for Environmental Protection (KDEP) of the availability of this report.
- Discussion of the results of this corrective action assessment in a public forum at least 30 days prior to the selection of the remedy (40 CFR §257.96(e)),
- Prepare a semi-annual report describing the progress in selecting and designing the remedy (40 CFR §257.97(a)),
- Prepare a final report describing the selected remedy (40 CFR §257.97), and,
- Establish and initiate a corrective action program (40 CFR §257.98).

FIGURES



SOURCE: PORTION OF THE USGS 7.5-MINUTE SERIES TOPOGRAPHIC QUADRANGLE MAP - OWENSBORO EAST, KY - 1983

Civil & Environmental Consultants, Inc.
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OWENSBORO MUNICIPAL UTILITIES
ELMER SMITH STATION ASH PONDS
OWENSBORO, DAVIESS COUNTY, KY

SITE LOCATION MAP

DRAWN BY: MGN	CHECKED BY: HTW	APPROVED BY: HTW*	FIGURE NO: 1
DATE: APRIL 17, 2019	DWG SCALE: 1 " = 2,000 '	PROJECT NO: 164-014.0015	

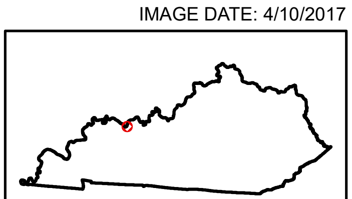
Signature on File *

J:\gis_support\other_office_projects\PGH\164-014\Maps\Task 0015 - Assmt of Corr Measures\FIG1_164014_EN15_SLM.mxd - 4/17/2019 - 3:38:38 PM (mnemecek)

SOURCE: ESRI WORLD IMAGERY / ARCGIS MAP SERVICE: HTTP://GOTO.ARCGISONLINE.COM/MAPS/WORLD_IMAGERY. LAST ACCESSED: 4/17/2019
IMAGE DATE: 4/10/2017

Legend

- GMS Monitoring Well
- OMU Municipal Production Well
- Geologic Cross-Section Transect
- Approximate Limits of Water Treatment Plant Expansion
- Approximate Site Boundary



200 0 200 400
Feet

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OWENSBORO MUNICIPAL UTILITIES
ELMER SMITH STATION ASH PONDS
OWENSBORO, DAVIESS COUNTY, KY

SITE AND VICINITY AERIAL MAP
WITH GMS WELLS

DRAWN BY: MGN	CHECKED BY: MGN	APPROVED BY: HTW*	FIGURE NO:
DATE: APR 17, 2019	SCALE: 1 " = 400 '	PROJECT NO: 164-014	2

Signature on File *

J:\gis_support\other_office_projects\PGH\164-014\Maps\Task 0015 - Assmt of Corr Measures\FIG2_164014_EN15_S&VAM.mxd - 4/17/2019 - 3:37:23 PM (mmemecek)

Civil & Environmental Consultants, Inc.
333 Baldwin Road
Pittsburgh, Pennsylvania 15205

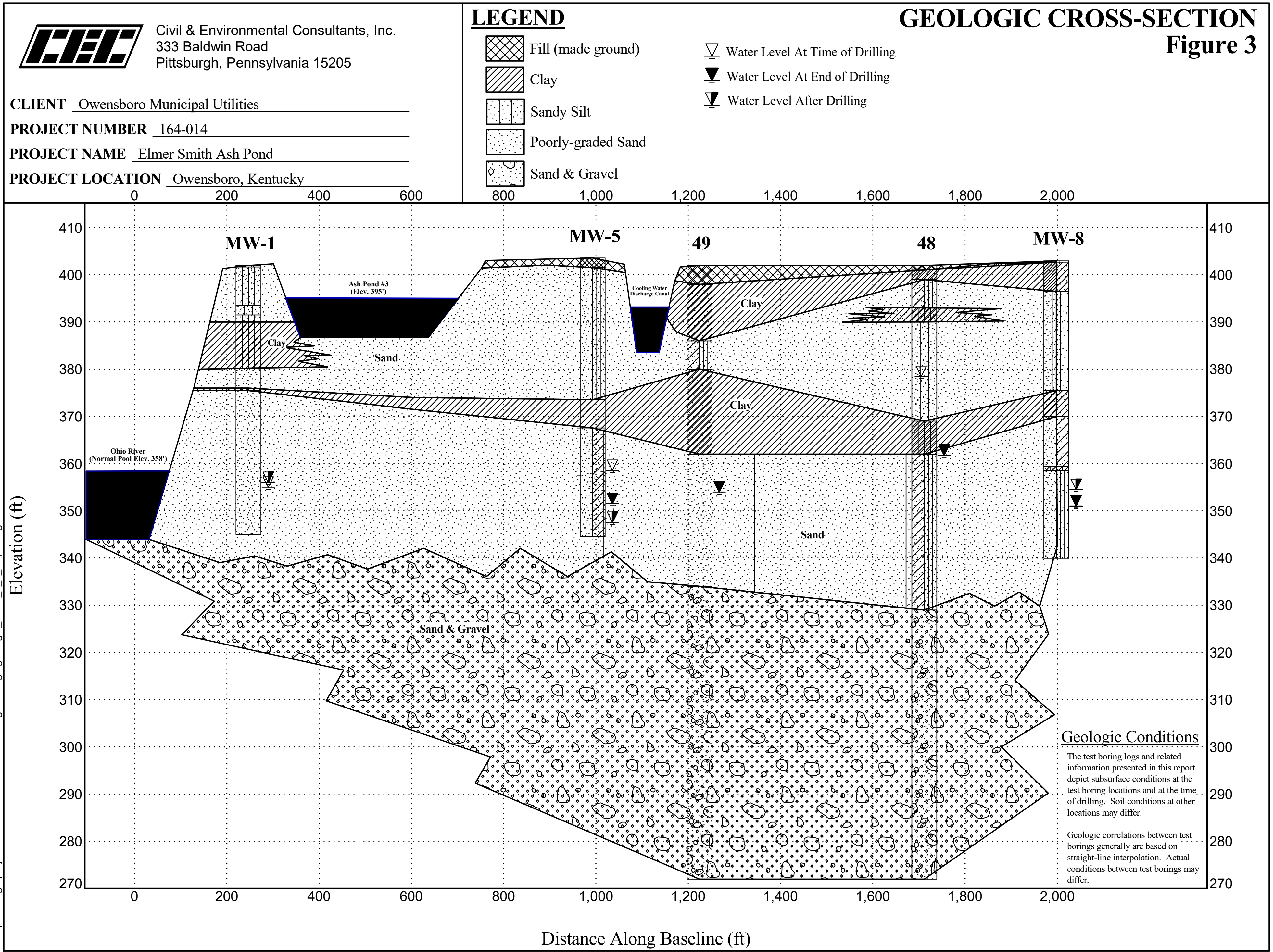
CLIENT Owensboro Municipal Utilities

PROJECT NUMBER 164-014

PROJECT NAME Elmer Smith Ash Pond

PROJECT LOCATION Owensboro, Kentucky

GEOLOGIC CROSS-SECTION
Figure 3



Geologic Conditions

The test boring logs and related information presented in this report depict subsurface conditions at the test boring locations and at the time of drilling. Soil conditions at other locations may differ.

Geologic correlations between test borings generally are based on straight-line interpolation. Actual conditions between test borings may differ.

\\svr-pittsburgh\projects\2016\164-014\-Field Data\gINT Logs\geologic_xsect_c_c_wopz1d.gdw

NOTE: THE WATER LEVELS PRESENTED HEREIN ARE APPLICABLE TO THE LOCATION AND TIME OF MEASUREMENT. WATER LEVELS MAY FLUCTUATE THROUGH TIME. POTENTIOMETRIC CONTOURS GENERATED FROM THIS DATA ARE CONSTRUCTED BY INTERPOLATION BETWEEN POINTS OF KNOWN STATIC WATER LEVEL ELEVATIONS AND USING KNOWLEDGE OF SPECIFIC SITE CONDITIONS. ACTUALSTATIC WATER LEVELS AT LOCATIONS BETWEEN THE MONITORING POINTS MAY DIFFER FROM THOSE DEPICTED.

SOURCE: ESRI WORLD IMAGERY / ARCGIS MAP SERVICE: HTTP://GOTO.ARCGISONLINE.COM/MAPS/WORLD_IMAGERY. LAST ACCESSED: 4/17/2019
IMAGE DATE: 4/10/2017

Legend

- OMU Municipal Production Well
- MW-1 579.45 GMS Monitoring Well — Groundwater Elevation (feet above mean sea level)
- Equipotential Line
- Approximate Limits of Molybdenum Plume
- Approximate Limits of Water Treatment Plant Expansion
- Approximate Site Boundary

PROJECT LOCATION

200 0 200 400 Feet

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OWENSBORO MUNICIPAL UTILITIES
ELMER SMITH STATION ASH PONDS
OWENSBORO, DAVIESS COUNTY, KY

POTENTIOMETRIC SURFACE MAP
DECEMBER 27, 2018

DRAWN BY: MGN	CHECKED BY: MGN	APPROVED BY: HTW*	FIGURE NO: 4
DATE: APR 17, 2019	SCALE: 1 " = 400 '	PROJECT NO: 164-014	

Signature on File *

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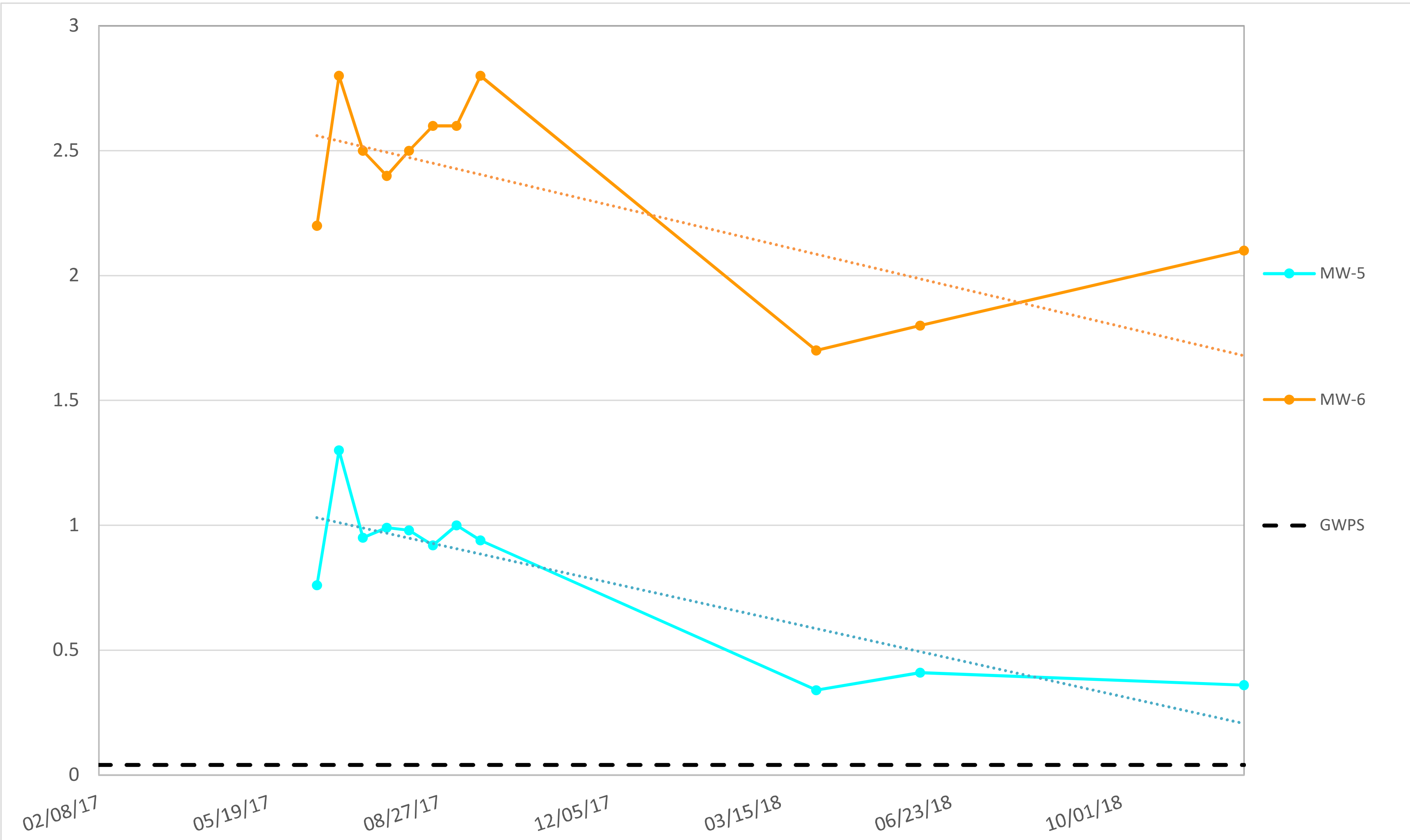
Owensboro Municipal Utilities

Molybdenum [mg/L]



TABLES

TABLE 1
Groundwater Elevation Summary
OMU Elmer Smith Station Ash Ponds
Owensboro, KY
(all measurements are in feet)

Well ID (AKGWA #)	Location Relative to Ash Ponds	Ground Surface Elevation (AMSL)	TOC Elevation (AMSL)	Measurement Date	Depth to Water Measurement (ft BTOC)	Groundwater Elevation (AMSL)
MW-1 (8006-9522)	Upgradient	402.00	404.53	12/8/2016	48.51	356.02
				12/13/2016	48.07	356.46
				2/8/2017	45.69	358.84
				3/8/2017	40.68	363.85
				4/6/2017	43.51	361.02
				5/3/2017	45.91	358.62
				5/15/2017	43.46	361.07
				6/16/2017	49.94	354.59
				6/29/2017	46.72	357.81
				7/13/2017	49.81	354.72
				7/27/2017	49.99	354.54
				8/9/2017	49.15	355.38
				8/23/2017	50.38	354.15
				9/6/2017	50.31	354.22
				9/20/2017	50.04	354.49
				10/10/2017	49.55	354.98
				4/5/2018	34.75	369.78
				6/5/2018	46.61	357.92
				12/12/2018	43.97	360.56
				12/27/2018	35.66	368.87
MW-2 (8006-9523)	Upgradient (Background)	402.75	405.55	12/8/2016	49.21	356.34
				12/13/2016	48.74	356.81
				2/8/2017	46.29	359.26
				3/8/2017	41.24	364.31
				4/6/2017	44.16	361.39
				5/3/2017	45.48	360.07
				5/15/2017	44.02	361.53
				6/16/2017	50.02	355.53
				6/29/2017	47.17	358.38
				7/13/2017	50.16	355.39
				7/27/2017	50.23	355.32
				8/9/2017	50.75	354.80
				8/23/2017	50.97	354.58
				9/6/2017	50.95	354.60
				9/20/2017	50.69	354.86
				10/10/2017	50.20	355.35
				4/5/2018	35.70	369.85
				6/5/2018	47.22	358.33
				12/12/2018	44.51	361.04
				12/27/2018	36.85	368.70
MW-3 (8006-9524)	Upgradient	403.78	406.39	12/8/2016	49.88	356.51
				12/13/2016	49.43	356.96
				2/8/2017	46.95	359.44
				3/8/2017	41.64	364.75
				4/6/2017	44.56	361.83
				5/3/2017	45.90	360.49
				5/15/2017	44.51	361.88
				6/16/2017	50.06	356.33
				6/29/2017	47.29	359.10
				7/13/2017	50.64	355.75
				7/27/2017	50.69	355.70
				8/9/2017	51.35	355.04
				8/23/2017	51.65	354.74
				9/6/2017	51.43	354.96
				9/20/2017	51.25	355.14
				10/10/2017	50.82	355.57
				4/5/2018	36.10	370.29
				6/5/2018	47.84	358.55
				12/12/2018	45.16	361.23
				12/27/2018	37.61	368.78

Notes: AMSL = Above Mean Sea Level
TOC = Top of Casing
Ft BTOC = Feet Below Top of Casing

TABLE 1
Groundwater Elevation Summary
OMU Elmer Smith Station Ash Ponds
Owensboro, KY
(all measurements are in feet)

Well ID (AKGWA #)	Location Relative to Ash Ponds	Ground Surface Elevation (AMSL)	TOC Elevation (AMSL)	Measurement Date	Depth to Water Measurement (ft BTOC)	Groundwater Elevation (AMSL)
MW-4 (8006-9525)	Downgradient	406.44	408.02	12/8/2016	54.44	353.58
				12/13/2016	54.06	353.96
				2/8/2017	51.22	356.80
				3/8/2017	52.97	355.05
				4/6/2017	54.99	353.03
				5/3/2017	55.75	352.27
				5/15/2017	53.95	354.07
				6/16/2017	58.65	349.37
				6/29/2017	57.60	350.42
				7/13/2017	58.20	349.82
				7/27/2017	58.73	349.29
				8/9/2017	58.97	349.05
				8/23/2017	59.48	348.54
				9/6/2017	58.73	349.29
				9/20/2017	57.75	350.27
				10/10/2017	57.15	350.87
				4/5/2018	48.85	359.17
				6/5/2018	51.97	356.05
				12/12/2018	50.92	357.10
				12/27/2018	48.87	359.15
MW-5 (8005-9530)	Downgradient	403.56	406.16	6/16/2017	56.37	349.79
				6/29/2017	56.66	349.50
				7/13/2017	56.62	349.54
				7/27/2017	57.03	349.13
				8/9/2017	57.05	349.11
				8/23/2017	57.45	348.71
				9/6/2017	57.11	349.05
				9/20/2017	56.12	350.04
				10/10/2017	55.51	350.65
				4/5/2018	45.14	361.02
				6/5/2018	50.11	356.05
				12/12/2018	49.16	357.00
				12/27/2018	46.58	359.58
MW-6 (8006-9531)	Downgradient	405.23	407.35	6/16/2017	57.96	349.39
				6/29/2017	57.40	349.95
				7/13/2017	57.96	349.39
				7/27/2017	58.16	349.19
				8/9/2017	58.55	348.80
				8/23/2017	58.82	348.53
				9/6/2017	58.65	348.70
				9/20/2017	57.41	349.94
				10/10/2017	56.84	350.51
				4/5/2018	46.53	360.82
				6/5/2018	51.56	355.79
				12/12/2018	50.53	356.82
				12/27/2018	48.35	359.00
MW-7 (8006-9532)	Downgradient (Background)	418.26	421.11	6/16/2017	72.90	348.21
				6/29/2017	73.25	347.86
				7/13/2017	72.87	348.24
				7/27/2017	73.81	347.30
				8/9/2017	74.31	346.80
				8/23/2017	74.31	346.80
				9/6/2017	73.71	347.40
				9/20/2017	73.79	347.32
				10/10/2017	73.70	347.41
				4/5/2018	67.61	353.50
				6/5/2018	69.37	351.74
				12/12/2018	66.12	354.99
				12/27/2018	65.11	356.00
MW-8 (8007-1801)	Downgradient	402.97	405.82	12/27/2018	49.51	356.31

Notes: AMSL = Above Mean Sea Level
TOC = Top of Casing
Ft BTOC = Feet Below Top of Casing

TABLE 2

Groundwater Analytical Summary - CCR Rule Assessment Monitoring (2018)

OMU Elmer Smith Station

Owensboro, KY

Sample ID		MW-2			MW-4			MW-5			MW-6			MW-7			MW-8	Duplicate[1]			Equipment Blank			Groundwater
Collection Date		4/5/18	6/5/18	12/12/18	4/5/18	6/5/18	12/12/18	4/5/18	6/5/18	12/12/18	4/5/18	6/5/18	12/12/18	4/5/18	6/5/18	12/12/18	12/27/18	4/5/18	6/5/18	12/12/18	4/5/18	6/5/18	12/12/18	**Protection Standard**
Total Metals	**Units**																							
Antimony	mg/L	<0.0060	NA	NA	<0.0060	NA	NA	<0.0060	NA	NA	<0.0060	NA	NA	<0.0060	NA	NA	<0.0060	<0.0060	NA	NA	<0.0060	NA	NA	0.006
Arsenic	mg/L	<0.010	NA	NA	<0.010	NA	NA	<0.010	NA	NA	<0.010	NA	NA	<0.010	NA	NA	<0.010	<0.010	NA	NA	<0.010	NA	NA	0.010
Barium	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	**0.11**	**0.12**	<0.10	<0.10	<0.10	<0.10	**0.13**	**0.12**	**0.13**	**0.13**	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	2
Beryllium	mg/L	<0.00040	NA	NA	<0.00040	NA	NA	<0.00040	NA	NA	<0.00040	NA	NA	<0.00040	NA	NA	<0.00040	<0.00040	NA	NA	<0.00040	NA	NA	0.004
Boron	mg/L	NA	<0.10	**0.11**	NA	**11**	**5.6**	NA	**12**	**10**	NA	**10**	**11**	NA	<0.10	<0.10	<0.10	NA	**10**	0.14	NA	<0.10	<0.10	0.33
Cadmium	mg/L	<0.0050	NA	NA	<0.0050	NA	NA	<0.0050	NA	NA	<0.0050	NA	NA	<0.0050	NA	NA	<0.0050	<0.0050	NA	NA	<0.0050	NA	NA	0.005
Calcium	mg/L	NA	**53**	**100**	NA	**180**	**100**	NA	**150**	**120**	NA	**180**	**170**	NA	**100**	**99**	**84**	NA	**180**	**100**	NA	<0.20	**0.36**	139.5
Chromium	mg/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	**0.021**	<0.020	<0.020	<0.020	**0.22**	<0.020	<0.020	**0.020**	<0.020	<0.020	<0.020	<0.020	<0.020	4.10
Cobalt	mg/L	<0.0040	NA	NA	<0.0040	NA	NA	<0.0040	NA	NA	<0.0040	NA	NA	<0.0040	NA	NA	<0.0040	<0.0040	NA	NA	<0.0040	NA	NA	0.098
Lead	mg/L	<0.015	NA	NA	<0.015	NA	NA	<0.015	NA	NA	<0.015	NA	NA	<0.015	NA	NA	<0.015	<0.015	NA	NA	<0.015	NA	NA	0.015
Lithium	mg/L	<0.10	NA	NA	<0.10	NA	NA	<0.10	NA	NA	<0.10	NA	NA	<0.10	NA	NA	<0.10	<0.10	NA	NA	<0.10	NA	NA	0.040
Mercury	mg/L	<0.00020	NA	NA	<0.00020	NA	NA	<0.00020	NA	NA	<0.00020	NA	NA	<0.00020	NA	NA	<0.00020	<0.00020	NA	NA	<0.00020	NA	NA	0.002
Molybdenum	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	**0.34**	**0.41**	**0.36**	**1.7**	**1.8**	**2.1**	<0.10	<0.10	<0.10	<0.10	**1.7**	<0.10	<0.10	<0.10	<0.10	<0.10	0.10
Selenium	mg/L	<0.030	NA	NA	<0.030	NA	NA	<0.030	NA	NA	<0.030	NA	NA	<0.030	NA	NA	<0.030	<0.030	NA	NA	<0.030	NA	NA	0.050
Thallium	mg/L	<0.0050	NA	NA	<0.0050	NA	NA	<0.0050	NA	NA	<0.0050	NA	NA	<0.0050	NA	NA	<0.0050	<0.0050	NA	NA	<0.0050	NA	NA	0.002
Anions																								
Chloride	mg/L	NA	**18**	**18**	NA	**37**	**27**	NA	**62**	**49**	NA	**130**	**37**	NA	**21**	**19**	**24**	NA	**37**	**18**	NA	<1.0	<2.0	50
Fluoride	mg/L	<2.0	**0.30**	<2.0	<2.0	<0.50	<2.0	**2.3**	**1.9**	<2.0	<2.0	<0.50	<2.0	<2.0	**0.22**	<2.0	<2.0	<2.0	<0.50	<2.0	<2.0	<0.10	<2.0	4
Sulfate	mg/L	NA	**36**	**19**	NA	**370**	**140**	NA	**390**	**260**	NA	**400**	**550**	NA	**84**	**91**	**59**	NA	**370**	**19**	NA	<1.0	<5.0	154.3
Radium																								
Radium-226	pCi/L	<0.25 (+/-0.13)	<0.193 (+/-0.098)	<0.28 (+/-0.17)	**0.49 (+/-0.23)**	**0.32 (+/-0.18)**	<0.23 (+/-0.15)	<0.13 (+/-0.11)	**0.2 (+/-0.13)**	<0.61 (+/-0.35)	<0.19 (+/-0.13)	**0.29 (+/-0.16)**	<0.27 (+/-0.2)	**0.21 (+/-0.16)**	**0.32(+/-0.15)**	<0.21 (+/-0.14)	<0.28 (+/-0.2)	**0.25 (+/-0.16)**	**0.32 (+/-0.17)**	<0.25 (+/-0.15)	<0.18 (+/-0.11)	<0.16 (+/-0.12)	<0.38 (+/-0.16)	9.32
Radium-228	pCi/L	<0.94 (+/-0.4)	NA	<0.84 (+/-0.42)	<0.98 (+/-0.48)	NA	<0.82 (+/-0.39)	<1.01 (+/-0.45)	NA	<0.76 (+/-0.36)	<0.98 (+/-0.45)	NA	<0.72 (+/-0.34)	<0.97 (+/-0.48)	NA	<0.73 (+/-0.36)	<0.70 (+/-0.33)	<0.98 (+/-0.43)	NA	<0.81 (+/-0.41)	<1.17 (+/-0.54)	NA	<0.7 (+/-0.31)	
pH																								
pH	s.u.	NA	**7.7**	**7.6**	NA	**7.5**	**7.8**	NA	**7.5**	**8.0**	NA	**7.3**	**7.8**	NA	**7.0**	**7.6**	**7.0**	NA	**7.4**	**6.1**	NA	**6.6**	**7.4**	8.01
Total Dissolved Solids																								
Total Dissolved Solids	mg/L	NA	**260**	**420**	NA	**1,100**	**570**	NA	**1,200**	**840**	NA	**1,500**	**1,100**	NA	**570**	**490**	**420**	NA	**1,100**	**420**	NA	**44**	**30**	950.80

= Appendix III constituent (fluoride is included on both Appendix III & IV lists)

= Appendix IV constituent (fluoride is included on both Appendix III & IV lists)

Bold indicates result detected above laboratory reporting limit

1.8 = Appendix IV constituent quantified at Statistically Significant Level (exceeding Groundwater Protection Standard)

NA = Not analyzed for this constituent

[1]Duplicate sample collected at MW-6 (4/5/18), MW-4 (6/5/18), MW-2 (12/12/18)